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200 East Groundwater Aggregate Area Management Study Report

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ACRONYMS AND ABBREVIATIONS

AAMS	aggregate area management study
AAMSR	aggregate area management study report
AFAN	ammonium fluoride-ammonium nitrate
AKART	all known, available, and reasonable treatment technologies
ARAR	applicable or relevant and appropriate requirement
ASD	ammonia scrubber distillate
ASIL	acceptable source impact level
BAT	est available technology
BDAT	best demonstrated available treatment technologies
BWIP	Basalt Waste Isolation Project
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
CMS	Corrective Measures Studies
CPF	Cancer Potency Factor
CRP	Community Relations Plan
CSL	chemical sewer
CWA	Clean Water Act
CWL	cooling water
DCG	Derived Concentration Guide
DNAPL	dense non-aqueous phase liquid
DOE/RL	U.S. Department of Energy, Richland Operations Office
DOE	U.S. Department of Energy
DQO	data quality objective
EC	evaporator-crystallizer
Ecology	Washington State Department of Ecology
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
ERA	expedited response actions
FFS	focused feasibility study
FS	feasibility study
FWQC	Federal Water Quality Criteria
GIS	Geographic Information System
HBL	Health Based Level
HEAST	Health Effects and Assessment Summary Tables
HEHF	Hanford Environmental Health Foundation
HPPS	Hanford Past-Practice Strategy
HVAC	heating, ventilation, and air conditioning
IRM	interim remedial measure
ITS	in-tank solidification

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ACRONYMS AND ABBREVIATIONS (cont.)

LDR	land disposal restriction
LERF	Liquid Effluent Retention Facility
LFI	limited field investigation
LLBG	low-level burial grounds
LLRW	low-level radioactive waste
LLWMA	low-level waste management area
LLWMU	low-level waste management unit
MCL	maximum contaminant levels
MCLGs	maximum contaminant level goals
MEPAS	Multimedia Environmental Pollutant Assessment System
MIBK	methyl isobutyl ketone
MTCA	Model Toxics Control Act
NAAQS	National Ambient Air Quality Standards
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants Network
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRDWL	Nonradioactive Dangerous Waste Landfill
NSPS	New Source Performance Standards
NSTF	Near Surface Test Facility
NTU	nephelometric turbidity unit
OGWMN	Westinghouse Hanford Operational Groundwater Monitoring
OSM	Office of Sample Management
PARCC	precision, accuracy, representativeness, completeness
PCB	polychlorinated biphenyl
PDD	process condensate
PNL	Pacific Northwest Laboratory
PUREX	plutonium uranium extraction
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RA	risk assessment
RAO	remedial action objective
RAP	Remedial Action Policy
RARA	Radiation Area Remedial Action
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
REDOX	reduction and oxidation
RfD	Reference Doses

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ACRONYMS AND ABBREVIATIONS (cont.)

RFI	RCRA Facility Investigations
RI	remedial investigation
RLS	Radionuclide Logging System
ROD	record of decision
RRI	relative risk index
SALDS	State-Approved Liquid Disposal Structure
SARA	Superfund Amendments and Reauthorization Act
SCD	steam condensate
SDWA	Safe Drinking Water Act
SMCLs	secondary maximum contaminant levels
T-BACT	toxic best available control technology
TBC	to-be-considered material
TCLP	toxic characteristic leaching procedure
TEDF	treated effluent disposal facility
TLV	Threshold Limit Value
TOC	total organic carbon
TOX	total organic halogens
TRAC	Tracks Radioactive Components
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
TRU	transuranic
TSD	treatment, storage, or disposal
USC	U.S. Code
USGS	U.S. Geological Survey
UV	ultra violet
WAC	Washington Administrative Code
WESF	Waste Encapsulation Storage Facility
WIDS	Waste Information Data System
WIPP	Waste Isolation Pilot Plant
WPCA	Washington State Water Pollution Control Act

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200 EAST GROUNDWATER AAMS EXECUTIVE SUMMARY

This report presents the results of an aggregate area management study (AAMS) for the 200 East Groundwater Aggregate Area in the 200 Areas of the U.S. Department of Energy (DOE) Hanford Site in Washington State. This scoping level study provides the basis for initiating Remedial Investigation/Feasibility Study (RI/FS) activities under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA); or Resource Conservation and Recovery Act (RCRA)Facility Investigations (RFI) and Corrective Measures Studies (CMS). This report also integrates select RCRA treatment, storage or disposal (TSD) closure activities with CERCLA and RCRA past practice investigations.

Through the experience gained to date on developing work plans, closure plans, and permit applications at the Hanford Site, the parties to the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) have recognized that all past practice investigations must be managed and implemented under one characterization and remediation strategy, regardless of the regulatory agency lead (as defined in the Tri-Party Agreement). In particular, the parties have identified a need for greater efficiency over the existing RI/FS and RFI/CMS investigative approaches, and have determined that, to expedite the ultimate goal of cleanup, much more emphasis needs to be placed on initiating and completing waste management unit cleanup through interim measures.

This streamlined approach is described and justified in the *Hanford Federal Facility Agreement and Consent Order Change Package,* dated May 16, 1991 (Ecology et al. 1991). To implement this approach, the three parties have developed the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a) for streamlining the past practice remedial action process. This strategy provides new concepts for the following:

- Accelerating decision-making by maximizing the use of existing data consistent with data quality objectives

- Undertaking expedited response actions (ERAs) and/or interim remedial measures (IRMs), as appropriate, to either remove threats to human health and welfare and the environment, or to reduce risk by reducing toxicity, mobility, or volume of contaminants.

The *Hanford Site Past-Practice Strategy* (DOE/RL 1992a) describes the concepts and framework for the RI/FS (or RFI/CMS) process in a manner that has 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 strategy focuses on reaching early decisions to initiate and complete cleanup projects, maximizing the use of existing data, coupled with focused short time-frame investigations, where necessary. As more data become

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available on contamination problems and associated risks, the details of the longer term investigations and studies will be better defined.

The strategy includes three paths for interim decision-making and a final remedy-selection process for the operable unit that incorporates the three paths and integrates the various contaminant plumes addressed in those paths. The three paths for interim decision-making include the ERA, IRM, and limited field investigation (LFI) paths. The strategy requires that aggregate area management study reports (AAMSRs) be prepared to evaluate existing groundwater contamination data to support initial path decisions. This AAMSR is one of ten reports that will be prepared for each of the ten aggregate areas defined in the 200 Areas.

The near-term past practice strategy for the 200 Areas provides for ERAs, IRMs, and LFIs for individual waste management units, waste management unit groups, and groundwater plumes, and recommends separate source and groundwater operable units. Initial recommendations for each of the groundwater plumes within the 200 East Groundwater Aggregate Area are provided in the report. Work plans will initially focus on limited intrusive investigations at the highest priority plumes as established in the AAMSR. The goal of this initial focus is to establish whether interim remedial measures are justified. Plumes identified as candidate ERAs will be further evaluated following the *Site Selection Process for Expedited Response Actions at the Hanford Site* (Gustafson 1991).

While these elements may mitigate specific contamination problems through interim actions, the process of final remedy selection must be completed for the operable unit or aggregate area to reach closure. The aggregation of information obtained from the LFIs and interim actions may be sufficient to perform the cumulative risk assessment and to define the final remedy for operable unit or aggregate area. If the data are not sufficient, additional investigations and studies will be performed to the extent necessary to support final remedy selection. These investigations would be performed within the framework and process defined for RI/FS programs.

Several integration issues exist that are generic to the overall past practice process for the 200 Areas and include the following:

- **Future Work Plan Scope.** Although the current practice for implementing RI/FS (RFI/CMS) activities is through operable unit based work plans, individual LFI/IRMs may be more efficiently implemented using LFI/IRM-specific work plans.

- **Groundwater Operable Units.** A general strategy recommended for the 200 Areas is to define separate operable units for groundwater affected by 200 Areas source terms. This requires that groundwater be removed from the scope of the existing source operable units and new groundwater-specific operable units be established. Recommendations for groundwater operable units are developed in the groundwater AAMSRs.

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- **Work Plan Prioritization.** Although priorities are established in the AAMSR for operable units within the aggregate area, priorities between aggregate areas have yet to be established. The integration of priorities at the 200 Areas level is considered a prerequisite for establishing a schedule for past practice activities in the 200 Areas.

It is intended that these integration issues be resolved following the completion of all ten AAMSRs (Draft A) scheduled for September 1992. Resolution of these issues will be based on a decisions/consensus process among the Washington State Department of Ecology (Ecology), the U.S. Environmental Protection Agency (EPA), and DOE. Following resolution of these issues a schedule for past practice activities in the 200 Areas will be prepared.

Background, environmental setting, and known contamination data are provided in Sections 2.0, 3.0, and Section 4.1. This information provides the basis for development of the preliminary conceptual model in Section 4.2 and assessing health and environmental concerns in Section 5.0. Preliminary applicable or relevant and appropriate requirements (ARARs) (Section 6.0) and preliminary remedial action technologies (Section 7.0) are also developed based on this data. Section 8.0 provides a discussion of the data quality objectives. Data needs identified in Section 8.0 are based on data gaps determined during the development of the conceptual model, human health and environmental concerns, ARARs, and remedial action technologies. Recommendations in Section 9.0 are developed using all the information provided in the sections which precede it.

The Hanford Site, operated by the DOE, occupies about 1,450 km^2 (560 mi^2) of the southeastern part of Washington north of the confluence of the Yakima and Columbia Rivers. The Hanford Site was established in 1943 to produce plutonium for nuclear weapons using production reactors and chemical processing plants. The 200 East Groundwater Aggregate Area includes the Hanford Site's 200 East Area plus other surrounding land where the contamination has spread.

Between 1944 and the present, the 200 Areas have housed various chemical processing plants for extracting plutonium, uranium, and fission products from irradiated fuels and secondary waste streams.

The 200 East Groundwater Aggregate Area contains a large variety of waste disposal and storage facilities. High-level wastes were stored in underground single-shell tanks. Low-level wastes such as cooling and condensate water were allowed to infiltrate into the ground through cribs, ditches, and open ponds. Detailed descriptions of waste management units that may impact groundwater are provided in Section 2.3.

There are several ongoing programs that affect activities in the 200 East Groundwater Aggregate Area (Section 2.7). These programs include RCRA, the Hanford Surplus Facilities Program, the Radiation Area Remedial Action Program, the Hanford Site Single-Shell Tank

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Program, and the Defense Waste Management Program. These programs do not affect groundwater remedial activities.

Discussions of surface hydrology and geology are provided on a regional, Hanford Site, and aggregate area basis in Section 3.0. The section also describes the flora and fauna, land use, water use and human resources of the 200 East Area and vicinity.

A preliminary site conceptual model is presented in Section 4.0. Section 4.1 presents the chemical and radiological data that are available for the groundwater in the 200 East Groundwater Aggregate Area and organizes the results in terms of the various plumes.

A preliminary assessment of potential impacts to human health and the environment is presented in Section 4.2. This assessment includes a discussion of release mechanisms, potential transport pathways, and a preliminary conceptual model of human and ecological exposure based on these pathways. Physical, radiological, and toxicological characteristics of the known and suspected contaminants at the aggregate area are also discussed.

Health and environmental concerns are presented in Section 5.0. The preliminary qualitative evaluation of potential human health concerns is intended to provide input to the plume evaluation and recommendation process.

Potential ARARs to be used in developing and assessing various remedial action alternatives at the 200 East Groundwater Aggregate Area are discussed in Section 6.0.

Preliminary remedial action technologies are presented in Section 7.0. The process includes identification of remedial action objectives, determination of general response actions, and identification of specific process options associated with each option type. The process options are screened based on their effectiveness, implementability and cost. The screened process options are combined into alternatives and the alternatives are described.

Data quality is addressed in Section 8.0. The section provides a summary of data needs identified for the 200 East Groundwater Aggregate Area. The data needs provide the basis for development of detailed data quality objectives in subsequent work plans.

Section 9.0 provides management recommendations for the 200 East Groundwater Aggregate Area based on the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a). Criteria for selecting appropriate *Hanford Site Past-Practice Strategy* paths (ERA, IRM, and final remedy selection) for individual plumes are developed in Section 9.1. As a result of this process, 1 plume (Strontium-90) is recommended for an ERA. There are seven contaminants grouped into 3 operational plumes recommended for IRMs. Nineteen contaminants are proposed for LFIs, to determine if IRMs are justified. There are over 60 constituents for which the final remedy selection path is recommended. Finally, the tritium plume is proposed for a risk assessment. Two groundwater operable units are defined for the 200 East Area, GW-OU-3 and GW-OU-4. These are defined based on a groundwater hydrological divide, and

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encompass the contaminants listed for ERAs, IRMs, LFIs, final remedy, and risk assessment. Based on the relative priorities of the plumes in each groundwater operable unit, it is recommended that GW-OU-4 be given higher priority than GW-OU-3 for follow-up action.

The data evaluation process is discussed in Section 9.2. Recommendations for defining operable unit boundaries and prioritizing operable units for work plan development are provided in Section 9.3. Included in Section 9.3 are the interactions with RCRA and on-going CERCLA investigations. All recommendations for future characterization needs will be more fully developed and implemented through work plans. Sections 9.4 and 9.5 provide recommendations for focused feasibility and treatability studies, respectively. Section 9.6 discusses characterization activities which will be done on an aggregate area scale.

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1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Hanford Site in Washington State is organized into numerically designated operational areas including the 100, 200, 300, 400, 600, and 1100 Areas (Figure 1-1). The U.S. Environmental Protection Agency (EPA), in November 1989, included the 200 Areas of the Hanford Site on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Inclusion on the NPL initiates the Remedial Investigation (RI) and Feasibility Study (FS) process for characterizing the nature and extent of contamination, assessing risks to human health and the environment, and selection of remedial actions.

This report presents the results of an aggregate area management study (AAMS) for the 200 East Groundwater Aggregate Area located in the 200 Areas. The study provides the basis for initiating RI/FS under CERCLA or under the Resource Conservation and Recovery Act (RCRA) Facility Investigations (RFI) and Corrective Measures Studies (CMS). This report also integrates RCRA treatment, storage, or disposal (TSD) closure activities with CERCLA and RCRA past practice investigations.

This chapter describes the overall aggregate area management study (AAMS) approach for the 200 Areas, defines the purpose, objectives and scope of the AAMS, and summarizes the quality assurance (QA) program and contents of the report.

1.1 OVERVIEW

The 200 Areas, located near the center of the Hanford Site, encompasses the 200 West, East and North Areas which contain reactor fuel processing and waste management facilities.

Under the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement), signed by the Washington State Department of Ecology (Ecology), DOE, and EPA (Ecology et al. 1990), the 200 NPL Site encompasses the 200 Areas and selected portions of the 600 Area. The 200 NPL Site is divided into 8 waste area groups largely corresponding to the major processing plants (e.g., B Plant and T Plant), and a number of isolated operable units located in the surrounding 600 Area. Each waste area group is further subdivided into one or more operable units based on waste disposal information, location, facility type, and other site characteristics. The 200 NPL site includes a total of 44 operable units including 20 in the 200 East Area, 17 in the 200 West Area, 1 in the 200 North Area, and 6 isolated operable units. The intent of defining operable units was to

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group associated waste management units together, so that they could be effectively characterized and remediated under one work plan.

The Tri-Party Agreement also defines approximately 25 RCRA TSD groups within the 200 Areas which will be closed or permitted (for operation or postclosure care) in accordance with the Washington State Dangerous Waste Regulations (Washington Administrative Code [WAC 173-303]). The TSD facilities are often associated with an operable unit and are required to be addressed concurrently with past-practice activities under the Tri-Party Agreement.

This AAMS is one of ten studies that will provide the basis for past practice activities for operable units in the 200 Areas. In addition, the AAMS will be collectively used in the initial development of an area-wide groundwater model, and conduct of an initial site-wide risk assessment. Recent changes to the Tri-Party Agreement (Ecology et al. 1991), and the *Hanford Site Past-Practice Strategy* document (DOE/RL 1992a) establish the need and provide the framework for conducting AAMS in the 200 Areas.

1.1.1 Tri-Party Agreement

The Tri-Party Agreement was developed and signed by representatives from the EPA, Ecology, and DOE in May 1989, and revised in 1990 and 1991. The scope of the agreement covers all CERCLA past practice, RCRA past practice, and RCRA TSD activities on the Hanford Site. The purpose of the Tri-Party Agreement is to ensure that the environmental impacts of past and present activities are investigated and appropriately remediated to protect human health and the environment. To accomplish this, the Tri-Party Agreement provides a framework and schedule for developing, prioritizing, implementing, and monitoring appropriate response actions.

The 1991 revision to the Tri-Party Agreement requires that an aggregate area approach be implemented in the 200 Areas based on the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a). This strategy requires the conduct of AAMS which are similar in nature to an RI/FS scoping study. The Tri-Party Agreement change package (Ecology et al. 1991) specifies that 10 Aggregate Area Management Study Reports (AAMSR) (major milestone M-27-00) are to be prepared for the 200 Areas. Further definition of aggregate areas and the AAMS approach is provided in Sections 1.2 and 1.3.

1.1.2 Hanford Site Past-Practice Strategy

The *Hanford Site Past-Practice Strategy* was developed between Ecology, EPA, and DOE to streamline the existing RI/FS and RFI/CMS processes. A primary objective of this strategy is to develop a process to meet the statutory requirements and integrate CERCLA RI/FS and RCRA Past Practice RFI/CMS guidance into a singular process for the Hanford Site that ensures protection of human health and welfare and the environment. The strategy refines the existing past practice decision-making process as defined in the Tri-Party Agreement. The fundamental principle of the strategy is a bias-for-action by optimizing the use of existing data, integrating past practice with RCRA TSD closure investigations, focusing the RI/FS process, conducting interim remedial actions, and reaching early decisions to initiate and complete cleanup projects on both operable-unit and aggregate-area scale. The ultimate goal is the comprehensive cleanup or closure of all contaminated areas at the Hanford Site at the earliest possible date in the most effective manner.

The process under this strategy is a continuum of activities whereby the effort is refined based upon knowledge gained as work progresses. Whereas the strategy is intended to streamline investigations and documentation to promote the use of interim actions to accelerate cleanup, it is consistent with RI/FS and RFI/CMS processes. An important element of this strategy is the application of the observational approach, in which characterization data are collected concurrently with cleanup.

For the 200 Areas the first step in the strategy is the evaluation of existing information presented in AAMSR. Based on this information, decisions are made regarding which strategy path(s) to pursue for further actions in the aggregate area. The strategy includes three paths for interim decision making and a final remedy-selection process that incorporates the three paths and integrates sites not addressed in those paths. As shown on Figure 1-2, the three paths for decision making are the following:

- Expedited response action (ERA) path, where an existing or near-term unacceptable health or environmental risk from a site is determined or suspected, and a rapid response is necessary to mitigate the problem

- Interim remedial measure (IRM) path, where existing data are sufficient to indicate that the site poses a risk through one or more pathways and additional investigations are not needed to screen the likely range of remedial alternatives for interim actions; if a determination is made that an IRM is justified, the process proceeds to select an IRM remedy and a focused feasibility study (FFS), if needed, to select a remedy

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- Limited field investigation (LFI) path, where minimum site data are needed to support IRM or other decisions, and are obtained in a less formal manner than that needed to support a final Record of Decision (ROD). Data generated from a LFI may be sufficient to directly support an interim ROD. Regardless of the scope of the LFI, it is a part of the RI process, and not a substitute for it.

The process of final remedy selection must be completed for the aggregate area to reach closure. The aggregation of information obtained from LFI and interim actions may be sufficient to perform the cumulative risk assessment and to define the final remedy for the aggregate area or associated operable units. If the data are not sufficient, additional investigations and studies will be performed to the extent necessary to support final remedy selection. These investigations would be performed within the framework and process defined for RI/FS or RFI/CMS programs.

1.2 200 NPL SITE AGGREGATE AREA MANAGEMENT STUDY PROGRAM

The overall approach and scope of the 200 Areas AAMS program is based on the Tri-Party Agreement and the *Hanford Site Past-Practice Strategy*.

1.2.1 Overall Approach

As defined in the 1991 revision to the Tri-Party Agreement, the AAMS program for the 200 Areas consists of conducting a series of ten AAMS for eight source (Figures 1-3, 1-4, and 1-5) and two groundwater aggregate areas delineated in the 200 East, West, and North Areas. Table 1-1 lists the aggregate areas, the type of study, and associated operable units. With the exception of 200-IU-6, isolated operable units associated with the 200 NPL site (Figure 1-5) are not included in the AAMS program. Generally, the quantity of existing information associated with isolated operable units is not considered sufficient to require study on an aggregate area basis prior to work plan development. Operable unit 200-IU-6 is addressed as part of the B Plant AAMS because of similarities in waste management units (i.e., ponds).

The eight source AAMS are designed to evaluate source terms on a plant-wide scale. Source AAMS are conducted for the following aggregate areas (waste area groups) which largely correspond to the major processing plants including the following:

- U Plant
- Z Plant

- S Plant
- T Plant
- PUREX
- B Plant
- Semi-Works
- 200 North.

The groundwater beneath the 200 Areas is investigated under two groundwater AAMS on an area-wide scale (i.e., 200 West and 200 East Areas). Groundwater aggregate areas were delineated to encompass the geography necessary to define and understand the local hydrologic regime, and the distribution, migration and interaction of contaminants emanating from source terms. The groundwater aggregate areas are considered an appropriate scale for developing conceptual and numerical groundwater models.

The U.S. Department of Energy, Richland Field Office (DOE/RL) functions as the "lead agency" for the 200 AAMS program. Depending on the specific AAMS, EPA and/or Ecology function as the "Lead Regulatory Agency" (Table 1-1). Through periodic (monthly) meetings information is transferred and regulators are informed of the progress of the AAMS such that decisions established under the *Hanford Site Past-Practice Strategy* (e.g., is an ERA justified?) (Figure 1-2) can be quickly and collectively made between the three parties. These meetings will continually refine the scope of AAMS as new information is evaluated, decisions are made and actions taken. Completion milestones for AAMS are defined in Ecology et al. (1991) and duplicated in Table 1-1. All AAMSR are submitted as Secondary Documents which are defined in the Tri-Party Agreement as informational documents.

1.2.2 Process Overview

Each AAMS consists of three steps: 1) the analysis of existing data and formulation of a preliminary conceptual model, 2) identification of data needs and evaluation of remedial technologies, and 3) conduct of limited field characterization activities. Steps 1 and 2 are components of an AAMSR. Step 3 is a parallel effort for which separate reports will be produced.

The first and primary task of the AAMS investigation process involves the search, compilation and evaluation of existing data. Information collected for these purposes includes the following:

- Facility and process descriptions and operational histories for waste sources
- Waste disposal records defining dates of disposal, waste types, and waste quantities
- Sampling events of waste effluents and affected media
- Site conditions including the site physiography, geology, hydrology, meteorology, ecology, demography, and archaeology
- Environmental monitoring data for affected media including air, surface water, sediment, soil, groundwater and biota.

Collectively this information is used to identify contaminants of concern, to determine the scope of future characterization efforts, and to develop a preliminary conceptual model of the aggregate area. Although data collection objectives are similar, the types of information collected depend on whether the study is a source or groundwater AAMS. The data collection step serves to avoid duplication of previous efforts and facilitates a more focused investigation by the identification of data gaps.

Topical reports referred to as Technical Baseline Reports are initially prepared to summarize facility information. These reports describe individual waste management units and unplanned releases contained in the aggregate area as identified in the Waste Information Data System (WIDS) (WHC 1991a). The reports are based on review of current and historical Hanford Site reports, engineering drawings and photographs and are supplemented with site inspections and employee interviews. Information contained in the reports is summarized in the AAMSR. Other topical reports are used as sources of information in the AAMSR. These reports are as follows:

- U Plant Geologic and Geophysics Data Package
- Z Plant Geologic and Geophysics Data Package
- S Plant Geologic and Geophysics Data Package
- T Plant Geologic and Geophysics Data Package

- PUREX Geologic and Geophysics Data Package
- B Plant Geologic and Geophysics Data Package
- 200 N Geologic and Geophysics Data Package
- Semiworks Geologic and Geophysics Data Package
- Hydrologic Model for the 200 West Groundwater Aggregate Area
- Hydrologic Model for the 200 East Groundwater Aggregate Area
- Unconfined Aquifer Hydrologic Test Data Package for the 200 West Groundwater Aggregate Area
- Unconfined Aquifer Hydrologic Test Data Package for the 200 East Groundwater Aggregate Area
- Confined Aquifer Hydrologic Test Data Package for the 200 Groundwater Aggregate Area Management Studies
- Groundwater Field Characterization Report
- 200 West Area Borehole Geophysics Field Characterization
- 200 East Area Borehole Geophysics Field Characterization.

The general scope of the topical reports related to this AAMSR is described in Section 8.0.

Information on waste sources, pathways, and receptors is used to develop a preliminary conceptual model of the aggregate area. In the preliminary conceptual model, the release mechanisms and transport pathways are identified. If the conceptual understanding of the site is considered inadequate, limited field characterization activities can be undertaken as part of the study. Field characterization activities occurring in parallel with and as part of the AAMS process include the following:

- Expanded groundwater monitoring programs (non-Contract Laboratory Program [CLP]) at approximately 80 select existing wells to identify contaminants of concern and refine groundwater plume maps

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- In situ assaying of gamma-emitting radionuclides at approximately 10 selected existing boreholes per aggregate area to develop radioelement concentration profiles in the vadose zone.

Wells, boreholes, and analytes are selected based on a review of existing environmental data which is undertaken early in the AAMS process. Field characterization results will be presented later in topical reports.

After the preliminary conceptual model is developed, health and environmental concerns are identified. The purpose of this determination is to provide one basis for determining recommendations and prioritization for subsequent actions at waste management units. Potential applicable or relevant and appropriate requirements (ARARs) and potential remedial technologies are identified. In cases where the existing information is sufficient, the *Hanford Site Past-Practice Strategy* allows for a focused FS or CMS to be initiated prior to the completion of the study.

Data needs are identified by evaluating the sufficiency of existing data and by determining what additional data are necessary to adequately characterize the aggregate area, refine the preliminary conceptual model and potential ARARs, and/or narrow the range of remedial alternatives. Determinations are made regarding the level of uncertainty associated with existing data and the need to verify or supplement the data. If additional data are needed, the intended data uses are identified, data quality objectives (DQO) established and data priorities set.

Each AAMSR results in management recommendations for the aggregate area including the following:

- The need for ERA, IRM, and LFI or whether to remain in the final remedy selection path
- Definition and prioritization of operable units
- Prioritization of work plan activities
- Integration of RCRA TSD closure activities
- The conduct of field characterization activities
- The need for treatability studies

- Identification of waste management units addressed entirely under other operational programs.

The waste management units recommended for ERA, IRM, or LFI actions are considered higher priority units that require rapid response. Lower priority waste management units will generally follow the conventional process for RI/FS. In spite of this distinction in the priority of sites, RI/FS activities will be conducted for all the waste management units. In the case of the higher priority waste management units, rapid response operations will be followed by conventional RI/FS activities, although these activities may be modified because of knowledge gained through the remediation activities. In the case of the lower priority waste management units, an area-wide RI/FS will be prepared which encompasses these units.

Based on the AAMSR, a decision is made on whether the study has provided sufficient information to forego further field investigations and prepare a FS. An RI/FS work plan (which may be limited to LFI activities) will be developed and executed. The background information normally required to support the preparation of a work plan (e.g., site description, conceptual model, DQO, etc.) is developed in the AAMSR. The future work plans will reference information from the AAMSR. They will also include the rationale for sampling and analysis, will present detailed, unit-specific DQO, and will further develop physical site models as the data allows. In some cases, there may be insufficient data to support any further analysis than is provided in the AAMSR, so an added level of detail in the work plan may not be feasible.

All ten AAMS are scheduled to be completed by September 1992. This will facilitate a coordinated approach to prioritizing and implementing future past practice activities for the entire 200 Areas.

1.3 PURPOSE, SCOPE, AND OBJECTIVES

The purpose of conducting an AAMS is to compile and evaluate the existing body of knowledge and conduct limited field characterization work to support the *Hanford Site Past-Practice Strategy* decision-making process for an aggregate area. The AAMS process is similar in nature to the RI/FS scoping process prior to work plan development and is intended to maximize the use of existing data to allow a more limited and focused RI/FS. Deliverables for an AAMS consist of the AAMSR and health and safety, project management, and Information Management Overview (IMO) plans.

Specific objectives of the AAMS include the following:

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- Assemble and interpret existing data including operational and environmental data
- Describe site conditions
- Conduct limited new site characterization work if data or interpretation uncertainty could be reduced by the work (results from this work may not be available for the AAMSR, but will be included in subsequent topical reports)
- Develop a preliminary conceptual model
- Identify contaminants of concern, and their distribution
- Identify potential ARARs
- Define preliminary remedial action objectives, screen potential remedial technologies, and if possible provide recommendations for focused FS
- Recommend treatability studies to support the evaluation of remedial action alternatives
- Define data needs, establish general DQOs and set data priorities
- Provide recommendations for ERA, IRM, LFI or other actions
- Redefine and prioritize, as data allow, operable unit boundaries
- Define and prioritize, as data allow, work plan and other past practice activities with emphasis on supporting early cleanup actions and records of decisions
- Integrate RCRA TSD closure activities with past practice activities.

Information on single-shell and double-shell tanks is presented in Sections 2.0 and 4.0 of selected AAMSRs. The AAMSR is not intended to address remediation related to the tanks. Nonetheless, the tank information is presented because known and suspected releases from the tanks may influence the interpretation of contamination data at nearby waste management units. Information on other facilities and buildings is also presented for this same reason. However, because these structures are addressed by other programs, the AAMSR does not include recommendations for further action at these structures.

Depending on whether an aggregate area is a source or groundwater aggregate area, the scope of the AAMS varies. Source AAMS focus on source terms, and the environmental

media of interest include air, biota, surface water, surface soil, and the unsaturated subsurface soil. Accordingly, detailed descriptions of facilities and operational information are provided in the source AAMSR. In contrast, groundwater AAMS focus on the saturated subsurface and on groundwater contamination data. Descriptions of facilities in the groundwater AAMSR are limited to liquid disposal facilities and reference is made to source AAMSR for detailed descriptions. The description of site conditions in source AAMSR concentrate on site physiography, meteorology, surface water hydrology, vadose zone geology, ecology, and demography. Groundwater AAMSR summarize regional geohydrologic conditions and contain detailed information regarding the local geohydrology on an area-wide scale. Correspondingly, other sections of the AAMSR vary depending on the environmental media of concern.

1.4 QUALITY ASSURANCE

A limited amount of field characterization work is performed in parallel with preparation of the AAMSR. To help ensure that data collected are of sufficient quality to support decisions, all work will be performed in compliance with *Quality Assurance*, DOE Order 5700.6C (DOE 1991), as well as Westinghouse Hanford's existing QA manual, WHC-CM-4-2 (WHC 1988a), and with procedures outlined in the QA program plan, WHC-EP-0383 (WHC 1990a), specific to CERCLA RI/FS activities. This QA program plan describes the various plans, procedures, and instructions that will be used by Westinghouse Hanford to implement the QA requirements. Standard EPA guidance documents such as the *Contract Laboratory Program Statement of Work for Organic Analysis* (EPA 1988a) will also be followed.

1.5 ORGANIZATION OF REPORT

In addition to this introduction, the AAMSR consists of the following nine sections and appendices:

- Section 2.0, Facility, Process and Operational History Descriptions, describes the major facilities, waste management units and unplanned releases within the aggregate area. A chronology of waste disposal activities is established and waste generating processes are summarized.

- Section 3.0, Site Conditions, describes the physical, environmental, and sociological setting including geology, hydrology, ecology, meteorology, and demography.

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- Section 4.0, Preliminary Conceptual Site Model, summarizes the conceptual understanding of the aggregate area with respect to types and extent of contamination, exposure pathways and receptors.

- Section 5.0, Health and Environmental Concerns, identifies chemicals used or disposed within the aggregate area that could be of concern regarding public health and/or the environment and describes and applies the screening process for determining the relative priority of follow-up action at each waste management unit.

- Section 6.0, Potentially Applicable or Relevant and Appropriate Requirements, identifies federal and state standards, requirements, criteria, or limitations that may be considered relevant to the aggregate area.

- Section 7.0, Preliminary Remedial Action Technologies, identifies and screens potential remedial technologies and establishes remedial action objectives for environmental media.

- Section 8.0, Data Quality Objectives, reviews QA criteria on existing data, identifies data gaps or deficiencies, and identifies broad data needs for field characterization and risk assessment. The DQO and data priorities are established.

- Section 9.0, Recommendations, provides guidance for future past practice activities based on the results of the AAMS. Recommendations are provided for ERA at problem sites, IRM, LFI, refining operable unit boundaries, prioritizing work plans, and conducting field investigations and treatability studies.

- Section 10.0, References, list reports and documents cited in the AAMSR.

- Appendix A, Supplemental Data, provides supplemental data supporting the AAMSR.

The following plans are included and will be used to support past practice activities in the aggregate area:

- Appendix B: Health and Safety Plan

- Appendix C: Project Management Plan

- Appendix D: Information Management Overview

Community relations requirements for the 200 East Groundwater Aggregate Area can be found in the *Community Relations Plan for the Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1989).

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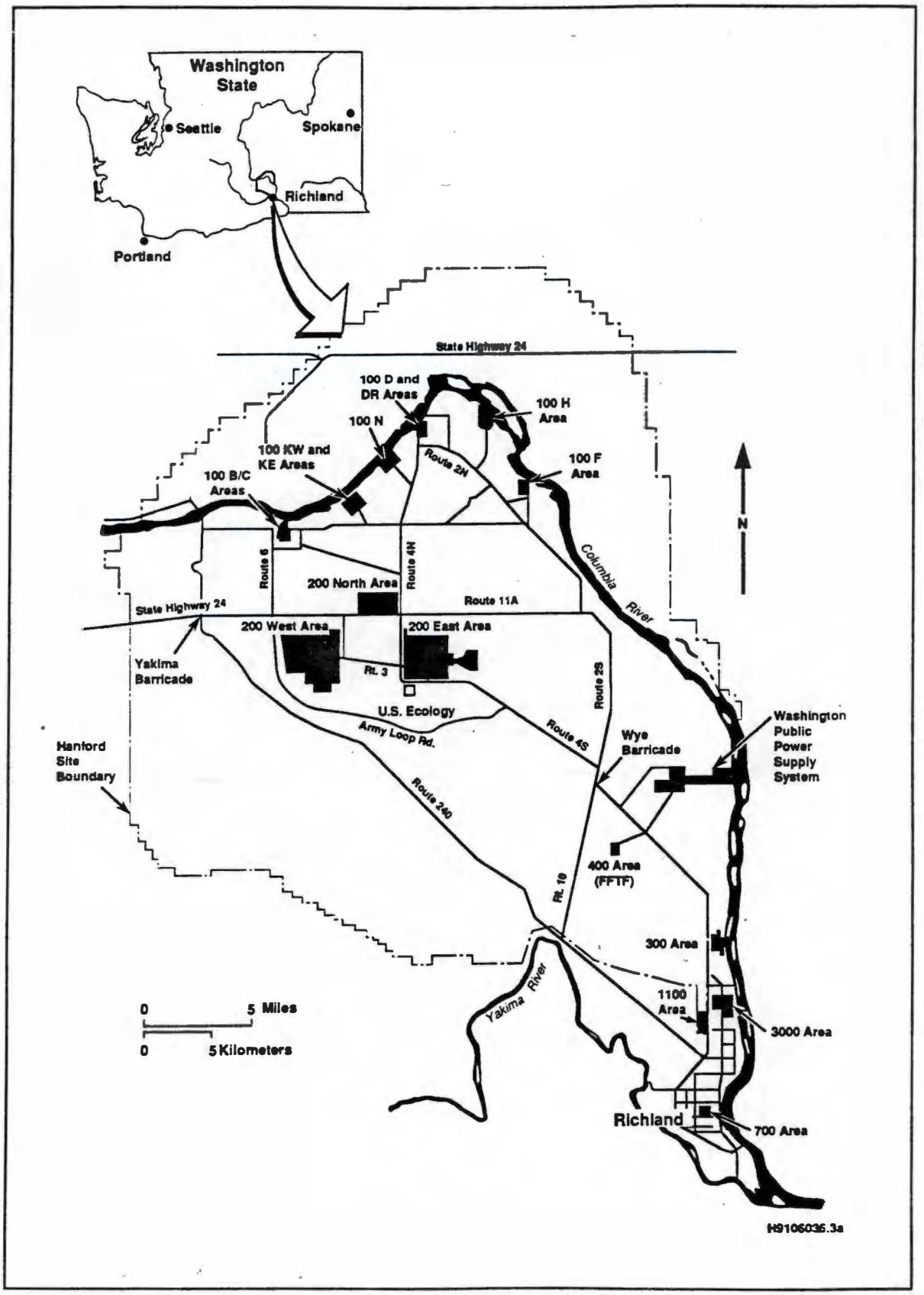

Figure 1-1. Hanford Site Map.

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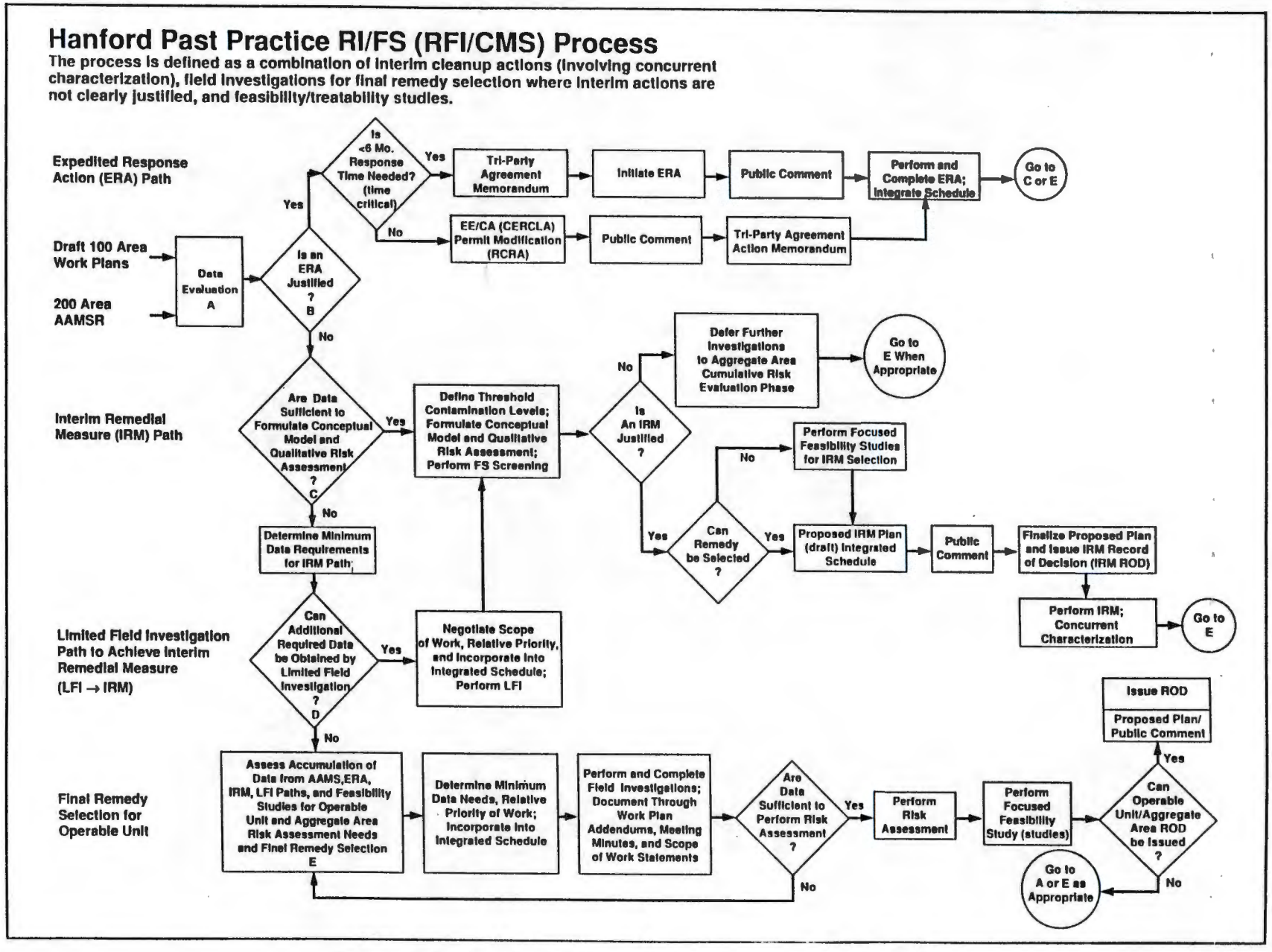

Figure 1-2. Hanford Site Past-Practice Strategy Flow Chart.

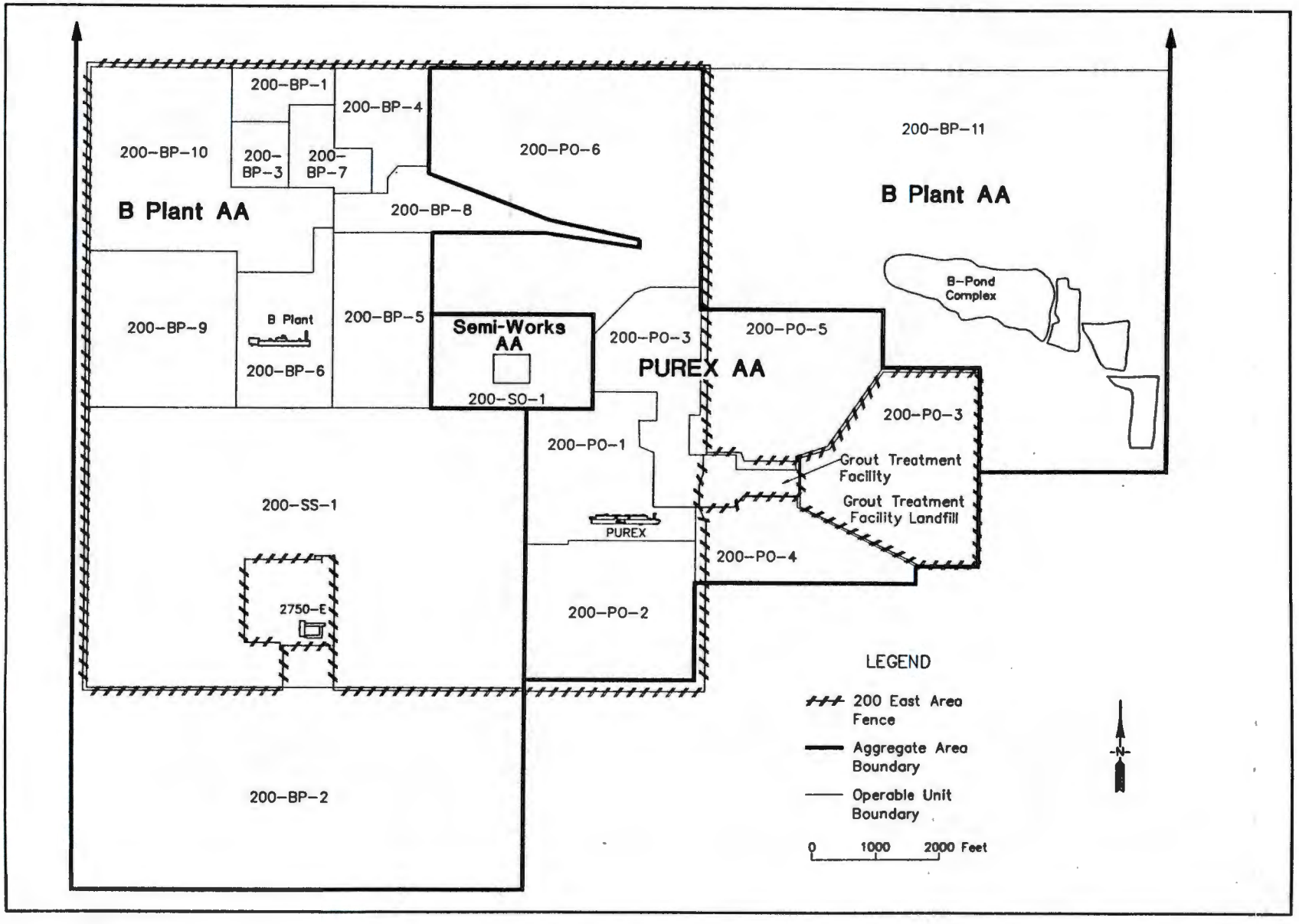

Figure 1-3. 200 East Aggregate Areas.

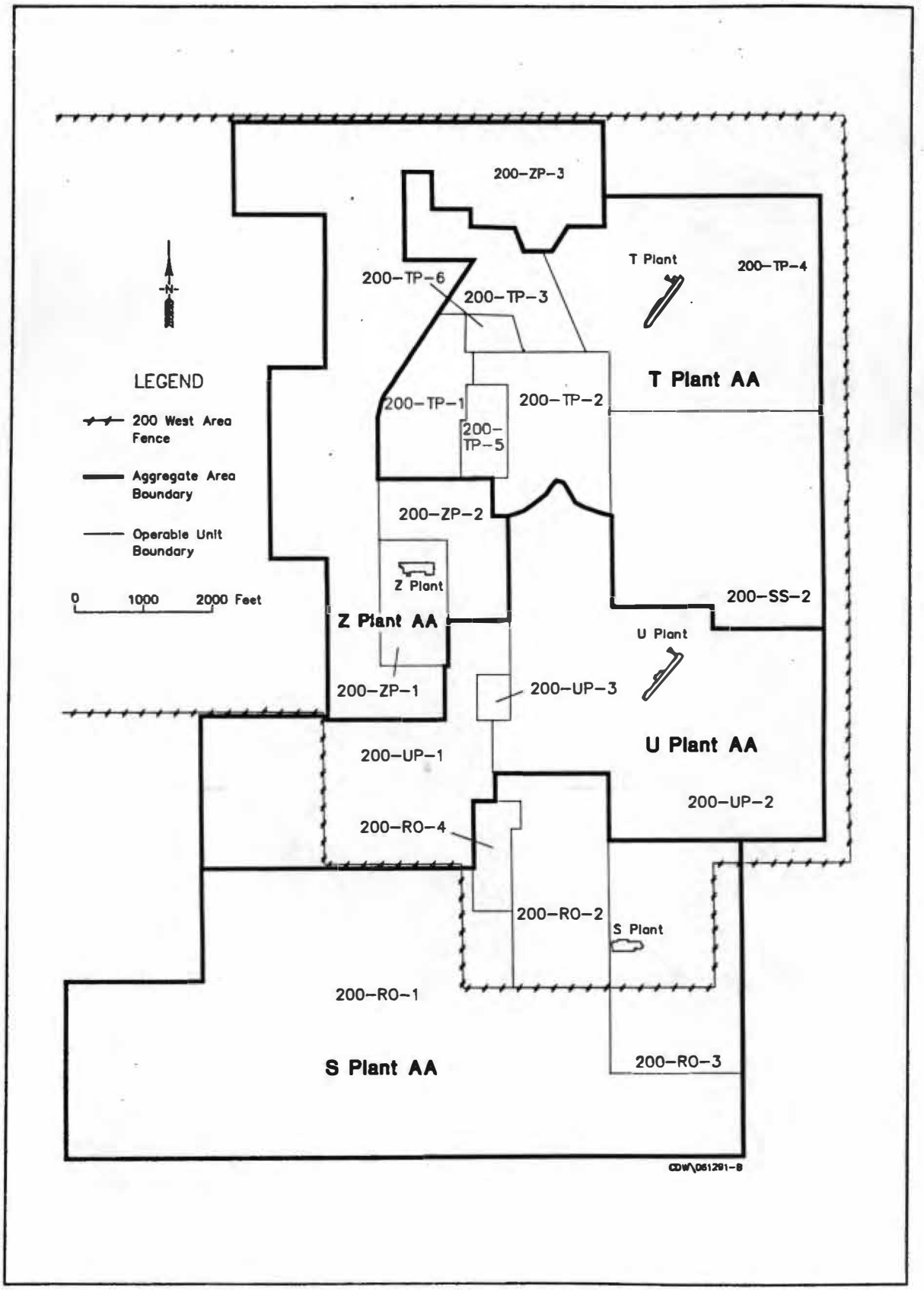

Figure 1-4. 200 West Aggregate Areas.

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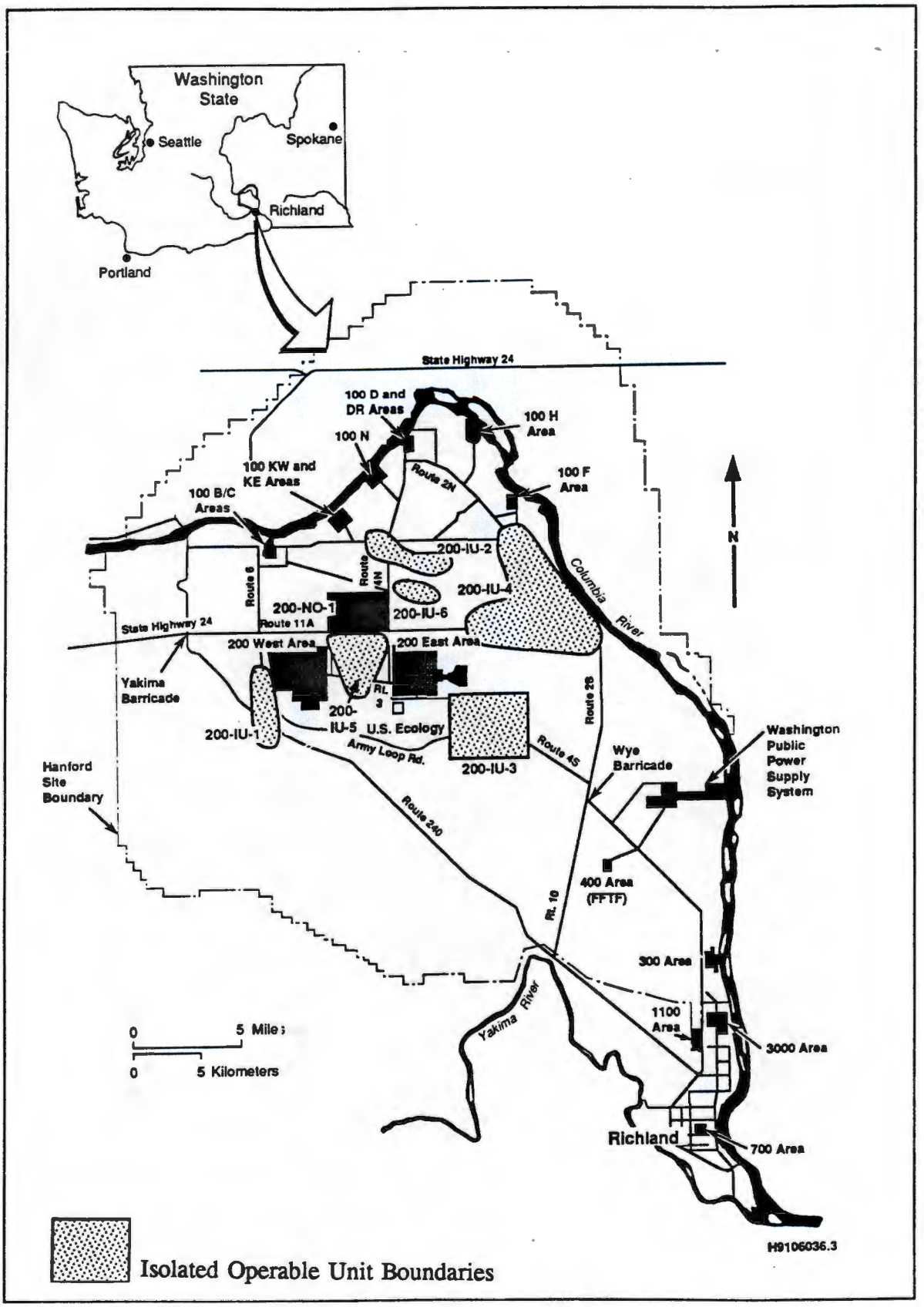

Figure 1-5. 200 NPL Site Isolated Operable Units.

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Table 1-1. Overall Aggregate Area Management Study (AAMS) Schedule for the 200 NPL Site.

AAMS Title	Operable Units	AAMS Type	Lead Regulatory Agency	M-27-00 Interim Milestones
U Plant	200-UP-1 200-UP-2 200-Up-3	Source	Ecology	M-27-02, January 1992
Z Plant	200-ZP-1 200-ZP-2 200-ZP-3	Source	EPA	M-27-03, February 1992
S Plant	200-RO-1 200-RO-2 200-RO-3 200-RO-4	Source	Ecology	M-27-04, March 1992
T Plant	200-TP-1 200-TP-2 200-TP-3 200-TP-4 200-TP-5 200-TP-6 200-SS-2	Source	EPA	M-27-05, April 1992
PUREX	200-PO-1 200-PO-2 200-PO-3 200-PO-4 200-PO-5 200-PO-6	Source	Ecology	M-27-06, May 1992
B Plant	200-BP-1 200-BP-2 200-BP-3 200-BP-4 200-BP-5 200-BP-6 200-BP-7 200-BP-8 200-BP-9 200-BP-10 200-BP-11 200-IU-6 200-SS-1	Source	EPA	M-27-07, June 1992
Semi-Works	200-SO-1	Source	Ecology	M-27-08, July 1992
200 North	200-NO-1	Source	EPA	M-27-09, August 1992
200 West	NA	Ground Water	EPA/Ecology	M-27-10, September 1992
200 East	NA	Ground Water	EPA/Ecology	M-27-11, September 1992

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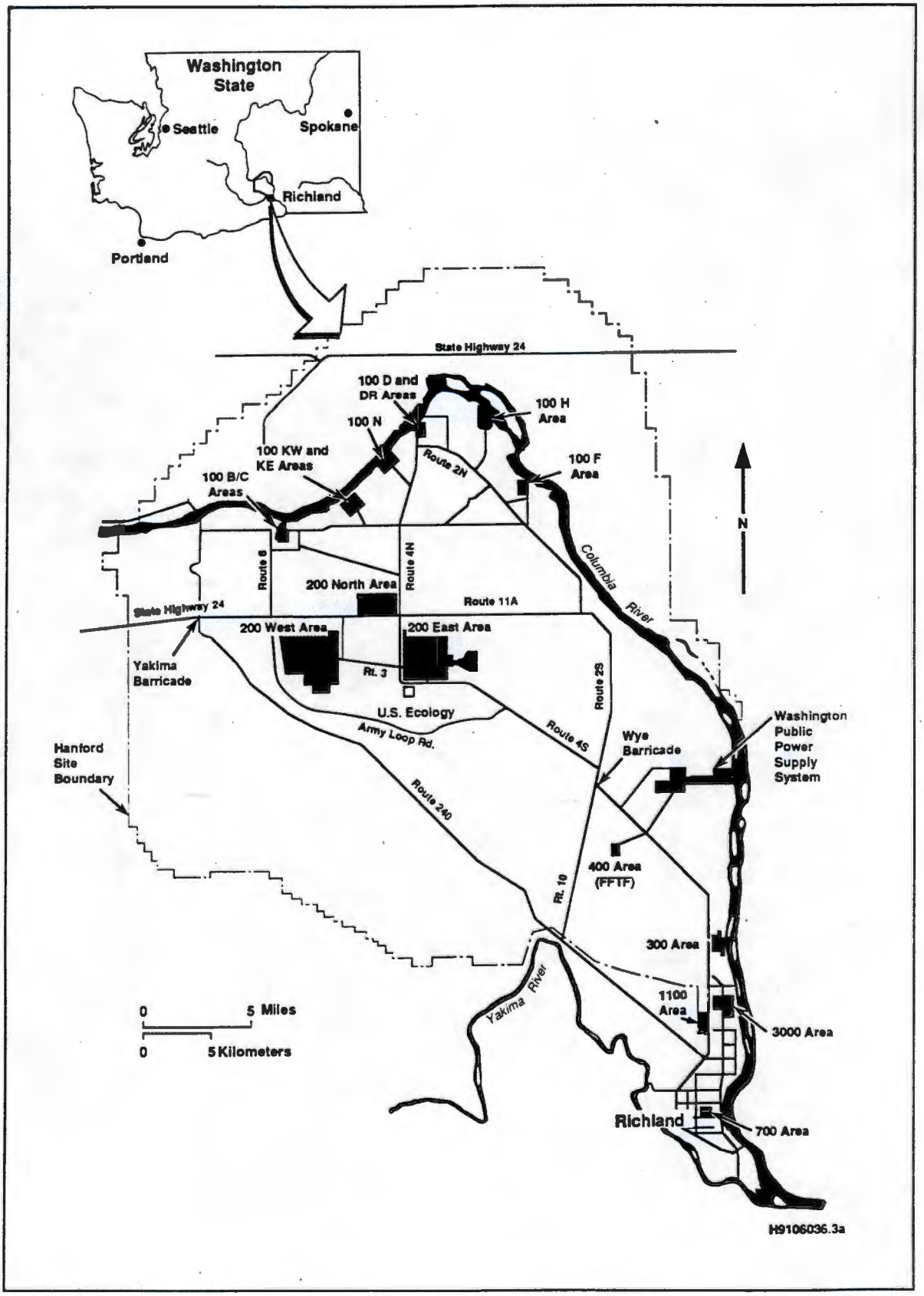

Figure 1-1. Hanford Site Map.

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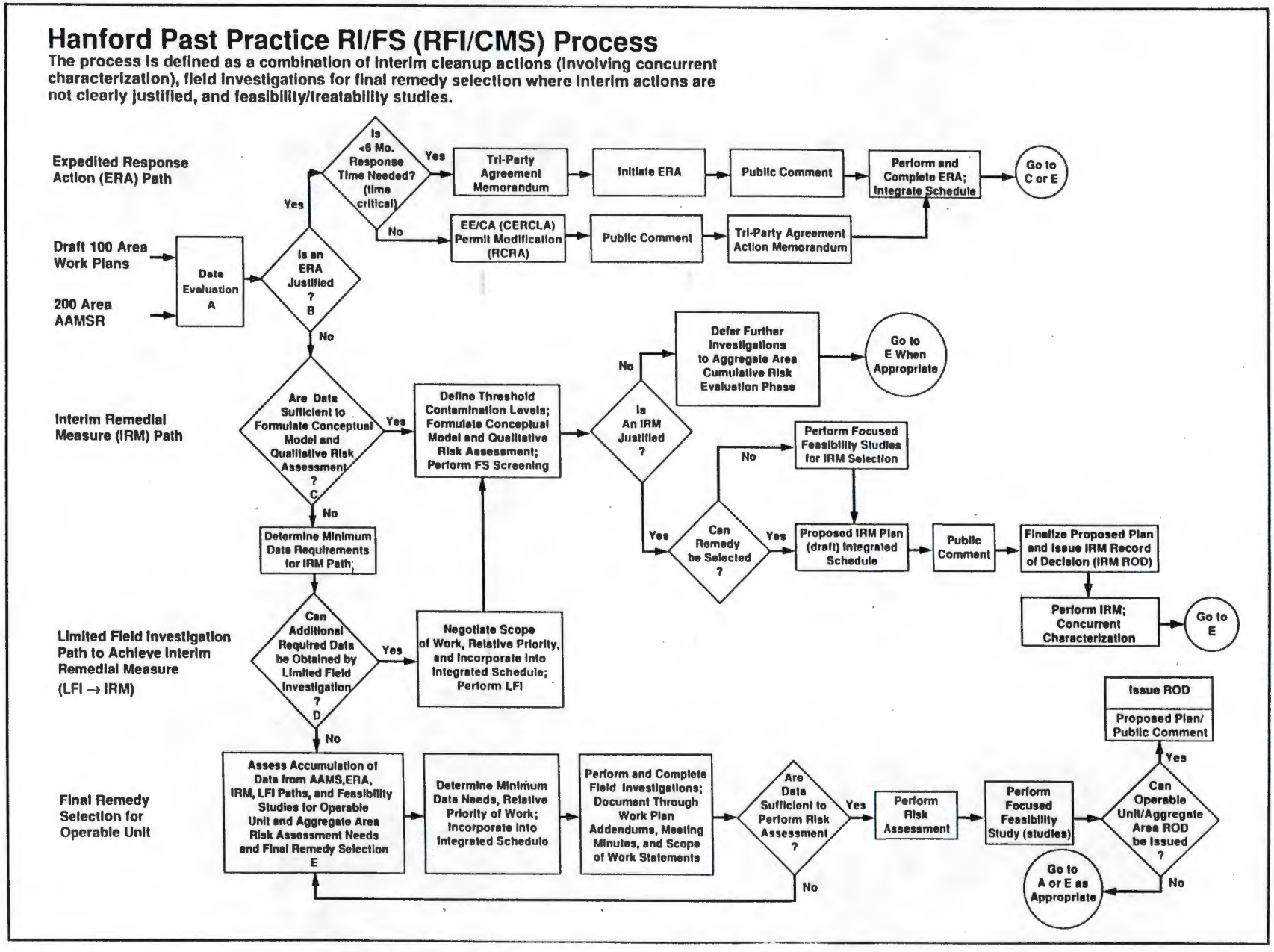

Figure 1-2. Hanford Site Past-Practice Strategy Flow Chart.

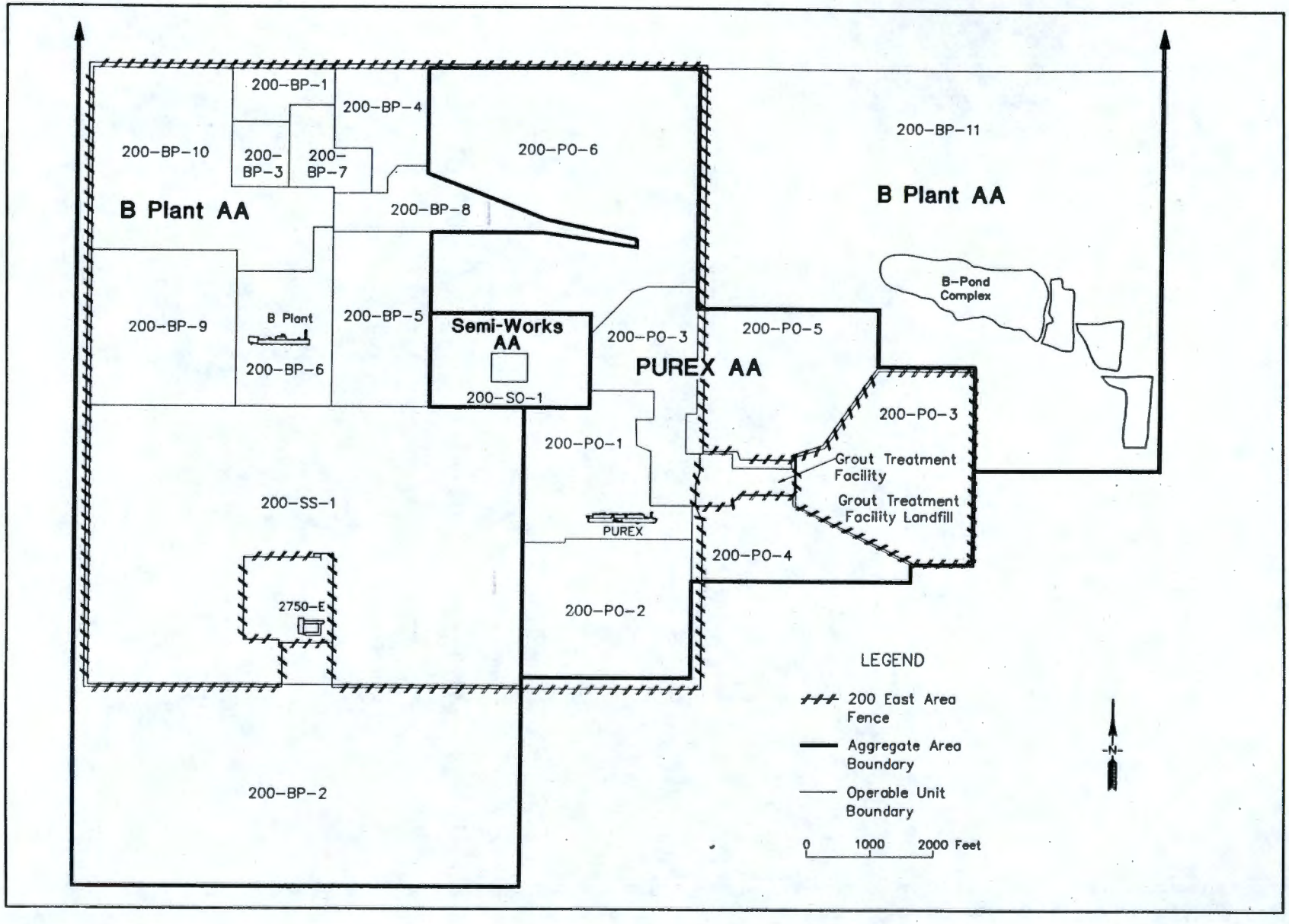

Figure 1-3. 200 East Aggregate Areas.

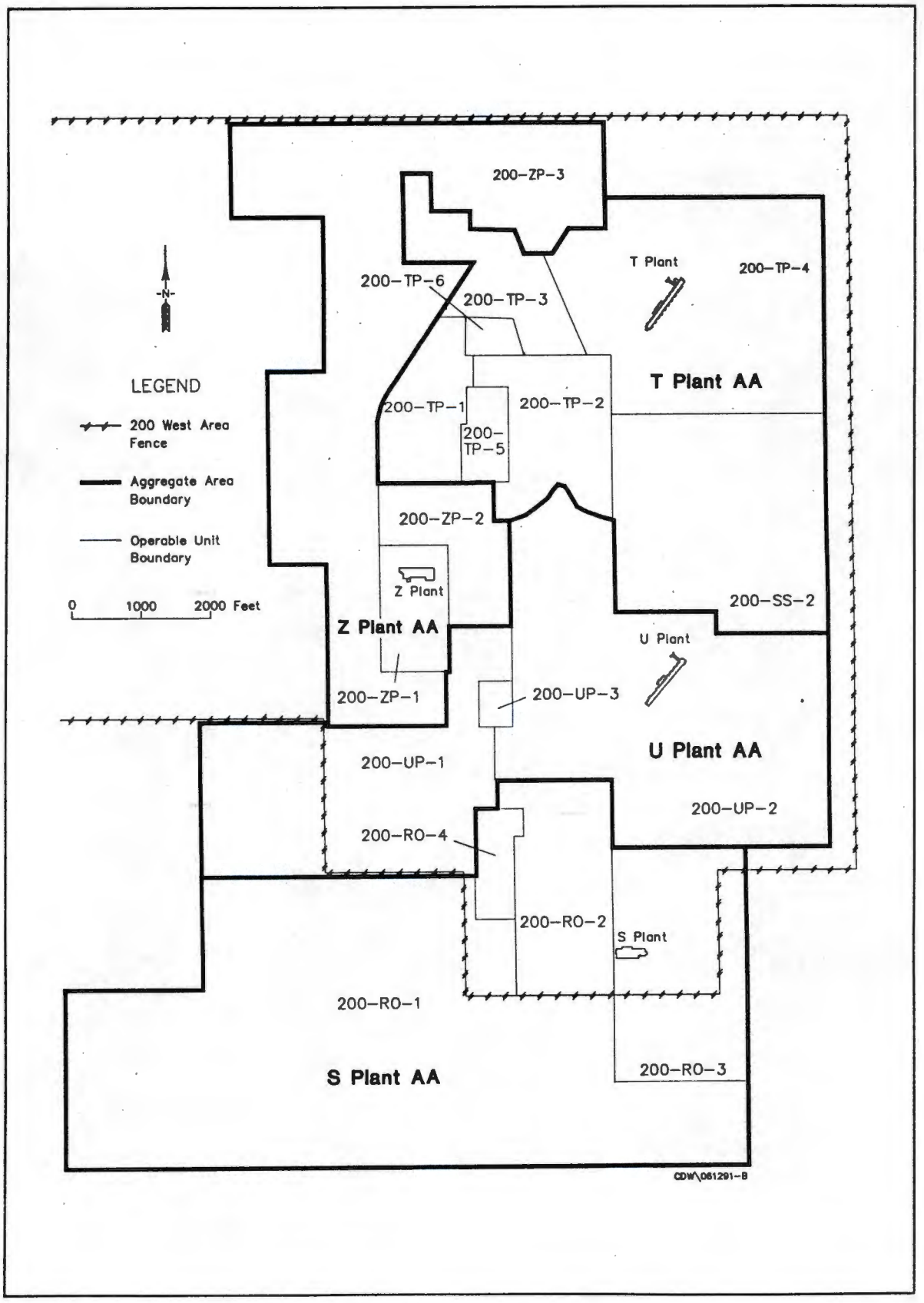

Figure 1-4. 200 West Aggregate Areas.

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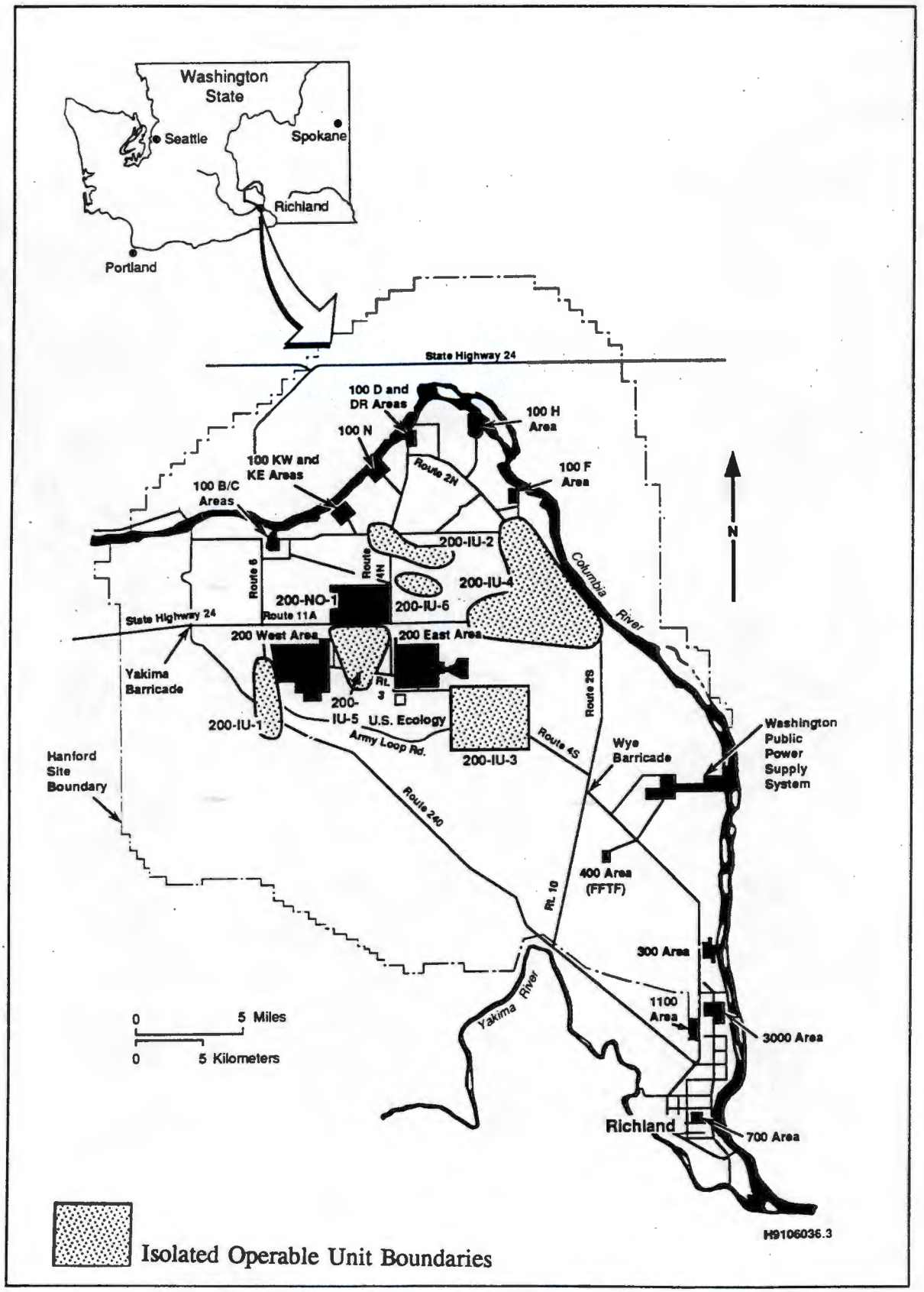

Figure 1-5. 200 NPL Site Isolated Operable Units.

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Table 1-1. Overall Aggregate Area Management Study (AAMS) Schedule for the 200 NPL Site.

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Z Plant	200-ZP-1 200-ZP-2 200-ZP-3	Source	EPA	M-27-03, February 1992
S Plant	200-RO-1 200-RO-2 200-RO-3 200-RO-4	Source	Ecology	M-27-04, March 1992
T Plant	200-TP-1 200-TP-2 200-TP-3 200-TP-4 200-TP-5 200-TP-6 200-SS-2	Source	EPA	M-27-05, April 1992
PUREX	200-PO-1 200-PO-2 200-PO-3 200-PO-4 200-PO-5 200-PO-6	Source	Ecology	M-27-06, May 1992
B Plant	200-BP-1 200-BP-2 200-BP-3 200-BP-4 200-BP-5 200-BP-6 200-BP-7 200-BP-8 200-BP-9 200-BP-10 200-BP-11 200-IU-6 200-SS-1	Source	EPA	M-27-07, June 1992
Semi-Works	200-SO-1	Source	Ecology	M-27-08, July 1992
200 North	200-NO-1	Source	EPA	M-27-09, August 1992
200 West	NA	Ground Water	EPA/Ecology	M-27-10, September 1992
200 East	NA	Ground Water	EPA/Ecology	M-27-11, September 1992

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2.0 FACILITY, PROCESS, AND OPERATIONAL HISTORY DESCRIPTION

Section 2.0 of the 200 East Groundwater Aggregate Area Management Study Report (AAMSR) presents historical data and physical descriptions of waste management units and unplanned releases that potentially impact groundwater in the three 200 East source aggregate areas and the 200 North Aggregate Area. Detailed physical descriptions and historical data on waste sources and disposal practices are presented in the four AAMSRs for the PUREX Plant, B Plant, Semi-Works, and 200 North Aggregate Areas. This information is summarized in this section, generally organized by aggregate area in the order listed above. The focus of Section 2.0 is on those waste management units and unplanned releases that potentially could impact groundwater. Section 3.0 describes the environmental setting of those waste management units. Section 4.0 discusses the contaminants detected in the 200 East Area groundwater and qualitatively relates these contaminants to waste management units and unplanned releases.

Section 2.1 describes the location of the 200 East Groundwater Aggregate Area, Section 2.2 summarizes the history of operations for the four aggregate areas, Section 2.3 describes the waste management units and unplanned releases that could potentially impact groundwater, and Section 2.4 describes the waste generating processes in the four aggregate areas that could potentially affect groundwater quality. Section 2.5 discusses interactions with other aggregate areas or operable units. Sections 2.6 and 2.7 discuss interactions with Resource Conservation and Recovery Act (RCRA) and other Hanford programs. Section 2.8 describes the groundwater monitoring facilities that are currently active in the 200 East Area. Facilities, topography, and monitoring wells are shown in detail on Plates 1, 2, and 3, respectively.

2.1 LOCATION

The Hanford Site, operated by the U.S. Department of Energy (DOE), occupies about 1,450 km^2 (560 mi^2) of the southeastern part of Washington State north of the confluence of the Yakima and Columbia Rivers (Figure 1-1). The 200 East Groundwater Aggregate Area is a controlled area of approximately 20 km^2 (7.7 mi^2) near the middle of the Hanford Site. The 200 East Groundwater Aggregate Area is about 8 km (5 mi) from the Columbia River and 11 km (6.8 mi) from the nearest Hanford boundary. There are 21 operable units grouped into four aggregate areas: PUREX Plant, B Plant, Semi-Works, and 200 North (Figures 1-1 and 1-3). The 200 East Groundwater Aggregate Area encompasses groundwater that underlies these four aggregate areas.

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2.2 HISTORY OF OPERATIONS

The Hanford Site, established in 1943, was originally designed, built, and operated to produce plutonium for nuclear weapons using production reactors and chemical reprocessing plants. In March 1943, construction began on three reactor facilities (B,D, and F Reactors) and three chemical processing facilities (B,T, and U Plants). After World War II, six more reactors were built (H, DR, C, KW, KE and N Reactors). Beginning in the 1950's, energy research and development, isotope use, and other activities were added to the Hanford operation. In early 1964, a presidential decision was made to begin shut down of the reactors. Eight of the reactors were shut down by 1971. The N Reactor operated through 1987; and was placed on cold standby status in October 1989. Westinghouse Hanford was notified September 20, 1991, that they should cease preservation and proceed with activities leading to a decision on ultimate decommissioning of the reactor. These activities are scoped within a N Reactor shutdown program which is scheduled to be completed in 1999.

Operations in the 200 Areas (West and East) are mainly related to separation of special nuclear materials from spent nuclear fuel. Spent nuclear fuel is fuel that has been withdrawn from a nuclear reactor following irradiation. The 200 East Groundwater Aggregate Area consists of four main processing areas (Figures 1-1 and 1-3).

- PUREX, where tributyl phosphate processes separate plutonium from spent uranium fuel rods
- B Plant, where bismuth phosphate processes separated plutonium from spent uranium fuel
- Semi-Works, where plutonium separation technology was developed before full-scale implementation
- 200 North, where irradiated nuclear fuel rods were stored before processing.

The 200 Areas also contain nonradioactive support facilities, including transportation maintenance buildings, service stations, and a coal-fired powerhouse for process steam production, steam transmission lines, raw water treatment plants, water storage tanks, electrical maintenance facilities, and subsurface sewage disposal systems.

2.2.1 PUREX Plant Aggregate Area

The major processes conducted at PUREX Plant Aggregate Area have been involved with uranium and plutonium recovery.

The 202-A Building (PUREX Plant) is one of the primary PUREX Plant Aggregate Area facilities. The PUREX process is an advanced solvent extraction process that uses a tributyl phosphate in normal paraffin hydrocarbon solvent for recovering uranium and plutonium from nitric acid solutions of irradiated uranium. This process occurred between 1955 and 1972. After 11 years of nonoperation, the building resumed operations in November 1983. It is currently in a standby mode.

The PUREX Plant Aggregate Area contains eight tank farms. The 241-A, 241-AX, and 241-C Tank Farms are currently inactive and have undergone initial stabilization. The 241-AN, 241-AP, 241-AW, 241-AY, and 241-AZ Tank Farms are currently active.

2.2.2 B Plant Aggregate Area

The major processes at the B Plant Aggregate Area involved extraction of plutonium from nuclear fuels; purification, precipitation, and encapsulation of cesium and strontium from PUREX-derived waste streams; various waste handling processes such as evaporation; and transfer of single-shell tank waste.

The 221-B Building is one of the primary B Plant Aggregate Area facilities. It began operation in 1945, separating plutonium by bismuth phosphate chemical methods. It ceased operation in 1952, then began various waste treatment operations in 1965. Several additions to the 221-B Building, such as the 225-B Waste Encapsulation and Storage Facility (WESF) and the 221 Cask Transfer Facility were constructed during this period.

Waste evaporators and in-tank solidification (ITS) units have been used in the 241-B, 241-BX, and 241-BY Tank Farms to minimize the volume of the tanked waste. Also, some B Plant Aggregate Area tank wastes were transferred to the U Plant Aggregate Area for uranium recovery, then returned to the B Plant Aggregate Area and disposed to the ground.

2.2.3 Semi-Works Aggregate Area

The Semi-Works Aggregate Area was composed of two primary facilities: the 201-C Process Building and the Critical Mass Laboratory (209-E Building). The 201-C Process Building was constructed in 1949 as a pilot plant for reprocessing reactor fuel using the Reduction-Oxidation (REDOX) process. In 1954 the 201-C Process Building was converted to a pilot plant for the PUREX process and functioned in this capacity until 1956 when operations were terminated. In 1961 the 201-C Process Building was again converted, this time to recover strontium from fission product waste. This facility operated until 1967, during which time it was also used for recovery of cerium, technetium, and promethium. Decommissioning work began in 1983.

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The Critical Mass Laboratory (209-E Building) operated from 1960 to 1983. Criticality experiments and research were conducted at this location. Currently, the laboratory is closed, although the administrative offices are occasionally used.

2.2.4 200 North Aggregate Area

The 200 North Aggregate Area's primary function was to store irradiated fuel from the plutonium reactors in the 100 Area. Three buildings, the 212-N, 212-P, and 212-R Buildings were constructed in 1944 for this purpose. After 1952, the buildings were no longer used to store irradiated fuel.

The 212-N Building currently is sealed and stores 2,332 m^3 (82,400 ft^3) of solid waste. The 212-P Building has been used by Hanford electricians for transformer maintenance and as a temporary polychlorinated biphenoyl (PCB) storage area. The 212-R Building is currently in laid-away status, meaning that it could be reactivated for its original purpose within six months. From 1982 to 1986, the 212-R Building was used for the maintenance, decontamination, and repair of contaminated railroad equipment.

2.3 FACILITIES AND STRUCTURES POTENTIALLY IMPACTING GROUNDWATER

The 200 East Groundwater Aggregate Area contains a large variety of waste disposal and storage facilities that were associated with the operations in the three 200 East source aggregate areas (PUREX Plant, B Plant, and Semi-Works) and the 200 North Aggregate Area. High-level wastes were stored in underground tanks. Low-level wastes such as cooling and condensate water were allowed to infiltrate into the ground through ponds, cribs, and open ditches. However some high-level waste has been disposed of in cribs and trenches and unplanned releases have introduced high-level waste into units that normally received low-level waste. These waste types are defined in DOE Order 5820.2:

- High-level waste is defined as: highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid waste derived from the liquid that contains a combination of transuranic (TRU) waste and fission products in concentrations as to require permanent isolation.

- The TRU waste is defined as: without regard to source or form, radioactive waste that at the end of institutional control periods is contaminated with alpha-emitting concentrations greater than 100 nCi/g. Heads of Field Elements

can determine that other alpha contaminated wastes peculiar to a specific site must be managed as a TRU waste.

- Low-level waste is defined as: radioactive waste not classified as high-level waste, TRU waste, spent nuclear fuel, or IIe(2) byproduct material as defined by this Order. Test specimens of fissionable material irradiated for research and development only, and not for production of power or plutonium, may be classified as low-level waste, provided the concentration of TRU waste is less than 100 nCi/g.

A discussion and detailed description of the waste management units and waste disposal practices are presented in the individual source AAMSRs for the four aggregate areas. Also included in those reports is a description of unplanned releases from waste disposal, transfer, or storage units in each of the four aggregate areas.

This section identifies and consolidates waste management units and unplanned releases that may potentially impact groundwater in the three 200 East source aggregate areas and the 200 North Aggregate Area. The waste management units within each aggregate area are divided into categories that are consistent with each source aggregate area management study (AAMS). Presented below is a description of waste management categories and the method for evaluating the potential impact on groundwater for each waste management unit and unplanned release. Table 2-1 lists the waste management units within the four source aggregate areas. Tables 2-2 and 2-3 present information used in the screening process to evaluate impact to groundwater, with a summary of waste management screening presented in Table 2-4. Tables 2-5 and 2-6 present the radionuclide and chemical waste discharge inventory for these waste management units and unplanned releases. Plate 1 shows facility locations.

The waste management unit categories are defined as follows:

- **Tanks and Vaults.** Tanks and vaults store radioactive liquid wastes generated by uranium and plutonium processing activities. Several types of tanks are present in the aggregate areas including catch tanks, settling tanks, and storage tanks. The catch tanks are generally associated with diversion boxes and other transfer units and were designed to accept overflow and spills; wastes collected in catch tanks were transferred to storage tanks. Settling tanks were used to settle particulates in liquid wastes prior to transfer to cribs. Storage tanks were used to collect and store large quantities of liquid wastes. Storage tanks include single-shell tanks and double-shell tanks, which are described in each source AAMSR.

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Vaults typically are deep underground concrete structures that contain tanks as well as associated pumps, valves, and agitators. Vaults as such do not hold wastes themselves, rather they provide containment for other types of storage features and associated plumbing.

- **Cribs and Drains.** Cribs, drains, and drain fields were designed to percolate low-level radioactive process waste or noncontact liquid waste into the ground without exposing it to the open air. Cribs and drain fields are shallow excavations that are either backfilled with permeable material or held open by wood structures, both of which are covered with an impermeable layer. Water flows directly into the backfilled material or covered open space and percolates into the vadose zone. Drains, referred to as french drains, generally deliver wastewater at a greater depth [to depths of 12 m (40 ft)] and are constructed of steel or concrete pipes that are either open or filled with gravel. The drain diameters are less than their height and are therefore registered as Class V underground injection wells under the Safe Drinking Water Act.

- **Reverse Wells.** Most of the reverse wells were installed to dispose of waste liquid directly to the subsurface. The 216-B-5 Reverse Well discharged liquid waste directly to the groundwater. The reverse wells were generally designed for disposal of low-level liquid process or laboratory wastes. Often, their use was short-lived due to clogging of formation pores around the well screen. The diameter of these wells is less than the height, therefore they are registered as underground injection wells. By 1954 all reverse wells at the Hanford Site had been removed from service (Fecht et al. 1977).

- **Ponds, Ditches, and Trenches.** Ponds were designed to percolate high volumes of low-level liquid wastewater and noncontact wastewater into the vadose zone. Ditches are long, unlined excavations used to convey wastewaters to the ponds. Several ditches often supplied wastewater to one pond.

  Trenches are generally open, unlined, shallow excavations used for disposal of low-liquid discharges such as sludge often having a high salt content. Trenches were generally used for short periods (less than one year) and were deactivated when the discharge rate exceeded the soil infiltration rate or when the volume of the liquid waste discharge reached 10% of the soil column volume beneath the trench. Trenches were generally backfilled after use.

- **Septic Tanks and Associated Drain Fields.** These structures generally received sanitary wastewater and sewage. The drain fields are similar to tile fields consisting of lengths of perforated pipe laid in excavations and covered with gravel.

- **Transfer Facilities, Diversion Boxes, and Pipelines.** Liquid wastes were transferred through a system of control structures, diversion boxes, pipelines, and valve pits. These structures are enclosures either containing jumpers or valved manifolds, which enable solution transfers via pipelines between various processes and storage facilities. Diversion boxes and receiving vaults are designed to contain leaks from the transfer operation. Pipelines are not waste management units according to the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement). High-level waste transfer pipelines will be addressed in detail under the Hanford Surplus Facilities program. Lines associated with waste management units will be addressed along with its respective units.

- **Basins.** Retention basins are typically concrete structures (including a concrete bottom) which were used for intermittent storage of liquid wastes before transfer to ponds, ditches, and cribs.

- **Burial Sites.** Burial sites are locations for the disposal of solid wastes. These solid waste disposal facilities include caissons and various types of burial trenches. A burial ground generally consists of one or more of these solid waste disposal facilities. Caissons consist of concrete/steel chambers set below ground surface with an associated steel riser pipe through which waste packages were dropped into the caisson. Drop chutes consist of vertical steel casing or open-ended 55-gallon drums welded end to end and set vertically in an excavation. After filling with solid waste packages, the drop chutes were backfilled and capped with concrete. Burial trenches are open excavations. Most of the older trenches are unlined. Some of the more recently excavated trenches have either asphalt pads or polyethylene sheet linings. Solid wastes were generally placed in 55-gallon drums or boxes, which then were set into the trench. Generally an earthen cover was placed over the burial trenches.

- **Unplanned Releases.** Unplanned releases consist of releases to the atmosphere, soil, or groundwater from the waste management units listed above. The unplanned releases of interest to the 200 East Groundwater AAMS are those releases of wastewater with sufficient volume to reach the water table. These are generally confined to leakages from the single-shell tanks.

Evaluating Potential for Releases of Contaminants to Groundwater. The following sections discuss both waste management units designed to release liquid waste to the ground and unplanned releases that may have affected groundwater. The evaluation focuses on the potential for liquid waste to reach the groundwater. Waste management units were identified as potentially contributing contaminants to groundwater based on a combination of the following criteria:

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- Discharge of liquids from the waste management unit to the vadose zone
- Discharge of liquids containing radionuclide or hazardous materials from the waste management unit to the vadose zone
- Comparison between the reported volume of liquid discharged to a unit and the estimated vadose zone soil column pore volume underlying the waste management unit
- Evaluation of geophysical logs indicating movement of liquid or contaminants to the unconfined aquifer.

Another mechanism that potentially has aided downward contaminant migration is the flow of contaminated liquids down the casing of poorly sealed wells. This mechanism is suspected in some cases, but has not been quantified. While this mechanism has not been evaluated directly in this report, review of gross gamma logs should have revealed elevated levels for wells on which such flow has occurred.

The soil column pore volume calculations are analogous to the calculations in the *Expedited Response Action Proposal for the 200 East Area Carbon Tetrachloride Plume* (DOE/RL 1991a). The volume of liquid required for a wetting front to migrate downward to the water table was estimated based on the dimensions of the base of the waste unit, conservative estimates of soil porosity, and the depth to the water table. Two soil porosities were considered: a low value (0.1) and a high value (0.3). This range of porosities should also account for drainable volumes (field capacities) for these soils. The typical depth from the bottom of the waste management unit to the water table varies across the 200 East and North Areas from 50 to 87 m (164 to 230 ft). Lateral flow or potential perching of the wetting front on a less permeable layer was not considered in this calculation. If the reported volume discharged to the waste management unit exceeded the low pore space volume estimated beneath the waste management unit (assuming a 0.1 porosity), then the unit was listed as having a potential to migrate to the groundwater. This assumption is conservative because typical porosities in Hanford soils in the vadose zone are greater than 0.2. The hydraulic conductivity of unsaturated Hanford soils in the vadose zone is very low (Section 3.5.2.1.3), therefore the transit time for unsaturated flow is too long for contaminants to reach the groundwater via unsaturated flow. In addition, this approach assumes vertical flow only. It is highly probable that some lateral spreading of the wetting front would occur.

The results of this screening are presented in Table 2-2. When interpreting the results from the calculations, note that this is a simplified, one-dimensional model that neglects lateral spreading and assumes that discharged liquid is distributed evenly across the waste management unit area and that the discharge volumes in the Waste Inventory Data System

(WIDS, WHC 1991a) are accurate. Therefore, evaluations are to be viewed as conservative approximations that estimate the relative importance of each disposal site. Table 2-2 also identifies waste management units that may have had a significant impact on groundwater flow. Units that discharged greater than 100,000 m^3 (3,500,000 ft^3) of liquid were placed in this category. The choice of 100,000 m^3 (3,500,000 ft^3) was chosen because it is, except for the ponds, one or two orders of magnitude greater than typical soil column pore volume estimates. In addition, sources of noncontaminated water (plant irrigation, water supply leaks, construction practices including water compaction of bedding and backfill soils during pipeline placement, etc.) likely contributed water to the vadose zone that may have mixed with waste and contributed to downward migration. However, this potential contribution cannot be quantified. Thus, it has been neglected in this evaluation.

Geophysical log information presented in this report is a summary of the geophysical logs reviewed for each source aggregate area. A description of the review procedure and general log quality and availability is presented in Appendix A for each AAMSR. The logs reviewed were gross gamma logs; the primary sources for these logs were Fecht et al. (1977) and periodic reports (Hanlon 1991).

The gross gamma logs for each well were compared to the geologic log to identify variabilities in the gross gamma response which could be attributed to changes in lithology. Gross gamma responses that could not be attributed to lithology were called out as possible indications of contamination. The gross gamma log evaluations are semiquantitative due to the different log vintages, and lack of quantitative calibration of the various scintillation probes. It is possible that some of the elevated responses are due to radionuclides sorbed to the well casing as annular material rather than radionuclides in the soil, but this would still indicate that contamination has penetrated to that depth. Liquid discharges from waste management units were identified as potentially impacting the uppermost aquifer if an elevated gamma response was noted below or within 10 m (33 ft) of the water table. Elevated gross gamma response within 10 m (33 ft) of the water table should cover areas where the water table has changed elevation and areas where contaminants may have drained out of the lower vadose zone. The results of this screening are presented in Table 2-3. This screening method is limited because wells where logging can be performed are often some distance from the facility being monitored and a release to the soil, even if present, may not be detected due to shielding from intervening soil. It should be noted that failure to detect elevated gross gamma levels in monitoring wells does not disprove downward contaminant migration, as the wells may not intercept the zone through which migration may have occurred. The geophysical logs serve better as positive proof of contaminant migration.

Table 2-1 presents the waste management units that have the potential to impact the unconfined aquifer. The locations of these waste management units are shown on Plate 1. The following sections further screen the waste management units within each aggregate area using the process described in the introduction to Section 2.3. A complete description of

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each waste management unit is presented in the source AAMSRs. Table 2-4 presents the results of the screening process to identify waste management units that potentially impact the unconfined aquifer. Tables 2-5 and 2-6 present information found regarding the estimated quantities of contaminants discharged to these waste management units.

2.3.1 PUREX Plant Aggregate Area

2.3.1.1 Tanks and Vaults. There are eight tank facilities within the PUREX Plant Aggregate Area: the 241-A, 241-AN, 241-AP, 241-AW, 241-AX, 241-AY, 241-AZ, and 241-C Tank Farms. In addition to the tank farms, there are six catch tanks and three vaults in the PUREX Plant Aggregate Area.

The following twelve tanks in the PUREX Plant Aggregate Area are either assumed leakers or have unplanned releases associated with them (Hanlon, 1991):

- 241-A-103 Tank
- 241-A-104 Tank/UPR-200-E-125
- 241-A-105 Tank/UPR-200-E-126
- 241-AX-102 Tank
- 241-AX-104 Tank
- 241-C-101 Tank/UPR-200-E-136
- 241-C-110 Tank
- 241-C-111 Tank
- 241-C-201 Tank
- 241-C-202 Tank
- 241-C-203 Tank/UPR-200-E-137
- 241-C-204 Tank.

To evaluate the potential for these releases to impact groundwater using the comparison of the vadose zone pore volume to the release volume, the area is required over which the

liquid wastes were released. This information is not available for unplanned releases from the tanks. Therefore, the potential for impact to groundwater could not be evaluated.

Gross gamma radiation logs for the 241-A, -AX and -C Tank Farms do not indicate release of contaminants to the groundwater from these tank farms. The 241-A Tank Farm has elevated gamma levels from the surface to 32 m (105 ft); the 241-AX Tank Farm has elevated gamma levels from the surface to 12 m (39 ft), and the 241-C Tank Farm has elevated gamma levels from the surface to 21 m (69 ft).

Two unplanned releases are associated with the 244-AR Vault. The volume of liquid released in UPR-200-E-70 is not known so the potential for impact to the groundwater could not be evaluated. The other unplanned release, UPR-200-E-59, did not involve the release of liquid to the soil.

2.3.1.2 Cribs and Drains. Twenty-four cribs and 16 french drains were identified within the PUREX Plant Aggregate Area (WHC 1991a).

Based on a comparison of the waste volume at each waste management unit with the pore volume in the soil column below the unit, the following cribs and french drains potentially contributed contaminants to groundwater:

- 216-A-3 Crib
- 216-A-4 Crib
- 216-A-5 Crib
- 216-A-6 Crib
- 216-A-7 Crib
- 216-A-8 Crib
- 216-A-9 Crib
- 216-A-10 Crib
- 216-A-21 Crib
- 216-A-24 Crib
- 216-A-27 Crib
- 216-A-30 Crib
- 216-A-36A Crib
- 216-A-36B Crib
- 216-A-37-1 Crib
- 216-A-37-2 Crib
- 216-A-45 Crib
- 216-A-11 French Drain
- 216-A-12 French Drain
- 216-A-13 French Drain
- 216-A-16 French Drain
- 216-A-17 French Drain.

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- 216-A-15 French Drain

The results of this screening are presented in Table 2-2.

In addition to potentially contributing contaminants to the groundwater, the following cribs may have had significant impact on the groundwater flow:

- 216-A-5 Crib
- 216-A-6 Crib
- 216-A-8 Crib
- 216-A-9 Crib
- 216-A-10 Crib
- 216-A-24 Crib
- 216-A-30 Crib
- 216-A-36B Crib
- 216-A-37-1 Crib
- 216-A-37-2 Crib
- 216-A-45 Crib.

Gross gamma log results were reviewed for the PUREX Plant Aggregate Area cribs and drains. The results of this review are presented in Table 2-3. The gross gamma logs support the potential for impact to the unconfined aquifer from the following cribs:

- 216-A-8 Crib
- 216-A-10 Crib
- 216-A-24 Crib
- 216-A-27 Crib
- 216-A-36A Crib.

Gamma results for several of the remaining cribs and drains indicate the presence of gamma-emitting radionuclides in the vadose zone but at depths above the water table.

A summary of the screening is presented in Table 2-4. An inventory of the radionuclides and chemicals discharged to the waste units that potentially impact groundwater is presented in Tables 2-5 and 2-6.

2.3.1.3 Reverse Well. One reverse well, 299-E24-111 Injection Well, is located in the PUREX Plant Aggregate Area. This well did not receive contaminated waste and the volume it received would not have significantly impacted the groundwater flow.

2.3.1.4 Ditches and Trenches. The two ditches and four trenches in the PUREX Plant Aggregate Area were designed to percolate low-level wastewater from various sources into the ground. Based on a comparison of the waste volume at each unit with the pore volume in the soil column below the unit, the following trenches and ditch potentially contributed contaminants to the groundwater:

- 216-A-19 Trench
- 216-A-20 Trench
- 216-A-29 Ditch.

The results of this screening are presented in Table 2-2.

In addition to potentially contributing contaminants to the groundwater, the 216-A-29 Ditch may have significantly impacted groundwater flow because of the large waste volume the ditch received.

Gross gamma log evaluations of the ditches and trenches are summarized in Table 2-3. These geophysical results do not provide evidence that contaminants have reached the groundwater from the ditches or trenches in the PUREX Plant Aggregate Area.

A summary of the screening is presented in Table 2-4. The inventory of wastes discharged to the three trenches and one ditch potentially contributing contaminants to groundwater is shown in Tables 2-5 and 2-6.

2.3.1.5 Septic Tanks and Associated Drain Fields. Seven septic tanks and associated drain fields were identified in the PUREX Plant Aggregate Area (WHC 1991a). No radionuclides or hazardous chemicals are associated with these waste management units. Therefore, these are not considered potential contributors of contaminants to groundwater. However, the 2607-E6 Septic Tank/Drain Field potentially may have affected the groundwater flow, as indicated in Table 2-2.

2.3.1.6 Transfer Facilities, Diversion Boxes, and Pipelines. Diversion boxes and sumps house the switching facilities where wastes can be routed from one process line to another. Twenty-seven diversion boxes were identified in the PUREX Plant Aggregate Area. The following three diversion boxes are associated with unplanned releases involving liquid waste being discharged to the soil:

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- 241-A-151 Diversion Box/UN-200-E-25, UN-200-E-26, UN-200-E-31
- 241-C-152 Diversion Box/UN-200-E-82
- 241-CR-151 Diversion Box/UN-200-E-81.

The volume of liquid for the unplanned releases associated with the 241-A-151 Diversion Box is not known. The volume of liquid for the unplanned releases associated with the 241-C-152 and 241-CR-151 Diversion Boxes is known, but the area that was covered by the releases is not known. Therefore, the potential of liquid reaching the groundwater is not known. Details of the unplanned releases are in Table 2-1.

2.3.1.7 Basins. Seven retention basins were identified within the PUREX Plant Aggregate Area: the 207-A Retention Basins and the 216-A-42 Retention Basin. These basins are open settling ponds where wastewater was held before overflowing into a ditch. The 207-A Retention Basins consist of six rubber-lined holding basins (WHC 1991a). The 216-A-42 Retention Basin consists of three covered concrete-lined sections. No liquid unplanned releases are associated with the retention basins in the PUREX Plant Aggregate Area. One geophysical log was examined near the 216-A-42 Retention Basin. No elevated gamma levels were detected in this log.

2.3.1.8 Burial Sites. There are five burial grounds (216-E-1, -8, -12A, -12B, and -13 Burial Grounds) and one burning pit (200-E Burning Pit) in the PUREX Plant Aggregate Area. The burial grounds reportedly received solid waste only, although some drummed liquids may have been disposed of without being reported. However, the quantity of such occasional disposal was probably not sufficient to allow liquids to migrate all the way to groundwater. Therefore, the driving force for the migration of contaminants from the burial grounds is natural recharge, which in the 200 East Area is low (see Section 3.5.2.2.1). Although contaminants may migrate from these burial grounds to the unconfined aquifer in the future, for the purposes of this study the current potential of contaminants reaching the unconfined aquifer from the burial grounds is low.

2.3.1.9 Unplanned Releases. The majority of the unplanned releases reported in the PUREX Plant Aggregate Area were confined to shallow surface spills. Many of these spills were remediated by either removing the affected soil or covering the spill area with uncontaminated fill material. Based on the low natural recharge rates in the 200 East Area, the potential for these unplanned releases in the PUREX Plant Aggregate Area to contribute contaminants to the unconfined aquifer is low. Nine unplanned releases were previously discussed with the waste management unit they were associated with. Screening of unplanned releases could not be done because the surface area of the releases is not known.

2.3.2 B Plant Aggregate Area

2.3.2.1 Tanks and Vaults. Tanks and vaults were constructed to handle and store liquid wastes generated by plutonium processing. Three tank farms, 241-B, 241-BX, and 241-BY, are present at B Plant. The following twenty tanks in the B Plant Aggregate Area are either assumed leakers or have unplanned releases associated with them (Hanlon, 1991):

- 241-B-101 Single-Shell Tank
- 241-B-103 Single-Shell Tank
- 241-B-107 Single-Shell Tank/UPR-200-E-116
- 241-B-110 Single-Shell Tank/UPR-200-E-127, UPR-200-E-128
- 241-B-111 Single-Shell Tank
- 241-B-112 Single-Shell Tank
- 241-B-201 Single-Shell Tank/UPR-200-E-129
- 241-B-203 Single-Shell Tank/UPR-200-E-130
- 241-B-204 Single-Shell Tank
- 241-BX-101 Single-Shell Tank
- 241-BX-102 Single-Shell Tank/UPR-200-E-131, UPR-200-E-132
- 241-BX-103 Single-Shell Tank/Unnumbered UPR
- 241-BX-108 Single-Shell Tank/UPR-200-E-133
- 241-BX-110 Single-Shell Tank
- 241-BX-111 Single-Shell Tank
- 241-BY-103 Single-Shell Tank
- 241-BY-105 Single-Shell Tank
- 241-BY-106 Single-Shell Tank

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- 241-BY-107 Single-Shell Tank

- 241-BY-108 Single-Shell Tank/UPR-200-E-135.

Estimated volumes of tank releases are presented in Table 2-2. To evaluate the potential for these releases to impact groundwater using the comparison of the vadose zone pore volume to the release volume, the area is required over which the liquid wastes were released. This information is not available for the unplanned releases from the single-shell tanks. Therefore, the potential for impact to groundwater could not be evaluated using this criterion.

Geophysical logs (gross gamma logs) were reviewed for the 241-B, 241-BX, and 241-BY Tank Farms to evaluate the potential of migration of gamma-emitting radionuclides to groundwater from the unplanned releases at this facility.

In the 241-B Tank Farm, elevated levels of gamma activity were detected within the backfill material around the tanks and near the surface, and within the Hanford sand beneath the bottom of the tanks. Elevated gamma activity at the base of the backfill and extending into the upper reach of the Hanford sand occurs near tanks 251-B-101, -105, -106, -107, and -110. Because of the limited depth of the wells, the possibility that gamma emitters may have reached the groundwater cannot be ruled out or confirmed.

In the 241-BX Tank Farm, elevated gamma activity is present within the backfill material around the tanks and near the surface. In addition, elevated gamma activity is indicated beneath the 241-BX-107 and 241-BX-111 Tanks within the Hanford sand. No definite migration is in evidence from the gamma logs available. Because of the limited depth of the wells, the possibility that gamma emitters may have reached the groundwater cannot be ruled out or confirmed.

In the 241-BY Tank Farm, elevated gamma activity is present within the backfill material around the tanks and near the surface, and within the Hanford sand beneath the tanks. Elevated gamma radiation is detected to the total depth of wells located near tanks 241-BY-102, -103, -104, -105, -107, and -108. The possibility that gamma emitters have reached the groundwater cannot be ruled out or confirmed.

2.3.2.2 Cribs, Drains, and Drain Fields. Twenty-four cribs and two french drains are present at the B Plant Aggregate Area. The cribs and drains typically received intermediate and low-level waste for disposal.

Based on a comparison of the waste volume in each unit with the pore volume in the soil column below the unit, the following cribs in the B Plant Aggregate Area may have contributed contaminants to the groundwater:

- 216-B-7A and B Cribs
- 216-B-8TF Crib and Tile Field
- 216-B-9TF Crib and Tile Field
- 216-B-10A Crib
- 216-B-12 Crib
- 216-B-14 Crib
- 216-B-15 Crib
- 216-B-16 Crib
- 216-B-18 Crib
- 216-B-19 Crib
- 216-B-44 Crib
- 216-B-45 Crib
- 216-B-46 Crib
- 216-B-47 Crib
- 216-B-48 Crib
- 216-B-49 Crib
- 216-B-50 Crib
- 216-B-55 Crib
- 216-B-57 Crib
- 216-B-62 Crib.

The results of the screening are presented in Table 2-2.

In addition, the screening presented in Table 2-2 indicates that the following cribs may have had a significant impact on the groundwater flow:

- 216-B-12 Crib
- 216-B-55 Crib
- 216-B-62 Crib.

Gross gamma logs were reviewed, as available, for the waste management units potentially contributing contaminants to groundwater (Table 2-3). Based on this screening, the following cribs in the B Plant Aggregate Area show evidence of contaminants reaching the groundwater:

- 216-B-14 Crib
- 216-B-16 Crib
- 216-B-45 Crib
- 216-B-46 Crib

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- 216-B-43 Crib
- 216-B-44 Crib
- 216-B-50 Crib.

A summary of the screening is presented in Table 2-4. An inventory of the contaminants discharged to these waste management units is presented in Tables 2-5 and 2-6.

2.3.2.3 Reverse Wells. There are five reverse wells, 216-B-4, -5, -6, -11A, and-11B, located in the B Plant Aggregate Area. The reverse wells were used to inject wastewater into the ground at a greater depth than possible with cribs or french drains. The 216-B-5 Reverse Well discharged waste directly to the groundwater. Based on the screening process presented in Table 2-2, all four of the other reverse wells potentially contributed contaminants to the groundwater. Gross gamma logs indicate that the 216-B-5 Reverse Well contributed contaminants to the groundwater. No gross gamma logs were available to evaluate the 216-B-4 and -6 Reverse Wells. The gamma logs available for the 216-B-11A and -11B Reverse Wells do not indicate contribution of contaminants to the groundwater.

2.3.2.4 Ponds, Ditches, and Trenches. The ponds, ditches, and trenches in the B Plant Aggregate Area were designed to percolate wastewater into the ground. There are seven ponds, six ditches, and 29 trenches in the B Plant Aggregate Area.

The 216-B-3, 216-A-25, and 216-N-8 Ponds potentially contributed contaminants to the groundwater based on the screening presented in Table 2-2. The potential contribution of contaminants to the groundwater by the 2101-M Pond and the 216-B-3A, -3B, and -3C Ponds is unknown because the liquid volume received by these ponds is unknown. Because of the large liquid volume received by the 216-B-3 and 216-A-25 Ponds, they have had a significant impact on groundwater flow.

There is no evidence of release of contaminants to the groundwater based on the gross gamma radiation logs available for these ponds.

The 216-B-2-1, 216-B-2-2, 216-B-3-1, and 216-B-3-2 Ditches may have potentially contributed contaminants to the groundwater based on the screening presented in Table 2-2. The potential contribution of contaminants to the groundwater by the 216-B-2-3 and 216-B-3-3 Ditches is unknown because the liquid volume received by these ditches is unknown. Because of the large liquid volume that passed through the 216-B-2-1, 216-B-3-1, and 216-B-3-2 Ditches they may have had a significant impact on groundwater flow.

There is no evidence of release of contaminants to the groundwater based on the available gross gamma radiation logs available for the ditches.

Based on the screening in Table 2-2, the following trenches in the B Plant Aggregate Area may have contributed contaminants to the groundwater:

- 216-B-20 Trench
- 216-B-21 Trench
- 216-B-22 Trench
- 216-B-23 Trench
- 216-B-24 Trench
- 216-B-26 Trench
- 216-B-28 Trench
- 216-B-29 Trench
- 216-B-30 Trench
- 216-B-31 Trench
- 216-B-32 Trench
- 216-B-33 Trench
- 216-B-34 Trench
- 216-B-36 Trench
- 216-B-37 Trench
- 216-B-40 Trench
- 216-B-52 Trench
- 216-B-53A Trench
- 216-B-63 Trench.

Because of the large liquid volume received by the 216-B-63 Trench, it may have had a significant impact on groundwater flow. There is no evidence of release of contaminants to the groundwater based on the available gross gamma radiation logs available for the trenches. A summary of the screening process is presented in Table 2-4. The inventory of wastes discharged to these waste management units is presented in Tables 2-5 and 2-6.

2.3.2.5 Septic Tanks and Associated Drain Fields. Nineteen septic tanks and their associated drain fields are identified for the B Plant Aggregate Area. The septic tanks accept sanitary wastewater and sewage for discharge.

Some of the septic tanks apparently have contributed a significant volume of water to the unconfined aquifer, based on the volumes indicated in Table 2-2. However, no contaminants are known to be associated with this effluent, so the potential for contributing contaminants to the groundwater likely does not exist. It is possible that these discharges can be interacting in the vadose zone with discharges from other facilities. As indicated in Table 2-2, some septic tanks probably affect the water table and groundwater flow.

2.3.2.6 Transfer Facilities, Diversion Boxes, and Pipelines. Catch tanks were designed to collect releases from transfer facilities, diversion boxes, and pipelines. Any unplanned

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releases were small; therefore, no releases to the groundwater apparently occurred from these facilities.

2.3.2.7 Basins. There are three basins within the B Plant Aggregate Area. They are concrete-lined, open settling ponds designed to hold wastewater before it is released to ditches. No discharge of effluent to the soil is reported for the 207-B and 216-B-64 Retention Basins.

The 216-B-59B Retention Basin was initially the 216-B-59 Trench. This retention basin is referred to as 216-B-59/59B Trench/Retention Basin in Tables 2-1, 2-2, and 2-4. The screening in Table 2-2 does not indicate the possible migration of waste to the uppermost aquifer from this waste management unit.

2.3.2.8 Burial Sites. There are 13 identified solid waste burial sites in the B Plant Aggregate Area: the 200-E Powerhouse Ash Pit, the 216-E-2, -2A, -3, -4, -5, -5A, -6, -7, -9, and -10 Burial Grounds. No liquids are reported to have been disposed of at these sites. Therefore, the driving force for the migration of contaminants down from the burial grounds is natural recharge, which in the 200 East Area is low. Although contaminants may migrate from these burial grounds to the unconfined aquifer in the future, for the purposes of this study the potential is low for contribution of contaminants to the unconfined aquifer from these burial grounds.

2.3.2.9 Unplanned Releases. Sixty unplanned releases are included in the B Plant Aggregate Area. Unplanned releases associated with tanks are included above in Section 2.3.2.1. Other unplanned releases are of small scale and are unlikely to have a potential impact to groundwater. Known unplanned releases are summarized in Section 2.0 of the B Plant AAMSR.

2.3.3 Semi-Works Aggregate Area

2.3.3.1 Tanks and Vaults. Three storage tanks are located within the Semi-Works Aggregate Area. No unplanned releases or leaks are reportedly associated with these units.

2.3.3.2 Cribs and Drains. Seven cribs were identified within the Semi-Works Aggregate Area. Radionuclides and hazardous materials in the liquid reportedly discharged to these seven cribs.

Based on a comparison of waste volume in each crib with the pore volume in the soil column below the crib, the following may have contributed contaminants to the unconfined aquifer:

- 216-C-1 Crib
- 216-C-3 Crib
- 216-C-4 Crib
- 216-C-6 Crib
- 216-C-10 Crib.

The results of the screening are presented in Table 2-2.

Available gross gamma logs were reviewed to further evaluate the potential of migration of liquid discharges in cribs 216-C-1, 216-C-5, and 216-C-10 to the unconfined aquifer. A summary of this evaluation is presented in Table 2-3. Based on this review, there is no evidence of release of contaminants from the cribs to the unconfined aquifer.

A summary of the screening is presented in Table 2-4. The waste inventory for these six cribs is presented in Tables 2-5 and 2-6.

2.3.3.3 Reverse Wells. One reverse well, 216-C-2, was identified in the Semi-Works Aggregate Area. The volume of waste received by the reverse well is unknown so the potential of contaminants having reached the unconfined aquifer is unknown.

2.3.3.4 Ponds, Ditches, and Trenches. One pond, 216-C-9, and one ditch, the 200 East Powerhouse Ditch, were identified in the Semi-Works Aggregate Area. Based on a comparison of waste volume at the units with the pore volume in the soil column below the units, both the 216-C-9 Pond and the Powerhouse Ditch have potentially contributed contaminants to the unconfined aquifer. In addition, both the pond and the ditch may have significantly impacted the groundwater flow based on the large volume of liquid waste they received.

One gross gamma radiation log was available for the 216-C-9 Pond. The results of this review are presented in Table 2-3. No evidence of release of contaminants to the groundwater is in evidence from this gamma log.

The waste inventory of the 216-C-9 Pond and the 200 East Powerhouse Ditch are presented in Table 2-5 and 2-6.

2.3.3.5 Septic Tanks and Associated Drain Fields. Two septic tanks and associated drain fields were identified within the Semi-Works Aggregate Area.

The volume of waste received by these septic tanks is not known so the impact on groundwater cannot be determined. There are no radioactive or hazardous wastes reported for these septic tanks and drain fields.

2.3.3.6 Transfer Facilities, Diversion Boxes, and Pipelines. Control structures, diversion boxes, and valve pits are most often concrete structures that were designed to contain leaks from transfer and drainage operations. Therefore, contaminants from these structures may migrate to the unconfined aquifer through unplanned releases. No unplanned releases are associated with the two valve pits and two diversion boxes in the Semi-Works Aggregate Area. Therefore, the potential for impact of groundwater quality from these units is low.

2.3.3.7 Basins. There are no basins identified in the Semi-Works Aggregate Area.

2.3.3.8 Burial Sites. One burial ground, 218-C-9, is located in the Semi-Works Aggregate Area. Wastes disposed of in the burial ground was limited to solid waste. Therefore, the driving force for the migration of contaminants from the burial grounds is natural recharge, which is low in the 200 East Area. Although contaminants may migrate from the burial ground to the unconfined aquifer in the future, for the purposes of this study the potential is low for contribution of contaminants to the unconfined aquifer from the burial ground.

2.3.3.9 Unplanned Releases. Four unplanned releases have been identified in the Semi-Works Aggregate Area. These releases were of a small enough scale that it is unlikely that they could potentially impact groundwater.

2.3.3.10 Newly Identified Sites. There are seven newly identified sites in the Semi-Works Aggregate Area. The sites and the little information about them are presented in Table 2-1. Not enough information (volume, surface area) is available to evaluate the impact of these sites on groundwater.

2.3.4 200 North Aggregate Area

2.3.4.1 Tanks and Vaults. One tank, the 212-P Transformer Oil Tank, is located in the 200 North Aggregate Area. No unplanned releases or leaks have been reported for this tank.

2.3.4.2 Cribs, Drains, and Drain Fields. There are no cribs or drains located in the 200 North Aggregate Area.

2.3.4.3 Reverse Wells. There are no reverse wells located in the 200 North Aggregate Area.

2.3.4.4 Ponds, Ditches, and Trenches. The ponds and trenches in the 200 North Aggregate Area were designed to percolate liquid waste into the ground. The ponds in the 200 North Aggregate Area include the 216-N-1 Pond, the 216-N-4 Pond, and the 216-N-6 Pond. The trenches are the 216-N-2 Trench, the 216-N-3 Trench, the 216-N-5 Trench, and the 216-N-7 Trench.

Based on a comparison of the waste discharged at each unit with the pore volume in the soil column below the unit, all of the ponds and trenches in the 200 North Aggregate Area may have contributed contaminants to the unconfined aquifer. In addition, the three ponds may have had a significant impact on groundwater flow. The results of this screening are presented in Table 2-2.

A summary of the screening by soil pore capacity and gross gamma logs is presented in Table 2-4, with an inventory of waste discharged to these units presented in Tables 2-5 and 2-6.

2.3.4.5 Septic Tanks and Associated Drain Fields. Three septic tanks and their associated drain fields are identified for the 200 North Aggregate Area. The septic tanks received sanitary wastewater and sewage for disposal. The volume of this waste discharge is not known; therefore, the potential impact on the groundwater is not known. Contaminants are not known to have been associated with this effluent, so the potential for contributing contaminants to the groundwater is unlikely.

2.3.4.6 Transfer Facilities, Diversion Boxes, and Pipelines. In the 200 North Aggregate Area there are no diversion boxes; however, there are three main pipelines which carried waste to the ponds from each of the irradiated fuel storage basins. No unplanned releases are associated with these pipelines.

2.3.4.7 Basins. There are no retention basins within the 200 North Aggregate Area.

2.3.4.8 Unplanned Releases. There are two unnumbered unplanned release sites in the 200 North Aggregate Area. The history of these releases is not known.

2.4 WASTE GENERATING PROCESSES THAT POTENTIALLY AFFECT GROUNDWATER QUALITY

Operations in the 200 East Area and the 200 North Area have been related mainly to nuclear fuel separation. Each of these operations generated liquid waste. The following sections briefly describe the waste generating processes and associated waste streams for each of the four source areas in the 200 East Groundwater Aggregate Area. Greater details can be found in the appropriate source AAMSR. Solid waste disposal is not considered in this

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section because the driving force for the migration of contaminants from solid waste disposal sites is natural recharge, which in the 200 East Area is low. Although contaminants from solid waste disposal sites may migrate to the groundwater in the future, for the purposes of this study the potential for solid waste contaminants reaching the groundwater is considered to be low.

2.4.1 PUREX Plant Aggregate Area

The primary waste generating processes in the PUREX Plant Aggregate Area are associated with the operation of the 202-A Building and its ancillary support facilities. Operations in the 202-A Building complex have included the recovery of uranium and plutonium from spent reactor fuels, treatment and/or storage of liquid and solid wastes, and discharge of gaseous and liquid effluents that meet environmental release criteria. This section describes the primary waste generating processes and the associated building locations in the PUREX Plant Aggregate Area including:

- 202-A Building and 293-A Building (PUREX Process)
- 242-A Evaporator (Waste Volume Reduction Process)
- 241-A-431 Condenser Building in the 241-A Tank Farm (Tank Farm Condensate).

Table 2-7 summarizes the available information about the waste streams produced within the aggregate area. In addition, some waste management units within the aggregate area received wastes from outside facilities. Some of the B Plant waste was sent to the 241-A, 241-AX, and 241-C Tank Farms. The 201-C Building (Semi-Works) waste was also sent to the 241-C Tank Farm. Sections 2.4.1.1 through 2.4.1.3 describe the PUREX Plant Aggregate Area waste generating processes that were previously mentioned.

2.4.1.1 PUREX Process. The 202-A Building was the primary location of the PUREX process. The PUREX chemical separation processes are based on dissolving jacketed fuel rods in nitric acid and conducting multiple purification operations on the resulting aqueous nitrate solution. The goal is to extract, purify, and concentrate the uranium, plutonium and neptunium produced from the declad fuel elements. The driving forces for the separations consist of concentration changes, temperature changes, and chemical additions. The process steps include fuel-element decladding, uranium metal dissolution, solvent extraction, ion exchange, and product load-out.

The PUREX process begins with zirconium cladding on fuel elements being removed in an ammonium fluoride-ammonium nitrate (AFAN) solution. Ammonium nitrate is required

to react with the ammonia and hydrogen that evolve during decladding due to the potential combustion hazard. Nitric acid is used to dissolve declad fuel elements for the solvent extraction process. The solvent extraction process used a light phase solvent, tributyl phosphate, in a normal paraffin hydrocarbon (kerosene) diluent to extract the uranium, plutonium, and neptunium from the fission products. The organic phase is sent to the partitioning cycle where the plutonium is partitioned from the uranium and neptunium. The plutonium stream is routed through two additional solvent-extraction cycles for further purification. After purification, the plutonium stream is concentrated. The other stream from the partition cycle, which bears the neptunium and uranium, is routed to the final uranium cycle where neptunium is separated. The aqueous neptunium stream is sent to the backcycle waste system for concentration and recycling to the solvent-extraction column. The uranium stream is routed to a column that strips the uranium from the organic stream with an aqueous nitric acid solution. The uranium product, uranyl nitrate hexahydrate, is then stored in tanks until it is shipped to the UO_3 Plant in the U Plant Aggregate Area.

The 202-A Building is the source of five liquid effluent streams. These liquid effluent streams are the process condensate (PDD), cooling water (CWL), steam condensate (SCD), chemical sewer (CSL), and ammonia scrubber distillate (ASD). The PDD stream comes from the concentration stages of the PUREX process. The concentration changes are provided by dilution with water and by removal of water by boiling. Most, but not all, of the water removed by boiling is recycled back into the dilution stages of the process. The fraction of water not recycled is disposed of through the PDD stream. Steam condensate and warm water constitute the liquid effluents from the PUREX process in the CWL, SCD, and most of the CSL streams. The steam condensate and warm water effluents are the condensed steam used for boiling process solutions and the warmed cooling water used for condensing the resulting process vapors. The rest of the CSL stream comes from ventilation, heating, water services, and room drainage (mostly shower rooms, water coolers, housekeeping water, and steam and water leaks, together with occasional chemical leaks). The ASD stream is the result of the first step in fuel dissolution, which produces large quantities of gaseous ammonia. The ammonia is scrubbed from the offgas with water to prevent releasing the ammonia to the air. Then the resulting ammonia solution is boiled to concentrate the ammonia and radionuclides for disposal to underground storage tanks. The condensed vapor becomes the ASD stream.

One of the secondary facilities within the PUREX process is the 293-A Building. This building houses the back-up facility, which removes nitrogen oxides from the dissolver offgas stream then converts them to nitric acid. Offgases are treated with hydrogen peroxide to remove the nitrogen oxides. The nitric acid is then recycled into the PUREX process via the 206-A Building.

Process wastes from the 202-A Building were discharged to various waste management units including the following:

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- 216-A-1 and 216-A-2 Cribs
- 216-A-21 and 216-A-27 Cribs
- 216-A-11 and 216-A-12 French Drains
- 216-A-18 and 216-A-19 Trenches
- 216-A-29 Ditch/discharged to 216-B-3 Pond
- 241-A, 241-AX, and 241-C Tank Farms
- 216-A-42 Retention Basin/discharged to the 216-A-30 Crib, 216-A-37-2 Crib, and 216-B-3 Pond via the 216-A-29 Ditch.

2.4.1.2 Waste Volume Reduction Process. The 242-A Evaporator started operation in 1977. The purpose of this facility is to reduce the volume of radioactive liquid waste by evaporating water from the feed solution to produce a concentrated salt solution. The solution separates upon cooling to form salt cake and residual liquor. This process reduces the number of double-shell tanks required to store this type of waste by 35 to 60%.

The 242-A Building contains the evaporator vessel, supporting process equipment, and the principal process components of the evaporator-crystallizer (EC) system. The building comprises two adjoining, structurally independent structures, designated A and B. Structure A houses the processing and service areas while structure B houses operating and personnel support areas.

Process condensate from the 242-A Evaporator flows into one of the three cells at the 207-A Retention Basins until it reaches operational capacity. At this time the steam condensate flow is diverted to one of the two remaining cells. The cell that has reached capacity is then sampled and analyzed at the 222-S Laboratory for radionuclides as an indication of process control. The steam condensate from the full diversion basin is then discharged to the 216-B-3 Pond if the analytical results are within set radionuclide limits.

Process wastes were discharged to various waste management units including the following:

- 216-A37-1 Crib
- 207-A Retention Basins/discharged to double-shell tanks.

2.4.1.3 Tank Farm Condensate. Condensate waste from the 241-A Tank Farm was condensed in the 241-A-431 Building. The waste was then directed to eight waste management units. The condensate was primarily water and included entrained radionuclides and chemicals from the waste in the tanks. The following waste management units received condensate waste:

- 216-A-9 Crib
- 216-A-16 and 216-A-17 French Drains
- 216-A-23A and 216-A-23B French Drains
- 216-A-19 and 216-A-20 Trenches
- 216-A-34 Trench.

2.4.2 B Plant Aggregate Area

Several processes have operated in the B Plant Aggregate Area since the construction of the original 221-B Building in 1945.

The 221-B Building (B Plant) was the second fuel reprocessing plant at the Hanford Site to separate plutonium from other fission products. The 221-B Building originally used the bismuth phosphate process to recover plutonium from irradiated uranium fuel pellets and operated from 1945 to 1952. In 1968, the plant was restarted with a new process to recover cesium and strontium from single-shell tank wastes. The plant continued this mission until 1984. The 221-B Building also has a low-level radioactive waste concentration process that reduces the volume of wastes by evaporating water from them. This process has not been used since 1986.

Equipment conversions were made at 221-B Building beginning in 1986 to process NCAW and a test quantity of 80,000 L (20,000 gal) was processed. However, this mission for the 221-B Building has not been approved and the current processing mission of the 221-B Building has not been defined. The 225-B Building includes the WESF, which was designed to convert strontium and cesium solutions that were recovered at the 221-B Building, crystallize them, and store them in stainless steel cylinders that are immersed in a cooling water bath. Other waste generating processes in the B Plant Aggregate Area include the 242-B Evaporator used to reduce liquid volume in single-shell tanks and two ITS units (ITS-1 and ITS-2) that directly evaporated water from single-shell tanks.

Table 2-7 summarizes the available information about the waste streams produced within the aggregate area. Sections 2.4.2.1 through 2.4.2.11 describe the B Plant Aggregate Area waste generating processes in more detail.

2.4.2.1 221-B Building Bismuth Phosphate Plutonium Recovery Process. This was the original process for which the 221-B Building was designed and constructed in 1945. This process was designed to separate and concentrate the small amounts of plutonium contained in the irradiated fuel pellets produced in the 100 Area reactors. In the bismuth phosphate process, all of the material contained within the irradiated fuel pellets was discarded as waste except for the recovered plutonium.

The first step in the bismuth phosphate process was to remove the aluminum cladding surrounding the fuel. This was done by dropping the pellets into a tank containing a solution of sodium hydroxide which preferentially dissolved the aluminum surrounding the pellet. Sodium nitrate was added to the solution to prevent the formation of excessive quantities of hydrogen gas during the dissolution of the aluminum metal. The waste solution from the cladding dissolution step contained sodium aluminate, sodium nitrate, and sodium nitrite as well as small amounts of fission products. This waste solution was combined with the first-cycle decontamination waste and transferred to single-shell tank storage (Waite 1991).

The next step in the process was to dissolve the uranium and extract the plutonium. The decladded uranium slugs were rinsed with water and dissolved in 50 to 60% nitric acid. Excess uranium metal remained in the dissolver as a heel to increase the rate of dissolution. The completion of the dissolving step was determined by specific gravity that was measured with a pair of bubbler tubes immersed in the solution (Ballinger and Hall 1991).

The plutonium was recovered from the dissolved uranium solution by adding sodium nitrate solution to convert the plutonium to the +4 valence state. Next, bismuth nitrate and phosphoric acid were added. Sulfuric acid was also used at this point in the process. The resulting precipitate of bismuth phosphate carried 99% of the plutonium with it. This precipitate was separated from the solution in a solid-bowl centrifuge, and the solution was transferred to single-shell tank storage as the metal waste stream (Ballinger and Hall 1991). The metal waste stream contained the bulk of the uranium and approximately 90% of the long-lived fission products (e.g., ^{137}Cs and ^{90}Sr) (Waite 1991).

Once the plutonium had been extracted in the precipitate, it went through two decontamination cycles to purify it further. In the first decontamination cycle, the precipitate was washed in the centrifuge and dissolved in strong nitric acid. The valence of the plutonium was then adjusted to +6 by the addition of a sodium dichromate solution and a precipitate of bismuth phosphate was again formed using bismuth nitrate, phosphoric acid, and sodium metabismuthate. However, this time the precipitate captured some of the fission products that were not extracted in the first liquid waste stream and the plutonium remained

in solution. The precipitate was separated from the liquid product stream, dissolved in nitric acid, and transferred as a liquid to be mixed with other liquid wastes from the first decontamination cycle.

Following separation from the waste precipitate, a precipitate containing the plutonium was formed from the product solution using ammonium fluorosilicate, ferrous ammonium sulfate, bismuth oxynitrate, and phosphoric acid. The plutonium-containing precipitate was separated from the solution and the solution was transferred to single-shell tank storage along with the other liquid wastes from the first contamination cycle. The plutonium product precipitate was dissolved in nitric acid prior to further processing (Ballinger and Hall 1991). The waste stream from the first decontamination cycle contained almost 10% of the long-lived fission products and was sent to single-shell tank storage (Waite 1991).

The second decontamination cycle was performed on the plutonium solution remaining from the first decontamination cycle to further purify it by removing additional fission products from the plutonium solution. The same process was used for the second decontamination cycle as was used for the first decontamination cycle. The waste stream from the second cycle contained less than 0.1% of the fission products. This was sent to single-shell tanks for storage until 1948. Because of limited tank space, the second-cycle waste supernatant was discharged directly to cribs and trenches from 1948 until the 221-B Building was shut down in 1952. This included second cycle material that had previously been stored in tanks (Waite 1991).

The product from the bismuth phosphate process was a dilute plutonium nitrate solution. This was transferred to the 224-B Concentration Facility to be purified and reduced in volume. The solution was first oxidized with sodium bismuthate. Next, phosphoric acid was added to precipitate byproduct followed by centrifugation. Product solution was treated with hydrogen fluoride and lanthanum salt to precipitate byproduct. Following separation by centrifuge, product solution was treated with oxalic acid, hydrofluoric acid, and lanthanum salt to precipitate plutonium and lanthanum fluoride. These solids were centrifuged from the solution and washed with water. The plutonium fluoride metathetically evolved to form plutonium hydroxide by digestion with hot potassium hydroxide. The solid hydroxides were centrifuged and dissolved in nitric acid to form plutonium nitrate, which was transferred in cans to the Isolation Building (the 231-Z Building in the Z Plant Aggregate Area).

The plutonium nitrate-lanthanum nitrate solution sent to the Isolation Building was treated with ammonium sulfite and sulfate. In addition, it was treated with hydrogen peroxide to form plutonium peroxide in two precipitations followed by dissolving in nitric acid. The final plutonium nitrate was concentrated in a still and then concentrated in a sample can by evaporation to a thick paste. The liquid waste stream from the 224-B Concentration Facility concentration processing was initially discharged to the 241-B-361

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Settling Tank when processing began in 1945. The overflow from the settling was discharged to the 216-B-5 Reverse Well.

Beginning in 1947, the 224-B Concentration Facility waste was routed to the 241-B-201 through 241-B-204 (208,000 L, 55,000 gal capacity) Single-Shell Tanks for settling before being discharged to cribs. This discharge continued until the bismuth phosphate process was shut down in 1952. The primary concern about the waste streams from the 224-B Concentration Facility was plutonium. The majority of the plutonium remained in the tanks after settling. However, the waste from this facility was the primary contributor of plutonium to the ground from all of the tank waste discharges (Ballinger and Hall 1991).

2.4.2.2 221-B Building Strontium and Cesium Recovery. In 1963, the 221-B Building began recovering strontium, cerium, and rare earths using an acid-side, oxalate-precipitation process as part of the Phase I processing for the 221-B Building Waste Fractionization Project. A centrifuge was used to separate the phases. The lead, cerium, and rare earth fractions were dissolved in nitric acid and stored. The strontium fraction was thermally concentrated and stored. Portions of the strontium and rare earths produced in Phase I were pumped by underground transfer line to the Semi-Works for purification of the ^{90}Sr fraction and separation of the rare earth fraction in ^{144}Ce and a rare earth fraction including ^{147}Pm. Phase I processing at the 221-B Building ended in June 1966 to accommodate Phase III construction.

The objective of the Phase I processing was to restore services to the 221-B Building after its extended shutdown and to accumulate an inventory of fission products. The Phase II portion of the project was the installation of facilities necessary to demonstrate a process system for packaging the long-lived fission products as a small volume concentrated waste. The purpose of Phase III was to provide waste fractionization facilities in the 221-B Building for processing high level wastes from PUREX Plant Aggregate Area and the B Plant Aggregate Area tank farms into fractions that could be immobilized and contained more safely.

The Phase III Waste Fractionization processing began at the 221-B Building in 1968. This process separated the long-lived radionuclides, ^{90}Sr and ^{137}Cs, from high-level PUREX and REDOX wastes and stored a concentrated solution of ^{90}Sr and ^{137}Cs at the 221-B Building. Individual tanks at the B Plant Aggregate Area contained up to 35 MCi of ^{90}Sr or ^{137}Cs at concentrations up to 10,000 Ci/gal. The combined storage capacity of the tanks was estimated to be 85 MCi of ^{90}Sr and 25 MCi of ^{137}Cs.

Three processes were used for the waste fractionization. The first process was the feed preparation and solvent extraction of current acid wastes generated by the 202-A Building and stored at PUREX Plant Aggregate Area and REDOX tank farms. The solids in these wastes contained about 55% of the strontium and 70% of the rare earths. The solids,

consisting mostly of silicates, phosphates, and sulfates, were treated by a carbonate-hydroxide metathesis solution to convert the sulfates to carbonate-hydroxide solids. These solids were then separated from the solution by centrifuge and dissolved in nitric acid to recover the fission products. The dissolved fission products were combined with original acid waste supernate after it had been treated to form feed for the solvent extraction columns by adding a metal-ion complexing agent, a pH buffer, and a pH adjustment solution.

The feed went through a series of solvent extraction columns. The solvent used was a mixture of di(2-ethylhexyl) phosphoric acid extractant and tributyl phosphate modifier in a normal paraffin hydrocarbon diluent. The strontium, cerium, and other rare earths were extracted from the aqueous phase into the solvent. The aqueous fraction contained the cesium and was routed to the 241-A or 241-AX underground tank farms in the PUREX Plant Aggregate Area for temporary storage to allow the decay of short-lived activity.

The strontium fraction was stripped from the solvent with dilute nitric acid and thermally concentrated with the Cell 5 concentrator for storage in tanks in the 221-B Building Cells 6 to 8. The cerium and rare earth fraction was stripped from its solvent with nitric acid, combined with organic wash wastes, and sent to single-shell tank storage. The solvent was washed and recycled for reuse.

The second process used was a feed preparation and solvent extraction process for processing stored sludge wastes from the 241-A, 241-AX, and 241-SX Tank Farms. The sludge was sluiced with supernate and water and pumped out of the tanks to the 244-AR or 244-SR Vault. At these vaults, the sluicing water was decanted for storage to await treatment for cesium removal. The sludge, containing the bulk of the fission products, was dissolved in nitric acid and transferred to the 221-B Building for treatment.

At the 221-B Building, the rare earths and strontium were precipitated as sulfates using lead sulfate as a carrier to separate them from iron and aluminum. A sodium hydroxide-sodium carbonate metathesis was performed to convert the sulfates to hydroxides and carbonates and to eliminate the bulk of the lead. The product cake was centrifuged, dissolved with nitric acid, and accumulated for solvent extraction treatment. The solvent extraction was similar to the solvent extraction for the current acid waste, except that the waste aqueous fraction from the initial solvent extraction containing the rare earths and the solvent wash wastes were thermally concentrated at the 221-B Building using the Cell 20 concentrator and transferred to immobilization processing (in-tank solidification).

The third waste fractionation process was the ion exchange of stored cesium supernates and sluicing solutions. High-level tank farm supernates and sluicing water containing ^{137}Cs was passed through an ion-exchange column at the 221-B Building. The cesium and a small fraction of sodium were adsorbed on a synthetic alumino-silicate zeolite. About 97% of the adsorbed sodium and 0.5% of the loaded cesium were designed to be removed from the

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column with a dilute ammonium and carbonate-ammonium hydroxide scrub solution. Following this, the remaining cesium was removed with a concentrated mixture of ammonium carbonate and ammonium hydroxide. The cesium was thermally concentrated in the Cell 20 concentrator and stored in tanks in 221-B Building Cells 14 and 17. The waste from the adsorption step was routed directly to in-tank solidification. The column wash wastes and scrubs were thermally concentrated in the Cell 23 concentrator prior to transfer to in-tank solidification. In 1974, the 221-B Building began using Cell 38 to perform final purification of the cesium prior to processing at the WESF. The WESF is described in Section 2.4.4. The strontium solvent extraction process operated until 1978. Cesium final purification ended in 1983 and strontium purification ended in 1984.

Wastewater continues to be generated from the 221-B Building from heating, ventilation, and air conditioning (HVAC) systems, floor drains, and steam condensate drains. This stream is known as the B Plant Chemical Sewer Stream and was disposed of to the 216-B-63 Trench. In February 1992, the effluent piping was revised to allow the chemical sewer stream to be discharged to the B Plant Cooling Water Stream which ultimately reaches the 216-B-3 Pond.

2.4.2.3 221-B Building Waste Concentration Process. The waste fractionization process described in Section 2.4.2 included a thermal evaporation concentrator in Cell 23 to concentrate process wastewaters prior to disposal. This system was used to concentrate low-level radioactive waste after the cesium and strontium waste fractionization process was shut down in 1984. Double-shell tank waste was received at the 221-B Building to be processed through the low-level waste concentrator until 1986. The 221-B Building received no double-shell tank wastes after April 1986 and processing of these wastes was complete by late 1986. Other sources of the low-level waste included miscellaneous sumps and drains in the WESF, which diverted decontamination waste solutions generated in the WESF process cells. Another contributor was a liquid collection system located beneath the 40 cells in the 221-B Building that collected cell drainage from decontamination work and water washdowns in the processing section of the 221-B Building. The concentrator also processed wastes produced by the cleanout of various process vessels at the 221-B Building and WESF through 1986 (Peterson 1990a).

The concentrator process consisted of a vertical, single-pass, shell-and-tube thermal-recirculated and steam-heated evaporator. The evaporator had two bundles of tubes that contained low-pressure steam to heat the process feed. The tube bundles heated the feed to the boiling point and vaporized it. The evaporated liquid passed through a high-efficiency de-entrainer to remove entrained liquid droplets and was condensed as process condensate (Peterson 1990a). The process condensate was disposed of in the 216-B-12 Crib beginning in May 1967 when disposal to the 216-B-12 Crib began again. In November 1973, the process condensate was diverted to the 216-B-62 Crib. Disposal continued to this crib until

the concentrator was shut down (RHO 1986). The process condensate is known as the B Plant Process Condensate Stream.

The steam that was used to heat the feed was condensed by the heating process and was collected as steam condensate. The steam condensate was disposed of to 216-B-3 Pond until September 1967. In 1967, it was diverted to the 216-B-55 Crib (Peterson 1990b). The steam condensate is known as the B Plant Steam Condensate Stream.

The liquid remaining in the evaporator was reduced in volume by the removal of water through evaporation. The concentrated liquid waste was transferred to tank farm storage. The concentrator was shut down in January 1987 for repairs to its de-entrainment system (Peterson 1990b). The concentrator was restarted in April 1988 and over 2,000,000 L (500,000 gal) of flush water was processed through the concentrator to ensure that residuals from past processing were removed. The flush water was disposed of in double-shell tank underground storage (Peterson 1990a).

2.4.2.4 225-B Building Waste Encapsulation and Storage Facility. In 1974, four processes were undertaken at the WESF in the 225-B Building located west of, and attached to, the 221-B Building. Three processes were discontinued in 1984 and one process, capsule storage, is still in operation.

The first process converted purified cesium carbonate to cesium chloride. The cesium carbonate was converted to cesium chloride by the addition of 12 M hydrochloric acid. Carbon dioxide and heat were released during the reaction. The cesium chloride solution was cooled with a cooling coil and air sparging through mixing. The offgas from the acidification process was vented through a de-entrainer, condenser, and a scrubber which neutralized the hydrochloric acid. The cesium chloride solution was transferred to an electrically heated melter crucible which boiled the liquid away and then melted the cesium chloride salt. The molten cesium chloride was poured into capsules.

The second process converted strontium nitrate to strontium fluoride. The strontium nitrate was transferred to a precipitation tank and powdered sodium fluoride was added to precipitate the strontium as a slurry of strontium fluoride. The slurry was filtered to produce a cake that was allowed to dry and self-heat. The cake was loaded into a furnace boat which was placed into a furnace at a sintering temperature of 800 °C (1,472 °F) to remove water and nitrate volatiles. The sintered strontium fluoride was dumped or air chiseled out of the furnace boat and loaded into a capsule and compacted.

The third process was the encapsulation of the strontium and cesium. Two capsules were used to encapsulate the material; an inner capsule which contained the cesium or strontium, and an outer capsule which enclosed the inner capsule. The capsules arrived at the WESF with one end welded on. Ultrasonic inspection was performed by the

manufacturer to verify weld penetration. At the WESF, the capsules were first degreased with acetone and weighed. After the inner capsule was filled it was purged with helium and sealed by welding a cap on the open end. Weld inspection was done visually and by a helium leak detection process in a vacuum chamber. A final check was done using a bubble test.

Following testing, the capsules were decontaminated by placing them in a capsule scrubber and an electropolisher. After decontamination, the capsule was placed into an outer capsule and a cap was welded onto the open end of the outer capsule. The outer capsules were subjected to additional inspections using ultrasonic scanning followed by calorimetry to determine curie levels. The finished capsule was weighed and the known weights of the inner and outer capsules subtracted. The net weight of the capsule content was divided into the curie content to give the curie output per gram. Capsules that did not pass testing were disassembled and reworked. The contents were removed from the defective capsule and the process was repeated. The rejected capsule was discarded as solid waste.

The final process conducted at the WESF is capsule storage. This storage process continues to operate to maintain the inventory of capsules stored at the WESF. The finished capsules are smear sampled for loose residual contamination and decontamination if necessary. A surface contamination of less than 200 ct/min is required before the capsule can be stored in the capsule storage area. The completed capsule is transferred using pool cell tongs to one of eight capsule storage pools. The capsule is transferred through a transfer aisle filled to a depth of 3 m (9 ft) with demineralized water and placed in one of the storage pools that is filled to a depth of 3.3 to 4 m (11 to 13 ft) of water. The water provides both radiation shielding and a means of removing heat generated by the radioactive decay of the capsule contents. Each storage pool contains a vertical turbine pump that circulates the pool water continuously. The recirculated water passes through the tube side of a heat exchanger and is returned to the bottom of the pool cell. Raw water passes through the shell side of the heat exchanger to cool the pool water. If the pool water becomes contaminated, it is diverted to the 221-B Building low-level waste header (see Section 2.4.3). The raw water that is used for cooling passes through the heat exchanger and is discharged through the 216-B-2-3 Ditch to the 216-B-3 Pond. In an emergency, cooling water is diverted to the 216-B-63 Trench. The flowrate of cooling water used for WESF capsule storage cooling is about 5.7 m^3/min (1,500 gal/min) (Peterson 1990c). The cooling water is known as the B Plant Cooling Water Stream.

2.4.2.5 242-B Evaporator System. In December 1951, the 242-B Thermal Evaporation System was placed into operation at a location south of the 241-B Tank Farm. The evaporator was installed to evaporate cladding/first cycle waste and reduce the waste volume (Waite 1991). The evaporator was a steam-heated pot evaporator that operated at atmospheric pressure (Jungfleisch 1984). The liquors were partially boiled down to produce a more concentrated waste. The water that was evaporated from the waste was discharged as

242-B Evaporator process condensate to the 216-B-11A and 216-B-11B Reverse Wells. The evaporator bottoms were initially placed into single-shell tank storage (Anderson 1990). In 1954, evaporator bottoms from the 242-B Evaporator were discharged to the 216-B-37 Trench (Maxfield 1979). The 242-B Evaporator was shut down in December 1954 and was never restarted (Anderson 1990).

2.4.2.6 In-Tank Solidification Process. Two in-tank solidification units were installed in the 241-BY Tank Farm. The objective of the in-tank solidification units was to heat waste liquors while they were inside of a single-shell tank and remove water leaving a solid salt cake behind in the tank. The first unit, ITS-1, began operation in March 1965. It used a hot air sparge into the tank. The air sparging was done on one individual tank. The hot air caused water in the tank to evaporate leaving the air and solids behind (Anderson 1990). The evaporated water was condensed and discharged to the 216-B-50 Crib. The cooling water was discharged to the 216-B-2-2 and 216-B-3-2 Ditches.

The second unit, ITS-2, began operation in February 1968. This unit used electrical immersion heaters to heat the tank contents. The heated liquor was then transferred to other tanks. In August 1971, ITS-1 was modified to become a cooler for ITS-2. Both units were shut down in June 1974.

2.4.2.7 Wastes Generated at the 221-U Building. In 1952, the previously unused 221-U Building began operation with a process using tributyl phosphate in a kerosene (paraffin hydrocarbon) diluent to recover uranium metal from metal waste that was in single-shell tank storage at the 221-B and 221-T Buildings. The aqueous phase waste stream from the solvent extraction process was neutralized with sodium hydroxide and transferred to the B Plant Aggregate Area for storage in single-shell tanks.

In addition to tributyl phosphate wastes, evaporator condensate from the 221-U Building was transferred to the 216-B-12 Crib for disposal between November 1952 and December 1957. Lanthanum fluoride wastes from the 221-U Building were also stored in single-shell tanks in the 241-B Tank Farm.

2.4.2.8 In-Tank Scavenging. A ferrocyanide scavenging process began in 1954 to attempt to reduce the volume of wastes that had to be stored in single-shell tanks. The objective of the scavenging process was to precipitate the soluble long-lived ^{137}Cs from the 221-U Building uranium recovery waste supernatant that had been stored in B Plant Aggregate Area single-shell tanks. The other principal long-lived fission product, ^{90}Sr, was already essentially insoluble in the neutralized uranium recovery waste and precipitated without adding scavenging chemicals. However, during the later operational years of the process, calcium nitrate or strontium nitrate were added to enhance the precipitation of the ^{90}Sr.

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After precipitation, the waste was allowed to settle in single-shell tank storage and the solid precipitate particles settled to the bottom of the tanks as sludge. Following settling, the supernate was decanted from the sludge, tested for the applicable discharge requirements, and discharged to the ground.

Beginning in 1954, the newly-generated uranium recovery waste was scavenged in the 221-U Building and transferred to the B Plant Aggregate Area for settling in the single-shell tanks. Then it was discharged to the ground either through cribs or specific retention trenches. This scavenging process ended in June 1957.

Starting in May 1955, scavenging was also done on 221-U Building tributyl phosphate wastes that had previously been stored in single-shell tanks. The wastes were pumped to the 244-CR Vault in the PUREX Plant Aggregate Area where they were scavenged. The waste was then routed back to single-shell tanks for settling and the supernatant subsequently was pumped to the ground. This was referred to as "in-tank farm" scavenging. The scavenging in the 244-CR Vault ended in December 1957 and the last of these wastes was discharged to the ground in January 1958 (Waite 1991). Waste management units that received tributyl phosphate waste are the 216-B-14 through 216-B-19 Cribs, the 216-B-20 through 216-B-34 Trenches, the 216-B-42 Trench, the 216-B-43 through 216-B-49 Cribs, and the 216-B-52 Trench.

2.4.2.9 Wastes Generated at the 202-A Building. The 202-A Building produced coating wastes from the dissolution of the irradiated fuel pellet cladding that were disposed of to single-shell tanks in the 241-B and 241-BY Tank Farms.

2.4.2.10 Wastes Generated at S Plant. The S Plant located in 200 West operated between 1951 and 1967 and used a methyl isobutyl ketone (MIBK) solvent extraction process to accomplish the separation of uranium and plutonium from the irradiated fuel pellets. High level wastes were transferred to the 241-B-103 Single-Shell Tank. Waste from ion exchange processing was transferred to the 241-BX-101, 241-BX-103, and 241-BX-106 Single-Shell Tanks storage.

2.4.2.11 Analytical Laboratory Programs. The 222-B Laboratory supported operations at the 221-B Building complex and other 200 Area facilities with laboratory services. A liquid waste stream was generated from the laboratory facility that included sample disposal waste and hood and hot cell cleanup waste. Sampling and testing equipment, gloves, empty containers, and other materials were buried as solid waste. Laboratory liquid wastes were directed to the 216-B-6 Reverse Well from April 1945 to December 1949 and to the 216-B-10A Crib from December 1949 to January 1952.

2.4.3 Semi-Works Aggregate Area

The primary waste generating activities at the Semi-Works Aggregate Area include historical operations in the 201-C Process Building (Semi-Works Complex) and the Critical Mass Laboratory (209-E Building). Other facilities that generated wastes include:

- 276-C Solvent Handling Facility
- 291-C Ventilation System Stack
- 215-C Gas Preparation Building
- 271-C Aqueous Makeup and Control Building.

For the facilities listed, the following sections describe the waste generating processes, the resulting waste streams, and waste stream disposition and disposal. The discussions incorporate information from reference sources reviewed for this report, including Anderson (1990), Nielsen (1990), Cummings (1989), and Evans and Tomlinson (1954). Additional information regarding the nature of waste generating processes and resulting waste streams was not found during document review. Semi-Works waste producing processes and waste stream characteristics are summarized on Table 2-7.

2.4.3.1 201-C Process Building (Semi-Works Complex). A primary component of the Semi-Works Aggregate Area is a five-celled chemical processing facility, the 201-C Process Building, with ten support facilities surrounding it. The building complex was constructed in 1949 as a pilot plant for the reprocessing of reactor fuel using the REDOX process. In 1954, the facility was converted to a pilot plant for the PUREX process. It continued in this capacity until it was shut down in 1956. As a pilot fuel reprocessing plant, nuclear reactor fuel was brought into the facility and dissolved. The plutonium was separated, purified, loaded, and shipped out to other Hanford Site facilities.

After extensive cleaning and decontamination, the buildings were modified and put back into operation in 1961 for the recovery of strontium from fission product waste. Megacurie quantities of strontium were recovered, purified, and loaded into casks for offsite shipment. The facility was known as the Strontium Semi-Works during this period. The last processing operation, performed in 1967, was the recovery of cerium, technetium, and promethium.

The REDOX process was used to separate uranium and plutonium from fission products and from each other. The basis of the process was the extraction of uranium and plutonium from an aqueous, high-salt solution into an organic solvent MIBK or hexone. This operation was conducted continuously in columns, packed with Raschig rings, through

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which the aqueous and organic phases were passed countercurrently. Uranium and plutonium were separated by converting the plutonium to a lower valence state, in which form it was preferentially extracted back into an aqueous phase of high-salt content in a second column. Uranium was then returned to an aqueous phase of low-salt content in a third column. The products were purified further in similar, additional cycles (Evans and Tomlinson 1954).

The PUREX process used tributylphosphate in kerosene solvent to extract plutonium and uranium from acid solutions of irradiated uranium. Nitric acid was used to promote extraction of plutonium and uranium as opposed to metallic nitrates used in the REDOX process (Cummings 1989).

The strontium recovery process was performed utilizing a complex liquid organic ion exchanger, di-2-ethyl-hexyl phosphoric acid, to extract strontium from acid solutions of waste fuels (Cummings 1989).

Liquid waste streams from the 201-C Process Building consisted of wastes from the pilot REDOX and PUREX recovery activities in the 1950's, and from strontium, cerium, promethium, and technetium recovery in the 1960's. Before commencing the actual pilot recovery activities, extensive "cold-run" trials were conducted routinely using nonradioactive materials to verify the operational status of the equipment. The following discussion summarizes the waste streams generated from these processes.

Wastes generated during the REDOX process included coating wastes from decladding of aluminum fuels in a boiling sodium nitrate/sodium hydroxide solution. The waste stream was composed primarily of uranium, plutonium, sodium hydroxide, sodium aluminate, sodium nitrate and nitrite, and sodium silicate. The waste solution was transferred to a tank separate from the high level waste. During the REDOX processes, Zircaloy-clad fuels were declad in an ammonium nitrate-ammonium fluoride mixture. The REDOX waste stream was composed of large volumes of aluminum nitrate, zirconium oxide, sodium fluoride, sodium nitrate, potassium fluoride, uranium, and plutonium. Other wastes associated with the REDOX process included chromate, sodium sulfate, and ferric hydroxide compounds in addition to many of the other compounds listed. Waste streams from the REDOX process were slightly acidic and contained fission products. The coating wastes from the aluminum and Zircaloy-clad fuels decladding were neutralized with caustic acid.

The PUREX process generated wastes from decladding of aluminum and Zircaloy fuels which were reportedly identical to those generated from REDOX decladding. During the PUREX process, a potassium permanganate, sodium carbonate, and nitric acid wash was used to separate organic compounds from a process extraction solvent prior to reuse of the solvent. The PUREX organic wash wastes primarily included sodium nitrate, sodium carbonate, manganese oxide, and uranium. Acidic PUREX wastes were neutralized

high-level wastes containing nitrate, ferrous sulfate, ferrous phosphate, sodium, and aluminum.

Limited information from Cummings (1989) indicates that the strontium recovery process in the 201-C Process Building used a complex liquid organic ion exchanger, di-2-ethyl-hexyl phosphoric acid, to extract strontium from acid solutions of waste fuels. No information regarding specific characteristics of wastes derived from cerium, technetium, and promethium recovery were found in the documents reviewed.

Radioactive condensates derived from processes associated with REDOX and PUREX between 1953 and 1957 contained ^{137}Cs, ^{106}Ru, ^{90}Sr, ^{239}Pu and uranium based on information from WIDS (WHC 1991a). Cummings (1989) reported the presence of additional radionuclides including tritium, ^{60}Co, and ^{238}U in the waste stream. Nonradioactive constituents in PUREX process condensates included dilute nitric acid and other inorganic contaminants. Process condensates generated between 1964 and 1969 at the 201-C Process Building were acidic.

Limited information was obtained regarding the nature of cold-run wastes derived from start-up trials for Semi-Works processing. Historical cold-run wastes are likely characterized by high-salt content, low organics, and as neutral to basic.

Unspecified wastes were also derived from the 201-C Process Building hot shop sink.

Wastes from the 201-C Process Building were chemically and radiologically contaminated, and their disposition was accomplished in accordance with their radiological content. In general, high-level wastes were stored in underground tanks in the 200 East Area tank farms, and intermediate level wastes were routed in cribs in the Semi-Works Aggregate Area for disposal. Low-level wastes were discharged in the 216-C-9 Pond.

High-level process wastes from 201-C Process Building had been routed to the 241-CX-70 and 241-CX-71 Storage Tanks from 1952 to 1957. PUREX wastes were routed to the 241-CX-72 Storage Tank during 1955, and later, wastes with high levels of radioactivity from the strontium recovery process were routed to the tank. Unspecified material from the 201-C Process Building hot shop sink was routed to the 241-CX-71 Storage Tank. Neutralized acidic wastes from the PUREX process were also routed to the 241-C Tank Farm. Acidic wastes from the 201-C Process Building may have been neutralized with crushed lime in the 241-CX-71 Storage Tank, prior to discharge of the process wastes in the 216-C-1 Crib. Decontamination "flushes" of the 241-CX-71 Storage Tank following cessation of PUREX operations utilized potassium permanganate, caustic soda, hydrogen peroxide, tartaric acid, nitric acid, sodium fluoride, oxalic acid, and commercial cleaning agents "Oakite 31" and "Turco 4128A."

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Waste streams from processing activities in the 201-C Processing Building were routed to onsite cribs, based on the characteristics of the following streams:

- Acidic, radioactive wastes from REDOX operations in 1953 and 1954 were discharged to the 216-C-3 Crib. Acidic process condensates from PUREX and strontium recovery operations were discharged to the 216-C-6 Crib between 1955 and 1964, and to the 216-C-6 Crib from 1964 to 1969 (strontium recovery).

- High-salt, neutral-to-basic process condensates and cold-run wastes from REDOX and PUREX operations were discharged to the 216-C-1 Crib between 1953 and 1957, and to the 216-C-5 Crib in 1955 (PUREX).

Additionally, low-level process cooling water and other unspecified waste streams from the 201-C Process Building (and other site buildings as discussed below) were discharged to the 216-C-9 Pond between 1957 and 1985. The bulk of the waste is reported from 201-C Process Building since 1967.

2.4.3.2 Critical Mass Laboratory. The Critical Mass Laboratory housed in the 209-E Building was in operation from 1960 to 1983 to conduct criticality experiments with plutonium nitrate and enriched uranium solutions. Experiments were also performed using solid special nuclear materials and fuels. During this period, the number of experiments performed in the Critical Mass Laboratory averaged 15 per year with a maximum of 50 a year (Nielsen 1990).

The laboratory generated mostly acidic liquid waste containing mainly ^{137}Cs, ^{106}Ru, ^{90}Sr, plutonium, uranium, and some nitrates. These wastes are further characterized as neutron reflector tank water (Nielsen 1990).

The 216-C-7 Crib received about 60,000 L (16,000 gal) of liquid waste from the Critical Mass Laboratory transferred through the Critical Mass Laboratory Valve Pit. In the documents reviewed no other waste management units received process waste from the laboratory.

2.4.3.3 276-C Solvent Handling Facility. The 276-C Solvent Handling Facility contained equipment and tanks for the treatment and storage of process solvents used in the 201-C Process Building operations. Radiologically contaminated, intermediate-level, low-salt, neutral-to-basic organic wastes had been discharged to the 216-C-4 Crib between 1955 and 1965.

2.4.3.4 291-C Ventilation System Stack. The 291-C Ventilation System provided exhaust air ventilation for operation cells and process vessel vents from the 201-C Process Building. Exhaust air was discharged from the 291-C Ventilation System stack after passing various

filters. Between 1953 and 1958 low-salt, neutral-to-basic stack drainage and ventilation filter seal water drainage were discharged at the 216-C-2 Reverse Well.

2.4.3.5 215-C Gas Preparation Building and 271-C Aqueous Makeup and Control Building. The 215-C Gas Preparation Building and 271-C Aqueous Makeup and Control Building provided support services for the 201-C Process Building. Acid wastes from these facilities had been discharged to the 216-C-1 Crib (along with similar wastes from the 201-C Process Building) between 1953 and 1957.

2.4.4 200 North Aggregate Area

The facilities of the 200 North Aggregate Area were built to temporarily store irradiated fuel elements produced in the plutonium reactors in the 100 Area. Relatively little waste was generated from these storage facilities, hence there are few waste management units in the 200 North Aggregate Area.

The water used to store, shield, and cool the fuel was discharged into the ground via ponds. In addition, sediment that collected in the bottom of the storage basins was discharged to trenches following the shutdown of the storage facilities. Table 2-7 summarizes the available information about the waste streams produced within the aggregate area.

2.4.4.1 Irradiated Fuel Storage Operations. Three 200 North Aggregate Area buildings, the 212-N, 212-P, and 212-R Storage Facilities, contained storage basins and transfer facilities for moving buckets of irradiated fuel elements from the 100 Area into and out of the lead casks which were transported in railroad wellcars to the 200 North Aggregate Area. The fuel elements were irradiated in the reactors in the 100 Area and discharged from the reactors directly into water-filled basins adjacent to the reactors. The fuel elements were then placed into special "buckets" which were in turn hoisted into the lead casks. Approximately 105 fuel elements, weighing about 384 kg (845 lb), were placed into a bucket. The buckets were loaded into the lead-shielded casks, which weighed about 15,400 kg (17 tons), and three casks were loaded onto each railroad wellcar for transport to the 200 North Aggregate Area storage facilities. The casks were filled with water and cooled with pipes through which water flowed to prevent overheating and localized hot spots in the buckets.

At the 212 Buildings, the casks were lifted out of the wellcars by crane and lowered into a water-filled transfer pit. As a cask was lowered, its cover was removed by a ledge at the top of the pit. The cover was moved aside and a yoke was lowered from the overhead crane to pick up each bucket for transfer to the storage basin.

Irradiated fuel elements were stored in the basins for about 40 to 60 days in the early years. Water continuously flowed through the basins to prevent localized hot spots. Two wells located just east of the 212-R Storage Facility supplied the water to the storage basins. This water was unfiltered, meaning that dissolved and suspended solids in the water had the potential to be exposed to radiation from the fuel elements. Each storage facility had heating equipment to keep the water from freezing. Water overflow from the storage basin in each of the storage facilities basin was transported by an underground pipeline to its associated pond located about 275 m (900 ft) south of the storage facility.

Each of the three ponds, 216-N-1, 216-N-4, and 216-N-6, consisted of depressions existing in the natural terrain. Except for an occasional berm, no excavation or other effort was made to define or enhance the pond formation. The discharged water dispersed by evaporation and percolation into the soil.

Cooling time, or the time between the discharge of an irradiated fuel element and its processing, was used primarily to reduce the radioactivity of gaseous fission products (primarily iodine) by allowing the radioactive decay of the short-lived radionuclides before the dissolution of the fuel in the separation plants.

When the irradiated fuel was ready to be transferred to the separations processing areas, the transfer procedure was reversed to return the buckets to the casks and onto the wellcars. The wellcars were transferred to the separations plants by rail where they were again unloaded.

The storage of the irradiated fuel elements in the facilities in the 200 North Aggregate Area was found to be unnecessary because the storage basins at the reactors in the 100 Areas were large enough to store the fuel elements for the shorter periods that were eventually found to be adequate. However, in the processing configuration in use at Hanford from 1945 to 1952, the separations plants had processed fuel faster than the reactors had produced it. Therefore, when problems interrupted production at the separations facilities (B Plant or T Plant), the fuel elements had been stored in the 200 North storage facilities so that production at the reactors could continue. Later, the separations plants resumed production and worked off the extra quantity of fuel elements. In 1952, however, the B Plant separations facility was shut down and replaced by a more efficient process at the S Plant, and the T Plant operated at a reduced rate of production. The output from the reactor areas had increased by the construction of new reactors and the output from the existing reactors also had increased. By 1952, there was no longer a need for the excess fuel storage facilities in the 200 North Aggregate Area and the 212-N, 212-P, and 212-R facilities were shut down in June 1952.

The water that flowed through the storage basins in the 200 North Aggregate Area had the potential to become contaminated through exposure to radiation from the fuel elements,

through particulate contamination from the surface of the fuel elements, or by leakage through the aluminum cladding that enclosed the irradiated fuel elements.

Leakage through the aluminum cladding surrounding the fuel element was less likely before 1952 when reactor power levels were stepped-up to increase production. The most likely means for a cladding-failed fuel element to reach the 200 North Aggregate Area may have been through mechanical shock caused by handling. The fact that low levels of radiation have been detected underground at several 200 North Aggregate Area waste management units indicates that a small amount of radioactivity may have escaped the cladded fuel elements by some means.

All the 212 Storage Facilities were shut down in June 1952. As part of the shutdown procedure, the fuel storage basins were drained and cleaned. The water and sediment in the storage basins were disposed of by pumping to shallow [approximately 2 m (6 ft)] trenches located about 30 m (100 ft) northwest of each storage building. The trenches were immediately backfilled after disposal. The basin in the 212-N Building was first drained and cleaned in 1947 for a special test that is not documented. The water and basin sediments from this first cleanout were placed in the 216-N-2 Trench. The 212-N Storage Basin was drained and cleaned for the shutdown in 1952 and the cleanout wastes were placed in the 216-N-3 Trench. The storage basins in the 212-P and 212-R Buildings were cleaned only once in 1952, and the wastes were placed in the 216-N-5 and 216-N-7 Trenches, respectively.

Each of the three 200 North Aggregate Area storage facilities was surrounded with a high-security fence and guard towers. A gatehouse was located about 50 m (164 ft) south of the building. Each gatehouse had a septic tank and drain field south of its location. The fences, guard towers, and gatehouses have been partially removed so that only concrete foundations remain.

2.4.4.2 Electrical Maintenance Activities. Since 1982 the 212-P Storage Facility has been used as an electrical maintenance facility by Hanford electricians and as a temporary storage area for PCBs. Transformers and capacitors requiring servicing have been worked on at this facility. Drained items were occasionally stored on an asphalt pad at the site. The PCB-contaminated soils are temporarily stored in a small aboveground tank. Other PCB-contaminated wastes are stored in drums in a storage facility adjacent to the 212-P Building and inside the 212-P Building.

2.4.4.3 Railroad Car Maintenance Activities. From the spring of 1982 until the fall of 1986 the 212-R Storage Facility was used as a railroad car maintenance site. Railcars needing brake or wheel bearing maintenance were brought to the site, decontaminated, and repaired. The decontamination was done by wiping the surfaces of the equipment with swabs wetted with a liquid solvent. The decontamination wastes were placed in bags and

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transported to solid waste burial sites outside of the 200 North Aggregate Area. Although no longer used as a maintenance site, two locomotive engines and two wellcars (one without wheels) were spotted on the rail spur in front of the 212-R Building during a site visit in May 1992. They are surrounded by chain and marked as a surface contamination site.

2.5 INTERACTIONS WITH OTHER AGGREGATE AREAS OR OPERABLE UNITS

The 200 East Groundwater Aggregate Area interacts with several other organizational units involved in the remedial action process on the Hanford Site. These features include other groundwater aggregate areas, source aggregate areas, and operable units. These interactions can take place at various scales including within the 200 East Groundwater Area, between the 200 West and 200 East (and 200 North) Areas, and across the entire Hanford Site. The interactions can be hydrologic, operational (administrative), and regulatory. This section discusses these interactions.

This study, the 200 East Groundwater AAMS, recommends future investigative actions for groundwater beneath an area slightly larger than the 200 East and 200 North Areas administratively delineated on the Hanford Site (see Section 2.1). The study addresses groundwater contamination originating from facilities in the 200 East and 200 North Areas, and so its areal extent (which is somewhat loosely defined) includes as much of the administrative "600 Area" as needed to encompass the spread of contamination (plumes) in the unconfined aquifer from the 200 East and 200 North Areas. Also, because of the same difference in focus, the areal coverage is also different from the combined area of the three 200 East source aggregate areas (PUREX Plant, B Plant, and Semi-Works) and the 200 North source aggregate area.

The 200 East Groundwater Aggregate Area must nevertheless be compatible with the three 200 East source aggregate areas and the 200 North Aggregate Area, since the contamination addressed in the study must have originated from waste management units in these source areas which discharged to the vadose zone in sufficient quantities to impact the groundwater system (see Section 2.3). It is also possible that some vadose zone (or perched water zones) still hold contamination from these facilities which can yet be mobilized, and may still impact groundwater quality. In this way, remedial actions in the source aggregate areas may affect remedial options for the groundwater aggregate area.

Implementation of remedial actions based on the 200 Areas groundwater AAMS (East and West) can also interact in a variety of ways. Most significantly, changes in the geohydrologic system in the 200 East Area can directly change flow pathways of groundwater migrating from the 200 West Area. Currently the effect of large discharges to the ground occurring in the 200 East Area causes a mounding of the groundwater beneath the site, and thereby affects groundwater to the west. This effect is partly to stagnate (reduce

the gradient of) the groundwater in the region between the two 200 Areas (where stagnation primarily underlies the western portion of the 200 East Area) and partly to divert these flows toward the north or south around the mound. This hydrologic linkage would also extend to remedial actions that may be recommended for the 200 West Groundwater Aggregate Area. Pump and treat, or containment alternatives can cause similar effects (qualitatively although probably not quantitatively if at a smaller scale of discharge). The cause and effect relationship can also occur in the opposite direction (200 East to 200 West), since alteration of groundwater flow in the 200 West Area may affect groundwater flow beneath the 200 East Area.

There is also potentially a similar interaction with the 100 Areas operable units in that contamination from the 200 East Groundwater Aggregate Area (particularly the northern portion) if unremediated could pass through Gable Gap and reach the Columbia River through one or more of the 100 Areas (under present groundwater conditions it could be any of these). This would complicate monitoring of concentration changes in those areas and could even interfere with remediation that might be proposed for these areas. Because of uncertainties in flow patterns and future modifications in groundwater recharge, this possibility is a very uncertain, long term, and limited inference.

Finally, the 200 East Groundwater AAMS also interacts with the operable units in the 200 East and 200 North source aggregate areas by defining new groundwater operable units. An operable unit is a portion or aspect of a remedial action site which can best be planned and remediated as a single entity. At the Hanford Site, an operable unit is usually a group of waste management units which are spatially close to each other and generally share a similar disposal history. Prior to the AAMS process, 12 of the 21 operable units in the 200 East and 200 North areas were also considered for groundwater contamination (i.e., were also groundwater operable units). These included:

- 200-BP-1
- 200-BP-2
- 200-BP-3
- 200-BP-4
- 200-BP-11
- 200-IU-6
- 200-NO-1
- 200-PO-1
- 200-PO-2
- 200-PO-4
- 200-PO-5
- 200-SO-1.

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These earlier groundwater operable units are proposed to be replaced with groundwater operable units which are defined more on the basis of flow patterns and plume distribution (see Section 9.3).

2.6 INTERACTION WITH RESOURCE CONSERVATION AND RECOVERY ACT PROGRAMS

Groundwater monitoring is currently being performed at 14 RCRA TSD units and one nondangerous waste facility (i.e., the Solid Waste Landfill). Of the 19 RCRA TSD units, most will be closed under interim status, and a final status permit is being, or will be sought for the remainder. RCRA-regulated facilities include the Nonradioactive Dangerous Waste Landfill (NRDWL), located approximately 5.5 km (3.5 mi) southeast of the 200 East Area. The NRDWL is included with 200 East Area RCRA facilities in this section due to the presence of tritium and ^{129}I groundwater contaminant plumes that have been identified in this area during 200 East Area groundwater monitoring (Section 4.1.4). The NRDWL, along with the Solid Waste Landfill, are parts of the old Central Landfill Complex. Although not currently an RCRA-regulated facility, the Solid Waste Landfill has monitoring wells meeting RCRA compliance standards and is included here for completeness.

The RCRA groundwater monitoring projects are conducted at three levels, as described below:

- **A background monitoring program.** The purpose of this program is to gather data from upgradient monitoring wells to determine the levels of constituents and parameters in groundwater unaffected by the monitored RCRA facility.

- **An indicator evaluation program.** The purpose of this program is to compare background monitoring program data with indicator program data to determine if significant differences exist between upgradient and downgradient groundwater constituents or parameters. This program is frequently run simultaneously with the background monitoring program, if possible.

- **A groundwater quality assessment program.** The purpose of this program is to determine if the groundwater is being adversely affected by wastes managed at the monitored RCRA facility. It is initiated if the indicator program shows significant differences.

Several RCRA groundwater monitoring projects may be encompassed in the 200 East Groundwater Aggregate Area. As of December 31, 1991, the associated RCRA groundwater

monitoring projects and their respective groundwater monitoring program status are as follows:

- **Grout Treatment Facility.** This project is currently in a groundwater quality assessment program.

- **216-B-3 Pond.** This project is currently in a groundwater quality assessment program.

- **216-A-29 Ditch.** This project is currently in a groundwater quality assessment program.

- **216-A-36B Crib.** This project is currently in an indicator evaluation program.

- **216-A-10 Crib.** This project is currently in an indicator evaluation program.

- **216-B-63 Trench.** This project is currently in a background monitoring program.

- **Liquid Effluent Retention Facility.** This project is currently in a background monitoring program.

- **2101-M Pond.** This project is currently in an indicator evaluation program.

- **Low-Level Waste Management Area 1 (LLWMA 1).** This project is currently in a groundwater quality assessment program.

- **Low-Level Waste Management Area 2 (LLWMA 2).** This project is currently in an indicator evaluation program.

- **Single-Shell Tanks Waste Management Area A/AX.** This project is currently in a background monitoring program.

- **Single-Shell Tanks Waste Management Area BX/BY.** This project is currently in a background monitoring program.

- **Single-Shell Tanks Waste Management Area C.** This project is currently in a background monitoring program.

- **Nonradioactive Dangerous Waste Landfill.** This project is currently in an indicator evaluation program.

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As discussed above, the Solid Waste Landfill is included in this section for completeness, although the facility is not currently regulated under RCRA. Monitoring wells are currently sampled quarterly for chemical parameters required under the Washington Administrative Code (WAC) 173-304-490 (Minimum Functional Standards for Solid Waste Handling), volatile chlorinated hydrocarbons, tritium, and other constituents.

These projects are described in greater detail in Section 2.8.2.

Existing groundwater contamination detected from RCRA monitoring wells is expected to be largely mitigated under a Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedial action program. During implementation of the CERCLA program, it is anticipated that RCRA site-specific groundwater cleanup levels and procedures will be identified, considered, and incorporated as potential applicable or relevant and appropriate requirements (ARARs). In the event that remediation is not completed in a timely manner, the Tri-Party Agreement is revised, or that future releases from RCRA facilities are detected, remediation under RCRA authority could be initiated.

Hanford Site monitoring programs are discussed in Section 2.8. The integration of potential 200 East Groundwater Aggregate Area remedial actions with other programs is discussed in more detail in Section 9.3.3 of this AAMSR.

2.7 INTERACTIONS WITH OTHER HANFORD PROGRAMS

In addition to the RCRA groundwater monitoring program discussed in Section 2.6, and other groundwater programs discussed in Sections 2.8 and 2.9, several other ongoing Hanford programs have potential to interact with characterization and remedial activities related to the 200 East Groundwater AAMS. These programs include the following:

- Hanford Site Single-Shell Tank Programs
- Emergency Response Action Programs
- Effluent Treatment Programs
- Decommissioning and Decontamination Program
- Surplus Facilities Program
- Defense Waste Management Program
- Remedial Technology Development Programs.

Each of these programs and their interaction is discussed briefly below, based on information provided in the *Environmental Restoration and Waste Management Site-Specific Plan for the Richland Operations Office* (DOE/RL 1991b).

2.7.1 Hanford Site Single-Shell Tank Programs

The Hanford Site Single-Shell Tank Programs include the near-term waste management activities related to interim storage of waste in single-shell tanks, and long-term decommissioning. As part of the Hanford Site Single-Shell Tank Program, RCRA closure plans are developed for single-shell tanks and ancillary equipment. Currently, the single-shell RCRA closure plans incorporate groundwater assessment and mitigation activities being planned as part of the 200 East Groundwater AAMSR. Following remediation of single-shell tank facilities, related soil and groundwater contamination is anticipated to be remediated under either the CERCLA or RCRA Past Practices program.

2.7.2 Emergency Response Action Programs

Currently, no Emergency Response Action Programs relevant to the 200 East Groundwater Aggregate Area have been identified. In the event that future Emergency Response Action Programs are initiated, the feasibility of transferring remedial technologies to the 200 East Groundwater AAMS will be assessed. Potential remediation technologies associated with the 200 East Groundwater AAMS are discussed in Section 7.0.

2.7.3 Effluent Treatment Programs

The Effluent Treatment Program is implemented as part of the Hanford Defense Waste Management Program, as discussed in Section 2.7.6. The Effluent Treatment Program is responsible for developing best available technologies (BAT) for regulated effluents being produced throughout the Hanford Site. In addition, several classes of effluents are being evaluated for BAT treatment and subsequent disposal to soil as part of the W-049H project near the 200 East Area. As a result, the Effluent Treatment Program interacts with the 200 East Groundwater AAMS in several ways.

First, groundwater that may be extracted for treatment during remediation activities in the 200 East Groundwater Aggregate Area may be similar to liquids being evaluated under the Effluent Treatment Program, and may therefore be adaptable to the BAT developed. This interaction is further discussed in Section 7.0. Secondly, as part of the Effluent Treatment Program milestones discussed in the Tri-Party Agreement, process effluent discharges to existing cribs and ditches in the 200 East Area will be discontinued. Third, it

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is anticipated that some of the effluent temporarily stored in the Liquid Effluent Retention Basin (currently under construction east of the 200 East Area) will be discharged to soil at a proposed state-approved liquid disposal facility (SALDS). The proposed SALDS facility (Project W-049H) is a candidate site 3.5 km (2.1 mi) east of the 200 East Area and just east from the current 216-B-3 Pond System. Project W-049H will accept treated effluent from the 200 Areas that meets discharge limits without additional treatment. Modeling has been performed to assess the groundwater mounding effects and other potential changes to the groundwater flow pattern in this area. A second proposed SALDS facility (Project C-018H) is scheduled for construction just north of 200 West Area that will provide standby treatment and discharge for effluent that does not meet discharge limits for W-049H. Additional information obtained from this project and related support programs will be used during 200 East Groundwater AAMS assessment and remediation activities.

2.7.4 Decommissioning and Decontamination Program

The Hanford Decommissioning and Decontamination Program is primarily concerned with decontamination and decommissioning of buildings and other structures with elevated levels of radioactivity. The Decommissioning and Decontamination Program does not typically involve mixed waste issues or groundwater studies.

2.7.5 Surplus Facilities Program

The Hanford Surplus Facilities Program is responsible for the surveillance and decommissioning of surplus facilities at the Hanford Site. As with the Hanford Site Single-Shell Tank closure projects, the Surplus Facilities Program is anticipated to incorporate data from 200 East Groundwater AAMS characterization and remedial activities to address RCRA groundwater mitigation requirements. Remediation of soil and groundwater contamination related to past waste disposal activities at surplus facilities is expected to be deferred to the AAMS program.

The Surplus Facilities Program also implements the Radiation Area Remedial Action (RARA) program. The RARA program is primarily concerned with management and control of surface soil contamination and does not directly interact with groundwater activities.

2.7.6 Defense Waste Management Program

The Hanford Defense Waste Management Program is responsible for operation and maintenance of active waste management units and facilities. Several of these waste management units are currently RCRA interim status facilities. During the final permitting of

active RCRA waste management units, data from remedial assessment and mitigation for the 200 East Groundwater AAMS will likely be incorporated into the RCRA permits. The Defense Waste Management Program includes activities implemented under the Effluent Treatment Program as discussed in Section 2.7.3.

2.7.7 Remedial Technology Development Programs

Innovative technologies for use in remedial action at Hanford are evaluated by several groups and organizations. These organizations include the DOE Office of Technology Development, Westinghouse Integrated Programs and Demonstrations (funded by the DOE Office of Technology Development), and the Pacific Northwest Laboratory (PNL). It is anticipated that technologies developed or evaluated by these groups will be applied to remedial actions implemented as part of the 200 East Groundwater AAMS, as practical.

2.8 GROUNDWATER MONITORING FACILITIES

Groundwater monitoring facilities within the 200 East Area include single piezometers, nested (multiple) piezometers, and groundwater monitoring wells. They have been constructed to monitor discrete horizons within the unconsolidated sediments, as well as the deeper confined basalt aquifers within the Saddle Mountains Basalt. In addition, other nearby wells monitor horizons within the Wanapum and Grande Ronde Basalts. Plate 3 shows the location of all groundwater monitoring wells within and adjacent to the 200 East Area.

Groundwater monitoring facilities at the Hanford Site are associated with five monitoring programs: the Westinghouse Hanford Operational Groundwater Monitoring Network (OGWMN), RCRA, CERCLA, the PNL Environmental Monitoring Program, and the Hanford Sanitary Water Quality Surveillance program administered by Hanford Environmental Health Foundation (HEHF). These programs all help determine the impact of Hanford past, present, and future waste disposal practices on human health and the environment across the Hanford Site. The Hanford Sanitary Water Quality Surveillance program is the only one that does not monitor groundwater within the 200 East Area.

Monitoring wells at the Hanford Site were first installed in 1944 and continue to the present. During this period, three general well designs were implemented, as shown in Figure 2-1 (Serkowski and Jordan 1989). Regardless of the design used, the vast majority of wells at the Hanford Site were drilled using the cable-tool method. The oldest and simplest design consists of a single 15- to 20-cm (6- to 8-in.) diameter carbon-steel casing, which is perforated at the top of the aquifer to allow groundwater to enter the well. This design has two major shortcomings: (1) the well lacks a seal that is necessary to block downward

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movement of contaminants along the outside of the casings; and (2) the size of the perforations are often too large to prevent the entry of sand into the well. In the early 1980s, a modified design was developed to address these design problems. In the modified design, an 20-cm (8-in.) carbon-steel casing was installed to a depth slightly above the aquifer and perforated along its entire length. A 15-cm (6 in.) carbon-steel casing was then inserted into the first casing and drilling continued to the desired depth. A telescoping stainless-steel screen assembly was lowered to the bottom of the well and the 15-cm (6-in.) casing was pulled back to expose the screen. A grout mixture was poured into the annulus between the two casings and allowed to flow out through the perforations to create a seal between the well and the formation. Finally, a cement surface seal was installed to inhibit erosion at the well head.

Beginning in 1986 and continuing to the present, the sealed, screened well design was further modified to more closely conform with RCRA well construction guidelines (Serkowski and Jordan 1989). The implemented changes include placing a sand pack around the screen, sealing the well with bentonite granules or other dry sealant, removing the outer casing as sealant is injected, and completing the well with 10-cm (4-in.) diameter stainless-steel casing. To lessen the back-pull friction and permit removal of the temporary outer casing, several progressively smaller casings are often used in deeper wells.

A program was initiated in 1986 to renovate the older wells to this new standard by perforating the casing, installing a liner, and grouting the annular spaces. Wells that were closest (less than 300 m, 1,000 ft) to liquid waste disposal facilities were assigned the highest priority under this program.

Groundwater monitoring wells that are currently being constructed at the Hanford Site are being completed in accordance with requirements set forth in the Washington State Administrative Code (WAC 173-160 through 162) as well as *RCRA Groundwater Monitoring Technical Enforcement Guidance Document* requirements (EPA 1986a).

Piezometers were installed on the Hanford Site to assist in evaluations of potentiometric surfaces and hydraulic gradients. Borings with nested piezometers originally were installed with separate screen depths but with sand filling the well casing the entire distance between screened intervals. Many of these have since been retrofitted with proper seals between screened materials. Others have been abandoned (Newcomer et al. 1992a).

To support the 200 East Groundwater AAMS, a sampling and analysis program is underway which includes a classification of Hanford Site wells based on their fitness for sampling. In a previous screening of wells at the Hanford Site (Golder Associates 1989), 70% of the wells evaluated require remediation of their installation or decommissioning. As part of the sampling and analysis program, maps of the groundwater contaminant plumes are anticipated to be periodically updated.

2.8.1 Westinghouse Operational Groundwater Monitoring Network

The DOE maintains a groundwater monitoring program for the Hanford Site as part of its waste management responsibilities. This monitoring program is based on DOE Order 5484.1, "Environmental Protection, Safety, and Health Protection Information Reporting Requirements." These requirements mandate the evaluation of impacts of Hanford Site operations on the aquifers from liquid waste discharges to the ground.

Westinghouse Hanford is the operations and engineering contractor for the DOE at the Hanford Site. As part of the requirements imposed by DOE Order 5484.1, Westinghouse Hanford manages the facilities within the Hanford Site. Westinghouse Hanford, therefore, conducts an Operational Surveillance Program to control the impact of effluent releases and waste management practices at and near the waste management units.

One component of this surveillance program is the OGWMN. The OGWMN was originally established to observe the response of groundwater to storage and disposal of radioactive waste in soil at the 200 Areas. Groundwater monitoring in other operational areas of the Hanford Site was conducted by contractors responsible for these sites or was conducted by PNL as part of its groundwater monitoring program. In 1987, DOE consolidated all operational responsibilities into a single contract to be carried out by one contractor, and a five-year contract was awarded to Westinghouse Hanford.

The scope of this consolidation was to expand the OGWMN to incorporate all waste management units at the Hanford Site (including the 100, 200, 300, 400, 600, and 1100 Areas). Even after consolidation, the emphasis of the network remains on the 200 Areas, due in part to the significance of the 200 Areas as the major waste disposal areas on the Hanford Site.

Historically, the OGWMN program has emphasized the monitoring of radioactive constituents and nitrates. In 1985 the list of constituents monitored was expanded to include other hazardous chemicals. The OGWMN now routinely includes both radiological as well as nonradiological constituents in groundwater analyses. Table 2-8 lists the constituents analyzed for under the OGWMN program. The OGWMN program is intended to provide environmental data to Hanford Site waste management programs. Specific objectives of the OGWMN program include the following:

- Assess the quality of groundwater under waste management units to determine compliance with applicable water quality standards

- Monitor the performance of active and inactive waste management units

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- Determine the impact to the groundwater from waste management unit activities.

The groundwater monitoring network (1990) for the 200 Areas consists of 166 wells. Of these, 86 wells were installed to monitor groundwater of the uppermost aquifer (for which this uppermost aquifer system primarily exhibits unconfined conditions but also contains localized areas of semiconfined to confined conditions), 9 wells were installed to monitor groundwater of the confined aquifer, and the remaining 71 wells monitor the vadose zone. The 9 confined aquifer wells monitor the Rattlesnake Ridge and Mabton interbeds. Within the 200 Areas, there were 50 wells sampled during the 1990 calendar year. Of these, 14 groundwater monitoring wells of the 200 East Area were selected to monitor 8 waste management units which include the 216-A-37-1, -37-2, -30, -45, and -8 Cribs around the PUREX Plant and the 210-B-62, 216-B-5 and -55 Cribs around the B Plant. These wells are summarized on Table 2-9.

The sampling frequencies of wells within the OGWMN are based on a variety of different objectives. Wells monitoring active liquid waste management units are sampled monthly. Wells monitoring inactive waste management units containing radionuclides with a high potential for being mobilized are sampled monthly. Wells monitoring inactive waste management units containing radionuclides with a low potential for being mobilized are also sampled monthly or quarterly, depending upon the level and trend of concentration. Wells monitoring background concentrations are sampled semiannually. Samples from these wells are collected by PNL for Westinghouse Hanford and analyzed for the following radionuclides: ^{90}Sr, ^{129}I, tritium, total U, and ^{239}Pu. These parameters were chosen for analysis based upon effluent inventories and historical groundwater monitoring results.

2.8.2 Resource Conservation and Recovery Act Monitoring Units

The RCRA groundwater monitoring program monitors active and recently inactive hazardous waste treatment, storage, or disposal units at the Hanford Site which are governed by RCRA regulations. There are currently 15 RCRA monitoring projects ongoing within the 200 East Area. These units are shown on Figure 2-2 and the wells are summarized in Table 2-10. The RCRA projects are monitored under three programs: (1) a background monitoring program; (2) an indicator evaluation program; and (3) a groundwater quality assessment program. The background and indicator evaluation programs provide two phases of detection level monitoring (DOE/RL 1992b).

Once a groundwater monitoring well has been installed, a background monitoring program is also commenced. Samples and water levels are obtained from upgradient well(s) and analyzed quarterly to obtain relevant background groundwater quality for the unit. These samples are analyzed for several general constituents. The specific site parameters are

listed in the appropriate sections that follow. Due to the termination of the analytical support contract, sampling was temporarily halted on June 1, 1990 and restarted on June 6, 1991 under a new analytical laboratory. Therefore, current interpretations are based on a limited quantity of new data.

Once background groundwater quality has been determined an indicator evaluation program commences. During this program groundwater samples and water levels are obtained semiannually. Indicator data are then compared to background data. If significant differences are identified, then a groundwater quality assessment plan must be implemented. Groundwater monitoring wells installed under the RCRA program must meet the requirements set forth in WAC 173-160 through 162, and current RCRA regulations. The following is a brief discussion of the RCRA units within the 200 East Area and their associated groundwater monitoring well networks (Figure 2-2).

2.8.2.1 Low-Level Burial Grounds. The 200 East Area Low-Level Burial Grounds (LLBG) consist of two low-level waste management areas. These are LLWMA 1 and LLWMA 2 (Figures 2-4 and 2-5). A permit application has been submitted to Ecology for these facilities (DOE/RL 1989d). The RCRA groundwater monitoring program for these LLBGs began in 1988 and is continuing under interim status (DOE/RL 1992b).

The LLWMA 1 is located within the northwest corner of the 200 East Area covering an area of 38.2 ha (94.4 acres) and is operating under an interim-status groundwater quality assessment plan. This waste management area contains all of the 218-E-10 Burial Ground. Only the southern portion of the burial ground is active while the northern portion is unused and set aside for future waste disposal. The 218-E-10 Burial Ground began receiving waste in 1960 consisting of primarily drag-off waste, failed equipment (tanks, pumps, ovens, agitators, heater, vehicles, hoods, and accessories), and mixed industrial waste from PUREX Plant, B Plant and N Reactor. The disposal of this waste continues at the present time.

There are currently 16 groundwater monitoring wells associated with LLWMA 1. Quarterly groundwater sampling at LLWMA 1 began in 1988. These wells are sampled for several constituents (Table 2-11). During the second phase of sampling (indicator evaluation program), the specific conductance in upgradient Well 299-E28-26 exceeded the established critical mean (492.78 μmhos/cm). In 1990, an interim-status groundwater quality monitoring program was started. The specific conductance in Well 299-E28-26 has decreased to an acceptable level, but downgradient Wells 299-E32-3 and 299-E32-5 have exceeded the critical mean for the specific conductance.

The LLWMA 2 area covers 70.1 ha (173.1 acres) and is located in the northeast corner of the 200 East Area (Figure 2-5). It is composed entirely of the 218-E12B Burial Ground. This burial ground began receiving waste in 1968 which includes miscellaneous dry waste, submarine reactor compartments, and transuranic waste.

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Groundwater monitoring for LLWMA 2 is currently in Phase II detection monitoring. There are currently 14 groundwater monitoring wells associated with LLWMA 2. The well samples are analyzed for the same constituents as well samples from LLWMA 3. There were no detected chemical constituents in groundwater above regulatory standards in 1991, but in Wells 299-E27-9 and 299-E34-2 the turbidity exceeded the 1 nephelometric turbidity unit (NTU) limit.

2.8.2.2 Single-Shell Tanks. There are three RCRA single-shell tank waste management areas within the 200 East Area. These waste management areas group adjoining tank farms and include the 241-B, -BY, and -BX Tank Farms, the 241-A and -AX Tank Farms, and the 241-C Tank Farm. Within these three waste management areas are six tank farm facilities with a total of 66 single-shell tanks that range in size from 208,000 to 3,800,000 L (55,000 to 1,000,000 gal). The single-shell tanks were decommissioned as disposal facilities in 1980 but because they are currently storing hazardous and radioactive wastes they have been designated as RCRA facilities.

The single-shell tanks are a RCRA past practice unit for which a draft closure plan was submitted to the Washington State Department of Ecology (Ecology) (DOE/RL 1989a). Locations of the facilities and their associated groundwater monitoring networks are shown in Figure 2-6. Table 2-10 contains a summary of single-shell tank facilities and their associated groundwater monitoring wells. Groundwater monitoring beneath the single-shell tanks is by an interim-status RCRA detection level groundwater monitoring network that was initiated in 1989. Sampling was initiated within the tank farm in February 1990 but was suspended until 1991 because of lack of analytical laboratory support. Sampling resumed in July 1991 at all three waste management areas. Quarterly background samples are currently being collected at the tank farms for those wells completed for calendar years 1989 and 1990. There are currently 18 groundwater monitoring wells included in the 200 East Area network for the tank farm facilities.

Installation of six new groundwater monitoring wells began in August 1991. These monitoring wells were completed in December 1991 and were designed to monitor the upper portion of the unconfined aquifer.

Groundwater samples from single-shell tank monitoring wells are analyzed for drinking water standards, indicator parameters, and water quality parameters as well as ammonium, tritium, total organics, ^{137}Cs, uranium, plutonium, ^{60}Co, ^{90}Sr, and gamma scans (Table 2-12).

2.8.2.3 216-B-3 Pond. The 216-B-3 Pond System consists of a main pond and three pond lobes (Figure 2-7). These ponds are located east of the 200 East Area and are used for wastewater disposal. Wastewater primarily comes from the PUREX and B Plants, and additional waste effluent comes from the 242-A Evaporator, 244-AR Vaults, 241-A-702

Vessel Ventilation System, 283-E Water Treatment Facility, and the 284-E Powerhouse. This waste consists of cooling water, PUREX Plant chemical sewer, steam condensates, liquid effluent, and filter backwash. The 216-B-3 Pond System began receiving waste in 1945 and continues to the present. In the early 1980's the three lobes, 216-B-3A, 216-B-3B, and 216-B-3C, were constructed to handle greater waste volumes. The four ponds cover an area of 40 ha (98 acres) and are a maximum of 6 m (20 ft) deep. Currently, the 216-B-3B Pond is not in use. A closure/post closure plan for this RCRA unit has been submitted (DOE/RL 1989b). The 216-B-3 Pond System is part of the 200-BP-11 Operable Unit, which is regulated under the CERCLA program.

The groundwater monitoring network consists of 2 upgradient wells (299-E18-1 and 299-E32-4) and 18 downgradient wells. Wells are sampled for the general groundwater constituents listed in Table 2-13 and these site specific parameters: hydrazine, tritium, ammonium, total organics, herbicides, pesticides, enhanced volatiles, PCBs and acid/bases/neutrals. Sampling is on two schedules; wells older than 1988 are sampled semiannually, and those younger are sampled quarterly. The 216-B-3 Pond System is currently in assessment monitoring status. Wells 699-43-41E and 699-43-41 both have a history of high total organic halogen (TOX) concentrations, however, the TOX levels are declining with time. Wells 699-42-40A, 699-43-42J, and 699-43-43 were detected to be above the background levels for Total Organic Carbon (TOC) in 1991. Tritium was also detected in the downgradient wells in concentrations up to 180,000 pCi/L.

2.8.2.4 Grout Treatment Facility. The Grout Treatment Facility is located in the eastern-central portion of the 200 East Area (Figure 2-8). At the Grout Treatment Facility, selected radioactive and hazardous waste is mixed with grout. The slurry is then poured into underground vaults for curing. This produces stabilized cement-like blocks which are suitable for long-term, in-place storage. Currently these vaults are under construction. From August 1988 to July 1989, one vault was filled during a demonstration campaign. The first pouring with dangerous waste is scheduled for the end of 1992.

The Grout Treatment Facility is a treatment and disposal facility regulated under RCRA (EPA 1989a) and Washington State Dangerous Waste regulations (Ecology 1991a). There are 8 monitoring wells in the detection network. Wells continue to be sampled quarterly. This will allow data collected for the background study to be comparable for all monitoring wells. The groundwater is analyzed for several site-specific parameters: arsenic, chromium, selenium, and ^{99}Tc (Table 2-14). Currently, there are no readings that are above the acceptable limits. Evidence suggests that some contamination is coming from the Grout Treatment Facility. The downgradient wells' constituent levels are higher than the upgradient wells. Due to the proximity to the several active cribs, trenches, and ponds, this is only speculation.

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2.8.2.5 216-A-29 Ditch. The 216-A-29 Ditch was located east of the 200 East Area extending from the PUREX Plant to the 216-B-3 Pond System (Figure 2-9). This facility was an excavated unlined trench used to carry effluent from the PUREX chemical sewer to the 216-B-3 Pond System. There have been substantial discharges of sodium hydroxide and sulfuric acid during the usage of this ditch. The 216-A-29 Ditch had been in service from 1955 until termination in July 1991. The facility has been backfilled and interim stabilized with vegetation. It is a RCRA unit in which the preliminary closure/postclosure plans have been prepared by DOE (1987).

The groundwater monitoring network consists 20 wells of which 3 are upgradient wells. These wells were analyzed for drinking water and water quality parameters (Table 2-15). The sampling program was scheduled to begin in 1990 but due to the absence of a laboratory this program did not get under way until July 1991. Consequently, there is insufficient information to make conclusions on the groundwater beneath the 216-A-29 Ditch.

2.8.2.6 216-A-36B and 216-A-10 Cribs. The 216-A-36B and 216-A-10 Cribs are located in the PUREX Plant Aggregate Area, approximately 300 m (1,200 ft) and 121 m (400 ft), respectively, south of the PUREX Plant (Figures 2-10 and 2-11). Both cribs received waste from this facility and were permanently retired in 1987. The RCRA closure/postclosure plans for the 216-A-36B and 216-A-10 Cribs are to be submitted in March 1996 in accordance with the Hanford Federal Facility Agreement and Consent Order milestone M-20-34 (Ecology et al. 1990).

The 216-A-36B Crib received solutions containing ammonium, fluoride, nitrate, tritium, ^{90}Sr, ^{137}Cs, ^{106}Ru and U starting in 1965. These solutions were derived from nuclear fuel decladding operations. In 1966 the crib, then called the 216-A-36 Crib, was divided into two sections. One section was removed from service at this time. The remaining section, referred to as the 216-A-36B Crib, remained in service until 1987 with a temporary closure from 1972 to 1982.

The groundwater monitoring network consists of seven wells of which one is upgradient (299-E17-17). The wells are sampled semiannually for the general parameters plus the site-specific constituents: tritium, ammonium, uranium, and gamma (Table 2-16). In 1990 there were elevated levels of nitrates in Wells 299-E17-5, 299-E17-9, 299-E17-14, 299-E17-15, 299-E17-16, and 299-E17-17, tritium in all wells, and total beta in Wells 299-E17-6, 299-E17-14, and 299-E17-15. The 1991 sample data have not been interpreted so the current analyte levels are unconfirmed.

The 216-A-10 Crib is 84 m (275 ft) long and 14 m (45 ft) deep. Starting in 1956, the process distillate discharge waste streams were disposed of in this crib. The waste consisted of aliphatic hydrocarbon compounds, organic complexes, and radionuclides including

plutonium, uranium, ^{90}Sr, ^{60}Co, ^{134}Ce, ^{137}Cs, ^{103}Ru, ^{106}Ru, and tritium. As mentioned previously, this crib was retired in 1987 and replaced by the 216-A-45 Crib.

In 1988 the 216-A-10 Crib was placed on an interim-status RCRA groundwater monitoring network. This network consists of eight monitoring wells, of which two are upgradient (Wells 299-E24-18 and 299-E25-36) (DOE/RL 1992c). These wells are sampled semiannually. The site-specific analytical parameters are uranium, tritium, and gamma (Table 2-17). In 1990 (the most current date available) the network indicated elevated chemical levels. Nitrates above 45,000 ppb, although showing a decrease from 1989 to 1990; tritium, was variable but increasing during this same period. Gross beta was elevated only in Well 299-E24-16 in early 1989 but diminished to acceptable levels by the end of the year.

2.8.2.7 216-B-63 Trench. This trench is located in the central portion of the 200 East Area east of B Plant (Figure 2-12). This facility started service in 1970 and is still actively receiving nondangerous waste, a combination of steam condensate and raw water, from B Plant. Between 1970 and 1985 there had been releases of sulfuric acid and sodium hydroxide. No radioactive waste reportedly has been disposed of, but in 1970 radioactive soil was dredged from the trench. In 1985 controls were added to avoid further unplanned releases of hazardous and radioactive waste. Because the 216-B-63 Trench is not expected to receive additional hazardous substances, DOE/RL has proposed that the trench be closed under RCRA interim status, although it will continue to receive wastewater not regulated under RCRA.

There are currently ten monitoring wells in the groundwater network. Six of these wells are upgradient (Wells 299-E27-8, 299-E27-9, 299-E34-8, 299-E34-10, 299-E27-11, and 299-E27-17). The site-specific parameters are tritium, uranium, volatile organics, and a gamma scan (Table 2-18). Sampling was scheduled to start in 1990 but was postponed due to lack of laboratory facilities. Currently, there are no data available from this network.

2.8.2.8 Liquid Effluent Retention Facility. The Liquid Effluent Retention Facility (LERF) is currently under construction east of LLWMA 1 outside the fenced 200 East Area (Figure 2-13). This site is 16 ha (39 acres) and will consist of four 25,000,000 L (6.5 million gallons) double-lined surface impoundments with leachate collection systems and floating covers. These impoundments will be used to store effluent suspected of containing listed waste constituents (DOE/RL 1992c). The 242-A Evaporator process condensate effluent is regulated as a dangerous waste under WAC 173-303 (Ecology 1991a).

There are four groundwater monitoring wells in the current network. Sampling of these wells is on a quarterly basis and started in June 1991. These samples are analyzed for the general parameters as well as ammonia, tritium, and 1-butanol (Table 2-19). To date, there has been no evidence of elevated levels that exceed regulatory standards.

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2.8.2.9 2101-M Pond. The 2101-M Pond is an unlined, U-shaped trench located west of the 2101-M Building (Figure 2-14). It was put in service in 1953 to receive wastewater from the 2101-M Building heating and air conditioning system. The Basalt Waste Isolation Project laboratories also discharged into the pond between 1981 and 1985. A closure plan for this facility was submitted to Ecology for review (DOE/RL 1989c).

The groundwater monitoring network consists of four groundwater monitoring wells of which Well 299-E18-1 is upgradient. These wells are sampled semiannually for the general parameters plus volatile organics, tritium, turbidity, radium, uranium, technetium, barium, copper, inductively coupled plasma metals as well as alpha, beta and gamma radiation (Table 2-20). To date, there have been no constituent concentrations in the groundwater above acceptable levels.

2.8.2.10 Nonradioactive Dangerous Waste Landfill. Located approximately 5.5 km (3.5 mi) southeast of the 200 East Area, the NRDWL is a 4 ha (10 acre) part of the Central Landfill Complex (Figure 2-15). This facility had received dangerous waste from 1975 to 1985 and continued to receive asbestos waste until 1988. A closure plan (DOE/RL 1990a) for the NRDWL was submitted to Ecology in 1990, and as part of the Tri-Party Agreement, the NRDWL will be retired.

A groundwater monitoring network of seven wells was established in 1986 and is currently on a semiannual sampling schedule. Three of the seven wells are located upgradient of the facility (Wells 699-26-35A, 699-26-35C, and 699-26-34). All water samples are analyzed for tritium, volatile chlorinated hydrocarbons, and the general water quality constituents listed in Table 2-21. Well 299-25-34B had an elevated TOC reading of 1,025 ppb in April 1990. The allowable limit is 940.8 ppb. In 1991 the well was resampled and found to be below 500 ppb and acceptable. There was also an elevated reading for tritium due to a migrating tritium plume originating in the 200 East Area that moved to the southeast. A pulse of the plume had passed beneath the NRDWL in 1988 to 1989 and tritium values are declining.

2.8.2.11 Solid Waste Landfill. The solid waste landfill is adjacent to the NRDWL, 5.5 km (3.5 mi) southeast of the 200 East Area (Figure 2-15). This facility is active and under the jurisdiction of the Benton-Franklin County Health Department. This is not an RCRA site but is included here for clarity. This 27 ha (66 acre) facility has been accepting waste since 1972. This waste includes paper wastes, construction debris, asbestos wastes and lunchroom wastes. In addition to the solid waste, liquid waste was disposed of in trenches from 1975 to 1987. This liquid consisted of 3,000,000 L to 5,700,000 L (1 to 1.5 million gallons) of sewage waste and 380,000 L (100,000 gal) of wash water from the Hanford bus garage.

The eight well groundwater monitoring network was set up in 1987. These wells are sampled quarterly and analyzed for a selected group of constituents (Table 2-22).

2.8.3 Comprehensive Environmental Response, Compensation and Liability Act

The Hanford Site is organized into numerically designated operational areas including the 100, 200, 300, 400, 600, and 1100 Areas. The 100, 200, 300, and 1100 Areas are listed on the EPA's National Priorities List (NPL). The *Hanford Site Past-Practice Strategy* (DOE/RL 1992a) outlines procedures for approaching the various sites within the framework of the CERCLA guidelines. Under the Tri-Party Agreement, the 200 NPL Site was divided into ten aggregate areas. Currently, the 200 East Area is divided into three source aggregate areas containing 20 operable units and the 200 North Aggregate Area is a separate source area and operable unit (Figures 1-3 and 1-5). There are also five other 200 Area isolated operable units (in addition to 200-IU-6 in the B Plant Aggregate Area).

Of these 26 operable units, the 200-BP-1 Operable Unit is currently the only operating CERCLA operable unit under investigation in the 200 East Area. In accordance with milestones M-15-02A, M-15-02B, and M-15-02C, draft reports to Ecology and EPA are due in May 1993 for 200-BP-1 Feasibility Study Phase 1 and Phase 2; April 1994 for 200-BP-1 Remedial Investigation Phase 2; and March 1995 for 200-BP-1 Feasibility Study Phase 3 (Ecology et al. 1991).

The 200-BP-1 Operable Unit is located in the center, along the north boundary of the 200 East Area. This operable unit consists of ten inactive cribs and contains three unplanned releases. Two of the cribs received ITS condensate waste. Seven of the cribs received waste from the 221-U Building, mainly tributyl phosphate supernate process waste, in the late 1950's. The last crib was never used. There is a concentration of man-made radionuclides, ^{137}Cs and ^{90}Sr, as well as cyanide and nitrate compounds in the soil beneath the cribs. This contamination is believed to extend to the unconfined aquifer.

Nine groundwater monitoring wells have been installed during 1992. Six of these wells monitored the unconfined aquifer and the remaining three sampled the uppermost confined aquifer. Samples will be analyzed for the parameters listed in Table 2-23. This project is still in the investigative stage and has just begun to collect data. These wells are summarized in Table 2-24.

2.8.4 Pacific Northwest Laboratory Environmental Monitoring Network

The PNL, operated for the DOE by Battelle Memorial Institute (Contract No. DE-AC06-76-RLO 1830), assesses the impact of Hanford Site operations on the groundwater. This program is performed independently of the other monitoring programs discussed above.

This groundwater monitoring network is designed to comply with the environmental surveillance portions of DOE Order 5400.1. As such, it evaluates existing and potential pathways of exposure to radioactivity and hazardous chemicals from site operations. The objectives of this program are as follows:

- Verify compliance with environmental laws and regulations
- Verify compliance with environmental commitments
- Characterize impacts of Hanford Site operations to the environment.

Although PNL's groundwater monitoring program is performed independently of the other programs, data collected from all monitoring programs at the Hanford Site are used to assess the groundwater quality across the site. Sampling schedules from each of the site groundwater monitoring programs are reviewed by project staff in context with the requirements for the environmental surveillance needs. A supplemental monitoring program is developed each year to meet the objectives of the groundwater surveillance program.

For calendar year 1990 there were 110 wells sampled in and around the 200 East Area (Evans et al. 1990). These included wells from the RCRA, OGWMN, and other monitoring programs. These wells are summarized on Table 2-25.

2.8.5 Hanford Sanitary Water Quality Surveillance

Sanitary water quality surveillance on the Hanford Site is conducted as a joint effort by the HEHF Environmental Health Services, and PNL Environmental Health Sciences Department. The HEHF oversees surveillance in the areas of chemical and microbial quality, while PNL efforts focus on radiological quality.

The primary purpose of the surveillance program is to protect the health of persons consuming water on the Hanford Site by regulating sanitary water with applicable drinking water standards. There are no groundwater wells within the 200 East Area that are used as a supply of drinking water. The nearest drinking water wells to the 200 East Groundwater Aggregate Area are Well 699-41-900-C at the Yakima Barricade, Well S28-EO at the Patrol Training Academy, and 3 wells including 499-SJ, 499-SO8, and 499-SO7 within the 400 Area (Fast Flux Test Facility).

Drinking water constituents that are monitored for under this program include selected inorganics, volatile organics, microbiological constituents, and radiological constituents including total alpha and beta, tritium, and ^{90}Sr. These constituents are sampled quarterly.

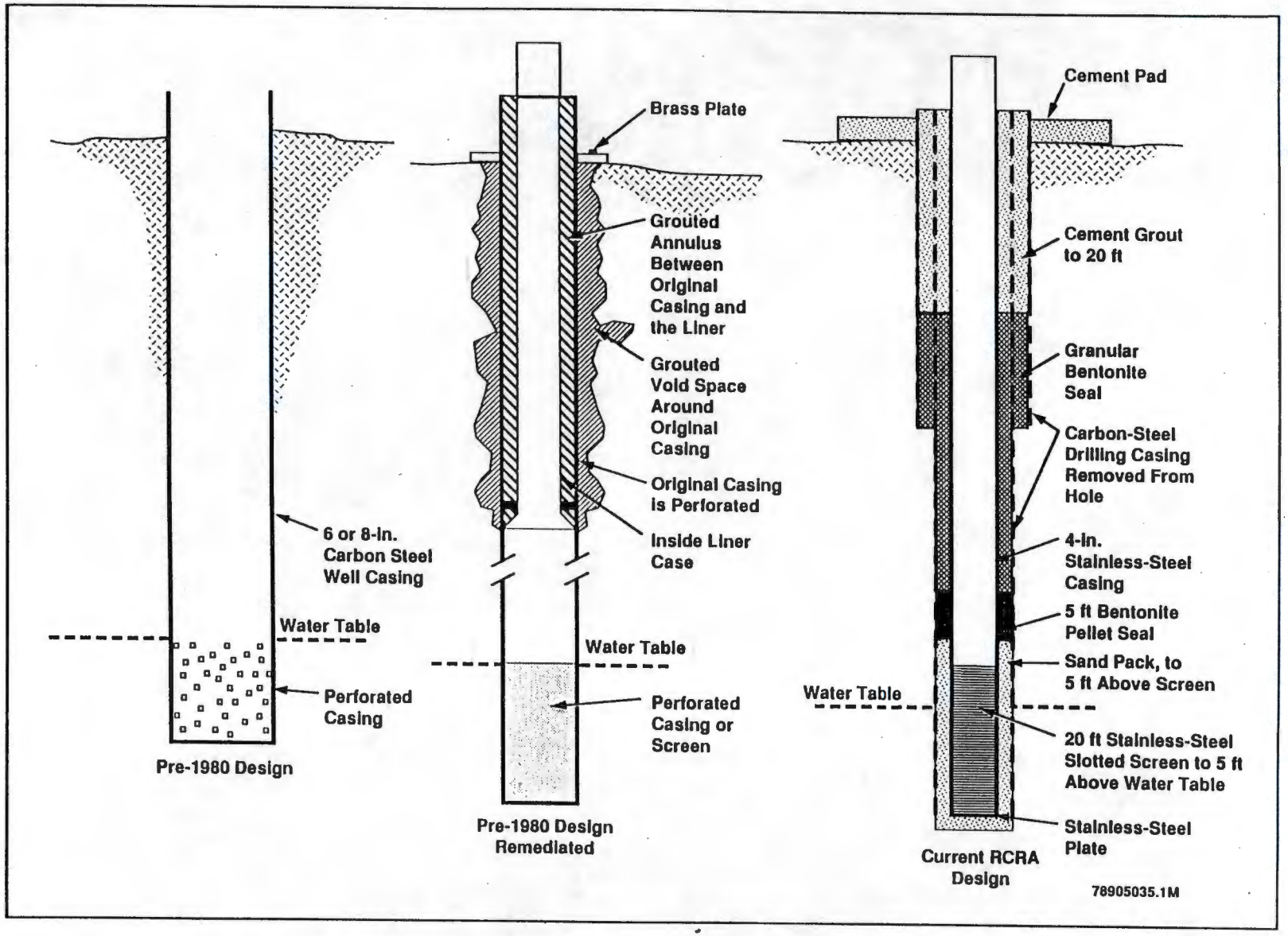


Figure 2-1. Schematic Design of Typical Hanford Site Monitoring Wells (Serkowski and Jordan 1989).

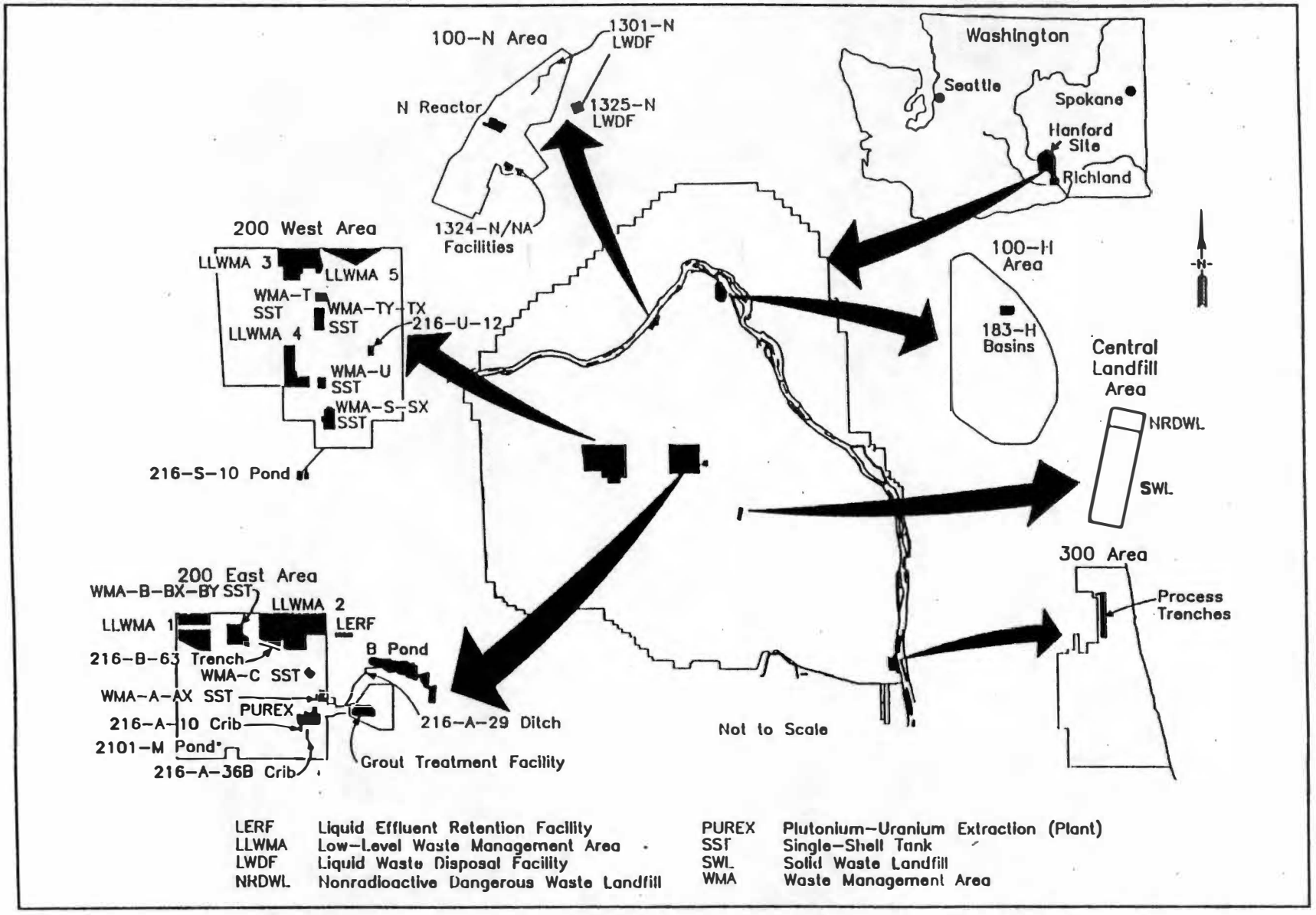
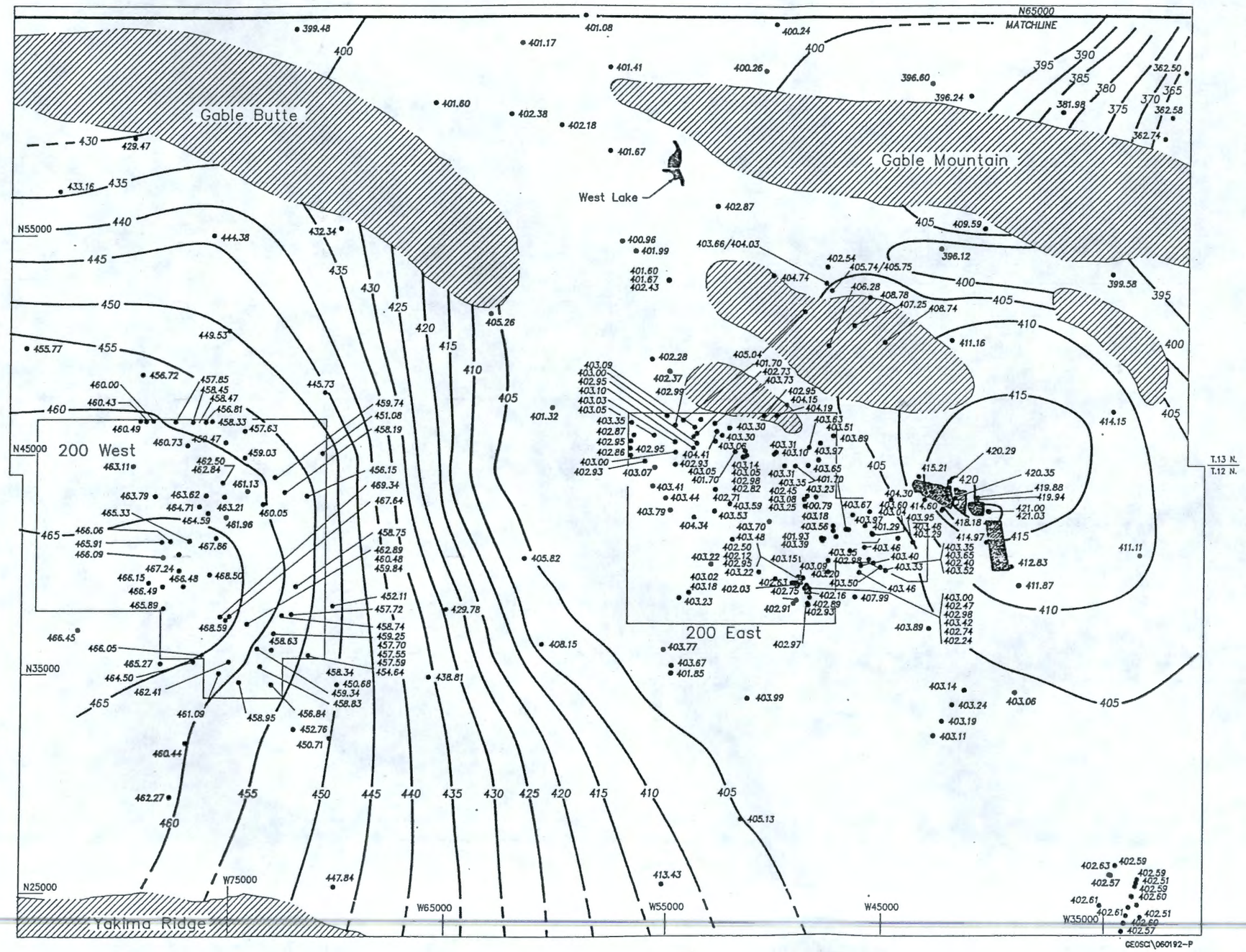


Figure 2-2. Location of RCRA Facilities at the Hanford Site (DOE/RL 1991b).



200 Areas Water Table Elevation December 1991

411.49 • Water table elevation (feet above mean sea level)

395 Groundwater table elevation contour interval = 5ft

Ponds

Areas where the basalt surface is generally above the water table

The 200 Areas water table elevation map has been prepared by the Geosciences Group, Environmental Division, of Westinghouse Hanford Company.

Note: To convert to metric, multiply elevation (ft) by 0.3048 to obtain elevation (m).

0 1 Mile

0 1 Kilometer

-N-

Figure 2-3. 200 Areas Water Table Elevation for December 1991 (Kasza et al. 1992).

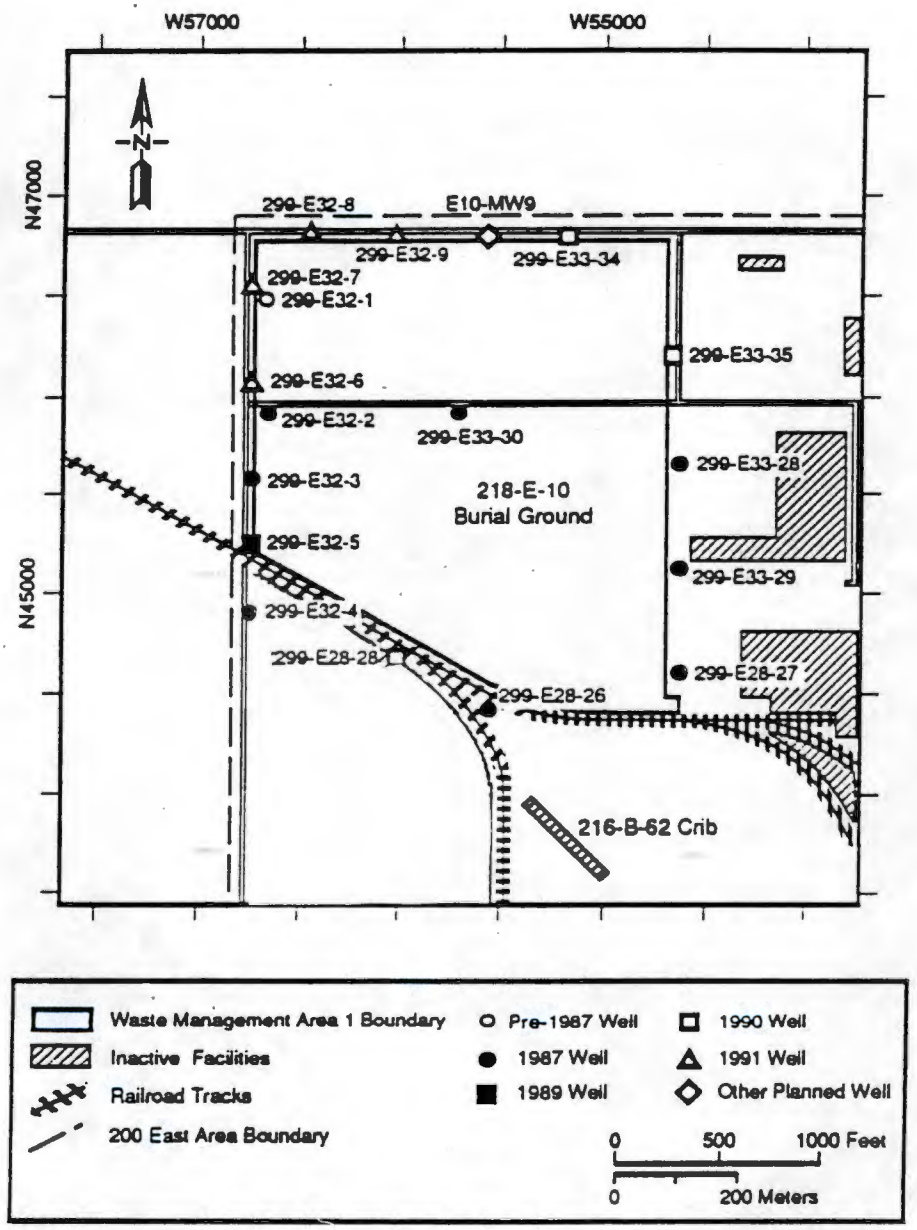


Figure 2-4. Monitoring Well Locations for the Low-Level Waste Management Area 1.

9 2 1 2 7 5 1 1 6 0

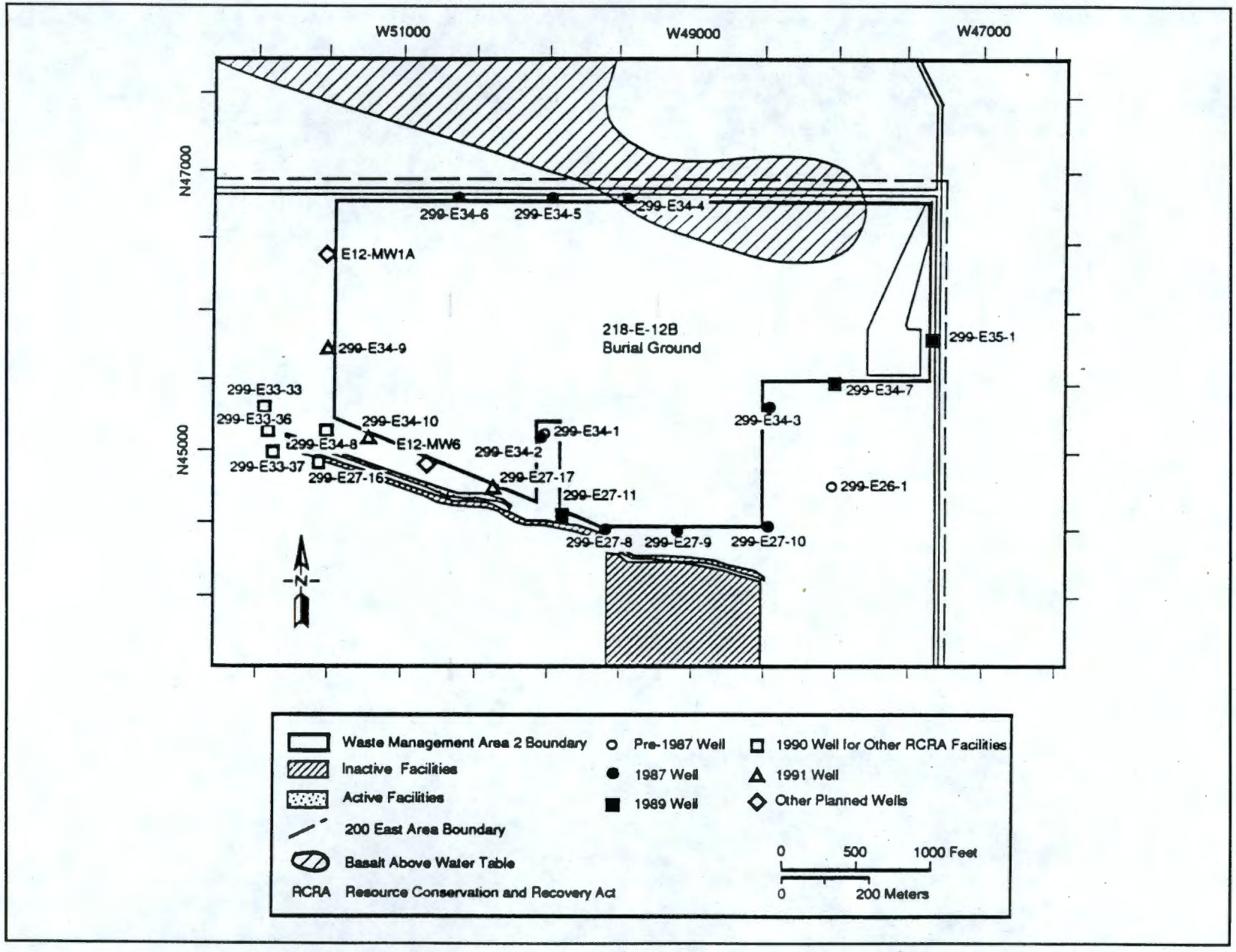
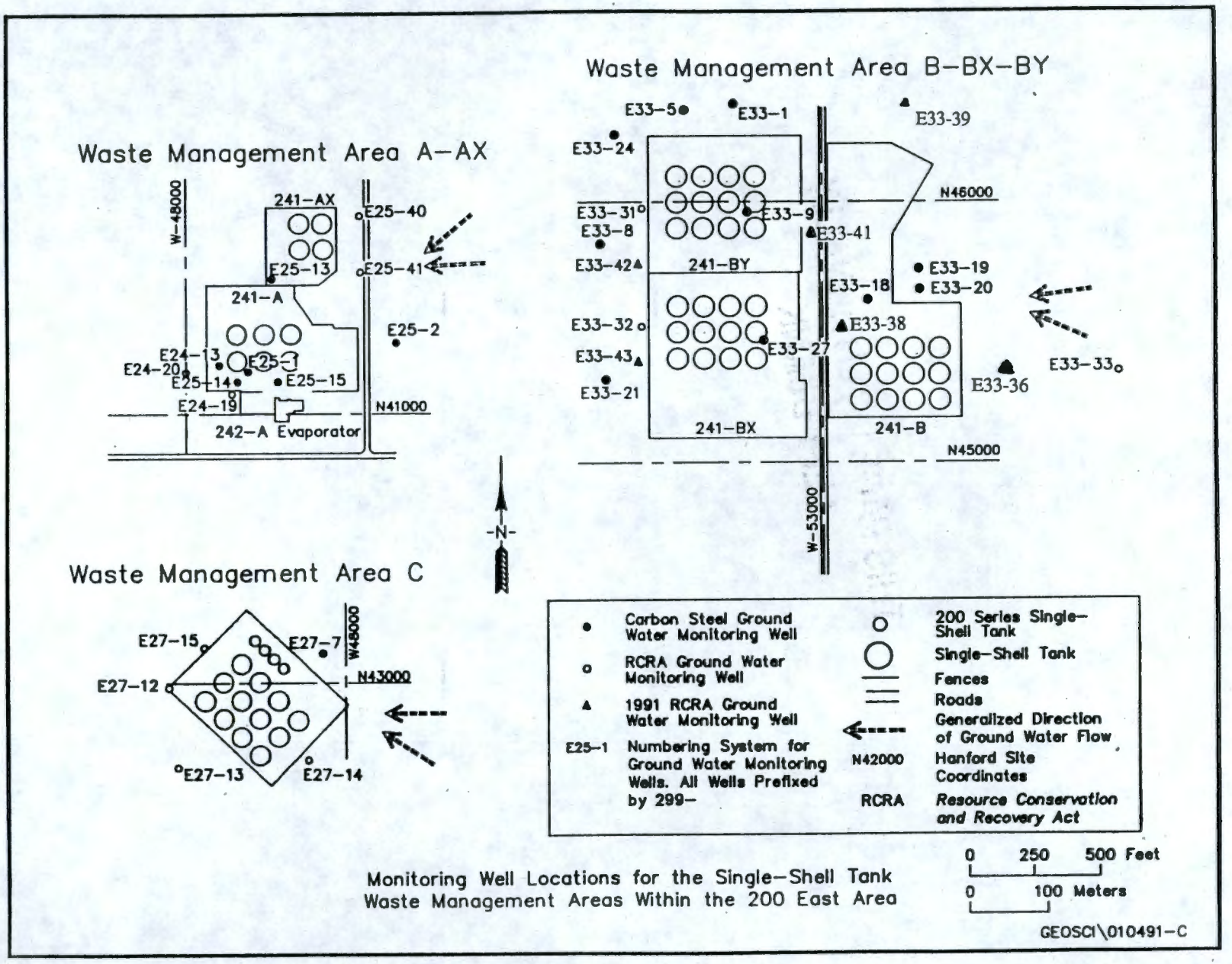


Figure 2-5. Monitoring Well Locations for the Low-Level Waste Management Area 2.



Monitoring Well Locations for the Single–Shell Tank Waste Management Areas Within the 200 East Area

Figure 2-6. Monitoring Well Locations for the Single-Shell Tank Waste Management Areas in the 200 East Area.

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Table 2-5. Radionuclide Waste Inventory Summary for Units Potentially Contributing Contaminants to Groundwater.

Waste Management Unit	Quantity of Reported Radionuclides (Ci)																		Reported Waste Volume Received (L)
	Am-241	Co-60	Cs-137	H-3	I-129	Pm-147	Pu-238	Pu-239	Pu-240	Pu-241	Total Pu in grams	Ru-106	Sn-113	Sr-90	U-238	Total U	Alpha	Beta	
PUREX Plant Aggregate Area																			
216-A-3 Crib			0.0455								0.2	1.52E-07		0.0431		0.559	0.0123	0.182	3,050,000
216-A-4 Crib		0.0226	6.93					7.99	2.16		140	4.38E-08		4.39	0.134	0.133	8.6	2.21	6,210,000
216-A-5 Crib		3.32	12.1					3.71	1		65	1.08E-07		41.6	0.0881	0.0877	3.99	109	1,630,000,000
216-A-6 Crib		0.18	10.5					2.09	0.548		35.6	5.5E-06		44.1	0.0553	0.055	2.19	291	3,400,000,000
216-A-7 Crib		0.00204	2.31					0.0571	0.0154		1	1.1E-07		0.431	0.00228	0.00227	0.0614	5.29	326,000
216-A-8 Crib			522	0.346							50	4.69E-05		51.5		0.123	3.07	1110	1,150,000,000
216-A-9 Crib		0.00583	4.65	4000				0.0285	0.0077		0.5	3.63E-08		11	0.00008	7.57E-05	0.0307	31	981,000,000
216-A-10 Crib	0.773		80.5	18500	0.107		0.329	3.39		42.3	350	0.309		8.25		0.081	28.1	360	3,210,000,000
216-A-21 Crib		0.471	78.5					8.56	2.31		150	1.45E-06		7.51	0.0653	0.065	9.21	166	77,900,000
216-A-24 Crib		0.0219	268					0.289	0.0779		5.06	1.32E-06		18.3	0.0168	0.0167	9.21	166	77,900,000
216-A-27 Crib		0.3	32.4					5.51	1.49		96.5	1.38E-05		24.5	0.0228	0.0227	5.92	112	23,200,000
216-A-30 Crib			117	16.4		0.429		0.0751			73.1	0.0814	0.00315	102		0.1	4.64	432	7,110,000,000
216-A-36A Crib		0.71	847					4.57	1.23		80	0.000116		978	0.0486	0.0484	4.91	3630	1,070,000
216-A-36B Crib	0.217		350	507	0.00842	1.99		0.0569		0.558	178	3.17	0.000579	331		0.0398	1.1	1360	317,000,000
216-A-37-1 Crib	0.000369		0.0947	1600	0.00426	0.0919		0.000201			0.0283	0.0415	0.00252	0.0542		0.0109	0.00845	0.508	377,000,000
216-A-37-2 Crib	0.0982		0.204	6.13		0.196		373				0.0407	0.00157	0.307		0.0172	0.105	1.85	1,090,000,000
216-A-45 Crib	0.11		0.0097	3850	0.0111	0.0421	0.00613	0.0556		0.658		0.0133	6.56E-05	0.00834		0.00225	0.0551	0.112	103,000,000
216-A-11 French Drain																			100,000
216-A-12 French Drain																			100,000
216-A-13 French Drain																			100,000
216-A-15 French Drain																			10,000,000
216-A-16 French Drain																			122,000
216-A-17 French Drain																			60,000
216-A-18 Trench		0.00179	0.0444					0.00571	0.00154		0.1	2.75E-12			0.472	0.469	0.00614	0.172	488,000
216-A-19 Trench		0.00179	0.0444					0.00571	0.00154		0.1	2.75E-12			13.1	13	0.00614	0.17	1,100,000
216-A-20 Trench		0.00179	0.0444					0.00571	0.00154		0.1	2.75E-12			0.135	0.135	0.00614	0.17	96,000
B Plant Aggregate Area																			
216-B-7A&B Cribs	0	0.012	43.2	0			0	246	66.2	0	4300	0		2200	0.061	0.0606	264	4490	43,600,000
216-B-8 Crib and Tile Field	0	0.009	19.8	0			0	1.7	0.462	0	30	0		5.58	0	0.0151	1.84	49.3	27,200,000
216-B-9 Crib and Tile Field	0	0.0009	3.92	0			0	9.94	2.68	0	174	0		5.52	0.0152	0.0151	10.7	2	36,000,000
216-B-10A Crib	0	0.00099	0.401	0			0	0.56	0.151	0	9.8	0		0	1.89	0.00302	0.602	4.55	9,990,000
216-B-10B Crib	0	0	0.0001	0			0	0	0	0	0	0		0	0.0002	2.49E-07	2.91E-06	5.31E-07	28,000
216-B-12 Crib	0	0.232	716	0			0	21.4	5.76	0	374	0.0001		0	79.3	6.96	23	1540	520,000,000
216-B-14 Crib	0	0.103	114	0			0	1.43	0.385	0	25	0		172	0.073	0.0726	1.53	567	8,710,000
216-B-15 Crib	0	0.109	92.4	0			0	0.285	0.077	0	5	0		87.3	0.0348	0.0348	0.307	357	6,320,000

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Table 2-5. Radionuclide Waste Inventory Summary for Units Potentially Contributing Contaminants to Groundwater.

Waste Management Unit	Quantity of Reported Radionuclides (Ci)																		Reported Waste Volume Received (L)
	Am-241	Co-60	Cs-137	H-3	I-129	Pm-147	Pu-238	Pu-239	Pu-240	Pu-241	Total Pu in grams	Ru-106	Sn-113	Sr-90	U-238	Total U	Alpha	Beta	
216-B-16 Crib	0	0.103	296	450			0	0.571	0.154	0	10	0		302	0.108	0.107	0.614	1180	5,600,000
216-B-17 Crib	0	0.0204	100	0			0	0.571	0.154	0	10	0		68.9	0.119	0.118	0.614	330	3,410,000
216-B-18 Crib	0	0.103	114	0			0	0.571	0.154	0	10	0		81.8	0.0791	0.0786	0.614	385	8,520,000
216-B-19 Crib	0	0.117	126	0			0	0.571	0.154	0	10	0		88.3	0.0606	0.0605	0.614	418	6,400,000
216-B-43 Crib	0	0.0157	130	170			0	0.0285	0.0077	0	0.5	0		574	0.00456	0.00454	0.0307	1400	2,120,000
216-B-44 Crib	0	0.0848	309	450			0	0.856	0.231	0	15	0		1200	0.00076	0.000756	0.921	2990	5,600,000
216-B-45 Crib	0	0.0899	666	390			0	0.571	0.154	0	10	0		1180	0.00228	0.00227	0.614	3640	4,920,000
216-B-46 Crib	0	0.0899	88.9	536			0	1.142	0.308	0	20	0		631	0.0636	0.0635	1.23	1440	6,700,000
216-B-47 Crib	0	0.0179	66.6	0			0	0.285	0.0766	0	5	0		261	0.00228	0.00227	0.307	650	3,710,000
216-B-48 Crib	0	0.0179	200	327			0	0.285	0.077	0	5	0		547	0.00076	0.000757	0.307	1490	4,090,000
216-B-49 Crib	0	0.0899	182	536			0	0.856	0.231	0	15	0		1140	0.106	0.106	262	2360	6,700,000
216-B-50 Crib	0	0.0283	51.2	90			0	0.0136	0.00368	0	0.239	0		3.39	0.0001	0.000095	0.0147	105	54,800,000
216-B-55 Crib	3.8E-06		13.7	2.68			0	3.8E-06	0	0	0.653	5.01E-05		7.23		0.0268	0.0423	40.9	1,230,000,000
216-B-57 Crib	0	0.0147	226	0			0	0.0106	0.00287	0	0.187			1.83	0.00029	0.000297	0.0115	437	84,400,000
216-B-62 Crib	0.103		·135	14.7				0.0023			0.755	0.0049		74.6		0.01	0.105	418	282,000,000
216-B-4 Reverse Well	No inventory data is contained in WIDS, however, the presence of TRU and fission products is mentioned.																	1	10,000
216-11A&B Reverse Wells	0	0.00143	21.3	0			0	0.228	0.0616		4	0.425		2.01	0.00456	0.00454	0.246	44.9	29,600,000
216-B-5 Reverse Well	0		29.2	0			0	244	65.7		4270	1.03E-11		25.5	0	0	262	108	30,600,000
216-B-6 Reverse Well	No inventory data is contained in WIDS, however, the presence of TRU and fission products is mentioned.																	1	6,000,000
216-A-25 Pond	0.000528		204	213							428	0.000162		257		4.24	27.5	939	307,000,000,000
216-B-3 Pond	3.96		93.5	790			0.0026	0.799			250	1.42		101		2.1	16.2	390	240,000,000,000
216-N-8 Pond																			unknown
216-B-2-1 Ditch	Waste inventory is included in the 216-B-3 Pond inventory.																		149,000,000,000
216-B-2-2 Ditch			0.314	0					0.0024	0	0.042			147	0	1.57E-05	0.00258	295	49,700,000
216-B-3-1 Ditch	Waste inventory is included in the 216-B-3 Pond inventory.																		149,000,000,000
216-B-3-2 Ditch	Waste inventory is included in the 216-B-3 Pond inventory.																		149,000,000,000
216-B-20 Trench	0	0.0899	684	0			0	0.0742	0.02	0	1.3	0		340	0.118	0.117	0.0798	2000	2,680,000
216-B-21 Trench	0	0.133	169	0			0	0.58	0.136	0	10.3	0		318	0.226	0.225	0.632	965	4,670,000
216-B-22 Trench	0	0.274	20.5	0			0	0.148	0.0342	0	2.6	0		176	0.14	0.139	0.16	398	4,740,000
216-B-23 Trench	0	0.137	50.9	0			0	0.102	0.0277	0	1.8	0		62.5	0.0523	0.052	0.111	226	4,520,000
216-B-24 Trench	0	0.21	58.6	0			0	0.44	0.119	0	77	0		78	0.0825	0.082	0.473	0.274	4,700,000
216-B-26 Trench	0	0.223	438	0			0	0.143	0.385	0	2.5	0		475	0.197	0.196	0.0153	1800	3,760,000
216-B-28 Trench	0	0.0537	10.7	0			0	0.32	0.0862	0	5.6	0		49.5	0.101	0.1	0.34	121	5,880,000
216-B-29 Trench	0	0.165	27.4	0			0	0.0628	0.0169	0	1.1	0		84.8	0.115	0.115	0.0675	226	4,420,000
216-B-30 Trench	0	0.0397	1570	0			0	0.12	0.0323	0	2.1	0		265	0.0295	0.0293	0.129	3540	4,780,000
216-B-32 Trench	0	0.0397	58.6	0			0	0.148	0.04	0	2.6	0		113	0.00368	0.00367	0.16	339	4,770,000
216-B-33 Trench	0	0.0327	127	0			0	0.674	0.182	0	11.8	0		18.1	0.0067	0.00667	0.724	281	4,740,000
216-B-34 Trench	0	0.014	7.91	0			0	0.325	0.0878	0	5.7	0		18.1	0.0285	0.0283	0.35	51.7	4,800,000
216-B-36 Trench	0	0.0011	336	0			0	0.0457	0.0123	0	0.8	0		199	0.00532	0.00532	0.0491	1040	1,940,000
216-B-37 Trench	0	0.0157	1350	0			0	0.114	0.0308	0	2	0		6.56	0.00121	0.00121	0.123	2600	4,320,000

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Table 2-5. Radionuclide Waste Inventory Summary for Units Potentially Contributing Contaminants to Groundwater.

Waste Management Unit	Quantity of Reported Radionuclides (Ci)																		Reported Waste Volume Received (L)
	Am-241	Co-60	Cs-137	H-3	I-129	Pm-147	Pu-238	Pu-239	Pu-240	Pu-241	Total Pu in grams	Ru-106	Sn-113	Sr-90	U-238	Total U	Alpha	Beta	
216-B-40 Trench	0	0.00031	153	0			0	0.0571	0.0154	0	1	0		115	0.00117	0.017	0.0614	523	1,640,000
216-B-52 Trench	0	0.113	160	0			0	1.08	0.293	0	19	0		4.92	0.01	0.00998	1.17	317	8,530,000
216-B-53A Trench	0	0.0335	0.0559	0			0	5.71	1.54	0	100	0		0.0538	0.076	0.00756	6.14	0.246	549,000
216-B-63 Trench	0.0348		0.625	2.12				0.0108			0.573	2.39E-07		2.41		0.15	0.0742	6.32	7,220,000,000
Semi-Works Aggregate Area																			
216-C-1 Crib		0.002	0.0455	70				0.4579	0.123		8	1.89E-08		85.5	0.0988				23,400,000
216-C-3 Crib		0.0014	0.0424								1	8.3E-11		8.04	0.0153				5,000,000
216-C-4 Crib		0.0018	0.0433								1	5.35E-10		11.8	0.0011				170,000
216-C-5 Crib		0.0018	0.0444								1	1.38E-10		4.2	0.0182				37,900
216-C-6 Crib		0.0025	0.0465								0.1	2.73E-08		28.8	0.0001				530,000
216-C-10 Crib		0.0113	0.0855								0.15	8.95E-08		3.45	0.00001				897,000
216-C-9 Pond			0.703								0.338	8.66E-08		2.43					1,030,000,000
200 East Powerhouse Ditch																			13,800/mo
200 North Aggregate Area																			
216-N-1 Pond			0.0813					0.0571	0.0154		1	3.32E-13		0.0713	0.00152	0.00151	0.0614	0.3	946,000,000
216-N-4 Pond			0.0813					0.0571	0.0154		1	3.32E-13		0.0713	0.00152	0.00151	0.0614	0.3	946,000,000
216-N-6 Pond			0.0813					0.0571	0.0154		1	3.23E-13		0.0713	0.00152	0.00151	0.0614	0.3	946,000,000
216-N-2 Trench			0.0785									4.73E-14		0.0687				0.29	7,500,000
216-N-3 Trench			0.0881									1.49E-12		0.0777				0.326	7,600,000
216-N-5 Trench			0.0881									1.49E-12		0.0777				0.326	7,600,000
216-N-7 Trench			0.0881									1.49E-12		0.0777				0.326	7,600,000

Source: WIDS (WHC 1991a).

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Table 2-6. Chemical Waste Inventory Summary for Units Potentially Contributing Contaminants to Groundwater.

Waste Management Unit	Quantity of Reported Chemical Waste (kg)											Waste Volume Received (L)
	Aluminum Nitrate	Ammonium Carbonate	Ammonium Nitrate	BP	Fluoride	Ferrocyanide	Nitrate	Nitrite	Nitric Acid	Normal Paraffin Hydrocarbons	Oxalate	
PUREX Plant Aggregate Area												
216-A-3 Crib												3,050,000
216-A-4 Crib							300					6,210,000
216-A-5 Crib							1,000,000					1,630,000,000
216-A-6 Crib							10,000					3,400,000,000
216-A-7 Crib										180,000		326,000
216-A-8 Crib			320,000	130,000						46,000		1,150,000,000
216-A-9 Crib							300,000					981,000,000
216-A-10 Crib												3,210,000,000
216-A-21 Crib		400,000					9,000					77,900,000
216-A-24 Crib			200,000	90,000						30,000		77,900,000
216-A-27 Crib		300,000					5,000					23,200,000
216-A-30 Crib							16,000					7,110,000,000
216-A-36A Crib												1,070,000
216-A-36B Crib												317,000,000
216-A-37-1 Crib							600					377,000,000
216-A-37-2 Crib												1,090,000,000
216-A-45 Crib												103,000,000
216-A-11 French Drain							100					100,000
216-A-12 French Drain							100					100,000
216-A-13 French Drain							1					100,000
216-A-15 French Drain									1			10,000,000
216-A-16 French Drain							1					122,000
216-A-17 French Drain							1					60,000
216-A-18 Trench							730					488,000
216-A-19 Trench							20,000					1,100,000
216-A-20 Trench							210					96,000
B Plant Aggregate Area												
216-B-7A&B Cribs			22,000		240,000		1,800,000				60,000	43,600,000
216-B-8 Crib and Tile Field			160,000		25,000		1,400,000				6,000	27,200,000
216-B-9 Crib and Tile Field							1,000					36,000,000
216-B-10A Crib							1,000		1,000			9,990,000
216-B-10B Crib									2			28,000
216-B-12 Crib			1,800,000									520,000,000
216-B-14 Crib						5,000	1,500,000					8,710,000
216-B-15 Crib						3,300	90,000					6,320,000

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Table 2-6. Chemical Waste Inventory Summary for Units Potentially Contributing Contaminants to Groundwater.

Waste Management Unit	Quantity of Reported Chemical Waste (kg)											Waste Volume Received (L)
	Aluminum Nitrate	Ammonium Carbonate	Ammonium Nitrate	BP	Fluoride	Ferrocyanide	Nitrate	Nitrite	Nitric Acid	Normal Paraffin Hydrocarbons	Oxalate	
216-B-16 Crib						3,000	1,100,000					5,600,000
216-B-17 Crib						1,800	1,100,000					3,410,000
216-B-18 Crib						5,000	1,000,000					8,520,000
216-B-19 Crib						3,400	1,500,000					6,400,000
216-B-43 Crib						1,100	400,000					2,120,000
216-B-44 Crib						3,000	800,000					5,600,000
216-B-45 Crib						2,600	90,000					4,920,000
216-B-46 Crib						4,000	1,200,000					6,700,000
216-B-47 Crib						2,000	700,000					3,710,000
216-B-48 Crib						2,200	1,000,000					4,090,000
216-B-49 Crib						4,000	1,500,000					6,700,000
216-B-50 Crib		9,100	10,000				1,500					54,800,000
216-B-55 Crib			90,000									1,230,000,000
216-B-57 Crib		12,000										84,400,000
216-B-62 Crib												282,000,000
216-B-4 Reverse Well									1,000			10,000
216-11A&B Reverse Wells												29,600,000
216-B-5 Reverse Well	5,000				50,000		400,000				12,000	30,600,000
216-B-6 Reverse Well									10,000			6,000,000
216-A-25 Pond												307,000,000,000
216-B-3 Pond												240,000,000,000
216-N-8 Pond												unknown
216-B-2-1 Ditch												149,000,000,000
216-B-2-2 Ditch												49,700,000
216-B-3-1 Ditch												149,000,000,000
216-B-3-2 Ditch												149,000,000,000
216-B-20 Trench						2,500	1,100,000					2,680,000
216-B-21 Trench												4,670,000
216-B-22 Trench						2,500	900,000					4,740,000
216-B-23 Trench						2,400	1,000,000					4,520,000
216-B-24 Trench						2,500	600,000					4,700,000
216-B-26 Trench						3,100	800,000					3,760,000
216-B-28 Trench						2,700	1,000,000					5,880,000
216-B-29 Trench						2,600	700,000					4,420,000
216-B-30 Trench						2,500	1,100,000					4,780,000
216-B-32 Trench						2,500	1,000,000					4,770,000
216-B-33 Trench						2,500	1,700,000					4,740,000
216-B-34 Trench						2,600	1,900,000					4,800,000
216-B-36 Trench					5,000		160,000	18,000				1,940,000
216-B-37 Trench					50,000		1,700,000	200,000				4,320,000

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Table 2-6. Chemical Waste Inventory Summary for Units Potentially Contributing Contaminants to Groundwater.

Waste Management Unit	Quantity of Reported Chemical Waste (kg)											Waste Volume Received (L)
	Aluminum Nitrate	Ammonium Carbonate	Ammonium Nitrate	BP	Fluoride	Ferrocyanide	Nitrate	Nitrite	Nitric Acid	Normal Paraffin Hydrocarbons	Oxalate	
216-B-40 Trench				153	4,000		130,000	15,000				1,640,000
216-B-52 Trench				160		5,000	2,100,000					8,530,000
216-B-53A Trench							1					549,000
216-B-63 Trench												7,220,000,000
Semi-Works Aggregate Area												
216-C-1 Crib									15,000			23,400,000
216-C-3 Crib							20					5,000,000
216-C-4 Crib										24,000		170,000
216-C-5 Crib							8,000					37,900
216-C-6 Crib							330					530,000
216-C-10 Crib												897,000
216-C-9 Pond												1,030,000,000
200 East Powerhouse Ditch												13,800/mo
200 North Aggregate Area												
216-N-1 Pond												946,000,000
216-N-4 Pond												946,000,000
216-N-6 Pond												946,000,000
216-N-2 Trench												7,500,000
216-N-3 Trench												7,600,000
216-N-5 Trench												7,600,000
216-N-7 Trench												7,600,000

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Table 2-6. Chemical Waste Inventory Summary for Units Potentially Contributing Contaminants to Groundwater.

Waste Management Unit	Quantity of Reported Chemical Waste (kg)									Waste Volume Received (L)
	Phosphate	Potassium	Sodium Aluminate	Sodium Dichromate	Sodium	Sulfate	Sulfuric Acid	TBP	Tributyl Phosphonate	
PUREX Plant Aggregate Area										
216-A-3 Crib										3,050,000
216-A-4 Crib				110	4,000					6,210,000
216-A-5 Crib										1,630,000,000
216-A-6 Crib										3,400,000,000
216-A-7 Crib								100,000		326,000
216-A-8 Crib										1,150,000,000
216-A-9 Crib										981,000,000
216-A-10 Crib										3,210,000,000
216-A-21 Crib				300	11,000					77,900,000
216-A-24 Crib										77,900,000
216-A-27 Crib				200	6,000					23,200,000
216-A-30 Crib										7,110,000,000
216-A-36A Crib										1,070,000
216-A-36B Crib										317,000,000
216-A-37-1 Crib										377,000,000
216-A-37-2 Crib										1,090,000,000
216-A-45 Crib										103,000,000
216-A-11 French Drain										100,000
216-A-12 French Drain										100,000
216-A-13 French Drain										100,000
216-A-15 French Drain										10,000,000
216-A-16 French Drain										122,000
216-A-17 French Drain										60,000
216-A-18 Trench										488,000
216-A-19 Trench										1,100,000
216-A-20 Trench										96,000
B Plant Aggregate Area										
216-B-7A&B Cribs	130,000	400,000				15,000				43,600,000
216-B-8 Crib and Tile Field	500,000	40,000				70,000	1,400,000			27,200,000
216-B-9 Crib and Tile Field										36,000,000
216-B-10A Crib				100		1,000				9,990,000
216-B-10B Crib										28,000
216-B-12 Crib										520,000,000
216-B-14 Crib	40,000					50,000				8,710,000
216-B-15 Crib	50,000					60,000				6,320,000

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Table 2-6. Chemical Waste Inventory Summary for Units Potentially Contributing Contaminants to Groundwater.

Waste Management Unit	Quantity of Reported Chemical Waste (kg)									Waste Volume Received (L)
	Phosphate	Potassium	Sodium Aluminate	Sodium Dichromate	Sodium	Sulfate	Sulfuric Acid	TBP	Tributyl Phosphonate	
216-B-16 Crib	70,000					110,000				5,600,000
216-B-17 Crib	60,000					90,000				3,410,000
216-B-18 Crib	50,000					70,000				8,520,000
216-B-19 Crib	100,000					90,000				6,400,000
216-B-43 Crib	21,000					29,000				2,120,000
216-B-44 Crib	40,000					60,000				5,600,000
216-B-45 Crib	41,000					60,000				4,920,000
216-B-46 Crib	70,000					100,000				6,700,000
216-B-47 Crib	40,000					60,000				3,710,000
216-B-48 Crib	60,000					80,000				4,090,000
216-B-49 Crib	60,000					80,000				6,700,000
216-B-50 Crib										54,800,000
216-B-55 Crib										1,230,000,000
216-B-57 Crib										84,400,000
216-B-62 Crib										282,000,000
216-B-4 Reverse Well						11				10,000
216-11A&B Reverse Wells										29,600,000
216-B-5 Reverse Well	29,000	80,000				3,300				30,600,000
216-B-6 Reverse Well				100			10,000			6,000,000
216-A-25 Pond										307,000,000,000
216-B-3 Pond										240,000,000,000
216-N-8 Pond										unknown
216-B-2-1 Ditch										149,000,000,000
216-B-2-2 Ditch										49,700,000
216-B-3-1 Ditch										149,000,000,000
216-B-3-2 Ditch										149,000,000,000
216-B-20 Trench	80,000					100,000				2,680,000
216-B-21 Trench										4,670,000
216-B-22 Trench	40,000					80,000				4,740,000
216-B-23 Trench	60,000					60,000				4,520,000
216-B-24 Trench	34,000					50,000				4,700,000
216-B-26 Trench	40,000					60,000				3,760,000
216-B-28 Trench	50,000					80,000				5,880,000
216-B-29 Trench	35,000					50,000				4,420,000
216-B-30 Trench	70,000					110,000				4,780,000
216-B-32 Trench	60,000					90,000				4,770,000
216-B-33 Trench	100,000					110,000				4,740,000
216-B-34 Trench	80,000					90,000				4,800,000
216-B-36 Trench	40,000		24,000			8,000				1,940,000
216-B-37 Trench	400,000					90,000				4,320,000

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Table 2-6. Chemical Waste Inventory Summary for Units Potentially Contributing Contaminants to Groundwater.

Waste Management Unit	Quantity of Reported Chemical Waste (kg)									Waste Volume Received (L)
	Phosphate	Potassium	Sodium Aluminate	Sodium Dichromate	Sodium	Sulfate	Sulfuric Acid	TBP	Tributyl Phosphonate	
216-B-40 Trench	31,000		20,000			7,000				1,640,000
216-B-52 Trench	80,000					80,000				8,530,000
216-B-53A Trench										549,000
216-B-63 Trench										7,220,000,000
Semi-Works Aggregate Area										
216-C-1 Crib										23,400,000
216-C-3 Crib										5,000,000
216-C-4 Crib									14,000	170,000
216-C-5 Crib										37,900
216-C-6 Crib										530,000
216-C-10 Crib										897,000
216-C-9 Pond										1,030,000,000
200 East Powerhouse Ditch										13,800/mo
200 North Aggregate Area										
216-N-1 Pond										946,000,000
216-N-4 Pond										946,000,000
216-N-6 Pond										946,000,000
216-N-2 Trench										7,500,000
216-N-3 Trench										7,600,000
216-N-5 Trench										7,600,000
216-N-7 Trench										7,600,000

Source: WIDS (WHC 1991a).

9 2 1 2 7 5 1 2 5 4

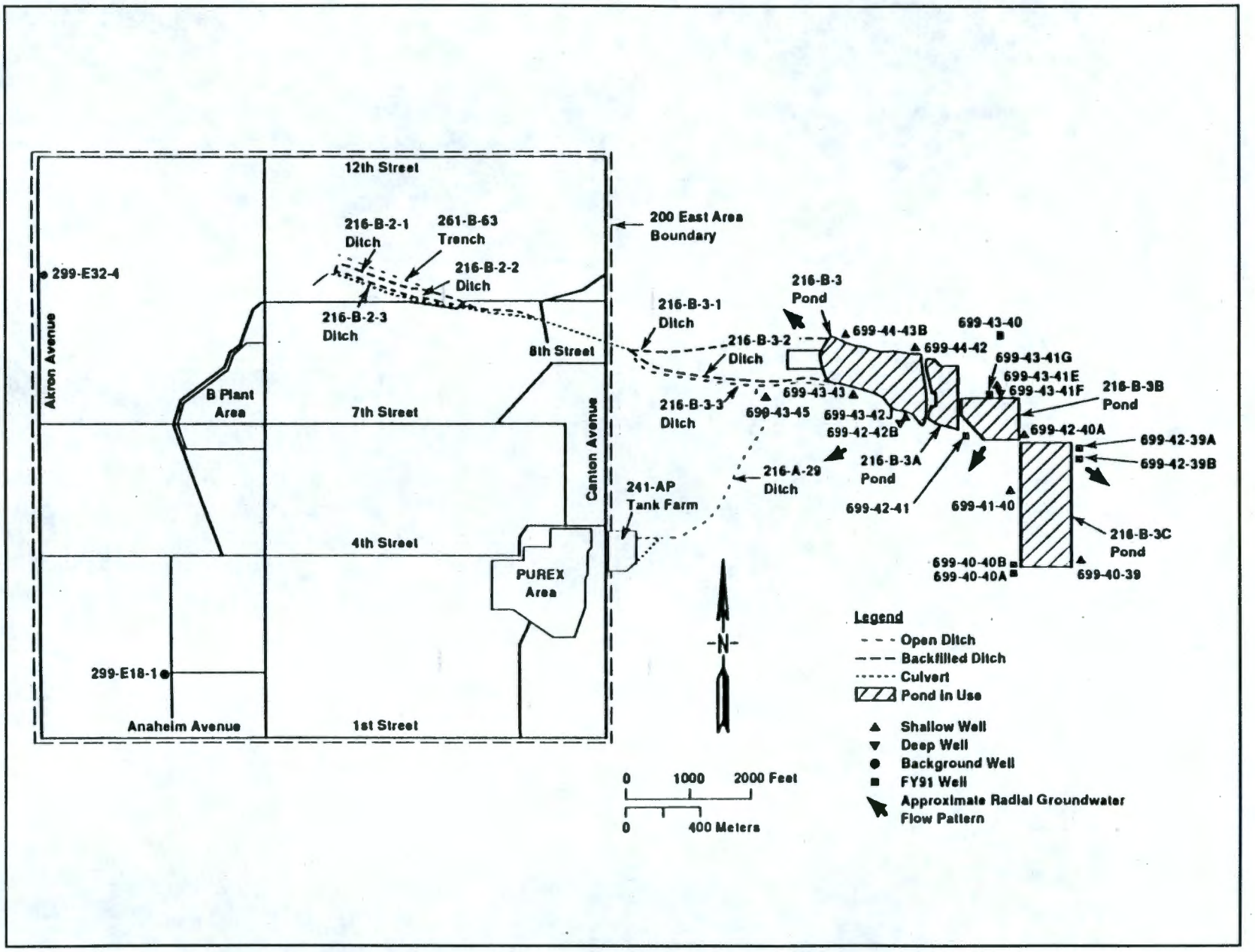

Figure 2-7. Monitoring Well Locations for the 216-B-3 Pond System.

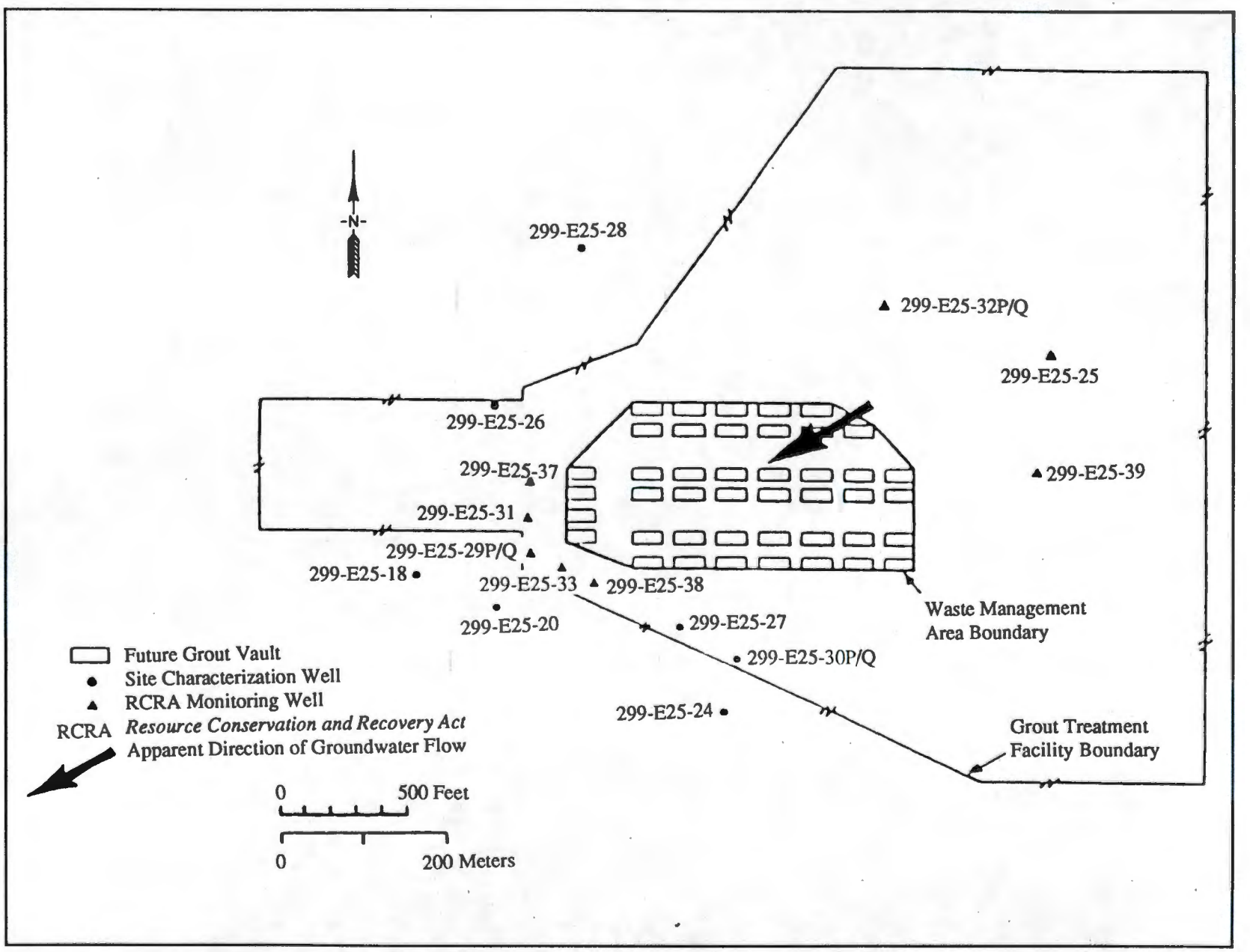

Figure 2-8. RCRA Monitoring Well Locations for the Grout Treatment Facility.

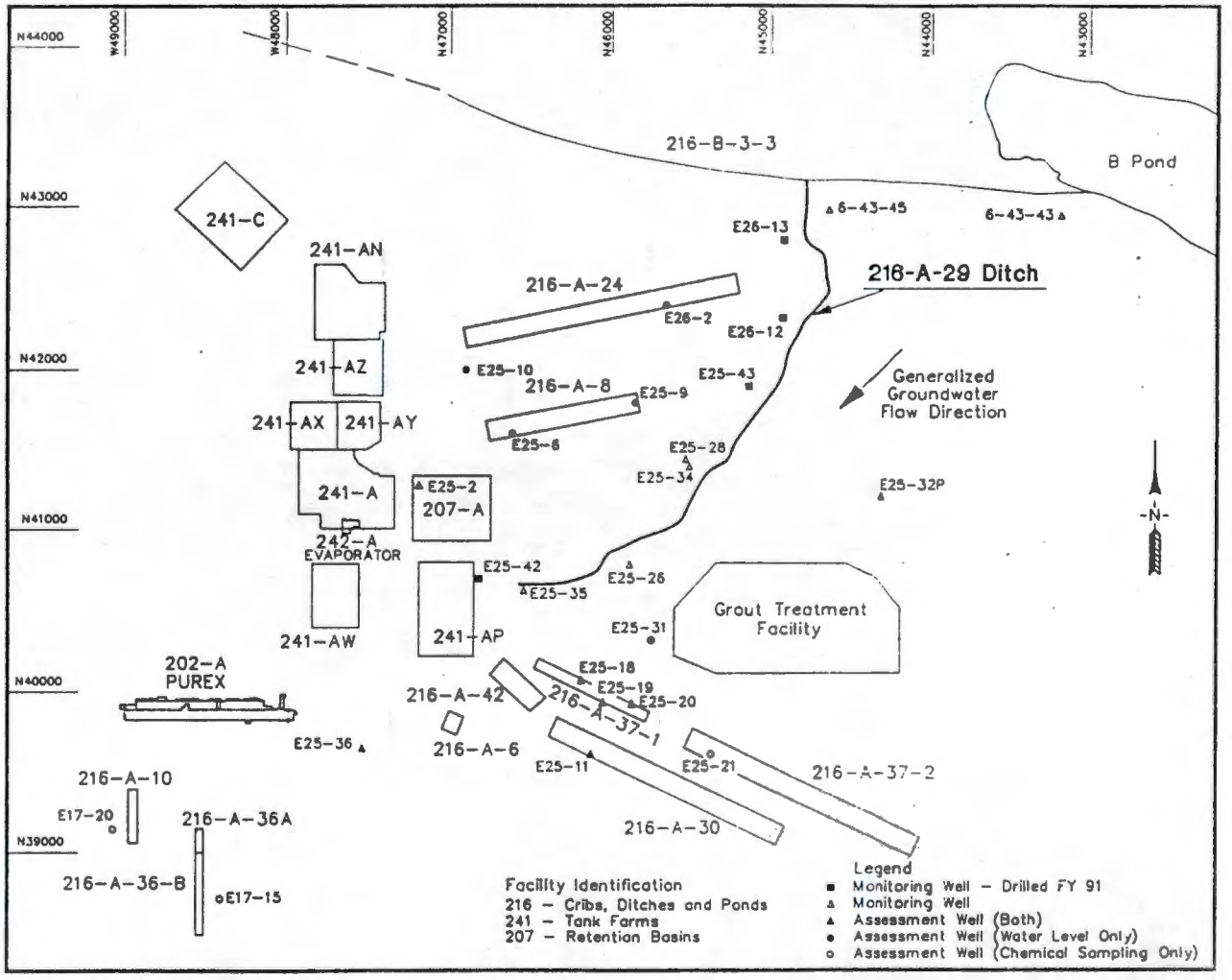

Figure 2-9. Monitoring Well Locations for the 216-A-29 Ditch.

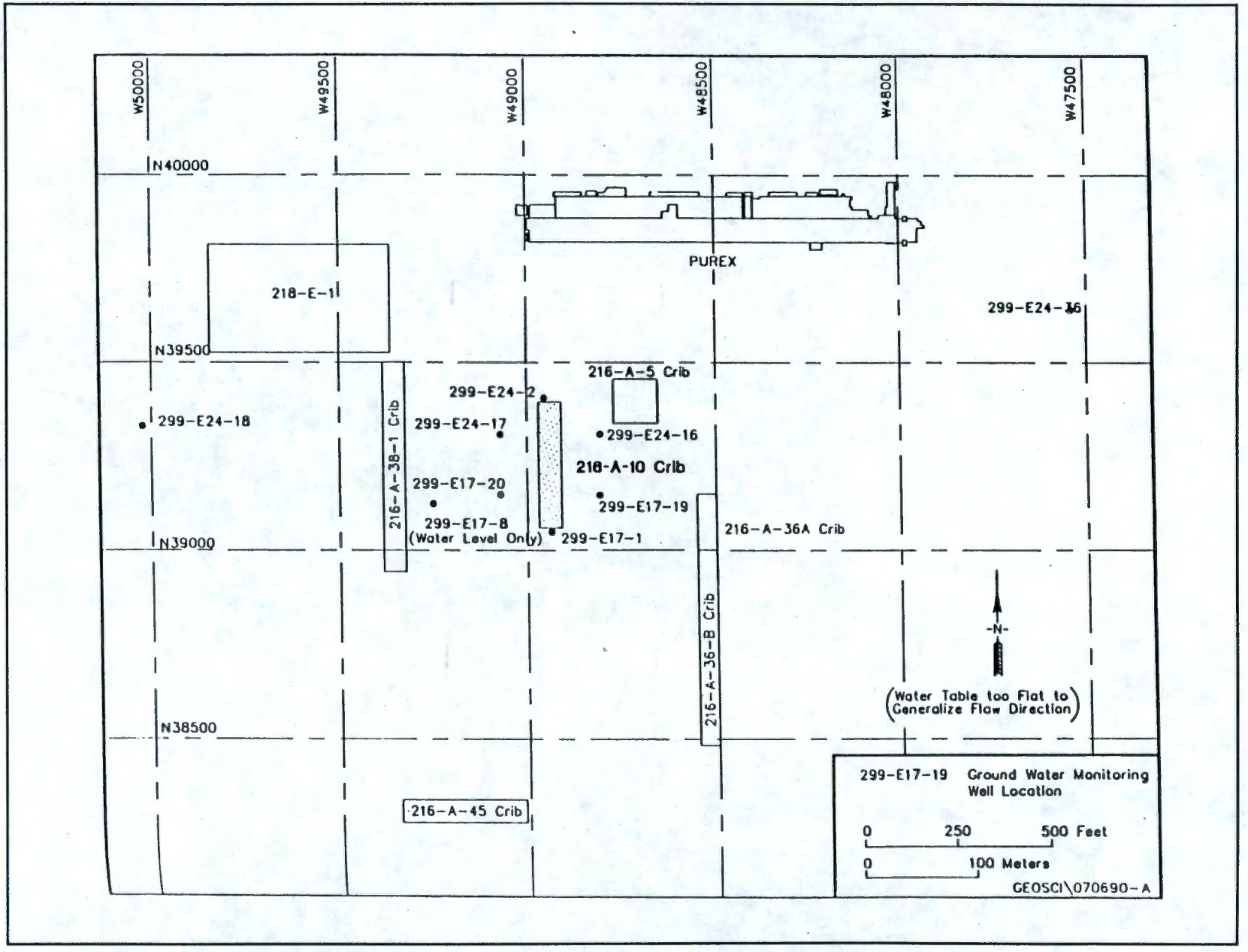

Figure 2-10. Monitoring Well Locations for the 216-A-10 Crib.

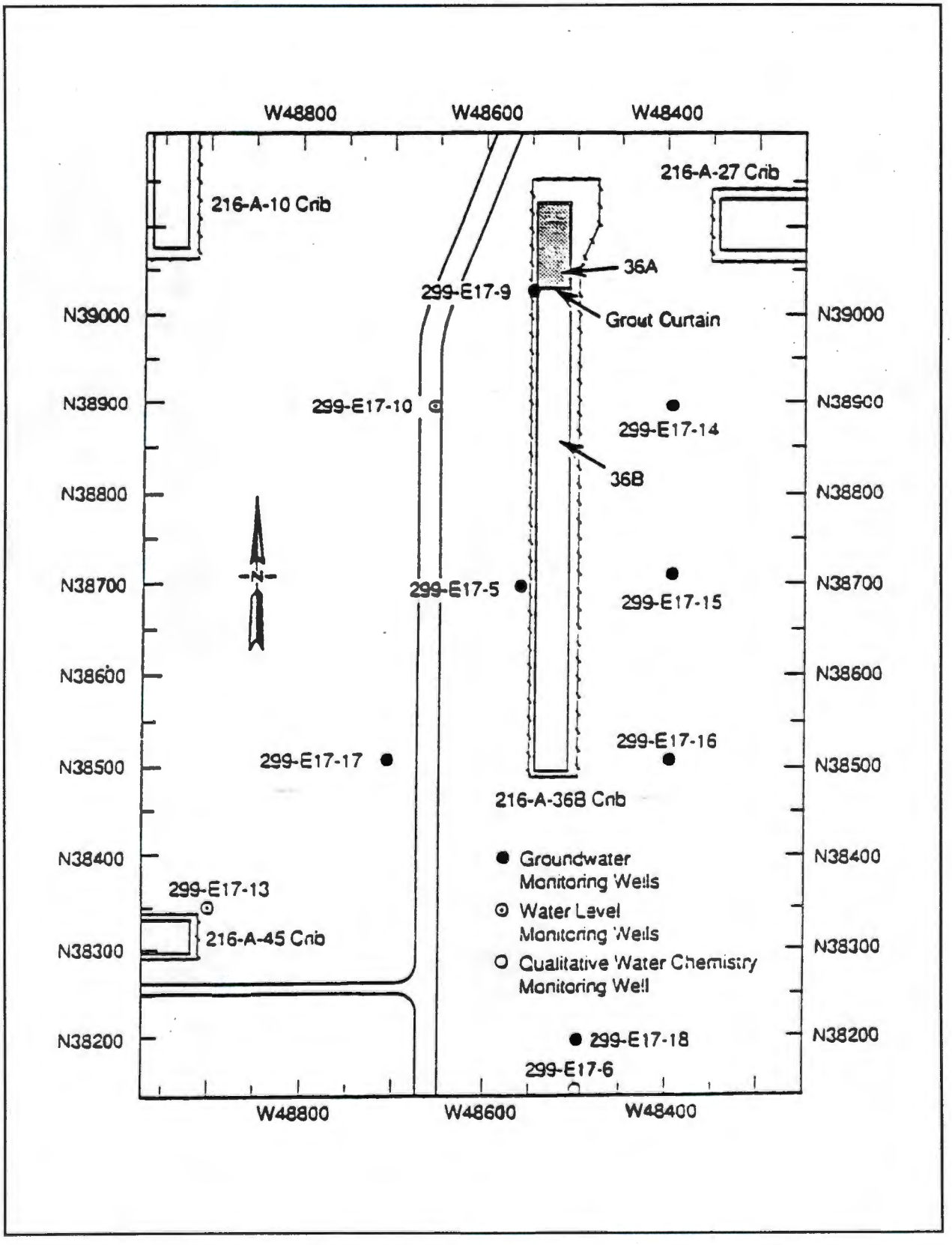

Figure 2-11. Monitoring Well Locations for the 216-A-36B Crib.

9 2 1 2 7 5 1 1 6 7

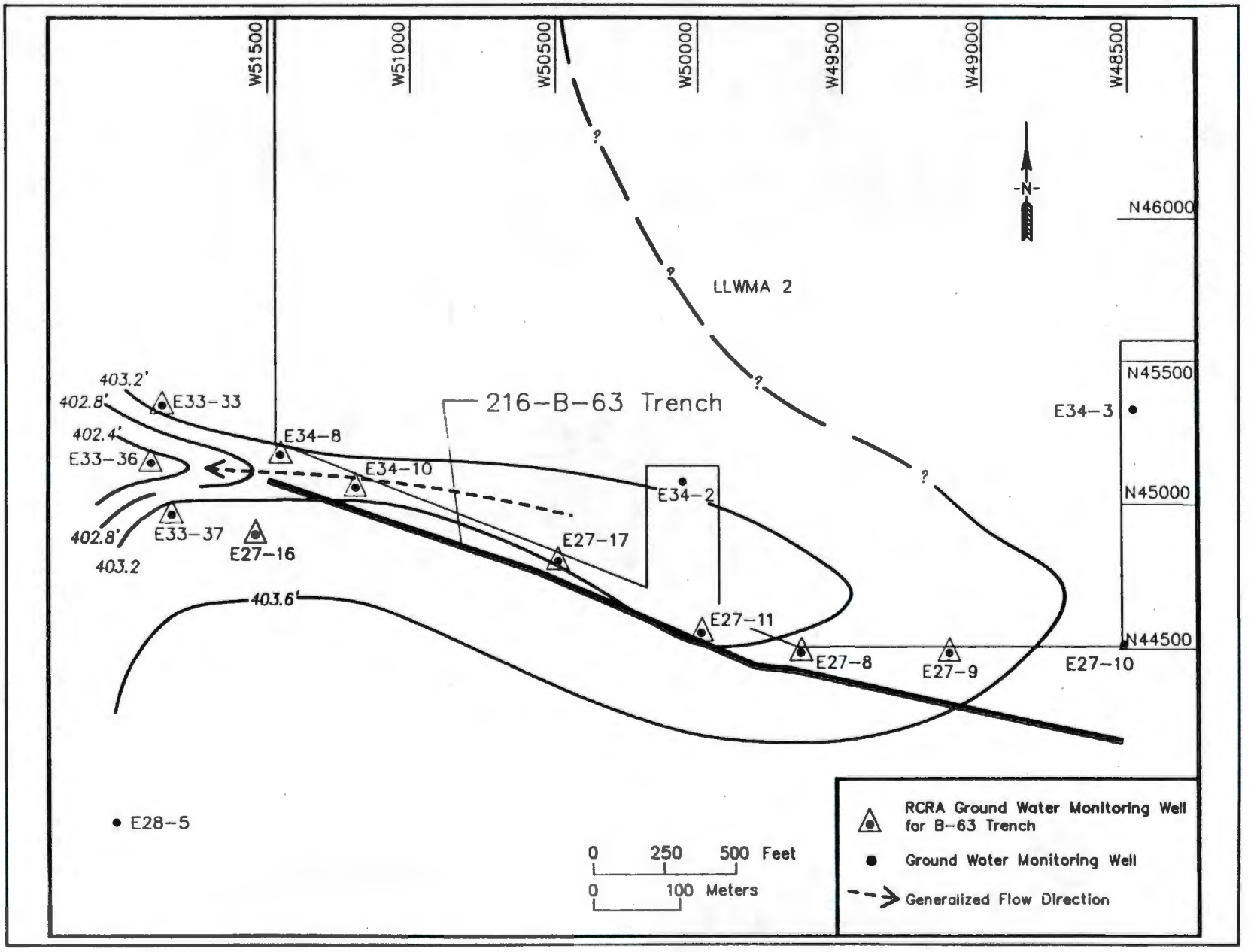

Figure 2-12. Monitoring Well Locations for the 216-B-63 Trench.

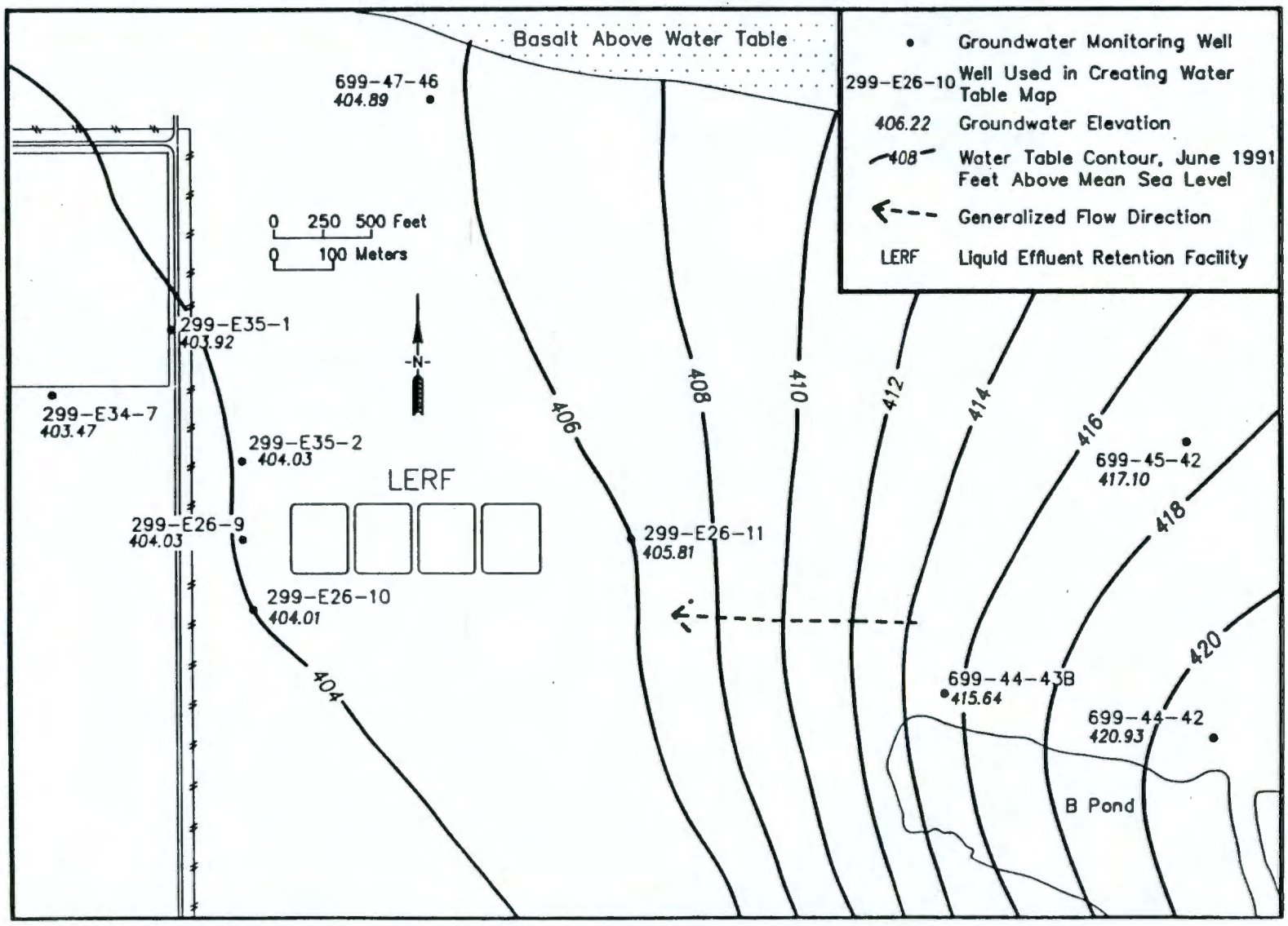

Figure 2-13. Monitoring Well Locations for the Liquid Effluent Retention Facility, June 1991.

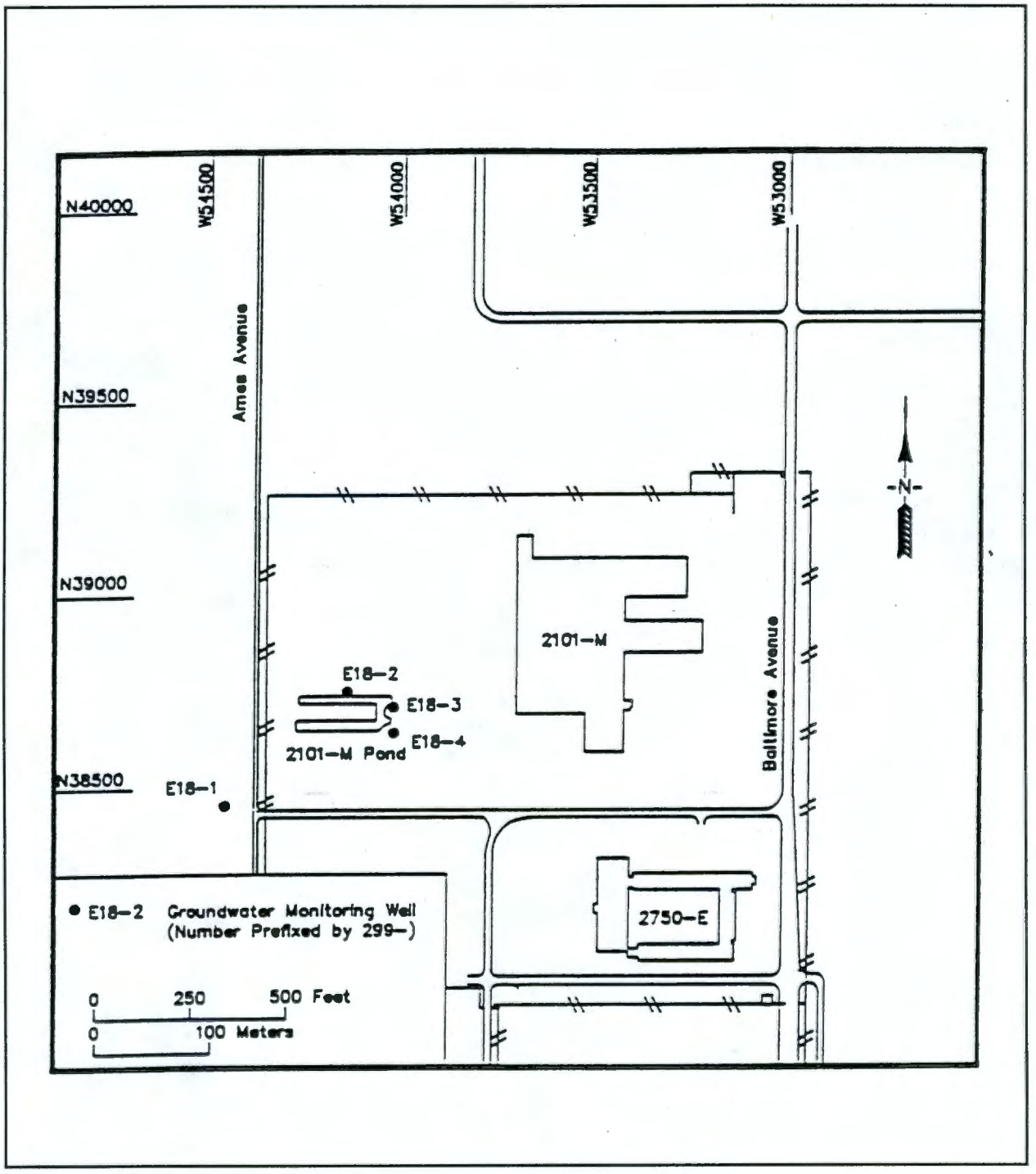

Figure 2-14. Monitoring Well Locations for the 2101-M Pond.

9 2 1 2 7 5 1 1 7 0

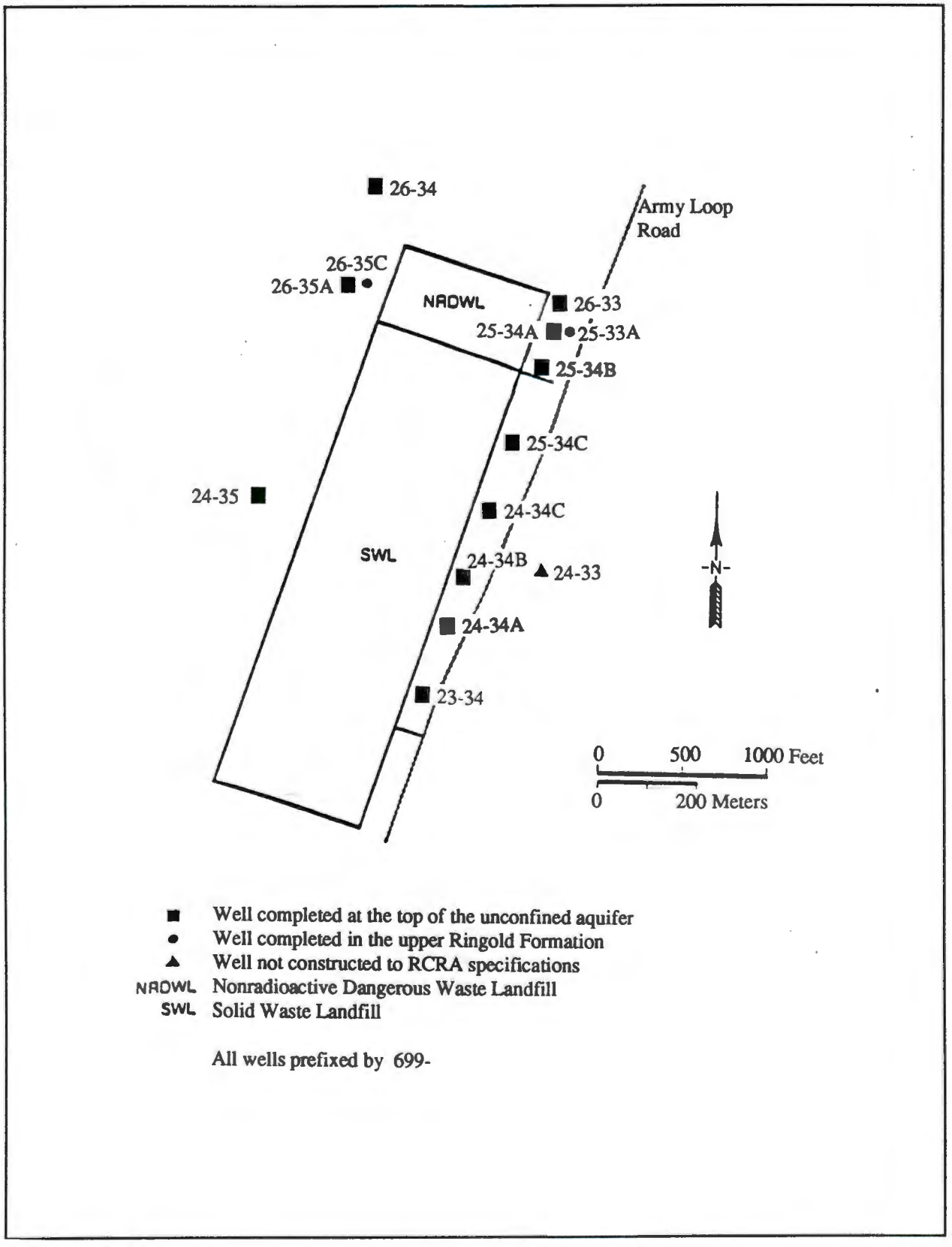

Figure 2-15. Monitoring Well Locations for the Nonradioactive Dangerous Waste Landfill and Solid Waste Landfill.

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Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
PUREX Plant Aggregate Area				
Plants, Buildings, and Storage Areas				
204-AR Waste Unloading Station	1982-Present *Active*	Receives wastes generated from decontamination and regeneration operations in 100 Area; from recovery, fuels fabrication, and laboratory operations in 300 Area; from decontamination operations in 400 Area; Waste is chemically adjusted prior to pumpout to double-shell tanks	No	Contains 1,966 (catch tank only)
241-A-431 Ventilation Building	1955-1969 *Inactive*	Contains radioactively contaminated equipment and concrete	No	Unknown
241-C-801 Support Facility	1962-1976 *Inactive*	This unit is a radioactively contaminated structure	No	Unknown
242-A Evaporator	1977-Present *Active*	Dilute noncomplexed radioactive waste; PUREX Dilute misc. waste; PUREX cladding removal waste; complexed radioactive waste; NaNO3 is used to regenerate ion exchange column, Turco 4518 or NaOH is used for decontamination applications, a Dow-Corning antifoam agent is used in the evaporator vessel	No	Unknown
244-AR Lift Station	1975-Present *Active*	Transports waste from processing and decontamination operations	Yes	Unknown

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
		Tanks and Vaults		
241-A-101 Single-Shell Tank	1956-1980 *Inactive*	PUREX carbonate wash waste, organic wash waste, high-level waste; B Plant high-level waste (Waste Fractionization); supernatant with B Plant high-level waste, PUREX high-level waste, double-shell slurry feed, and complexed and noncomplexed wastes from 241-A, -AX, -BX, -SX Tanks	No	Contains 3,602,340
241-A-102 Single-Shell Tank	1956-1980 *Inactive*	PUREX carbonate wash waste; PUREX high-level waste; B Plant high-level waste (Waste Fractionization); supernatant with PUREX high-level waste, B Plant high-level waste, PUREX sludge supernatant, evaporator waste, noncomplexed and complexed waste, and double-shell slurry feed from 241-A, -AX, -AY, -AZ, -BX, -C, and -SX Tank Farms and 244-AR Vault	No	Contains 154,980
241-A-103 Single-Shell Tank	1956-1980 *Inactive*	PUREX carbonate wash waste, organic wash waste, high-level waste; B Plant high-level waste (Waste Fractionization); Waste Fractionization ion exchange waste; and supernatant with B Plant high-level waste, Waste Fractionization ion exchange waste, PUREX high-level waste, PUREX sludge supernatant, and double-shell slurry feed from 241-A, -AX, -BY, and -C Tank Farms and 244-AR, -CR Vaults	Yes	Contains 1,398,600

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-A-104 Single-Shell Tank	1958-1975 *Inactive*	PUREX carbonate wash waste, organic wash waste, high-level waste; Waste Fractionization (B Plant) ion exchange waste; and supernatant with PUREX sludge supernatant from the 241-A Tank Farm and 244-AR Vault	Yes	Contains 105,840
241-A-105 Single-Shell Tank	1962-1971 *Inactive*	PUREX inorganic wash waste and supernatant with PUREX high-level waste from the 241-A Tank Farm	Yes	Contains 71,820
241-A-106 Single-Shell Tank	1957-1980 *Inactive*	PUREX organic and inorganic wash waste; PUREX carbonate wash waste; PUREX high-level waste; B Plant high-level waste; supernatant with PUREX high-level waste, B Plant high-level waste, and complexed concentrate from the 241-A Tank Farm, 244-AR Vault, and the B-302 Tanks	No	Contains 472,500
241-AN-101 Double-Shell Tank	1981-Present *Active*	100/300 Area customer waste; salt well liquor; dilute noncomplexed waste	No	Contains 2,074,406
241-AN-102 Double-Shell Tank	1981-Present *Active*	Dilute and concentrated complexant waste	No	Contains 4,145,026
241-AN-103 Double-Shell Tank	1981-Present *Active*	Salt well liquor and dilute noncomplexed waste	No	Contains 3,599,927
241-AN-104 Double-Shell Tank	1981-Present *Active*	Dilute noncomplexed waste and double-shell slurry feed	No	Contains 4,023,893
241-AN-105 Double-Shell Tank	1981-Present *Active*	Dilute noncomplexed waste and double-shell slurry feed	No	Contains 4,288,872
241-AN-106 Double-Shell Tank	1981-Present *Active*	Dilute and concentrated phosphate waste from 100-N Area	No	Contains 3,853,549

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-AN-107 Double-Shell Tank	1981-Present *Active*	Dilute and concentrated complexant wastes	No	Contains 4,076,888
241-AP-101 Double-Shell Tank	1986-Present *Active*	PUREX ammonia scrubber feed waste	No	Contains 4,023,893
241-AP-102 Double-Shell Tank	1986-Present *Active*	Dilute noncomplexed customer waste; unit is the Grout Treatment Facility feed tank	No	Contains 503,460
241-AP-103 Double-Shell Tank	1986-Present *Active*	PUREX ammonia scrubber feed	No	Contains 4,296,442
241-AP-104 Double-Shell Tank	1986-Present *Active*	Dilute noncomplexed waste; unit is designated as a receiver tank	No	Contains 75,708
241-AP-105 Double-Shell Tank	1986-Present *Active*	Double-shell slurry feed	No	Contains 3,126,750
241-AP-106 Double-Shell Tank	1986-Present *Active*	Neutralized cladding removal waste	No	Contains 4,288,872
241-AP-107 Double-Shell Tank	1986-Present *Active*	Unknown	No	Contains 4,266,159
241-AP-108 Double-Shell Tank	1986-Present *Active*	Unknown	No	Contains 700,301
241-AW-101 Double-Shell Tank	1980-Present *Active*	Double-shell slurry feed and dilute noncomplexed waste	No	Contains 4,258,588
241-AW-102 Double-Shell Tank	1980-Present *Active*	Unit is designated as the 241-A Evaporator feed tank	No	Contains 3,910,330
241-AW-103 Double-Shell Tank	1980-Present *Active*	PUREX decladding supernate and TRU sludge	No	Contains 2,449,161

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-AW-104 Double-Shell Tank	1980-Present *Active*	Double-shell slurry feed and dilute noncomplexed waste	No	Contains 4,262,374
241-AW-105 Double-Shell Tank	1980-Present *Active*	Supernate and TRU PUREX decladding sludge	No	Contains 3,418,227
241-AW-106 Double-Shell Tank	1980-Present *Active*	Unit is designated as the 241-A Evaporator receiver tank; waste may be complexed or noncomplexed waste	No	Contains 2,002,483
241-AX-101 Single-Shell Tank	1965-1980 *Inactive*	Fission product waste; PUREX organic wash waste; PUREX high & low-level waste; B Plant high-level waste (waste fractionization); and supernatant with fission product waste, PUREX sludge supernatant, organic wash waste, and double-shell slurry feed from 241-A and 241-AX Single-Shell Tanks	No	Contains 2,827,440
241-AX-102 Single-Shell Tank	1966-1980 *Inactive*	PUREX high & low-level wastes; PUREX organic wash waste; B Plant high-level waste (waste fractionization); and supernatant with PUREX high-level waste, complexant concentrate, B Plant high-level waste, and complexed waste from 241-A, -AX, and -C Tanks, 244-AR Vault, and TK-417	Yes	Contains 147,420
241-AX-103 Single-Shell Tank	1965-1980 *Inactive*	PUREX high & low-level wastes; PUREX organic and inorganic wash waste; B Plant low-level & high-level waste (waste fractionization); supernatant with PUREX high-level and sludge supernatant from 241-A, -AX, -AZ, and -C Tanks, 244-AR Vault, and AX-152 Tank	No	Contains 423,360

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-AX-104 Single-Shell Tank	1966-1976 *Inactive*	PUREX high & low-level wastes; PUREX organic and inorganic wash waste; B Plant high-level waste (waste fractionization); and supernatant with PUREX high-level and sludge supernatant waste from 241-A and -AX Tanks and 244-AR-002 Tank	Yes	Contains 26,460
241-AY-101 Double-Shell Tank	1971-Present *Active*	Sr and Cs depleted, neutralized, high-level waste from B Plant; dilute noncomplexed waste from single-shell tanks; dilute complexed waste; PUREX and b Plant high-level waste and supernatant with complexed waste from -A and -AX Tank Farms	No	Contains 3,384,158
241-AY-102 Double-Shell Tank	1972-Present *Active*	Neutralized high-level waste and double-shell slurry feed; dilute noncomplexed waste; supernatant with double-shell slurry feed and noncomplexed waste from -A and -BX Tank Farms	No	Contains 3,724,845
241-AZ-101 Double-Shell Tank	1976-Present *Active*	Dilute B Plant high-Sr waste; complexed waste; double-shell slurry feed, and noncomplexed waste; aging waste (NCAW) from PUREX; supernatant with complexed waste, double-shell slurry feed, and noncomplexed waste from the -A, -AX, -BX, and -C Tank Farms	No	Contains 3,675,635
241-AZ-102 Double-Shell Tank	1976-Present *Active*	Dilute B Plant high-Sr waste and complexed waste; aging waste (NCAW) from PUREX; supernatant with complexed waste from -AX Tank Farm	No	Contains 3,599,927
241-C-101 Single-Shell Tank	1946-1970 *Inactive*	Bismuth phosphate metal waste; tributyl phosphate waste and PUREX coating waste	Yes	Contains 332,640

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-C-102 Single-Shell Tank	1946-1976 *Inactive*	Bismuth phosphate metal waste; tributyl phosphate waste; PUREX coating waste; thorium high-level waste; PUREX organic wash waste; and supernatant with organic wash wastes and coating wastes from 241-A, -AX, and -C Single-Shell Tanks	No	Contains 1,614,060
241-C-103 Single-Shell Tank	1946-1979 *Inactive*	PUREX coating waste; tributyl phosphate; supernatant with tributyl phosphate waste, coating waste, PUREX high-level waste, B Plant high-level waste, B Plant waste fractionization low-level waste, PUREX sludge supernatant, PUREX low-level waste, waste fractionization, PUREX, sludge, PUREX organic wash waste, laboratory waste, decontamination waste, REDOX ion exchange waste, REDOX high-level waste, noncomplexed waste, waste fractionization ion exchange waste, N Reactor waste, PNL waste, and evaporator bottoms from 241-A, -B, -BX, and -C Tank Farms. This unit was used as the receiver for operating P-10 saltwater systems within the 241-C Farm	No	Contains 737,100

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-C-104 Single-Shell Tank	1946-1980 *Inactive*	PUREX coating waste; bismuth phosphate metal waste; PUREX low-level & high-level waste; thorium low-level & high-level waste; PUREX organic wash waste; supernatant containing metal waste, PUREX organic wash waste, PUREX low-level & high-level waste, coating waste, complexed waste, PNL waste, N Reactor complexed waste, waste fractionization exchange waste, decontamination waste, B Plant low-level & high-level waste, evaporator bottoms; REDOX high-level waste, and tributyl phosphate waste from 241-A, -AX, -C, -BY, -TY, and -U Tanks	No	Contains 1,115,100
241-C-105 Single-Shell Tank	1947-1979 *Inactive*	PUREX coating waste; tributyl phosphate waste; PUREX sludge supernatant; REDOX supernatant; and supernatant with tributyl phosphate waste, coating waste, PUREX sludge supernatant, REDOX supernatant, PUREX high-level waste, REDOX high-level waste, noncomplexed waste, B Plant waste fractionization low-level and metal wastes from 241-A, -AX, -AY, -B, -C, and -TX Tanks; and solids with PUREX sludge supernatant, coating waste, and cesium feet from 241-AX and -A Single-Shell Tanks	No	Contains 567,000
241-C-106 Single-Shell Tank	1947-1979 *Inactive*	PUREX coating waste; B Plant low-level waste (waste fractionization); supernatant with PUREX high-level waste, and tributyl phosphate waste from 241-A and -C Tank Farms; solids with PUREX sludge supernatant from 241-A Single-Shell Tank Farm	No	Contains 865,620

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-C-107 Single-Shell Tank	1946-1978 *Inactive*	Bismuth phosphate first-cycle waste; Hot Semiworks waste; tributyl phosphate; PUREX coating waste; Hanford Laboratory Operations waste; supernatant with PUREX coating waste, PNL waste, PNL waste, N Reactor waste, laboratory waste, decontamination waste, waste fractionization ion exchange waste, and evaporator bottoms waste from 241-C and -BX Tanks	No	Contains 1,273,860
241-C-108 Single-Shell Tank	1947-1976 *Inactive*	Bismuth phosphate first-cycle waste; Hot Semiworks waste; tributyl phosphate; PUREX coating waste; supernatant with tributyl phosphate waste, coating waste, PUREX organic wash waste, fractionization ion exchange waste, PNL waste; N Reactor waste, laboratory waste, decontamination waste, and REDOX high-level waste from 241-C Single-Shell Tank Farm	No	Contains 249,480
241-C-109 Single-Shell Tank	???-1976 *Inactive*	Bismuth phosphate first-cycle waste; Hot Semiworks waste; tributyl phosphate; PUREX coating waste; supernatant with PUREX coating waste, Hot Semiworks waste, evaporator bottoms, and ion exchange waste from 241-C Single-Shell Tank Farm	No	Contains 249,480
241-C-110 Single-Shell Tank	1946-1976 *Inactive*	Bismuth phosphate first-cycle waste; tributyl phosphate; supernatant with PUREX organic wash waste, ion exchange waste, coating waste, evaporator bottoms, and REDOX ion exchange waste	Yes	Contains 759,780

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-C-111 Single-Shell Tank	1946-1976 *Inactive*	Bismuth phosphate first-cycle waste; PUREX organic wash waste, tributyl phosphate waste, PUREX coating waste; evaporator bottoms; Hot Semiworks waste; and supernatant with evaporator bottoms, coating waste, and tributyl phosphate waste from 241-B and -C tanks	Yes	Contains 215,460
241-C-112 Single-Shell Tank	???-1976 *Inactive*	Tributyl phosphate waste; PUREX coating waste; Hot Semiworks waste; supernatant with coating waste, tributyl phosphate waste, and ion exchange waste from 241-C Single-Shell Tank Farm	No	Contains 393,120
241-C-201 Single-Shell Tank	1953-1977 *Inactive*	Bismuth phosphate metal waste and strontium Semiworks waste	Yes	Contains 7,560
241-C-202 Single-Shell Tank	1953-1977 *Inactive*	Bismuth phosphate metal waste; strontium Semiworks waste; supernatant with bismuth phosphate metal waste from 241-C-201 Single-Shell Tank	Yes	Contains 3,780
241-C-203 Single-Shell Tank	1953-1976 *Inactive*	PUREX high-level waste	Yes	Contains 18,900
241-C-204 Single-Shell Tank	1953-1977 *Inactive*	PUREX high-level waste	Yes	Contains 11,340
241-C-302A Catch Tank	1956-Present *Active*	Transports wastes from processing and decontamination operations	No	Contains 13,627
241-A-302B Catch Tank	1956-1980 *Inactive*	Transports wastes from processing and decontamination operations	No	Contains 12,247
241-A-350 Catch Tank	1956-Present *Active*	Transports wastes from processing and decontamination operations	No	Variable

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-A-417 Catch Tank	1956-Present *Active*	Collects condensate from the 241-A-401 Condenser House	No	Contains 120,431
241-A-152CT Catch Tank	???-Present *Active*	Transports wastes from processing and decontamination operations	No	Contains 10,040
241-C-301C Catch Tank	1946-1985 *Active*	Transports wastes from processing and decontamination operations	No	Contains 120,600
244-A Receiving Vault	1975-Present *Active*	This unit receives waste from several tank farms	No	Contains 13,956
244-AR Vault	1977-Present *Active*	Transports wastes from processing and decontamination operations	Yes	Variable
244-CR Vault	1988-Present *Active*	Transports wastes from processing and decontamination operations	No	Variable
Cribs and Drains				
216-A-1 Crib	1955-1966 *Inactive*	Depleted uranium waste from cold startup run in the 202-A Building	Yes	98,400
216-A-2 Crib	1956-1964 *Inactive*	Organic wastes from 202-A Building	Yes	230,000
216-A-3 Crib	1956-1982 *Inactive*	Received waste from 203-A Building, uranyl nitrate hexahydrate storage pit drainage liquid from 203-A Pump House	Yes	3,050,000
216-A-4 Crib	1955-1958 *Inactive*	Laboratory cell drainage from 201-A Building and 291-A-1 Stack drainage	Yes	6,210,000
216-A-5 Crib	1955-1966 *Inactive*	Process condensate from 202-A Building	Yes	1,630,000,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
216-A-6 Crib	1955-1970 *Inactive*	Steam condensate, equipment disposal tunnel floor drainage, water-filled door drainage, and waste from 202-A Building	Yes	3,400,000,000
216-A-7 Crib	1955-1966 *Inactive*	Catch tank overflow, sump waste, pump pit drainage from the 241-A-152 Diversion Box, TBP-Soltrol organic inventory from 202-A Building	Yes	326,000
216-A-8 Crib	1955-1991 *Inactive*	Condensate from 241-A, -AX, -AY, -AZ Tank Farms, cooling water from the contact condenser in the 241-A-431 Building	Yes	1,150,000,000
216-A-9 Crib	1956-1969 *Inactive*	Acid fractionator condensate and cooling water from 202-A Building; N Reactor decontamination waste, acid fractionator condensate from 202-A Building	Yes	981,000,000
216-A-10 Crib	1956-1987 *Inactive*	Nonradioactive water, process condensate from 201-A Building	Yes	3,210,000,000
216-A-21 Crib	1957-1965 *Inactive*	Sump waste from 293-A Building, laboratory cell drainage from the 202-A Building, 291-A-1 Stack drainage	Yes	77,900,000
216-A-24 Crib	1958-1966 *Inactive*	Condensate from 241-A and -AX Single-Shell Tank Farms	Yes	820,000,000
216-A-27 Crib	1965-1970 *Inactive*	Sump waste from 293-A Building, lab cell drainage from 202-A Building, 291-A-1 Stack drainage	Yes	23,200,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
216-A-30 Crib	1961-1991 *Inactive*	Steam condensate, equipment disposal tunnel floor and water-filled door drainage, and slug storage basin overflow waste from the 202-A Building	Yes	7,110,000,000
216-A-31 Crib	1964-1966 *Inactive*	Organic waste from 202-A Building	Yes	10,000
216-A-32 Crib	1959-1966 *Inactive*	202-A crane maintenance facility floor, sink and shower drainage	Yes	4,000
216-A-36A Crib	1965-1966 *Inactive*	Ammonia scrubber waste from 202-A Building	Yes	1,070,000
216-A-36B Crib	1966-1987 *Inactive*	Ammonia scrubber waste from 202-A Building	Yes	317,000,000
216-A-37-1 Crib	1977-1991 *Inactive*	Process condensate from 241-A Evaporator	Yes	377,000,000
216-A-37-2 Crib	1983-Present *Active*	Steam condensate from PUREX Plant	Yes	1,090,000,000
216-A-38-1 Crib	Not used	The site was never used	No	0
216-A-39 Crib	1966 *Inactive*	Floor drainage from 241-AX-801-B Building	Yes	20
216-A-41 Crib	1968-1974 *Inactive*	296-A-13 Stack drainage	Yes	10,000
216-A-45 Crib	1987-1989 *Inactive*	Process condensate from 202-A Building	Yes	103,000,000
216-A-11 French Drain	1956-1972 *Inactive*	Trap Pit No. 1 drainage from 202-A Building	Yes	100,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
216-A-12 French Drain	1955-1972 *Inactive*	Steam trap Pit No. 3 drainage from 202-A Building	Yes	100,000
216-A-13 French Drain	1956-1962 *Inactive*	Seal water from air sampler vacuum pumps in 202-A Building	Yes	100,000
216-A-14 French Drain	1956-1972 *Inactive*	Vacuum cleaner filter and blower pit drainage from 202-A Building	Yes	1,000
216-A-15 French Drain	1955-1972 *Inactive*	Drainage from 216-A-10 Process Condenser Sampler Pit	Yes	10,000,000
216-A-16 French Drain	1956-1968 *Inactive*	Floor drainage and 296-A-11 Stack drainage from 241-A-431 Building	Yes	122,000
216-A-17 French Drain	1956-1969 *Inactive*	Floor drainage and 296-A-11 Stack drainage from 241-A-431 Building drainage from 241-A-431 Building	Yes	60,000
216-A-22 French Drain	1956-1957 *Inactive*	Drainage from 203-A Building truck layout apron, sump waste from 203-A Building enclosure	Yes	10,000
216-A-23A French Drain	1957-1969 *Inactive*	Deentrainer tank condensate, backflush waste from 241-A-431 Building	Yes	6,000
216-A-23B French Drain	1957-1969 *Inactive*	Deentrainer tank condensate, backflush waste from 241-A-431 Building	Yes	6,000
216-A-26 French Drain	1965-1991 *Inactive*	Floor drainage from the 291-A Fan Control House	Yes	Unknown
216-A-26A French Drain	1959-1965 *Inactive*	Floor drainage from the 291-A Fan Control House	Yes	1,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
216-A-28 French Drain	1958-1966 *Inactive*	203-A Building enclosure sumps, heating coil condensate from uranyl nitrate hexahydrate tanks	Yes	30,000
216-A-33 French Drain	1955-1964 *Inactive*	Did not receive any waste	No	0
216-A-35 French Drain	1963-1966 *Inactive*	Seal cooling water from air sampler vacuum pumps in 202-A Building	Yes	10,000
216-C-8 French Drain	1962-1965 *Inactive*	Ion exchange waste from 271-CR Building	Yes	10,000
Reverse Wells				
299-E24-111 Injection Well	1980-1982 *Inactive*	Experimental well, 11 injections of calcium, chloride, solutions	Yes	0[a]
Ponds, Ditches, and Trenches				
216-A-18 Trench	1955-1956 *Inactive*	Depleted uranium from the cold startup run at 202-A Building	Yes	488,000
216-A-19 Trench	1955-1956 *Inactive*	241-A-431 Building contact condenser cooling water, depleted uranium waste from cold startup run at 202-A Building	Yes	1,100,000
216-A-20 Trench	1955-1956 *Inactive*	241-A-431 Building contact condenser cooling water, depleted uranium waste from cold startup run at 202-A Building	Yes	961,000
216-A-40 Trench	1968-1979 *Inactive*	Diverted cooling water and steam condensate from 244-AR Vault	Yes	946,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
216-A-29 Ditch	1955-1991 *Inactive*	202-A chemical sewer, acid fractionator condensate, condenser cooling water, process cooling water, seal cooling water from air sampler vacuum pumps in 202-A Building	Yes	10,400,312
216-A-34 Ditch	1955-1957 *Inactive*	Cooling water from contact condenser in 241-A-431 Building	Yes	Unknown
Septic Tanks and Associated Drain Fields				
2607-EA Septic Tank & Field	1976-Present *Active*	Sanitary wastewater and sewer	Yes	60/day
2607-EC Septic Tank & Field	1955-Present *Active*	Sanitary wastewater and sewer	Yes	450/day
2607-ED Septic Tank & Field	1980-Present *Active*	Sanitary wastewater and sewer	Yes	280/day
2607-EG Septic Tank & Field	1953-Present *Active*	Sanitary wastewater and sewer	Yes	170/day
2607-EJ Septic Tank & Field	1980-Present *Active*	Sanitary wastewater and sewer	Yes	320/day
2607-EL Septic Tank & Field	1983-Present *Active*	Sanitary wastewater and sewer	Yes	7,900/day
2607-E6 Septic Tank & Field	1954-Present *Active*	Sanitary wastewater and sewer	Yes	43,500/day
Transfer Facilities, Diversion Boxes, and Pipelines				
241-A-A Diversion Box	1956-Present *Active*	Transports waste from processing and decontamination operations	No	Variable

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-A-B Diversion Box	1956-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-A-151 Diversion Box	1956-Present *Active*	Transports waste from processing and decontamination operations	Yes	Variable
241-A-152 Diversion Box	1956-1980 *Inactive*	Transports waste from processing and decontamination operations	No	Variable
241-A-153 Diversion Box	1956-1985 *Inactive*	Transports waste from processing and decontamination operations	No	Variable
241-AN-A Diversion Box	1981-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AN-B Diversion Box	1981-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AR-151 Diversion Box	1983-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AW-A Diversion Box	1980-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AW-B Diversion Box	1980-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AX-A Diversion Box	1965-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AX-B Diversion Box	1965-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AX-151 Diversion Box	???-Present *Active*	Receives wastes from 202-A PUREX plant	No	Variable

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-AX-152DS Diversion Box	1965-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AX-155 Diversion Box	1983-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AY-151 Diversion Box	???-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AY-152 Diversion Box	1985-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AZ-151DS Diversion Box	1976-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AZ-152 Diversion Box	1977-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-C-151 Diversion Box	1946-1985 *Active*	Transports waste from processing and decontamination operations	No	Variable
241-C-152 Diversion Box	1946-1985 *Active*	Transports waste from processing and decontamination operations	Yes	Variable
241-C-153 Diversion Box	1946-1985 *Inactive*	Transports waste from processing and decontamination operations	No	Variable
241-C-252 Diversion Box	1946-1985 *Inactive*	Transports waste from processing and decontamination operations	No	Variable
241-CR-151 Diversion Box	1946-1985 *Inactive*	Transports waste from processing and decontamination operations	Yes	Variable
241-CR-152 Diversion Box	1946-1985 *Inactive*	Transports waste from processing and decontamination operations	No	Variable

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-CR-153 Diversion Box	1946-1985 *Inactive*	Transports waste from processing and decontamination operations	No	Variable
241-ER-153 Diversion Box	1945-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
216-A-524 Control Structure	1957-1966 *Inactive*	Unit contains radioactive piping and cement	No	Variable
241-AP Valve Pit	1986-Present *Active*	Transports waste from processing and decontamination operations	No	Variable
241-AX-501 Valve Pit	???-Present *Active*	Receives and routes tank farm condensate	No	Variable
Basins				
207-A Retention Basins	1976-Present *Active*	Waste streams from the 242-A Evaporator	No	Variable
216-A-42 Retention Basin	1978-Present *Active*	Chemically or radioactively contaminated diversions from the PUREX chemical sewer line, cooling water line, and steam condensate discharge	No	Variable
Burial Sites and Burning Pits				
218-E-1 Burial Ground	1945-1954 *Inactive*	Mixed fission products and transuranic dry waste	No	3,030 m^3
218-E-8 Burial Ground	1958-1959 *Inactive*	Mixed fission products and transuranic waste, repair and construction wastes from 293-A and PUREX new crane addition	No	2,265 m^3
218-E-12A Burial Ground	1953-1968 *Inactive*	Dry waste and acid-soaked material	No	15,249 m^3

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
218-E-12B Burial Ground	1966-Present *Active*	Navy reactor subcomponents	No	Unknown
218-E-13 Burial Ground	1966 *Inactive*	Pieces of concrete from pipe trench	No	184 m^3
200-E-Burning Pit	1950-1970 *Inactive*	Radioactive waste	No	1,500 m^3
Unplanned Releases				
UN-200-E-10	1957	PUREX tube bundles	No	Unknown
UN-200-E-11	1957	Spots along railroad tracks of unknown origin	No	Unknown
UN-200-E-12	1957	Contaminated liquid from a burial box	Yes	Unknown
UN-200-E-13	1958	216-A-4 Crib became plugged and flooded ground	Yes	Unknown
UN-200-E-15	1959	216-A-4 Crib became plugged causing ground contamination	Yes	Unknown
UN-200-E-16	1959	241-C-105 to 241-C-108 overground transfer line broke	Yes	Unknown
UN-200-E-18	1959	Moisture from vent pipe bonnet at the A-8 Proportional Sample Pit	Yes	Unknown
UN-200-E-19	1959	Moisture from vent pipe bonnet at the A-6 Proportional Sample Pit	Yes	Unknown
UN-200-E-20	1959	PUREX tube bundles	No	Unknown
UN-200-E-22	1959	General contamination around 291-A Stack	No	Unknown
UN-200-E-25	1960	Leakage from 241-A-151 Diversion Box	Yes	Unknown

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
UN-200-E-26	1960	Leakage from 241-A-151 Diversion Box	Yes	Unknown
UN-200-E-27	1960	Near the 244-CR Vault	No	Unknown
UN-200-E-28	1961	Fission products from a process vessel steam coil	Yes	Unknown
UN-200-E-31	1961	Leakage from 241-A-151 Diversion Box	Yes	Unknown
UN-200-E-33	1964	Leaking tube bundle burial box	Yes	Unknown
UN-200-E-35	1966	Contaminated concrete	No	Unknown
UN-200-E-39	1968	Pressurized ammonia scrubber waste containing fission products	No	Unknown
UN-200-E-40	1968	Vent line valve at the 216-A-36B Crib	No	Unknown
UN-200-E-42	1972	Thought to be from 244-AR Diverter Tank	No	Unknown
UN-200-E-47	1974	Contaminated soil of unknown origin in 241-A Tank Farm	No	Unknown
UN-200-E-48	1974	241-A-106 pump pit contaminated parking lot	No	Unknown
UN-200-E-49	1975	Thermocouple well contaminated road	No	Unknown
UN-200-E-56	1979	Unknown	No	Unknown
UN-200-E-58	1980	Contaminated tumbleweeds near 218-E-1 Burial Ground	No	Unknown
UN-200-E-60	1981	Contaminated dirt from an overfilled dump truck	No	Unknown
UN-200-E-62	1982	Liquid from pressure test assembly	Yes	Unknown

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
UN-200-E-65	1982	Wind spread contamination from 241-A-151 Diversion Box	No	Unknown
UN-200-E-67	1984	An old, contaminated pipe encasement	No	Unknown
UN-200-E-68	1985	Wind spread contamination from 241-C-151 Diversion Box	No	Unknown
UN-200-E-72	1985	Previously buried contaminated waste of unspecified origin	No	Unknown
UN-200-E-81	1969	PUREX coating waste via the transfer line from the 202-A Building to the 102-C waste storage tank via 241-CR-151 Diversion Box	Yes	136,274
UN-200-E-82	1969	Feed line from 241-C-105 Tank to the 221-B Building	Yes	9,842
UN-200-E-86	1971	Line no. 812, used to transfer process waste from AR Vault to C Farm	Yes	Unknown
UN-200-E-88	1980	Unknown, associated with TC-4 railroad spur	No	Unknown
UN-200-E-91	1980	Migration of low-level radioactivity from 241-C Tank Farm	No	Unknown
UN-200-E-94	1979	Possible moisture from 216-A-24 Crib	No	Unknown
UN-200-E-96	1980	Residue contamination from PUREX 291-A Stack and Diversion Box	No	Unknown
UN-200-E-97	1980	Unknown source south of PUREX near railroad tunnel	No	Unknown
UN-200-E-99	1980	Near the 244-CR Vault	Yes	Unknown
UN-200-E-100	1986	Spill to ground	Yes	Unknown

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
UN-200-E-107	1952	Tributyl phosphate from 221-U Building	Yes	Unknown
UN-200-E-114	1974	Value Pit outside the 202-A Building	No	Unknown
UN-200-E-117	1972	Liquid spurting out of ground near PUREX area	Yes	Unknown
UN-200-E-118	1957	107-C effluent tank released airborne contamination	No	Unknown
UN-200-E-142	1986	Diesel fuel	Yes	76
UPR-200-E-17	1959	Uranium from 216-A-22 Crib	Yes	Unknown
UPR-200-E-21	1959	216-A-6 Crib overflowed contaminating ground	Yes	Unknown
UPR-200-E-24	1960	Collapse of burial box of 218-E-12A	No	Unknown
UPR-200-E-29	1961	216-A-6 Crib overflowed	Yes	Unknown
UPR-200-E-30	1961	Collapse of burial box at 218-E-12A	No	Unknown
UPR-200-E-50	1974	Wind spread contamination from 241-C Tank Farm	No	Unknown
UPR-200-E-53	1978	Contamination spread by uncovering previously buried waste at the 218-E-1 Burial Ground	No	Unknown
UPR-200-E-59	1979	Contaminated mud and tumbleweeds from 216-A-40 Trench used by swallows to build nests at 244-AR Vault	No	Unknown
UPR-200-E-66	1984	Wind spread contamination from 216-A-42 Retention Basin	No	Unknown
UPR-200-E-70	1984	Contamination during a jumper removal at 244-A Lift Station	Yes	Unknown

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
UPR-200-E-106	1946	Contaminated paper towels	No	Unknown
UPR-200-E-115	1974	Liquid from AX-103 Pump Pit	Yes	Unknown
UPR-200-E-119	1969	High-level waste	No	Unknown
UPR-200-E-125	1975	Waste from the 241-A-104 Single-Shell Tank	Yes	9,450
UPR-200-E-126	1963	241-A-105 Single-Shell Tank	Yes	18,900
UPR-200-E-136	1946-1970	241-C-101 Single-Shell Tank	Yes	64,260 to 90,720
UPR-200-E-137	1947-1978	241-C-203 Single-Shell Tank	Yes	1,512
B Plant Aggregate Area Tanks and Vaults				
241-B-101 Single-Shell Tank	May 1945-1974	$Bi(PO)_4$ metal waste; PUREX coating waste: B Plant high-level waste (Cell 23); evaporator bottoms from 241-B tanks	Yes	Contains 428,000
241-B-102 Single-Shell Tank	Oct 1945-1978	$Bi(PO)_4$ metal waste; PUREX coating waste; supernatant containing B Plant low-level, ion exchange, evaporator bottoms	No	Contains 110,000
241-B-103 Single-Shell Tank	Dec 1953-1977	$Bi(PO)_4$ metal waste; PUREX coating waste; B Plant low level waste, ion exchange, evaporator bottoms, N Reactor, organic wash, PNL, REDOX high-level waste, coating waste, decon, tributyl phosphate and lab waste	Yes	Contains 223,000
241-B-104 Single-Shell Tank	Aug 1946-1972	$Bi(PO)_4$ 2-C and 1-C; evaporator bottoms from 241-B Tanks	No	Contains 1,404,000
241-B-105 Single-Shell Tank	Jan 1947-1972	$Bi(PO)_4$ 2-C and 1-C; flush water containing evaporator bottoms from 241-B Tanks	No	Contains 1,580,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-B-106 Single-Shell Tank	Sept 1947-1977	$Bi(PO)_4$ 2-C and 1-C; Hanford Lab operations, evaporator bottoms, tributyl phosphate waste, 224-U waste, PNL, B Plant low-level, ion exchange	No	Contains 443,000
241-B-107 Single-Shell Tank	May 1945-1969	PUREX coating waste, $Bi(PO)_4$ 1-C and 2-C, evaporator bottoms	Yes	Contains 625,000
241-B-108 Single-Shell Tank	1945-1977	$Bi(PO)_4$ 1-C and 2-C, PUREX coating waste, evaporator bottoms, ion exchange from 241-B and -BY Tank Farms	No	Contains 356,000
241-B-109 Single-Shell Tank	Jan 1946-1977	$Bi(PO)_4$ 1-C, PUREX coating waste, evaporator bottoms, ion exchange 224-U waste, coating waste from 241-B, -BY, -S Tank Farms	No	Contains 481,000
241-B-110 Single-Shell Tank	May 1945-1971	$Bi(PO)_4$ 2-C and 1-C, fission product waste, B Plant high-level waste fractionization, B Plant Cells 5 and 6; B Plant flushes, ion exchange	Yes	Contains 931,000
241-B-111 Single-Shell Tank	Nov 1945-1976	$Bi(PO)_4$ 2-C, fission product waste, ion exchange (waste fractionization), B Plant Cells 5 and 6	Yes	Contains 897,000
241-B-112 Single-Shell Tank	April 1946-1977	$Bi(PO)_4$ 2-C, fission product waste, evaporator bottoms from 241-B and -BX B Plant Cells 5 and 6, ion exchange	Yes	Contains 125,000
241-B-201 Single-Shell Tank	1952-1971	224-U wastes (lanthanum fluoride)	Yes	Contains 110,000
241-B-202 Single-Shell Tank	1951-1977	224-U wastes (lanthanum fluoride), B Plant high-level waste	No	Contains 102,000
241-B-203 Single-Shell Tank	1951-1977	224-U wastes (lanthanum fluoride)	Yes	Contains 193,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-B-204 Single-Shell Tank	1951-1977	224-U wastes (lanthanum fluoride), B Plant flushes	Yes	Contains 189,000
241-B-301B Catch Tank	1945-June 1984	Processing and decon wastes	No	Variable
241-B-302B Catch Tank	1945-July 1985	Processing and decon wastes	No	Variable
241-B-361 Settling Tank	April 1945-Sep 1947	Low salt, alkaline radioactive from cell washings collected in 5-6W Cell in 221-B and from 224-B. Solids primarily $Bi(PO)_4$	No	Contains 121,000
241-BX-101 Single-Shell Tank	Jan 1948-1972	$Bi(PO)_4$ metal waste; B Plant low-level waste, ion exchange (waste fractionization), evaporator bottoms, N Reactor, organic wash, REDOX ion exchange waste, tributyl phosphate and coating waste	Yes	Contains 163,000
241-BX-102 Single-Shell Tank	June 1948-1971	$Bi(PO)_4$ metal waste, diatomaceous earth, tributyl phosphate, metal, and coating waste, B Plant low level, evaporator bottoms	Yes	Contains 363,000
241-BX-103 Single-Shell Tank	Sept 1948-1977	$Bi(PO)_4$ metal waste; PUREX high- and low-level waste and sludge supernatant; exchange, evaporator bottoms, N Reactor, organic wash, PNL, REDOX ion exchange waste, coating waste, decon, tributyl phosphate and lab waste, B Plant low-level	Yes	Contains 250,000
241-BX-104 Single-Shell Tank	1949-1980	$Bi(PO)_4$ metal waste; PUREX coating waste, ion exchange (waste fractionization) evaporator bottoms, REDOX high-level, complexed and noncomplexed waste, double-shell slurry feed, tributyl phosphate and lab waste, B Plant low-level, ion exchange	No	Contains 374,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-BX-105 Single-Shell Tank	1949-1980	$Bi(PO)_4$ metal waste, tributyl phosphate waste, coating, ion exchange waste; evaporator bottoms, complexed and noncomplexed waste, double-shell slurry feed	No	Contains 193,000
241-BX-106 Single-Shell Tank	1949-1977	$Bi(PO)_4$ metal waste, tributyl phosphate waste, coating, ion exchange waste; evaporator bottoms, B Plant low-level, organic wash, REDOX ion exchange waste from 241-B, -BX, and -BY tanks	No	Contains 174,000
241-BX-107 Single-Shell Tank	Sept 1948-1977	$Bi(PO)_4$ 1-C, tributyl phosphate waste, ion exchange waste from the 241-BX Tank Farm	No	Contains 133,000
241-BX-108 Single-Shell Tank	1949-1974	$Bi(PO)_4$ 1-C, tributyl phosphate waste, coating, ion exchange waste from the 241-BX and -C Tanks	Yes	Contains 98,000
241-BX-109 Single-Shell Tank	1950-1974	$Bi(PO)_4$ 1-C; ion exchange (waste fractionization), tributyl phosphate waste, tributyl phosphate waste from the 241-BY and -C Tanks	No	Contains 731,000
241-BX-110 Single-Shell Tank	1949-1977	$Bi(PO)_4$ 1-C, ion exchange (waste fractionization), tributyl phosphate waste, evaporator bottoms, coating waste, B Plant 1-C from the 241-B and -C Tank Farms. It is an ITS-2 Unit	Yes	Contains 753,000
241-BX-111 Single-Shell Tank	1950-1977	$Bi(PO)_4$ 1-C, ITS-2 bottoms and recycle systems, evaporator bottoms, coating waste, ion exchange waste, 1-C from the 241-BY Tanks	Yes	Contains 870,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-BX-112 Single-Shell Tank	1950-1977	Ion exchange (waste fractionization), evaporator bottoms, coating waste, 1-C from the 241-C Tanks	No	Contains 625,000
241-BX-302A Catch Tank	1948-July 1985	Processing and decon wastes	No	Variable
241-BX-302B Catch Tank	1948-July 1985	Processing and decon wastes	No	Variable
241-BX-302C Catch Tank	1948-July 1985	Processing and decon wastes	No	Variable
241-BY-101 Single-Shell Tank	Jan 1950-1971	$Bi(PO)_4$ metal waste, tributyl phosphate waste, evaporator bottoms from the 241-BY and -C Tank Farms. This is an ITS-2 Unit	No	Contains 1,465,000
241-BY-102 Single-Shell Tank	1950-1977	$Bi(PO)_4$ metal waste, tributyl phosphate and coating waste, evaporator bottoms from the 241-BX, -BY and -C farms. This is an ITS-2 Unit	No	Contains 1,291,000
241-BY-103 Single-Shell Tank	Nov 1950-May 1973	$Bi(PO)_4$ metal waste, PUREX coating waste, evaporator bottoms, coating and tributyl phosphate waste, PUREX high-level and organic wash wastes from 241-BX, -BY, -C, and -B Tanks. This is an ITS-2 Unit	Yes	Contains 1,514,000
241-BY-104 Single-Shell Tank	1950-1977	$Bi(PO)_4$ metal waste, tributyl phosphate and coating waste, evaporator bottoms from the 241-BX, -BY and -C Tank Farms, and ion exchange waste. This is an ITS-2 Unit	No	Contains 1,536,000
241-BY-105 Single-Shell Tank	June 1951-1974	tributyl phosphate waste, $Bi(PO)_4$ metal waste and coating waste, evaporator bottoms from the 241-BY and -C Tank Farms, concrete. This is an ITS-2 Unit	Yes	Contains 1,904,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-BY-106 Single-Shell Tank	1953-1977	I-C and $Bi(PO)_4$ 1-C waste, tributyl phosphate waste, coating waste, evaporator bottoms from 241-BY and -C Tank Farms. It is an ITS-2 Unit	Yes	Contains 2,430,000
241-BY-107 Single-Shell Tank	December 1950-1974	tributyl phosphate waste, $Bi(PO)_4$ 1-C waste and coating waste, evaporator bottoms from the 241-BY and -C Tank Farms. This is an ITS-2 Unit	Yes	Contains 1,007,000
241-BY-108 Single-Shell Tank	April 1951-1972	$Bi(PO)_4$ 1-C waste, evaporator bottoms from the 241-BY and -C Tank Farms. This is an ITS-2 Unit	Yes	Contains 863,000
241-BY-109 Single-Shell Tank	1953-1979	Supernatant containing tributyl phosphate waste, PUREX coating waste, $Bi(PO)_4$ metal waste, evaporator bottoms, PUREX organic wash waste from the 241-B, -BX, -BY, and -C Tank Farms. This is an ITS-2 Unit	No	Contains 1,601,000
241-BY-110 Single-Shell Tank	1952-1979	$Bi(PO)_4$ 1-C waste, tributyl phosphate waste, evaporator bottoms, coating waste from the 241-BY and -C Tank Farms, and the WR-241 Tank	No	Contains 1,507,000
241-BY-111 Single-Shell Tank	1952-1977	$Bi(PO)_4$ metal waste, tributyl phosphate waste, PUREX coating waste, organic wash waste, evaporator bottoms, coating waste, and organic was waste from the 241-BY and -C Tank Farms. This is an ITS-2 Unit.	No	Contains 1,737,000
241-BY-112 Single-Shell Tank	1951-1976	$Bi(PO)_4$ metal waste, tributyl phosphate waste, coating waste, evaporator bottoms from the 241-B, -BX, -BY, and -C Tank Farms. This is an ITS-2 Unit	No	Contains 1,102,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
244-BXR Receiving Vault	1948-July 1985	Process and decon wastes	No	Variable
241-ER-311 Catch Tank	1945-present/*active*	Process and decon wastes	Yes	Variable
270-E Cond. Neutralization Tank	1952-1976	Sludge	No	Contains 14,000
Cribs and Drains				
216-B-7A & B Crib	Oct 1946-May 1967	224-B via overflow from 201-B Tank, cell drainage from Tank 5-6 in 221-B, equipment cleanout waste from 224-B, decon and construction waste from 221-B	Yes	43,600,000
216-B-8TF Crib and Tile Field	April 1948-July 1953	2-C supernatant from 221-B, cell drainage and other waste from Tank 5-6, decon and cleanup waste generated i shutdown of 224-B	Yes	27,200,000
216-B-9TF Crib and Tile Field	Aug 1948-July 1951	Cell drainage and other liquid waste via Tank 5-6 in 221-B	Yes	36,000,000
216-B-10A Crib	Dec 1949-Jan 1952	Decon sink and sample slurper waste from 222-B and floor drainage from 292-B	Yes	9,990,000
216-B-10B Crib	June 1969-Oct 1973	Decon sink and shower waste from 221-B, overflow from 216-10A	Yes	28,000
216-B-12 Crib	Nov 1952-Nov 1973	Process condensate from 221-U and 224-U waste evaporators, construction waste from 221-B and process condensate from 221-B	Yes	520,000,000
216-B-14 Crib	Jan 1956-Feb 1956	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	8,710,000
216-B-15 Crib	April 1956-Dec 1956	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	6,320,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
216-B-16 Crib	April 1956-Aug 1956	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	5,600,000
216-B-17 Crib	Jan 1956-Jan 1956	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	3,410,000
216-B-18 Crib	March 1956-April 1956	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	8,520,000
216-B-19 Crib	Feb 1957-Oct 1957	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	6,400,000
216-B-43 Crib	Nov 1954	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	2,120,000
216-B-44 Crib	Nov 1954-March 1955	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	5,600,000
216-B-45 Crib	April 1955-June 1955	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	4,920,000
216-B-46 Crib	Sept 1955-Dec 1955	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	6,700,000
216-B-47 Crib	Sept 1955	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	3,710,000
216-B-48 Crib	Nov 1955	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	4,090,000
216-B-49 Crib	Nov 1955-Dec 1955	Scavenged tributyl phosphate supernatant from 221-U during uranium recovery operations	Yes	6,700,000
216-B-50 Crib	Jan 1965-Jan 1974	Waste storage tank condensate from the ITS-1 unit in the 241-BY Tank Farms	Yes	54,800,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
216-B-55 Crib	Sept 1967-present *Active*	Steam condensate from 221-B	Yes	1,230,000,000
216-B-56 Crib	Not Used	Waste storage tank condensate from the ITS-2 unit in the 241-BY Tank Farm	No	0
216-B-57 Crib	Feb 1968-June 1973	Waste storage tank condensate from the ITS-2 unit in the 241-BY Tank Farm	Yes	84,400,000
216-B-60 Crib	Nov 1967	Cell cleanout solid and liquid waste from the 24 in. sewer in 221-B	Yes	18.9 m^3
216-B-61 Crib	Not Used	Not used	No	0
216-B-62 Crib	Nov 1973-present *Active*	Process condensate from the 221-B Separations Facilities	Yes	282,000,000
Chem TF North of 2703-E	Unknown	Mixed Waste	Yes	Unknown
216-B-13 French Drain	Aug 1947-June 1976	291-B stack drainage	Yes	28,000
216-B-51 French Drain	Jan 1956-Jan 1958	Flush drainage from the BC Crib pipeline	Yes	1,000
Reverse Wells				
216-B-4 Reverse Well	April 1945-Dec 1949	291-B stack drainage and floor drainage from 292-B	Yes	10,000
216-B-5 Reverse Well	April 1945-Oct 1947	Supernatant overflow from the 216-B-361 settling tank waste via Tank 5-6 in 221-B and liquid waste from 224-B. Cell drainage and other liquid waste via Tank 5-6 in 221-B	Yes	30,600,000
216-B-6 Reverse Well	April 1945-Dec 1949	Decontamination sink and sample slurper waste from 222-B	Yes	6,000,000
216-B-11A & -11B Rev. Well	Dec 1951-Dec 1954	Process condensate from the 242-B Evaporator	Yes	29,600,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
Ponds, Ditches, and Trenches				
216-B-3 Pond	April 1945-Present *Active*	221-B steam condensate and process cooling water, 284-E Powerhouse water, 244-CR, -AR, and 242-A cooling water, 202-A process, condenser, and air sampler vacuum pump cooling water, 202-A chem sewer, fractionator condensate, WESF cooling water	Yes	240,000,000,000
216-B-3A Pond	Oct 1983-Present *Active*	221-B steam condensate and process cooling water, 284-E Powerhouse water, 244-CR, -AR, and 242-A cooling water, 202-A process, condenser, and air sampler vacuum pump cooling water, 202-A chem sewer, fractionator condensate, WESF cooling water	Yes	Not reported
216-B-3B Pond	June 1984-present *Active*	221-B steam condensate and process cooling water, 284-E Powerhouse water, 244-CR, -AR, and 242-A cooling water, 202-A process, condenser, and air sampler vacuum pump cooling water, 202-A chem sewer, fractionator condensate, WESF cooling water	Yes	Not reported
216-B-3C Pond	1985-present *Active*	221-B steam condensate and process cooling water, 284-E Powerhouse water, 244-CR, -AR, and 242-A cooling water, 202-A process, condenser, and air sampler vacuum pump cooling water, 202-A chem sewer, fractionator condensate, WESF cooling water	Yes	Not reported
216-E-28 Contingency Pond	Constructed in 1986; never used	Emergency diversion pond for the 216-B-3 Pond system	No	0

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
216-A-25 Pond	Dec 1957-1987	Process cooling water from 202-A, contact condenser cooling water from 241-A-431, surface condenser cooling water from 241-A-401, 284-E Powerhouse wastewater, cooling water and steam condensate from 244-AR Vault, 242-A steam condensate cooling water and B Plant cooling water	Yes	307,000,000,000
216-N-8 Pond	1958-1987	Sewage sludge from Hanford construction camp	Yes	Unknown
2101-M Pond	1983-present *Active*	Swamp-cooler condensate and overflow drain wastewater from the 2101-M air conditioning system. Barium chloride lab waste solution, nitric and hydrochloric acid. Waste from the BWIP laboratory.	Yes	Not reported
216-B-2-1 Ditch	April 1945-Nov 1963	Steam condensate, process cooling water, chem sewer from 221-B waste, 284-E Powerhouse water, 241-CR vault cooling water	Yes	149,000,000,000
216-B-2-2 Ditch	Nov 1963-May 1970	Steam condensate, process cooling water, chem sewer from 221-B waste, 284-E Powerhouse water, 241-CR vault cooling water, ITS-1 and -2 cooling water, cleanup waste from 207-B Retention Basin	Yes	49,700,000
216-B-2-3 Ditch	1970-1987	221-B cooling water, 241-CR vault cooling water, condenser cooling water from ITS-1 and -2 cooling water	Yes	Not reported

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
216-B-3-1 Ditch	April 1945-July 1964	Steam condensate, process cooling water, chem sewer from 221-B waste, 284-E Powerhouse waste, 241-CR vault cooling water, 242-A process cooling water and chem sewer, 202-A acid fractionator condensate, 202-A air sampler vacuum pumps seal cooling water	Yes	149,000,000
216-B-3-2 Ditch	July 1964-Sept 1970	Steam condensate, process cooling water, chem sewer from 221-B waste, 284-E Powerhouse waste, 241-CR vault cooling water, 242-A process cooling water and chem sewer, 202-A acid fractionator condensate, 202-A air sampler vacuum pumps seal cooling water, ITS-1 condenser cooling water	Yes	149,000,000
216-B-3-3 Ditch	Sept 30, 1970-present *Active*	221-B cooling water, 202-A chem sewer, ITS-1 and -2 cooling water, 244-CR cooling water	Yes	Not reported
216-B-20 Trench	Aug 1956-Sept 1956	Scavenged tributyl phosphate waste from 221-U	Yes	4,680,000
216-B-21 Trench	Sept 1956-Oct 1956	Scavenged tributyl phosphate waste from 221-U	Yes	4,670,000
216-B-22 Trench	Oct 1956	Scavenged tributyl phosphate waste from 221-U	Yes	4,740,000
216-B-23 Trench	Oct 1956	Scavenged tributyl phosphate waste from 221-U	Yes	4,520,000
216-B-24 Trench	Oct 1956-Nov 1956	Scavenged tributyl phosphate waste from 221-U	Yes	4,700,000
216-B-25 Trench	Nov 1956-Dec 1956	Scavenged tributyl phosphate waste from 221-U	Yes	3,760,000
216-B-26 Trench	Dec 1956-Feb 1957	Scavenged tributyl phosphate waste from 221-U	Yes	5,880,000
216-B-27 Trench	Feb 1957-April 1957	Scavenged tributyl phosphate waste from 221-U	Yes	4,420,000
216-B-28 Trench	April 1957-June 1957	Scavenged tributyl phosphate waste from 221-U	Yes	5,050,000
216-B-29 Trench	June 1957-July 1957	Scavenged tributyl phosphate waste from 221-U	Yes	4,840,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
216-B-30 Trench	July 1957	Scavenged tributyl phosphate waste from 221-U	Yes	4,780,000
216-B-31 Trench	July 1957-Aug 1957	Scavenged tributyl phosphate waste from 221-U	Yes	4,740,000
216-B-32 Trench	Aug 1957-Sept 1957	Scavenged tributyl phosphate waste from 221-U	Yes	4,770,000
216-B-33 Trench	Sept 1957-Oct 1957	Scavenged tributyl phosphate waste from 221-U	Yes	4,740,000
216-B-34 Trench	Oct 1957	Scavenged tributyl phosphate waste from 221-U	Yes	4,870,000
216-B-35 Trench	Feb 1954-March 1954	1-C supernatant from 221-B	Yes	1,060,000
216-B-36 Trench	March 1954-April 1954	1-C supernatant from 221-B	Yes	1,940,000
216-B-37 Trench	Aug 1954	1-C bottom supernatant waste from the 242-B waste evaporator	Yes	4,320,000
216-B-38 Trench	July 1954	1-C supernatant from 221-B	Yes	1,430,000
216-B-39 Trench	Dec 1953-Nov 1954	1-C supernatant from 221-B	Yes	1,540,000
216-B-40 Trench	April 1954-July 1954	1-C supernatant from 221-B	Yes	1,640,000
216-B-41 Trench	Nov 1954	1-C supernatant from 221-B	Yes	1,440,000
216-B-42 Trench	Jan 1955-Feb 1955	Scavenged tributyl phosphate waste from 221-U	Yes	1,500,000
216-B-52 Trench	Dec 1957-Jan 1958	Scavenged tributyl phosphate waste from 221-U	Yes	8,530,000
216-B-53A Trench	Oct 1965-Nov 1965	Waste from the 300 Area Hanford lab operations	Yes	549,000
216-B-53B Trench	Nov 1962-March 1963	Waste from the 300 Area Hanford lab Operations (321 Building)	Yes	15,100
216-B-54 Trench	March 1963-Oct 1965	Waste from the 300 Area Hanford Laboratories operations	Yes	999,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
216-B-58 Trench	Nov 1965-June 1967	PNL waste from the 300 Area	Yes	413,000
216-B-63 Trench	March 1970-present *Active*	Effluent from 221-B, 225-B, and 271-B floor drains and chem sewer wastes	Yes	7,220,000,000
Septic Tanks and Associated Drain Fields				
2607-EB Septic Tank and DF	1951-present *Active*	Sanitary wastewater and sewage	Yes	20/day
2607-EH Septic Tank and DF	1983-unknown	Sanitary wastewater and sewage	Yes	1,360/day
2607-EK Septic Tank and DF	1980-present *Active*	Sanitary wastewater and sewage	Yes	24,200/day
2607-EM Septic Tank and DF	1984-present *Active*	Sanitary wastewater and sewage	Yes	6,380/day
2607-EN Septic Tank and DF	Pre 1980-present *Active*	Sanitary wastewater and sewage	Yes	2,060/day
2607-EO Septic Tank and DF	Circa 1985-present *Active*	Sanitary wastewater and sewage	Yes	2,120/day
2607-EP Septic Tank and DF	1984-present *Active*	Sanitary wastewater and sewage	Yes	1,875/day
2607-EQ Septic Tank and DF	1985-present *Active*	Sanitary wastewater and sewage	Yes	10,500/day
2607-ER Septic Tank	Unknown-present *Active*	Sanitary wastewater and sewage	Yes	Unknown
2607-GF Septic Tank	Unknown	Sanitary wastewater and sewage	Yes	Unknown
2607-E1 Septic Tank and DF	1970-present *Active*	Sanitary wastewater and sewage	Yes	21,555/day

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
2607-E2 Septic Tank and DF	Pre 1980-present *Active*	Sanitary wastewater and sewage	Yes	2,380/day
2607-E3 Septic Tank and DF	1944-present *Active*	Sanitary wastewater and sewage	Yes	14,400/day
2607-E4 Septic Tank and DF	1944-present *Active*	Sanitary wastewater and sewage	Yes	240/day
2607-E7B Septic Tank	Unknown	Sanitary wastewater and sewage	Yes	Unknown
2607-E8 Septic Tank and DF	1978-present *Active*	Sanitary wastewater and sewage	Yes	7,400/day
2607-E9 Septic Tank and DF	1951-present *Active*	Sanitary wastewater and sewage	Yes	Unknown
2607-E11 Septic Tank and DF	Circa 1985-present *Active*	Sanitary wastewater and sewage	Yes	3,160/day
Transfer Facilities and Diversion Boxes				
241-B-151 Diversion Box	1945-June 1984	Processing and decon wastes	Yes	Unknown
241-B-152 Diversion Box	1945-June 1984	Processing and decon wastes	Yes	Unknown
241-B-153 Diversion Box	1945-June 1984	Processing and decon wastes	Yes	Unknown
241-B-154 Diversion Box	1945-June 1984	Processing and decon wastes	No	Unknown
241-B-252 Diversion Box	1945-June 1984	Processing and decon wastes	No	Unknown
241-BR-152 Diversion Box	1948-June 1984	Processing and decon wastes	No	Unknown
241-BX-153 Diversion Box	1948-June 1983	Processing and decon wastes	No	Unknown
241-BX-154 Diversion Box	1948-July 1985	Processing and decon wastes	No	Unknown

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-BX-155 Diversion Box	1948-June 1984	Processing and decon wastes	No	Unknown
241-BXR-151 Diversion Box	1948-June 1984	Processing and decon wastes	No	Unknown
241-BXR-152 Diversion Box	1948-June 1984	Processing and decon wastes	No	Unknown
241-BXR-153 Diversion Box	1948-June 1984	Processing and decon wastes	No	Unknown
241-BYR-152 Diversion Box	1950-June 1984	Processing and decon wastes	No	Unknown
241-BYR-153 Diversion Box	1950-June 1984	Processing and decon wastes	No	Unknown
41-BYR-154 Diversion Box	1950-June 1984	Processing and decon wastes	No	Unknown
241-ER-151 Diversion Box	1945-present *Active*	Processing and decon wastes	No	Unknown
241-ER-152 Diversion Box	1945-present *Active*	Processing and decon wastes	No	Unknown
Basins				
207-B Retention Basin	April 1945-present *Active*	Process cooling water from equipment jackets in 221-B	No	Not reported
216 B-59/59B Trench/Retention Basin	Dec 1967-present *Active*	Diverted cooling water from 221-B	Yes	477,000
216-B-64 Retention Basin	Never used	Never used	No	0
Burial Sites				
200-E Powerhouse Ash Pit	1943-present *Active*	Ash from the 200 East Powerhouse	No	63,000 m^3
218-E-2 Burial Ground	1945-1953	Source unknown; contains MFP/TRU dry wastes	No	9,033 $m^{3a/}$ 9,056 $m^{3b/}$

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
218-E-2A Burial Ground	1945-1955	Source unknown; also used as a storage site	No	Unknown
218-E-3 Burial Ground	1954	Source unknown; site exhumed	No	NA
218-E-4 Burial Ground	Feb 1955-1956	No trenches suspected; contaminated equipment was stored above ground	No	1,586 $m^{3a/}$ 1,585 $m^{3b/}$
218-E-5 Burial Ground	1954-1956	Industrial mixed waste and small boxes. North end contains railroad boxcars contaminated with UNH	No	3,172 $m^{3a/}$ 3,113 $m^{3b/}$
218-E-5A Burial Ground	1956-1959	Waste from L Cell (202-A burial package); four large boxes containing failed equipment and industrial wastes. D-2 Column from PUREX buried	No	6,173 $m^{3a/}$ 6,226 $m^{3b/}$
218-E-6 Burial Ground	Fall 1955	Wooden shack and other items from 291-B stack area were placed in a trench and burned	No	0
218-E-7 Burial Ground	1947-1952	Lab and sample waste; mixed MFP/TRU wastes	No	170 $m^{3a/}$ 170 $m^{3b/}$
218-E-9 Burial Ground	1953-1958	Storage site for fission product equipment contaminated in U recovery program at the tank farm	No	Unknown
218-E-10 Burial Ground	1960-present *Active*	Failed equipment and mixed industrial waste, PUREX cover and centrifuge blocks	No	21,764 $m^{3a/}$ 153,000 $m^{3b/}$
UN-200-E-1	Oct 14, 1966	Failure of 221-B to 241-BX-154 waste line	Yes	Unknown
UN-200-E-2	Nov 18, 1947	Radioactive particulate matter	No	Unknown
UN-200-E-3	Nov 21, 1951	Failure of 221-B to 241-BX waste line	Yes	Unknown
UN-200-E-7	Nov 30, 1954	Cell wash water from 5-9 Tank	Yes	19,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
UN-200-E-9	Sept 15, 1955	Tributyl phosphate scavenged supernatant	Yes	42,000
UN-200-E-14	1958	216-B-3 pond water	Yes	Unknown
UN-200-E-41	July 19, 1972	Line leak including C_s-137	Yes	Unknown
UN-200-E-43	Jan 10, 1972	Liquid from 102-BY Pump	Yes	Unknown
UN-200-E-44	Aug 16, 1972	BCS cribline leak	Yes	Unknown
UN-200-E-45	Aug 26, 1974	Mixed waste from 241-B-154 Diversion Box	Yes	Unknown
UN-200-E-52	Aug 1, 1975	Steam from E-5-2 strontium concentrator	Yes	Unknown
UN-200-E-54	July 20, 1977	Contaminated wash water	Yes	2
UN-200-E-55	April 27, 1979	Presumably wind-blown materials	No	Unknown
UN-200-E-61	Oct 31, 1981	Contamination resulting from burial operations	No	Unknown
UN-200-E-63	June 4, 1981	Vegetation absorbed radionuclides	No	Unknown
UN-200-E-64	Oct 12, 1984	Ants transported radionuclides from 216-B-64 Retention Basin	No	Unknown
UN-200-E-69	June 19, 1984	Flush water spilled beneath a burial box	Yes	Unknown
UN-200-E-76	Jan 4, 1968	9-2 Tank line to 241-B-110 Tank	Yes	Unknown
UN-200-E-79	June 1953	Leaks in line between 242-B Evaporator and 207-B Retention Basin	Yes	Unknown
UN-200-E-80	June 17, 1946	Underground waste line south of 221-B Building	Yes	Unknown
UN-200-E-83	1958 to 1989	Contaminants spread from BC Controlled Area by wildlife	No	Unknown

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
UN-200-E-85	July 20, 1972	Suspected leak in 18-1 waste line	Yes	Unknown
UN-200-E-87	1945-1953	Seepage from underground pipe joints south of 221-B Building	Yes	Unknown
UN-200-E-89	1978	Airborne release from 241-BX Tank Farm	No	Unknown
UN-200-E-90	Sept 1980	Material from 291-B Stack sand filter	No	Unknown
UN-200-E-92	1981	Russian thistles accumulated along East perimeter fence	No	Unknown
UN-200-E-95	Sept 1980	Series of small releases on railroad spur between 218-E-2A and 218-E-5	No	Unknown
UN-200-E-101	1986	Contaminated weeds between 242-B Evaporator and 241-B Tank Farm fence	No	Unknown
UN-200-E-103	Mar 8, 1972	BCS crib line leak	Yes	Unknown
UN-200-E-105	Dec 15, 1952	First cycle liquid waste from 107-BY Tank Farm	Yes	87,000
UN-200-E-109	Nov 11, 1953	Concentrated tributyl phosphate waste	Yes	570
UN-200-E-110	Aug 7, 1955	241-BY-112 Tank at the 112-BY Pit	Yes	Unknown
UN-200-E-112	Feb 12, 1979	Ion-exchange liquid	Yes	Unknown
UN-200-E-140	April 23, 1986	PCB contaminated oil	Yes	7.6
UPR-200-E-4	Fall 1951	Leakage from 241-B-151 Diversion Box	Yes	Unknown
UPR-200-E-5	Mar 20, 1951	Depleted uranium from BX-102 Tank	Yes	Unknown
UPR-200-E-6	1954	Leakage from 241-B-153 Diversion Box	Yes	Unknown

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
UPR-200-E-32	Nov 7, 1963	A coil leak in 221-B Building contaminated primary low-level cooling water discharged through the 207-B Retention Basin and 216-B-2-1 Ditch	Yes	4,900,000
UPR-200-E-34	June 1964	Coil leak at the F-15 PUREX Tank	Yes	Unknown
UPR-200-E-38	Jan 4, 1968	Leak from 241-B-152 Diversion Box	Yes	Unknown
UPR-200-E-51	May 1977	15 Kg of cadmium nitrate was released from PUREX Tank TK-324 to the 216-B-3 Pond and 216-B-3-3 Ditch	Yes	Unknown
UPR-200-E-73	1951-1952	Leakages and spills from 241-B-151 Diversion Box	Yes	Unknown
UPR-200-E-74	Spring 1954	Leakages and spills from 241-B-152 Diversion Box	Yes	Unknown
UPR-200-E-75	1954-1955	Leakages from 241-B-153 Diversion Box	Yes	Unknown
UPR-200-E-77	1946	Metal waste solution with fission products spilled from 241-B-154 Diversion Box	Yes	Unknown
UPR-200-E-78	Oct 1955	Mixed fission product salt waste	Yes	Unknown
UPR-200-E-84	March 1953	241-ER-311 Catch Tank leak of acid	Yes	6,500
UPR-200-E-108	Unknown	Supernatant leak between 241-B-102 and 101 Tanks	Yes	Unknown
UPR-200-E-116	Nov 20, 1972	Caustic flush water containing Cs-137, Y-90, Sr-90 from 241-B-107 Tank	Yes	Unknown
UPR-200-E-127	1968	Liquid with 2,000 Ci of Cs-137 from 241-B-110 Tank	Yes	30,000

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
UPR-200-E-128	169	Liquid with 4,300 Ci of Cs-137 from 241-B-110 Tank	Yes	31,000
UPR-200-E-129	1968	Liquid with 420 Ci of CS-137 from 241-B-201 Tank	Yes	4,500
UPR-200-E-130	1951-1977	Lathium fluoride from 241-B-203 Tank	Yes	11,000
UPR-200-E-131	1948-1971	51,000 Ci of Cs-137 from 241-BX-102	Yes	Unknown
UPR-200-E-132	1974	500 Ci liquid from 241-BX-102	Yes	9,500
UPR-200-E-133	1949-1974	Tank leak from 241-BX-108 containing 500 Ci Cs-137	Yes	9,500
UPR-200-E-134	1973	PUREX coating waste leaked from 241-BX-103 Tank	Yes	19,000
UPR-200-E-135	1955-1972	Tributyl phosphate waste from 241-BX-108 Tank	Yes	19,000
UPR-200-E-138	Mar 22, 1970	1,000 Ci Sr-90 released to 216-B-2-2 Ditch	Yes	Unknown
No number	1951	Overflow of 241-BX-103 Tank	Yes	100,000-300,000
Semi-Works Aggregate Area				
Plants, Buildings, and Storage Areas				
Tank Storage Area	Unknown	5 Steel tanks from 201-C Process Building	No	Unknown
Tanks and Vaults				
241-CX-70 Storage Tank	1952-1957	High-level process waste	No	Contains 40,000
241-CX-71 Storage Tank	1952-1957	201-C Building, Hot Shop	No	Contains 14,400
241-CX-72 Storage Tank	1957-1976	PUREX Pilot Plant	No	7,500

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
Cribs and Drains				
216-C-1 Crib	1953-1957	201-C Building REDOX, PUREX Pilot Plant, 215 Gas Preparation and 271-C Aqueous Makeup and Control Building	Yes	23,400,000
216-C-3 Crib	1953-1954	201-C Building, 215-C Building, 271-C Building	Yes	5,000,000
216-C-4 Crib	1955-1965	276-C Building	Yes	170,000
216-C-5 Crib	1955	201-C Building REDOX, PUREX Pilot Plant	Yes	37,900
216-C-6 Crib	1955-1964	201-C Building REDOX, PUREX Pilot Plant, 241-CX vault floor drains	Yes	530,000
216-C-7 Crib	1961-Present	Critical Mass Laboratory	Yes	60,000
216-C-10 Crib	1964-1969	201-C Process Building	Yes	897,000
Reverse Well				
216-C-2 Reverse Well	1953-1988	291-C Stack	Yes	Unknown
Ponds, Ditches, and Trenches				
216-C-9 Pond	1953-1985	209-E Building, 226-C, 201-C, 215-C, 209-C	Yes	1,030,000,000
200 East Powerhouse Ditch	1943-Present	284-E Power Plant	Yes	13,800/mo
Septic Tanks				
2607-E-5 Septic Tank & Field	1949-Present	Critical Mass Laboratory, mobile offices	Yes	Unknown
2607-E-7A Septic Tank & Field	1983-Present	Critical Mass Laboratory	Yes	Unknown

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
Transfer Facilities, Diversion Boxes, and Pipelines				
Semi-Works Valve Pit	???-late 1980s	201-C Process Building	No	Variable
Critical Mass Laboratory Valve Pit	???-Present	Critical Mass Laboratory	No	Variable
241-C-154 Diversion Box	???-1985	Promethium transfer line from B Plant	No	Variable
Burial Sites				
218-C-9 Burial Ground	1985-1989	Decommissioning rubble from 201-C Process Building	No	2,265 m^3
Unplanned Releases				
UN-200-E-36	July 1967	Beta/gamma sources	Yes	Unknown
UN-200-E-37	July 1967	Beta/gamma sources	Yes	Unknown
UN-200-E-98	Sept 1980	Strontium 90 source	No	Unknown
UN-200-E-141	Sept 1984	Uranyl nitrate spill	Yes	208.2
Newly Identified Sites				
216-C-9 Pond Diversion Box	???	209-E Building, 226-C, 201-C, 209-C	No	Variable
Critical Mass Laboratory Valve Box	???	Unknown	No	Unknown
Soils Holding Tank	???	Soil	No	Unknown
Critical Mass Laboratory Dry Well North	???	Unknown	Unknown	Unknown
Critical Mass Laboratory Dry Well East	???	Unknown	Unknown	Unknown

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
241-C Waste Line Unplanned Release No. 1	1957	241-C Process Building/Tank Farm Line	Yes	Unknown
241-C Waste Line Unplanned Release No. 2	1957	241-C Process Building/Tank Farm Line	Yes	Unknown
200 North Aggregate Area Tanks and Vaults				
212-P Transformer Oil Tank	1982-present/active	Transformer Oil containing PCBs	No	Unknown
Ponds, Ditches, and Trenches				
216-N-1 Pond	1944-1952/inactive	Cooling water from 212-N Building	Yes	946,000,000
216-N-4 Pond	1944-1952/inactive	Cooling water from 212-P Building	Yes	946,000,000
216-N-6 Pond	1944-1952/inactive	Cooling water from 212-R Building	Yes	946,000,000
216-N-2 Trench	1947/inactive	Low activity water and sludge from 212-N basin	Yes	7,500,000
216-N-3 Trench	1952/inactive	Low activity water and sludge from 212-N basin	Yes	7,600,000
216-N-5 Trench	1952/inactive	Low activity water and sludge from 212-P basin	Yes	7,600,000
216-N-7 Trench	1952/inactive	Low activity water and sludge from 212-R basin	Yes	7,600,000
Septic Tanks and Associated Drain Fields				
2607-N Septic Tank/Drain Field	1944-1952/inactive	Sanitary wastewater and sewage from 2734-N guard house	Yes	Unknown
2607-P Septic Tank/Drain Field	1944-1952/inactive	Sanitary wastewater and sewage from 2734-P guard house	Yes	Unknown

Table 2-1. Summary of 200 East Area Waste Management Units.

Waste Management Unit	Years in Service/*Status*	Source Description	Liquid Discharge to Soil	Waste Volume Received (L)
2607-R Septic Tank/Drain Field	1944-1952/inactive	Sanitary wastewater and sewage from 2734-R guard house	Yes	Unknown
Transfer Facilities, Diversion Boxes, and Pipelines				
212-N to 216-N-1 Pipeline	1944-1952/inactive	Cooling water overflow	No	Unknown
212-P to 216-N-4 Pipeline	1944-1952/inactive	Cooling water overflow	No	Unknown
212-R to 216-N-6 Pipeline	1944-1952/inactive	Cooling water overflow	No	Unknown
Burial Sites				
Ballast Pits	Unknown	Unknown	Unknown	Unknown
Unplanned Releases				
Unnumbered	Unknown	Unknown	Unknown	Unknown
Unnumbered	Unknown	Unknown	Unknown	Unknown

Source description and waste volumes from WIDS (WHC 1991a).

[a] Source: WHC/1991a.
[b] Source: Maxfield 1979.
[c] 299-E24-111 Injection Well never received waste. It did receive eleven 4,000 L injections of liquid for radionuclide migration data.

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Table 2-2. Soil Column Calculation of Potential for Migration of Liquid Discharges to the Unconfined Aquifer.

Liquid Discharge Source	Liquid Effluent Volume Received By Soil (m^3)	Soil Column Pore Volume Range (m^3)[a/]	Indicates Possible Migration to Uppermost Aquifer[b/]	Significant Impact on Groundwater Flow[c/]
PUREX Plant Aggregate Area				
241-A-103 Tank	Unknown	--	No	No
241-A-104 Tank	Unknown	--	No	No
241-A-105 Tank	776	--	No	No
241-AX-102 Tank	Unknown	--	No	No
241-AX-104 Tank	Unknown	--	No	No
241-C-101 Tank	64 to 91	--	No	No
241-C-110 Tank	Unknown	--	No	No
241-C-111 Tank	Unknown	--	No	No
241-C-201 Tank	Unknown	--	No	No
241-C-202 Tank	Unknown	--	No	No
241-C-203 Tank	1.5	--	No	No
241-C-204 Tank	Unknown	--	No	No
244-AR Vault	Unknown	--	No	No
216-A-1 Crib	98	660 to 1,980	No	No
216-A-2 Crib	230	307 to 921	No	No
216-A-3 Crib	3,050	317 to 952	Yes	No
216-A-4 Crib	6,210	316 to 948	Yes	No
216-A-5 Crib	1,630,000	975 to 2,925	Yes	Yes
216-A-6 Crib	3,400,000	7,675 to 23,024	Yes	Yes
216-A-7 Crib	326	73 to 220	Yes	No
216-A-8 Crib	1,150,000	11,747 to 35,241	Yes	Yes
216-A-9 Crib	981,000	6,685 to 20,054	Yes	Yes
216-A-10 Crib	3,210,000	9,357 to 28,072	Yes	Yes
216-A-21 Crib	77,900	791 to 2,373	Yes	No
216-A-24 Crib	820,000	18,000 to 54,000	Yes	Yes
216-A-27 Crib	23,200	1,665 to 4,996	Yes	No

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Table 2-2. Soil Column Calculation of Potential for Migration of Liquid Discharges to the Unconfined Aquifer. Page 2 of 9

Liquid Discharge Source	Liquid Effluent Volume Received By Soil (m^3)	Soil Column Pore Volume Range (m^3)[a/]	Indicates Possible Migration to Uppermost Aquifer[b/]	Significant Impact on Groundwater Flow[c/]
216-A-30 Crib	7,110,000	10,586 to 31,758	Yes	Yes
216-A-31 Crib	10	567-1,701	No	No
216-A-32 Crib	4	446 to 1,337	No	No
216-A-36A Crib	1,070	910 to 2,729	Yes	No
216-A-36B Crib	317,000	4,533 to 13,598	Yes	Yes
216-A-37-1 Crib	377,000	5,293 to 15,879	Yes	Yes
216-A-37-2 Crib	1,090,000	10,190 to 30,569	Yes	Yes
216-A-39 Crib	.02	315 to 945	No	No
216-A-41 Crib	10	79 to 237	No	No
216-A-45 Crib	103,000	19,358 to 58,074	Yes	Yes
216-A-11 French Drain	100	4 to 11	Yes	No
216-A-12 French Drain	100	4 to 11	Yes	No
216-A-13 French Drain	100	6 to 17	Yes	No
216-A-14 French Drain	1	4 to 12	No	No
216-A-15 French Drain	10,000	10 to 29	Yes	No
216-A-16 French Drain	122	7 to 22	Yes	No
216-A-17 French Drain	60	7 to 22	Yes	No
216-A-22 French Drain	10	23 to 68	No	No
216-A-23A French Drain	6	7 to 22	No	No
216-A-23B French Drain	6	7 to 22	No	No
216-A-26 French Drain	Unknown	10 to 31	No	No
216-A-26A French Drain	1	6 to 17	No	No
216-A-28 French Drain	30	64 to 191	No	No
216-A-35 French Drain	10	23 to 70	No	No
216-C-8 French Drain	10	20 to 61	No	No
216-A-18 Trench	488	4,350 to 13,050	No	No
216-A-19 Trench	1,100	411 to 1,232	Yes	No

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Table 2-2. Soil Column Calculation of Potential for Migration of Liquid Discharges to the Unconfined Aquifer.

Liquid Discharge Source	Liquid Effluent Volume Received By Soil (m^3)	Soil Column Pore Volume Range (m^3)[a]	Indicates Possible Migration to Uppermost Aquifer[b]	Significant Impact on Groundwater Flow[c]
216-A-20 Trench	961	425 to 1,274	Yes	No
216-A-40 Trench	946	6,072 to 18,215	No	No
216-A-29 Ditch	10,400,312	14,341 to 43,024	Yes	Yes
216-A-34 Ditch	Unknown	3,997 to 11,990	No	No
2607-EA Septic Tank/Drain Field	350[d]	Unknown	No	No
2607-EC Septic Tank/Drain Field	6,077[d]	Unknown	No	No
2607-ED Septic Tank/Drain Field	1,226[d]	Unknown	No	No
2607-EG Septic Tank/Drain Field	2,420[d]	Unknown	No	No
2607-EJ Septic Tank/Drain Field	1,400[d]	Unknown	No	No
2607-EL Septic Tank/Drain Field	25,942[d]	Unknown	No	No
2607-E6 Septic Tank/Drain Field	603,345[d]	Unknown	Yes	Yes
241-A-151 Diversion Box	Unknown	--	No	No
241-C-152 Diversion Box	9.8	--	No	No
241-CR-151 Diversion Box	136.3	--	No	No
B Plant Aggregate Area				
241-B-101 Tank	Unknown	--	No	No
241-B-103 Tank	Unknown	--	No	No
241-B-107 Tank	Unknown	--	No	No
241-B-110 Tank	61	--	No	No
241-B-111 Tank	Unknown	--	No	No
241-B-112 Tank	Unknown	--	No	No
241-B-201 Tank	4.5	--	No	No
241-B-203 Tank	1	--	No	No

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Table 2-2. Soil Column Calculation of Potential for Migration of Liquid Discharges to the Unconfined Aquifer.

Liquid Discharge Source	Liquid Effluent Volume Received By Soil (m^3)	Soil Column Pore Volume Range (m^3)[a/]	Indicates Possible Migration to Uppermost Aquifer[b/]	Significant Impact on Groundwater Flow[c/]
241-B-204 Tank	Unknown	--	No	No
241-BX-101 Tank	Unknown	--	No	No
241-BX-102 Tank	9.5	--	No	No
241-BX-103 Tank	100 to 300	--	No	No
241-BX-108 Tank	9.5	--	No	No
241-BX-110 Tank	Unknown	--	No	No
241-BX-111 Tank	Unknown	--	No	No
241-BY-103 Tank	Unknown	--	No	No
241-BY-105 Tank	Unknown	--	No	No
241-BY-106 Tank	Unknown	--	No	No
241-BY-107 Tank	Unknown	--	No	No
241-BY-108 Tank	19	--	No	No
241-ER-311 Catch Tank	6.5	--	No	No
216-B-7A&B Cribs	43,600	186 to 558	Yes	No
216-B-8TF Crib and Tile Field	27,200	17,580 to 52,730	Yes	No
216-B-9TF Crib and Tile Field	36,000	8,660 to 25,990	Yes	No
216-B-10A Crib	9990	155 to 465	Yes	No
216-B-10B Crib	28	6,100 to 18,300	No	No
216-B-12 Crib	520,000	6,100 to 18,300	Yes	Yes
216-B-14 Crib	8,710	5,890 to 17,670	Yes	No
216-B-15 Crib	6,320	5,890 to 17,670	Yes	No
216-B-16 Crib	5,600	5,890 to 17,670	Yes	No
216-B-17 Crib	3,410	5,890 to 17,670	No	No
216-B-18 Crib	8,520	5,890 to 17,670	Yes	No
216-B-19 Crib	6,400	5,890 to 17,670	Yes	No
216-B-43 Crib	2,100	3,400 to 10,200	No	No
216-B-44 Crib	5,600	3,295 to 9,885	Yes	No

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Table 2-2. Soil Column Calculation of Potential for Migration of Liquid Discharges to the Unconfined Aquifer.

Liquid Discharge Source	Liquid Effluent Volume Received By Soil (m^3)	Soil Column Pore Volume Range (m^3)[a/]	Indicates Possible Migration to Uppermost Aquifer[b/]	Significant Impact on Groundwater Flow[c/]
216-B-45 Crib	4,920	3,295 to 9,885	Yes	No
216-B-46 Crib	6,700	3,243 to 9,730	Yes	No
216-B-47 Crib	3,710	3,452 to 10,355	Yes	No
216-B-48 Crib	4,090	3,347 to 10,042	Yes	No
216-B-49 Crib	6,700	3,295 to 9,885	Yes	No
216-B-50 Crib	54,800	3,295 to 9,885	Yes	No
216-B-55 Crib	1,230,000	6,073 to 18,220	Yes	Yes
216-B-57 Crib	84,400	1,925 to 5,775	Yes	No
216-B-60 Crib	18.9	146 to 438	No	No
216-B-62 Crib	282,000	3,860 to 11,580	Yes	Yes
Chem TF North of 2703-F	Unknown	Unknown	No	No
216-B-13 French Drain	28	29 to 118	No	No
216-B-51 French Drain	1	45 to 135	No	No
216-B-4 Reverse Well	10	.8 to 2.3	Yes	No
216-B-5 Reverse Well	30,600	0	Yes	No
216-B-6 Reverse Well	6,000	.5 to 1.4	Yes	No
216-B-11 A&B Reverse Wells	29,600	56.4 to 169.12	Yes	No
216-B-3 Pond	240,000,000	760,840 to 2,282,510	Yes	Yes
216-A-25 Pond	307,000,0000	229,870 to 689,620	Yes	Yes
216-N-8 Pond[e/]	Unknown	0	Yes	No
216-M Pond	Unknown	--	No	No
216-B-3A Pond	Unknown	--	No	No
216-B-3B Pond	Unknown	--	No	No
216-B-3C Pond	Unknown	--	No	No
216-B-2-1 Ditch	149,000,000	37,120 to 111,360	Yes	Yes
216-B-2-2 Ditch	49,700	24,600 to 73,800	Yes	No

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Table 2-2. Soil Column Calculation of Potential for Migration of Liquid Discharges to the Unconfined Aquifer.

Liquid Discharge Source	Liquid Effluent Volume Received By Soil (m^3)	Soil Column Pore Volume Range (m^3)[a/]	Indicates Possible Migration to Uppermost Aquifer[b/]	Significant Impact on Groundwater Flow[c/]
216-B-2-3 Ditch	Unknown	--	No	No
216-B-3-1 Ditch	149,000,000	8,037 to 24,111	Yes	Yes
216-B-3-2 Ditch	149,000,000	23,230 to 69,700	Yes	Yes
216-B-3-3 Ditch	Unknown	--	No	No
216-B-20 Trench	4,680	4,560 to 13,670	Yes	No
216-B-21 Trench	4,670	4,650 to 13,950	Yes	No
216-B-22 Trench	4,740	4,600 to 13,800	Yes	No
216-B-23 Trench	4,520	4,465 to 13,390	Yes	No
216-B-24 Trench	4,700	4,560 to 13,670	Yes	No
216-B-25 Trench	3,760	4,420 to 13,260	No	No
216-B-26 Trench	5,880	4,465 to 13,390	Yes	No
216-B-27 Trench	4,420	4,465 to 13,390	No	No
216-B-28 Trench	5,050	4,510 to 13,530	Yes	No
216-B-29 Trench	4,840	4,510 to 13,530	Yes	No
216-B-30 Trench	4,780	4,510 to 13,530	Yes	No
216-B-31 Trench	4,740	4,510 to 13,530	Yes	No
216-B-32 Trench	4,770	4,510 to 13,530	Yes	No
216-B-33 Trench	4,740	4,510 to 13,530	Yes	No
216-B-34 Trench	4,870	4,510 to 13,530	Yes	No
216-B-35 Trench	1,060	1,730 to 5,190	No	No
216-B-36 Trench	1,940	1,730 to 5,190	Yes	No
216-B-37 Trench	4,320	1,710 to 5,130	Yes	No
216-B-38 Trench	1,430	1,685 to 5,055	No	No
216-B-39 Trench	1,540	1,685 to 5,055	No	No
216-B-40 Trench	1,640	1,640 to 4,920	Yes	No
216-B-41 Trench	1,440	1,640 to 4,920	No	No
216-B-42 Trench	1,500	1,755 to 5,265	No	No

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Table 2-2. Soil Column Calculation of Potential for Migration of Liquid Discharges to the Unconfined Aquifer.

Liquid Discharge Source	Liquid Effluent Volume Received By Soil (m^3)	Soil Column Pore Volume Range (m^3)[a/]	Indicates Possible Migration to Uppermost Aquifer[b/]	Significant Impact on Groundwater Flow[c/]
216-B-52 Trench	8,530	5,240 to 15,710	Yes	No
216-B-53A Trench	549	543 to 1,630	Yes	No
216-B-53B Trench	15.1	1,370 to 4,120	No	No
216-B-54 Trench	999	1,823 to 5,470	No	No
216-B-58 Trench	413	1,880 to 5,640	No	No
216-B-63 Trench	7,220,000	3,650 to 10,940	Yes	Yes
2607-EB Septic Tank/Tile Field	300[d/]	--	No	No
2607-EH Septic Tank/Drain Field	4,468[d/]	--	No	No
2607-EK Septic Tank/Drain Field	106,000[d/]	1,706 to 5,118	Yes	Yes
2607-EM Septic Tank/Drain Field	18,600[d/]	1,168 to 3,505	Yes	No
2607-EN Septic Tank/Drain Field	9,022[d/]	288 to 864	Yes	No
2607-EO Septic Tank/Drain Field	5,400[d/]	688 to 2,064	Yes	No
2607-EP Septic Tank/Drain Field	56,475[d/]	--	No	No
2607-EQ Septic Tank	26,800[d/]	440 to 1,320	Yes	No
2607-ER Septic Tank	Unknown	--	No	No
2607-GF Septic Tank	Unknown	--	No	No
2607-E1 Septic Tank/Drain Field	173,000[d/]	7,386 to 22,158	Yes	Yes
2607-E2 Septic Tank/Drain Field	10,400[d/]	27,000 to 84,000	No	No
2607-E3 Septic Tank/Tile Field	252,000[d/]	--	Yes	Yes
2607-E4 Septic Tank/Tile Field	4,200[d/]	--	No	No
2607-E7B Septic Tank	Unknown	--	No	No

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Table 2-2. Soil Column Calculation of Potential for Migration of Liquid Discharges to the Unconfined Aquifer.

Liquid Discharge Source	Liquid Effluent Volume Received By Soil (m^3)	Soil Column Pore Volume Range (m^3)[a/]	Indicates Possible Migration to Uppermost Aquifer[b/]	Significant Impact on Groundwater Flow[c/]
2607-E8 Septic Tank/Drain Field	37,800[d/]	6,900 to 20,880	Yes	No
2607-E9 Septic Tank/Drain Field	Unknown	--	No	No
2607-E11 Septic Tank/Drain Field	8,070[d/]	1,035 to 3,105	Yes	No
216-B-59/59B Trench/Retention	477	1,800 to 5,400	No	No
Semi-Works Aggregate Area				
216-C-1 Crib	23,400	91 to 274	Yes	No
216-C-3 Crib	5,000	392 to 1,175	Yes	No
216-C-4 Crib	170	161 to 484	Yes	No
216-C-5 Crib	37.9	161 to 484	No	No
216-C-6 Crib	530	161 to 484	Yes	No
216-C-7 Crib	60	323 to 967	No	No
216-C-10 Crib	897	161 to 484	Yes	No
216-C-2 Reverse Well	Unknown	78 to 235	No	No
216-C-9 Pond	1,030,000	64,500 to 193,700	Yes	Yes
200 East Powerhouse Ditch	246,813[d/]	40,000 to 120,000	Yes	Yes
2607-E-5 Septic Tank/Drain Field	Unknown	Unknown	No	No
2607-E-7A Septic Tank/Drain Field	Unknown	Unknown	No	No
200 North Aggregate Area				
216-N-1 Pond	946,000	22,980 to 68,930	Yes	Yes
216-N-4 Pond	946,000	43,450 to 130,340	Yes	Yes
216-N-6 Pond	946,000	32,370 to 97,120	Yes	Yes
216-N-2 Trench	7,500	246 to 737	Yes	No
216-N-3 Trench	7,600	491 to 1,473	Yes	No

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Table 2-2. Soil Column Calculation of Potential for Migration of Liquid Discharges to the Unconfined Aquifer. Page 9 of 9

Liquid Discharge Source	Liquid Effluent Volume Received By Soil (m^3)	Soil Column Pore Volume Range (m^3)[a/]	Indicates Possible Migration to Uppermost Aquifer[b/]	Significant Impact on Groundwater Flow[c/]
216-N-5 Trench	7,600	580 to 1,738	Yes	No
216-N-7 Trench	7,600	518 to 1,554	Yes	No
2607-N Septic Tank/Drain	Unknown	--	No	No
2607-P Septic Tank/Drain	Unknown	--	No	No
2607-R Septic Tank/Drain	Unknown	--	No	No

a/ Pore volume calculation: (waste unit section area) x (depth to groundwater) x (porosity). Low pore volume value reflects 0.1 porosity; higher pore volume value reflects 0.3 porosity. Pore volume calculation does not account for the ability of the soil to retain the liquid discharged.

b/ Yes, when liquid effluent volume received by soil exceeds the lower range of soil column pore volume.

c/ Yes, when discharge exceeded 100,000 m^3.

d/ Based on reported daily rates from first year through 1991.

e/ 216-N-8 Pond formed as a result of the rising water table. Before the pond was formed, the area received sewage sludge from the Hanford construction camp.

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Table 2-3. Summary of Well Geophysical Log Results For Units Potentially Contributing Contaminants to Groundwater. Page 1 of 5

Waste Management Unit	Number of Wells Reviewed	Elevated Gamma Log Response (m)	Evidence of Release to Groundwater
PUREX Plant Aggregate Area			
241-A-101 to 106 Tank Farm	54	0-32	No
241-AX-101 to 104 Tank Farm	32	0-12	No
241-C-101 to 112 Tank Farm	70	0-21	No
216-A-1 Crib	1	--	No
216-A-2 Crib	1	8-??	No
216-A-4 Crib	1	8-??	No
216-A-5 Crib	5	8-16	No
216-A-6 Crib	2	6-12	No
216-A-7 Crib	1	0-5	No
216-A-8 Crib	7	0-37 and 44-55	Yes
216-A-9 Crib	4	--	No
216-A-10 Crib	6	15-61	Yes
216-A-21 Crib	1	43-45	No
216-A-24 Crib	7	1-61	Yes
216-A-27 Crib	2	24-44 and 88-98	Yes
216-A-30 Crib	6	2-13	No
216-A-31 Crib	1	--	No
216-A-36A Crib	2	6-49 and 88-98	Yes
216-A-36B Crib	6	6-41 +	No
216-A-31-1 Crib	3	--	No
216-A-37-2 Crib	2	--	No
216-A-38 Crib	2	--	No
216-A-45 Crib	4	--	No
216-A-15 French Drain	1	--	No

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Table 2-3. Summary of Well Geophysical Log Results For Units Potentially Contributing Contaminants to Groundwater. Page 2 of 5

Waste Management Unit	Number of Wells Reviewed	Elevated Gamma Log Response (m)	Evidence of Release to Groundwater
216-A-26 French Drain	1	7-??	No
216-A-26A French Drain	1	7-??	No
216-A-18 Trench	1	--	No
216-A-19 Trench	1	--	No
216-A-20 Trench	1	--	No
216-A-40 Trench	1	--	No
216-A-29 Ditch	1	5-9	No
216-A-34 Ditch	1	--	No
216-A-42 Retention Basin	1	--	No
B Plant Aggregate Area			
241-B-1-1 to 112 Tank Farm	16	0-??	No
241-BX-101 to 112 Tank Farm	16	0-??	No
241-BY-101 to 112 Tank Farm	15	0-??	No
216-B-7 A & B Cribs	5	4-23	No
216-B-8 Crib & Tile Field	14	4-37	No
216-B-9 Crib & Tile Field	9	2-13	No
216-B-10 A Crib	1	Unknown	No
216-B-10-B Crib	1	Unknown	No
216-B-12 Crib	6	0-??	No
216-B-14 Crib	1	0-82	Yes
216-B-15 Crib	1	3-32	No
216-B-16 Crib	2	0-93	Yes
216-B-17 Crib	1	4-21	No
216-B-18 Crib	2	4-27	No
216-B-19 Crib	1	3-32	No
216-B-43 Crib	3	7-70	Yes
216-B-44 Crib	2	12-70	Yes

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Table 2-3. Summary of Well Geophysical Log Results For Units Potentially Contributing Contaminants to Groundwater.

Waste Management Unit	Number of Wells Reviewed	Elevated Gamma Log Response (m)	Evidence of Release to Groundwater
216-B-45 Crib	2	9-70	Yes
216-B-46 Crib	2	2-70	Yes
216-B-47 Crib	1	12-38	No
216-B-48 Crib	1	3-47	No
216-B-49 Crib	1	3-47	No
216-B-50 Crib	1	3-70	Yes
216-B-55 Crib	2	Unknown	No
216-B-56 Crib	1	0	No
216-B-57 Crib	1	8-21	No
216-B-61 Crib	2	0	No
216-B-62 Crib	4	10-35	No
216-B-51 French Drain	4	0	No
216-B-5 Reverse Well	2	82-101	Yes
216-B-6 Reverse Well	1	Unknown	No
216-B-11 A & B Reverse Wells	3	23-30	No
216-B-3 Pond	16	--	No
216-B-3A Pond	3	--	No
216-B-3B Pond	3	--	No
216-B-3C Pond	3	--	No
216-E-25 Pond	1	--	No
216-A-25 Pond	8	--	No
216-N-8 Pond	3	--	No
216-B-2-1 Ditch	8	--	No
216-B-2-2 Ditch	8	--	No
216-B-2-3 Ditch	8	--	No
216-B-3-1 Ditch	4	--	No
216-B-3-2 Ditch	4	--	No

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Table 2-3. Summary of Well Geophysical Log Results For Units Potentially Contributing Contaminants to Groundwater.

Waste Management Unit	Number of Wells Reviewed	Elevated Gamma Log Response (m)	Evidence of Release to Groundwater
216-B-3-3 Ditch	4	--	No
216-B-20 Trench	2	5-12	No
216-B-21 Trench	1	--	No
216-B-22 Trench	1	--	No
216-B-23 Trench	1	5-12	No
216-B-24 Trench	2	--	No
216-B-25 Trench	1	1-??	No
216-B-26 Trench	2	--	No
216-B-27 Trench	1	1-7	No
216-B-28 Trench	2	--	No
216-B-29 Trench	1	--	No
216-B-30 Trench	0	Unknown	No
216-B-31 Trench	4	1-??	No
216-B-32 Trench	2	10-11	No
216-B-33 Trench	2	7-9	No
216-B-34 Trench	4	--	No
216-B-35 Trench	1	6-??	No
216-B-36 Trench	2	0-21	No
216-B-37 Trench	2	0-??	No
216-B-38 Trench	2	0-??	No
216-B-39 Trench	--	--	No
216-B-40 Trench	--	--	No
216-B-41 Trench	1	8-19	No
216-B-42 Trench	2	5-11	No
216-B-52 Trench	1	9-??	No
216-B-53A Trench	1	--	No
216-B-53B Trench	--	--	No

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Table 2-3. Summary of Well Geophysical Log Results For Units Potentially Contributing Contaminants to Groundwater. Page 5 of 5

Waste Management Unit	Number of Wells Reviewed	Elevated Gamma Log Response (m)	Evidence of Release to Groundwater
216-B-54 Trench	1	--	No
216-B-58 Trench	1	--	No
216-B-63 Trench	3	--	No
216-B-154 Diversion Box	2	--	No
216-BX-155 Diversion Box	3	Unknown	No
216-B-361 Settling Tank	2	--	No
216-BX-302B Catch Tank	2	--	No
216-BX-302C Catch Tank	2	--	No
216-B-64 Retention Basin	2	--	No
218-E-2 Burial Ground	2	--	No
218-E-3 Burial Ground	1	--	No
218-E-4 Burial Ground	1	--	No
218-E-5 Burial Ground	2	--	No
218-E-5A Burial Ground	2	--	No
218-E-9 Burial Ground	2	--	No
218-E-10 Burial Ground	12	--	No
Semi-Works Aggregate Area			
216-C-1 Crib	1	2-12	No
216-C-5 Crib	1	0-3	No
216-C-10 Crib	1	--	No
216-C-9 Pond	1	--	No
218-C-9 Burial Ground	1	--	No

Source = PUREX, B, Semi-Works AAMSRs.
??: Elevated gama log response of well. The depth interval of elevated gamma-ray activity extends deeper than the well.

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Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
PUREX Plant Aggregate Area				
241-A-103 Tank	1956-1980	No	No	No
241-A-104 Tank	1958-1975	No	No	No
241-A-105 Tank	1962-1972	No	No	No
241-AX-102 Tank	1966-1980	No	No	No
241-C-101 Tank	1946-1970	No	No	No
241-C-110 Tank	1946-1976	No	No	No
241-C-111 Tank	1946-1976	No	No	No
241-C-201 Tank	1953-1977	No	No	No
241-C-202 Tank	1953-1977	No	No	No
241-C-203 Tank	1953-1976	No	No	No
241-C-204 Tank	1953-1977	No	No	No
244-AR Vault	1977-Present	No	No logs	No
216-A-1 Crib	1955-1966	No	No	No
216-A-2 Crib	1956-1964	No	No	No
216-A-3 Crib	1956-1982	Yes	No	Yes
216-A-4 Crib	1955-1958	Yes	No	Yes
216-A-5 Crib	1955-1966	Yes	No	Yes
216-A-6 Crib	1955-1970	Yes	No	Yes

Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
216-A-7 Crib	1955-1966	Yes	No	Yes
216-A-8 Crib	1955-1991	Yes	Yes	Yes
216-A-9 Crib	1956-1969	Yes	No	Yes
216-A-10 Crib	1956-1987	Yes	Yes	Yes
216-A-21 Crib	1957-1965	Yes	No	Yes
216-A-24 Crib	1958-1966	Yes	Yes	Yes
216-A-27 Crib	1965-1970	Yes	Yes	Yes
216-A-30 Crib	1961-1991	Yes	No	Yes
216-A-31 Crib	1964-1966	No	No	No
216-A-32 Crib	1959-1966	No	No logs	No
216-A-36A Crib	1965-1966	Yes	Yes	Yes
216-A-36B Crib	1966-1987	Yes	No	Yes
216-A-37-1 Crib	1977-1991	Yes	No	Yes
216-A-37-2 Crib	1983-Present	Yes	No	Yes
216-A-39 Crib	1966	No	No logs	No
216-A-41 Crib	1968-1974	No	No logs	No
216-A-45 Crib	1987-1989	Yes	No	Yes
216-A-11 French Drain	1956-1972	Yes	No logs	Yes
216-A-12 French Drain	1955-1972	Yes	No logs	Yes

Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
216-A-13 French Drain	1956-1962	Yes	No logs	Yes
216-A-14 French Drain	1956-1972	No	No logs	No
216-A-15 French Drain	1955-1972	Yes	No	Yes
216-A-16 French Drain	1956-1968	Yes	No logs	Yes
216-A-17 French Drain	1956-1968	Yes	No logs	Yes
216-A-22 French Drain	1956-1957	No	No logs	No
216-A-23A French Drain	1957-1969	No	No logs	No
216-A-23B French Drain	1957-1969	No	No logs	No
216-A-26 French Drain	1965-1991	No	No	No
216-A-26A French Drain	1959-1965	No	No	No
216-A-28 French Drain	1958-1966	No	No logs	No
216-A-35 French Drain	1963-1966	No	No logs	No
216-C-8 French Drain	1962-1965	No	No	No
216-A-18 Trench	1955-1956	No	No	No
216-A-19 Trench	1955-1956	Yes	No	Yes
216-A-20 Trench	1955-1956	Yes	No	Yes
216-A-40 Trench	1968-1979	No	No	No
216-A-29 Ditch	1955-1991	Yes	No	Yes
216-A-34 Ditch	1955-1957	No	No	No

Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
2607-EA Septic Tank/Drain Field	1976-Present	No	No logs	No
2607-EC Septic Tank/Drain Field	1955-Present	No	No logs	No
2607-ED Septic Tank/Drain Field	1980-Present	No	No logs	No
2607-EG Septic Tank/Drain Field	1953-Present	No	No logs	No
2607-EJ Septic Tank/Drain Field	1980-Present	No	No logs	No
2607-EL Septic Tank/Drain Field	1983-Present	No	No logs	No
2607-E6 Septic Tank/Drain Field	1954-Present	Yes	No logs	Yes
241-A-151 Diversion Box	1956-Present	No	No logs	No
241-C-152 Diversion Box	1946-1985	No	No logs	No
241-CR-151 Diversion Box	1946-1985	No	No logs	No
B Plant Aggregate Area				
241-B-101 Tank	1945-1974	No	No	No
241-B-103 Tank	1953-1977	No	No	No
241-B-107 Tank	1945-1969	No	No	No
241-B-110 Tank	1945-1971	No	No	No
241-B-111 Tank	1945-1976	No	No	No
241-B-112 Tank	1946-1977	No	No	No
241-B-201 Tank	1952-1971	No	No	No
241-B-203 Tank	1951-1977	No	No	No

Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
241-B-204 Tank	1951-1977	No	No	No
241-BX-101 Tank	1948-1972	No	No	No
241-BX-102 Tank	1948-1971	No	No	No
241-BX-103 Tank	1948-1977	No	No	No
241-BX-108 Tank	1949-1974	No	No	No
241-BX-110 Tank	1949-1977	No	No	No
241-BX-111 Tank	1950-1977	No	No	No
241-BY-103 Tank	1950-1977	No	No	No
241-BY-105 Tank	1951-1974	No	No	No
241-BY-106 Tank	1953-1977	No	No	No
241-BY-107 Tank	1950-1974	No	No	No
241-BY-108 Tank	1951-1972	No	No	No
241-ER-311 Catch Tank	1945-Present	No	No	No
216-B-7A&B Cribs	1946-1967	Yes	No	Yes
216-B-8TF Crib	1948-1953	Yes	No	Yes
216-B-9TF Crib	1948-1951	Yes	No	Yes
216-B-10A Crib	1949-1952	Yes	No	Yes
216-B-10B Crib	1952-1973	Yes	No	Yes
216-B-12 Crib	1952-1973	Yes	Yes	Yes

Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
216-B-14 Crib	1956	Yes	Yes	Yes
216-B-15 Crib	1956	Yes	No	Yes
216-B-16 Crib	1956	Yes	Yes	Yes
216-B-17 Crib	1956	No	No	No
216-B-18 Crib	1956	Yes	No	Yes
216-B-19 Crib	1957	Yes	No	Yes
216-B-43 Crib	1954	No	Yes	Yes
216-B-44 Crib	1954-1955	Yes	Yes	Yes
216-B-45 Crib	1955	Yes	Yes	Yes
216-B-46 Crib	1955	Yes	Yes	Yes
216-B-47 Crib	1955	Yes	No	Yes
216-B-48 Crib	1955	Yes	No	Yes
216-B-49 Crib	1955	Yes	No	Yes
216-B-50 Crib	1965-1974	Yes	Yes	Yes
216-B-55 Crib	1967-Present	Yes	No	Yes
216-B-57 Crib	1968-1973	Yes	No	Yes
216-B-60 Crib	1967	No	No	No
216-B-62 Crib	1973-Present	Yes	No	Yes
Chem TF North of 2703-F	Unknown	No	No logs	No

Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
216-B-13 French Drain	1947-1976	No	No logs	No
216-B-51 French Drain	1956-1958	No	No	No
216-B-4 Reverse Well	1945-1949	Yes	No logs	Yes
216-B-5 Reverse Well	9145-1947	Yes	Yes	Yes
216-B-6 Reverse Well	1945-1949	Yes	No	Yes
216-B-11 A&B Reverse Wells	1951-1954	Yes	No	Yes
216-B-3 Pond	1945-Present	Yes	No	Yes
216-A-25 Pond	1957-1987	Yes	No	Yes
216-N-8 Pond[e/]	1958-1987	Yes	No	Yes
216-M Pond	1983-Present	No	No	No
216-B-3A Pond	1983-Present	No	No	No
216-B-3B Pond	1984-Present	No	No	No
216-B-3C Pond	1985-Present	No	No	No
216-B-2-1 Ditch	1945-1963	Yes	No	Yes
216-B-2-2 Ditch	1963-1970	Yes	No	Yes
216-B-2-3 Ditch	1970-1987	No	No	No
216-B-3-1 Ditch	1945-1964	Yes	No	Yes
216-B-3-2 Ditch	1964-1970	Yes	No	Yes
216-B-3-3 Ditch	1970-Present	No	No	No

Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
216-B-20 Trench	1956	Yes	No	Yes
216-B-21 Trench	1956	Yes	No	Yes
216-B-22 Trench	1956	Yes	No	Yes
216-B-23 Trench	1956	Yes	No	Yes
216-B-24 Trench	1956	Yes	No	Yes
216-B-25 Trench	1956	No	No	No
216-B-26 Trench	1956-1957	Yes	No	Yes
216-B-27 Trench	1957	No	No	No
216-B-28 Trench	1957	Yes	No	Yes
216-B-29 Trench	1957	Yes	No	Yes
216-B-30 Trench	1957	Yes	No	Yes
216-B-31 Trench	1957	Yes	No	Yes
216-B-32 Trench	1957	Yes	No	Yes
216-B-33 Trench	1957	Yes	No	Yes
216-B-34 Trench	1957	Yes	No	Yes
216-B-35 Trench	1954	No	No	No
216-B-36 Trench	1954	Yes	No	Yes
216-B-37 Trench	1954	Yes	No	Yes

Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
216-B-38 Trench	1954	No	No	No
216-B-39 Trench	1953-1954	No	No	No
216-B-40 Trench	1954	Yes	No	Yes
216-B-41 Trench	1954	No	No	No
216-B-42 Trench	1955	No	No	No
216-B-52 Trench	1957-1958	Yes	No	Yes
216-B-53A Trench	1965	Yes	No	Yes
216-B-53B Trench	1962-1963	No	No	No
216-B-54 Trench	1963-1965	No	No	No
216-B-58 Trench	1965-1967	No	No	No
216-B-63 Trench	1970-Present	Yes	No	Yes
2607-EB Septic Tank/Tile Field	1951-Present	No	No logs	No
2607-EH Septic Tank/Drain Field	1983-Present	No	No logs	No
2607-EK Septic Tank/Drain Field	1980-Present	Yes	No logs	Yes
2607-EM Septic Tank/Drain Field	1984-Present	Yes	No logs	Yes
2607-EN Septic Tank/Drain Field	1980-Present	Yes	No logs	Yes
2607-EN Septic Tank/Drain Field	1980-Present	Yes	No logs	Yes
2607-EO Septic Tank/Drain Field	1985-Present	Yes	No logs	Yes
2607-EP Septic Tank/Drain Field	1984-Present	No	No logs	No

Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
2607-EQ Septic Tank	1985-Present	Yes	No logs	Yes
2607-ER Septic Tank	Unknown-Present	--	No logs	No
2607-GF Septic Tank	Unknown	--	No logs	No
2607-E1 Septic Tank/Drain Field	1070-Present	Yes	No logs	Yes
2607-E2 Septic Tank/Drain Field	1980-Present	No	No logs	No
2607-E3 Septic Tank/Tile Field	1944-Present	Yes	No logs	Yes
2607-E4 Septic Tank/Tile Field	1944-Present	--	No logs	No
2607-E7B Septic Tank	Unknown	--	No logs	No
2607-E8 Septic Tank/Drain Field	1978-Present	Yes	No logs	Yes
2607-E9 Septic Tank/Drain Field	1951-Present	--	No logs	No
2607-E11 Septic Tank/Drain Field	1985-Present	Yes	No logs	Yes
216-B-59/59B Trench/Retention Basin	1967-Present	No	No logs	No
Semi-Works Aggregate Area				
216-C-1 Crib	1953-1957	Yes	No	Yes
216-C-3 Crib	1953-1954	Yes	No logs	Yes
216-C-4 Crib	1955-1965	Yes	No logs	Yes
216-C-5 Crib	1955	No	No	No
216-C-6 Crib	1955-1964	Yes	No logs	Yes

Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
216-C-7 Crib	1961-Present	No	No logs	No
216-C-10 Crib	1964-1969	Yes	No	Yes
216-C-2 Reverse Well	1953-1988	No	No logs	No
216-C-9 Pond	1953-1985	Yes	No	Yes
200 East Powerhouse Ditch	1943-Present	Yes	No logs	Yes
2607-E-5 Septic Tank/Drain Field	1949-Present	No	No logs	No
2607-E-7A Septic Tank/Drain Field	1983-Present	No	No logs	No

Table 2-4. Summary of Screening for Potential to Contribute Contaminants to the Unconfined Aquifer.

Liquid Discharge Source	Years In Service	Potential Based on Pore Volume Screening (Table 2-2)	Potential Based on Geophysical Logs (Table 2-3)	Potential to Contribute Contaminants to Groundwater
200 North Aggregate Area				
216-N-1 Pond	1944-1952	Yes	No logs	Yes
216-N-4 Pond	1944-1952	Yes	No logs	Yes
216-N-6 Pond	1944-1952	Yes	No logs	Yes
216-N-2 Trench	1947	Yes	No logs	Yes
216-N-3 Trench	1952	Yes	No logs	Yes
216-N-5 Trench	1952	Yes	No logs	Yes
216-N-7 Trench	1952	Yes	No logs	Yes
2607-N Septic Tank/Drain	1944-1952	No	No logs	No
2607-P Septic Tank/Drain	1944-1952	No	No logs	No
2607-R Septic Tank/Drain	1944-1952	No	No logs	No

a/ Pore volume calculation: (waste unit section area) x (depth to groundwater) x (porosity). Low pore volume value reflects .1 porosity; higher pore volume value reflects .3 porosity. Pore volume calculation does not account for the ability of the soil to retain the liquid discharged.

b/ Yes when liquid effluent volume received by soil exceeds the lower range of soil column pore volume.

c/ Yes when discharge exceeded 100,000m^3.

d/ Based on reported daily rates from first year through 1991.

e/ 216-N-8 pond formed as a result of the rising water table. Prior to the forming of the pond the area received sewage sludge from the Hanford construction camp.

Table 2-7. Summary of Waste-Producing Processes in the 200 East Groundwater Aggregate Area. Page 1 of 5

Process	Waste Generated	Major Chemical Constituents	Ionic Strength	pH	Organic Concentration	Radioactivity
PUREX Plant Aggregate Area						
Plutonium Uranium Extraction (PUREX 202-A Building)	Process waste	Nitric acid Tributyl phosphate Bismuth phosphate Paraffin hydrocarbon	High	Acidic (neutralized before disposal)	Low	High
	Wastewater	Nitrates	Low	Acidic to neutral/ basic	Low	Low
Waste Reduction (242 Evaporator)	Cooling water	Beta activity Cadmium Copper Potassium Sodium Nitrate	Unknown	Basic	Low	Low
Tank Farm Condensate (241-A-431 Building)	Wastewater	Unknown	Low	Neutral/basic	Low	Low
B Plant Aggregate Area						
Bismuth Phosphate	Process waste	Nitric acid				
	Aqueous process waste	Phosphoric acid Nitrate solution Uranium Plutonium	High	Acidic (neutralized)	Low	High
Lanthanum Fluoride	Process waste	Plutonium Sodium bismuthate Phosphoric acid	NA	NA	NA	High

Table 2-7. Summary of Waste-Producing Processes in the 200 East Groundwater Aggregate Area. Page 2 of 5

Process	Waste Generated	Major Chemical Constituents	Ionic Strength	pH	Organic Concentration	Radioactivity
	Aqueous process waste	Nitric acid Hydrogen fluoride Lanthanum salts				
Cesium and Strontium Recovery	Process waste	Hydrochloric acid Nitric acid Phosphoric acid	High	Acidic (neutralized)	Low	High
	Aqueous process waste	Normal paraffin hydrocarbon Ammonium carbonate Ammonium hydroxide				
PUREX Wastes	Cladding waste	Sodium hydroxide Nitric acid	High	Acidic (neutralized)	Low	High
	Process waste	Tributyl phosphate Paraffin hydrocarbon Nitrates	Low			Low
S Plant Wastes	Process waste	Nitric acid Sodium aluminate	High	Neutral/basic	Low	High
	Ion exchange waste	Hexone Uranium Plutonium				

Table 2-7. Summary of Waste-Producing Processes in the 200 East Groundwater Aggregate Area. Page 3 of 5

Process	Waste Generated	Major Chemical Constituents	Ionic Strength	pH	Organic Concentration	Radioactivity
Semi-Works Aggregate Area						
REDOX and PUREX Pilot Plants (201-C Process Building)	Aluminum coating waste	Sodium hydroxide Sodium aluminate Sodium nitrate Sodium nitrite Sodium silicate Uranium Plutonium	High	Neutralized acidic waste	Low	Low-High
	Zircaloy coating	Aluminum nitrate Zirconium oxide Sodium fluoride Sodium nitrate Potassium fluoride Uranium Plutonium	High	Neutralized acidic waste	Low	Low-High
	REDOX spent solvent	MIBK	Low	Neutral/basic	High	Intermediate
	Other REDOX wastes	Sodium aluminate Sodium hydroxide Sodium nitrate Chromate Sodium sulfate Ferric hydroxide Plutonium Uranium	Low		Low	Low-High

Table 2-7. Summary of Waste-Producing Processes in the 200 East Groundwater Aggregate Area. Page 4 of 5

Process	Waste Generated	Major Chemical Constituents	Ionic Strength	pH	Organic Concentration	Radioactivity
REDOX and PUREX Pilot Plants (cont.)	Radioactive condensates	Cesium-137 Ruthenium-106 Strontium-90 Plutonium-239 Uranium Tritium Cobalt-60 Uranium-238 Nitric acid Other inorganic contaminants	High	Acidic (neutralized)	Low	Low-High
	PUREX organic wash waste	Sodium nitrate Sodium carbonate Manganese oxide Uranium	High	Neutralized acidic waste	High	High
	PUREX acid process waste	Nitric acid Ferrous sulfate Ferrous phosphate Sodium Aluminum	High	Acidic (neutralized)	Low	High
	PUREX spent solvent waste	Tributyl phosphate Kerosene	Low	Neutral	High	Intermediate
	Hot Shop sink wastes					
	Cold-run wastes		High	Neutral/basic	Low	
Strontium Recovery Pilot Plant (201-C Process Building)	Process waste	Hydrochloric acid Nitric acid Di-2-ethylhexyl-phosphoric acid		Acidic (neutralized)	High	High

Table 2-7. Summary of Waste-Producing Processes in the 200 East Groundwater Aggregate Area. Page 5 of 5

Process	Waste Generated	Major Chemical Constituents	Ionic Strength	pH	Organic Concentration	Radioactivity
Critical Mass Laboratory (209-E Building)	Neutron reflector tank water	Cesium-137 Ruthenium-106 Strontium-90 Plutonium Uranium Nitrates		Acidic		Intermediate
276-Solvent Handling Facility			Low	Neutral/basic	High	Intermediate
291-C Ventilation Stack	Condensate and seal water drainage		Low	Neutral/basic	Low	Low
215-Gas Preparation Building, and 271-Aqueous Makeup and Control Building				Acidic		
200 North Aggregate Area						
Irradiated Fuel Storage	Basin water overflow	None	Low	Neutral	None	Low
Basin Cleanout	Sediment/sludge	None	Low	Neutral	None	Low
Contaminated Equip. Storage	Boxed solid waste	None	NA	NA	NA	Low
Electrical Maintenance	PCB contaminated oil	PCBs	NA	NA	High	Low
Railroad Maintenance	Radioactive solid waste	None	NA	NA	NA	Low

NA = No information available

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Table 2-8. Chemical Parameters for OGWMN Well Samples.

PUREX Plant Cribs Sample Parameters	
Gross Beta	Anions
Gross Alpha	TOC
Tritium	VOA
TOX	1-129
lab pH	Uranium (total)
Conductivity	Sr-90
Filtered metals	Gamma scan
B Plant Cribs Sampling Parameters	
Gross Beta	Anions
Gross Alpha	TOC
Tritium	Sr-90
TOX	Pu-239
lab pH	Uranium (total)
Filtered metals	Gamma scan

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Table 2-9. OGWMN Wells Within the 200 East Area.

Facility	Crib Number	Well Number	Year of Installation	Depth of Screened Interval (feet)[c]	Formation Screened Within[a]	Depth to Water (feet)[b]
PUREX	216-A-37-1	299-E25-18	76	269-294	Unit E	276
Cribs		299-E25-20	76	268-293	Unit E	273
	216-A-27-2	299-E25-22	83	265-295	Unit E	271
		299-E25-24	83	270-290	Unit E	276
	216-A-30	299-E25-11	60	265-335	Unit E	278
		299-E16-2	60	265-336	Unit A	275
	216-A-45	299-E17-12	86	313-334	Unit E	319
		299-E17-13	86	317-337	Unit E	316
	216-A-8	299-E25-6	56	234-288	Unit E	257
		299-E25-9	56	233-288	Unit E	253
B Plant	210-B-62	299-E28-18	69	260-325	Unit E	289
Cribs		299-E28-21	62	257-325	Unit E	285
	216-B-5	299-E28-23	79	278-328	Unit E	N/A
	216-B-55	299-E24-13	69	270-338	Hlg	288

Well Network for calendar year 1992.
[a] Information obtained in Lindsey et al. (1992).
[b] Water level data obtained from Kasza et al. (1991).
[c] Information obtained in McGhan (1989), Ledgerwood (1992), and DOE/RL (1992b).
Unit E: Ringold Formation Unit E
Unit A: Ringold Formation Unit A
Hlg: Hanford formation lower gravel unit

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Table 2-10. RCRA Groundwater Monitoring Network Within the 200 East Area.

Facility	Type of Facility	Monitoring Well	Year of Installation	Depth of Screened Interval[c/]	Formation Screened Within[b/]	Current Depth to Water[a/]
LLWMA 1	Burial Ground	299-E28-26	87	278-325	Hlg	284
		299-E28-27	87	270-290	Hlg	277
		299-E28-28	90	275-295	Hlg	284
		299-E32-2	87	258-278	Unit E	267
		299-E32-3	87	266-286	Hlg	274
		299-E32-4	87	278-298	Hlg	283
		299-E32-5	89	270-290	Hlg	279
		299-E32-6	91	255-276	Hlg	261
		299-E32-7	91	247-267	Hlg	252
		299-E32-8	91	235-255	Hlg	238
		299-E32-9	91	231-251	Hlg	236
		299-E33-28	87	256-276	Hlg	261
		299-E33-29	87	263-283	Hlg	271
		299-E33-30	87	255-275	Unit E	261
		299-E33-34	90	219-239	Unit E	230
		299-E33-35	90	228-249	Hlg	240
LLWMA 2	Burial Ground	299-E27-8	87	226-246	Hlg	235
		299-E27-9	87	219-239	Hlg	226
		299-E27-10	87	DNF	Hlg	221
		299-E27-11	89	251-231	Hlg	240
		299-E27-17	91	223-244	Hlg	213
		299-E34-2	87	220-240	Hs/Hlg	227
		299-E34-3	87	193-213	Hlg	208
		299-E34-4	87	DNF	Hlg	DNF
		299-E34-5	87	171-191	Hlg	187
		299-E34-6	87	175-195	Hlg	195
		299-E34-7	89	194-205	Hlg	201
		299-E34-9	91	213-234	Hlg	222
		299-E34-10	91	225-246	Hlg	233
		299-E35-1	89	231-251	Hlg	194
WMA A-AX	Single Shell Tank	299-E24-19	89	280-300	Unit E	290
		299-E24-20	90	279-300	Unit E	286
		299-E25-40	89	252-273	Unit E	262

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Table 2-10. RCRA Groundwater Monitoring Network Within the 200 East Area.

Facility	Type of Facility	Monitoring Well	Year of Installation	Depth of Screened Interval[c/]	Formation Screened Within[b/]	Current Depth to Water[a/]
		299-E25-41	89	255-276	Unit E	267
WMA B-BY-BX	Single	299-E33-31	89	235-256	Hlg	244
	Shell	299-E33-32	89	246-267	Hlg	257
	Tanks	299-E33-33	89	227-248	Hlg	237
		299-E33-36	90	234-255	Hlg	245
		299-E33-41	90	270-245	Hlg	252
		299-E33-38	90	219-240	Hlg	229
		299-E33-39	90	208-229	Hlg	220
		299-E33-42	91	239-259	Hlg	251
		299-E33-43	91	250-271	Hlg	260
WMA C	Single	299-E27-12	89	247-267	Unit E	258
	Shell	299-E27-13	89	245-275	Unit E	266
	Tank	299-E27-14	89	246-267	Unit E	255
		299-E27-15	89	238-259	Unit E	250
		299-E27-7	82	241-281	Unit E	231
Liquid Effluent		299-E35-2	90	DNF	Hlg	198
Retention Facility		299-E26-9	90	DNF	Hlg	199
		299-E26-10	90	DNF	Hlg	198
		299-E26-11	90	DNF	Hlg	194
2101-M	Waste	299-E18-1	88	308-379	Unit E	317
	Pond	299-E18-2	88	308-329	Unit E	319
		299-E18-3	88	309-330	Hlg/Unit E	319
		299-E18-4	88	308-328	Unit E	319
216-B-63	Trench	299-E27-11	89	231-251	Hlg	240
		299-E27-16	90	239-260	Unit E	249
		299-E27-8	87	226-246	Unit E	235
		299-E27-9	87	219-239	Unit E	226
		299-E33-33	90	227-248	Unit E	237
		299-E33-36	90	234-255	Unit E	245
		299-E33-37	90	240-261	Unit E	250
		299-E34-8	90	228-248	Unit E	238
		299-E34-10	91	225-246	Unit E	233
		299-E27-17	91	223-244	Unit E	213

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Table 2-10. RCRA Groundwater Monitoring Network Within the 200 East Area.

Facility	Type of Facility	Monitoring Well	Year of Installation	Depth of Screened Interval[c/]	Formation Screened Within[b/]	Current Depth to Water[a/]
216-A-10	Crib	299-E24-18	88	308-329	Unit E	316
		299-E25-36	88	296-317	Unit E	304
		299-E17-19	88	304-324	Unit E	317
		299-E17-20	88	303-324	Unit E	316
		299-E24-16	88	304-324	Unit E	318
		299-E24-17	88	308-328	Unit E	317
		299-E17-1	55	303-333	Unit E	316
		299-E24-2	56	295-348	Unit E	315
216-A-36B	Crib	299-E17-16	88	309-329	Unit E	318
		299-E17-17	88	310-330	Unit E	317
		299-E17-18	88	309-329	Unit E	318
		299-E17-15	88	307-327	Unit E	319
		299-E17-14	88	310-330	Unit E	319
		299-E17-9	68	310-320	Unit E	315
		299-E17-5	65	298-335	Unit E	316
216-A-29	Ditch	299-E25-32P	88	259-279	Hlg	266
		299-E25-26	85	270-290	Hlg	265
		299-E25-28	86	320-340	Unit A	252
		299-E25-34	88	282-272	Hlg	259
		299-E25-35	88	260-281	Hlg	271
		299-E17-15	88	307-327	Hlg	319
		299-E17-20	88	303-324	Hlg	316
		299-E25-11	60	265-335	Undifferentiated	278
		299-E25-18	76	269-294	Undifferentiated	276
		299-E25-19	76	270-295	Undifferentiated	274
		299-E25-20	76	268-293	Undifferentiated	273
		299-E25-21	83	270-293	Hlg	273
		299-E25-31	87	259-279	Hlg	269
		299-E25-36	88	296-317	Hlg	304
		699-43-43	88	157-177	Hlg	164
		699-43-45	89	183-203	Hlg	193
		299-E25-42	91	268-289	Hlg	280
		299-E25-43	91	238-259	Hlg	246

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Table 2-10. RCRA Groundwater Monitoring Network Within the 200 East Area.

Facility	Type of Facility	Monitoring Well	Year of Installation	Depth of Screened Interval[c]	Formation Screened Within[b]	Current Depth to Water[a]
		299-E26-12	91	218-239	Hlg	227
		299-E26-13	91	DNF	Unit E	201
216-B-3	Pond	299-E18-1	88	308-329	Hlg	317
		299-E32-4	87	278-298	Hlg	283
		699-40-39	89	201-212	Unit A	128
		699-40-40A	91	215-226	Unit A	134
		699-40-40B	91	188-200	Unit A	128
		699-41-40	89	164-174	Unit A	130
		699-42-39A	91	169-180	Unit A	139
		699-42-39B	91	203-214	Unit A	141
		699-42-40A	81	139-171	Unit A	123
		699-42-41	91	134-155	Unit E	142
		699-42-42B	88	193-203	Unit A	166
		699-43-40	91	113-134	Unit A	123
		699-43-41E	89	136-146	Unit A	129
		699-43-41F	89	165-175	Unit A	129
		699-43-41G	91	188-199	Unit A	133
		699-43-42J	88	157-177	Unit A	162
		699-43-43	88	157-177	Unit A	165
		699-43-45	89	183-203	Unit A	193
		699-44-42	88	151-172	Unit A	158
		699-44-43B	89	156-176	Unit A	165
Grout Treatment		299-E25-25	85	269-289	Hlg	265
Facility		299-E25-31	87	259-279	Hlg	269
		299-E25-32P	88	259-279	Hlg	266
		299-E25-33	88	262-282	Hlg	247
		299-E25-37	89	260-280	Hlg	270
		299-E25-38	89	260-280	Hlg	270
		299-E25-39	90	DNF	Hlg	267
		299-E25-29P	87	256-330	Hlg	271
Nonradioactive		699-26-34	86	117-137	Hlg	125
Dangerous Waste		699-26-35A	86	120-140	Hlg	130
Landfill		699-26-35C	87	DNF	Hlg	129

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Table 2-10. RCRA Groundwater Monitoring Network Within the 200 East Area.

Facility	Type of Facility	Monitoring Well	Year of Installation	Depth of Screened Interval[c]	Formation Screened Within[b]	Current Depth to Water[a]
		699-26-33	86	123-143	Unit E	133
		688-25-34A	86	118-138	Hlg	127
		699-25-34B	86	118-138	Hlg	126
		699-25-33A	87	191-200	Hlg	126
Solid Waste		699-24-35	87	130-145	Hlg	133
Landfill		699-25-34C	87	124-139	Hlg	133
		699-24-34C	87	121-136	Hlg	130
		699-24-34B	87	122-137	Hlg	131
		699-24-34A	87	122-137	Hlg	130
		699-23-34	87	121-136	Hlg	130
		699-25-35A	86	DNF	DNF	DNF
		699-24-33	48	116-164	Hlg	122

Shading indicates upgradient wells.
DNF - Data not found.
[a] Water level data obtained for December 1991, from Kasza et al. (1991).
[b] Information obtained in DOE/RL 1992c.
[c] Information obtained in McGhan (1989), Ledgerwood (1992), and DOE/RL (1992b).
Hlg - Hanford formation lower gravel
Unit E - Ringold Formation unit E gravel
Unit A - Ringold Formation unit A gravel

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Table 2-11. Constituents Analyzed for at the Single-Shell Tanks.

Contamination Indicator Parameters	
pH	Total organic carbon (TOC)
Specific conductance	Total organic halogen (TOX)
Groundwater Quality Parameters	
Chloride	Phenols
Iron	Sodium
Manganese	Sulfate
Drinking Water Parameters	
Arsenic	Lindane
Barium	Methoxychlor
Cadmium	Mercury
Chromium	Nitrate
Coliform bacteria	Radium
Endrin	Silver
Fluoride	Selenium
Gross alpha	Toxaphene
Gross beta	2,4-D
Lead	2,4,5-Silvex
Site-Specific Parameters	
1,1,2,2-Tetrachloroethane	Cyanide
1,2-Dichloroethane	Ethylbenzene
1,2-Dichloropropane	Gamma Scan Plutonium
Acetone	Naphthalene
Benzene	Stratitium-90
Beryllium	Toluene
Bromoform	Tetrachloroethylene
Carbon tetrachloride	trans-1,1-Dichloroethylene
Cesium-137	Trichloroethylene
Chlorobenzene	Uranium
cis-1,1-Dichloroethylene	Vinyl Chloride
Copper	Xylenes

Source: DOE/RL 1991c

9 2 1 2 7 5 1 2 6 7

Table 2-12. Constituents Analyzed for at the Single-Shell Tanks.

Contamination Indicator Parameters	
pH	Total organic carbon (TOC)
Specific conductance	Total organic halogen (TOX)
Groundwater Quality Parameters	
Chloride	Phenols
Iron	Sodium
Manganese	Sulfate
Drinking Water Parameters	
Arsenic	Lindane
Barium	Methoxychlor
Cadmium	Mercury
Chromium	Nitrate
Coliform bacteria	Radium
Endrin	Silver
Fluoride	Selenium
Gross alpha	Toxaphene
Gross beta	2,4-D
Lead	2,4,5-Silvex
Site-Specific Parameters	
1,1,2,2-Tetrachloroethane	Cyanide
1,2-Dichloroethane	Ethylbenzene
1,2-Dichloropropane	Gamma Scan
Acetone	Naphthalene
Ammonium	Plutonium
Benzene	Strontium-90
Beryllium	Toluene
Bromoform	Tetrachloroethylene
Carbon tetrachloride	trans-1,1-Dichloroethylene
Cesium-137	Trichloroethylene
Chlorobenzene	Tritium
cis-1,1-Dichloroethylene	Uranium
Cobalt-60	Vinyl Chloride
Copper	Xylenes

Source: DOE/RL 1991c

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Table 2-13. Constituents Analyzed for at the 216-B-3 Pond.

Contamination Indicator Parameters	
pH	Total organic carbon (TOC)
Specific conductance	Total organic halogen (TOX)
Groundwater Quality Parameters	
Chloride	Phenols
Iron	Sodium
Manganese	Sulfate
Drinking Water Parameters	
Arsenic	Lindane
Barium	Methoxychlor
Cadmium	Mercury
Chromium	Nitrate
Coliform bacteria	Radium
Endrin	Silver
Fluoride	Selenium
Gross alpha	Toxaphene
Gross beta	2,4-D
Lead	2,4,5-TP Silvex
Site Specific Parameters	
Hydrazine	Tritium
Ammonium	Total organics
Assessment Monitoring Parameters	
Herbicides	Enhanced volatiles
Pesticides	Acid/Base/Neutrals
PCBs	

Source: DOE/RL 1992b

9 2 1 2 7 5 1 2 6 9

Table 2-14. Constituents Analyzed for at the Grout Treatment Facility.

Contamination Indicator Parameters	
pH	Total organic carbon (TOC)
Specific conductance	Total organic halogen (TOX)
Groundwater Quality Parameters	
Chloride	Phenols
Iron	Sodium
Manganese	Sulfate
Drinking Water Parameters	
Arsenic	Lindane
Barium	Methoxychlor
Cadmium	Mercury
Chromium	Nitrate
Coliform bacteria	Radium
Endrin	Silver
Fluoride	Selenium
Gross alpha	Toxaphene
Gross beta	2,4-D
Lead	2,4,5-TP Silvex
Site Specific Parameters	
Arsenic	Selenium
Chromium	Technetium-99
Long List	
Equivalent to 40 CFR 264, Appendix IX, "Groundwater Quality Monitoring List" (EPA 1989c)	

Source: DOE/RL 1992b

9 2 1 2 7 5 5 1 2 7 0

Table 2-15. Constituents Analyzed for at the 216-A-29 Ditch.

Contamination Indicator Parameters	
pH	Total organic carbon (TOC)
Specific Conductance	Total organic halogen (TOX)
Groundwater Quality Parameters	
Chloride	Phenols
Iron	Sodium
Manganese	Sulfate
Drinking Water Parameters	
Arsenic	Lindane
Barium	Methoxychlor
Cadmium	Mercury
Chromium	Nitrate
Coliform bacteria	Radium
Endrin	Silver
Fluoride	Selenium
Gross alpha	Toxaphene
Gross beta	2,4-D
Lead	2,4,5-TP Silvex
Site Specific Parameters	
Hydrazine	Ammonium
tritium	
Assessment Monitoring Parameters for the 216-A-29 Ditch	
Herbicides	Enhanced volatiles
Pesticides	Acid/Base/Neutrals
PCBs	Anions
	ICP metals

Source: DOE/RL 1992b

9 2 1 2 7 5 1 2 7 1

Table 2-16. Constituents Analyzed for at the 216-A-36B Crib.

Contamination Indicator Parameters	
pH	Total organic carbon (TOC)
Specific conductance	Total organic halogen (TOX)
Groundwater Quality Parameters	
Chloride	Phenols
Iron	Sodium
Manganese	Sulfate
Drinking Water Parameters	
Arsenic	Lindane
Barium	Methoxychlor
Cadmium	Mercury
Chromium	Nitrate
Coliform bacteria	Radium
Endrin	Silver
Fluoride	Selenium
Gross alpha	Toxaphene
Gross beta	2,4-D
Lead	2,4,5-TP Silvex
Site Specific Parameters	
Uranium	Ammonium
Tritium	Gamma

Source: DOE/RL 1992b

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Table 2-17. Constituents Analyzed for at the 216-A-10 Crib.

<u>Contamination Indicator Parameters</u>	
pH	Total organic carbon (TOC)
Specific conductance	Total organic halogen (TOX)
<u>Groundwater Quality Parameters</u>	
Chloride	Phenols
Iron	Sodium
Manganese	Sulfate
<u>Drinking Water Parameters</u>	
Arsenic	Lindane
Barium	Methoxychlor
Cadmium	Mercury
Chromium	Nitrate
Coliform bacteria	Radium
Endrin	Silver
Fluoride	Selenium
Gross alpha	Toxaphene
Gross beta	2,4-D
Lead	2,4,5-TP Silvex
<u>Site Specific Parameters</u>	
Uranium	Gamma
Tritium	

Source: DOE/RL 1992b

9 2 1 2 7 5 1 2 7 3

Table 2-18. Constituents Analyzed for at the 216-B-63 Trench.

Contamination Indicator Parameters	
pH	Total organic carbon (TOC)
Specific conductance	Total organic halogen (TOX)
Groundwater Quality Parameters	
Chloride	Phenols
Iron	Sodium
Manganese	Sulfate
Drinking Water Parameters	
Arsenic	Lindane
Barium	Methoxychlor
Cadmium	Mercury
Chromium	Nitrate
Coliform bacteria	Radium
Endrin	Silver
Fluoride	Selenium
Gross alpha	Toxaphene
Gross beta	2,4-D
Lead	2,4,5-TP Silvex
Site Specific Parameters	
Uranium	Gamma
Tritium	Volatile organics analysis

Source: DOE/RL 1992b

9 2 1 2 7 5 5 1 2 7 4

Table 2-19. Constituents Analyzed for at the Liquid Effluent Retention Facility.

Contamination Indicator Parameters	
pH	Total organic carbon (TOC)
Specific conductance	Total organic halogen (TOX)
Groundwater Quality Parameters	
Chloride	Phenols
Iron	Sodium
Manganese	Sulfate
Drinking Water Parameters	
Arsenic	Lindane
Barium	Methoxychlor
Cadmium	Mercury
Chromium	Nitrate
Coliform bacteria	Radium
Endrin	Silver
Fluoride	Selenium
Gross alpha	Toxaphene
Gross beta	2,4-D
Lead	2,4,5-TP Silvex
Site Specific Parameters for the Low-Level Burial Grounds	
Ammonia	1-Butanol
Tritium	

Source: DOE/RL 1992b

9 2 1 2 7 5 1 2 7 5

Table 2-20. Constituents Analyzed for at the 2101-M Pond.

Contamination Indicator Parameters	
pH	Total organic carbon (TOC)
Specific conductance	Total organic halogen (TOX)
Groundwater Quality Parameters	
Chloride	Phenols
Iron	Sodium
Manganese	Sulfate
Site Specific Parameters for the Low-Level Burial Grounds	
Volatile organics	Tritium*
Turbidity	Gamma scan*
Radium	Technetium-99*
Alpha	ICP metals
Beta	Barium
Uranium*	Copper

** These constituents will be analyzed to help establish background contamination and groundwater flow.*

Source: DOE/RL 1992b

9 2 1 2 7 5 5 1 2 7 6

Table 2-21. Constituents Analyzed for at the Nonradioactive Dangerous Waste Landfill.

Contamination Indicator Parameters	
pH	Total organic carbon (TOC)
Specific conductance	Total organic halogen (TOX)
Groundwater Quality Parameters	
Chloride	Phenols
Iron	Sodium
Manganese	Sulfate
Drinking Water Parameters	
Arsenic	Lindane
Barium	Methoxychlor
Cadmium	Mercury
Chromium	Nitrate
Coliform bacteria	Radium
Endrin	Silver
Fluoride	Selenium
Gross alpha	Toxaphene
Gross beta	2,4-D
Lead	2,4,5-TP Silvex
Site Specific Parameters	
Tritium	Volatile chlorinated hydrocarbons

Source: DOE/RL 1992b

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Table 2-22. Constituents Analyzed for at the Solid Waste Landfill.

Parameters and Constituents Required by WAC 173-304-490	
pH	Sulfate
Temperature	Dissolved iron
Conductivity	Dissolved zinc
Chloride	Chemical oxygen demand
Nitrate	Total organic carbon (TOC)
Ammonia as nitrogen	Total coliform
Site Specific Parameters	
Total organic halogen	
1,1,1-Trichloroethane	
Trichloroethylene	
Others	
Tritium	

Source: DOE/RL 1992b

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Table 2-23. Constituents Analyzed for Under the CERCLA Groundwater Monitoring Program.

Groundwater Quality Parameters	
pH	Total organic carbon (TOC)
Specific conductance	Total organic halogen (TOX)
Anions	Total dissolved solids
Drinking Water Parameters	
Hydrazine	Cyanide
Pesticides	Semivolatile organic compounds
Volatile organic compounds	Lindane
Coliform bacteria	Mercury
Gross alpha	Selenium
Gross beta	Lead
Other Parameters	Gamma Scan
Technetium-99	Cesium-137
Tritium	Uranium
U-Chem	Ruthenium-106
	Plutonium
	Strontium
	Cobalt-60

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Table 2-24. CERCLA Groundwater Monitoring Network. Page 1 of 2

Well Number	Year of Installation	Depth of Screened Interval (feet)[c/]	Formation Screened Within[b/]	Current Depth to Water (feet)[a/]
299-E28-26	87	278-325	Hlg	284
299-E28-27	87	270-290	Hlg	277
299-E28-28	90	275-295	Hlg	284
299-E32-02	57	258-278	Unit E	268
299-E32-05	87	270-290	Hlg	274
299-E33-01	54	215-235	Hlg	224
299-E33-03	54	219-231	Hlg	224
299-E33-04	54	215-231	Hlg	227
299-E33-05	55	218-235	Hlg	227
299-E33-07	55	215-230	Hlg	224
299-E33-12	53	305-385	Hlg	220
299-E33-13	53	210-235	Hlg	224
299-E33-14	53	212-227	Hlg	219
299-E33-15	53	222-237	Hlg	223
299-E33-18	50	240-260	Hlg	241
299-E33-24	67	219-241	Hlg	235
299-E33-26	69	DNF	Hlg	228
299-E33-28	87	256-276	Hlg	262
299-E33-29	87	263-283	Hlg	271
299-E33-30	87	255-275	Unit E	261
299-E33-31	89	235-256	Hlg	245
299-E33-32	89	246-267	Hlg	256
299-E33-33	89	227-248	Hlg	237
299-E33-34	91	219-239	Unit E	231
299-E33-35	DNF	228-249	Hlg	240
299-E33-38	90	DNF	Hlg	229
299-E33-40	91	DNF	Unit E	DNF
699-47-50	80	260-295	Basalt	179
699-47-60	48	235-277	Hlg/Unit E	249

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Table 2-24. CERCLA Groundwater Monitoring Network. Page 2 of 2

Well Number	Year of Installation	Depth of Screened Interval (feet)[c]	Formation Screened Within[b]	Current Depth to Water (feet)[a]
699-48-50	DNF	DNF	DNF	170
699-49-55A	61	125-135	Hlg	128
699-49-55B	55	175-226	Basalt	127
699-49-57A	56	144-161	Hlg	150
699-49-57B	56	220-230	Basalt	153
699-50-53A	55	142-159	Hlg	154
699-50-53B	90	215-225	Hs	155
699-52-54	90	157-167	Hlg	162
699-52-57	90	139-159	Hlg	155
699-53-55A	61	165-280	Hlg	175
699-53-55B	75	232-252	Hs	175
699-53-55C	75	187-220	Hs	174
699-54-57	55	245-321	Basalt	173
699-55-55	90	148-169	Hug	157
699-57-59	92	166-186	Hun	171
699-55-57	75	139-169	Hun	166

DNF - Data not found.
[a] Water level data obtained from Kasza et al. (1991).
[b] Information obtained in Lindsey et al. (1992).
[c] Information obtained in McGhan (1989), Ledgerwood (1992), and DOE/RL (1992b).
Hlg - Hanford formation lower gravel
Unit E - Ringold Formation unit E
Hs - Hanford formation sand
Hug - Hanford formation upper gravel
Hun - Hanford formation undifferentiated

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Table 2-25. PNL Groundwater Monitoring Well Network.

Well Number	Year of Installation	Depth of Screened Interval (ft)[c/]	Formation Screened Within[b/]	Current Depth to Water (ft)[a/]
299-E25-24	83	270-290	Unit E	276
299-E25-25	85	269-289	Lm	266
299-E25-26	86	270-290	Unit E	285
299-E25-27	85	274-294	Unit E	272
299-E25-28	86	320-340	Unit A	266
299-E25-29P	87	256-330	Unit E (bottom)	271
299-E25-3	54	270-312	Unit A	274
299-E25-30P	87	264-284	Unit E	274
299-E25-31	87	259-279	Unit E	269
299-E25-32P	88	260-280	Unit A	266
299-E25-33	88	262-282	Unit A	247
299-E25-34	88	252-272	Unit E	260
299-E25-35	88	260-281	Unit E	268
299-E25-36	88	296-317	Unit E	271
299-E25-37	89	260-280	Unit E	270
299-E25-38	89	260-280	Unit E	270
299-E25-6	85	234-288	Unit E	258
299-E25-9	56	233-288	Unit E	254
299-E26-1	48	217-227	Unit E	213
299-E26-2	58	220-265	Unit E	232
299-E26-4	58	225-281	Unit E	244
299-E26-6	60	250-290	Unit E	241
299-E26-8	82	226-296	Unit E	198
299-E27-10	87	212-240	Hlg	221
299-E27-5	62	262-333	Unit E	285
299-E27-7	82	241-281	Unit E	232
299-E27-8	87	226-246	Hlg	235
299-E27-9	87	220-239	Hlg	226

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Table 2-25. PNL Groundwater Monitoring Well Network. Page 2 of 5

Well Number	Year of Installation	Depth of Screened Interval (ft)[c/]	Formation Screened Within[b/]	Current Depth to Water (ft)[a/]
299-E28-12	DNF	DNF	DNF	305
299-E28-13	66	DNF	DNF	301
299-E28-16	68	270-323	Unit E	300
299-E28-17	69	289-335	Unit E	304
299-E28-18	69	260-325	Unit E	290
299-E28-21	69	257-325	Unit E	285
299-E28-23	69	260-325	Unit E	DNF
299-E28-24	80	277-327	Unit E	280
299-E28-25	80	279-328	Unit E	280
299-E28-26	87	279-299	Hlg	285
299-E28-27	87	270-290	Hlg	278
299-E28-7	48	270-335	Unit E	383
299-E28-9	57	290-340	Unit E	397
299-E32-1	57	241-271	Unit E	253
299-E32-2	87	258-278	Unit E	268
299-E32-3	87	266-286	Unit E	274
299-E13-14	56	320-353	Hlg	342
299-E13-19	57	310-360	Hlg/Unit E	324
299-E13-5	55	330-365	Hlg/Unit E	341
299-E16-2	60	265-336	Unit A/Hlg	275
299-E17-1	55	303-333	Unit E	317
299-E17-12	86	317-338	Unit E	319
299-E17-13	86	317-337	Unit E	317
299-E17-14	88	310-330	Unit E	320
299-E17-15	88	307-327	Unit E	320
299-E17-16	88	309-329	Unit E	318
299-E17-17	88	310-330	Unit E	317
299-E17-18	88	309-329	Unit E	318

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Table 2-25. PNL Groundwater Monitoring Well Network.

Well Number	Year of Installation	Depth of Screened Interval (ft)[c/]	Formation Screened Within[b/]	Current Depth to Water (ft)[a/]
299-E17-19	88	304-324	Unit E	317
299-E17-2	60	302-398	Unit A/Unit E	315
299-E17-20	88	303-324	Unit E	316
299-E17-5	65	298-335	Unit E	316
299-E17-6	65	300-460	Hlg	317
299-E17-8	66	303-362	Unit E	316
299-E17-9	68	310-320	Unit E	315
299-E18-1	88	308-329	Hlg	317
299-E18-2	88	308-329	Hlg	319
299-E18-3	88	309-330	Hlg/Unit E	319
299-E18-4	88	308-328	Hlg	319
299-E24-1	55	300-341	Unit E	313
299-E24-11	67	308-362	Unit A	315
299-E24-12	68	310-320	Unit E	300
299-E24-13	69	270-338	Unit E	288
299-E24-16	88	304-324	Unit E	318
299-E24-17	88	308-328	Unit E	317
299-E24-18	88	308-329	Unit E	317
299-E24-2	56	295-348	Unit E	286
299-E24-4	56	272-298	Unit A	293
299-E24-7	56	305-350	Hs	313
299-E24-8	56	280-372	Unit E	285
299-E25-11	60	265-335	Unit A	278
299-E25-13	63	256-315	Unit A	280
299-E25-17	76	273-295	Unit E	273
299-E25-18	76	269-294	Unit E	276
299-E25-19	76	270-295	Unit E	274
299-E25-2	55	276-316	Unit A	273

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Table 2-25. PNL Groundwater Monitoring Well Network. Page 4 of 5

Well Number	Year of Installation	Depth of Screened Interval (ft)[c/]	Formation Screened Within[b/]	Current Depth to Water (ft)[a/]
299-E25-20	76	268-293	Unit E	273
299-E25-21	83	270-293	Unit E	273
299-E25-22	83	265-295	Unit E	271
299-E25-23	83	273-304	Unit E	273
299-E32-4	87	278-298	Hlg	283
299-E33-1	54	215-235	Hlg	228
299-E33-10	55	259-285	Hlg	270
299-E33-12	53	305-385	Basalt	220
299-E33-18	50	240-260	Hlg	241
299-E33-20	56	225-251	Hlg	234
299-E33-21	57	235-275	Hlg	285
299-E33-24	67	219-241	Hlg	235
299-E33-25	69	199-233	Hlg	262
299-E33-28	87	256-276	Hlg	262
299-E33-29	87	263-283	Hlg	271
299-E33-3	54	219-231	Hlg	227
299-E33-30	87	255-275	Unit E	261
299-E33-5	55	218-235	Hlg	230
299-E33-7	55	215-230	Hlg	224
299-E33-8	53	230-257	Hlg	250
299-E33-9	49	252-262	Hlg	DNF
299-E34-1	61	215-230	Hlg	226
299-E34-2	87	220-240	Hs/Hlg	228
299-E34-3	87	193-213	Hlg	208

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Table 2-25. PNL Groundwater Monitoring Well Network. Page 5 of 5

Well Number	Year of Installation	Depth of Screened Interval (ft)[c/]	Formation Screened Within[b/]	Current Depth to Water (ft)[a/]
299-E34-5	87	171-191	Hlg	187
299-E34-6	87	175-195	Hlg	195

DNF - Data not found.
[a/] Water levels obtained in Kasza et al. (1991).
[b/] Information obtained in Lindsey et al. (1992).
[c/] Information obtained in McGhan (1989), Ledgerwood (1992), and DOE/RL (1992b).
Unit E - Ringold Formation unit E
Lm - Ringold Formation lower mud unit
Unit A - Ringold Formation unit A
Hlg - Hanford formation lower gravel
Hs - Hanford formation sand

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3.0 SITE CONDITIONS

The following sections describe the physical nature and setting of the Hanford Site and the 200 East Area. The site conditions are presented in the following sections:

- Physiography and Topography (Section 3.1)
- Meteorology (Section 3.2)
- Surface Hydrology (Section 3.3)
- Geology (Section 3.4)
- Hydrogeology (Section 3.5)
- Environmental Resources (Section 3.6)
- Human Resources (Section 3.7).

These sections incorporate information from other documents which are referenced as applicable.

3.1 PHYSIOGRAPHY AND TOPOGRAPHY

The Hanford Site (Figure 3-1) is situated within the Pasco Basin of south-central Washington. The Pasco Basin is one of a number of topographic depressions located within the Columbia Basin Subprovince of the Columbia Intermontane Province (Figure 3-2), a broad basin located between the Cascade Range and the Rocky Mountains. The Columbia Intermontane Province is the product of Miocene continental flood basalt volcanism and regional deformation that occurred over the past 17 million years. The Pasco Basin is bounded on the north by the Saddle Mountains, on the west by Umtanum Ridge, Yakima Ridge, and the Rattlesnake Hills, on the south by Rattlesnake Mountain and the Rattlesnake Hills, and on the east by the Paulouse slope (Figure 3-1).

The physiography of the Hanford Site is dominated by the low-relief plains of the Central Plains physiographic region and anticlinal ridges of the Yakima Folds physiographic region (Figure 3-3). Surface topography seen at the Hanford Site is the result of (1) uplift of anticlinal ridges, (2) Pleistocene cataclysmic flooding, and (3) Holocene eolian activity (DOE 1988b). Uplift of the ridges began in the Miocene epoch and continues to the present. Cataclysmic flooding occurred when ice dams in western Montana and northern Idaho were

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breached, allowing large volumes of water to spill across eastern and central Washington. The last major flood occurred about 13,000 years ago, during the late Pleistocene epoch. Anastomosing flood channels, giant current ripples, bergmounds, and giant flood bars are among the landforms created by the floods. Since the end of the Pleistocene epoch, winds have locally reworked the flood sediments, depositing dune sands in the lower elevations and loess (windblown silt) around the margins of the Pasco Basin. Generally, sand dunes have been stabilized by anchoring vegetation except where they have been reactivated where vegetation is disturbed (Figure 3-4).

A series of numbered areas have been delineated at the Hanford Site. The 100 Areas are situated in the northern part of the Hanford Site adjacent to the Columbia River in an area commonly called the "Horn." The elevation of the "Horn" is between 119 and 143 m (390 and 470 ft) above mean sea level (msl) with a slight increase in elevation away from the river. The 200 Areas are situated on a broad flat area called the 200 Areas Plateau. The 200 Areas Plateau is near the center of the Hanford Site at an elevation of approximately 198 to 229 m (650 to 750 ft) above msl. The plateau decreases in elevation to the north, northwest, and east toward the Columbia River, and plateau escarpments have elevation changes of between 15 to 30 m (50 to 100 ft).

The 200 East Area is situated on the 200 Areas Plateau on a relatively flat prominent terrace (Cold Creek Bar) formed during the late Pleistocene flooding (Figure 3-5). Cold Creek Bar trends generally east to west and is bisected by a flood channel that trends north to south. This terrace drops off rather steeply to the north and northwest with elevation changes between 15 and 30 m (50 to 100 ft).

The topography of the 200 East Area is generally flat (Figure 3-1). The elevation ranges from approximately 225 m (740 ft) above msl in the southern part of the B Plant Aggregate Area to about 133 m (435 ft) above msl in the northern part of the B Plant Aggregate Area. A detailed topographic map is provided as Plate 2.

3.2 METEOROLOGY

The following sections provide information on Hanford Site meteorology including precipitation (Section 3.2.1), wind conditions (Section 3.2.2), and temperature variability (Section 3.2.3).

The Hanford Site lies east of the Cascade Mountains and has a semi-arid climate because of the rainshadow effect of the mountains. The weather is monitored at the Hanford Meteorology Station, located between the 200 East and 200 West Areas, and at other points situated through the reservation. The following sections summarize the Hanford Site meteorology.

3.2.1 Precipitation

The Hanford Site receives an annual average of 16 cm (6.3 in.) of precipitation. Precipitation falls mainly in the winter, with about half of the annual precipitation occurring between November and February. The maximum 25 yr/24 h storm event has been calculated at 3.8 cm (1.5 in.) (Stone et al. 1983). The maximum 100 yr/24 hr storm event is approximately 5 cm (2 in.). Average winter snowfall ranges from 13 cm (5.3 in.) in January to 0.8 cm (0.31 in.) in March. The record snowfall of 62 cm (24.4 in.) occurred in February 1916 (Stone et al. 1983). During December through February, snowfall accounts for about 38% of all precipitation in those months.

The average yearly relative humidity at the Hanford Site for 1946 to 1980 was 54.4%. Humidity is higher in winter than in summer. The monthly averages for the same period range from 32.2% for July to 80% in December. Atmospheric pressure averages are higher in the winter months, and record absolute highs and lows also occur in the winter.

3.2.2 Winds

The Cascade Mountains have considerable effect on the wind regime at the Hanford Site by serving as a source of cold air drainage. This gravity drainage results in a northwest to west-northwest prevailing wind direction. The average mean monthly speed for 1945 to 1980 is 3.4 m/s (7.7 mph). Peak gust speeds range from 28 to 36 m/s (63 to 80 mph) and are generally southwest or west-southwest winds (Stone et al. 1983).

Figure 3-6 shows wind roses for the Hanford Telemetry Network (Stone et al. 1983). The gravity drainage from the Cascades produces a prevailing west-northwest wind in the 200 East Area. In July, hourly average wind speeds range from a low of 2.3 m/s (5.2 mph) from 9 to 10 a.m. to a high of 6 m/s (13.0 mph) from 9 to 10 p.m.

3.2.3 Temperature

Based on data from 1914 to 1980, minimum winter temperatures vary from -33 °C (-27 °F) to -6 °C (+22 °F), and maximum summer temperatures vary from 38 °C (100 °F) to 46 °C (115 °F). Between 1914 and 1980, a total of 16 days with temperatures -29 °C (-20 °F) or below had been recorded. There are 10 days of record when the maximum temperature failed to go above -18 °C (0 °F). Prior to 1980, there were three summers on record when the temperatures were 38 °C (100 °F) or above for 11 consecutive days (Stone et al. 1983).

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3.3 SURFACE HYDROLOGY

3.3.1 Pasco Basin Surface Hydrology

Surface drainage enters the Pasco Basin from several other basins, which include the Yakima River Basin, Walla Walla River Basin, Palouse/Snake Basin, and Big Bend Basin (Figure 3-7). Within the Pasco Basin, the Columbia River is joined by major tributaries including the Yakima, Snake, and Walla Walla Rivers. No perennial streams originate within the Pasco Basin. Columbia River inflow to the Pasco Basin is recorded at the United States Geological Survey (USGS) gage below Priest Rapids Dam, and outflow is recorded below McNary Dam. Average annual flow at these recording stations is approximately 1.1 x 10^{11} m^3 (8.7 x 10^7 acre-ft) at the USGS gage and 1.6 x 10^{11} m^3 (1.3 x 10^8 acre-ft) at the McNary Dam gage (DOE 1988b).

Total estimated precipitation over the basin averages less than 15.8 cm/yr (6.2 in./yr). Mean annual runoff from the basin is estimated to be less than 3.1 x 10^7 m^3/yr (2.5 x 10^4 acre-ft/yr), or approximately 3% of the total precipitation. The remaining precipitation is assumed to be lost through evapotranspiration with a small component (perhaps less than 1%) recharging the groundwater system (DOE 1988b).

3.3.2 Hanford Site Surface Hydrology

Primary surface water features associated with the Hanford Site, located near the center of the Pasco Basin, are the Columbia and Yakima Rivers and their major tributaries, the Snake and Walla Walla Rivers. West Lake, about 4 hectares (10 acres) in area and less than 0.9 m (3 ft) deep, is the only natural lake within the Hanford Site (DOE 1988b). Wastewater ponds, cribs, and ditches associated with nuclear fuel reprocessing and waste disposal activities are also present on the Hanford Site.

The Columbia River flows through the northern part and along the eastern border of the Hanford Site. This section of the river, the Hanford Reach, extends from Priest Rapids Dam to the headwaters of Lake Wallula (the reservoir behind McNary Dam). Flow along the Hanford Reach is controlled by Priest Rapids Dam. Several drains and intakes are also present along this reach, including irrigation outfalls from the Columbia Basin Irrigation Project, the Washington Public Power Supply System (WPPSS) Nuclear Project 2, and Hanford Site intakes for onsite water use. Much of the northern and eastern parts of the Hanford Site is drained by the Columbia River.

Routine water-quality monitoring of the Columbia River is conducted by the U.S. Department of Energy (DOE) for both radiological and nonradiological parameters and has been reported by Pacific Northwest Laboratory (PNL) since 1973. The Washington State

Department of Ecology (Ecology) has issued a Class A (excellent) quality designation for Columbia River water along the Hanford Reach from Grand Coulee Dam, through the Pasco Basin, to McNary Dam. This designation requires that all industrial uses of this water be compatible with other uses, including drinking, wildlife habitat, and recreation. In general, the Columbia River water is characterized by a very low suspended load, a low nutrient content, and an absence of microbial contaminants (DOE 1988b).

Approximately one-third of the Hanford Site is drained by the Yakima River system. Cold Creek and its tributary, Dry Creek, are ephemeral streams on the Hanford Site that are within the Yakima River drainage system. Both streams drain areas along the western part of the Hanford Site and cross the southwestern part of the Hanford Site toward the Yakima River. Surface flow, which may occur during spring runoff or after heavier-than-normal precipitation, infiltrates and disappears into the surface sediments. Rattlesnake Springs, located on the western part of the Hanford Site, forms a small surface stream that flows for about 2.9 km (1.8 mi) before infiltrating into the ground.

3.3.3 200 East Area Surface Hydrology

The 200 East Area is not in a designated floodplain. Calculations of probable maximum floods for the Columbia River and the Cold Creek Watershed indicate that the 200 East Area is not expected to be inundated under maximum current flood conditions (Skaggs and Walters 1981).

The following sections describe surface water bodies within each of the 200 East source aggregate areas, and the potential for flooding related to these structures. Locations of facilities described are identified on Plate 1.

3.3.3.1 PUREX Plant Aggregate Area. No natural surface water bodies exist in the PUREX Plant Aggregate Area. The only existing man-made surface water bodies are the 207-A Retention Basins and the open stretches of the 216-A-29 Ditch. The 216-A-29 Ditch is located outside the perimeter fence, southeast of the southeast corner of the 241-A Tank Farm. The ditch empties into the 216-B-3-3 Ditch and terminates at the 216-B-3 Pond. During the fall of 1991, the physical configuration of the 216-A-29 Ditch was modified. The southern portion of the ditch located within the Grout Treatment Facility was stabilized and filled to grade. The section of the ditch north of the Grout Treatment Facility has been cleared of vegetation and regraded to produce gentle sidewall slopes. These discontinuous open portions of the ditch represent minor, if any, flooding potential due to the lack of drainage area and the nature of the ditch soils that allow infiltration surface water into the ground. The 207-A Retention Basins present no threat of flooding because the north basins discharge into the other waste management units.

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3.3.3.2 B Plant Aggregate Area. The 216-N-8 Pond (West Pond), located 1.2 km (0.75 mi) northeast of the 216-A-25 Pond (Gable Mountain Pond) is the only naturally occurring body of water on the Hanford Site. Prior to the creation of Gable Mountain Pond, West Pond was an intermittent seasonal pond located in a natural basin at the base of Gable Mountain. After the introduction of large quantities of water to Gable Mountain Pond in 1957, the water table in the area was raised sufficiently to provide year-round water to West Pond.

The existing man-made surface water bodies in the B Plant Aggregate Area include the 2101-M Pond, 216-B-3 Pond, 216-B-3A Pond, 216-B-3B Pond, 216-B-3C Pond, 216-B-3-3 Ditch, 216-B-63 Ditch, and the 207-B Retention Basin.

The 2101-M Pond, located near the 200 East Powerhouse, receives small quantities of wastewater and generally contains less than 15 cm (6 in.) of standing water. The pond lost water through evaporation and infiltration to soil.

The 216-B-3 Pond is part of a pond system that receives water from the 216-B-3-3 Ditch, and includes "lobes" designated as the 216-B-3A Pond, the 216-B-3B Pond (currently inactive), and the 216-B-3C Pond. The 216-B-3 Pond System is located 1,100 m (3,500 ft) east of the 200 East Area perimeter fence. The potential for flooding from the 216-B-3 Pond System is minimized by the lack of any catchment area and the presence of a dike system surrounding the ponds. Also, the water level in the 216-B-3A Pond can be controlled by discharge to either the 216-B-3B or the 216-B-3C Ponds. Water from the 216-B-3C Pond infiltrates rapidly into the gravelly bottom soils. If necessary, water can also be diverted to the 216-E-25 Contingency Pond located north of the 216-B-3 Pond System.

The 216-B-3-3 Ditch is an open structure that originates just south of the 200 East Area perimeter fence and is fed by the 216-B-2 Pipeline. The ditch discharges to the 216-B-3 Pond System. The open portions of the ditch represent minor, if any, flooding potential due to the lack of a contributing catchment area, the high bermed sides of the ditch, and rapid infiltration of surface water to soil.

The 216-B-3 Emergency Ditch, located east of the 207-B Retention Basin, is a closed-end percolation ditch that receives chemical sewer water from the 221-B Building which is then discharged to soil. Flooding potential for this ditch is low again due to the lack of catchment and rapid infiltration of surface water to soil beneath the ditch.

The 207-B Retention Basin, located 610 m (2,000 ft) northeast of the 221-B Building, is a concrete-lined basin that receives cooling water from the 221-B Building and discharges it to the 216-B-2 Pipeline. The 207-B Retention Basin has no catchment area and therefore presents no flooding threat.

3.3.3.3 Semi-Works Aggregate Area. The Semi-Works Aggregate Area has no natural surface water bodies. The only existing man-made surface water body is the 200 East Powerhouse Ditch located along the southern boundary of the aggregate area. The ditch receives cooling brines from batch processes and boiler blowdown rinsate from the 200 East Powerplant. The flow rate from the powerhouse facility to the ditch is estimated at 12,300,000 L/month (3,250,000 gal/month). Ditch effluent is also dispersed by evaporation and infiltration to the soil column along the ditch. Ditch effluent flows eastward and is discharged to an approximately 76 cm-diameter (30 in.) corrugated metal pipe connected to the 216-B-3 Pond System. There is, again, no flooding threat from this feature.

3.4 GEOLOGY

The following sections provide information pertaining to geologic characteristics of south-central Washington, the Hanford Site, and the 200 East Area. Topics included are the regional tectonic framework (Section 3.4.1), Pasco Basin and Hanford Site stratigraphy (Section 3.4.2), known or suspected faulting and other subsurface structures in the Gable Mountain-200 East Areas (Section 3.4.3), and 200 East Area geology (Section 3.4.4).

The geologic characterization of the Hanford Site, including the 200 East Area, is the result of many previous site investigation activities at Hanford. These activities include the siting of nuclear reactors, characterization activities for the Basalt Waste Isolation Project (BWIP), waste management activities, and related geologic studies supporting these efforts. Geologic investigations have included regional and Hanford Site surface mapping, borehole/well sediment logging, field and laboratory sediment classification, borehole geophysical studies (including gamma radiation logging), and in situ and laboratory hydrogeologic properties testing.

3.4.1 Regional Tectonic Framework

The following sections provide information on reginoal (southcentral Washington) geologic structure, structural geology of the Pasco Basin and the Hanford Site, and regional and Hanford Site seismology.

3.4.1.1 Regional Geologic Structure. The Columbia Plateau is a part of the North American continental plate and lies in a back-arc setting east of the Cascade Range. It is bounded on the north by the Okanogan Highlands, on the east by the Northern Rocky Mountains and Idaho Batholith, and on the south by the High Lava Plains and Snake River Plain (Figure 3-8).

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The Columbia Plateau can be divided into three informal structural subprovinces (Figure 3-9): Blue Mountains, Palouse, and Yakima Fold Belt (Tolan and Reidel 1989). These structural subprovinces are delineated on the basis of their structural fabric, unlike the physiographic provinces that are defined on the basis of landforms. The Hanford Site is located in the Yakima Fold Belt Subprovince near its junction with the Palouse Subprovinces.

The principal characteristics of the Yakima Fold Belt (Figure 3-10) are a series of segmented, narrow, asymmetric anticlines that have wave lengths between 5 and 32 km (3 and 19 mi) and amplitudes commonly less than 1 km (0.6 mi) (Reidel 1984; Reidel et al. 1989a). The northern limbs of the anticlines generally dip steeply to the north, are vertical, or even overturned. The southern limbs generally dip at relatively shallow angles to the south. Thrust or high-angle reverse faults with fault planes that strike parallel or subparallel to the axial trends are principally found on the north sides of these anticlines. The amount of vertical stratigraphic offset associated with these faults varies but commonly exceeds hundreds of meters. These anticlinal ridges are separated by broad synclines or basins that, in many cases, contain thick accumulations of Tertiary- to Quaternary-age sediments. The Pasco Basin is one of the larger structural basins in the Yakima Fold Belt Subprovince.

Deformation of the Yakima folds occurred under a north-south compression and was contemporaneous with the eruption of the basalt flows (Reidel 1984; Reidel et al. 1989a). Deformation occurred during the eruption of the Columbia River Basalt Group and continued through the Pliocene epoch, into the Pleistocene epoch, and perhaps to the present.

3.4.1.2 Pasco Basin and Hanford Site Structural Geology. The Pasco Basin, in which the Hanford Site is located, is a structural depression bounded on the north by the Saddle Mountains anticline, on the east by the Palouse Slope, on the west by Umtanum Ridge, Yakima Ridge, and Rattlesnake Hills anticlines, and on the south by the Rattlesnake Mountain anticline (Figure 3-11). The Pasco Basin is divided by the Gable Mountain anticline, the easternmost extension of the Umtanum Ridge anticline, into the Wahluke syncline in the north, and the Cold Creek syncline in the south. Both the Cold Creek and Wahluke synclines are asymmetric and relatively flat-bottomed structures. The north limbs of both synclines dip gently (approximately 5°) to the south and the south limbs dip steeply to the north. The deepest parts of the Cold Creek syncline, the Wye Barricade depression, and the Cold Creek depression, are approximately 12 km (7.5 mi) southeast of the Hanford Site 200 Areas, and just to the west-southwest of the 200 West Area, respectively. The deepest part of the Wahluke syncline lies just north of Gable Gap.

The 200 East Area is situated on the generally southward dipping north limb of the Cold Creek syncline about 4 to 7 km (2.5 to 4.5 mi) north of the syncline axis. The Gable Mountain-Gable Butte segment of the Umtanum Ridge anticline lies approximately 3.2 km (2 mi) north of the 200 East Area. The axes of the anticline and syncline are separated by a distance of 9 to 10 km (5.6 to 6.2 mi) and the crest of the anticline (as now exposed) is over

200 m (656 ft) higher than the uppermost basalt layer in the syncline axis. As a result, the basalts and overlying sediments dip to the south and southwest beneath the 200 East Area.

3.4.1.3 Regional and Hanford Site Seismology. Eastern Washington, especially the Columbia Plateau region, is a seismically inactive area when compared to the rest of the western United States (DOE 1988b). The historical seismic record for eastern Washington began in approximately 1850, and no earthquakes large enough to be felt during this period had epicenters on the Hanford Site. The closest regions of historical moderate-to-large earthquake generation are in western Washington and Oregon and western Montana and eastern Idaho. The most significant event relative to the Hanford Site is the 1936 Milton-Freewater, Oregon, earthquake that had a magnitude of 5.75 and that occurred more than 90 km (54 mi) away. The largest Modified Mercalli Intensity for this event was felt about 105 km (63 mi) from the Hanford Site at Walla Walla, Washington, and was VII.

Geologic evidence of past moderate or possibly large earthquake activity is shown by the anticlinal folds and faulting associated with Rattlesnake Mountain, Saddle Mountain, and Gable Mountain. The currently recorded seismic activity related to these structures consists of micro-size earthquakes. The suggested recurrence rates of moderate- and larger-size earthquakes on and near the Hanford Site are measured in geologic time (tens of thousands of years).

3.4.2 Pasco Basin and Hanford Site Stratigraphy

This section summarizes regional stratigraphic characteristics of the Columbia River Basalt Group and the overlying sediments. Specific references to the Hanford Site and the 200 East Area are made where applicable to describe the general occurrence of these units within the Pasco Basin. Much of the text is modified from Lindsey et al. (1992), with additional information in Section 3.4.2.1 (Regional Columbia River Basalt Group) included from DOE (1988). Information in Section 3.4.2.2 (Ellensburg Formation) was included from Delaney et al. (1991) and DOE (1988). Additional information regarding distinguishing features of the sediments overlying the basalt was taken from Bjornstad (1990) and cited where applicable.

The principal geologic units within the Pasco Basin include the Miocene age basalt of the Columbia River Basalt Group, and overlying late Miocene to Pleistocene unconsolidated sediments (Figure 3-12). Sedimentary interbeds within the Columbia River Basalts collectively comprise the Ellensburg Formation. Older Cenozoic sedimentary and volcaniclastic rocks underlying the basalts are not exposed at the surface near the Hanford Site. The basalts and sediments thicken into the Pasco Basin and generally reach maximum thicknesses in the Cold Creek syncline. The suprabasalt sedimentary sequence at the

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Hanford Site pinches out against the anticlinal structures of Saddle Mountains, Gable Mountain/Umtanum Ridge, Yakima Ridge, and Rattlesnake Hills.

The suprabasalt sediment sequence is up to approximately 230 m (750 ft) thick and is dominated by laterally extensive deposits assigned to the late Miocene- to Pliocene-age Ringold Formation and the Pleistocene-age Hanford formation (Figure 3-13). Locally occurring strata informally referred to as pre-Missoula gravels, Plio-Pleistocene unit, and early "Palouse" soil comprise the remainder of the sedimentary sequence. The pre-Missoula gravels are encountered between the Ringold Formation and Hanford formation in the east-central Cold Creek syncline and at the east end of Gable Mountain anticline. The pre-Missoula gravels have not been identified in the 200 East Area. As discussed in Sections 3.4.2.4 and 3.4.2.6, the Plio-Pleistocene unit and the early "Palouse" soil are encountered in the western Cold Creek syncline in the vicinity of the 200 West Area. Most of these sediments, particularly the Ringold Formation, are at least partially consolidated. Relatively thin surficial deposits of eolian sand, loess, alluvium, and colluvium discontinuously overlie the Hanford formation.

The following sections describe the stratigraphic characteristics of the Columbia River Basalt Group (Section 3.4.2.1), Ellensburg Formation (Section 3.4.2.2), Ringold Formation (Section 3.4.2.3), Plio-Pleistocene unit (Section 3.4.2.4), pre-Missoula gravels (Section 3.4.2.5), early "Palouse" soils (Section 3.4.2.6), Hanford formation (Section 3.4.2.7), and surficial deposits (Section 3.4.2.8).

Stratigraphic features of the Saddle Mountains Basalt and the Ellensburg Formation are described for the following reasons:

- Groundwater elevation data presented by DOE (1988), Kasza and Schatz (1989), Kasza et al. (1990), Kasza et al. (1991), and Jackson (1992) indicate that a downward hydraulic gradient exists between the uppermost aquifer in the suprabasalt sediments and the confined aquifers of the Saddle Mountains Basalt-Ellensburg Formation interbeds. As discussed in Section 3.5, the uppermost aquifer is dominated by unconfined conditions, but is locally semiconfined to confined where the Ringold lower mud sequence is present. The data indicate that the downward gradient continues with depth through the Saddle Mountains Basalt and Ellensburg Formation interbeds (Section 3.4.2.2). The area over which the downward gradient is present occurs mainly in areas of artificial recharge at the Hanford Site, including liquid waste disposal sites associated with the 200 East Area. Because of the apparent vertical downward gradient, potential exists for migration of contaminated groundwater from the uppermost aquifer to deeper groundwater-bearing zones. Hydrostratigraphic units, groundwater flow, hydraulic parameters, and groundwater elevation contour maps are discussed in

detail in Sections 3.5.1 (Pasco Basin and Hanford Site Hydrogeology) and 3.5.2 (200 East Area Hydrogeology).

- Groundwater chemical data presented by Jensen (1987) and Graham et al. (1984) indicate that nitrate and tritium may have migrated vertically downward from the uppermost aquifer to the confined Rattlesnake Ridge aquifer. As discussed in Section 4.1.1, beta radiation has also been deferred in groundwater samples from the Rattlesnake Ridge aquifer. However, the vertical extent of these compounds and other chemical constituents in deeper confined aquifers is not well understood.

- Basalt intraflow structures (Section 3.4.2.1.2), erosional windows, and faults (none currently identified) (Section 3.4.3) could potentially represent conduits for downward groundwater migration in the 200 East Area. In general, previous Hanford Site investigations did not determine "how leaky" basalt intraflow structures and faults may be. Also, Graham et al. (1984) reported that some of the nitrate and tritium detections in the Rattlesnake Ridge aquifer can be attributed to downward groundwater migration through a poorly sealed well (299-E33-12). A similar conclusion applies to beta radiation detected in the Rattlesnake Ridge aquifer.

- The confined aquifers represent a potential source of future potable water supply on the Hanford Site, and are currently an important source of agricultural and domestic water adjacent to the Hanford Site.

3.4.2.1 Columbia River Basalt Group. The Columbia River Basalt Group (Figure 3-12) comprises an assemblage of tholeiitic, continental flood basalts of Miocene age. These flows cover an area of more 163,700 km^2 (63,000 mi^2) in Washington, Oregon, and Idaho and have an estimated volume of about 174,356 km^3 (40,800 mi^3) (Tolan et al. 1989). Isotopic age determinations indicate that basalt flows were erupted approximately 17 to 6 Ma (million years before present), with more than 98% by volume being erupted in a 2.5 million-year period (17 to 14.5 Ma) (Reidel et al. 1989b; Reidel and Fecht 1981).

Columbia River Basalt Group flows were erupted from north-northwest trending fissures of linear vent systems in north-central and northeastern Oregon, eastern Washington, and western Idaho (Swanson et al. 1979). The Columbia River Basalt Group is formally divided into five formations (from oldest to youngest): Imnaha Basalt, Picture Gorge Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. Of these, only the Picture Gorge Basalt is not known to be present in the Pasco Basin.

3.4.2.1.1 Saddle Mountains Basalt. The Saddle Mountains Basalt, divided into the Umatilla, Wilbur Creek, Asotin, Esquatzel, Pomona, Elephant Mountain, and Ice Harbor

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Members from bottom to top (Figure 3-12), forms the uppermost basalt unit throughout most of the Pasco Basin. Members of this formation were erupted intermittently over a period from about 14.5 to 6 Ma, during a waning phase of Columbia River Basalt Group volcanism. Distribution of the Saddle Mountains Basalt is limited compared with older Columbia River Basalt Group units, with many of its members confined to structural lows or paleoriver canyons (Reidel and Fecht, 1981; DOE 1988). The Wilbur Creek Member occurs north of Gable Mountain-Umtanum Ridge. The Asotin Member occurs in the north-central portion of the Cold Creek syncline, north and east of the 200 East Area. The Esquatzel Member is present in the central and east-central portions of the Cold Creek syncline. The Ice Harbor Member is confined primarily to the southern and eastern Pasco Basin and surrounding area. On anticlinal ridges bounding the Pasco Basin, the Saddle Mountains Basalt is locally absent, exposing the Wanapum and Grande Ronde Basalts.

On the Hanford Site, the Saddle Mountains Basalt reaches a maximum thickness of about 314 m (1,030 ft) near the 300 Area, and commonly reaches thicknesses of 280 m (918 ft) or more along the axis of the Cold Creek syncline southwest of the 200 West Area. Throughout most of the Hanford Site south of the Gable Mountain-Gable Butte structures, the Saddle Mountains Basalt is comprised primarily of the Umatilla, Esquatzel, Pomona, and Elephant Mountain Members. Maximum thicknesses of individual flows within the Saddle Mountains Basalt on the Hanford Site range from about 39 m (128 ft) for the Esquatzel Member, to about 87 m (285 ft) for the Umatilla Member. The Umatilla and the Esquatzel Members reach maximum thicknesses along the axis of the Cold Creek syncline southwest of the 200 West Area. The Pomona and Elephant Mountain Members are thickest along the eastern side of the Hanford Site and generally thin to the west.

Over part of the eastern portion of the Hanford Site, the Elephant Mountain Member consists of upper and lower flow units. The lower flow unit (Elephant Mountain flow) is separated from the upper flow unit (Ward Gap flow) by a sand and clay layer (Lindsey et al. 1992; Jensen 1987). A zone of fracturing has also been identified within the upper flow (Graham et al. 1984). Additional description of the distribution of the two flow units in the vicinity of the 200 East Area is provided in Section 3.4.4.1.

With a few localized exceptions, the Elephant Mountain Member is the uppermost unit beneath most of the Hanford Site. Near the 300 Area, the Ice Harbor Member is found stratigraphically above the Elephant Mountain Member. In the Gable Gap area, erosion has locally occurred down to the Umatilla Member (Myers and Price 1981; Graham et al. 1984; Figure 3-14). Additional areas of erosion of the Elephant Mountain Member to the southeast of Gable Gap, in the vicinity of the 200 East Area are discussed in Section 3.4.4.1. The areas of basalt erosion near Gable Gap and to the southeast are significant because they represent locations of potential groundwater intercommunication between the upper sedimentary interbeds of the Ellensburg Formation, and the unconfined groundwater system.

The potential for groundwater intercommunication between aquifers is further discussed in Sections 3.5.1.6.3 and 3.5.2.3.3.

Near the northwest corner of the Hanford Site, the Saddle Mountains Basalt thins to only 64 m (211 ft) or less, probably due to nondeposition and erosion. Farther to the north and northwest (near the southeast end of Umtanum Ridge and west of Gable Butte) the Pomona or Umatilla Members are the uppermost units of the Saddle Mountains Basalt. In this area, flows higher in the basalt sequence (Asotin, Esquatzel, Pomona, and Elephant Mountain Members), and the associated Ellensburg Formation sedimentary interbeds were not deposited, or have been completely removed by erosion. Drilling and geophysical information in DOE (1986 and 1988) is insufficient to determine whether the Ellensburg Formation sedimentary interbeds were truncated by erosion, or were pinched out between basalt flows. If the flows and interbeds were truncated by erosion, a zone of potential groundwater intercommunication between the interbed aquifers and the overlying unconfined groundwater system may be present.

3.4.2.1.2 Basalt Intraflow Structures and Cooling Joints. This section describes intraflow structures and cooling joints typical for Columbia River Basalt Group flows. Intraflow structures are primary, internal features or stratified portions of basalt flows exhibiting grossly uniform macroscopic characteristics. These features originate during the emplacement and solidification of each flow. Intraflow structures therefore differ from tectonically-induced fractures and joints formed after consolidation of the flow (DOE 1988). As applied to the Saddle Mountains Basalt, the intraflow structures are significant because they represent potential conduits for groundwater flow within the basalts and between intervening sedimentary interbeds.

Intraflow structures for typical Columbia River Basalt Group flows, including the Saddle Mountains Basalt, can be described according to their position in the flow top, flow interior, or flow bottom, and are shown diagrammatically on Figure 3-15. Flow top structures consist of vesicular to rubbly or brecciated basalt in the glassy, chilled upper crust of the flow. The predominant intraflow structures within flow interiors are zones characterized by patterns of cooling joints, commonly referred to as colonnade and entablature (Figure 3-15). Contacts between colonnade tiers and entablature may be distinct, or they may be gradational. Other intraflow features observed within flow interiors include pipes, cylinders, sheets of vesicles and vesiculated zones; and platy horizontal fracturing. The basal part of a typical Columbia River Basalt Group flow is predominantly a thin, glassy, chilled zone a few centimeters thick, which may be vesicular, rubbly, or brecciated. Additional detailed description of intraflow structures is presented by DOE (1988). Intraflow features may be continuous in flows over long distances but in some cases change abruptly. Lateral variation in thickness of intraflow structures can occur gradually in some flows and suddenly in others at a given location. Clays and other alteration minerals are common

along cooling joints and tend to retard the movement of fluids as well as increase sorptive properties.

Cooling joints in basalt flows are ubiquitous fractures that resulted from tensional stress in response to contraction of solidified portions of the flow as it cooled. Cooling joints form columns, subdivisions of columns, and zones of irregular basalt blocks. Cooling joints are primary features that are distinct from secondary tectonic fractures such as faults, shears, and joint sets.

At the Hanford Site in general, and in the 200 East Area in particular, little compiled intraflow or fracture information was available for the Saddle Mountains Basalt in the documents reviewed for this report. Moak and Wintczak (1980) compiled and reported cooling joint data from the Pomona flow entablature during mapping of the underground Near Surface Test Facility (NSTF) completed within Gable Mountain. However, the applicability of these data to subsurface occurrences of the Pomona Member and other flows of the Saddle Mountains Basalt near the 200 East Area is not discussed in the documents reviewed.

3.4.2.2 Ellensburg Formation. The Ellensburg Formation consists of all sedimentary units that occur between the basalt flows of the Columbia River Basalt Group in the central Columbia Basin. The age of the Ellensburg Formation is principally Miocene, although locally it may be equivalent to early Pliocene. The Ellensburg Formation generally displays two main lithologies: volcaniclastics (Reidel and Fecht 1981; Smith et al. 1989), and siliciclastics (DOE 1988). The volcaniclastics consist mainly of primary pyroclastic air fall deposits and reworked epiclastics derived from volcanic terrains west of the Columbia Plateau. Siliciclastic strata in the Ellensburg Formation consists of clastic, plutonic, and metamorphic detritus derived from the Rocky Mountain terrain. These two lithologies occur both individually and together in the Pasco Basin. A detailed discussion of the Ellensburg Formation in the Hanford Site is given by Reidel and Fecht (1981). Smith et al. (1989) provide a discussion of age equivalent units adjacent to the Columbia Plateau.

As discussed in Section 3.4.2, discussion of Ellensburg Formation is included in this report due to potential for downward migration of groundwater from the uppermost aquifer to the confined aquifers associated with the sedimentary interbeds. The stratigraphic names for individual units of the Ellensburg Formation are given in Figure 3-12. The Ellensburg Formation nomenclature was derived by considering the lateral extent of the upper and lower basalt flows bounding each of the interbeds. Each interbed name is valid only where the bounding flows occur within Pasco Basin and Hanford Site. The interbed names on Figure 3-12 are therefore applicable to the Pasco Basin and Hanford Site, except where the bounding flows are not present. From bottom to top, the sedimentary interbeds of the Ellensburg Formation associated with the Saddle Mountains Basalt include the Mabton interbed (dividing the Saddle Mountains Basalt from the underlying Wanapum Basalt), the

Cold Creek interbed, the Selah interbed, the Rattlesnake Ridge interbed, and the Levey interbed. For the Cold Creek interbed, Ellensburg Formation nomenclature applies to three separate stratigraphic intervals within the interbed, based on the areal extent of the Umatilla, Esquatzel, and Asotin flows as discussed in Section 3.4.2.2.2, below.

The following descriptions include Ellensburg Formation sedimentary interbeds from bottom to top for the Saddle Mountains Basalt.

3.4.2.2.1 Mabton Interbed. The Mabton interbed lies stratigraphically below the Umatilla Member of the Saddle Mountains Basalt and above the Priest Rapids Member of the Wanapum Basalt in the Pasco Basin. The Mabton interbed is thickest in the central Pasco Basin area (including the 200 East Area) and thins out in all directions. Vertical lithologic and textural changes in the Mabton interbed are relatively uniform. From bottom to top, the interbed generally consists of: (1) a thin, basal silty clay; (2) a quartzitic to arkosic sandstone with interlayered, tuffaceous sandstones and siltstones; (3) a fine-grained, tuffaceous, clayey quartzitic sandstone; and (4) a well-indurated, lapilli tuffstone, locally baked.

3.4.2.2.2 Cold Creek Interbed. The Cold Creek interbed refers to the sequence of Ellensburg sediments that occur stratigraphically between the Esquatzel and Umatilla Members of the Saddle Mountains Basalt. The Asotin Member of the Saddle Mountains Basalt partly controlled the distribution of the Cold Creek interbed. Three separate units of the interbed are identified on the basis of the bounding basalt flows. These intervals are the Umatilla-Esquatzel, Umatilla-Asotin, and Asotin-Esquatzel intervals. The Umatilla-Esquatzel interval is present over the much of the central part of the Hanford Site, including the 200 East Area. The Umatilla-Asotin and Asotin-Esquatzel intervals are present to the northeast of the 200 East Area where the Asotin Member of the Saddle Mountains Basalt occurs.

The Umatilla-Esquatzel interval is the thickest interval and has the largest areal extent. This interval is divided into two textural facies: (1) a finer-grained, tuffaceous sandstone facies; and (2) a coarser-grained sandstone and conglomerate facies with tuffaceous siltstone and clays. The coarser-grained facies follows an arcuate trend to the northwest across the central part of the Hanford Site. The coarser-grained facies represents the high-energy, main channel of a fluvial system which is interpreted to have flowed parallel to the flow front of the Asotin flow (to the northeast). The finer-grained facies is present along the southwest bounding-edge of the coarser-grained facies and in the southeastern part of the Hanford Site.

3.4.2.2.3 Selah Interbed. The Selah interbed is bounded on the top by the Pomona Member and on the bottom by the Esquatzel Member. The interbed is a variable mixture of silty to sandy vitric tuff, arkosic sands, tuffaceous clays, and locally thin stringers of predominantly basaltic gravels. The Selah interbed is found beneath most of the Hanford Site.

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3.4.2.2.4 Rattlesnake Ridge Interbed. The Rattlesnake Ridge interbed is bounded on the top by the Elephant Mountain Member and on the bottom by the Pomona Member. The interbed is up to 33 m (108 ft) thick and dominated by three facies at the Hanford Site: (1) a lower clay or tuffaceous sandstone; (2) a middle, micaceous-arkosic and/or tuffaceous sandstone; and (3) an upper, tuffaceous siltstone to sandstone. The unit is found beneath most of the Hanford Site.

3.4.2.2.5 Levey Interbed. The Levey interbed is the uppermost unit of the Ellensburg Formation and occurs between the Ice Harbor Member and the Elephant Mountain Member. It is confined to the vicinity of the 300 Area. The Levey interbed is a tuffaceous sandstone along its northern edge and a fine-grained tuffaceous siltstone to sandstone along its western and southern margins.

3.4.2.3 Ringold Formation. The Ringold Formation at the Hanford Site is up to 185 m (607 ft) thick in the deepest part of the Cold Creek syncline south of the 200 West Area and 170 m (558 ft) thick in the western Wahluke syncline near the 100B Area. The Ringold Formation pinches out against the Gable Mountain, Yakima Ridge, Saddle Mountains, and Rattlesnake Mountain anticlines. It is largely absent in the northern and northeastern parts of the 200 East Area and adjacent areas to the north in the vicinity of West Lake. The Ringold Formation is assigned a late Miocene to Pliocene age (Fecht et al. 1987; DOE 1988) and was deposited in alluvial and lacustrine environments (Bjornstad 1985; Fecht et al. 1987; Lindsey et al. 1991).

Recent studies of the Ringold Formation (Lindsey and Gaylord 1989; Lindsey et al. 1992) indicate that it is best described and divided on the basis of sediment facies associations and their distribution. Facies associations in the Ringold Formation (defined on the basis of lithology, petrology, stratification, and pedogenic alteration) include fluvial gravel, fluvial sand, overbank deposits, lacustrine deposits, and alluvial fan. The facies associations are summarized as follows.

- Fluvial gravel--Clast-supported granule to cobble gravel with a sandy matrix dominates the association. Intercalated sands and muds also are found. Clast composition is very variable, with common types being basalt, quartzite, porphyritic volcanics, and greenstones. Silicic plutonic rocks, gneisses, and volcanic breccias also are found. Sands in this association are generally quartzo-feldspathic, with basalt contents generally in the range of 5 to 25%. Low angle to planar stratification, massive channels, wide-shallow channels, and large-scale cross-bedding are found in outcrops. The association was deposited in a gravelly fluvial system characterized by wide, shallow shifting channels.

- Fluvial sand--Quartzo-feldspathic sands displaying cross-bedding and cross-lamination in outcrop dominate this association. These sands usually contain less

than 15% basalt lithic fragments, although basalt contents as high as 50% may be encountered. Intercalated strata consist of lenticular silty sands and clays up to 3 m (10 ft) thick and thin (<0.5 m) gravels. Fining upwards sequences less than 1 m (3 ft) to several meters thick are common in the association. Strata comprising the association were deposited in wide, shallow channels.

- Overbank deposits--This association predominantly consists of laminated to massive silt, silty fine-grained sand, and paleosols containing variable amounts of calcium carbonate. Overbank deposits occur as thin lenticular interbeds [<0.5 m to 2 m (<1.6 to 6 ft)] in the fluvial gravel and fluvial sand associations, and as thick [up to 10 m (33 ft)], laterally continuous sequences. These sediments record deposition in a floodplain under proximal levee to more distal floodplain conditions.

- Lacustrine deposits--Plane-laminated to massive clay with thin silt and silty sand interbeds displaying some soft-sediment deformation characterize this association. Coarsening upwards sequences less than 1 m (3 ft) to 10 m (30 ft) thick are common in the association. Strata comprising the association were deposited in a lake under standing water to deltaic conditions.

- Alluvial fan--Massive to crudely stratified, weathered to unweathered basaltic detritus dominates this association. These basaltic deposits are generally found around the periphery of the basin. This association was deposited largely by debris flows in alluvial fan settings.

The lower half of the Ringold Formation contains five separate stratigraphic intervals dominated by fluvial gravels. These gravels, designated units A, B, C, D, and E (Figure 3-13), are separated by intervals containing deposits typical of the overbank and lacustrine facies associations. The lowermost of the fine-grained sequences, overlying unit A, is designated the lower mud sequence. The uppermost gravel unit, unit E, grades upwards into interbedded fluvial sand and overbank deposits. These sands and overbank deposits are overlain by lacustrine-dominated strata.

Fluvial gravel units A and E correspond to the lower basal and middle Ringold units, respectively, as defined by DOE (1988). Gravel units B, C, and D do not correlate to any previously defined units. The lower mud sequence corresponds to the upper basal and lower units as defined by DOE (1988). The upper basal and lower units are not differentiated. The sequence of fluvial sands, overbank deposits, and lacustrine sediments overlying unit E corresponds to the upper unit as seen along the White Bluffs in the eastern Pasco Basin. This essentially is the same usage as originally proposed by Newcomb (1958) and Myers et al. (1979).

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3.4.2.4 Plio-Pleistocene Unit. Unconformably overlying the Ringold Formation in the western Cold Creek syncline in the vicinity of 200 West Area (Figures 3-11, 3-12 and 3-13) is the laterally discontinuous Plio-Pleistocene unit (DOE 1988; Baker et al. 1991). The unit is up to 25 m (80 ft) thick and divided into two facies: (1) sidestream alluvium and (2) calcic paleosol (Stage III and Stage IV) (DOE 1988; Baker et al. 1991). The calcic paleosol facies consists of massive calcium carbonate-cemented silt, sand, gravel (caliche) to interbedded caliche-rich and caliche-poor silts and sands. The basaltic detritus facies consists of weathered and unweathered basaltic gravels deposited as locally derived slope wash, colluvium, and sidestream alluvium. The Plio-Pleistocene unit appears to be correlative to other sidestream alluvial and pedogenic deposits found near the base of the ridges bounding the Pasco Basin on the north, west, and south. These sidestream alluvial and pedogenic deposits are inferred to have a late Pliocene to early Pleistocene age on the basis of stratigraphic position and magnetic polarity of interfingering loess units. The white color of the unit, high degree of cementation, and the presence of animal burrows and root traces in cores also support the pedogenic nature of the Plio-Pleistocene unit (Bjornstad 1990). Bjornstad (1990) also indicates that natural gamma activity within the Plio-Pleistocene unit is erratic, high in places and moderate to low elsewhere.

3.4.2.5 Pre-Missoula Gravels. Quartzose to gneissic clast-supported pebble to cobble gravel with a quartzo-feldspathic sand matrix underlies the Hanford formation in the east-central Cold Creek syncline and at the east end of Gable Mountain anticline east and south of the 200 East Area (Figures 3-11, 3-12 and 3-13). These gravels, called the pre-Missoula gravels (PSPL 1982), are up to 25 m (80 ft) thick, contain less basalt than underlying Ringold gravels and overlying Hanford deposits, have a distinctive white or bleached color, and sharply truncate underlying strata. The nature of the contact between the pre-Missoula gravels and the overlying Hanford formation is not clear. In addition, it is unclear whether the pre-Missoula gravels overlie or interfinger with the early "Palouse" soil and Plio-Pleistocene unit. Magnetic polarity data indicate the unit is no younger than early Pleistocene in age (>1 Ma) (Baker et al. 1991).

3.4.2.6 Early "Palouse" Soil. The early "Palouse" soil consists of up to 20 m (65 ft) of massive, brown-yellow, and compact loess-like silt and minor fine-grained sand (Tallman et al. 1979; 1981; Bjornstad 1984; DOE 1988). These deposits overlie the Plio-Pleistocene unit in the western Cold Creek syncline around the 200 West Area (Figures 3-11, 3-12 and 3-13). The unit is differentiated from overlying graded rhythmites (Hanford formation) by greater calcium carbonate content, massive structure in core, and high natural gamma response in geophysical logs (Bjornstad 1984; DOE 1988). This natural gamma response is due to the inherent stratigraphic properties of the unit, rather than from effects of radionuclide contamination. Other distinguishing features include uniform fine-grained texture, unconsolidated nature, and high mica content (Bjornstad 1990). Bjornstad also indicates that it may be difficult to differentiate the early "Palouse" soil from the underlying Plio-Pleistocene unit without careful analysis of calcium carbonate data and gross gamma logs.

The upper contact of the unit is poorly defined, and it may grade up-section into the lower part of the Hanford formation. Based on a predominantly reversed polarity the unit is inferred to be early Pleistocene in age (Baker et al. 1991).

3.4.2.7 Hanford Formation. The Hanford formation consists of pebble to boulder gravel, fine- to coarse-grained sand, and silt (Baker et al. 1991). These deposits are divided into three facies: (1) gravel-dominated; (2) sand-dominated; and (3) silt dominated facies. These facies are referred to as coarse-grained deposits, plane-laminated facies, and rhythmite facies, respectively by Baker et al. (1991). The silt dominated deposits also are referred to as the "Touchet Beds," while the gravelly facies are generally referred to as the Pasco Gravels. The Hanford formation is thickest in the Cold Creek bar in the vicinity of 200 West and 200 East Areas where it is up to 65 m (210 ft) thick (Figures 3-11, 3-12 and 3-13). The Hanford formation was deposited by cataclysmic flood waters that drained out of glacial Lake Missoula (Fecht et al. 1987; DOE 1988; and Baker et al. 1991). Hanford deposits are absent on ridges above approximately 385 m (1,260 ft) above sea level. The following sections describe the three Hanford formation facies.

3.4.2.7.1 Gravel-Dominated Facies. The gravel-dominated facies is dominated by coarse-grained basaltic sand and granule to boulder gravel. These deposits display massive bedding, planar to low-angle bedding, and large-scale planar cross-bedding in outcrop, while the gravels generally are matrix-poor and display an open-framework texture. Lenticular sand and silt beds are intercalated throughout the facies. Gravel clasts in the facies generally are dominated by basalt (50 to 80%). Other clast types include Ringold and Plio-Pleistocene rip-ups, granite, quartzite, and gneiss. The relative proportion of gneissic and granitic clasts in Hanford gravels versus Ringold gravels generally is higher (up to 20% as compared to less than 5%). Sands in this facies usually are very basaltic (up to 90%), especially in the granule-size range. Locally Ringold and Plio-Pleistocene rip-up clasts dominate the facies comprising up to 75% of the deposit. The gravel facies dominates the Hanford formation in the 100 Areas north of Gable Mountain, the northern part of 200 East Area, and the eastern part of the Hanford Site including the 300 Area. The gravel-dominated facies was deposited by high-energy flood waters in or immediately adjacent to the main cataclysmic flood channels.

3.4.2.7.2 Sand-Dominated Facies. The sand-dominated facies consists of fine-grained to coarse-grained sand and sand displaying plane lamination and bedding and less commonly plane cross-bedding in outcrop. These sands may contain small pebbles and rip-up clasts in addition to pebble-gravel interbeds and silty interbeds less than 1 m (3 ft) thick. The silt content of these sands is variable, but where it is low an open framework texture is common. These sands are typically very basaltic, commonly referred to as black or gray or salt and pepper sands. This facies is most common in the central Cold Creek syncline, in the central to southern parts of the 200 East and 200 West Areas, and in the vicinity of the WPPSS facilities. The sand-dominated facies was deposited in and adjacent to the main

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flood channelways as flow velocity decreased. Coarser-grained materials were deposited as channel competency was lost. The facies is transitional between gravel-dominated facies and silt-dominated facies.

3.4.2.7.3 Silt-Dominated Facies. The silt-dominated facies consists of thinly bedded, plane laminated and ripple cross-laminated silt and fine- to coarse-grained sand that commonly displays normally graded rhythmites similar to Bouma sequences, a few centimeters to several tens of centimeters thick in outcrop (Myers et al. 1979; DOE 1988). This facies dominates the Hanford formation throughout the central, southern, and western Cold Creek syncline within and south of 200 East and West Areas. These sediments were deposited under slackwater conditions and in backflooded areas (DOE 1988).

3.4.2.7.4 Clastic Dikes. The following description of clastic dikes was taken from Hoffmann et al. (1992), Connelly et al. (1992a), and Lindsey et al. (1992). In addition to the three Hanford formation facies outlined above, clastic dikes also are commonly found at the Hanford Site, including the 200 East Area. These dikes, while common in the Hanford formation, also are found locally in other sedimentary units in the Pasco Basin. The dikes do not occur in Holocene deposits, but are sometimes truncated by Hanford formation sediments and therefore their age is probably Pleistocene. Clastic dikes are found in all facies of the Hanford formation but they are more common in the finer-grained facies and rare in open-work gravel. Whether in the Hanford formation or other sedimentary units, clastic dikes generally cross-cut bedding, although they do locally parallel bedding. Clastic dikes have been omitted from Figure 3-13 because the stratigraphic distribution of the clastic dikes and cross cutting relationships with the suprabasalt sediments cannot be readily depicted.

The dikes may be simple and composed of one layer or filling, or composite and composed of multiple layers (typically vertical to subvertical) of alternating silt, sand, and granules, with silt and sand being most common. Individual layers may be millimeters to centimeters in thickness, with overall dike widths commonly one centimeter to over a meter. In some cases, filling materials can be traced to underlying, overlying or interbedded sediments. A geomorphic feature known as patterned ground may be present at locations where clastic dikes intersect the ground surface.

Origin of clastic dikes in the Columbia Plateau has been attributed to earthquakes, melting of buried ice and frozen sediments, upward injections of groundwater, thermal contraction of permafrost, desiccation cracks or deep frost cracks, and extension fracturing from sediment loading on unstable deposits. None of the suggested origins can explain all the physical characteristics of the clastic dikes, suggested that the dikes may have more than one origin. As a possible mechanism, Black (1980) proposed that the dikes were formed during Pleistocene cataclysmic flooding and are the result of hydraulic injection of water and sediment into cracks formed by the sudden loading of water on the ground surface.

3.4.2.8 Surficial Deposits. Surficial deposits consist of silt, sand, and gravel that form a thin (< 10 m [30 ft]) veneer across much of the Hanford Site. These sediments were deposited by a mix of eolian and alluvial processes.

3.4.3 Known or Suspected Faulting and other Subsurface Structures in the Gable Mountain-200 East Areas

At the Hanford Site, faults have been identified on the Umtanum Ridge-Gable Mountain structure and on the Yakima Ridge from geologic mapping, trenching and drilling (Figure 3-10 and 3-14). There is no direct evidence of faulting in the 200 East Area (Lindsey et al. 1992), but good exposures of faults are present in the Gable Mountain area north of the 200 East Area. Subsurface structures have also been identified between Gable Mountain and the 200 East Area during previous studies using borehole drill core and geophysical data. Like the intraflow structures of the Saddle Mountains Basalt (as discussed in Section 3.4.2.1.2), faults and tectonic fractures could potentially provide conduits for groundwater intercommunication between confined aquifers, and between the uppermost and confined systems. Vertical and horizontal offsets along faults can also potentially juxtapose highly permeable units and promote migration of contaminated groundwater.

The structural geology of the Hanford Site including the area between the 200 East Area and Gable Mountain is summarized by Lindsey et al. (1992), DOE (1988), and Myers and Price (1981). These discussions describe folding and faulting, results of geophysical studies, and tectonic brecciation and shearing of basalt. The following sections summarize information from these sources for structures near Gable Mountain (Section 3.4.3.1), and the area between Gable Mountain and the 200 East Area (Section 3.4.3.2). Section 3.4.3.3 discusses results of geophysical studies in the vicinity of the 200 East Area, and Section 3.4.3.4 discusses occurrences of tectonic brecciation and shearing. In general, very limited structural and geophysical data are available for the 200 East Area itself.

3.4.3.1 Gable Mountain Area Structures. Gable Mountain forms the eastern-most topographic expression of the Umtanum Ridge/Gable Mountain anticline, as discussed in Section 3.4.1.2 (Figures 3-10 and 3-14). The Gable Mountain anticline consists of a series of an echelon, southeast to northwest trending folds (Fecht 1978). Faults investigated on Gable Mountain during geologic mapping, trenching, and drilling include the west, central, and south faults. These faults are identified on Figure 3-10 as numbers 7M, 7N, and 7O respectively. The west and central faults are oriented roughly perpendicular to the axis of Gable Mountain. The fault nomenclature is presented by DOE (1988), and the faults are named based on their general geographic occurrence on Gable Mountain. The central fault is notable because the top of the Esquatzel Member of the Saddle Mountains Basalt has been offset by about 50 m (164 ft) of reverse, dip-slip movement along the fault. The south fault is oriented east/west (nearly parallel the trend of Gable Mountain) and has 12 m (39 ft) of

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reverse displacement. Several other faults in the Gable Mountain area were identified from borehole data or via trenching, including a northwest/southeast-striking fault with a shallow northward dip and 98 m (321 ft) of stratigraphic throw. DOE (1988) indicates that "topographic and structural relief" possibly suggests that a fault known as the Umtanum fault, and present along the Umtanum Ridge to the west of Gable Mountain Gable Butte may extend to the east end of Gable Mountain. Faults on Gable Mountain truncate Hanford formation sediments in addition to basalt (Lindsey et al. 1992).

3.4.3.2 Structures in the Area Between Gable Mountain and the 200 East Area. South of Gable Mountain, and about 5 km (3 mi) northeast of the 200 East Area, two faults were identified in borehole DB-10 (Figure 3-14). Repetition of the stratigraphic section of the Pomona, Esquatzel, and Asotin Members of the Saddle Mountains Basalt across the DB-10 faults indicates that they are reverse faults with about 55 m (180 ft) of combined, dip-slip offset. Additional boreholes drilled near DB-10 indicate that the upper fault in DB-10 is a north/south-striking structure that dips moderately to the west.

Other subsurface structures located in the area between Gable Mountain and the 200 East Area include the Pearl and Willa anticlines (Figure 3-14). These anticlines are small an echelon folds similar to those on Gable Mountain, and generally conform to bedrock areas lying above the water table (Lindsey et al. 1992; Figure 3-14). The folds have relatively small amplitudes that are generally less than about 6 m (20 ft). As further discussed by Lindsey et al. (1992) and in Section 3.4.4, the thin remnants of Ringold unit A gravels and the lower mud sequence found in the area between Gable Mountain and the 200 East Area are most common in the troughs separating the low amplitude anticlines.

A fracture zone was identified within the upper Elephant Mountain flow unit east of the 200 East Area, but is not believed to be regionally extensive (Graham et al. 1984). No additional details regarding the origin of the fracture zone were discussed.

3.4.3.3 Geophysical Investigations. The characteristics of potential faults and other subsurface structures between Gable Mountain and the 200 East Area, and the area east of the 200 East Area have been investigated via geophysical surveys. Previous investigations have utilized a variety of geophysical methods including gravity, magnetic, seismic refraction, and seismic reflection surveys. These investigations have provided relatively limited resolution of potential subsurface structures, however. Many of the investigations were completed in support of BWIP characterization activities (DOE 1988). Results of these investigations are summarized below, and describe subsurface structures that could affect groundwater flow.

During BWIP characterization activities a subsurface gravity and magnetic anomaly known as the May Junction linear was identified about 4.8 km (3.0 mi) east of the 200 East Area (Figure 3-14). The May Junction linear is roughly 3.5 km (2.2 mi) long and trends

north-northeast. Subsequent seismic refraction and seismic reflection lines were also used to examine the structure. The seismic refraction data could not determine whether the structure was fault-controlled, but results of seismic reflection surveys suggested a possible fault feature. The trend of the possible fault and other characteristics could not be determined from the seismic reflection data (DOE 1988). A sudden change in the top-of-basalt elevation contours occurs across the anomaly and the feature is currently interpreted to be a fault on the basis of the geologic and geophysical information. As discussed by Lindsey et al. (1992) and Delaney et al. (1991), the inferred fault is believed to affect Ringold Formation sediments but it is unclear whether younger sediments are truncated.

Seismic refraction surveys were used to investigate the faults identified in borehole DB-10, south of Gable Mountain (Section 3.4.3.1), but were not able to confirm the presence of these structures (DOE 1988). The refraction data did confirm the presence of a buried anticline in the borehole DB-10 area with a west-northwest to east-southeast orientation similar to the west anticline of Gable Mountain (DOE 1988). This structure would be approximately parallel to and northeast of the Willa anticline (Figure 3-14).

Other seismic refraction surveys in the central part of the Hanford Site and 200 East Area have been completed to determine depths to top of basalt and to delineate the structure and stratigraphy of the overlying unconsolidated sediments. The surveys generally have not been successful in characterizing potential faults and other structures within the basalts. Similarly, seismic reflection surveys in the vicinity of the 200 East Area have not been able to delineate bedrock structural features, and are complicated by difficulties in data processing and interpretation. Limited borehole geophysical logging (sonic, density, and gravity logs; and vertical seismic profiling) have mainly focused on the unconsolidated sediments or have not provided specific data about potential deeper faulting. As discussed in Section 3.4.1.3 low-magnitude earthquakes (up to about a magnitude of 2.0 to 3.0) in basalt have been recorded in the vicinity of the 200 East Area.

Conclusions regarding the structural integrity of the 200 East Area are probably similar to conclusions presented by DOE (1988) for the 200 West Area and vicinity (encompassing the BWIP reference repository location). For the 200 West Area, gravity and aeromagnetic data from previous studies indicated that the rock is not an evenly layered, homogenous mass. DOE (1988) concluded, however, that there is less geophysical variability in the 200 West Area than in adjacent structures such as the buried extension of Yakima Ridge to the west-southwest. DOE (1988) indicated that the 200 West Area and vicinity although probably not free of structures, contains smaller structures than the surrounding areas. Alternatively, the thickness of the unconsolidated sediments could conceivably mask potential structures.

3.4.3.4 Tectonic Brecciation and Shearing. As discussed by DOE (1988), field studies have identified tectonic brecciation and shear zones in basalt related to geologic structures in

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the Columbia River Basalt Group in the Pasco Basin and elsewhere. Tectonic breccias are attributed to localized fracturing of in-place rock in response to regional tectonic forces. Although undocumented, potential zones of the tectonic brecciation in the Saddle Mountains Basalt beneath the 200 East Area could, if present, represent significant structures for channeling groundwater flow. This is particularly so if potential brecciated zones are associated with larger fault structures such as those seen in borehole DB-10 (Figure 3-14), as discussed below. As discussed in Section 3.4.1.3 tectonic breccias may be associated with low-magnitude earthquakes (up to about a magnitude of 2.0 to 3.0) recorded at Coyote Rapids and Wooded Island.

In the thousands of feet of core drilled in the Columbia River Basalt Group flows of the Cold Creek syncline, zones of tectonic brecciation are relatively infrequent (DOE 1988). Where observed in core, brecciated zones are typically bounded by fracturing, resulting in a distinct demarcation between the zone and the surrounding intact rock. Breccia zones that do occur are most common in the Grande Ronde Basalt, followed by the Wanapum Basalt, and then the Saddle Mountains Basalt. The nearest occurrences to the 200 East Area of tectonic brecciation in the Saddle Mountains Basalt were observed in borehole DB-10 (Figure 3-14) (Pomona, Esquatzel, and Asotin Members), and are associated with the reverse faults discussed in Section 3.4.3.1. Tectonic brecciation was also noted in the Umatilla Member of the Saddle Mountains Basalt in borehole DB-11 [about 2 km (1.2 mi) west-northwest of the 200 West Area], and in borehole DC-12 [8 km (5.0 mi) south of the 200 East Area]. No breccia zones have been observed in the suprabasalt sediments, although a thin zone of slickensides, thought to be of tectonic origin, is present in the Ringold Formation in borehole DH-27 near the 200 West Area (DOE 1988).

Where they occur in boreholes in the Cold Creek syncline, tectonic breccias are similar in appearance to those observed in the gentle-dipping south limb of the Frenchman Hills anticline. This suggests that the breccias are not necessarily associated with areas of greatest deformation in a fold, and could possibly be related to other fault structures (DOE 1988). The repeated stratigraphic interval in borehole DB-10 is a candidate for such a fault, although similar repeats in section are not observed in adjacent boreholes. The magnitude of the feature in borehole DB-10 is therefore uncertain, but can indicate a potential conduit for intercommunication of the confined aquifers in the Ellensburg Formation sediments.

3.4.4 200 East Area Geology

The following sections describe the occurrence of the Saddle Mountains Basalt, Ellensburg Formation and suprabasalt sediments in the 200 East Area. The sections discuss notable stratigraphic characteristics, thickness variations, dip trends, and geometric relationships of the sediments. Stratigraphic variations pertinent to the 200 East Area are presented in the overall context of regional stratigraphic trends. Descriptions of the

suprabasalt units in Sections 3.4.4.4 through 3.4.4.7 are modified from Lindsey et al. (1992).

Geologic cross sections depicting the distribution of basalt and sedimentary units within or near the 200 East Area are presented on Figures 3-18 through 3-25. Figure 3-16 illustrates cross section locations, with a legend for symbols used provided on Figure 3-17. The cross sections are based on geologic information from wells shown on the figures as interpreted in Lindsey et al. (1992). To develop these stratigraphic interpretations, logs for wells and boreholes in the 200 East Area were reviewed and the most relevant logs were selected. Chamness et al. (1992a, 1992b, 1992c; Teel et al. 1992) provide a compilation of these geologic logs, a listing of other logs that are available, and additional geological, geochemical, and geophysical data available from these and other boreholes. This information was compiled as topical reports in support of the aggregate area management study reports for the PUREX Plant, B Plant, Semi-Works and 200 North Aggregate Areas. The cross sections depict subsurface geology in the 200 East Area. For each cross section, locations of pertinent source aggregate areas are identified for reference. Figures 3-26 through 3-40 present isopach maps depicting the thickness of the sedimentary units, and structure contour maps showing the elevation of the tops of each sedimentary unit and basalt. The structure contour and isopach maps are included from Lindsey et al. (1992).

Structure contours and isopach data on Figures 3-27 through 3-40 were extrapolated beyond actual known data points by incorporating the projected dip and change in unit thickness into the computer plotting routine. These dip and thickness data were based primarily on the projected orientation of the top of basalt, and assumed similar configuration of the suprabasalt sediments. On Figures 3-29 and 3-33, for example, Ringold Unit A and Unit E Gravels are shown as continuing to dip southward, beyond the south boundary of the 200 East Area (into the Cold Creek syncline) based on the continuous southward dip of the underlying basalt.

3.4.4.1 Saddle Mountains Basalt. During the 1970's and early- to mid-1980's, numerous boreholes were completed at the Hanford Site to characterize physical and chemical properties of the basalt bedrock and intervening sedimentary interbeds. The boreholes were completed in support of the BWIP and other Hanford Site programs. During review of the documents for the 200 East Groundwater Aggregate Area Management Study Report (AAMSR), specific data describing the thickness and stratigraphic characteristics of Saddle Mountains Basalt flows in the vicinity of the 200 East Area were found for boreholes DC-1/2, DDH-1, DB-5, DB-15, and DB-8. These boreholes are located up to about 1.6 km (1 mi) north, northeast, and east of the 200 East Area (Figure 3-14). The following discussion of Saddle Mountains Basalt stratigraphic and thickness characteristics near the 200 East Area is based primarily on borehole intercept data reported by Lindsey et al. (1992) and DOE (1988). For the 200 East Area itself, top-of-basalt elevation data were obtained from Connelly et al. (1992a) and thickness information for the Elephant Mountain flow was

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obtained from Reidel and Fecht (1981). No other information was found for the Saddle Mountains Basalt in the 200 East Area.

Near the 200 East Area, the Saddle Mountains Basalt consists of (from bottom to top) the Umatilla, Esquatzel, Pomona, and Elephant Mountain Members. With the exception of the Elephant Mountain Member, there is currently no indication of erosion or nondeposition of these flows between the 200 East Area and Gable Gap/Gable Butte. Near the 200 East Area, the entire Saddle Mountains Basalt/Ellensburg Formation interbeds package maintains a fairly uniform thickness of about 222 to 238 m (728 to 781 ft). Individual flows range in thickness from about 24 to 44 m (79 to 144 ft) for the Umatilla Member, 28 to 34 m (92 to 112 ft) for the Esquatzel Member, and 56 to 60 m (184 to 197 ft) for the Pomona Member. The Elephant Mountain Member thickens (where present) from about 21 m (69 ft) northwest of the 200 East Area to more than 36 m (118 ft) south of the area.

Figures 3-26 (Graham et al. 1984) and 3-27 (Connelly et al. 1992a) are isopach and top-of-basalt contour maps of the Elephant Mountain Member near the 200 East Area. The isopach map on Figure 3-26 shows the distribution of the upper and lower Elephant Mountain flow units (Section 3.4.2.1.1) and erosional areas. As shown on the map, the upper unit (Elephant Mountain flow) is present only in the extreme southeastern corner of the 200 East Area, and in the area to the east. The lower flow (Ward Gap flow) has been partially eroded over a northwest-southeast trending area extending from Gable Gap, to the area just east of the 200 East Area. Two areas are also identified on Figure 3-26 where the Elephant Mountain Member was identified or inferred by Graham et al. (1984) to be completely eroded. Much of the erosion occurred during deposition of the Ringold sediments and subsequent Pleistocene catastrophic flooding (Lindsey et al. 1992; Graham et al. 1984) (see Sections 3.1, 3.4.2.3, and 3.4.2.7). More recent interpretation of borehole information near the inferred erosional window at the northeastern corner of the 200 East Area has questioned the extent/existence of this feature, as illustrated by its absence on Figure 3-27. Also, Hoffmann et al. (1992) indicate that the northerly erosional window of the Elephant Mountain Member may be contiguous with the eroded area near Gable Gap to the north. Because of the relatively small number of deep boreholes north of the 200 East Area, the extent of the erosional windows are not clearly defined (Lindsey et al. 1992).

The areas of basalt erosion near Gable Gap and to the southeast are significant because they represent locations of potential aquifer intercommunication between the upper sedimentary interbeds of the Ellensburg Formation, and the uppermost aquifer system. Graham et al. (1984) present evidence for intercommunication between the unconfined groundwater system and groundwater from the Rattlesnake Ridge interbed of the Ellensburg Formation in this area (see Section 3.5.2). The Rattlesnake Ridge interbed lies directly below the Elephant Mountain Member (Section 3.4.2.2). In the Gable Gap area (Figure 3-14) erosion has cut down to the Umatilla Member, exposing the Rattlesnake Ridge, Selah,

and Cold Creek interbeds of the Ellensburg Formation (Section 3.4.2.2). The interbeds in this area are in hydraulic communication with the unconfined system in this area.

3.4.4.2 Ellensburg Formation. Near the 200 East Area, thickness data for the sedimentary interbeds of the Ellensburg Formation were reported by Myers and Price (1981) for boreholes DC-1/2, DDH-1, DB-5, DB-15, and DB-8 (Figure 3-14). Additional thickness information was available for the Rattlesnake Ridge interbed from Lindsey et al. (1992) for the 200 East Area and adjacent areas. Reported thicknesses of the interbeds ranged from 30 to 36 m (98 to 118 ft) for the Mabton interbed, 28 to 29 m (93 to 95 ft) for the Umatilla-Esquatzel interval of the Cold Creek interbed (where present), 5.5 to 6.7 m (18 to 22 ft) for the Selah interbed, and about 6.1 in the north to about 24 m in the south (20 to 79 ft) for the Rattlesnake Ridge interbed. The Umatilla-Esquatzel interval becomes the Umatilla-Asotin interval where the Asotin Member of the Saddle Mountains Basalt is present northeast of the 200 East Area (boreholes DB-5, DDH-1, DB-15 and beyond).

3.4.4.3 Ringold Formation. Within the 200 East Area, the Ringold Formation includes the fluvial gravels of unit A, the paleosol and lacustrine muds of the lower mud sequence, the fluvial gravels of unit E, and localized occurrences of fluvial gravels of unit C and sand and minor muds of the upper unit. Ringold strata are found throughout the southern two-thirds of the 200 East Area and overlie the basalt bedrock of the Elephant Mountain Member. Ringold units B and D are not found in the immediate vicinity of the 200 East Area.

The deepest Ringold unit in the 200 East Area, the fluvial gravels of unit A, thicken and dip to the south and southwest toward the axis of the Cold Creek syncline (Figures 3-28 and 3-29) although the southward dip indicated in the southern portion of Figure 3-29 is not controlled by well data. The top of the unit is a relatively flat surface that dips to the south into the Cold Creek syncline. Unit A generally pinches out in the central part of the area against structural highs in the underlying basalt. Thin, lenticular occurrences of unit A are found locally in the area between the northeast 200 East Area and Gable Mountain. Most of the Ringold gravels encountered in the central part of the 200 East Area probably belong to unit A (Lindsey et al. 1992). Intercalated lenticular sand and silt of the fluvial sand and overbank facies associations are found locally in the middle part of the unit A gravels in the southeastern part of the area. The Ringold unit A ranges in thickness from zero in the northern half of the 200 East Area, to 35 m (115 ft) or more east of the PUREX Plant Aggregate Area.

The overbank and lacustrine deposits of the lower mud sequence thicken and dip to the south and southwest in a manner similar to the Ringold unit A gravels (Figures 3-30 and 3-31). Within the central part of the 200 East Area the lower mud sequence is largely absent. Unlike the Ringold unit A gravels, the line along which the lower mud sequence pinches out is very irregular, and the nature of the pinchout varies from location to location. At some locations the lower mud sequence pinches out laterally against uplifted basalt, while at other

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locations the sequence is truncated by overlying Ringold unit E gravels or Hanford formation sediments (Figures 3-21, 3-22, and 3-25). In the area between Gable Mountain and the 200 East Area, and in the vicinity of the 216-B-3 Pond System, the lower mud sequence forms the uppermost part of the Ringold Formation and is overlain by the Hanford formation (e.g., Figures 3-18 and 3-19). Throughout the rest of the 200 East Area the lower mud sequence is overlain by the gravels of Ringold unit E. The lower mud sequence ranges in thickness from zero m along the pinchout line to more than 29 m (95 ft) south of the 200 East Area and south of the Gable Mountain Pond.

Fluvial gravels of Ringold unit E thicken to the south and southwest in the 200 East Area (Figure 3-32). The unit E gravels are largely restricted to the southern part of the 200 East Area, and are absent in the 216-B-3 Pond area and between the 200 East Area and Gable Mountain. The structure contour map for the top of unit E (Figure 3-33) shows a rise in the upper surface of the unit south of the 200 East Area, but this is an artifact of the computer contouring routine due to lack of data in that area (Connelly et al. 1992a). The top of the unit probably does not exceed an elevation of 140 m msl. Based on the stratigraphic relationships shown on the geologic cross sections on Figures 3-18 through 3-25, most of the Ringold gravels encountered beneath the central part of the 200 East Area are part of gravel unit A and not gravel unit E. In addition to gravelly sediments, strata typical of the Ringold fluvial sand and overbank facies associations may be encountered locally. However, predicting where these intercalated lithologies will occur is difficult. Maximum measured thickness of the unit E gravels in the vicinity of 200 East Area reaches about 35 m (115 ft) south of the 200 East Aggregate Area.

The fluvial gravels of Ringold unit C, and the overbank-dominated deposits of the upper unit have been identified near the southeast corner of the 200 East Area in borehole 699-37-43 (Figure 3-18). These units pinch out immediately north and west of the borehole, but thicken to the south-southwest into the Cold Creek syncline.

A contour map of the top of the Ringold Formation (pre-Hanford formation paleogeographic surface) is presented in Figure 3-34. The figure illustrates the complex nature of the pinchout of the Ringold unit A gravels, unit E gravels, and the lower mud sequence as discussed above. In the southwestern corner of the 200 East Area, and west and south of the 200 East Area, the unit E gravels form the top of the Ringold Formation. Within the central part of the 200 East Area, the unit E gravels pinch out and unit A gravels form the top of the Ringold Formation. The unit A gravels subsequently pinch out south of the northern boundary of the 200 East Area. The lower mud unit forms the top of the Ringold Formation east and northeast of the 200 East Area before pinching out irregularly.

3.4.4.4 Plio-Pleistocene Unit and Early "Palouse" Soil. The Plio-Pleistocene unit and early "Palouse" soil are not found within or near the 200 East Area. They are encountered

only in the vicinity of the 200 West Area approximately 5 km (3 mi) west of the 200 East Area.

3.4.4.5 Hanford Formation. In the 200 East Area, cataclysmic flood deposits of the Hanford formation overlie the Ringold Formation in the southern two-thirds of the area, but overly basalt bedrock directly in the northern third of the area where the Ringold Formation is absent. As discussed in Section 3.4.2, the Hanford formation is divided into three facies: (1) gravel-dominated, (2) sand-dominated, and (3) the silt-dominated facies. Typical lithologic successions consist of fining upwards packages, major fine-grained intervals, and laterally persistent coarse-grained sequences. Mineralogic and geochemical data were not used in differentiating units because of the lack of a comprehensive mineralogic and geochemical data set. Because of the variability of Hanford deposits, definition of stratigraphic sequences is arbitrary and lithologic contacts can be gradational.

The Hanford formation includes three stratigraphic sequences composed mostly of the gravel-dominated and sand-dominated facies. The stratigraphic sequences are essentially the same units as defined by Last et al. (1989). None of the three sequences are continuous across the 200 East Area, and the sequences display marked changes in thickness and continuity. The sequences are also lithologically heterogeneous. Two of the stratigraphic sequences are dominated by the gravel-dominated facies, and are designated the upper and lower gravel units. The third sequence consists of deposits of the sand-dominated facies with lesser intercalated sediments from the gravel-dominated and silt-dominated facies. This sequence is designated the sandy sequence, and is situated between the upper and lower gravel sequences where present.

The lower gravel sequence is dominated by deposits typical of the gravel-dominated facies, with locally-intercalated intervals of the sand-dominated facies. The lower gravel sequence ranges in thickness from zero to 44 m (135 ft) and is found throughout much of the 200 East Area (Figures 3-35 and 3-36). However, the unit is notably absent in the east-central part of the 200 East Area and to the west. The sequence may be present northeast and northwest of the 200 East Area, but because of the absence of the sandy sequence that separates the lower from the upper coarse sequences it is impossible to determine the true extent of the lower coarse sequence. The upper contact of the lower coarse sequence is placed at the top of the first gravel interval exceeding a thickness of 6 m (20 ft) below the sand-dominated strata of the overlying sandy sequence.

The sandy sequence consists of a heterogenous mix of sands typical of the sand-dominated facies. The sandy sequence is differentiated from the upper and lower gravel sequences on the basis of greater sand content. Silts typical of the slackwater facies are present, but are less abundant. The sandy sequence pinches out north of the 200 East Area, but dips and thickens to 90 m (295 ft) or more west of the 200 East Area (Figures 3-37 and 3-38). The sandy sequence is dominated by the sand-dominated facies to the north, and the

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silt-dominated facies to the south. Gravels commonly occur as individual fragments and as interbeds (typical of the gravel facies), especially in the north. Thin, lenticular silty paleosols (1 to 2 m [3 to 6 ft] thick) with high carbonate concentrations have been found in the northern part of the 200 East Area (Hoffmann et al. 1992). The sandy sequence probably contains the greatest concentration of clastic dikes, and is laterally equivalent with the lower fine sequence of the Hanford formation in the 200 West Area (Lindsey et al. 1991). Where the sandy sequence pinches out north of the 200 East Area it commonly interfingers with gravels of the overlying and underlying gravel sequences. Where this occurs the contact separating the sandy sequence from the other intervals is arbitrary. The lower contact of the sandy sequence is placed at the top of the highest gravelly interval in the lower gravel sequence, and the upper contact is placed at the top of the highest thick, sand-dominated interval.

The upper gravel sequence of the Hanford formation consists of deposits typical of the gravel-dominated facies, with local occurrences of the sand-dominated facies. The sequence ranges in thickness up to 55 m (180 ft) or more north and possibly west of the 200 East Area. In the northern part of 200 East Area the upper gravel sequence forms an elongate, northwest- to southeast-oriented body. North of the 200 East Area the unit becomes indistinguishable with the lower gravel sequence of the Hanford formation (Figure 3-39). The upper gravel sequence thins markedly to about 4 m (13 ft) just north of the B Plant Aggregate Area, and is not present in the east-central portion of the 200 East Area.

An isopach map for the entire Hanford formation is presented on Figure 3-40. The map depicts the general thickening of the formation towards the axis of the Cold Creek syncline.

3.4.4.6 Surficial Deposits. Holocene-age surficial deposits in the 200 East Area are dominated by fine- to medium-grained to occasionally silty eolian sands. These deposits have been removed from much of the area by construction activities. Where the eolian sands are found they tend to consist of thin (<3 m) sheets that cover the ground. Dunes are not generally well developed within the 200 East Area.

3.5 HYDROGEOLOGY

The following sections discuss Pasco Basin and Hanford Site hydrogeology (Section 3.5.1) and 200 East Area hydrogeology (Section 3.5.2). Each section discusses hydrostratigraphic units of interest, hydraulic properties, groundwater recharge, groundwater flow, and vadose zone characteristics.

3.5.1 Pasco Basin and Hanford Site Hydrogeology

The hydrogeology of the Pasco Basin and Hanford Site is characterized by a multi-aquifer system that consists of four hydrogeological units that correspond to the upper three formations of the Columbia River Basalt Group (Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt) and the sediments overlying the Columbia River Basalt Group (Figure 3-41). The basalt aquifers are usually confined and occur in the sedimentary interbeds of the Ellensburg Formation and the basalt flow top and flow bottom zones adjacent to the sedimentary interbeds. The uppermost aquifer in most places consists of the sediments comprised of fluvial, lacustrine, and glaciofluvial sediments. The uppermost aquifer is generally unconfined but is also semiconfined and confined in parts of the 200 Areas. The uppermost aquifer is contained largely within the Ringold Formation and Hanford formation. Within the sediments, a vadose zone of variable thickness overlies the uppermost aquifer. Perched water zones were also identified in the vadose zone and are associated with carbonate-rich strata in the 200 West Area and lenticular silty paleosols in the 200 East Area.

The following sections describe hydrogeologic characteristics of the basalt aquifers, unconfined aquifer, vadose zone, and potential perching horizons (Sections 3.5.1.1 through 3.5.1.4). Discussions incorporate general geologic and hydrologic material from Lindsey et al. (1992), Connelly et al. (1992a), Delaney et al. (1991), and specific information from other documents referenced where appropriate. Hydraulic properties are summarized for these lithologies based on published aquifer testing data for the Hanford Site. Groundwater recharge and flow for the Pasco Basin and the Hanford Site are discussed in Sections 3.5.1.5 and 3.5.1.6, respectively.

3.5.1.1 Basalt Aquifers. A number of regionally extensive, confined water-bearing zones are associated with Saddle Mountains Basalt-Ellensburg Formation hydrogeologic unit. As discussed in Section 3.4.2.1, confined aquifers associated with these interbeds are included in this report because of the potential for downward contaminant migration from the unconfined aquifer.

From bottom to top, the Saddle Mountains Basalt hydrogeologic unit is comprised of seven basalt flows (Umatilla, Wilbur Creek, Asotin, Esquatzel, Pomona, Elephant Mountain, and Ice Harbor Members). The hydrogeologic unit also includes the intervening sedimentary interbeds of the Ellensburg Formation (Mabton, Cold Creek, Selah, Rattlesnake Ridge, and Levey interbeds). As discussed in Sections 3.4.2.1 and 3.4.2.2, the Wilbur Creek and Ice Harbor flows and the Levey interbed are not present over much of the Hanford Site, including the 200 East and 200 West Areas. The Asotin flow is not present in the western and south-central portions of the Hanford Site. Within the confined aquifers, groundwater flow primarily occurs within the permeable sedimentary interbeds of the Ellensburg Formation and to a lesser extent within the adjacent flow top and flow bottom zones of the basalt flow members.

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Beneath most of the Hanford Site, the Rattlesnake Ridge interbed is the uppermost confined aquifer and is separated from the overlying unconfined aquifer system by the Elephant Mountain Member of the Saddle Mountains Basalt. The Elephant Mountain Member thins and has been removed locally by erosion between the 200 East Area and Gable Mountain (Section 3.4.2.1.1). In these areas, the Rattlesnake Ridge interbed is in contact with, and is thus a part of, the uppermost aquifer. At Gable Gap, erosional downcutting has also exposed the Elephant Mountain, Selah, and Cold Creek interbeds (as discussed in Section 3.4.4.1), placing these interbeds in hydraulic communication with the unconfined aquifer.

With the exception of the Rattlesnake Ridge interbed, most of the reported hydraulic property data for the Ellensburg Formation were obtained in the vicinity of the 200 West Area in support of the BWIP. Reported hydraulic conductivities for the interbeds range from 2×10^{-8} to 2×10^{-4} m/s (6.0×10^{-3} to 30 ft/day) (Ledgerwood and Deju 1976; Strait and Mercer 1987). Many of the Rattlesnake Ridge conductivity values included in this range were obtained from testing north of the 200 East Area. Reported transmissivities for the Rattlesnake Ridge aquifer range from 3×10^{-8} to 4×10^{-3} m^2/s (3×10^{-3} to 1.2×10^{3} ft^2/day) (Graham et al. 1981; Graham et al. 1984; DOE 1988) and are summarized by Newcomer et al. (1992a).

Within individual basalt flows, zones of increased permeability may be associated with vesicles, rubble zones, and other intraflow structures (Graham et al. 1984; Gephart et al. 1979). A description of basalt intraflow structures is presented in Section 3.4.2.1.2. The vesicle and rubble zones are usually found at the top and bottom flow boundaries and generally contribute to the interbed permeability (Graham et al. 1984). Hydraulic properties related to fracture and interflow zones associated with the Elephant Mountain Member in the vicinity of the 200 East Area are discussed in Section 3.5.2.1.

In addition to intraflow structures, tectonic fractures and faults, if present, can also potentially contribute to increased permeability if these structures are not closed or filled with clay gouge-like materials. As discussed in Sections 3.4.2.1.2 and 3.4.3, a limited amount of fault and fracture information was available from geological and geophysical investigations reviewed for this report.

3.5.1.2 Uppermost Aquifer System. The uppermost regional aquifer in the Pasco Basin and the Hanford Site generally occurs within fluvial/lacustrine sediments of the Ringold Formation and glaciofluvial sands and gravels of the Hanford formation. The uppermost aquifer system primarily displays unconfined conditions but also exhibits locally confined or semiconfined conditions, although for ease of discussion it is referred to simply as the unconfined aquifer. Groundwater ranges from less than 0.3 m (1 ft) below ground surface near West Lake and the Columbia and Yakima Rivers to greater than 110 m (350 ft) in the central portion of the Cold Creek syncline. The saturated thickness of the unconfined aquifer

ranges from approximately 67 m (220 ft) in the 200 West Area to zero north of the 200 East Area. This is where the aquifer thins and laps onto basalt that extends upward to an elevation above the water table.

Semiconfined to confined conditions occur locally in the otherwise unconfined aquifer at the Hanford Site. Within the lower part of the aquifer, semiconfined to confined groundwater exists in the Ringold unit A gravels where the unit is overlain by fine-grained sediments of the Ringold lower mud sequence. In the 200 West Area, the thickness of the Ringold unit A semiconfined to confined zone ranges from 38 m (125 ft) or more in the southeastern portion of the area to zero where the unit A gravels and the lower mud sequence pinch out near the northern and northeastern portions of the area, respectively. The confining zone overlying unit A gravels is up to 30 m (100 ft) thick below the south-central part of the 200 West Area. Semiconfining and confining conditions in the 200 East Area are discussed in Section 3.5.2.1.

A second type of confining condition has been identified near the water table in the north-central part of the 200 West Area and at a location about 600 m (2,000 ft) north of the 200 West Area. At these areas, drilling has indicated that the water table is locally confined beneath carbonate-rich sediments in the Ringold unit E gravels. The condition is apparently associated with carbonate buildup on gravel fragments and in the sediment pore spaces. During drilling, boreholes penetrating this layer (possibly 0.5 m [1.5 ft]) thick or more) have subsequently encountered water that immediately rises about 2 to 3 m (6.5 to 10 ft) or more above the gravel layer. The water level typically falls below the elevation of the carbonate-rich layer as drilling progresses deeper. Borehole data describing the confining condition are preliminary and hydrologic testing of these zones has not been completed. The lateral persistence of the confining condition near the 200 West Area is currently uncertain. Additionally, local zones of the Ringold lower mud sequence in the 216-B-3 Pond area east of the 200 East Area form semiconfining layers above the uppermost aquifer, and a distinct unconfined aquifer is not present (Connelly et al. 1992a) (see Section 3.5.2.2).

Because the uppermost aquifer transports potential chemical and radionuclide contaminants, it is generally the most characterized hydrologic unit beneath the Hanford Site. Numerous wells have been installed in the unconfined aquifer to obtain groundwater elevation data, samples for chemical analyses, and aquifer properties data.

3.5.1.2.1 Hydraulic Properties/Unconfined Portion of Uppermost Aquifer. The following discussion summarizes hydraulic properties data for the unconfined portion of the uppermost aquifer at the Hanford Site. It is organized to first reference the sources of the data followed by the testing methods used to acquire the data. Methods of analysis are presented along with several factors, or assumptions, which affect the final value and this is followed by a discussion of differences between testing methods applied. Finally the ranges

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of estimated aquifer hydraulic conductivity, storativity, specific yield, and porosity are presented.

Table 3-1 presents a summary of Hanford Site hydraulic conductivities and transmissivities based on data reported by Newcomer et al. (1992a), Connelly et al. (1992a), Delaney et al. (1991), Bjornstad (1990), and Last et al. (1989). The Hanford Site data for the unconfined portion of the uppermost aquifer are broken out separately for the Ringold Formation and for the Hanford formation on Table 3-1. Most of the unconfined aquifer data for the Ringold Formation (unit E gravels) represents testing results for the 200 West Area. Delaney et al. (1991) and Last et al. (1989) report data that also includes testing results from other Hanford Site areas. For comparison, Table 3-1 presents a summary of hydraulic conductivities and transmissivities for the 200 East Area (and adjacent locations), using data primarily from Newcomer et al. (1992a), Swanson et al. (1992), Connelly et al. (1992a), and supplemented with data from Delaney et al. (1991) and Last et al. (1989). Because of the geologic variability associated with the uppermost aquifer in the 200 East Area, hydraulic data were not broken out separately for the Ringold Formation and Hanford formation by Newcomer et al. (1992a) and Connelly et al. (1992a), and these data are not summarized separately on Table 3-1. This approach is consistent with that used by Connelly et al. (1992a) during evaluation of the Newcomer et al. (1992a) and Swanson et al. (1992) data for the 200 East Area hydrogeologic model.

Hydraulic conductivity and transmissivity data presented on Table 3-1 represent information obtained from a variety of aquifer testing methods. Data reported by Newcomer et al. (1992b) includes field testing results from Last et al. (1989), Graham et al. (1981), PNL file data, and older pumping/recovery data for the 200 West Area. During preparation of the 200 West Area hydrogeologic model, Connelly et al. (1992b) incorporated the Newcomer et al. (1992b) data for the unconfined portion of the uppermost aquifer, supplemented by previously unpublished slug test data for the Ringold E gravels collected over the last several years. Hydraulic data reported by Bjornstad (1990) includes results from aquifer pump tests, laboratory permeameter testing (vertical hydraulic conductivities), and some re-analysis of the Last et al. (1989) data. Data reported by Newcomer et al. (1992a) for the 200 East Area includes results of pumping, recovery tests, and slug tests from Last et al. (1989), Graham et al. (1984), Graham et al. (1981), PNL and Westinghouse Hanford Company (WHC) file data, and a variety of other sources.

Results of aquifer testing at the Hanford Site and the interpretation of the Table 3-1 summary data depend on several factors. These factors include the location and depth of wells tested, type of geologic material tested, well screen interval and construction features, type of geologic material tested, and analytical/data reduction methods. Major factors affecting field testing results are the heterogeneity of the sediments within the screened interval and whether the well screen is only partially penetrating the aquifer. Most of the aquifer analysis methods assume a fully penetrating well screen and a homogenous, isotropic

aquifer (e.g., Theis or modified Theis analysis). Differing estimates of saturated aquifer thickness produce different estimates of hydraulic conductivity reported in the references cited in the previous paragraph. Additionally, aquifer tests conducted using clustered piezometers in the same borehole may not represent true aquifer responses because of potential hydraulic intercommunication of the tested zones. Intercommunication can occur if the sandpack material used to isolate each open interval provides a conduit for groundwater migration between the tested zones through the well annulus. Newcomer et al. (1992b) report intercommunication for some nested wells in the 200 West Area.

Differences in field testing methods produce variations in the data. In general, hydraulic properties obtained from aquifer recovery tests may be the most representative of the actual aquifer conditions because the well response is not affected by fluctuations in pumping rates. Slug testing may provide a conservatively low estimate of hydraulic conductivity because of the limited volume of the aquifer stressed during testing. The size of sand particles used for the well screen filter pack may also affect interpretation of slug tests. In recent evaluations of slug interference testing at the Hanford Site, Spane (1992) suggests, however, that slug tests with large head displacements monitored in observation wells 3 to 30 m (10 to 100 ft) away from the test well may provide representative estimates of hydraulic conductivity and specific yield.

Evaluation of the hydraulic properties for the unconfined portion of the uppermost aquifer at the Hanford Site indicates that higher hydraulic conductivities and transmissivities are generally associated with the Hanford formation. As presented on Table 3-1, Hanford formation conductivity values vary widely from about 2×10^{-3} to 7×10^{-2} m/s (500 to 20,300 ft/day) and transmissivities vary from about 2×10^{-2} to 0.6 m^2/s (14,000 to 594,000 ft^2/day). In comparison, conductivities for the Ringold unit E gravels vary from about 2×10^{-7} to 2×10^{-3} m/s (0.06 to 600 ft/day). Transmissivities in the Ringold gravels vary from about 2×10^{-5} to 5×10^{-2} m^2/s (20 to 51,000 ft^2/day).

Graham et al. (1981) evaluate other hydraulic properties for the uppermost aquifer for the Hanford Site and conclude that the ratio of horizontal to vertical hydraulic conductivity ranges between 13 and 16, primarily because of anisotropy in the sedimentary structure of the deposits. For wells completed just below the water table in the Hanford formation, Graham et al. (1981) report specific yield values ranging from 0.15 to 0.18, and a storativity value of 0.07. Graham et al. (1981) estimate that the effective porosity of the uppermost aquifer ranges from 10 to 30%. The lower value is reportedly more representative of the Ringold Formation, and the higher value is representative of the Hanford formation sediments.

3.5.1.3 Vadose Zone. The vadose zone at the Hanford Site is composed of several units, including: (1) Holocene surficial deposits such as loess, sand dunes, alluvium, and talus; (2) Hanford formation; (3) early "Palouse" soils; (4) Plio-Pleistocene unit; and (5) Ringold

Formation. The vadose zone beneath the Hanford Site ranges in thickness from approximately 0.3 m (1 ft) thick near West Lake to approximately 110 m (350 ft) thick west of the 200 East Area (Last et al. 1989). Variable surface topography and the variable elevation of the water table in the underlying unconfined aquifer causes this observed variation in vadose zone thickness.

At the Hanford Site, much of the existing moisture content and hydraulic properties data for the unsaturated zone have been obtained from borehole soil samples collected in the 200 East and 200 West Areas. Determining unsaturated hydraulic conductivities and other vadose zone hydraulic properties via direct measurement is generally expensive and impractical because of the inherent complexity of factors affecting groundwater flow through unsaturated soils. For this reason, much of the unsaturated hydraulic conductivity data have been derived using theoretical, computer-based modeling methods (Van Genuchten et al. 1991) in conjunction with measured soil moisture retention contents and saturated hydraulic conductivity data.

The following discussions summarize moisture content and unsaturated hydraulic conductivity data for the 200 West Area vadose zone sediments reported by Connelly et al. (1992b) and Bjornstad (1990). Much of this information was obtained as part of ongoing performance assessment activities for the 200 West Area low-level burial grounds. As discussed above, these data were generated via computer modeling techniques using measured soil moisture and saturated hydraulic conductivity data. Unsaturated hydraulic conductivities may vary by orders of magnitude with varying moisture contents and among differing lithologies with significantly different soil textures. Results for the 200 West Area samples are further discussed in the 200 West Groundwater AAMSR. Unsaturated moisture contents and hydraulic conductivity data for the 200 East Area are discussed in Section 3.5.2.1.3. Section 3.5.2.1.3 also includes a background discussion of vadose zone soil transport and the Van Genuchten et al. (1991) modeling approach for deriving unsaturated conductivities.

For the 200 West Area, reported unsaturated hydraulic conductivities for two samples collected from the Ringold unit E gravels ranged from about 10^{-13} to 10^{-10} m/s (3×10^{-8} to 3×10^{-5} ft/day) at a moisture content of 10% to 2×10^{-5} to 1×10^{-4} m/s (6 to 30 ft/day) at saturation (26 to 46%), respectively. Bjornstad (1990) indicates, however, that the sample with a moisture content of 26% at saturation may have been significantly compacted or cemented. Therefore, the sample with the higher saturated hydraulic conductivity may be more representative of the Ringold unit E gravels, but too few samples were available for comparison. For the upper Ringold unit, the predicted unsaturated conductivities generally ranged from about 10^{-12} to 10^{-6} m/s (3×10^{-7} to 3×10^{-1} ft/day) at a moisture content of 10% to about 10^{-6} to 10^{-5} m/s (0.3 to 3 ft/day) at moisture contents of 32 to 42% (saturation). One of the upper Ringold unit samples had a relatively high saturated hydraulic conductivity of 3.7×10^{-4} m/s (1.0×10^{2} ft/day; drying conditions), and may therefore represent

sediments transitional into the Ringold unit E gravels in the borehole where the sample was collected.

A high degree of variability is present for unsaturated hydraulic conductivities associated with samples of Plio-Pleistocene unit soils from the 200 West Area. This unit is hydrologically important because of the calcareous paleosols that could cause lateral spreading and perched water table development from downward percolating water (Section 3.5.1.4). At saturated water contents of 33 to 52%, hydraulic conductivities ranged from about 10^{-8} to 10^{-3} m/s (3×10^{-3} to 3×10^{2} ft/day; drying conditions). These variations are mainly attributable differences in grain size and the degree of cementation and compaction.

Connelly et al. (1992b) report unsaturated conductivity data for the early "Palouse" soils in the 200 West Area were limited to two samples consisting of fine sand and silt. Measured laboratory saturated hydraulic conductivities were in the range of 1×10^{-6} m/s (0.3 ft/day). Additional data points would be required to assess variability in the unit.

For the Hanford formation, reported hydraulic conductivity testing results for all but one of 13 samples collected were obtained from the coarse-grained gravel facies with the remaining sample collected from the fine-grained facies. The derived unsaturated conductivity values, and measured saturated hydraulic conductivity values varied widely. At saturation moisture contents ranging from 34 to 52%, measured saturated conductivities ranged from about 10^{-7} to 10^{-3} m/s (3×10^{-2} to 3×10^{2} ft/day). Particle size analyses of the samples tested by Bjornstad (1990) indicated that some of the samples were sand and silt rather than gravels. If these samples are eliminated, the range of saturated hydraulic conductivities (moisture contents of 40 to 50%) for the gravel facies is much smaller, 10^{-4} to 10^{-3} m/s (3×10 to 3×10^{2} ft/day). It should be noted that calculated unsaturated conductivities range over several orders of magnitude at lower moisture contents and that finer-grained facies may have higher conductivities than a coarse-grained facies, for the same moisture content. Hydraulic conductivity values reported by Bjornstad (1990) corresponding to volumetric water contents ranging from 2 to 10% typically range from 2×10^{-13} to 7×10^{-9} m/s (6×10^{-8} to 2×10^{-3} ft/day).

Additional data regarding vadose zone conductivities and other hydraulic properties were obtained during infiltration and recharge studies (including lysimeter studies) at the Hanford Site. These hydraulic properties are discussed in Section 3.5.1.5.

3.5.1.4 Perched Water Zones. Perched water zones form when moisture moving downward through the vadose zone accumulates on top of low permeability soil lenses, highly cemented horizons, or above the contact between a fine-grained horizon and an underlying coarse-grained horizon as a result of the "capillary barrier" effect. If sufficient moisture accumulates, the soil pore space in these perching zones may become saturated. In this case, the capillary pressure within the horizon may locally exceed atmospheric pressure,

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and a perched water table condition may develop. Additional input of downward percolating moisture to this horizon may cause a hydraulic head buildup above the top of the horizon. Consequently, a monitoring well screened within or above this horizon would be observed to contain free water.

The Plio-Pleistocene unit and early "Palouse" soil form potential perching horizons within the vadose zone in the vicinity of the 200 West Area. The Plio-Pleistocene unit, consisting of calcium-carbonate cemented silt, sand, and gravel, occurs at 12 to 61 m (40 to 200 ft) deep and is up to 9 m (30 ft) thick. The early "Palouse" soil horizon, consisting of loess-like silt and minor fine-grained sand, ranges from 12 to 46 m (40 to 150 ft) deep and is up to 12 m (40 ft) thick in the vicinity of the 200 West Area. Neither the Plio-Pleistocene unit nor the early "Palouse" soil is found in the 200 East Area, however, silty paleosols have been identified that may serve as perching horizons (Hoffmann et al. 1992).

3.5.1.5 Groundwater Recharge. Natural and artificial sources recharge the unconfined aquifer within the sedimentary rocks of the Pasco Basin. Rainfall and runoff within area of basalt outcrop along the margins of the Pasco Basin recharge the basalt aquifers as does downward groundwater movement from the overlying sediments, but a lesser extent. Downward groundwater movement is discussed in Section 3.5.1.6. The following sections discuss natural and artificial groundwater recharge.

3.5.1.5.1 Natural Groundwater Recharge. Rainfall and runoff from the higher bordering elevations, water infiltrating from small ephemeral streams, and river water along influent reaches of the Yakima and Columbia Rivers naturally recharge the uppermost aquifer system within the Pasco Basin. The principal source of recharge occurs along the periphery of the basin where precipitation runoff infiltrates to the water table (Graham et al. 1981). Small ephemeral streams draining the western slopes, such as Cold Creek and Dry Creek, lose water to the ground as they spread out on the valley plain. Water conducted in these streams is lost through both infiltration to the ground and evapotranspiration to the air. Most of the infiltrating water eventually percolates to the water table. Larger rivers either gain or lose water to the aquifer depending on the river stage, location, and groundwater flow direction. The Yakima River, for example, recharges the unconfined aquifer along its reach from Horn Rapids to Richland, Washington. Along the Columbia River, some river water is transferred during high stages to bank storage as groundwater. Some of this bank storage may recharge the aquifer, but the rest will flow back into the river when the stage drops.

The Cold Creek and Dry Creek valleys to the west of the 200 West Area naturally recharge the unconfined aquifer. Gee (1987) reported that natural recharge to the 200 West Area is approximately 130,000 L/yr (34,000 gal/yr). Further discussion is presented in Section 3.5.2.2.1.

Natural precipitation infiltration at or near waste management units or unplanned releases may provide a driving force for mobilizing contaminants previously introduced to surface or subsurface soils. For this reason, many previous investigations focus on determining precipitation recharge rates at the Hanford Site. Previous field programs were designed to assess precipitation, infiltration, water storage changes, and evaporation to evaluate the natural water balance during the recharge process. Precipitation recharge values ranging from zero to 10 cm/yr (4 in./yr) are estimated from various studies.

The primary factors affecting precipitation recharge appear to be surface soil type, vegetation type, topography, and spatial and temporal variations in seasonal precipitation. In general, infiltration to soils is higher in the winter when precipitation is more frequent and evapotranspiration is low. Examples of precipitation recharge studies at the Hanford Site, and some of the conclusions reached, are given below:

- Gee and Heller (1985) describe various models used to estimate natural recharge rates. Many of the models use a water retention relationship for the soil. This is the relation between soil moisture content and the suction required to remove (or move) the moisture. Gee and Heller (1985) developed two of these models for soils in lysimeters on the Hanford Site. As an example of available data, the particle size distribution and the water retention curves of these two soils are shown on Figure 3-42. Additional data and information about possible models for unsaturated flow may be found in Brownell et al. (1975) and Rockhold et al. (1990).

- Moisture contents were obtained from a number of core-barrel samples in the 200 Areas (East and West) and varied from 1 to 18% (by weight), with most samples in the range of 2 to 6% (Last et al. 1989). The data appear to indicate zones of increased moisture content that can be interpreted as signs of moisture transport. Also, during monitoring well drilling near 200 West Area single-shell tanks, measured moisture contents in silty sediments have been as high 26 to 28% (by weight). The high moisture contents indicate local saturation or near-saturation in vadose zone sediments.

- Gee (1987) describes results of lysimeter studies and indicates greater soil moisture infiltration is associated with winter and early spring precipitation and runoff.

- Routson and Johnson (1990) describe a lysimeter study conducted at a location 1.6 km (1 mi) south of the 200 East Area. During much of the lysimeter's 13-year study period between 1972 and 1985, the ground surface above the lysimeter was kept unvegetated by using herbicides. No information regarding the soil types in which the lysimeter was installed is provided. To a precision of

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± 0.2 cm (0.08 in.), no downward moisture movement was observed in the instruments during periodic neutron-moisture measurements or as a conclusion of a final soil sample collection and moisture content analysis episode.

- Rockhold et al. (1990) also report on a weighing lysimeter study conducted at a grassy plot approximately 5 km (3 mi) northwest of the 300 Areas. The grassy test site was located in a broad, shallow topographic depression approximately 900 m (2,953 ft) wide, several hundred meters long, trending southwest. The area is covered with annual grasses (i.e., cheatgrass and bluegrass). The upper 3.5 m (11.5 ft) of the soil profile consist of slightly silty to silty sand (sandy loam) with an estimated saturated hydraulic conductivity of 9×10^{-5} m/s. Rockhold et al. (1990) estimate that approximately 0.8 cm (0.3 in.) of downward moisture movement occurred between July 1987 and June 1988. This represents approximately 7% of the total precipitation recorded in that area during that period.

- Fayer and Jones (1990) developed the computer model UNSAT-H to simulate the infiltration of recharge through typical Hanford vadose zone soils. To date, however, the model has been used only for very location-specific studies rather than the Hanford Site or the 200 Areas as a whole.

- Rockhold et al. (1990) discuss a gravel-covered lysimeter study conducted at the 622 Area Lysimeter Site, approximately 0.5 km (0.3 mi) east of the 200 West Area. Approximately 4 cm (1.6 in.) of downward moisture movement was observed in two gravel-covered lysimeters during 1988 and 1989. This represented approximately 25% of the total precipitation recorded in the area during the study period. The authors conclude that gravel placed on the soil surface reduces evaporation and facilitates precipitation infiltration.

- Smoot et al. (1989) conducted a modeling analysis and indicate that 68 to 86% of the precipitation falling on a gravel-covered site might infiltrate to a depth greater than 2 m (6 ft).

Smoot et al. (1989) present an example of the potential use of this vadose zone hydraulic parameter information in which precipitation infiltration and subsequent contaminant plume movement near a prototype single-shell tank was evaluated using a numerical computer code. Smoot et al. (1989) used the UNSAT-H computer code to predict the precipitation infiltration for several different soil horizon combinations and characteristics. The researchers used statistically generated precipitation values based on actual daily precipitation values recorded at the Hanford Site between 1947 and 1989 to simulate precipitation infiltration from January 1947 to December 2020. The same authors

also used the PORFLO-3 computer code to simulate ^{106}Ru and ^{137}Cs movement through the unsaturated zone.

3.5.1.5.2 Artificial Groundwater Recharge. Artificial recharge to the groundwater in the Pasco Basin comes from two sources: agricultural irrigation and liquid waste disposal operations on the Hanford Site. Agricultural land on the eastern and northern sides of the Columbia River and in the Cold Creek valley to the west of the Hanford Site is currently irrigated; however, the volume of irrigation water used has not been quantified. Possibly as much as 40% of this irrigation water reaches the water table (U.S. Bureau of Reclamation 1971).

Hanford liquid waste disposal practices artificially recharge mainly the 200 East and West Areas. Graham et al. (1981) estimate that historical artificial recharge from liquid waste disposal in the separations areas exceeded all natural recharge on the Hanford Site by a factor of ten. Zimmerman et al. (1986) report that between 1943 and 1980, 6.33×10^{11} L (1.7×10^{11} gal) of liquid wastes were discharged to the soil column in the 200 Areas. Artificial recharge is further discussed in Section 3.5.2.2.2. Potential recharge to the Rattlesnake Ridge confined aquifer is presented in Section 3.5.1.6.2.

3.5.1.6 Regional Groundwater Flow. Groundwater flow beneath the 200 East Area is affected by regional groundwater flow conditions. This section describes regional and Hanford Site groundwater flow patterns for the uppermost aquifer and basalt aquifers.

3.5.1.6.1 Unconfined Aquifer. The areal pattern of groundwater flow for the past and present in the uppermost aquifer can be determined from potentiometric surface maps presented on Figures 3-43 and 3-44. Areas of varying hydraulic conductivity in the sedimentary strata may cause localized deflection of groundwater flow from the general pattern shown on the figures.

Natural groundwater inflow to the unconfined aquifer primarily occurs along the western boundary of the Hanford Site. In the past, groundwater flow across the Hanford Site in the unconfined aquifer generally moved toward the east-northeast, although flow north of Gable Mountain was more to the north. Figure 3-43 is a hindcast map of the 1944 groundwater table, i.e., estimated from relatively few data points and estimates of flow. The uppermost aquifer ultimately discharges to the Columbia River, either near the 100 Areas, north of the 200 Areas through Gable Gap, or between the 100 Areas and the 300 Area, east of the 200 Areas.

Groundwater flow north of Gable Mountain now trends in a more northeasterly direction as a result of mounding in the 100 Areas and flow through Gable Gap. Figure 3-44 is a June 1991 groundwater table map for the Hanford Site. South of Gable Mountain, flow is interrupted locally by the groundwater mounds in the 200 Areas. Groundwater flow

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directions are affected to a large degree by wastewater discharge and groundwater mounding in the 200 East Area (Delaney et al. 1991). During periods of increased recharge from the 200 East Area, more of the recharge from the 200 West Area is diverted north through Gable Gap toward the 100 Areas. There is also a component of groundwater flow to the north between Yakima Ridge and Gable Butte from the 200 Areas. Because disposal of liquid waste to the soil column operations will continue to be reduced in the 1990's, this reduction in artificial recharge at the Hanford Site will continue a gradual reversion back toward natural conditions in the regional groundwater flow pattern. Because of increased irrigation in the Pasco Basin, the flow pattern will probably never match the 1944 flow pattern (Figure 3-43), but the flow direction may roughly approach previous flow directions.

Graham et al. (1981) calculate horizontal hydraulic gradients for the 200 West Area of 0.004 to 0.015 for data collected in December 1979. Before operations at the Hanford Site began in 1944, the hydraulic gradient in all but the southwestern-most portion of the Hanford Site was approximately 0.001 (5 ft/mi). These data indicate an overall increase in gradients across the site. The largest increase is in the vicinity of the groundwater mounds below the 200 Areas. Graham et al. (1981) estimate that vertical hydraulic gradients in the unconfined aquifer exceed 10% in some areas; however, these authors did not specify specific areas. Information on gradients and flow velocities is presented in Section 3.5.2.3.1.

3.5.1.6.2 Basalt Aquifers. Lateral groundwater movement within the Saddle Mountains Basalt hydrogeologic unit occurs from upland recharge areas along the periphery of the Pasco Basin and along anticlinal ridges to discharge areas along the Columbia River. A potentiometric surface map of the basalt aquifers is discussed in Section 3.5.2.3.3.

3.5.1.6.3 Unconfined/Basalt Aquifer Interconnection. Erosional windows through Saddle Mountains Basalt flows, areas of basalt nondeposition, or poor groundwater well seals may allow communication between the uppermost aquifer system and underlying confined aquifers (Ledgerwood and Deju 1976; Graham et al. 1984). Also, basalt intraflow structures or fractures could potentially serve as interconnections (Section 3.4.2.1.2).

In zones of potential intercommunication, contaminants could be transported from the shallow unconfined aquifer to deeper water bearing zones via advective transport or density-driven plumes. Downward gradients in erosional window areas, for example, could promote recharge to the deeper formations. Deju and Fecht (1979) and DOE (1988) present data indicating that overall potentiometric head decreases with depth in the Saddle Mountains Basalt causing downward gradients. Gradients in the Saddle Mountains Basalt, which are in contact with the overlying sediments, are believed to have been upward before the start of wastewater disposal (DOE 1988), but subsequently may have been reversed to a downward gradient (Graham et al. 1984; DOE 1988).

The interconnection of the unconfined aquifer and the Rattlesnake Ridge aquifer between the 200 East Area and Gable Gap/Gable Mountain is discussed in Section 3.5.2.3.2.

3.5.2 200 East Area Hydrogeology

Sections 3.5.2.1.1 through 3.5.2.1.4 describe the hydrogeologic characteristics of the basalt aquifers, unconfined aquifer, and vadose zone sediments in the 200 East Area. Sections 3.5.2.2 and 3.5.2.3 describe 200 East Area groundwater recharge and flow, respectively.

3.5.2.1 200 East Area Hydrostratigraphy. The primary hydrostratigraphic units in the 200 East Area are (1) the Rattlesnake Ridge interbed and deeper interbeds of the Ellensburg Formation (confined water-bearing zones); (2) the Elephant Mountain Member and deeper flows of the Saddle Mountains Basalt (confining horizons with local interflow zones); (3) the Ringold Formation (locally semiconfined to confined water-bearing zones in unit A gravels beneath the lower mud sequence, and unconfined aquifer in unit A and unit E gravels); and (4) the Hanford formation (unconfined aquifer and vadose zone sediments). The hydrogeologic designations for the 200 East Area were determined by reviewing borehole and well data summaries from Chamness et al. (1992a through 1992c) and Teel et al. (1992) and integrating these data with hydrostratigraphic data from Connelly et al. (1992a), Lindsey et al. (1992), and Hoffmann et al. (1992). Figure 3-45 summarizes hydrogeologic units identified in the 200 East Area.

3.5.2.1.1 Basalt Aquifers. Regionally confined aquifers exist within the Saddle Mountains Basalt-Ellensburg Formation hydrostratigraphic unit in the 200 East Area. From bottom to top, the confined water-bearing zones occur within the Mabton, Cold Creek, Selah, and Rattlesnake Ridge interbeds of the Ellensburg Formation, and associated Saddle Mountains Basalt flow tops/bottoms. The Wilbur Creek, Asotin, and Ice Harbor flows and the Levey interbed are not present in the 200 East Area (Section 3.4.2).

The uppermost regionally confined aquifer in the vicinity of the 200 East Area is generally contained in the Rattlesnake Ridge interbed of the Ellensburg Formation. The Rattlesnake Ridge interbed is confined on the top and bottom by the Elephant Mountain and Pomona Members of the Saddle Mountains Basalt, respectively. Where the Elephant Mountain Basalt is locally eroded north of the 200 East Area (Figures 3-27 and 3-28), the Rattlesnake Ridge interbed is in contact with the unconfined aquifer, and the uppermost confined aquifer is located in the Selah interbed. Transmissivity data for the Rattlesnake Ridge aquifer have been obtained from wells tested in the vicinity of the 200 East Area and are summarized by Newcomer et al. (1992c). The reported data were obtained from Graham et al. (1984), Strait and Moore (1982), Westinghouse Hanford files, and other sources since about 1981. Reported transmissivities range from 3×10^{-6} to 2×10^{-3} m^2/s (3 to 1,540

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ft^2/day). Many of the values are in the 1 x 10^{-4} to 1 x 10^{-3} m^2/s (100 to 1,000 ft^2/day) range.

An additional confined aquifer is associated with Elephant Mountain Basalt in the vicinity of the 200 East Area (Jensen 1987; Graham et al. 1984; Gephart et al. 1979). As discussed in Section 3.4.3.1, the Elephant Mountain Member is composed of separate upper and lower flows over part of this area (Figure 3-26). The figure shows that the lower flow (Ward Gap flow) is present only in the south eastern corner of the 200 East Area and the areas to the south and east. Where both flow units are present, a groundwater interflow zone consisting of sands and clays occurs between the upper and lower flows (Jensen 1987). Graham et al. (1984) describe the interflow zone as containing interconnecting vesicles and rubble. The interflow zone is referred to as the Elephant Mountain aquifer (Jensen 1987) but is not regionally extensive. As further discussed by Jensen (1987) and Graham et al. (1984), the Elephant Mountain aquifer is in contact with the unconfined aquifer in the northeastern corner of the 200 East Area where the lower Elephant Mountain flow is absent. The Elephant Mountain aquifer probably discharges to the unconfined aquifer, but it may be locally influenced by the groundwater mound under 216-B-3 Pond (Graham et al. 1984).

For the Elephant Mountain aquifer, Graham et al. (1981) reported a hydraulic conductivity of 622 m/day (190 ft/day). The aquifer reportedly exhibits higher transmissivities (8 x 10^{-6} to 7 x 10^{-3} m^2/s [7.5 to 6,120 ft^2/day]) than the bounding flows (Graham et al. 1984). Graham et al. (1984) also report a range of hydraulic conductivities of 10^{-7} to 10^{-3} m/day (3 x 10^{-3} to 3 x 10^{3} ft/day) for the flow top of the upper Elephant Mountain flow (Elephant Mountain II unit). In contrast, Deju and Fecht (1979) reported a hydraulic conductivity value for fractured zones within Saddle Mountains Basalt flow interiors of 1 x 10^{-7} m/s (3 x 10^{-2} ft/day).

3.5.2.1.2 Uppermost Aquifer System. The following discussion addresses the uppermost aquifer system that primarily is comprised of the unconfined aquifer but also includes localized semiconfined and confined areas. In contrast to the 200 West Area, hydrostratigraphic relationships associated with the unconfined aquifer in the vicinity of the 200 East Area are relatively complex because of the depositional and erosional history of the geologic units. The following discussions of 200 East Area hydrostratigraphy and hydraulic properties are modified from Connelly et al. (1992a). As discussed by Connelly et al. (1992a), the unconfined aquifer in the vicinity of the 200 East Area occurs primarily within sediments of the Ringold Formation and Hanford formation. In areas north of the 200 East Area where the Elephant Mountain flow has been eroded, the Rattlesnake Ridge interbed is also included in the unconfined aquifer system. The base of the unconfined aquifer is the Ringold lower mud unit where the latter unit is present in the southern and eastern portions of the 200 East Area (Figure 3-31). North of the 200 East Area, the unconfined system extends down to the top of the Elephant Mountain flow, or to the top of the Pomona flow where the Elephant Mountain flow has been eroded. As discussed in Sections 3.4.4.1 and

3.5.1.1, the unconfined system extends to the Umatilla flow near Gable Gap due to erosion of the overlying flows. In this area the unconfined aquifer is in hydraulic communication with the confined aquifers of the Ellensburg Formation interbeds. The thickness of the uppermost aquifer system varies considerably from near zero in the northern and northeastern portions of the area where basalt bedrock extends above the water table to more than 80 m to the south (Figure 3-46). A distinct unconfined system does not exist where the fine-grained sediments of the Ringold lower mud unit forms a semiconfining to confining layer above the uppermost aquifer near the 216-B-3 Pond.

Within the central part of the 200 East Area, the water table is located within the Ringold unit A gravels. This area coincides with locations where the fine-grained sediments of the Ringold lower mud sequence are not present to act as confining layer. In the southern part of the 200 East Area, the water table intersects gravelly sediments of Ringold unit E and the Hanford formation. The water table is near the contact of the Ringold Formation and Hanford formation beneath the central and southern portions of the 200 East Area. South and west of the 200 East Area the water table is present in the Ringold unit E gravels. In the northern part of the 200 East Area and in the area between the 200 East Area and Gable Gap/Gable Mountain, the water table generally lies within gravelly and sandy sediments of the Hanford formation, except in areas where basalt bedrock extends above the water table.

Figure 3-48 (Connelly et al. 1992a) represents the uppermost aquifer system. Connelly et al. report that information obtained from drilling and well installation near 216-B-3 Pond indicates that the unconfined aquifer is absent in this area. This condition can be described by comparing December 1991 water table elevations in the 200 East Area, shown on Figure 3-49, with top-of-unit elevations for the Ringold lower mud sequence shown on Figure 3-31. This comparison indicates that the water table and the top of the lower mud sequence nearly coincide in this area, and each have elevations varying between about 125 and 128 m (410 and 420 ft) above msl. In the 216-B-3 Pond area, the Ringold lower mud sequence appears to have little moisture, and water generally is not encountered during drilling until the underlying saturated gravels are encountered. The potentiometric surface for the gravels is approximately even with the top of the lower mud sequence because of locally confining conditions. The water table elevations therefore represent, in part, the potentiometric surface associated with semiconfined to confined groundwater in the Ringold lower mud sequence/unit A gravels. It is also possible that during periods of increased groundwater recharge from the 216-B-3 Pond System, mounded groundwater could extend above the upper surface of lower mud sequence and create a perched condition above the lower mud sequence. A similar condition may exist in the west-central part of the 200 East Area where Figure 3-31 shows the top of the lower mud sequence possibly extending above the 123 m (405 ft) groundwater table elevation. The lower mud unit elevation contours are based on limited borehole intercept data in this area however, and were extrapolated from known elevations below the water table.

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Hydraulic conductivity and transmissivity data for the unconfined aquifer in the 200 East Area are presented on Table 3-1. As discussed in Section 3.5.1.2, the transmissivity data are summarized primarily from Newcomer et al. (1992a), Swanson et al. (1992), and Connelly et al. (1992a). Additional transmissivity and hydraulic conductivity were reported for the 200 East Area by Delaney et al. (1991) and Last et al. (1989). The data are not summarized for individual geologic units due to the stratigraphic complexity of the unconfined system. Wide ranges of hydraulic conductivities [5×10^{-5} to 9×10^{-2} m/s (15 to 2,500 ft/day)] and transmissivities [9×10^{-7} to 0.7 m^2/s (0.9 to 670,000 ft^2/day)] were reported. For aquifer tests where transmissivity was the determined property reported by Newcomer et al. (1992a) and Swanson et al. (1992), equivalent hydraulic conductivities were derived by Connelly et al. (1992a) by dividing the reported transmissivity value by the thickness of the tested interval. Other factors affecting results of aquifer tests and interpretation of the data derived are discussed in Section 3.5.1.2. The original data tables from Newcomer et al. (1992a) and Connelly et al. (1992a) for the 200 East Area are provided as Appendix A Tables A-8 and A-9 of this report.

Using aquifer testing results from Newcomer et al. (1992a) and Swanson et al. (1992), Connelly et al. (1992a) prepared a hydraulic conductivity contour map for the 200 East Area (Figure 3-50). The map represents aquifer pump testing results (constant discharge tests) from wells installed in the shallow portion of the uppermost aquifer. As reported by Connelly et al. (1992a), the aquifer test results were predominantly analyzed by using the Cooper-Jacob straight line method. Connelly et al. (1992a) examined hydraulic conductivities derived from instantaneous injection/withdrawal tests for the study area but discarded them because values appeared to be "much lower" when compared to the pumping test data. Connelly et al. (1992a) lists several shortcomings of the injection/withdrawal test method as reasons for the lower values of the data. They include: (1) the limited areal extent of the test; (2) potential sandpack influences; (3) limited stress applied to the aquifer; (4) difficulty of obtaining a complete data set in quick response formations; and (5) the relatively low values of transmissivity for which the tests are interpretable. Connelly et al. (1992a) state that an attempt to incorporate slug test data into the hydraulic conductivity contour map produced a map that did not conform to the general hydrostratigraphic knowledge of the area. Therefore the data were excluded. Additional criteria for the exclusion of the injection withdrawal test results (based on magnitude) were not provided.

In general, the distribution of hydraulic conductivities on Figure 3-50 compares reasonably well with area geology depicted on Figure 3-47. Two high conductivity zones of about 0.03 m/s (10,000 ft/day) or greater are apparent on Figure 3-50. One of the zones extends from the north-central portion of the 200 East Area to the southeast. The second area is located between Gable Mountain and the prominent basalt subcrop area above the water table north of the 200 East Area. These higher conductivity areas are generally associated with the relatively permeable deposits of the Ringold unit A gravels and the Hanford formation. Conversely, lower conductivity values [about 30 m/day (100 ft/day) or

less] are present west and southwest of the 200 East Area in generally less-permeable Ringold E gravels. Near the southwestern corner of the 200 East Area, however, the low hydraulic conductivity values coincide with an area of Hanford gravels. Connelly et al. (1992a) indicate that Hanford deposits are thin in the latter area, and that tested interval is actually more representative of the less permeable Ringold unit E gravels.

3.5.2.1.3 Vadose Zone. In the vicinity of the 200 East Area, the vadose zone units primarily include the Ringold gravel unit A through the central and southern portions of the area and the Ringold lower mud unit to the east near 216-B-3 Pond. Because of the discontinuous nature of the Ringold Formation north of the central part of the 200 East Area, the vadose zone is dominantly comprised of Hanford formation sediments between the 200 East Area and Gable Mountain/Gable Gap. Areas of basalt outcrop above the water table north of the 200 East Area are also included in the vadose zone, as are sediments of the Ringold lower mud sequence in the 216-B-3 Pond area where the latter unit forms a semiconfining to confining layer above the uppermost aquifer.

The vadose zone beneath the 200 East Area ranges from about 104 m (317 ft) thick along the southern part of the eastern PUREX Plant Aggregate Area boundary to 37 m (123 ft) thick in the vicinity of the 216-B-3C Pond, based on December 1991 groundwater elevation levels (Figure 3-51). The observed variation in vadose zone thickness is the result of variations in both surface topography and elevation of the water table. As discussed in Section 3.5.2.1.2, the depth to groundwater in the 216-B-3 Pond area is influenced by the presence of the semiconfining to confining Ringold lower mud sequence. Water table elevations shown on Figure 3-50 in this area in part represent the potentiometric surface of deeper confined systems and may therefore underestimate the depth of the vadose zone.

The flow of water through unsaturated soils in the vadose zone depends on several factors, including most significantly the moisture content of the soil and its hydraulic properties. Although a variety of methods have been developed to measure a soil's hydraulic properties directly (in particular, unsaturated hydraulic conductivity) most of them are expensive and difficult to implement. An alternative to direct measurement of unsaturated hydraulic conductivity is to use theoretical methods that predict the conductivity based on measured soil moisture retention data and saturated hydraulic conductivity (Van Genuchten et al. 1991).

Van Genuchten's computer program RETC is commonly used to develop wetting and drying curves for soils, based on laboratory data. The program uses a nonlinear least squares fit to generate a θ-φ (θ being moisture content and φ being matric potential or suction head) curve from lab data. An example of the wetting and drying curves, and corresponding unsaturated hydraulic conductivity functions, is provided on Figure 4-52 for Hanford formation sediments in the vadose zone. A relative hydraulic conductivity function

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$K_r(\theta)$ is required to relate saturated hydraulic conductivity K_s, generally measured in the laboratory, to the unsaturated conductivity $K(\theta)$ function.

$$K(\theta) = K_s K_r(\theta)$$

Van Genuchten developed a closed form predictive function to generate relative hydraulic conductivities from the θ-φ data. With the saturated hydraulic conductivity (K_s) and the relative hydraulic conductivity function ($K_r(\theta)$), unsaturated hydraulic conductivity values ($K(\theta)$) can be generated for a specific moisture content. Examples of the $K(\theta)$ curves generated by this method for vadose zone soil samples from the 200 East Area are presented on Figures 3-53 through 3-56, as discussed below.

Rockhold et al. (1988) compare direct measurement of unsaturated hydraulic conductivities to those predicted from measured water retention data for three locations on the Hanford Site. Rockhold et al. (1988) find that each method produces results different from other methods and recommends that several methods should be used to determine unsaturated hydraulic conductivities. Only water retention data were reported in the sources reviewed for this report.

Knowledge of hydraulic conductivity values for a soil and a gradient allows the calculation of flow through that soil. Darcy's law, although originally conceived for saturated flow only, was extended by Richards to unsaturated flow, with the provisions that the soil hydraulic conductivity becomes a function of the water content of the soil, $K(\theta)$, and the driving force is predominantly differences in moisture level. The moisture flux, θ, in centimeters per second in one direction is then described by a modified form of Darcy's law commonly referred to as Richards' Equation (Hillel 1971) as follows:

$$q = K(\theta)\left(\frac{\partial\varphi}{\partial\theta}\right)\left(\frac{\partial\theta}{\partial x}\right) \text{ (Richard's Equation)}$$

where

- $K(\theta)$ is the water-content-dependent unsaturated hydraulic conductivity in cm/s
- $\partial\varphi/\partial\theta$ is the slope of the soil-moisture retention curve $\varphi(\theta)$ at a particular volumetric moisture content θ (a soil-moisture retention curve plots volumetric moisture content observed in the field or laboratory against suction values for a particular soil as shown in Figure 3-42 [Gee and Heller 1985]

- $\partial\theta/\partial x$ is the water content gradient in the x direction.

More complicated forms of this equation are also available to account for the effects of more than one-dimensional flow and the effects of other driving forces such as gravity.

In practice, applying Richards' Equation is quite difficult because the various parameters involved are difficult to measure and because soil properties vary depending on whether the soil is wetting or drying (hysteresis). As a result, soil heterogeneities affect unsaturated flow even more than saturated flow. Several investigators at the Hanford Site have measured the vadose zone moisture flux and hydraulic conductivity directly using lysimeters and permeameters, respectively (e.g., Rockhold et al. 1990; Routson and Johnson 1990). These direct measurements are discussed in the natural groundwater recharge section (Section 3.5.1.5.1).

Once the relationship between unsaturated hydraulic conductivity and moisture content is known for a particular lithologic unit, travel time can also be estimated for a steady-state flux passing through each layer by assuming a unit hydraulic gradient. Under the unit gradient condition, only the force of gravity is acting on water and all other forces are considered negligible. These assumptions may be met for flows due to natural recharge since moisture differences smooth out after sufficient time. Travel time for each lithologic unit of a set thickness and calculated for any given recharge rate, and the total travel time is equivalent to the sum of the travel times for each individual lithologic unit. To calculate the travel time for any particular site, the detailed layering of the lithologic units should be considered. For sites with artificial recharge (e.g., cribs and trenches), more complicated analyses are required to account for the effects of variable saturation.

Moisture content and vertical hydraulic conductivity data for the unsaturated zone have been obtained from 60 vadose zone soil samples collected in the 200 East Area and vicinity, and are reported by Connelly et al. (1992a). Hydraulic properties data were obtained for these samples as part of ongoing performance assessment work in the 200 East Area. The samples were collected from boreholes at the Grout Treatment Facility and AP Tank Farm in the eastern and central parts of PUREX Plant Aggregate Area, respectively; the 200-BP-1 Operable Unit in the B Plant Aggregate Area; the B Pond Area; and near the Ecology facility south of the southwest corner of the 200 East Area. The following samples were collected from the units listed:

- 2 samples - Ringold unit A gravels

- 2 samples - Ringold lower mud sequence

- 41 samples - Hanford sandy sequence

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- 15 samples - Hanford gravel sequence (lower and upper gravels undifferentiated).

For each of these samples, soil moisture retention data were measured, and soil moisture curves were generated from the data. Saturated hydraulic conductivity (K_s) values were also measured in the laboratory for these samples. As discussed in Section 3.5.1.3 for soil samples collected in the 200 West Area, unsaturated hydraulic conductivities may vary by orders of magnitude with varying moisture contents and among differing lithologies with significantly different soil textures. Figures 3-53 through 3-56 illustrate the variations in unsaturated hydraulic conductivity with moisture content for the Ringold Formation and Hanford formation samples tested. The following discussion summarizes results of the hydraulic properties testing for the unsaturated zone in the 200 East Area.

For the two Ringold lower mud samples tested, unsaturated hydraulic conductivities ranged from less than about 10^{-18} cm/s at a 10% moisture content, to about 10^{-9} cm/s at saturation moisture contents near 57% (Figure 3-53). Unsaturated conductivities for the two Ringold unit A gravel samples had wider variability, ranging from less than 10^{-18} to 10^{-10} cm/s at moisture contents near 10%, to 10^{-7} to 10^{-5} cm/s at saturation moisture contents of 38% and 57%, respectively for each of the samples. These differences are likely due to lithologic variations such as changes in the percentages of fine sand and silt with depth.

Samples of the Hanford formation sandy sequence and gravel sequence generally had higher saturated hydraulic conductivities than the Ringold Formation samples. Figure 3-54 and 3-55 are two sets of unsaturated conductivity curves for the Hanford sandy sequence. At a 10% moisture content, unsaturated conductivities ranged from about 10^{-16} to 10^{-5} cm/s, with many of the values falling in the 10^{-10} to 10^{-5} m/s range. At saturation, hydraulic conductivities ranged from about 10^{-6} to 10 cm/s, with many of the values falling in the 10^{-5} to 10^{-3} cm/s range. Lower range values of saturated hydraulic conductivity were measured in sandy-clay soils collected in the Hanford formation. Measured moisture contents for the Hanford formation sandy sequence samples at saturation had a wide range (24 to 52%).

Marked variability in unsaturated hydraulic conductivities and saturation moisture contents is also apparent for the Hanford formation gravelly sequence samples (Figure 3-56). At a 10% moisture content, unsaturated conductivities ranged from about 10^{-12} to 10^{-6} cm/s, with the sample from Well 3A-1 (Well 699-43-41H) (16.6 m depth) in the 216-3-B Pond area never reaching a volumetric moisture content this low. At saturation, hydraulic conductivities ranged from about 10^{-7} to 10^{-3} cm/s, and were generally lower than saturated hydraulic conductivities for the sandy sequence. Measured moisture contents for the Hanford formation gravelly sequence samples at saturation had a wide range (26 to 53%).

3.5.2.1.4 Perched Water Zones. As discussed in Section 3.5.1.4, the primary potential for perched water at the Hanford Site is associated with the calcareous paleosols of the Plio-Pleistocene unit and the early "Palouse" soil. These units are only present in the

vicinity of the 200 West Area and therefore do not form potential perching horizons near the 200 East Area. In the 200 East Area, potential silt lens paleosol perching horizons have been identified in the Hanford formation sands and gravels (Hoffmann et al. 1992). These layers are found locally and appear to be discontinuous. The Ringold lower mud sequence also represents a potential perching layer. Perching potential is greatest near the 200 East Powerhouse Ditch along the southern border of the Semi-Works Aggregate Area because of the large quantity of water being discharged. Perched water zones in the Hanford formation may also be possible near the 216-B-3 Pond System, and near former liquid waste disposal sites where considerable amounts of liquid were discharged to the soils. Up to 2.1 m (7 ft) of perched water have been found above the lower mud sequence in the vicinity of the 216-B-3C Pond lobe. Perched water was encountered during drilling of wells 299-E33-27 and 299-E33-41, near liquid discharge releases from the 102-BX Tank.

3.5.2.2 200 East Area Groundwater Recharge. Recharge to the unconfined aquifer within the 200 East Area is from artificial and possibly natural sources. If natural recharge occurs, it is only from precipitation. The only naturally occurring body of water (West Lake) in the 200 East Area is created by the outflow of the unconfined aquifer in the area. Artificial recharge occurs from several active and recently active cribs, trenches, ditches, ponds, and drains located throughout the 200 East Area, as well as from leaks in pipelines, transfer lines, and spills.

3.5.2.2.1 Natural Recharge. Within the 200 East Area, natural recharge originates from precipitation. As discussed in Section 3.2.1, annual precipitation for the Hanford Site is approximately 16 cm (6.3 in.). Evapotranspiration of precipitation is considered to reduce the amount of precipitation that reaches the groundwater significantly (Gee 1987). Estimates for the percentage of evapotranspiration range from 38 to 99%. The primary factors affecting precipitation recharge are surface soil type, vegetation type, topography, and spatial and temporal variations in seasonal precipitation. A modeling analysis (Smoot et al. 1989) indicated that 68 to 86% of the precipitation falling on a gravel-covered site might infiltrate to a depth greater than 2 m (6 ft). However, a study using a gravel-covered lysimeter at the 200 East Area indicated no recharge had occurred in soil 4.9 m (16 ft) below surface over a 16-year period (Rockhold et al. 1990). Gee (1987) conducted recharge analyses for two different soil types, and concluded that recharge rates vary from 0.1 cm/yr (0.04 in./yr) for a fine-textured soil with deep-rooted vegetation, to 10 cm/yr (4 in./yr) for a coarse-grained soil (gravel) devoid of vegetation. If recharge from precipitation does occur in the 200 East Area, by using the 0.1 cm/yr recharge rate, since most of the 200 East Area is covered by sparse vegetation and eolian sand, the total annual natural recharge volume for the 200 East Area can be estimated approximately at 19 million L/yr (5 million gal/yr). These values are significantly lower than the volumes of artificial discharges recorded throughout the 200 East Groundwater Aggregate Area (see also Section 3.5.2.2.2). As discussed in Section 3.5.1.5.1, Routson and Johnson (1990) conducted a lysimeter study 1.6 km (1mi) south of

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the 200 East Area and concluded that no downward moisture movement was observed over a 13 year period.

3.5.2.2.2 Artificial Recharge. Artificial recharge to the groundwater system began in 1944 and continues through the present. Sources of artificial recharge include cribs, ditches, trenches, ponds, basins, and drains. The following sections discuss sources of artificial recharge within the PUREX Plant, B Plant, Semi-Works, and 200 North Aggregate Areas, respectively. The location of these facilities are shown in Plate 1. Quantities of discharge to these facilities are shown in Table 2-2.

Artificial Recharge in the PUREX Plant Aggregate Area. The principal sources of artificial recharge within the PUREX Plant Aggregate Area include the 216-A-30 Crib and 216-A-29 Ditch, which both ceased operating in 1991. Other sources that have contributed significant volumes of wastewater discharge to the soil include the 216-A-5, -6, -8, -9, -10, -24, and -37-2 Cribs. The 216-A-37-2 Crib is the only currently active waste management unit within the PUREX Plant Aggregate Area.

There are also seven septic tank and drain fields reported to be active within the PUREX Plant Aggregate Area. These are the 2607-EA, -EC, -ED, -EG, -EJ, -EL, -E6 Septic Tanks and Drain Fields. The combined amount of wastewater discharged from these facilities between 1946 and 1992 is estimated to be 640 million liters (170 million gallons).

Artificial Recharge in the B Plant Aggregate Area. The principal source of artificial recharge within the B Plant Aggregate Area during the Hanford Site operational period has been the 216-A-25 Pond, which operated between 1957 and 1987. Other sources that have been active and have discharged significant volumes of wastewater to soils within the B Plant Aggregate Area include the 216-B-3 Pond; 216-B-12, 216-B-62, and 216-B-55 Cribs; the 216-B-2-1, 216-B-3-1, and 216-B-3-2 Ditches; and 216-B-63 Trench. Currently there are nine active waste management units: 216-B-55 and 216-B-62 Cribs; 216-B-3, 2101-M, 216-B-3A, 216-B-3B, and 216-B-3C Ponds; 216-B-3-3 Ditch; and 216-B-63 Trench. The 216-B-3 Pond, which is the second largest source of artificial recharge, has been in operation since 1945. It is a Resource Conservation and Recovery Act (RCRA) facility and a closure/postclosure plan (DOE/RL 1989b) has been prepared pending Ecology approval. The 216-B-3C Pond will become the main disposal pond for the 216-B-3 Pond System in the future. The 2101-M is also a RCRA facility, and a closure/postclosure plan has been submitted. Although it is still an active facility, the 216-B-55 Crib has not received any effluent in the last three to four years.

There are also 18 septic tanks and drain fields/tile fields that are actively discharging water to the soil. These are the 2607-EB, -EH, -EK, -EM, -EN, -EO, -EP, -EQ, -ER, -GF, -E1, -E2, -E3, -E4, -E7B, -E8, -E9, and -E11 Drain/Tile Fields. The combined discharge volumes are estimated at 97,650 L/day (25,800 gal/day), according to the Waste Information

Data System (WIDS) database (WHC 1991a). The combined amount of wastewater discharged from these facilities between 1951 and 1991 is estimated to be 720 million liters (190 million gallons).

Artificial Recharge in the Semi-Works Aggregate Area. The principal source of artificial recharge within the Semi-Works Aggregate Area is the 216-C-9 Pond, which operated between 1953 and 1985 and contributed 97% of the total volume of the wastewater discharged into the soil. The only active waste management unit within the Semi-Works Aggregate Area is the 216-C-7 Crib. There are also two septic tanks and drain fields reported to be active: the 2607-E-5 and 2607-E-7A Septic Tanks and Drain Fields. The combined amount of wastewater discharged to these facilities is estimated to be approximately 1.1 billion liters (280 million gallons).

The 200 East Powerhouse Ditch is currently active, which drains nonradioactive wastewater from the Semi-Works Aggregate Area into the 216-B-3 Pond System in the B Plant Aggregate Area. Its monthly flow rate is estimated to be 13.8 million L/month (3.6 million gal/month).

Artificial Recharge in the 200 North Aggregate Area. The principal historical sources of artificial recharge within the 200 North Aggregate Area include the 216-N-1, -4, and -6 Ponds, all which had operated between 1944 and 1952. Other significant sources of wastewater discharge include 216-N-2, -3, -5, and -7 Trenches. There are no waste management units presently active within the 200 North Aggregate Area. The combined amount of wastewater discharged from these facilities between 1944 and 1952 is estimated to be 2.9 billion liters (758 million gallons).

3.5.2.3 200 East Area Groundwater Flow. Groundwater has been actively monitored at the Hanford Site since 1944. This monitoring has been in response to artificial wastewater discharges to the soil which have impacted the natural flow system of the groundwater beneath the Hanford Site. Several monitoring programs, discussed in Section 2.8 have been implemented in the past to monitor the response of the unconfined aquifer to discharges from various sources throughout the Hanford Site.

3.5.2.3.1 Uppermost Aquifer

Historical Groundwater Flow Conditions. Data are not available on groundwater conditions before the construction and operation of the Hanford Site. However, the pre-Hanford groundwater flow conditions have been presented by Kipp and Mudd (1974). This "hindcast" map was developed from well data accumulated between 1948 and 1951.

Before the initiation of waste disposal activities at the Hanford Site in the mid-1940's, groundwater elevations across the 200 East Area varied from approximately 119 m (390 ft)

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above sea level at the western boundary to approximately 117 m (385 ft) at the eastern boundary (Figure 3-57). The general groundwater flow direction appears to have been from west to east across the Hanford Site with an average hydraulic gradient of 0.001 (Graham et al. 1981). These flow lines are shown on Figure 3-57. Vertical gradients within the upper unconfined aquifer were probably negligible although a slight upward gradient was present between the basalt aquifers and the unconfined aquifer due to recharge to the basalt aquifers at higher elevations at the edge of the Pasco Basin.

A persistent drop in hydraulic gradient has been observed over time between the 200 West and 200 East Areas where data provide sufficient resolution. This may be due in part to two hydrostratigraphic factors: (1) the Ringold Formation, which exhibits lower hydraulic conductivities than the Hanford formation, thins to the east, so the flow moves into the more permeable Hanford formation; and (2) the basalt dips in a southeasterly direction, which increases the saturated thickness of the unconfined aquifer.

Waste disposal activities at the Hanford Site have greatly affected groundwater flow in the unconfined aquifer. Within the 200 East Area, discharges to the various waste management units have created a groundwater mound in the vicinity of now closed 216-A-25 Pond and the active 216-B-3 Pond System. Conditions of the unconfined aquifer have varied with the amount of wastewater discharged from the various waste management units. These changes are shown on Figures 3-57 through 3-62, which depict groundwater contour elevations and flow directions for the years 1944, 1955, 1965, 1970, 1987, and 1991. The following discussion focuses on the historical effects that waste disposal practices have had on the dynamics of the unconfined aquifer.

Groundwater Flow from 1944 to 1955. In 1944, groundwater flow in the unconfined aquifer is thought to have occurred essentially from west to east across the site. Groundwater levels increased dramatically between 1944 and 1955 (Figures 3-57 and 3-58). Artificial recharge from wastewater discharges created a mound under the active 216-B-3 Pond. The elevation of groundwater in the vicinity of the mound increased by approximately 6 m (20 ft) during this time. Groundwater elevations within the upper Cold Creek valley rose 15 m (50 ft) in response to artificial recharge from agricultural irrigation. By 1955 groundwater mounding under the 216-B-3 Pond had altered the general west to east groundwater flow direction to more of a radial configuration east of the 200 East Area (Figure 3-58). Flow gradients increased to the east of the mound, and west of the mound the flow direction temporarily reversed to the west and redirected flows to the north and south. Groundwater flowing to the west due to this gradient reversal appears to have headed in part toward Gable Gap. The 1955 groundwater contour map also shows the mound was located directly under 216-B-3 Pond and elongated to the northwest due to the discharge of the 216-A-25 Pond. Groundwater flow from the 200 East Area in 1955 was directed to the southeast and east.

Groundwater Flow from 1955 to 1965. A comparison of the 1955 and 1965 groundwater contour maps (Figures 3-58 and 3-59) shows that the center of the mound remained stationary over this period while groundwater rose 3 m (10 ft) in elevation under the ponds. This rise may have been due to increased wastewater discharges from facilities in the PUREX Plant and B Plant Aggregate Areas from 1955 to 1965. The hydraulic gradient east of the mound increased slightly while flow west of the mound decreased in response to elevated groundwater levels from irrigation in the upper Cold Creek valley and waste disposal in the 200 West Area. Groundwater flow in 1965 from the 200 East Area was directed to the southeast and east, with the exception of a small component of flow from 216-A-25 Pond that was directed to the northwest and Gable Gap.

Groundwater Flow from 1970 to 1985. Groundwater contour maps for 1970 and 1987 (Figures 3-60 and 3-61) show that the mound has changed shape due to the closure of the 216-A-25 Pond. The mound is rounded instead of elongated, and flow to the west from the mound bifurcates into components directed to the northwest and to the southeast. Flow from the west into the 200 East Area (i.e., from 200 West Area) underwent a similar bifurcation to the northwest and southeast. The increased use of the 216-B-3 Pond and the construction of the 216-B-3A, -3B, -3C Pond lobes had elevated the groundwater under the 216-B-3 Pond System another 2 m (5 ft by 1987). At the same time, the water table elevation under the Gable Pond area had decreased 2 m (5 ft).

Groundwater Flow from 1987 to 1991. The configuration of the water table contours from 1987 to 1991 (Figure 3-61 and 3-62) remained relatively constant. The mound under the 216-B-3 Pond System appears to have maintained a peak water level of over 128 m (420 ft) in the center, although the gradient on the west bank of the mound appears less steep in 1991. This may be a result of change in the usage of the 216-B-3 Pond lobes.

Well Hydrographs. Well hydrographs prepared for four areas within and around the 200 East Area (Figures 3-63 through 3-66) show the response over time of the unconfined aquifer to wastewater discharges from the 200 East facilities. Also shown on these hydrographs are the historical operational periods of the waste management units located within each aggregate area.

Hydrographs from six wells within the PUREX Plant Aggregate Area were plotted in Figure 3-63. These wells all appear to be significantly impacted by historical discharges from the PUREX Plant. After the shutdown of the 216-A-5 and -6 Cribs in 1967, the water levels had dropped several feet until 1972 then gradually had leveled out until 1977. In 1977 water levels had increased corresponding to the start up of the 216-A-37-1 Crib. Water levels continued to rise until they leveled off in 1985. Water levels for all wells have decreased from 1986 to present because the 216-A-29 Ditch, the 216-A-8, -6, -5, and -37-1 Cribs were retired. The general consistency (parallel nature) of the hydrographs in Figure 3-

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63 indicates that generally the direction and approximate gradient have been maintained during the period of observation.

Hydrographs were prepared for four wells within the central portion of the B Plant Aggregate Area (Figure 3-64). The general trend of water levels within the B Plant Aggregate Area are very similar to those of the PUREX Plant Aggregate Area. Evident in this hydrograph is that water levels in wells decrease with increased distance from the mound center.

Hydrographs are included for four wells around the 216-B-3 Pond area (Figure 3-65). The effect of the expansion ponds can be seen in Wells 699-39-39 and 699-43-43. In general, all water levels around the 216-B-3 Pond System had risen from 1983 until 1989 due to the increased use of the ponds caused by the shutdown of the 216-A-25 Pond. As with B Plant, the farther the distance of the well from the mound center, the lower the water level. Since 1989, water levels in wells near the 216-B-3 Pond have decreased 0.3 to 1 m (1 to 3 ft) due to reduced effluent discharge rates.

Six wells were used to prepare hydrographs for the northern B Plant Aggregate Area (Figure 3-66). Water levels had risen in 1955 and continued to increase until 1990, except in Well 699-49-55A. This well is the farthest away from the ponds and close to B Plant. The well's trends seem to be the same as those in the B Plant hydrographs. The continued increase in water levels after the retirement of Gable Pond is probably due to the 216-B-3 Pond mound backing up the water under this area. The water levels are returning to an equilibrium at approximately the same rates in both of these areas.

Groundwater Flow Velocities. Groundwater flow in the unconfined aquifer within the 200 East Area occurs within the Hanford sandy and lower gravel units in the central and northern parts of the 200 East Area, as well as in the locally semiconfined area within the Ringold unit A beneath the 216-B-3 Pond System, and occurs within the Ringold fluvial gravel unit E at the south and southwest corner of the 200 East Area. The direction of the groundwater flow within the 200 East Area historically has been difficult to determine because of the lack of a pronounced horizontal hydraulic gradient, except in areas surrounding the 216-B-3 Pond. Before activity at the Hanford Site (1944), the average horizontal hydraulic gradient across the 200 Areas is estimated to be 0.001 [approximated from the 1944 contour map presented in Kipp and Mudd (1974)]. Using this along with hydraulic conductivity (k) of 6×10^{-3} m/s (1,600 ft/day; Table 3-1) and a porosity (n) of 0.3, the calculated average natural flow velocity (K and n obtained from Table 3-1) is 0.6 m/day (1.9 ft/day) to the east.

Artificial recharge from the waste management units within the 200 East Area, especially the 216-A-25 and 216-B-3 Ponds, has created groundwater mounds beneath the liquid waste disposal units, and significantly increased the overall groundwater elevation

within and to the east of the 200 East Area. The hydraulic gradients have also been increased markedly due to mounding underneath 216-B-3 Pond, up to a maximum of 0.005 directed both to the east and west. However, the hydraulic gradients are significantly reduced away from the mound, and a broad area of very low gradients extends across the western portion of the 200 East Groundwater Aggregate Area in a northwest-southeast trend. The central part of the 200 East Area has a gradient of roughly 0.0003, oriented both towards the northwest and southeast.

Hydraulic conductivity values from 30 existing wells within the 200 East Groundwater Aggregate Area range from 6×10^{-5} to 9×10^{-2} m/s (17 to 2.5×10^{4} ft/day) (Connelly et al. 1992a). A region of high hydraulic conductivity is oriented along a northwest-southeast trend in the northern and eastern parts of the study area (Figure 3-50). The hydraulic conductivity is generally lower [less than 3.5×10^{-3} (1,000 ft/day)] in the southwestern part of the 200 East Area (Figure 3-48). The high conductivity values are generally associated with the lower gravel unit of the Hanford formation, while the low conductivity values commonly correspond to unit E of the Ringold Formation. Vertical differences in hydraulic conductivity due to lithologic differences can be great, as shown by low values determined by slug and constant discharge tests for the Ringold unit A in the vicinity of the 216-B-3 Pond that are in the order of 3.5×10^{-6} to 3.5×10^{-4} m/s (1 to 100 ft/day).

Groundwater flow velocities of the unconfined aquifer within and near the 200 East Area have been difficult to determine because of the variability of hydraulic conductivity in a local scale, spatial and temporal occurrence of artificial recharges, and limited coverage of subsurface data. Based on groundwater level data of December 1991 (Kasza et al. 1991) and hydrologic properties of the 200 East Area discussed in Connelly et al. (1992a), the groundwater mound underneath the 216-B-3 Pond System has generated relatively fast groundwater flows radiating away from the mound. Hydraulic gradients around the mound range from 0.001 on the east to 0.005 on the west. The velocity of the groundwater flow (assuming a hydraulic conductivity of 3×10^{-3} to 1×10^{-2} m/s [1,000 to 4,000 ft/day] and an average porosity of 0.2) is approximately 2×10^{-5} to 7×10^{-5} m/s (5 to 20 ft/day) in the easterly direction, and approximately 7.5 to 30 m/day (25 to 100 ft/day) in the westerly direction from the mound into the 200 East Area.

Groundwater flow velocity decreases drastically away from the 216-B-3 Pond System. The velocities within the central and south-central 200 East Area are estimated to be between 3×10^{-6} to 9×10^{-6} m/s (1.0 to 2.6 ft/day), based on hydraulic gradients of 0.0001 and 0.0004 and an estimated hydraulic conductivity of 5×10^{-3} m/s (1,300 ft/day), and have either northwest or southeast flow direction. The northwestern flow, which passes through the Gable Mountain Gap and eventually reaches the Columbia River at the 100 Areas, has an estimated flow velocities of 2×10^{-6} m/s (0.7 ft/day) from 200 East Area to the Gable Mountain Gap.

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Flow to the east-southeast from the southern part of the 200 East Area trends toward the Columbia River to the north of 300 Area (Figure 3-62). The estimated generalized velocity of this flow path is 3 x 10^{-5} m/s (7.2 ft/day), assuming the aquifer is situated within the Hanford formation and the average hydraulic conductivity throughout the flow path is similar to the values associated with the Hanford formation (7 x 10^{-3} m/s [2,000 ft/day]). With this flow rate, the estimated time for groundwater from the 200 East Area to reach the Columbia River is 28 years. In comparison, Freshley and Graham (1988) estimate the travel time from the PUREX cribs southeast to the Columbia River to be 21 to 23 years, based on elapsed time between the release of tritium and its arrival at the river. Similarly, USGS (1987) estimate an average arrival time of 13 years for tritium to travel from the PUREX cribs to the river by assuming that most of the tritium was discharged to the ground after 1963.

Vertical Hydraulic Gradients. Groundwater monitoring wells that are screened within the upper portion of the unconfined aquifer exhibit a greater head than the few wells that are screened in the lower portion of the unconfined aquifer. This difference in groundwater levels indicates a downward vertical gradient. Downward vertical hydraulic gradients within the 200 East Area ranged from indistinguishable (zero) to 0.7 at groundwater mound underneath the 216-B-3 Pond System. Wells 6-43-42J and 6-42-42B are located near 216-B-3 Pond, and are screened in the upper and lower portions of the unconfined aquifer, respectively, within the Ringold unit A (Connelly et al. 1992a). Plots of hydrographs from these wells are shown on Figure 3-67. These wells have an approximate head difference of 0.6 m (2 ft) over a vertical distance of 9 m (30 ft), and thus the approximate value of the vertical gradient is calculated to be 0.07. As the amount of discharge from the 216-B-3 Pond and other waste management units decreases, the vertical gradients between these wells are also expected to decrease. In addition, these wells may represent conditions that are uncommon to most of the site as the presence of the Ringold lower mud sequence appears to create semiconfined to confined conditions in this area, and significant mounding of the water table is present at this location.

Wells 6-53-55B and 6-53-55C monitor the upper-middle and lower-middle of the unconfined aquifer within the erosional window at the northwestern part of the 200 East Area, and Well 6-53-55A previously monitored the top to the lower-middle of the unconfined aquifer before December 1990. These wells are all screened into the Hanford formation. Well 6-53-55A is presently screened about 9 m (30 ft) in the top of the aquifer. The vertical hydraulic gradient between Wells 6-53-55B and 6-53-55C is calculated to be 0.01, according to 1991 hydrologic data.

Other nested wells, 299-E25-29P and -29Q, 299-E-25-30P and -30Q, 299-E25-32P and -32Q, and 299-E25-34 and 299-E25-28, are located near the Grout Treatment Facility and 216-A-29 Ditch. From limited available data, values reported in Kasza et al. (1992) indicate that these wells all have indistinguishable vertical head differences.

The lower mud sequence of the Ringold Formation occurs only in the southernmost areas of the 200 East Area (Figure 3-30). This unit has a low hydraulic conductivity [1.9×10^{-10} m/s (5.3×10^{-5} ft/day)], and where this unit is present it acts as an aquitard separating the basal Ringold gravel (unit A) from the upper unconfined aquifer. However, its limited occurrence within the 200 East Area apparently does not affect the vertical hydraulic gradient at the lower unconfined aquifer significantly.

Generally, the vertical hydraulic gradient between the uppermost aquifer and the Rattlesnake Ridge aquifer is insignificant in most areas within the 200 East Area, except two zones where downward and upward gradients is notable. Downward hydraulic gradient exists in areas surrounding the 216-B-3 Pond System, at the eastern part of the 200 East Area (Kasza et al. 1991). An extensive area with observed upward hydraulic gradient is present around the West Lake, at the northwestern end of the 200 East Area. Connelly et al. (1992a) evaluate the vertical gradient between the uppermost aquifer and Rattlesnake Ridge aquifer through comparison of hydrographs for well clusters.

In general, the hydrographs evaluated by Connelly et al. (1992a) indicate that the head differential between the uppermost aquifer and the Rattlesnake Ridge aquifer is minimal in the northern portion of the 200 East Area and farther north. Table 3-2 summarizes vertical hydraulic gradient values and direction of the vertical component of groundwater flow for all well clusters. The greatest head differential occurs at the 299-E33-40/299-E33-07 well cluster. At this well cluster location, the vertical hydraulic gradient is estimated at 0.005 ft/ft (maximum) with an upward-directed vertical flow component. Connelly et al. (1992a) conclude that other well clusters do not exhibit major head differentials. Heads at cluster sites 699-49-55A/B and 699-49-47A/B indicate that there is virtually no vertical hydraulic gradient most of the year. During the fall and winter months, heads in the Rattlesnake Ridge aquifer are slightly greater than those in the uppermost aquifer, probably reflecting different recharge rates and/or different recharge areas for the two aquifers. The head differential at well cluster 699-50-53A/B indicates a slight upward gradient during all months of the year, with the greatest head differential during the early fall. The maximum vertical hydraulic gradient is 0.0037 ft/ft. For the well clusters north of the 200 East area evaluated by Connelly et al. (1992a), well cluster 699-54-57/699-55-57 shows the greatest head differential with a maximum vertical hydraulic gradient of 0.0038 ft/ft. Although these two wells are separated by horizontal distance of approximately 700 feet, Connelly et al. feel that the minimal horizontal hydraulic gradients in both the uppermost and the Rattlesnake Ridge aquifers in the vicinity of these monitoring wells do not preclude the comparison of hydraulic heads to assess the vertical hydraulic gradient and direction of the vertical flow component at this locality.

An interesting aspect of the hydrographs for the well clusters is the fact that head trends seen in the uppermost aquifer are typically mirrored in the Rattlesnake Ridge aquifer.

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This mirroring in the Rattlesnake Ridge aquifer is probably related to the hydraulic interconnectivity of these two aquifers.

Current Groundwater Flow Conditions. Kasza et al. (1991) have compiled water table measurements for the Hanford Site and have contoured the potentiometric surface of the unconfined aquifer for June 1991. Representative horizontal flow paths for the 200 East Groundwater Aggregate Area are shown on Figure 3-62 based on these data. In general, these flow paths show an overall trend of flow from west to east across the site, but this is largely modified by artificial recharge, especially to the 216-B-3 Pond System.

The mounding underlying 216-B-3 Pond System results on radial flow from that area and divides the east directed regional flow into two components of flow; one to the southeast and one to the northwest. The elevated water levels created by the mounding also result in a broad flattening of hydraulic gradients along a northwest-southeast trend that extends through the center at 200 East Area. Because of the mounding, horizontal flowpaths through the 200 East Area originate both to the west from eastward directed regional flow and to the east from reverse gradients created by mounding, with flow patterns converging at about the center of the area and dividing into components directed to the east-southeast and to the northwest. Flow to the east-southeast travels to the Columbia River where it discharges to the river from east of Gable Mountain to just north of 300 Area. Flow to the northwest passes through Gable Gap and reaches the Columbia River on the 100 Area.

The mound underlying 216-B-3 Pond is slowly receding at a rate of 0.2 m/yr (0.6 ft/yr), as shown by hydrographs (Figure 3-65), following the peaks discharge of wastewater to the area in the mid-1980's. If wells closer to the center of the mounding are also considered, then the dissipation rate has been approximately 0.4 m/yr (1 ft/yr) which reflects greater reduction at the mound's apex. The location of the mound also appears to be undergoing a slight shift to the northwest, perhaps due to a shifting of discharge to lobes A and C in 216-B-3 Pond. Discharge to the 216-B-3 Pond System and other current waste management units are scheduled to be shifted to the Project W-049H State-Approved Liquid Disposal Structure (SALDS) facility just to the east of the pond (along with a SALDS north of 200 West Area), as described in Section 2.7.4. The W-049H SALDS likely will maintain mounding at the water table to the west of 200 East Area, although the location shift may cause a slight reduction in flow directed toward Gable Gap.

Eventually, all artificial discharge in the 200 East Groundwater Aggregate Area is expected to cease, and mounding will dissipate completely over a 20- to 30- year period. Overall, water levels likely will remain elevated, largely due to recharge resulting from irrigation in upper Cold Creek valley to the east, but general trends will generally revert to natural conditions. Flows to the north and to Gable Gap from the 200 East Area will be eliminated, and most groundwater flow in the unconfined aquifer will occur to the east or southeast with a hydraulic gradient in the range of 0.002.

3.5.2.3.2 Basalt Aquifers. The main occurrence of groundwater in the basalt sequence beneath the 200 East Area is in the interbeds of the Ellensburg Formation. These interbed units generally offer the least resistance and greatest permeability for flow. The principal basalt aquifers within the 200 East Area include the three interbeds of the Ellensburg Formation within the Saddle Mountains Basalt Formation (Rattlesnake Ridge, Selah, Cold Creek) and the Mabton interbed that separates the Saddle Mountains and Wanapum Basalt Formations. Hydraulic properties of these interbeds are presented in Section 3.5.2.1.4.

The uppermost aquifer within the basalt is the Rattlesnake Ridge interbed. The Rattlesnake Ridge interbed is confined between the upper Elephant Mountain Member above and the Pomona Member below. The interbed is 15 to 25 m (50 to 82 ft) thick beneath the 200 East Area and generally thickens towards the west (Graham et al. 1981; 1984). Graham et al. (1984) identified two extensive areas of complete erosion: the area around West Lake and the area north of Gable Mountain. The authors infer an erosional window within the 200 East Area (see also Section 3.5.2.3.3). Intercommunication (recharge/discharge) between the overlying unconfined aquifer and the Rattlesnake Ridge interbed is possible through these erosional windows. Figure 3-68 shows the most complete groundwater levels for the Rattlesnake Ridge interbed. Also superimposed on this map are the water table elevations for the uppermost unconfined aquifer. In general there is a greater head within the unconfined aquifer at the western part of the 200 East Area, while the potentiometric head of the Rattlesnake Ridge confined aquifer becomes greater compared to the overlying unconfined aquifer towards the northwest of the 200 East Area.

Recharge from the overlying unconfined aquifers to the Rattlesnake Ridge aquifer occurs when the vertical hydraulic gradient is downward, and where the two aquifers are interconnected. Currently, a downward hydraulic gradient occurs around the 216-B-3 Pond area. It also apparently occurred near the Gable Mountain Pond in the late 1960's and early 1970's, when the pond was active and the unconfined groundwater level was higher. The possible existence of an erosional window around the vicinity of the Gable Mountain Pond was hypothesized by Graham et al. (1984), but no hard evidence supports this condition. Connelly et al. (1992a) suggest as an alternative that a well-developed fracture system in the Elephant Mountain Basalt could similarly provide intercommunication. Such intercommunication, if present, could provide for potential recharge to the Rattlesnake Ridge interbed from the unconfined aquifer, and the potential for contamination of the confined aquifer.

In other parts of the 200 East Area, upward vertical hydraulic gradient conditions exist and the Rattlesnake Ridge interbed discharges into the overlying unconfined aquifer where erosional windows are present. The major area of discharge is West Lake, northwest of the 200 East Area.

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Within the 200 East Area, confined groundwater flow of the Rattlesnake Ridge interbed is generally in from the east and north and out toward the west and northwest where it discharges to the overlying unconfined aquifer in the West Lake area. Another flow component originates from the 200 West Area eastward through the southernmost part of the 200 East Area towards the Columbia River. This flow pattern is similar to the flow of the unconfined aquifer, which suggests that flow within the Rattlesnake Ridge aquifer is influenced by seepage from the overlying unconfined aquifer, especially in the area of the 216-B-3 Pond.

Considerably less data are available for the deeper Selah, Cold Creek, and Mabton interbeds. Generally flow through these interbeds is predominantly west to east (Gephart et al. 1979). A slight upward gradient has been reported in some areas between these interbeds (Ledgerwood and Deju 1976).

3.5.2.3.3 Unconfined/Basalt Aquifer Intercommunication. The groundwater potentiometric map averaged across the Rattlesnake Ridge, Selah, and Cold Creek aquifers is presented in Figure 3-69 (DOE/RL 1988). A comparison of the potentiometric surfaces of the Rattlesnake Ridge interbeds and the unconfined aquifer is presented in Figure 3-68. Figure 3-26 shows the possible erosional windows within the Elephant Mountain Basalt Member (upper-most basalt unit within the 200 East Area), where the tilted capping basalt flows were removed by severe erosional processes (e.g., glacial floods), and the Rattlesnake Ridge interbed becomes directly overlain by the glaciofluvial sediments. Therefore, intercommunication may occur between the overlying unconfined aquifer and the Rattlesnake Ridge confined aquifer.

In the Elephant Mountain Basalt north of the 200 East Aggregate Area, Graham et al. (1984) identified two areas of complete erosion: the area around Gable Gap, and the area just north of the 200 East Area. These authors infer an erosional window within the northeast portion of the 200 East Aggregate Area from barometric efficiency analysis. Kasza et al. (1991) also identified an area around the 216-B-3 Pond of downward hydraulic gradient between the overlying unconfined aquifer (Ringold Formation) and the underlying Rattlesnake Ridge interbeds (Figure 3-70). If secondary fractures or unidentified erosional windows exist in the area of downward hydraulic gradient, flow from the uppermost aquifer system to the confined aquifer may occur.

In the area west of Gable Mountain, the potential exists for upward flow from the Rattlesnake Ridge aquifer to the uppermost aquifer due to apparent intercommunication between the aquifers (Figure 3-70), (Kasza et al. 1991). Discharges from basalt interbeds are likely to take place at the horn of Yakima River (Ledgerwood and Deju 1976).

Water table elevations have risen in response to artificial recharge from both wastewater discharges in the 200 East Area and from agricultural irrigation in areas to the

west. The elimination of wastewater discharges from waste management units on the Hanford Site will eventually dissipate the mounds that have existed under the 216-B-3 Pond System in the 200 East Area and reduce the downward vertical gradient between the upper unconfined aquifer and the underlying confined basalt aquifers. However, continued sanitary wastewater discharge within the 200 Areas and agricultural activities to the west will prevent the groundwater level from dropping down to the pre-1944 level.

3.6 ENVIRONMENTAL RESOURCES

The following sections discuss Hanford Site and 200 East Area environmental resources including flora and fauna (Section 3.6.1), land use (Section 3.6.2), and water use (Section 3.6.3).

3.6.1 Flora and Fauna

The Hanford Site is characterized as a cool desert or a shrub-steppe and supports a biological community typical of this environment. The 200 Areas Plateau in particular is represented by a number of plant, mammal, bird, reptile, amphibian, and insect species as discussed below.

3.6.1.1 Vegetation of the 200 Areas Plateau. The 200 Areas Plateau is characterized by native shrub steppe interspersed with large areas of disturbed ground with a dominant annual grass component. The native stands are classified as an *Artemisia tridentate/Poa sandbergii - Bromus tectorum* community (Rogers and Rickard 1977) meaning that the dominant shrub is big sagebrush (*Artemisia tridentate*) and the understory is dominated by the native Sandberg's bluegrass (*Poa sandbergii*) and the introduced annual cheatgrass (*Bromus tectorum*). Other shrubs that are typically present include gray rabbitbrush (*Chrysothamnus nauseosus*), green rabbitbrush (*C. viscidiflorus*), spiny hopsage (*Grayia spinosa*), and occasionally antelope bitterbrush (*Purshia tridentate*). Other native bunchgrasses that are typically present include bottlebrush squirreltail (*Sitanion hystrix*), Indian ricegrass (*Oryzopsis hymenoides*), needle-and-thread (*Stipa commode*), and prairie junegrass (*Koeleria cristata*). Common and important herbaceous species include turpentine cymopteris (*Cymopteris terebinthinus*), globemallow (*Sphaeraica munroana*), balsamroot (*Balsamorhiza careyana*), several milk vetch species (*Astragalus caricinus*, *A. sclerocarpus*, *A. succumbens*), long-leaf phlox (*Phlox longifolia*), the common yarrow (*Achillea millifolium*), pale evening-primrose (*Oenothera pallida*), thread-leaf phacelia (*Phacelia linearis*), and several daisy/fleabane species (*Erigeron poliospermus*, *E. Filifolius*, and *E. pumilus*). In all, well over 100 plant species have been documented to occur in native stands on the 200 Areas Plateau.

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Disturbed communities on the 200 Areas Plateau are primarily the result of either mechanical disturbance or range fires. Mechanical disturbance, including construction activities, soil borrow areas, road clearings, and fire breaks, results in drastic changes to the plant community. This type of disturbance usually entails a complete loss of soil structure and total disruption of nutrient cycling. The principle colonizers of mechanically disturbed areas are the annual weeds Russian thistle (*Salsola kali*), Jim Hill mustard (*Sisymbrium altissimum*), and bur-ragweed (*Ambrosia acanthicarpa*). If no further disturbance occurs, the areas will eventually become dominated by cheatgrass. All of these annual weeds are occasionally found in native stands, but only at relatively low frequencies.

Range fires also have dramatic effects on the overall ecosystem, the most obvious being the complete removal of sagebrush from the community, and the rapid increase in cheatgrass coverage. Unlike the native grasses, the other important shrubs, and many of the perennial herbaceous species, sagebrush is unable to resprout from rootstocks after being burned. Therefore, there is no dominant shrub component in burned areas until sagebrush is able to become re-established from seed. Burning also opens the community to the invasion by cheatgrass which is capable of quickly utilizing the nutrients that are released through burning. The extensive cover of cheatgrass may then prevent the re-establishment of many of the native species, including sagebrush. The species richness in formerly burned areas is usually much lower than in native stands, often consisting of only cheatgrass, Sandberg's bluegrass, Russian thistle, and Jim Hill mustard, with very few other species.

The vegetation in and around the ponds and ditches on the 200 Areas Plateau is significantly different from that of the surrounding dryland areas. Several tree species are present, especially cottonwood (*Populus trichocarpa*) and willows (*Salix* spp.). A number of wetland species are also present including several sedges (*Carex* spp.), bulrushes (*Scirpus* spp.), cattails (*Typha latifolia* and *T. angustifolia*), and pond-weeds (*Potamogeton* spp.).

3.6.1.2 Plant Species of Concern. The Washington State Department of Natural Resources, Natural Heritage Program classifies rare plants in the state of Washington in three different categories, depending on the overall distribution of the taxon and the state of its natural habitat. These categories are: *Endangered*, which is a "vascular plant taxon in danger of becoming extinct or extirpated in Washington within the near future if factors contributing to its decline continue. Populations of these taxa are at critically low levels or their habitats have been degraded or depleted to a significant degree"; *Threatened*, which is a "vascular plant taxon likely to become endangered within the near future in Washington if factors contributing to its population decline or habitat degradation or loss continue"; and *Sensitive*, which is a taxon that is "vulnerable or declining, and could become endangered or threatened in the state without active management or removal of threats" (definitions taken from Natural Heritage Program [1990]). Of concern to the Hanford Site, there are two Endangered taxa, two Threatened taxa, and at least eleven Sensitive taxa; these are listed in

Table 3-3. All four of the Threatened and Endangered taxa are presently candidates for the Federal Endangered Species List.

Of the two Endangered taxa, persistantsepal yellowcress is well documented along the banks of the Columbia River throughout the 100 Areas, and is unlikely to occur in the 200 Areas. The northern wormwood (*Artemisia campestris* spp. *borealis*) is known in the state of Washington by only two populations, one across from The Dalles, Oregon, and the other near Beverly, Washington, just north of the Hanford Site. This taxon has not been found on the Hanford Site, but would probably occur only on rocky areas immediately adjacent to the Columbia River if it were present. Neither of the Threatened taxa listed in Table 3-3 have been observed on the Hanford Site. The Columbia milk vetch (*Astragalus columbianus*) is known to be relatively common on the Yakima Firing Range, and has been documented to occur within 1.6 to 3.2 km (1 to 2 mi) to the west of the Hanford Site on both sides of Umtanum Ridge. This species could occur on the 200 Areas Plateau. Hoover's desert parsley (*Lomatium tuberosum*) inhabits the steep talus slopes near Priest Rapids Dam. Potentially, it could be found on similar slopes on Gable Mountain and Gable Butte, but has yet to be documented in these areas.

Of the eleven Sensitive species, five are inhabitants of aquatic or moist habitats and the other six are inhabitants of dry upland habitats. Dense sedge (*Carex densa*), shining flatsedge (*Cyperus rivuloris*), southern mudwort (*Limosella acoulis*), and false-pimpernel (*Lindernia anagallidea*) are all known to occur in the 100 Areas, especially near the 100 B-C Area, in or near the Columbia River. Some of these species could be present in or near ponds and ditches in the 200 Areas. The few-flowered collinsia (*Collinsia sparsiflora* var. *bruciae*) may also occur in these habitats. The gray cryptantha (*Cryptantha leucophaea*) occurs on open dunes throughout the Hanford Site. Piper's daisy (*Erigeron piperianus*) is fairly common on Umtanum Ridge and Rattlesnake Ridge, but has also been documented in the vicinity of B Pond, the A-24 Crib, and 100-H Area. Bristly cryptantha (*Cryptantha interrupta*) and dwarf evening-primrose (*Oenothera pygmaea*) have been found at the south end of the White Bluffs, approximately 3.2 km (2 mi) upstream from the 300 Area. The Palouse milk vetch (*Astragalus arrectus*) and coyote tobacco (*Nicotiana attenuata*) are not as well documented but are known to inhabit dry sandy areas such as the 200 Areas Plateau.

In addition to the three classifications for species of concern listed above, the Natural Heritage Program also maintains a "Monitor" list, which is divided into three groups. Group 1 consists of taxa in need of further field work before a formal status can be assigned. The tooth-sepal dodder (*Cuscuta denticulata*), which has been found in the state of Washington only on the Hanford Site, is the only taxon in this group that is of concern to Hanford operations. This parasitic species has been found in the area west of McGee Ranch. Group 2 of the Monitor list includes species with unresolved taxonomic questions. Thompson's sandwort (*Arenaria franklinii* var. *thompsonii*) is of concern to Hanford operations. However, the representatives of this species in the state of Washington are now believed to

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all be variety *franklinii* which is not considered particularly rare. Group 3 of the Monitor list includes taxa that are either more abundant or less threatened than previously believed. There are approximately 15 taxa on the Hanford Site that are included on this list.

3.6.1.3 Fauna of the 200 Areas Plateau. The mammals, birds, reptiles, amphibians inhabiting the 200 Areas Plateau are discussed below.

3.6.1.3.1 Mammals. The largest mammal occurring on the 200 Areas Plateau is the mule deer (*Odocoileus hemionus*). Although mule deer are much more common to riparian sites along the Columbia River, they are frequently observed foraging throughout the 200 Areas. Elk (*Cervus elaphus*) also occur at the Hanford Site but they have only been observed at the Arid Lands Ecology Reserve. Other mammal species common to the 200 Areas include badgers (*Taxidea taxus*), coyotes (*Canis latrans*), blacktail jackrabbits (*Lepus californicus*), Townsend ground squirrels (*Spermophilus townsendii*), Great Basin pocket mice (*Perognathus parvus*), pocket gophers (*Thomomys talpoides*), and deer mice (*Peromyscus maniculatus*). Badgers are known for their digging capability and have been implicated several times for encroaching into inactive burial grounds throughout the 200 Areas. The majority of the badger excavations in the 200 Areas are a result of badgers searching for prey (mice and ground squirrels). Coyotes are the principal predators, consuming such prey as rodents, insects, rabbits, birds, snakes and lizards. The Great Basin pocket mouse is the most abundant small mammal, which thrives in sandy soils and lives entirely on seeds from native and revegetated plant species. Townsend ground squirrels are not abundant in the 200 Areas but they have been seen at several different sites.

Other small mammals that occur in low numbers include the western harvest mouse (*Reithrodontomys megalotis*) and the grasshopper mouse (*Onychomys leucogaster*). Mammals associated more closely with buildings and facilities include Nuttall's cottontails (*Sylvilagus nuttallii*), house mice (*Mus musculus*), Norway rats (*Rattus norvegicus*), and some bat species. Bats probably play a minor role in the 200 Areas' ecosystem but no documentation is available on bat populations at the Hanford Site. Mammals such as skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), weasels (*Mustela* spp.), porcupines (*Erethizon dorsatum*), and bobcats (*Lynx rufus*) have only been observed on very few occasions.

3.6.1.3.2 Birds. Over 235 species of birds have been documented to occur at the Hanford Site (Landeen et al. 1991). At least 100 of these species have been observed in the 200 Areas. The most common passerine birds include starlings (*Sturnus vulgaris*), horned larks (*Ermophila alpestris*), meadowlarks (*Sturnella neglecta*), western kingbirds (*Tyranus verticalis*), rock doves (*Columba livia*), barn swallows (*Hirundo rustica*), cliff swallows (*Hirundo pyrrhonota*), black-billed magpies (*Pica pica*), and ravens (*Corvus corax*). Common raptors include the northern harrier (*Circus cyaneus*), American kestrel (*Falco sparvarius*), and red-tailed hawk (*Buteo jamaicensis*). Swainson's hawks (*Buteo swainsoni*) sometimes nest in the trees located at some of the army bunker sites that were used in the 1940's.

Golden eagles (*Aquila chrysaetos*) are observed infrequently. Burrowing owls (*Athene cunicularia*) nest at several locations throughout the 200 Areas. The most common upland game birds found in the 200 Areas are California quail (*Callipepla californica*) and Chukar partridge (*Alectoris chukar*); however, ring-necked pheasants (*Phasianus colchicus*) and gray partridge (*Perdix perdix*) may be found in limited numbers. The only native game bird common to the 200 Areas Plateau is the mourning dove (*Zenaida macroura*), which migrates south each fall. Other species of note which nest in undisturbed sagebrush habitats in the 200 Areas include sage sparrows (*Amphispiza belli*) and loggerhead shrikes (*Lanius ludovicianus*). Long-billed curlews (*Numenius americanus*) also use the sagebrush areas and revegetated burial grounds for nesting and foraging.

Waterfowl and aquatic birds visit 216-B-3 Pond and other areas where there is running or standing water. However, these areas (such as 216-A-29 Ditch) are becoming more scarce due to stabilization and remedial action cleanup activities. Aquatic birds and waterfowl common to 216-B-3 Pond on a seasonal basis include Canada geese (*Branta canadensis*), American coot (*Fulica americana*), mallard (*Anas platyrhynchos*), ruddy duck (*Oxyura jamaicensis*), redhead (*Aythya americana*), bufflehead (*Bucephala albeola*), and great blue heron (*Ardea herodius*).

3.6.1.3.3 Reptiles and Amphibians. Common reptiles include gopher snakes (*Pituophis melanoleucus*) and sideblotched lizards (*Uta stansburiana*). Other reptiles and amphibians that are infrequently observed include sagebrush lizards (*Sceloporus graciosus*), horned toads (*Phryosoma douglassii*), western spadefoot toads (*Scaphiopus intermontana*), yellow-bellied racer (*Coluber constrictor*), Pacific rattlesnake (*Crotalus viridis*), and striped whipsnake (*Masticophis taeniatus*). Both lizards and snakes are prey of mammalian and avian predators.

3.6.1.3.4 Insects. There are hundreds of insect species that inhabit the 200 Areas. Two of the most common groups of insects include several species of darkling beetles and grasshoppers. Harvester ants are also common and have been implicated in the uptake of radionuclides from some of the burial grounds in the 200 East Area. Harvester ants can excavate and bring up material from as far down as 5 to 6 m (15 to 20 ft). Other major groups of insects include bees, butterflies, and scarab beetles. Insects impact the surrounding plant community as well as serving as the prey base for many species of birds, reptiles and mammals.

3.6.1.4 Wildlife Species of Concern. Some animals which inhabit the Hanford Site have been given special status designations by the state and federal government. Some of these designations include state and federal threatened and endangered species, federal candidate, state monitor, state sensitive, and state candidate species. Species listed in Table 3-4 as state and\or federal threatened and endangered such as the bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrinus*), American white pelican (*Pelecanus erythroryhnchos*),

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ferruginous hawk (*Buteo regalis*), and sandhill crane (*Grus canadensis*) do not inhabit the 200 Areas. The bald eagle and American white pelican utilize the Columbia River and associated habitats for roosting and feeding. Peregrine falcons and sandhill cranes fly over the Hanford Site during migration. Ferruginous hawks nest on the Hanford Site but nesting has not been documented for this species on the 200 Areas Plateau. Other species listed in Table 3-4 as state and/or federal candidates and state monitor species such as burrowing owls, great blue herons, prairie falcons (*Falco mexicanus*), sage sparrows, and loggerhead shrikes are not uncommon to the 200 Areas Plateau.

3.6.2 Land Use

Operations in the 200 East Area have been related to nuclear fuels processing, separation, and recovery. Activities at the B Plant and PUREX Plant included processing of irradiated fuel rods for uranium and plutonium separation. In the Semi-Works Aggregate Area, pilot processes for plutonium and uranium extraction, strontium and other fission product recovery, and critical mass experiments were conducted. In the 200 North Aggregate Area fuel rods were stored temporarily before processing. Aggregate area facilities and process activities are described in detail in Sections 2.2 and 2.3. Waste management units that remain active are noted in Table 2-1. A summary of the land use within each of these facilities is presented below.

Access to the entire Hanford Site is administratively controlled and is expected to remain this way to ensure public health and safety and for reasons of national security.

The B Plant Aggregate Area is the location of the main B Plant facility (221-B Building), and related structures including the 222-B Laboratory, 224-B Concentrator, and 2101-M offices. Past activities at B Plant were primarily associated with plutonium extraction from spent fuel uranium fuel rods, and strontium and cesium recovery. Other buildings within the unit served mainly as powerplants and office and storage space. The B Plant is currently inactive.

The PUREX Plant Aggregate Area is the location of the PUREX Plant (202-A Building) and related structures including the 242-A Evaporator, 293-A Building, Grout Treatment Facility, and the 204-AR waste unloading station. Past activities include plutonium and uranium extraction from uranium fuel rods. Current activities at the PUREX Plant include waste treatment and storage at the Grout Treatment Facility, waste unloading at 204-AR facility, and liquid waste evaporation. The PUREX Plant is currently in standby mode.

The Semi-Works Aggregate Area is the site of the former Semi-Works complex (201-C Building) and related structures including the 291-C and 271-C Buildings, and the Critical

Mass Laboratory. Past activities include plutonium separation technology development; pilot extraction of strontium, cesium, and promethium from process waste; and criticality experiments. Semi-Works is currently decommissioned and the Critical Mass Laboratory has been converted to office space. Other structures have been demolished or currently serve as storage space.

3.6.3 Water Use

There is no consumptive use of groundwater within the 200 East Area. Water for drinking, emergency use, and facilities process is drawn from the Columbia River, treated, and imported to the 200 East Area. The nearest wells used to supply drinking water are located at the Yakima Barricade (Well 699-49-100-C) about 13 km (8 mi) west of the 200 East Area; at the Hanford Safety Patrol Training Academy (Well 699-S28-E0) about 25 km (16 mi) to the southeast; at the PNL Observatory (developed spring); and near the Fast Flux Test Facility in the 400 Area (Well 699-S1-8J) about 16 km (10 mi) to the southeast. The nearest water supply wells located offsite are about 21 km (13 mi) to the northwest (upgradient). The latter wells obtain their water from the basalt and the basalt interbeds (the Berkshire Well and Chateau Ste. Michelle No. 1 and No. 2), and are reportedly used for irrigation although they may also be used to supply drinking water. Three well for emergency cooling water supply are located near the B Plant in the 200 East Area.

3.7 HUMAN RESOURCES

The following sections provide an overview of the demography (Section 3.7.1), archaeology (Section 3.7.2), historical resources (Section 3.7.3), and community involvement (Section 3.7.4) relating to the Hanford Site and 200 East Area.

The environmental conditions at the 200 East Area must be evaluated in relationship to the surrounding population centers and other human resources. A very brief summary of demography, archaeology, historical resources, and community involvement is given below.

3.7.1 Demography

There are no residences on the Hanford Site. The nearest inhabited residences are farm homes on land located 10 km (6 mi) west of the 200 West Area at the orchard across from the Ste. Michelle vineyard, and on the farm next to the vineyard on Cold Creek and Highway 29. There are approximately 411,000 people living within a 80 km (50 mi) radius of the 200 Areas Plateau. The primary population centers are the cities of Richland,

Kennewick, and Pasco, located southeast of the Hanford Site, Prosser to the south, Sunnyside to the southwest, and Benton City to the southeast.

3.7.2 Archaeology

An archaeologic survey has been conducted of undeveloped portions of the 200 East Area by the Hanford Cultural Resources Laboratory. Isolated artifacts and sites of interest were identified in the 200 West Area but not within the 200 East Area. The closest site of interest is the remains of the White Bluffs Road, located approximately 15 km (9 mi) northwest of the aggregate area, which was previously an Indian trail.

3.7.3 Historical Resources

The only historic site near 200 East Area is the old White Bluffs road which is to the northwest. This site is not considered to be eligible for the National Register.

3.7.4 Community Involvement

A Community Relations Plan (Ecology et al. 1989) has been developed for the Hanford Site Environmental Restoration Program which includes any potentially affected community with respect to the 200 East Groundwater AAMSR. The Community Relations Plan includes a discussion on analysis of key community concerns and perceptions regarding the project, along with a list of all interested parties.

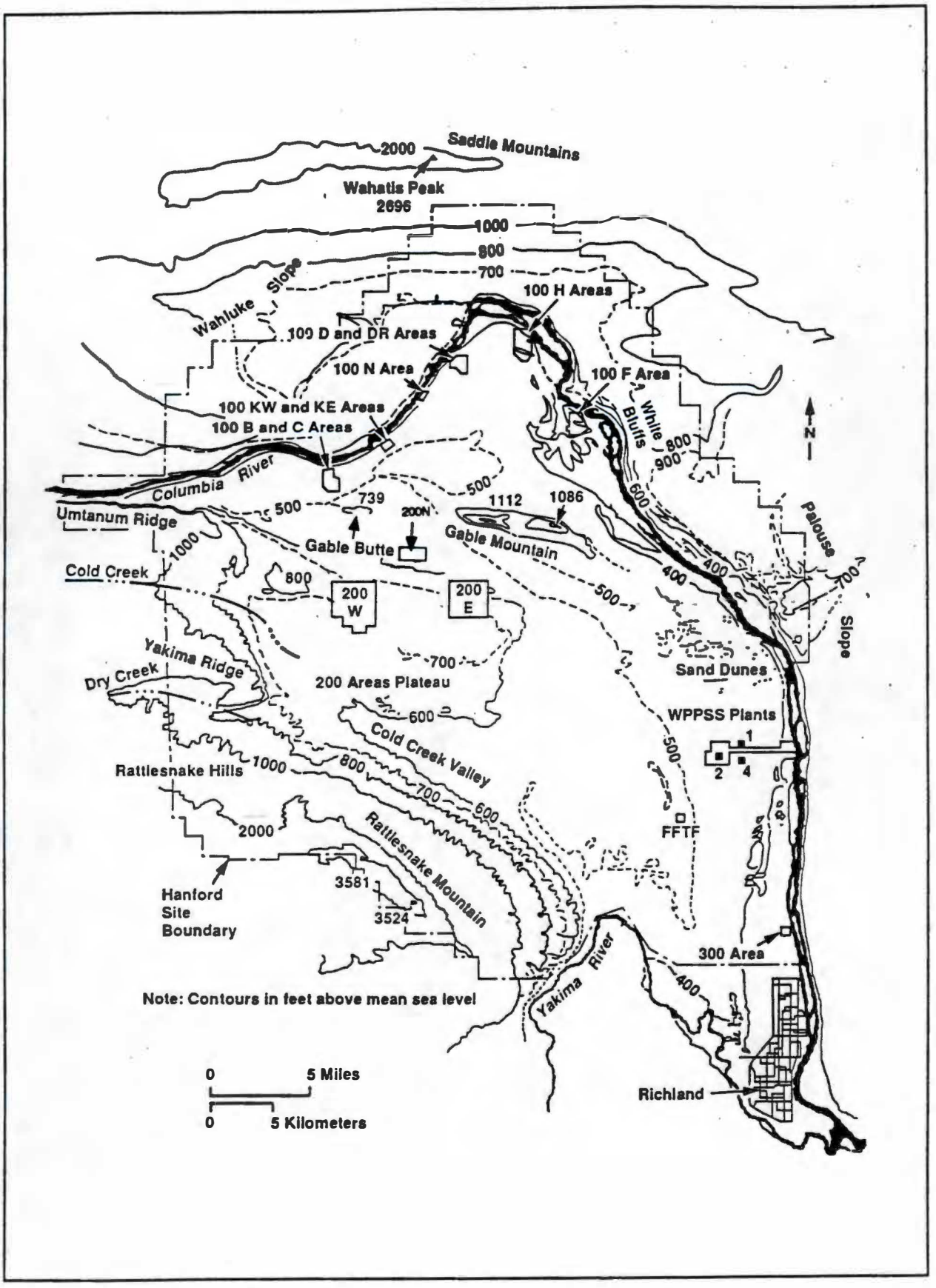

Figure 3-1. Topography and Location Map for the Hanford Site.

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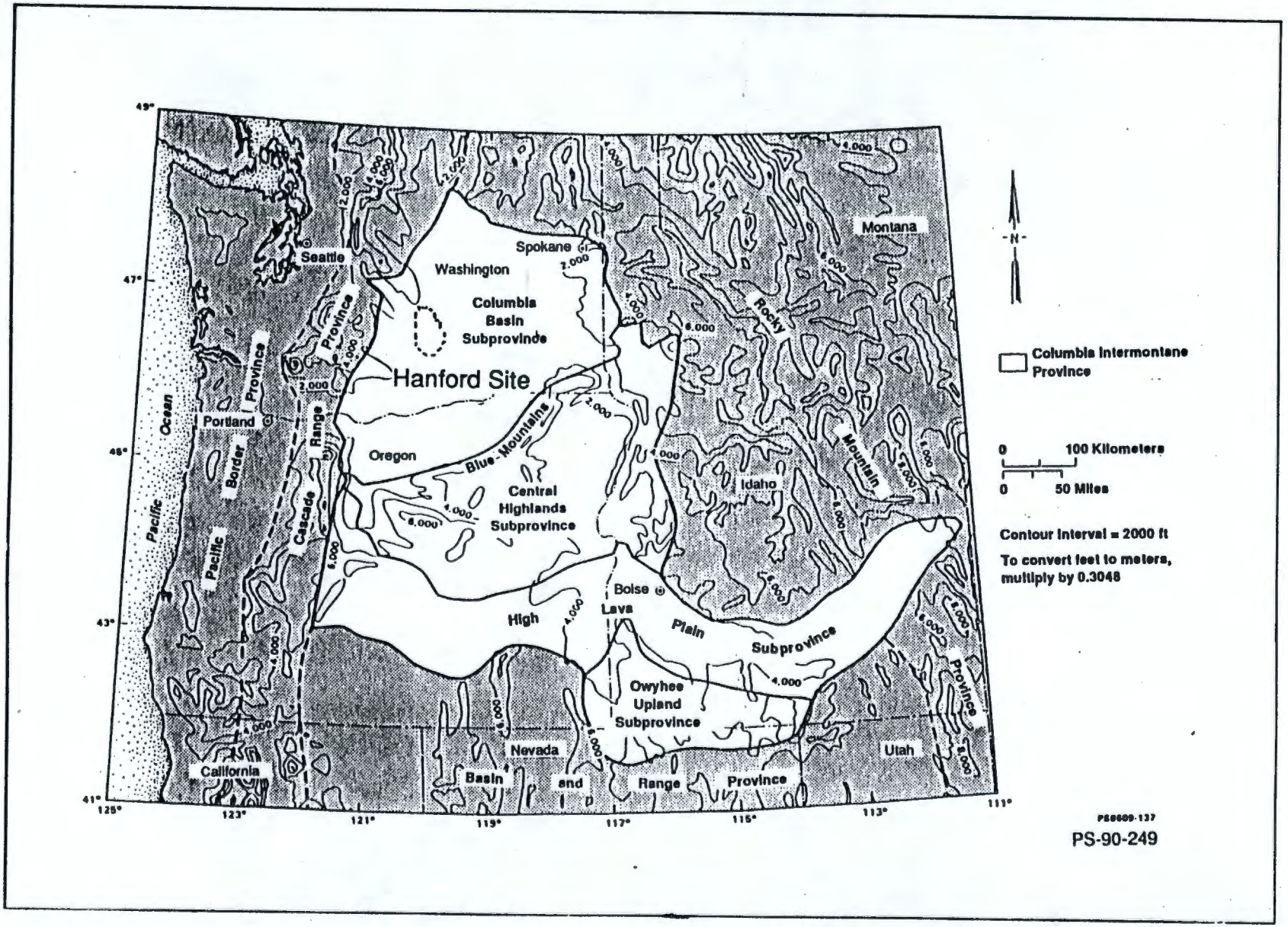

Figure 3-2. Divisions of the Columbia Intermontane Province and Adjacent Snake River Plains Province (DOE 1988).

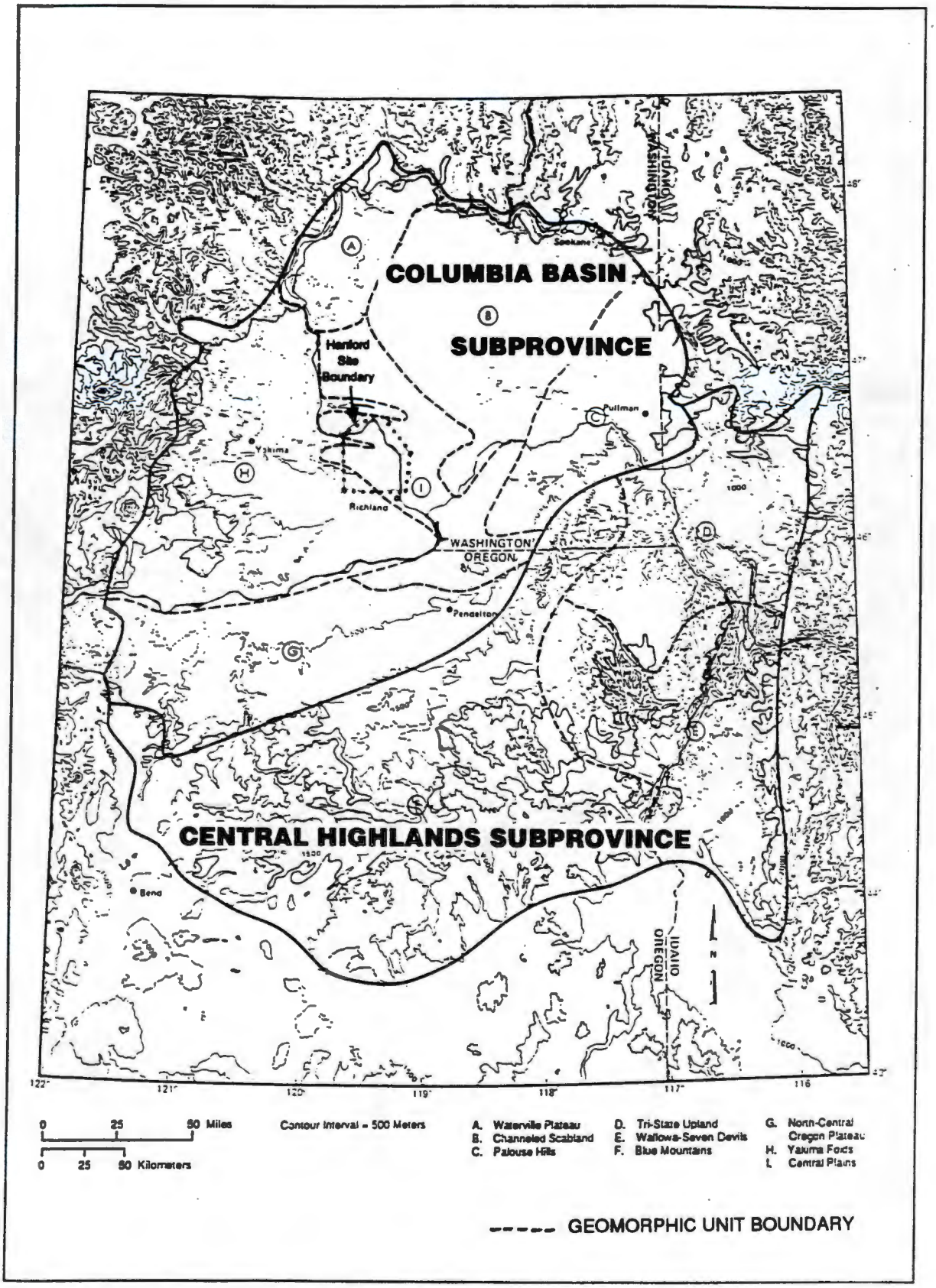

Figure 3-3. Geomorphic Units Within the Central Highlands and Columbia Basin Subprovinces that Contain the Columbia River Basalt Group (DOE 1988).

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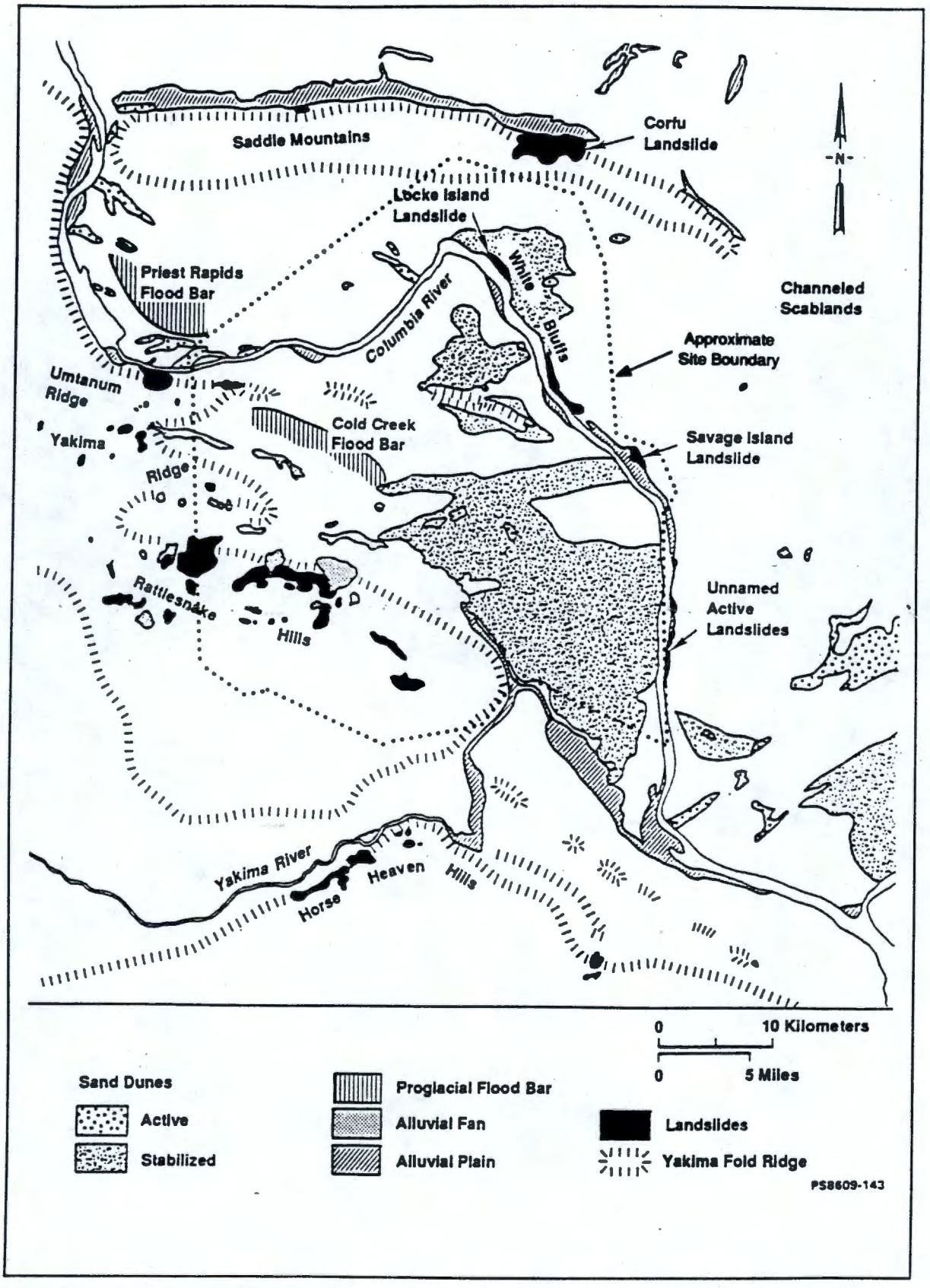

Figure 3-4. Landforms of the Pasco Basin and the Hanford Site (DOE 1988).

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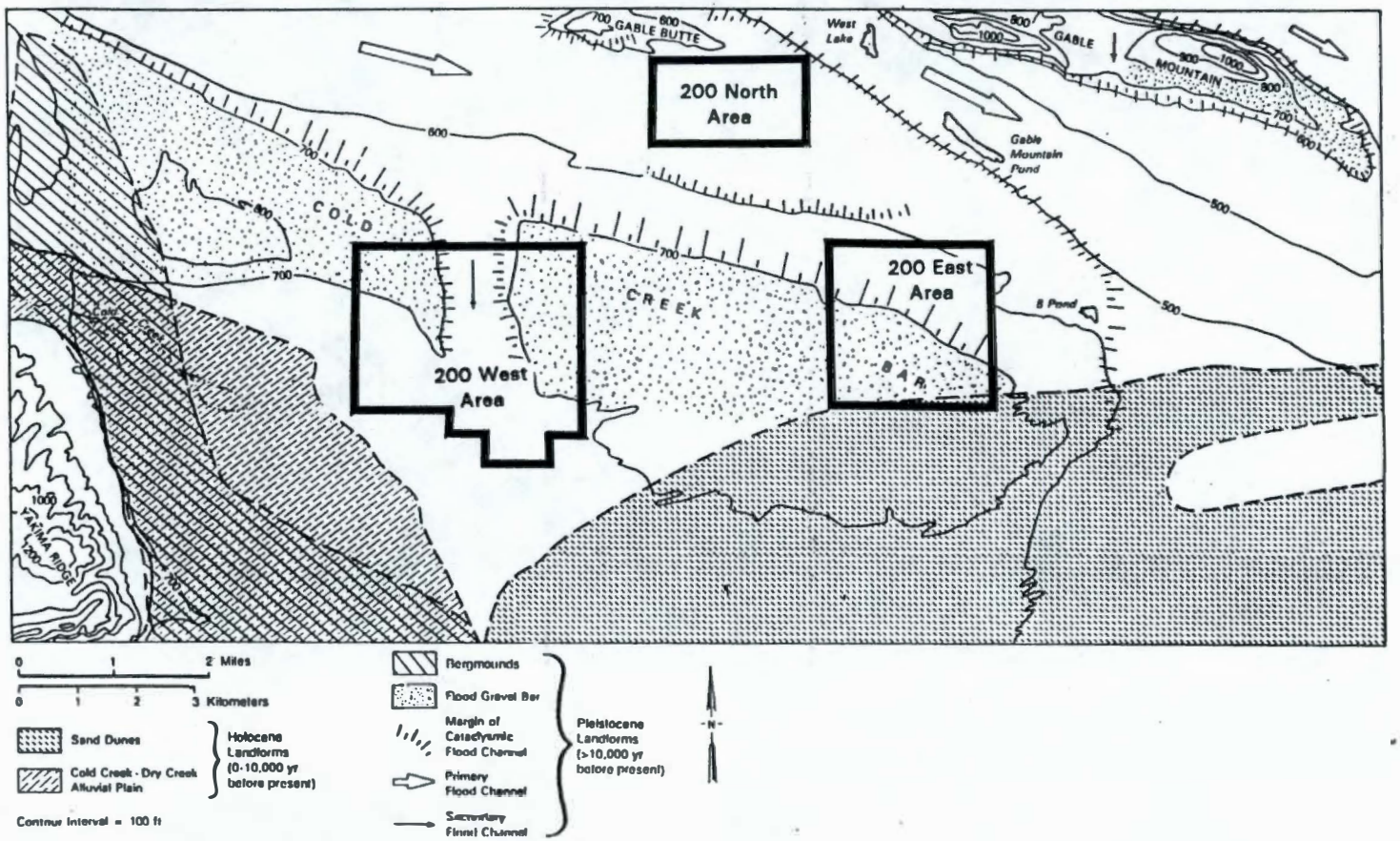

Figure 3-5. Geomorphic Features Surrounding the 200 Areas (Last et al. 1989).

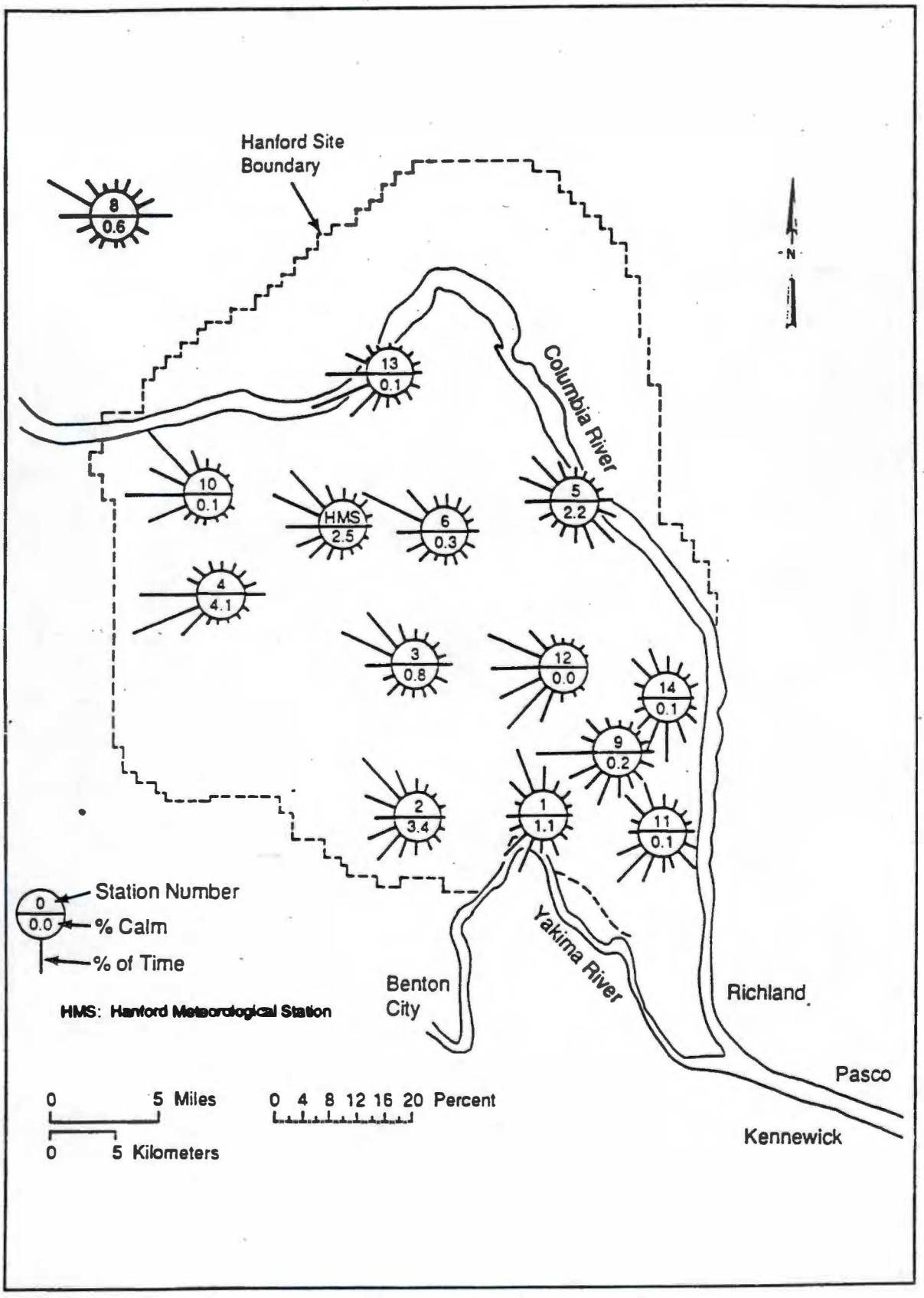

Figure 3-6. Hanford Site Wind Roses, 1979 through 1982 (Stone et al. 1983).

9 2 1 2 7 5 1 3 6 2

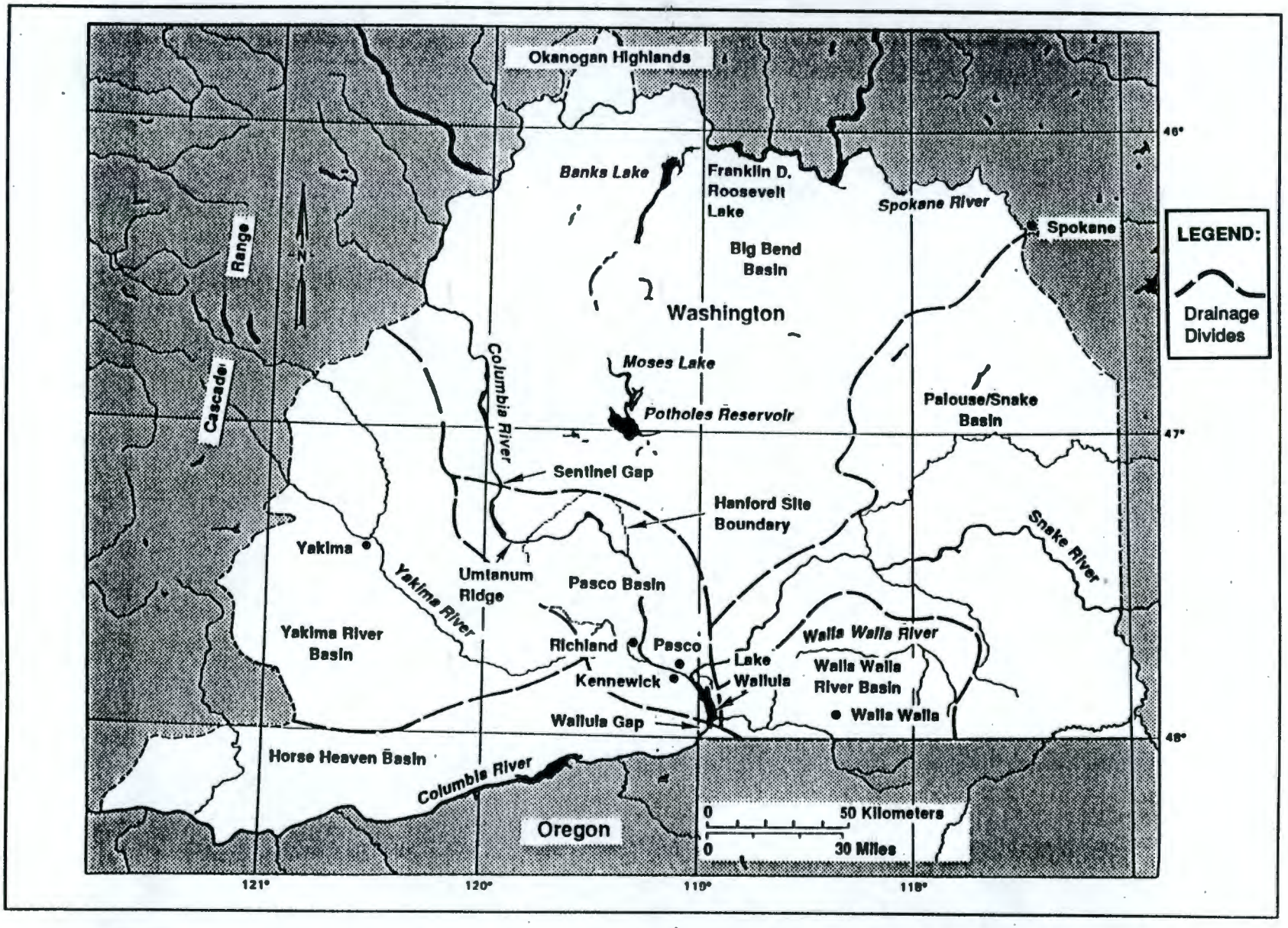

Figure 3-7. Hydrologic Basins Designated for the Washington State Portion of the Columbia Plateau (DOE 1988).

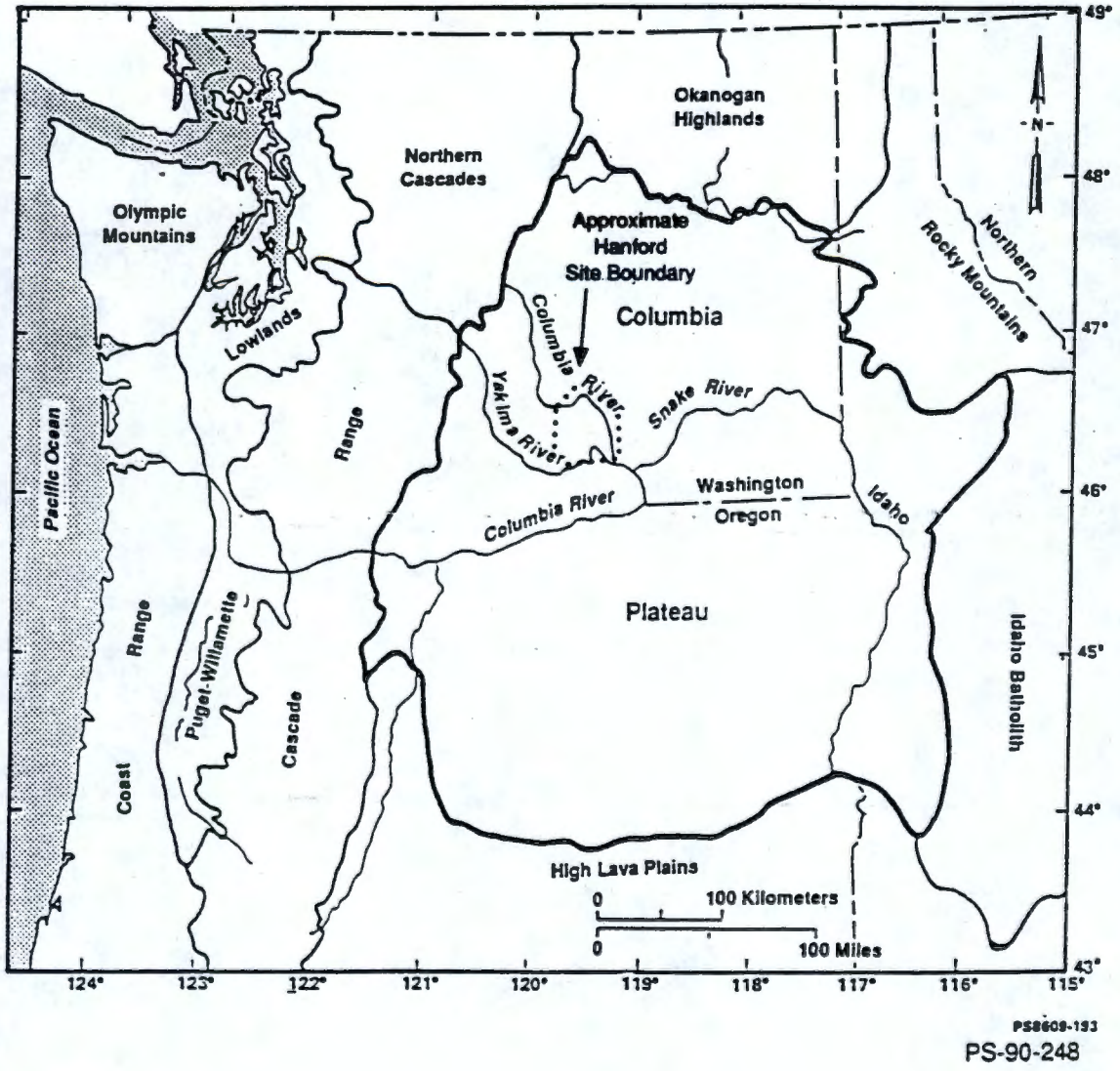

Figure 3-8. Columbia Plateau and Surrounding Structural Provinces (DOE 1988).

9 2 1 2 7 5 1 3 6 4

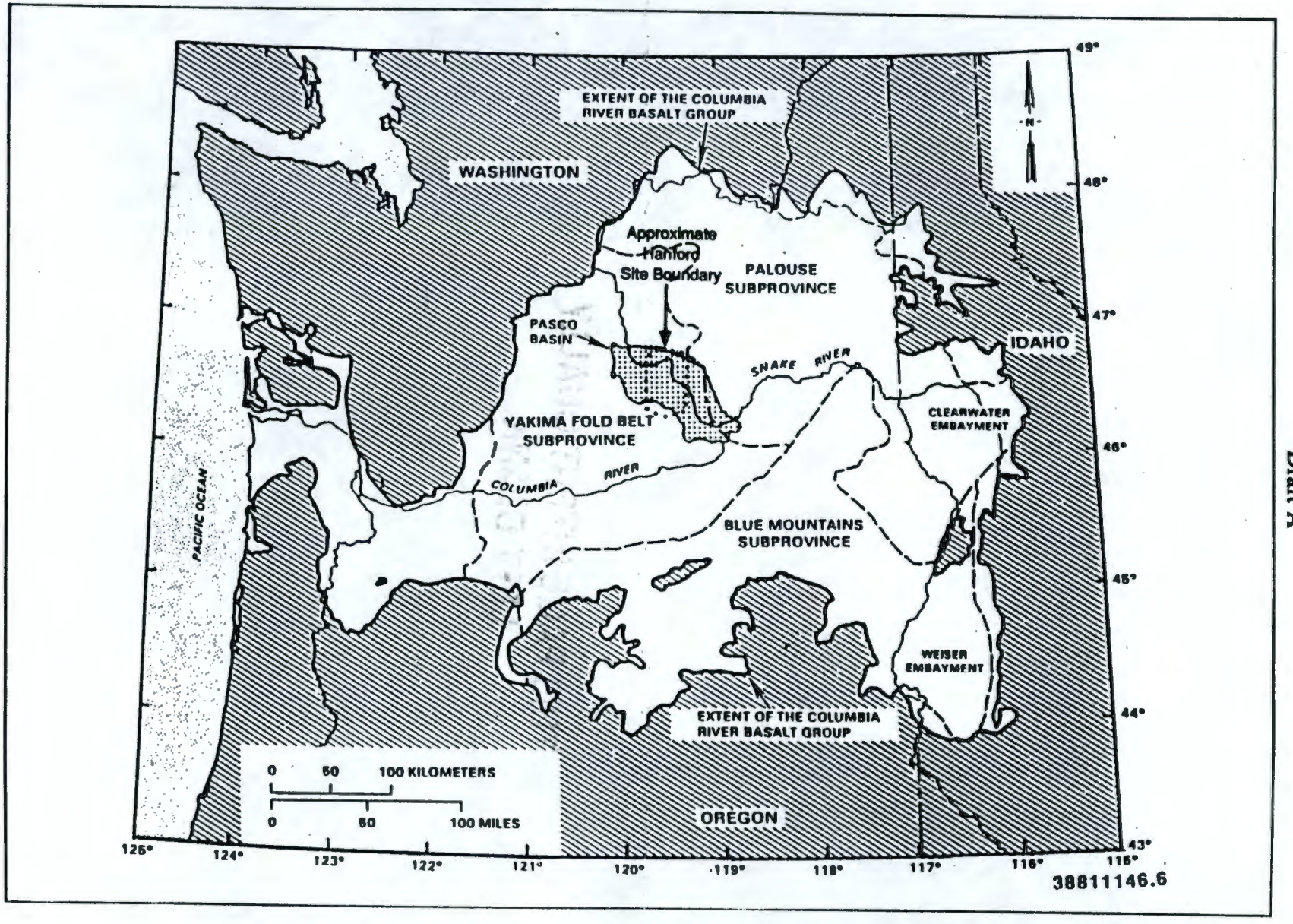

Figure 3-9. Structural Subprovinces of the Columbia Plateau (DOE 1988).

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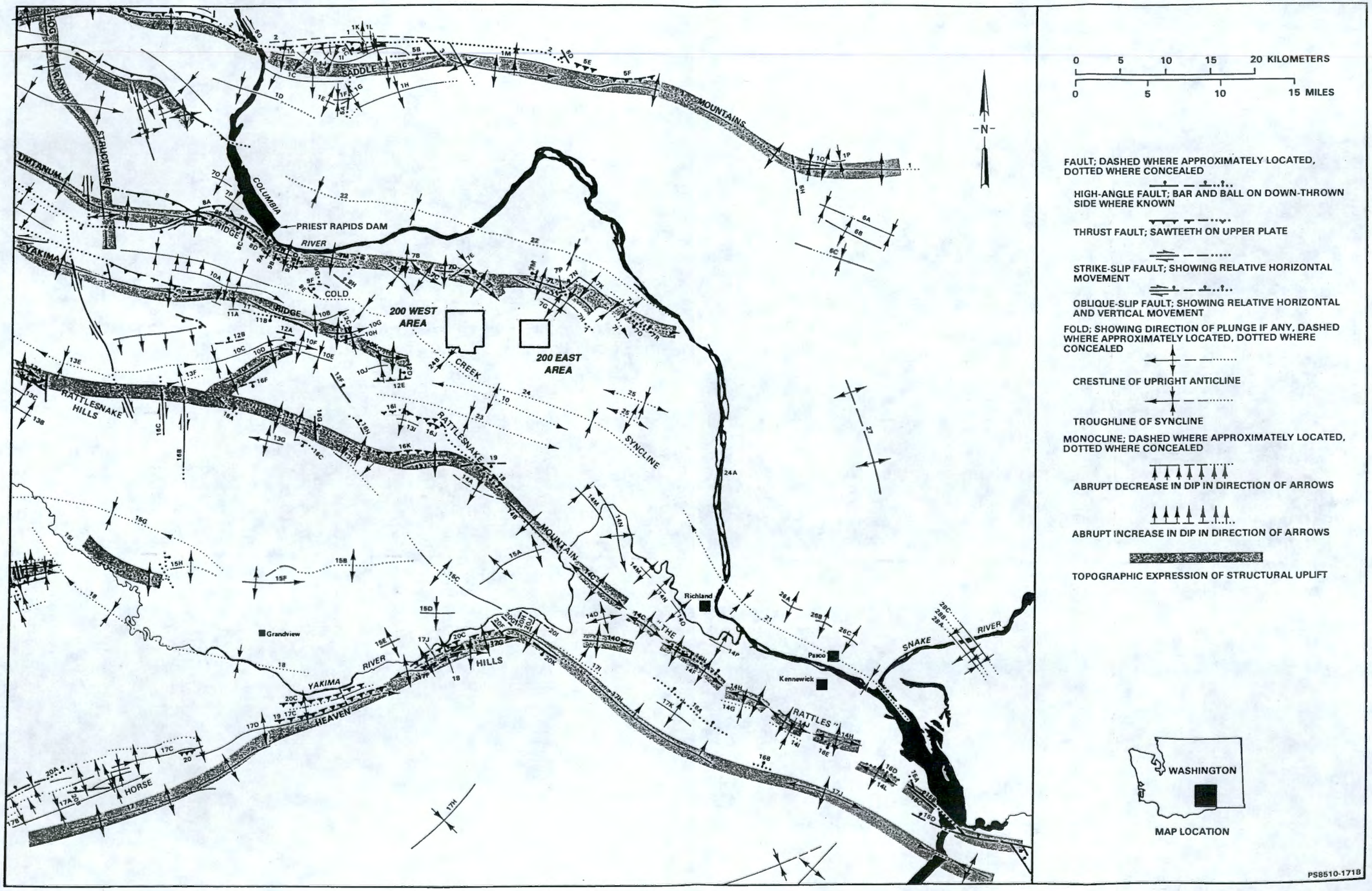

Figure 3-10. Structural Elements of the Yakima Fold Belt Subprovince (DOE 1988).

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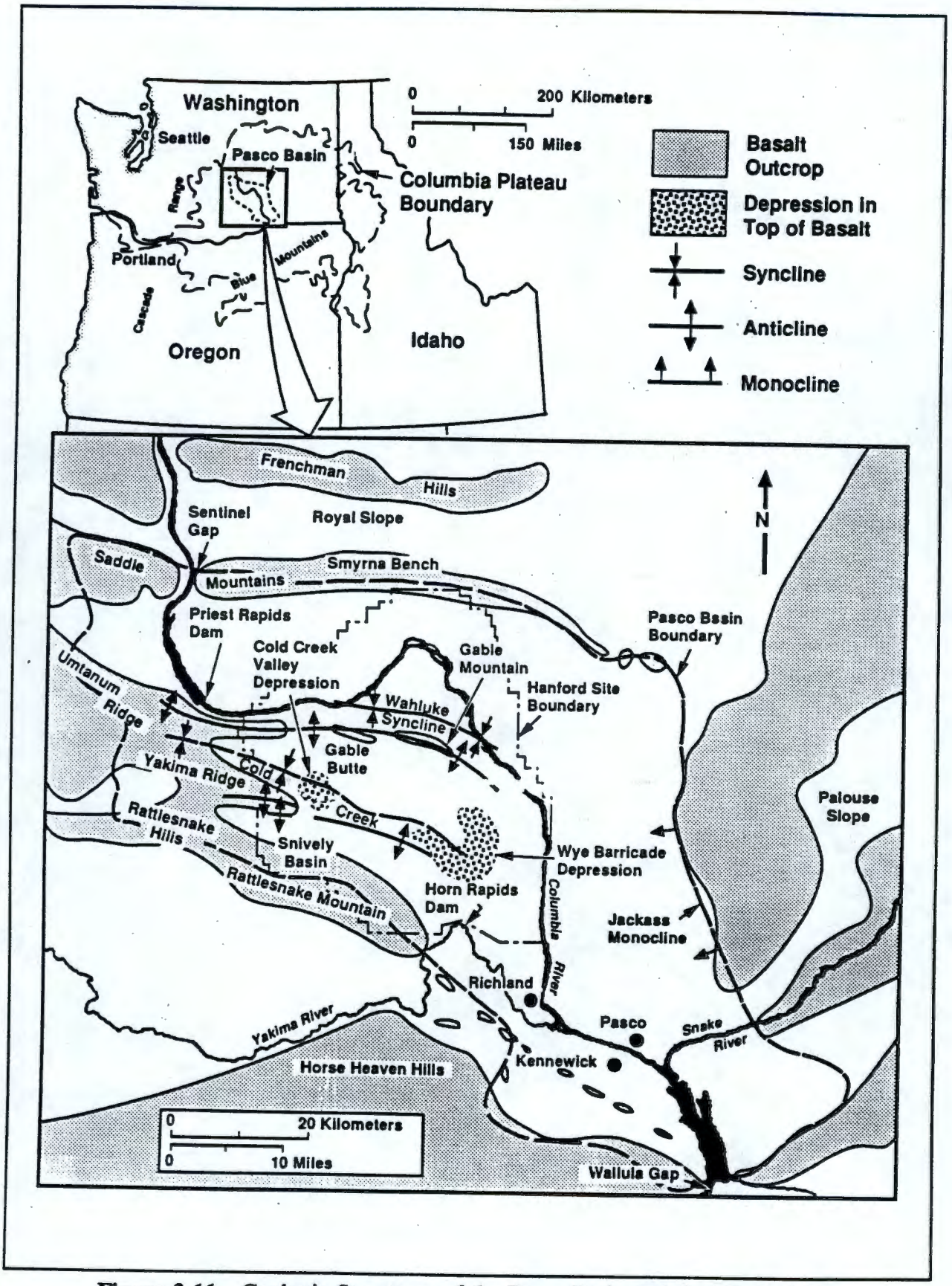

Figure 3-11. Geologic Structures of the Pasco Basin and the Hanford Site (Reidel et al. 1989).

9 2 1 2 7 5 1 3 6 7

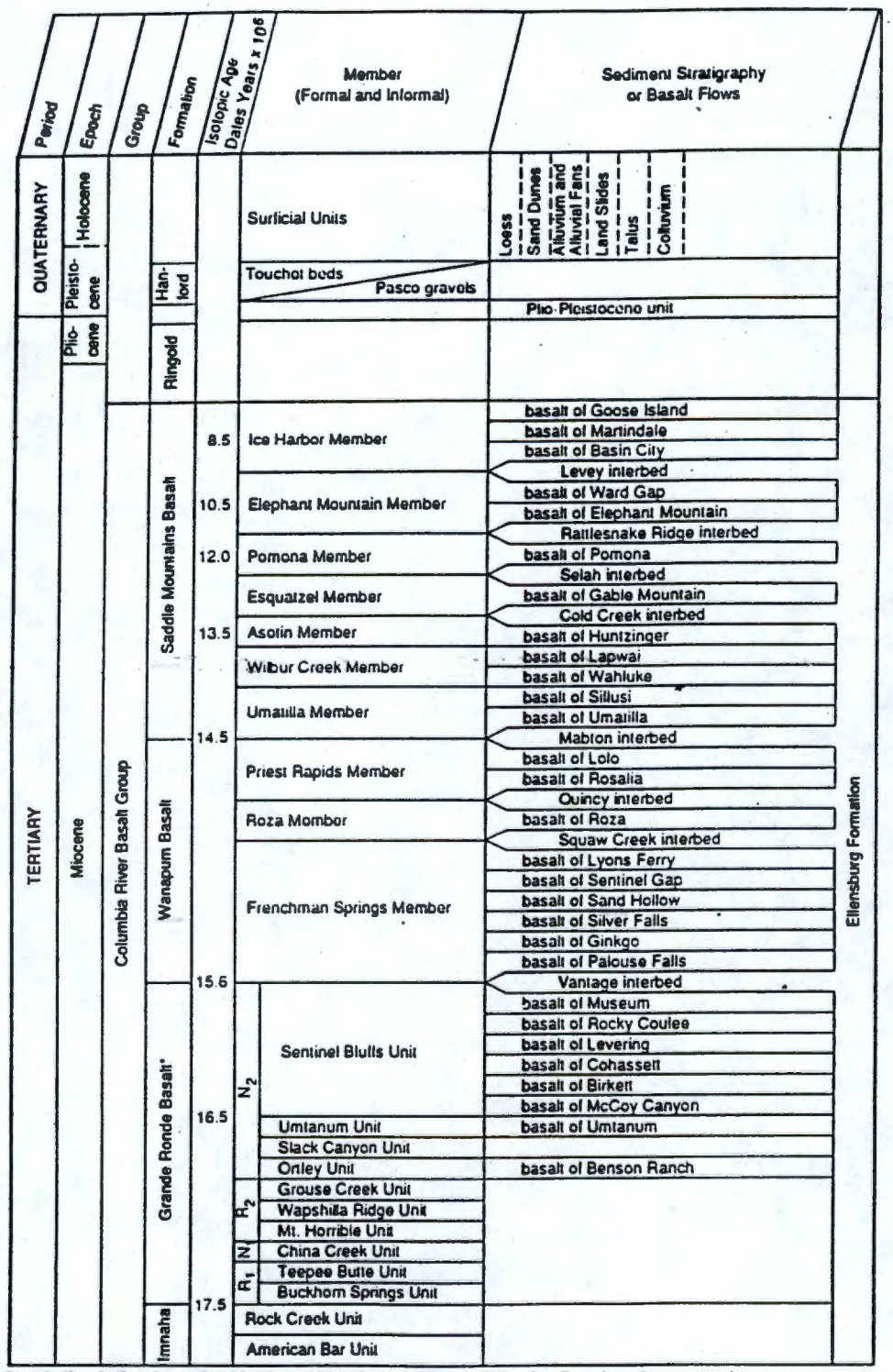

Figure 3-12. Generalized Stratigraphy of the Hanford Site (DOE 1988).

9 2 1 2 7 5 1 3 6 8

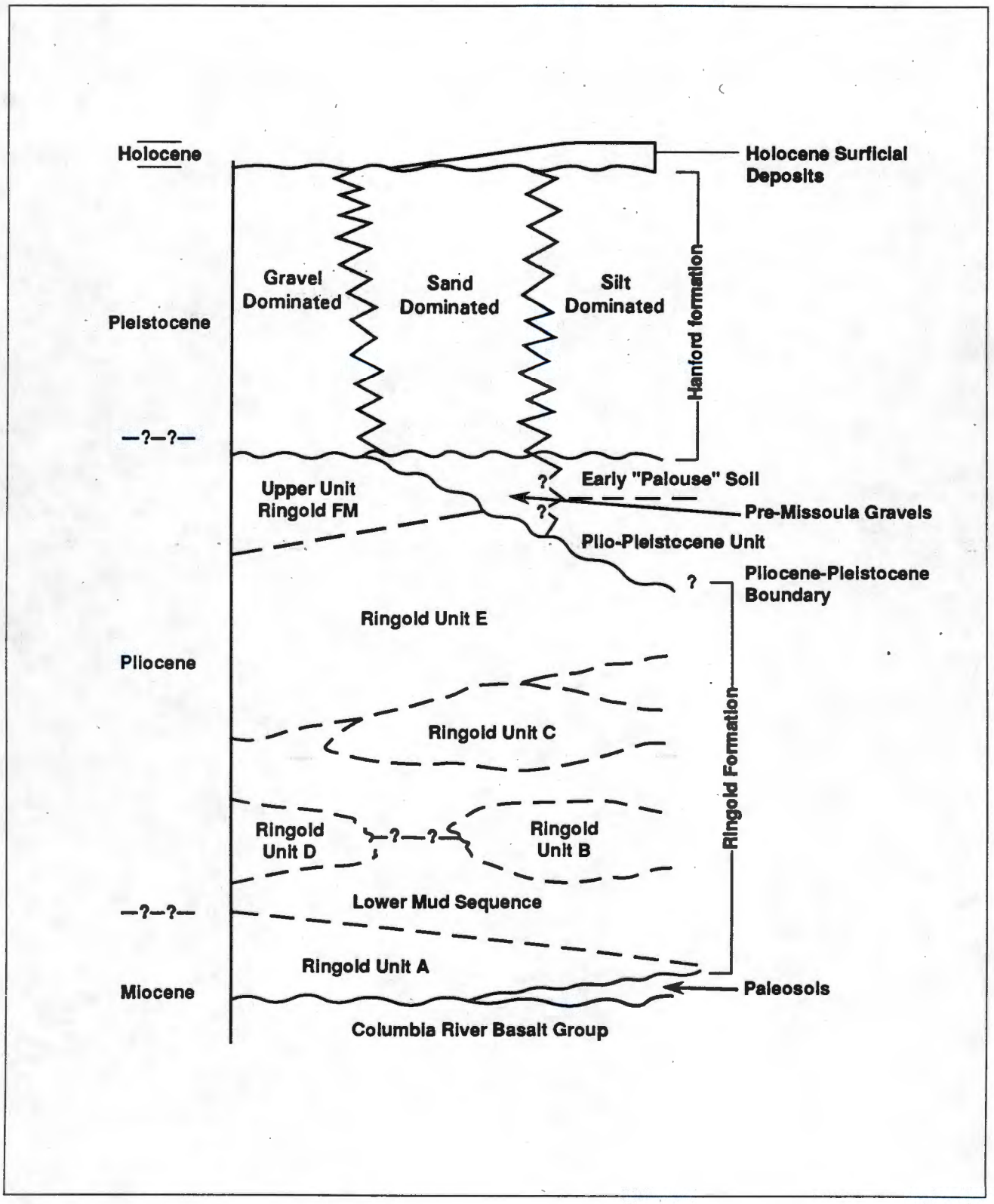

Figure 3-13. Generalized Stratigraphy of the Suprabasalt Sediments Beneath the Hanford Site (Lindsey et al. 1989).

9 2 1 2 7 5 1 3 6 9

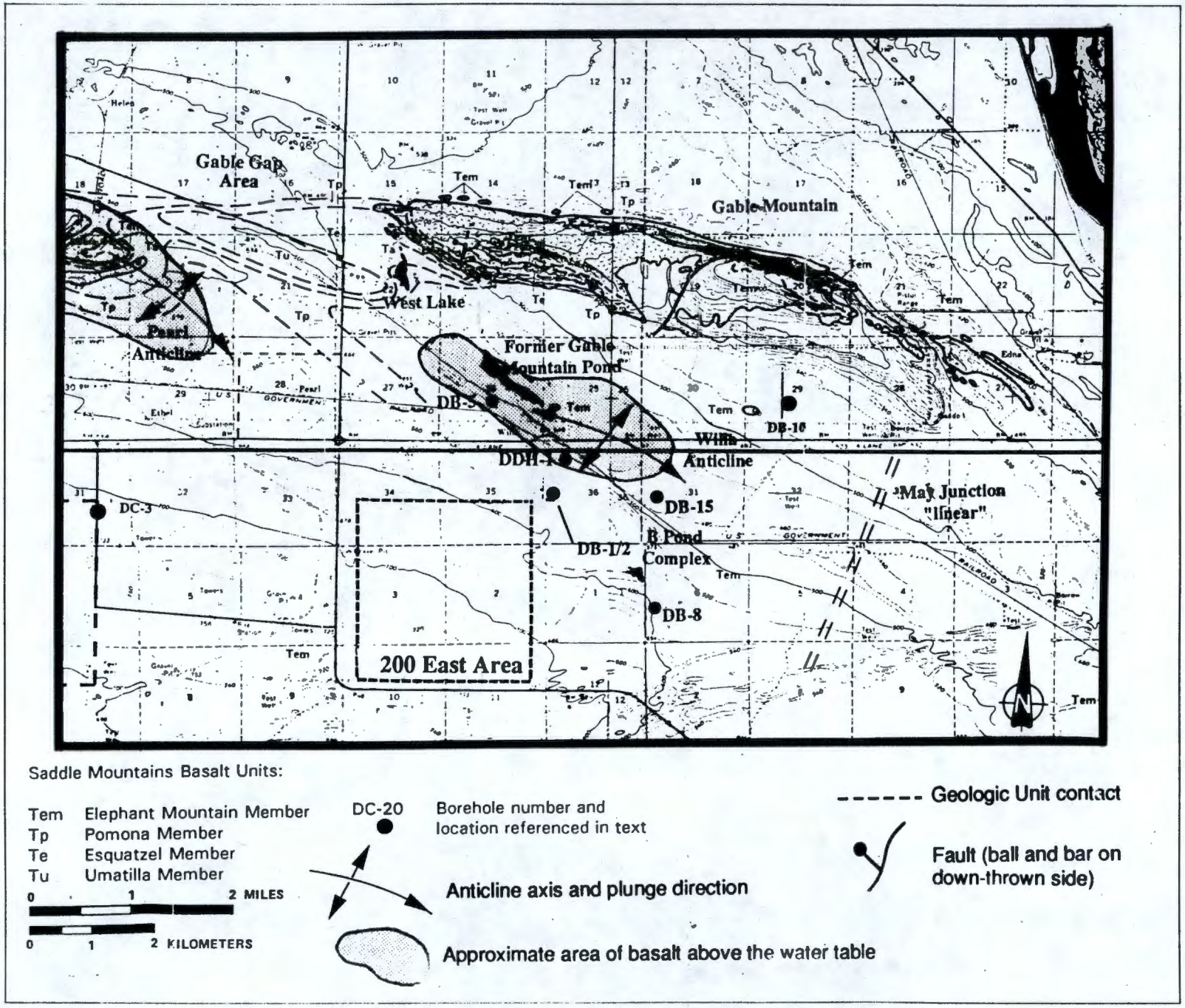

Figure 3-14. Bedrock Geology Map (modified from Meyers and Price 1981).

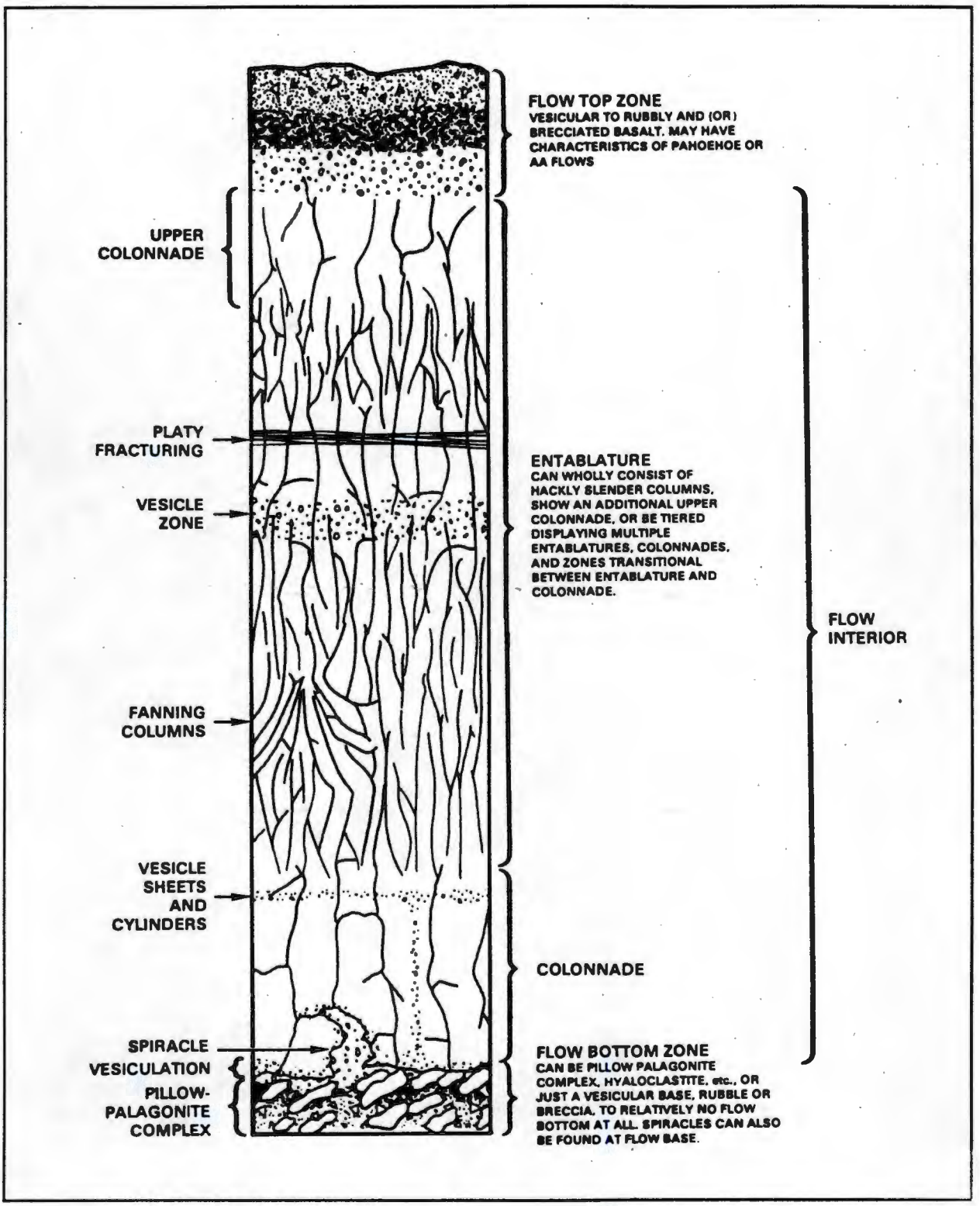

Figure 3-15. Idealized Columnar Section Showing the Variety of Intraflow Structures Possible in Columbia River Basalt Group Flows (Swanson et al. 1979).

9 2 1 2 7 5 1 3 7 1

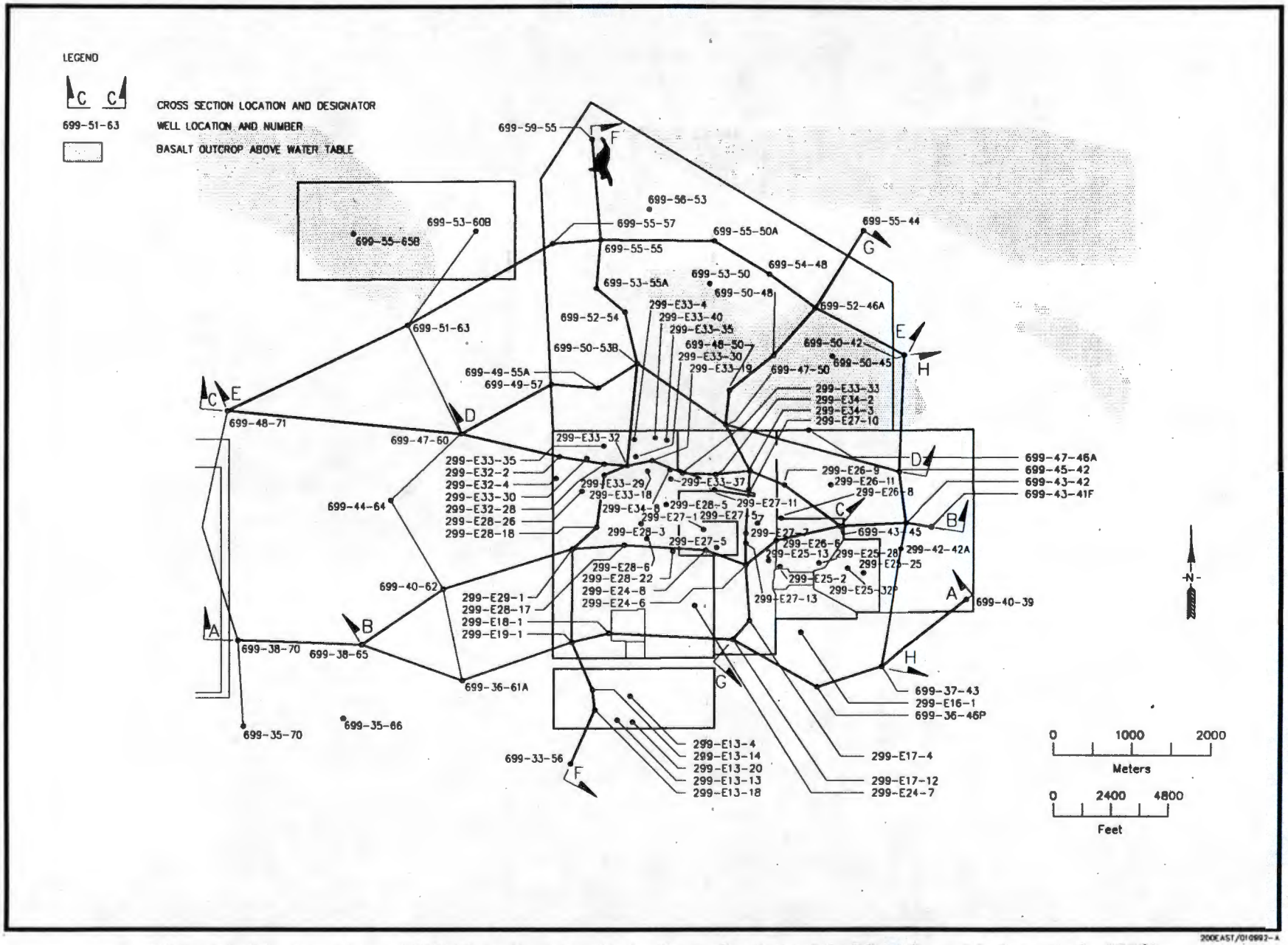

Figure 3-16. Location of 200 East Area Geologic Cross Sections (Modified from Lindsey et al. 1992).

Explanation

Grain Size Scale, Indicates Dominant Grain Size in an Interval

- Cobble–boulder Gravel
- Pebble Gravel
- Sand
- Clay/Silt

Additional Lithologic Symbols
Includes Subordinate Lithologies

- Clay rich
- Silt rich
- Sandy
- Pebbly to cobbly
- Bouldery
- Calcium carbonate present
- Basalt

Other Symbols

- Formational contact, ? where inferred
- Unit or sequence contact, ? where inferred
- Water Table Elevation (December 1991)

Unit Abbreviations

Eo – Eolian (Holocene) deposits
Hug – Upper Gravel Unit, Hanford formation
Hun – Undifferentiated Hanford formation
Hs – Sandy sequence, Hanford formation
Hlg – Lower Fine Gravel Unit, Hanford formation
H/R – Hanford/Ringold contact
PP – Plio–Pleistocene unit
UP – Upper unit, Ringold Formation
E – Gravel unit E, Ringold Formation
C – Gravel unit C, Ringold Formation
LM – Lower mud sequence, Ringold Formation
A – Gravel unit A, Ringold Formation
EM – Elephant Mountain Member, Saddle Mountains Basalt
RRI – Rattlesnake Ridge Interbed, Ellensburg Formation
P – Pomona Member, Saddle Mountains Basalt

NOTE:

1. Refer to Figure 3–16 for cross section locations and designation. Cross sections presented on Figures 3–18 through 3–25.
2. Figures based on Lindsey et al. 1992.

200east/2east002

Figure 3-17. Legend for Cross Sections.

9 2 1 2 7 5 1 3 7 3

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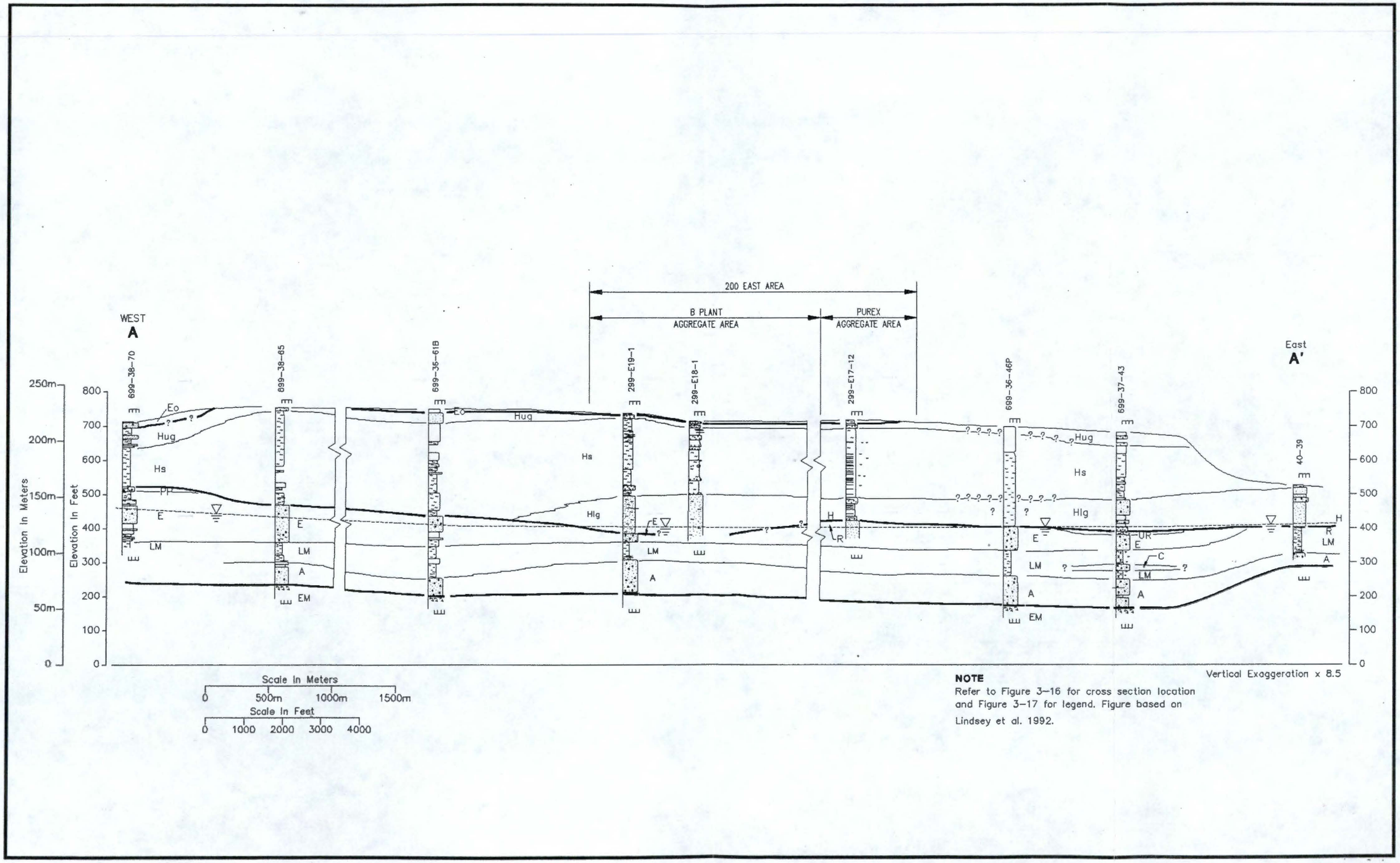
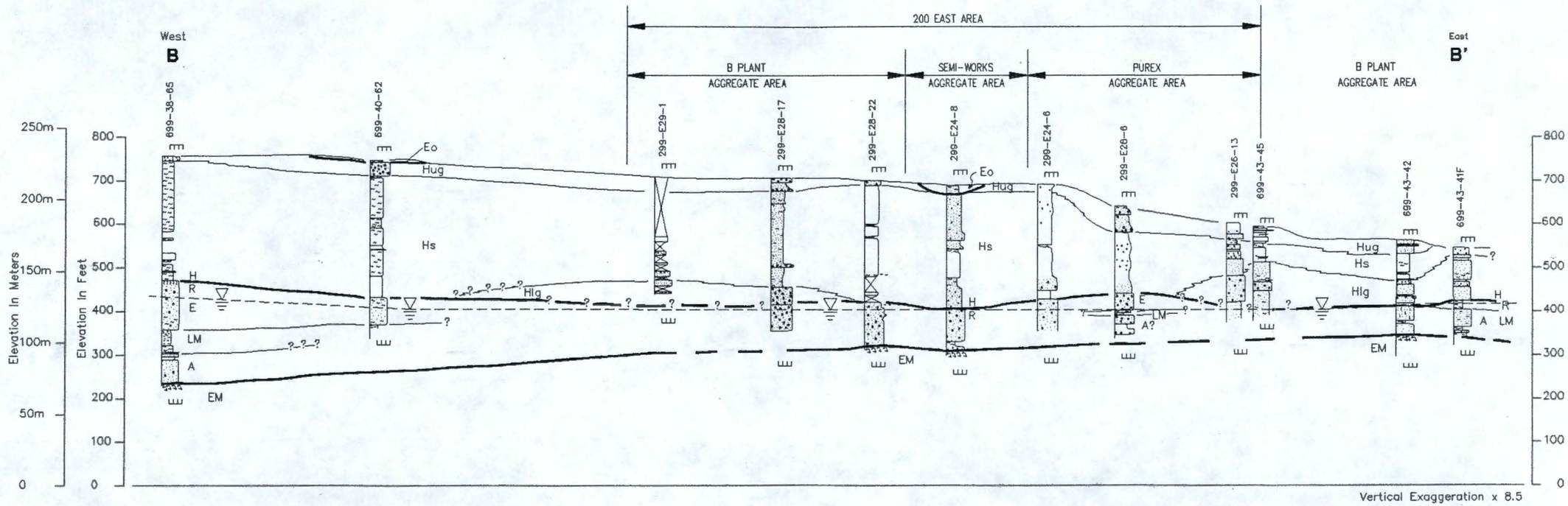
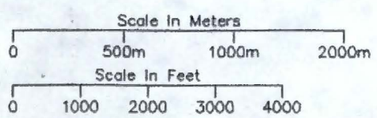


Figure 3-18. 200 East Area Geologic Cross Section A-A'.

9 2 1 2 7 5 1 3 7 4

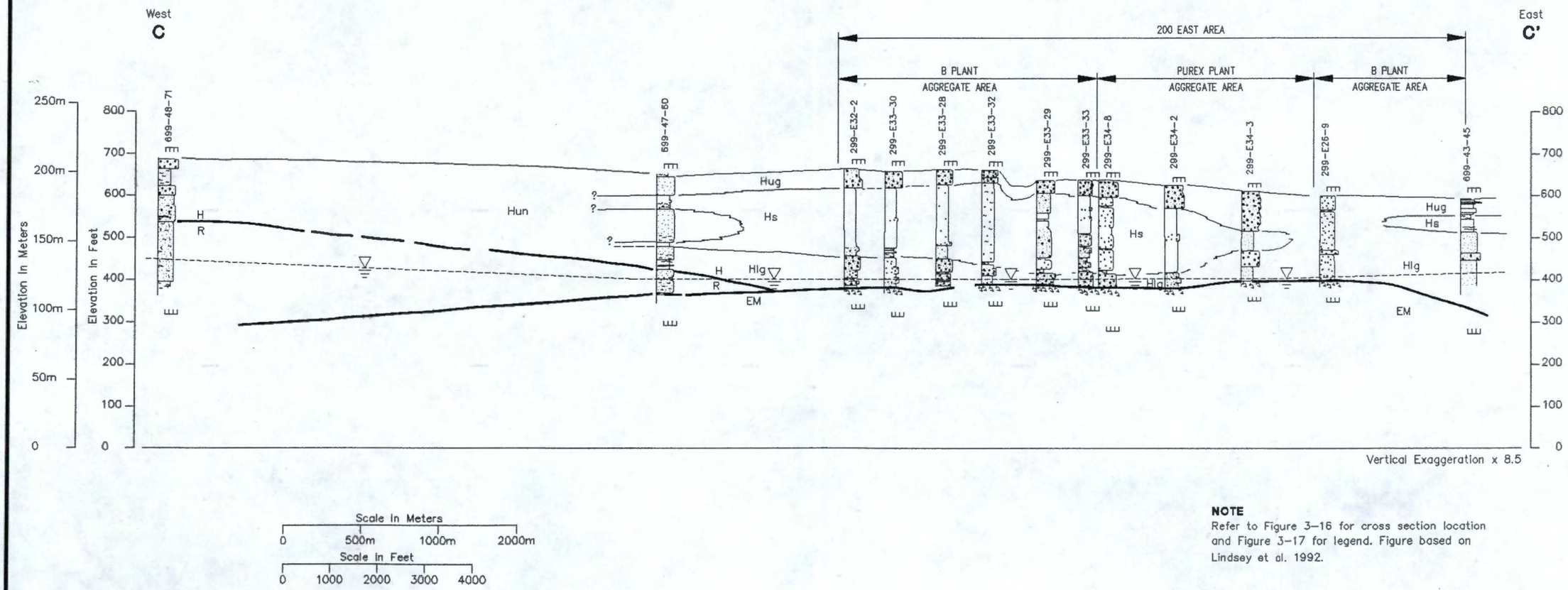




NOTE
Refer to Figure 3-16 for cross section location and Figure 3-17 for legend. Figure based on Lindsey et al. 1992.

Figure 3-19. 200 East Area Geologic Cross Section B-B'.

9 2 1 2 7 5 1 3 7 5



NOTE
Refer to Figure 3-16 for cross section location and Figure 3-17 for legend. Figure based on Lindsey et al. 1992.

Figure 3-20. 200 East Area Geologic Cross Section C-C'.

9 2 1 2 7 5 1 3 7 6

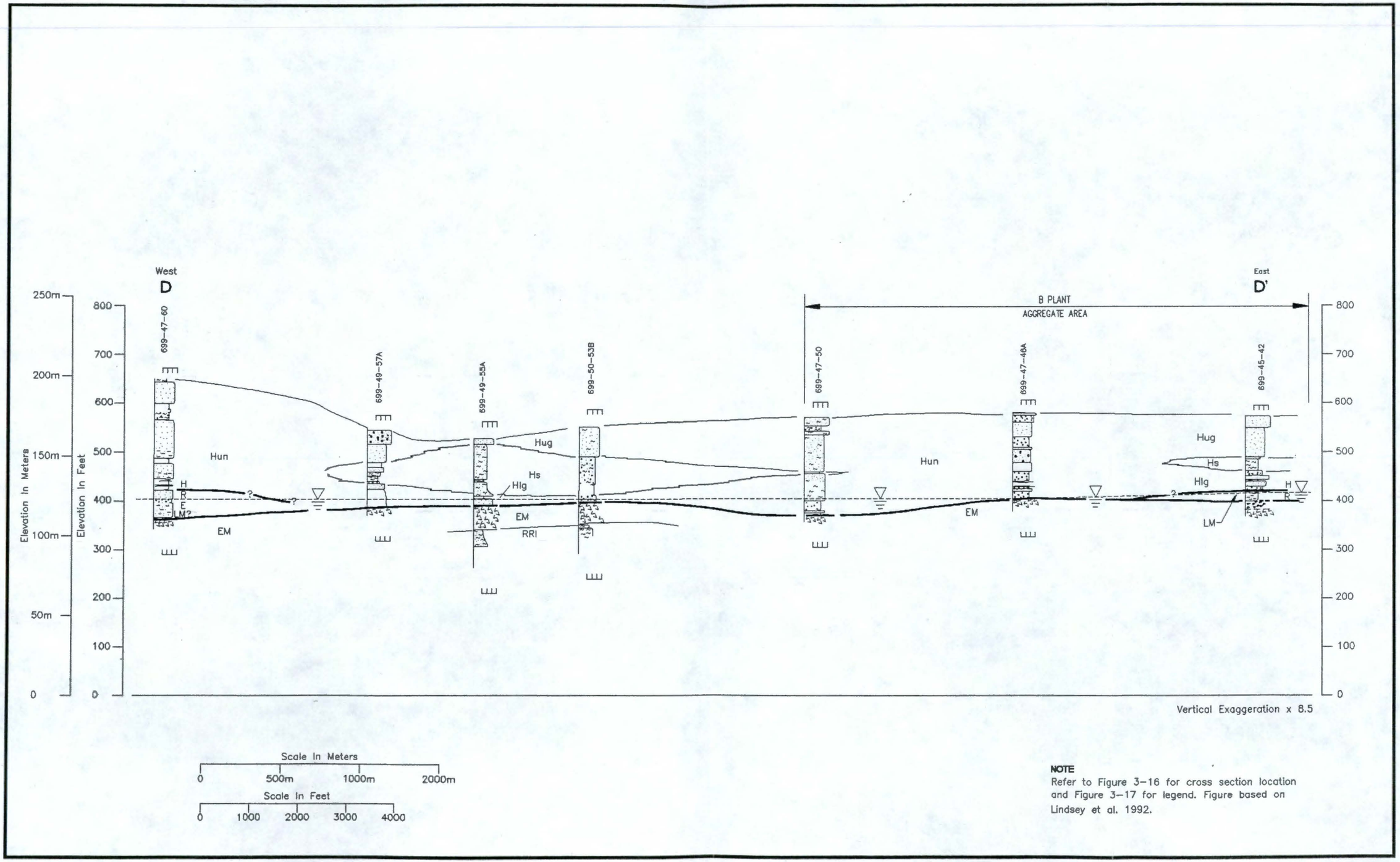
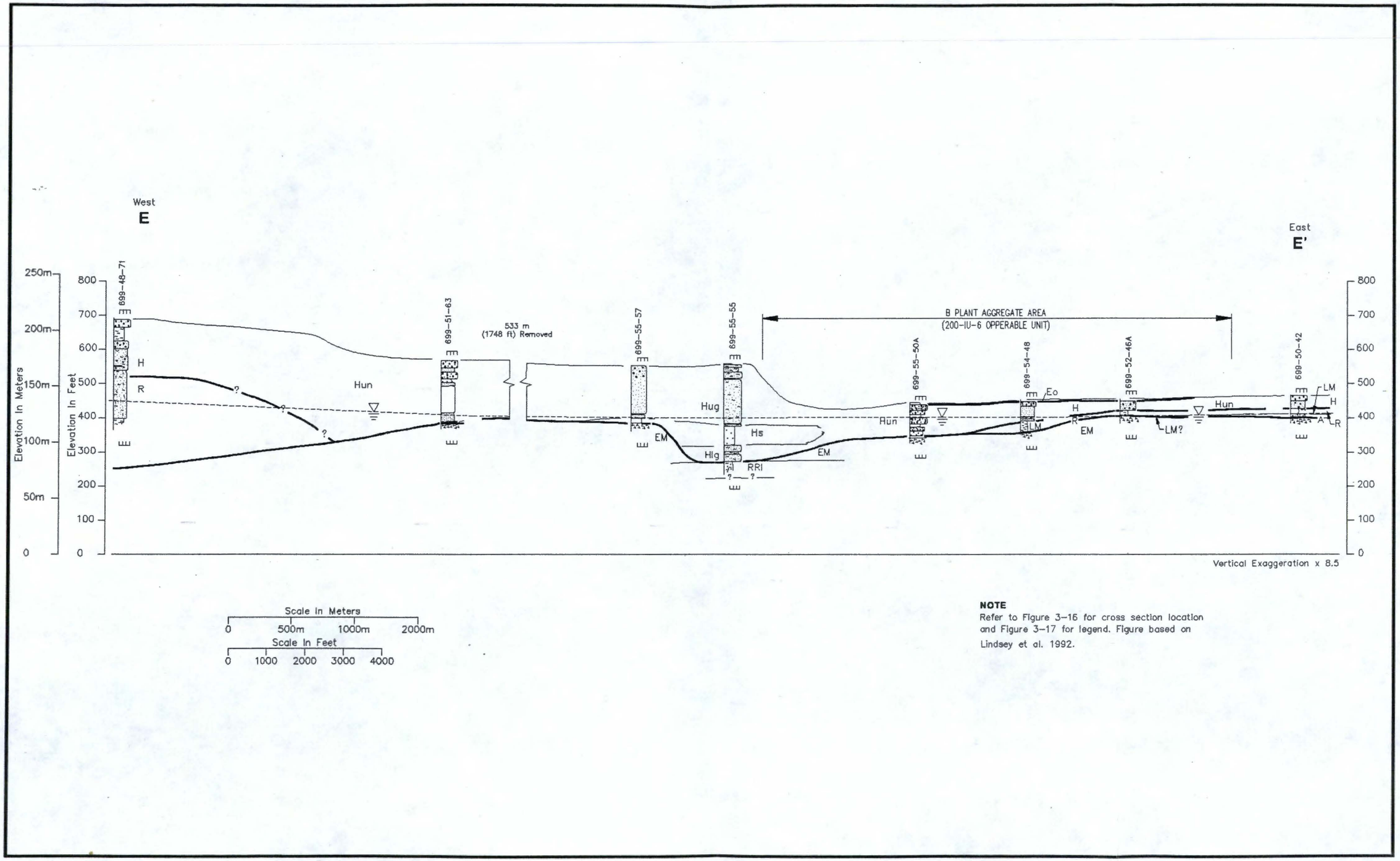


Figure 3-21. 200 East Area Geologic Cross Section D-D'.

9 2 1 2 7 5 1 3 7 7

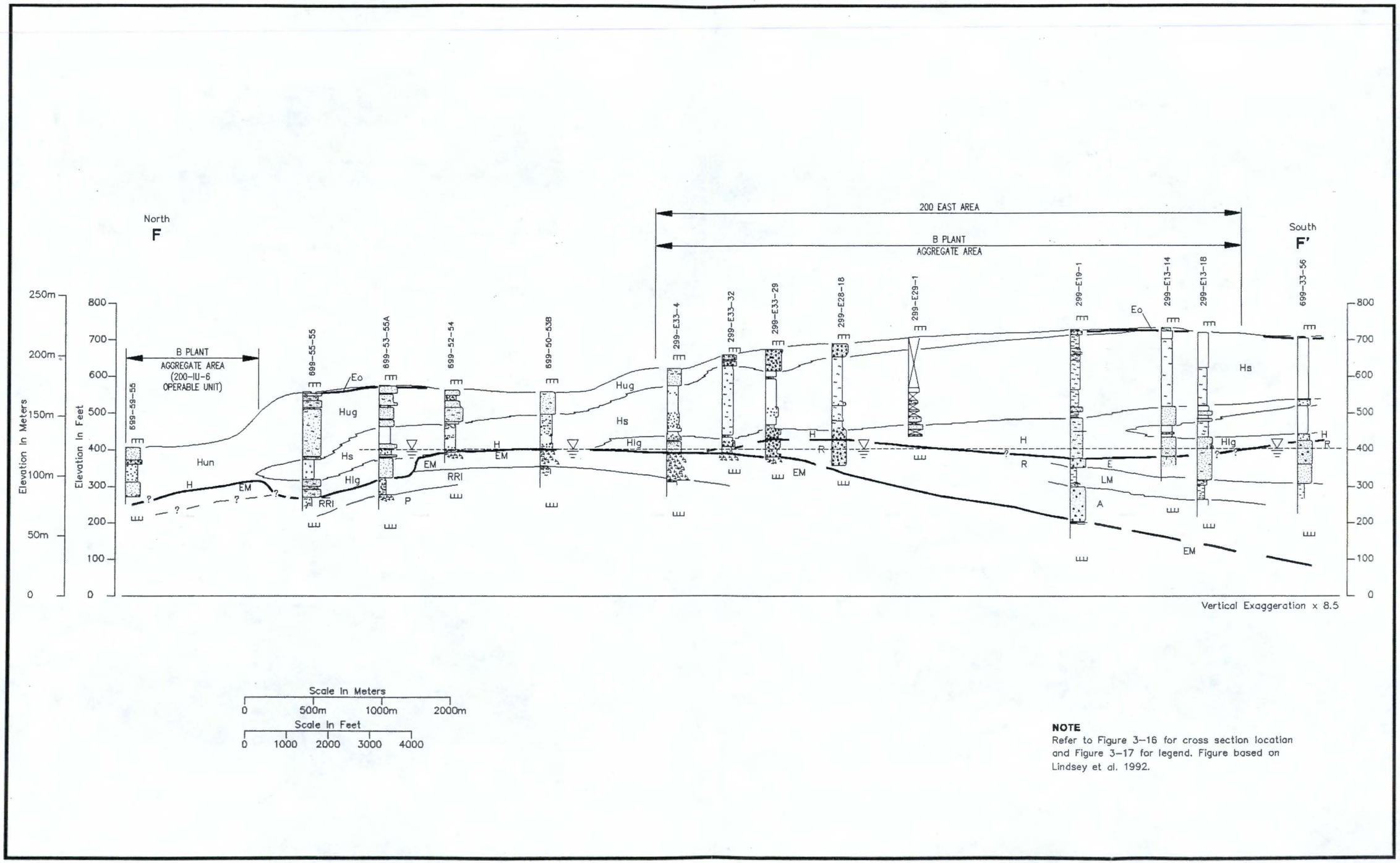


NOTE
Refer to Figure 3-16 for cross section location and Figure 3-17 for legend. Figure based on Lindsey et al. 1992.

Figure 3-22. 200 East Area Geologic Cross Section E-E'.

9 2 1 2 7 5 1 3 7 8

9 2 1 2 7 5 1 3 7 9



NOTE
Refer to Figure 3-16 for cross section location and Figure 3-17 for legend. Figure based on Lindsey et al. 1992.

Figure 3-23. 200 East Area Geologic Cross Section F-F'.

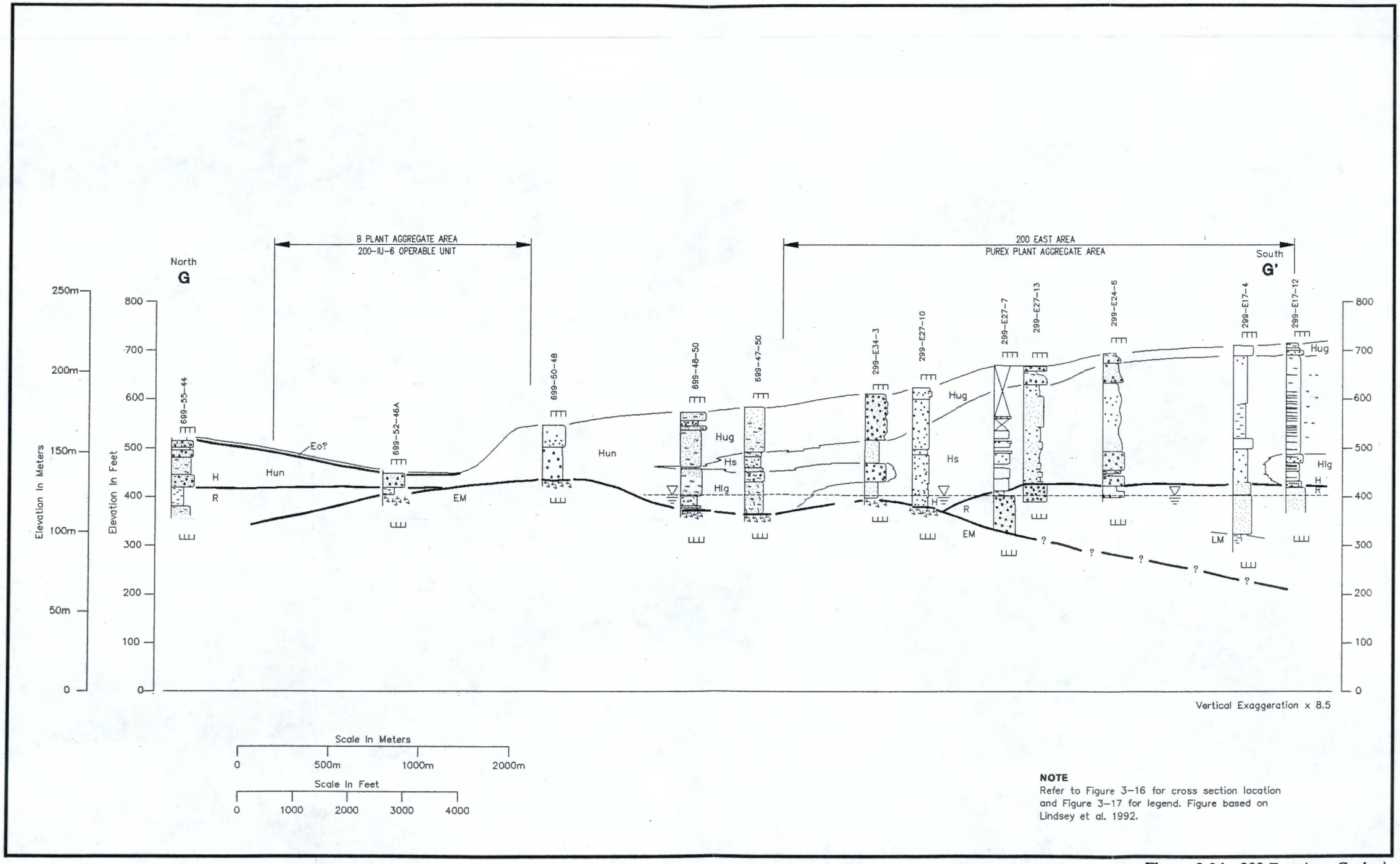


Figure 3-24. 200 East Area Geologic Cross Section G-G'.

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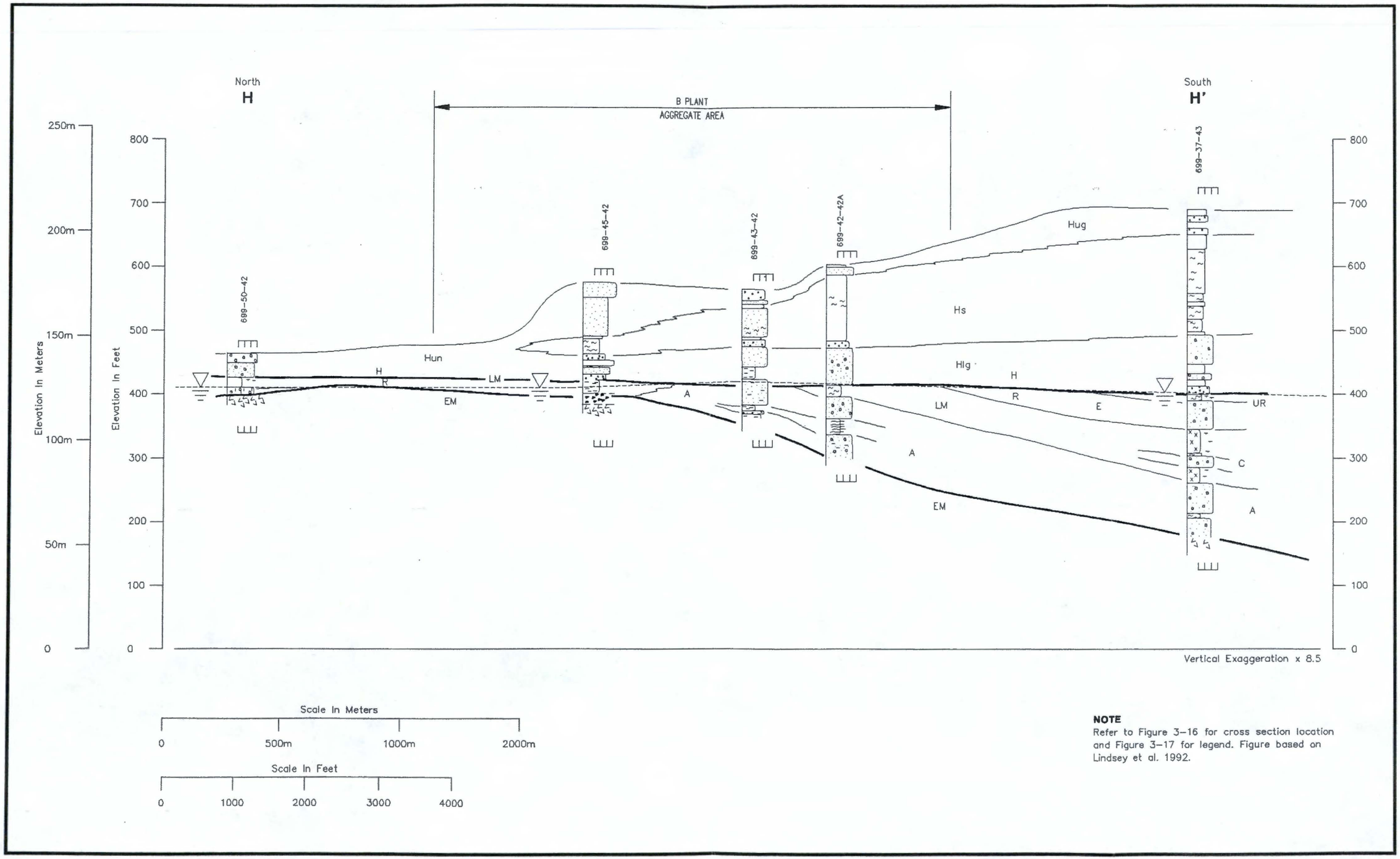

Figure 3-25. 200 East Area Geologic Cross Section H-H'.

9 2 1 2 7 5 1 3 8 1

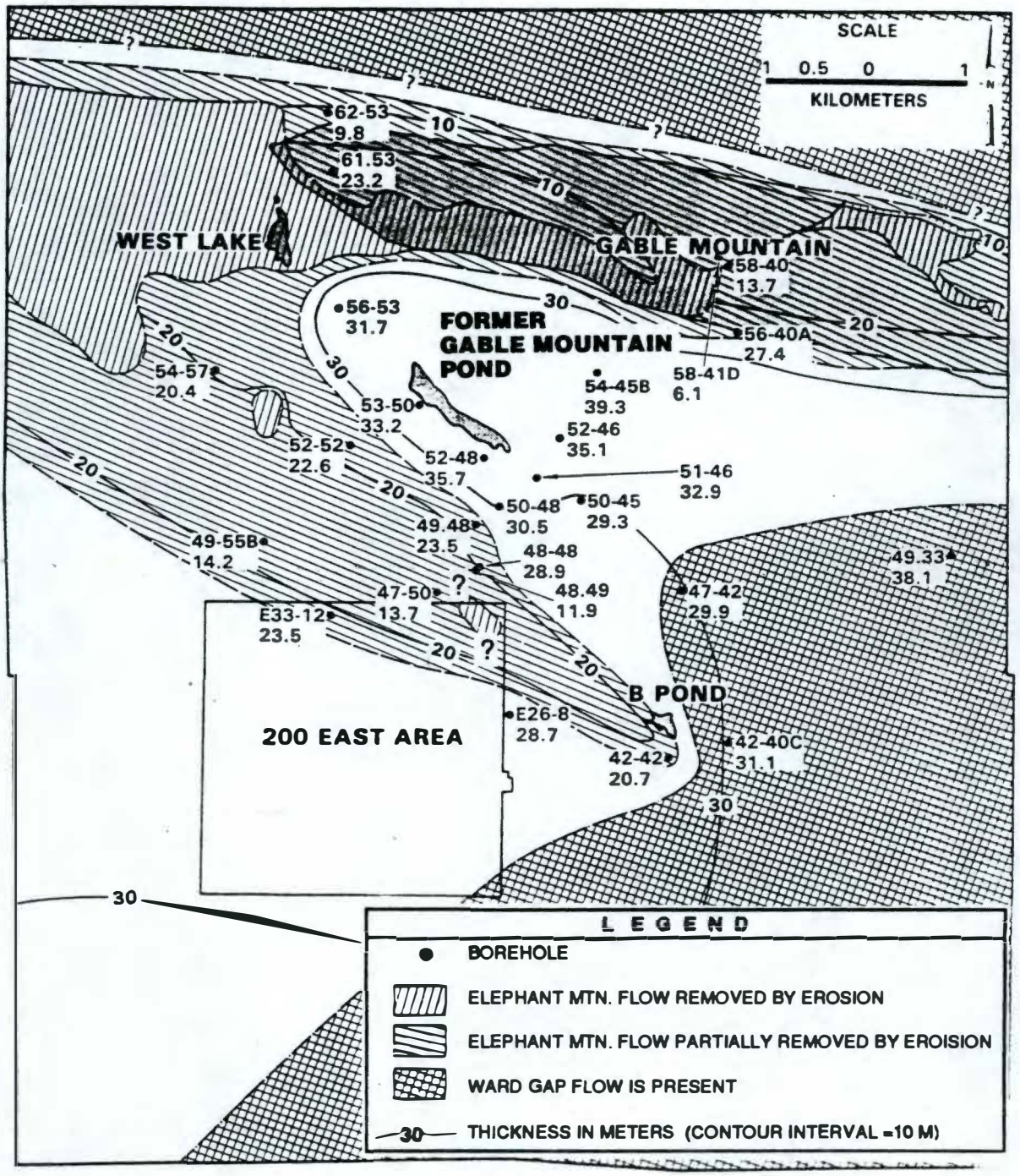

Figure 3-26. Isopach Map of the Elephant Mountain Member (Graham et al.,1984)

9 2 1 2 7 5 1 3 8 2

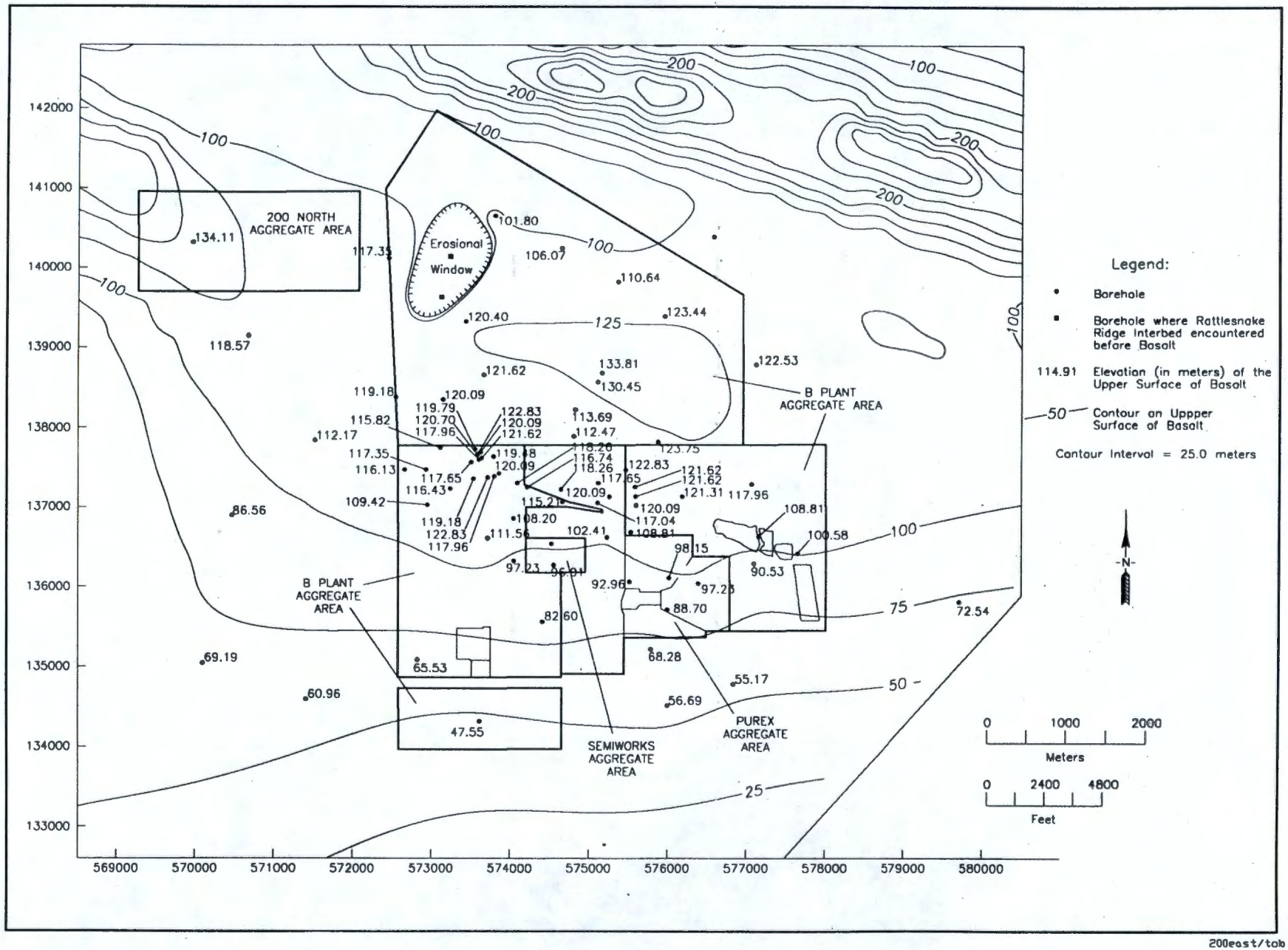

Figure 3-27. Structure Contour Map of the Top of Basalt (Connelly et al. 1992a).

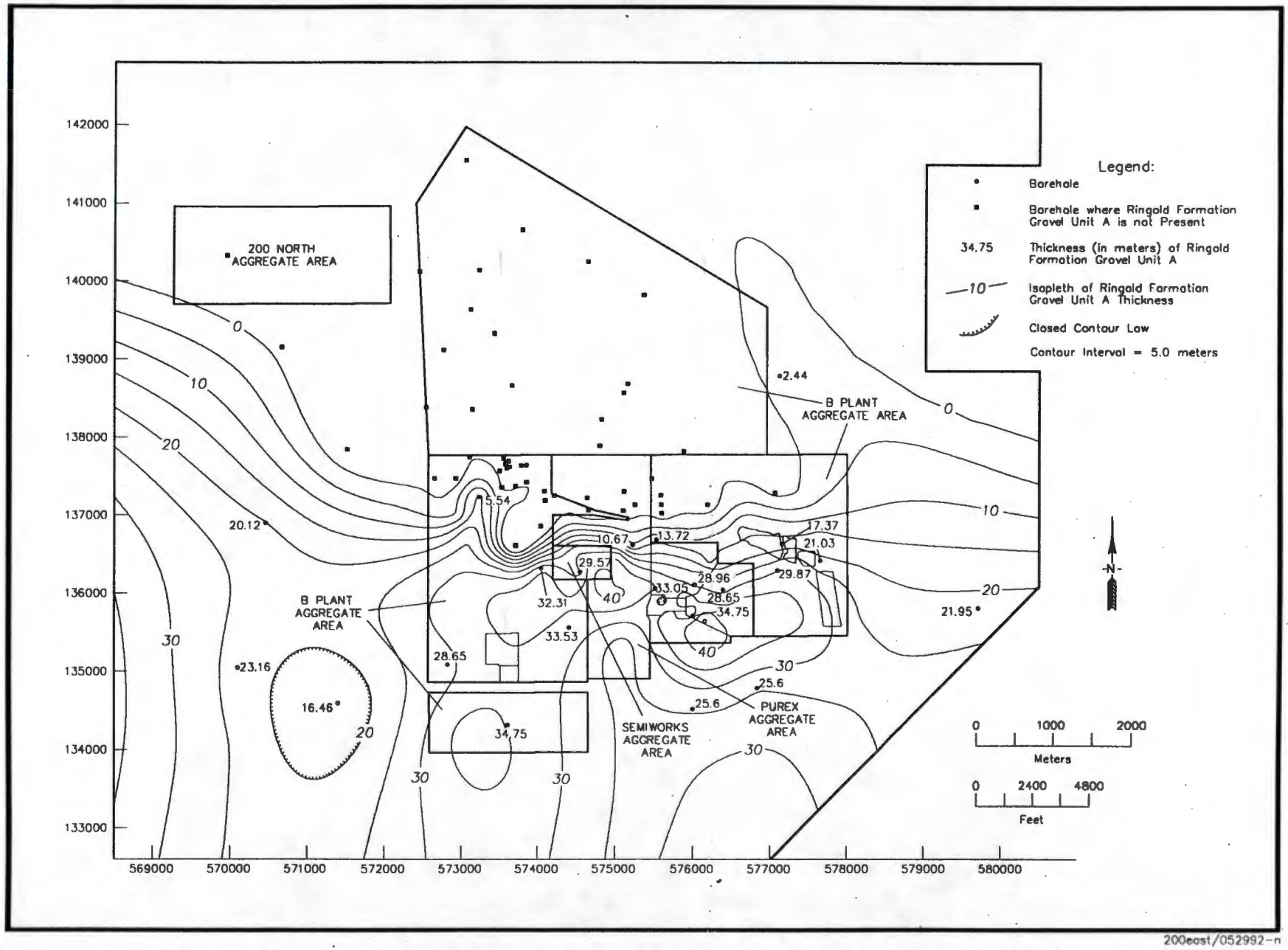

Figure 3-28. Isopach Map of the Ringold Formation Gravel Unit A (Connelly et al. 1992a).

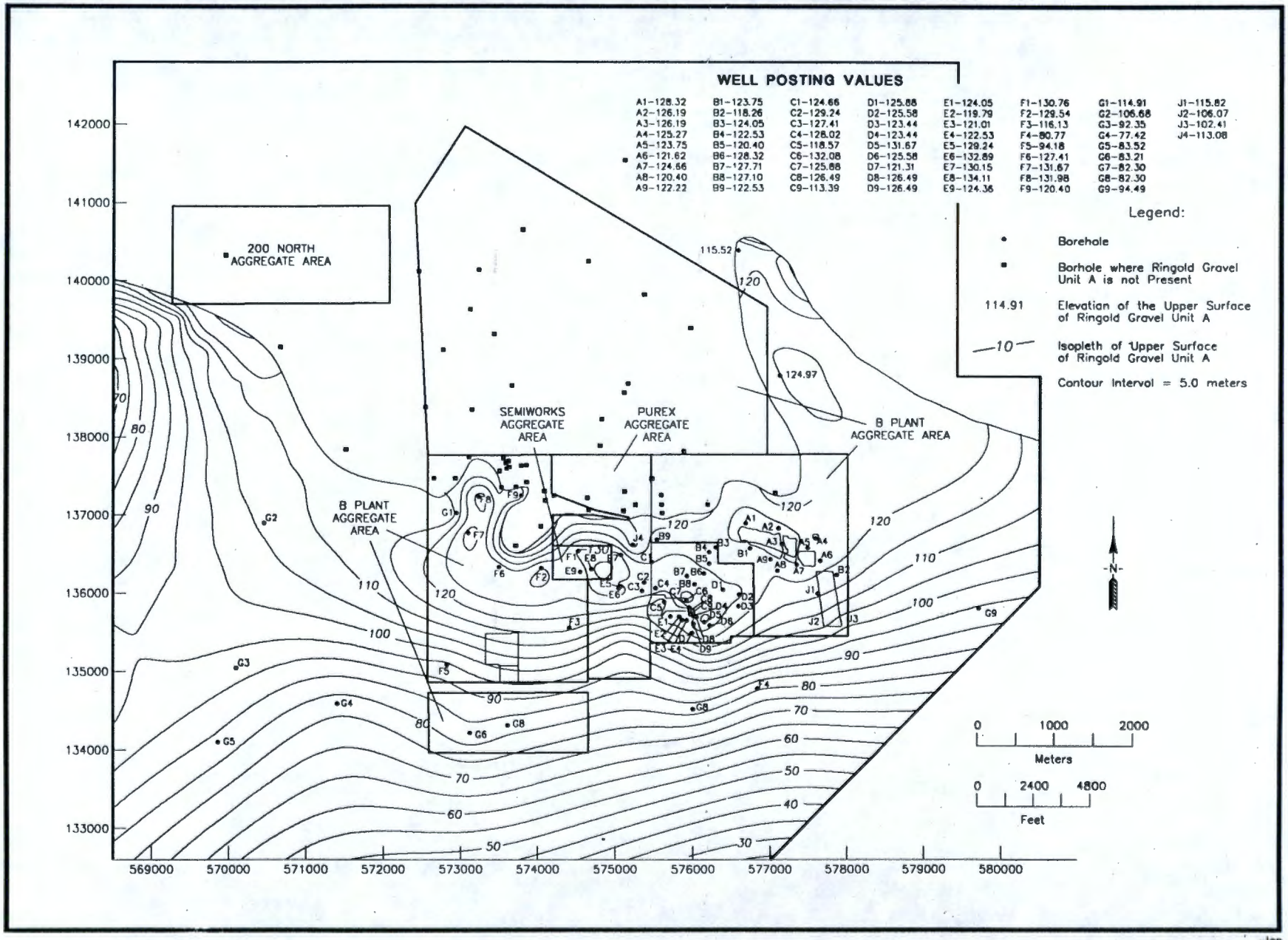

Figure 3-29. Structure Contour Map of the Top of the Ringold Formation Gravel Unit A (Connelly et al. 1992a).

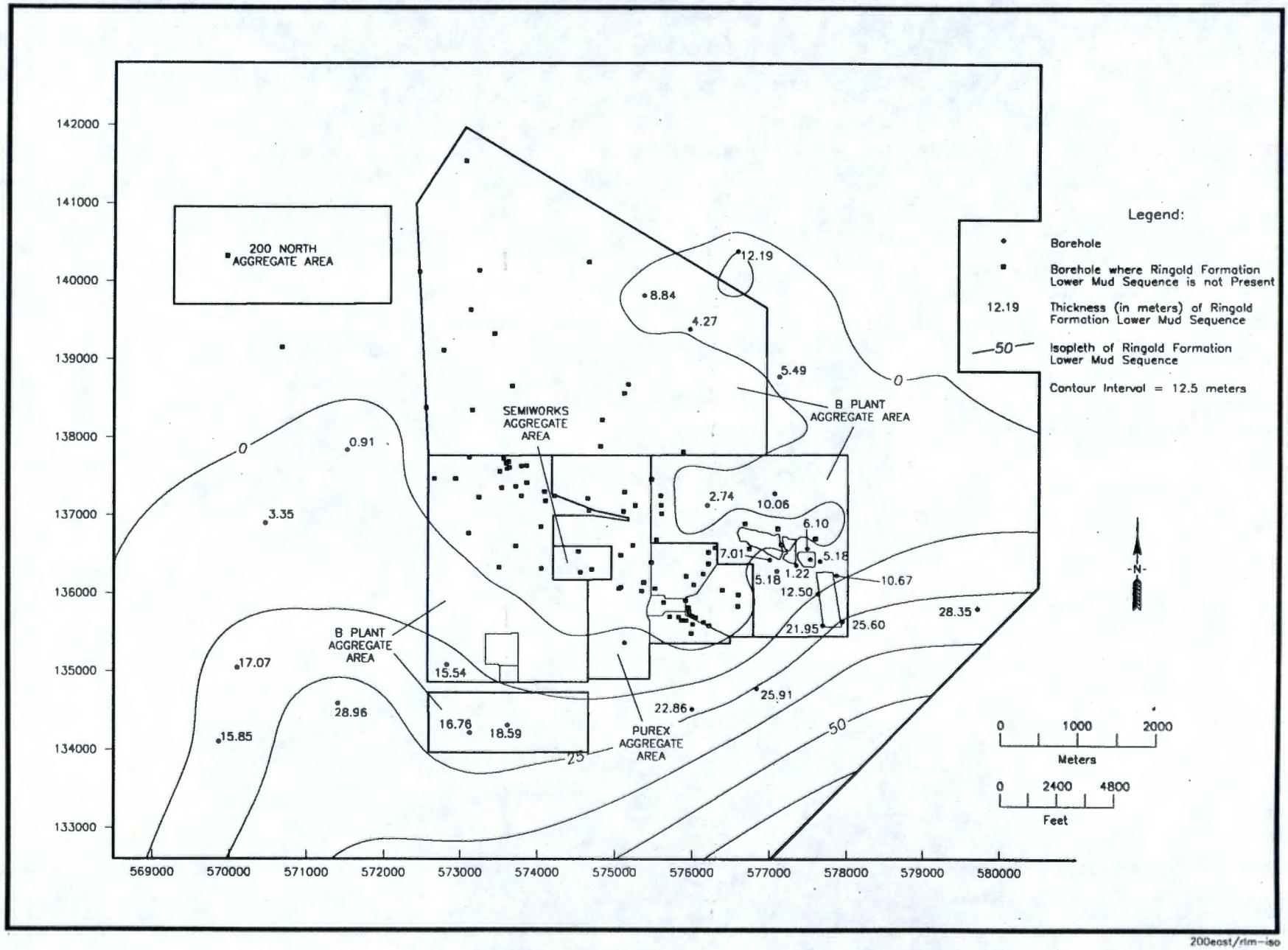

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Figure 3-30. Isopach Map of the Ringold Formation Lower Mud Sequence (Connelly et al. 1992a).

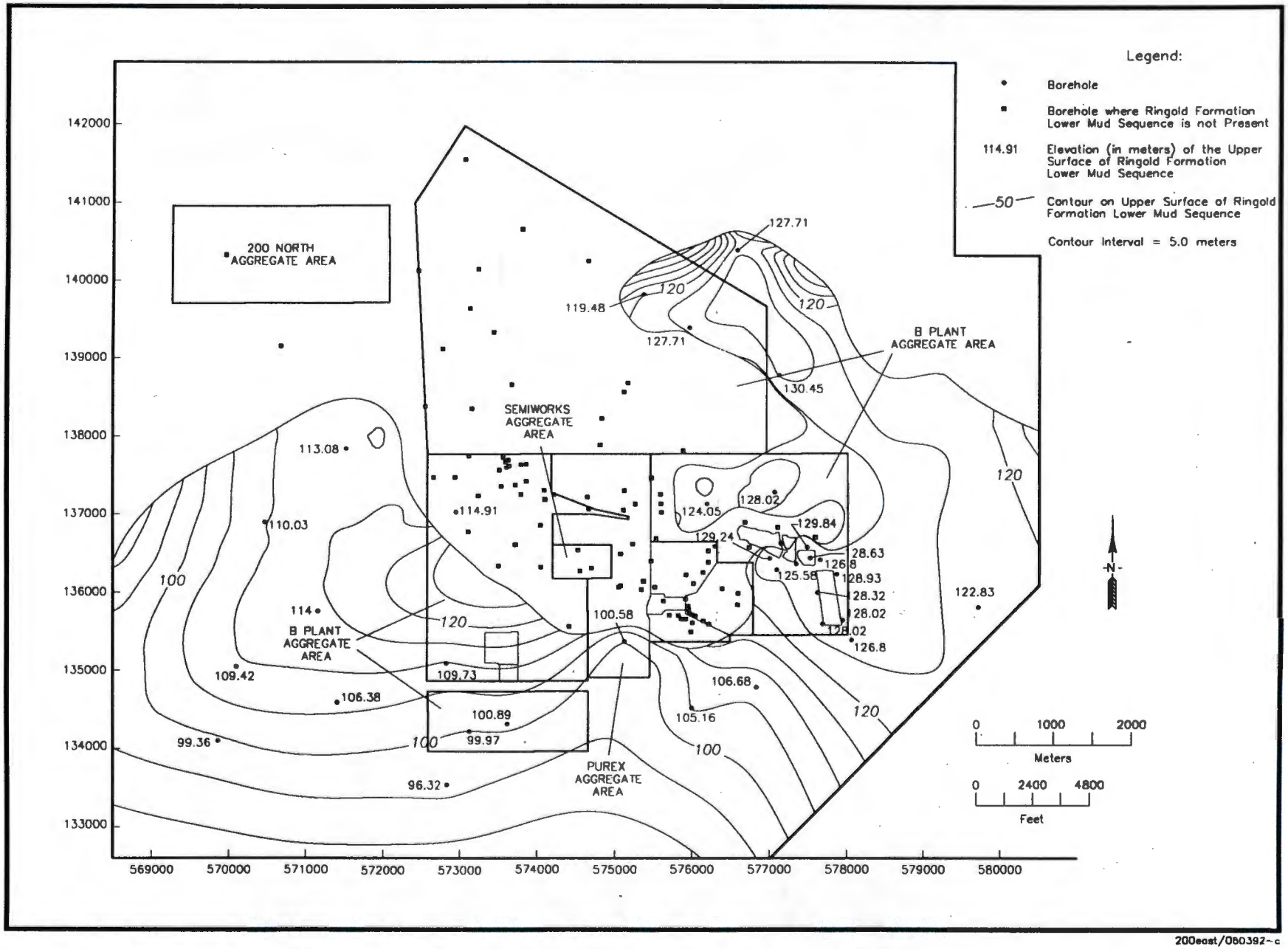

Figure 3-31. Structure Contour Map of the Top of the Ringold Formation Lower Mud Sequence (Connelly et al. 1992a).

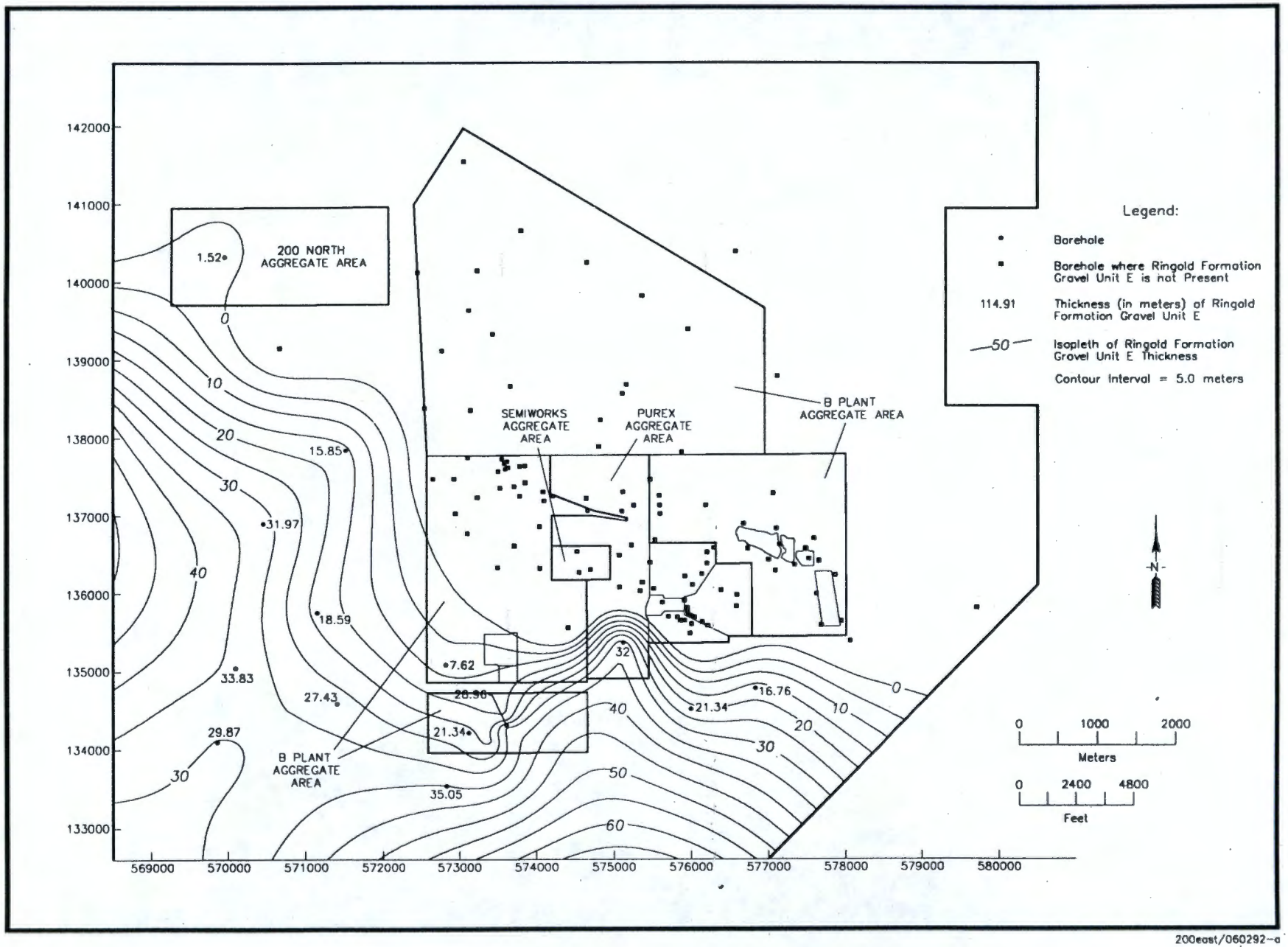

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Figure 3-32. Isopach Map of the Ringold Formation Gravel Unit E (Connelly et al. 1992a).

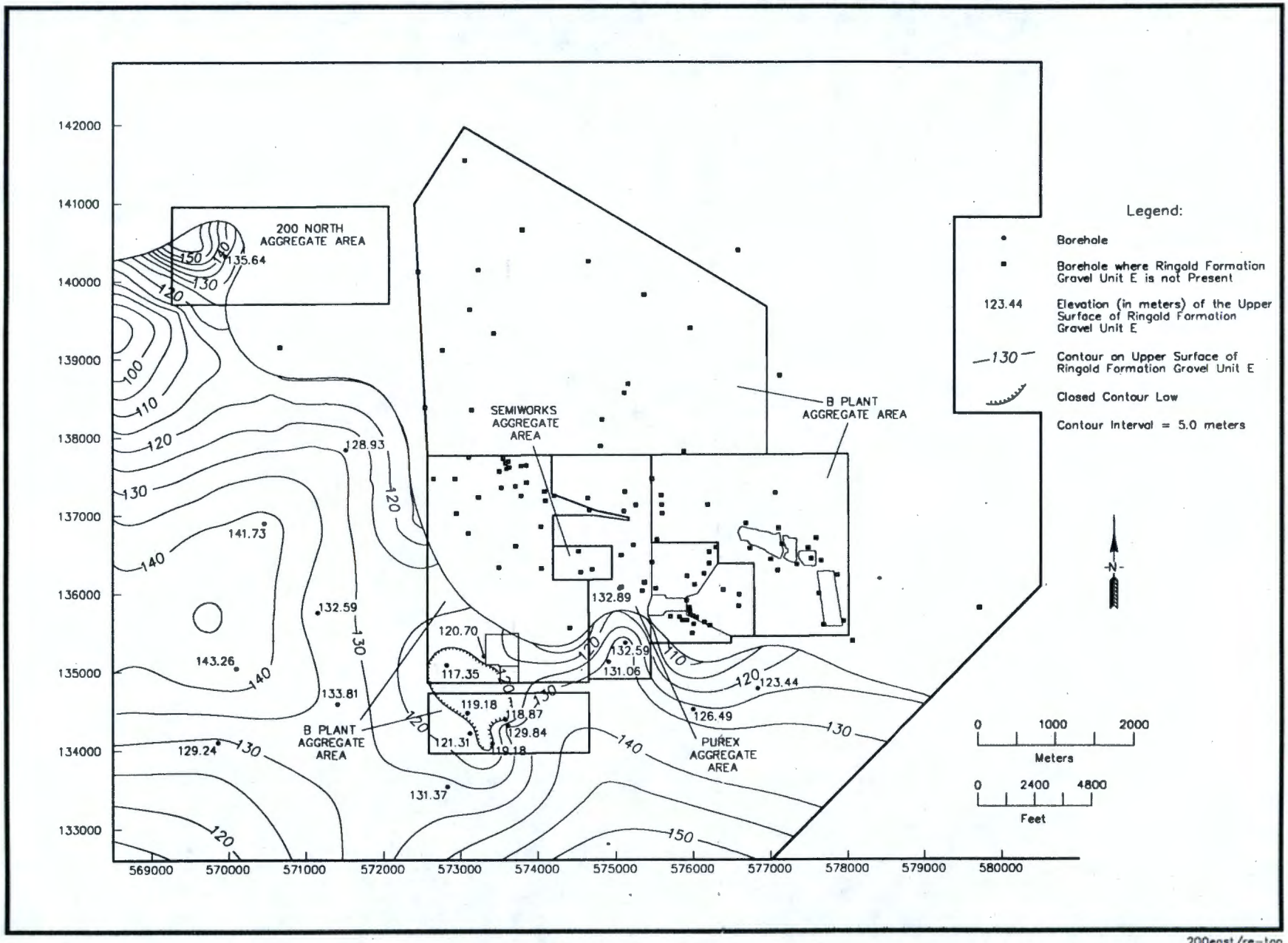

Figure 3-33. Structure Contour Map of the Top of the Ringold Formation Gravel Unit E (Connelly et al. 1992a).

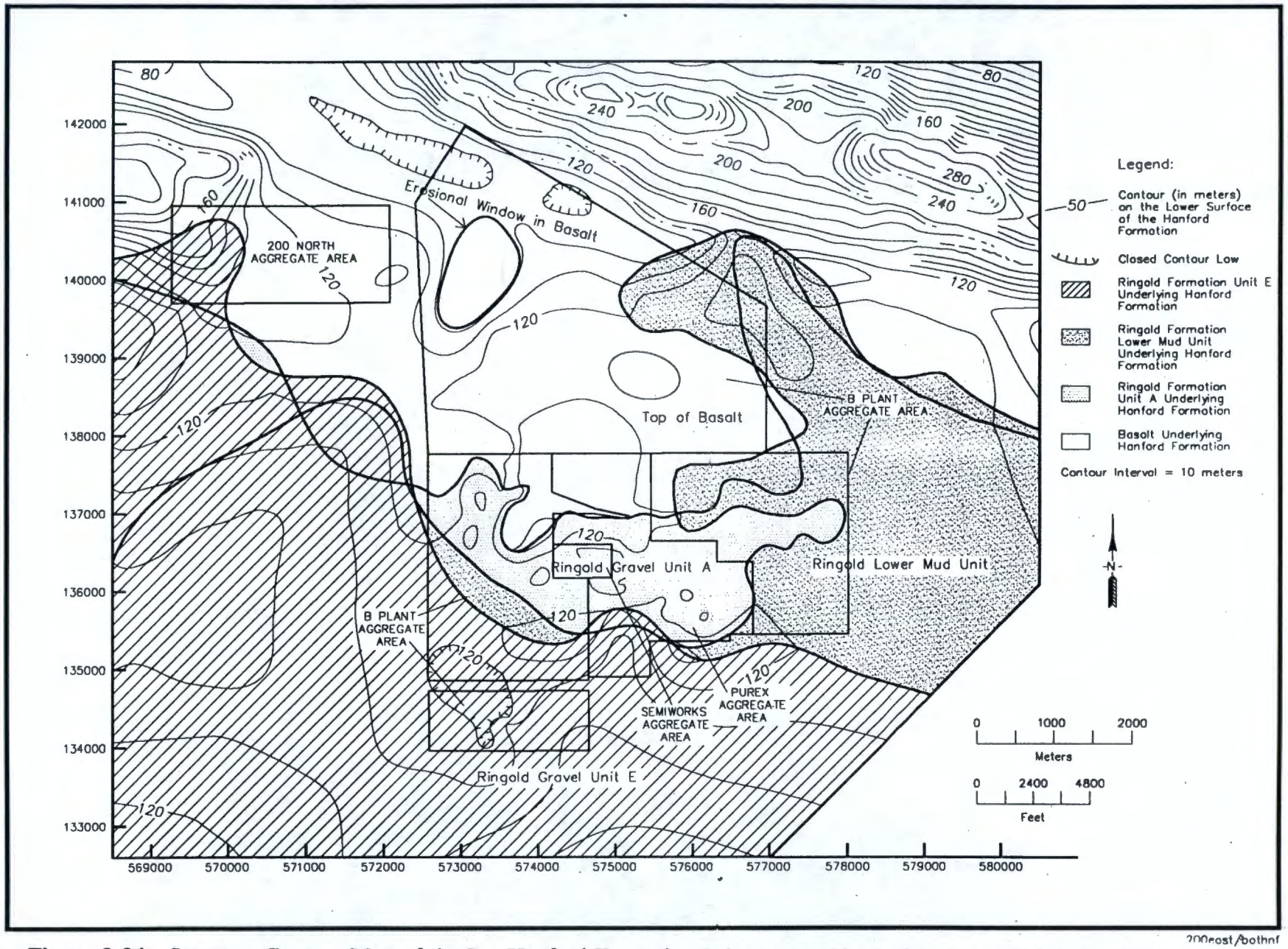

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Figure 3-34. Structure Contour Map of the Pre-Hanford Formation Paleogeographic Surface (Connelly et al. 1992a).

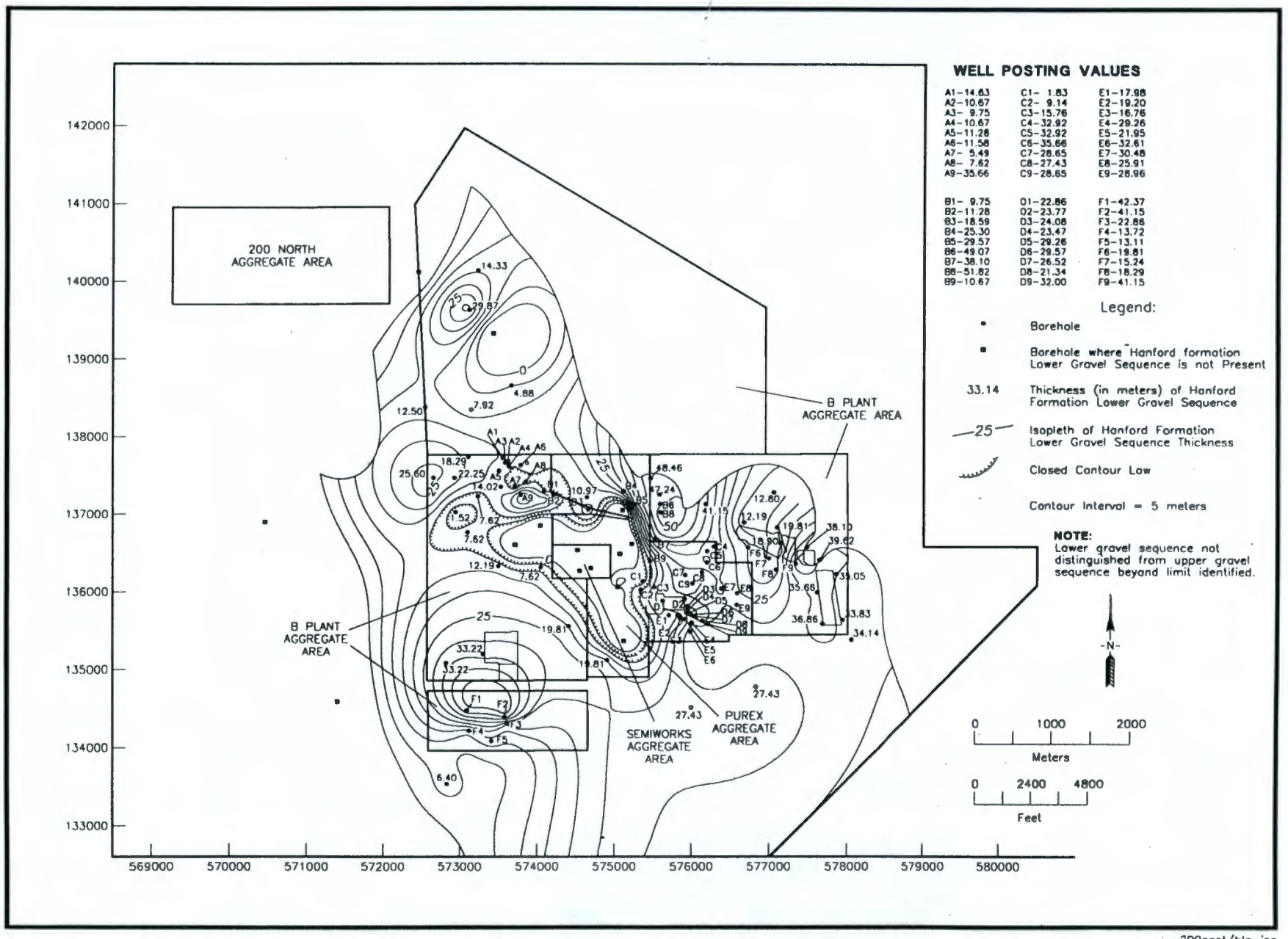


Figure 3-35. Isopach Map of the Hanford Formation Lower Gravel Sequence (Connelly et al. 1992a).

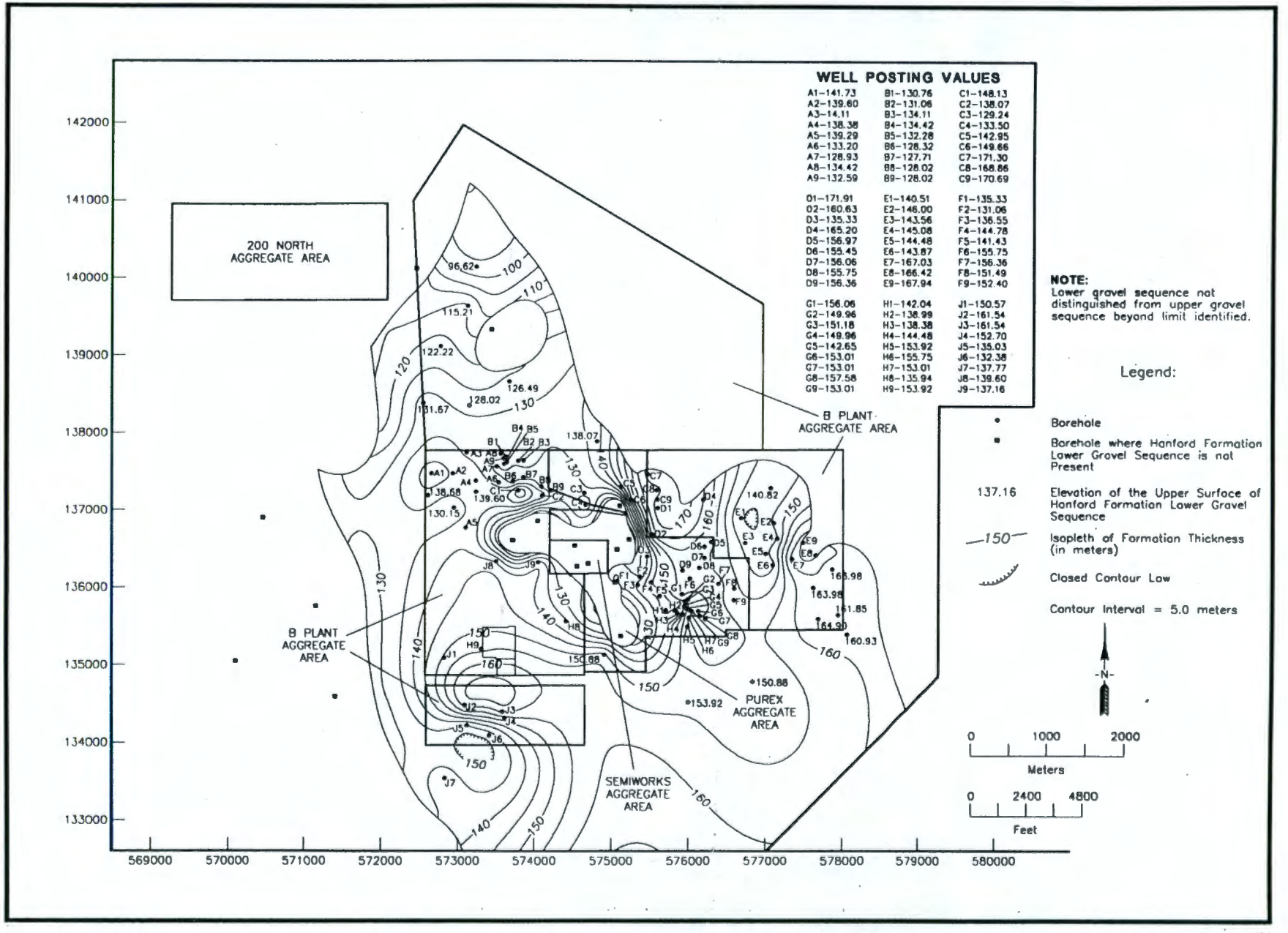


Figure 3-36. Structure Contour Map of the Top of the Hanford Formation Lower Gravel Sequence (Connelly et al. 1992a).

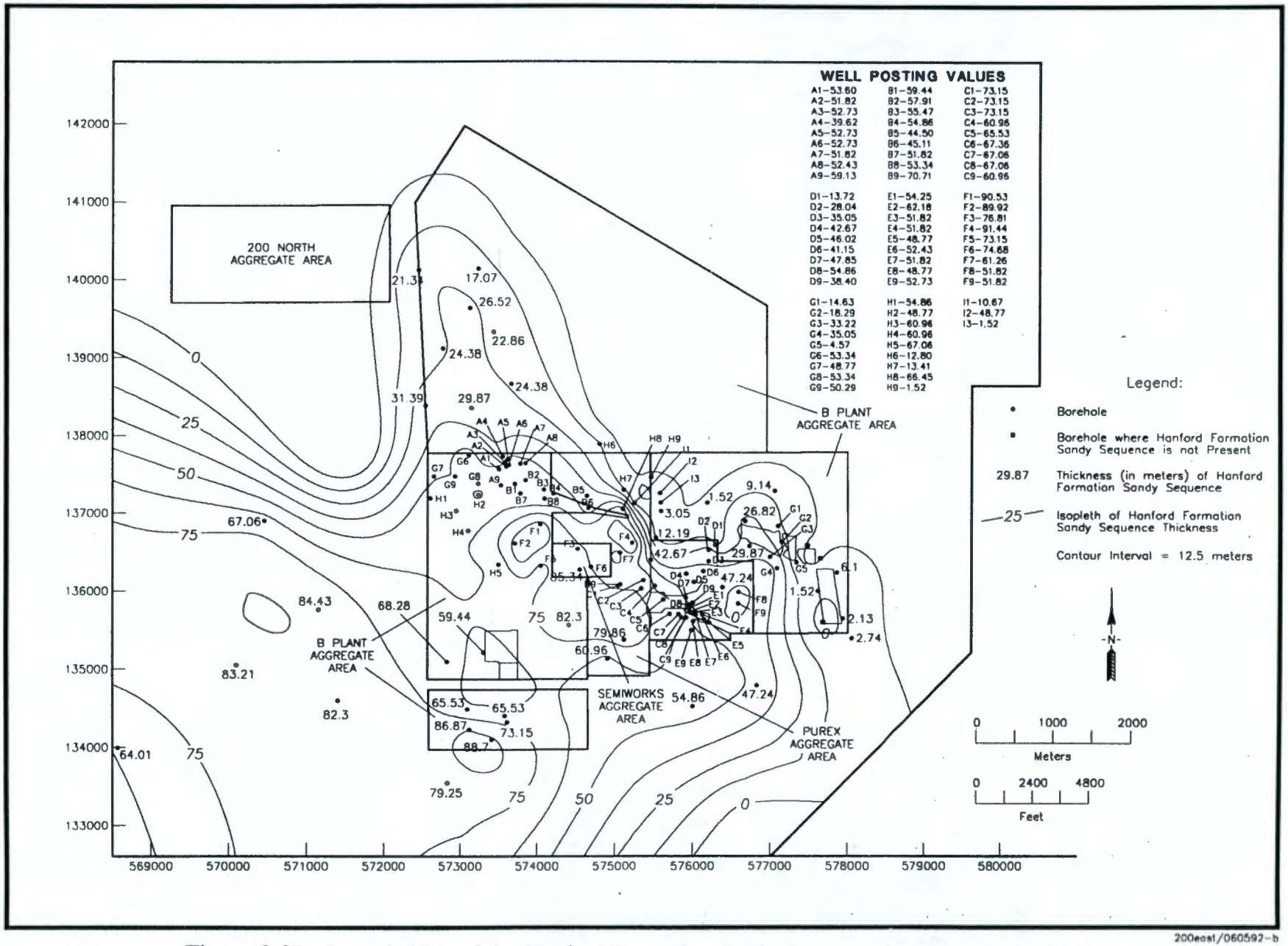


Figure 3-37. Isopach Map of the Hanford Formation Sandy Sequence (Connelly et al. 1992a).

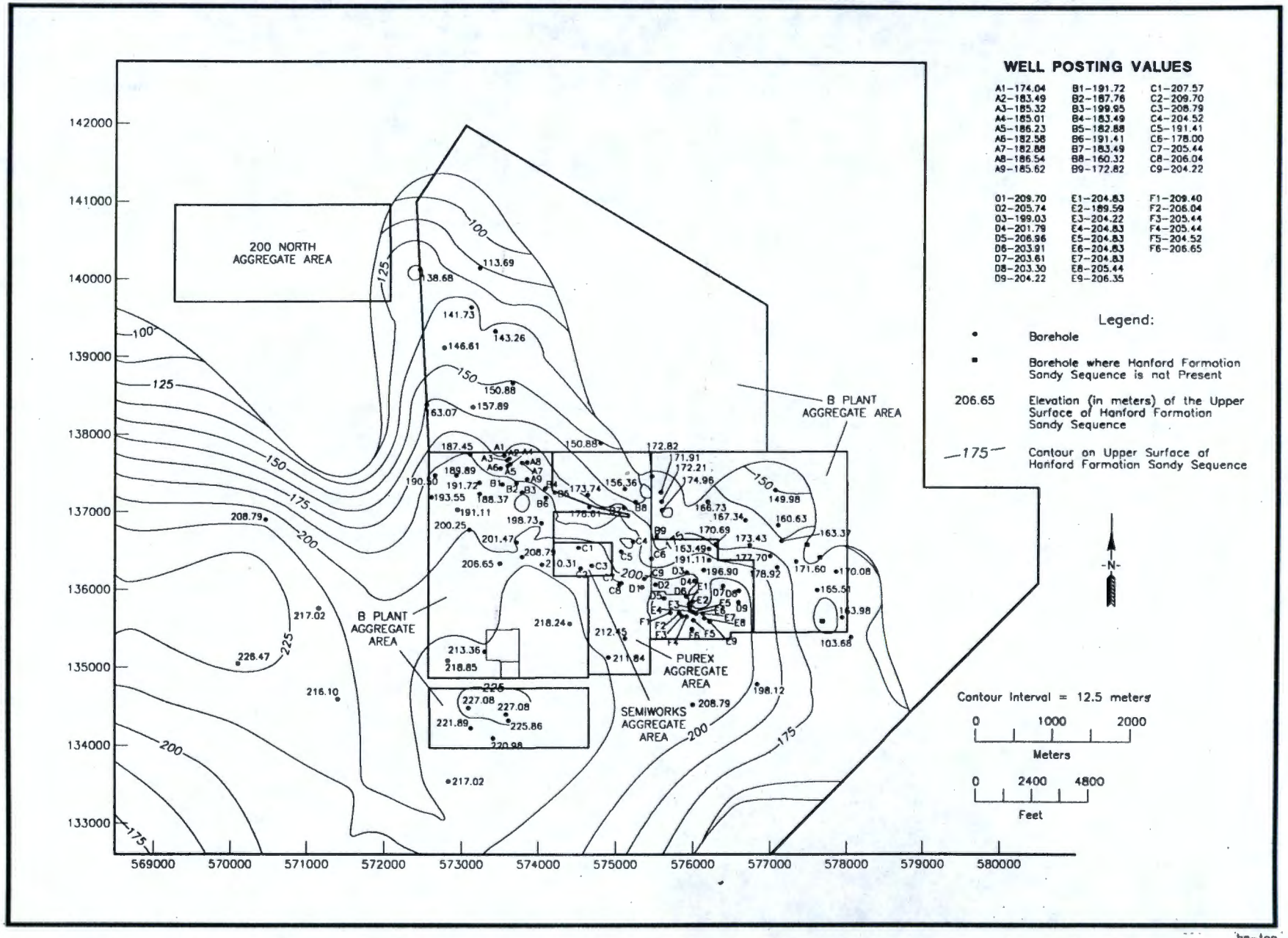


Figure 3-38. Structure Contour Map of the Top of the Hanford Formation Sandy Sequence (Connelly et al. 1992a).

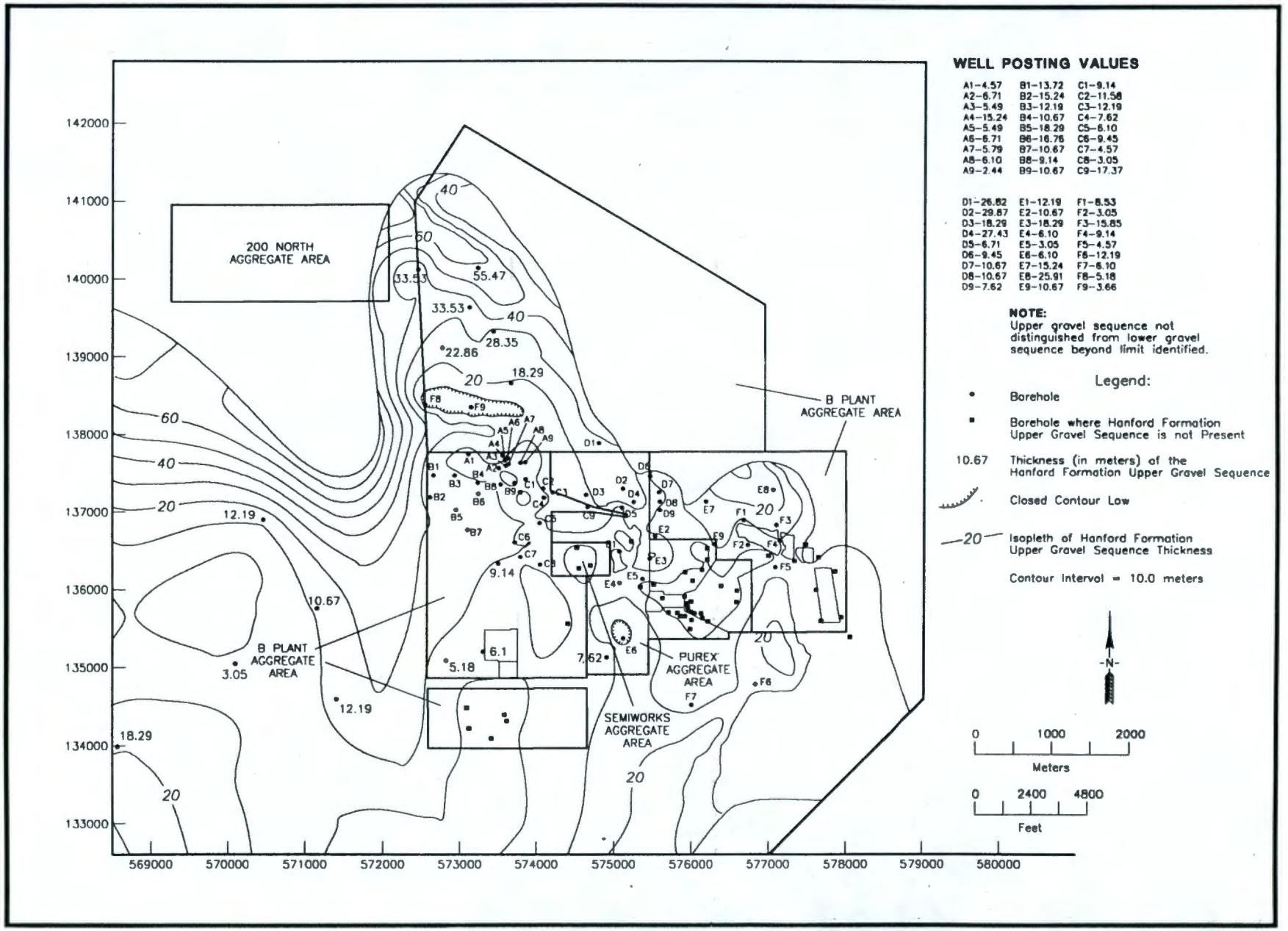


Figure 3-39. Isopach Map of the Hanford Formation Upper Gravel Sequence (Connelly et al. 1992a).

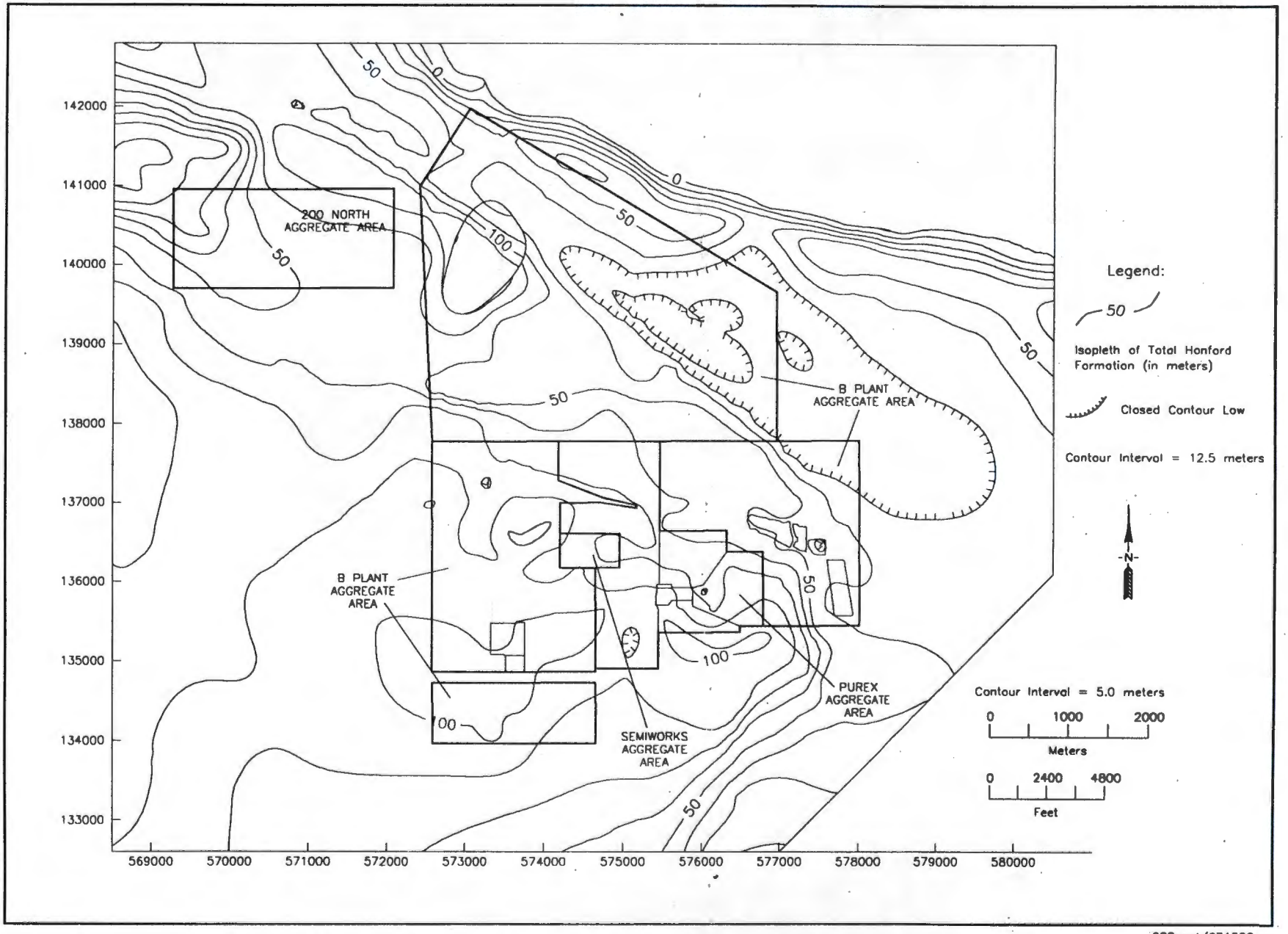


Figure 3-40. Isopach Map of the Entire Hanford Formation (Connelly et al. 1992a).

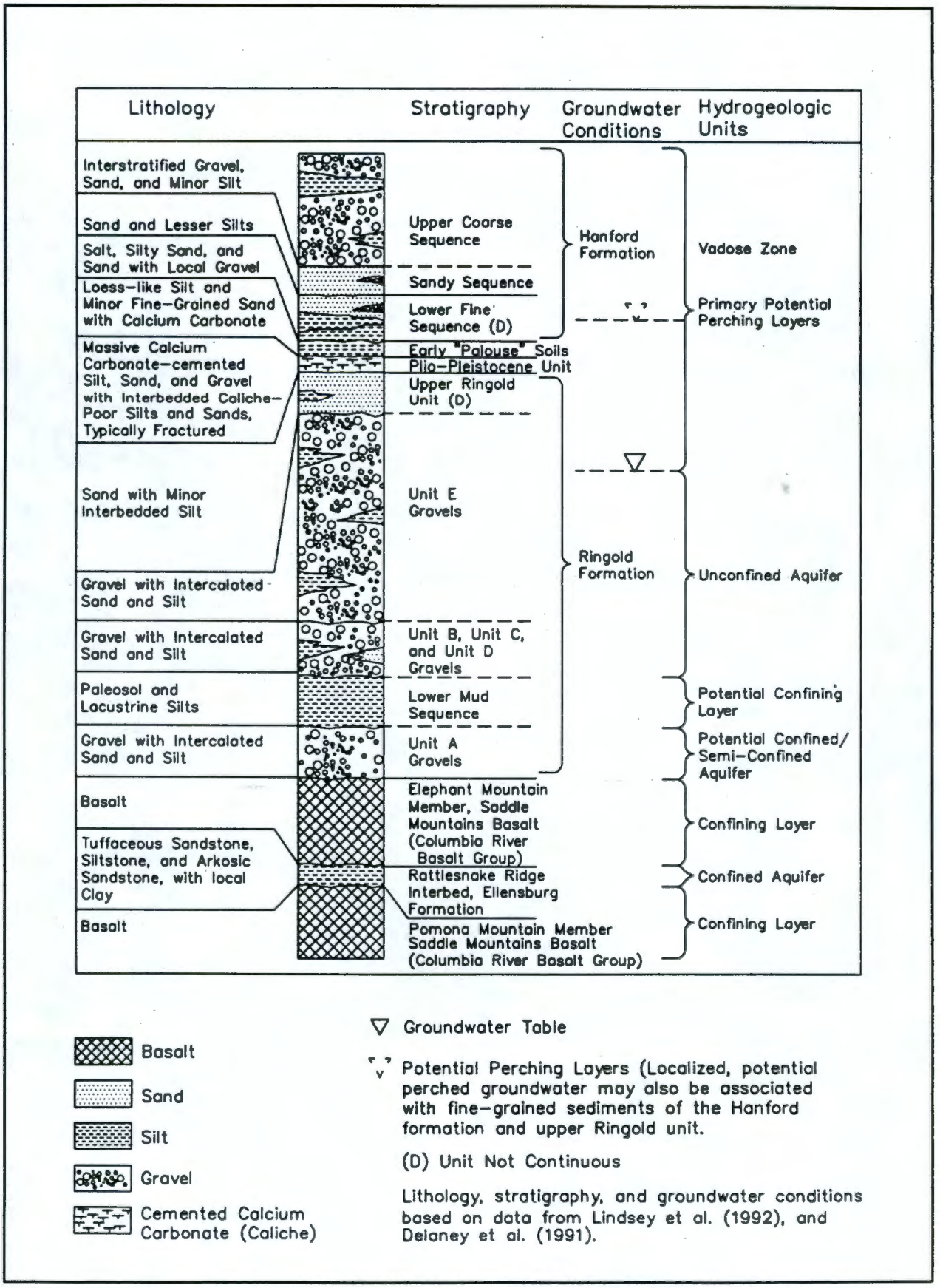
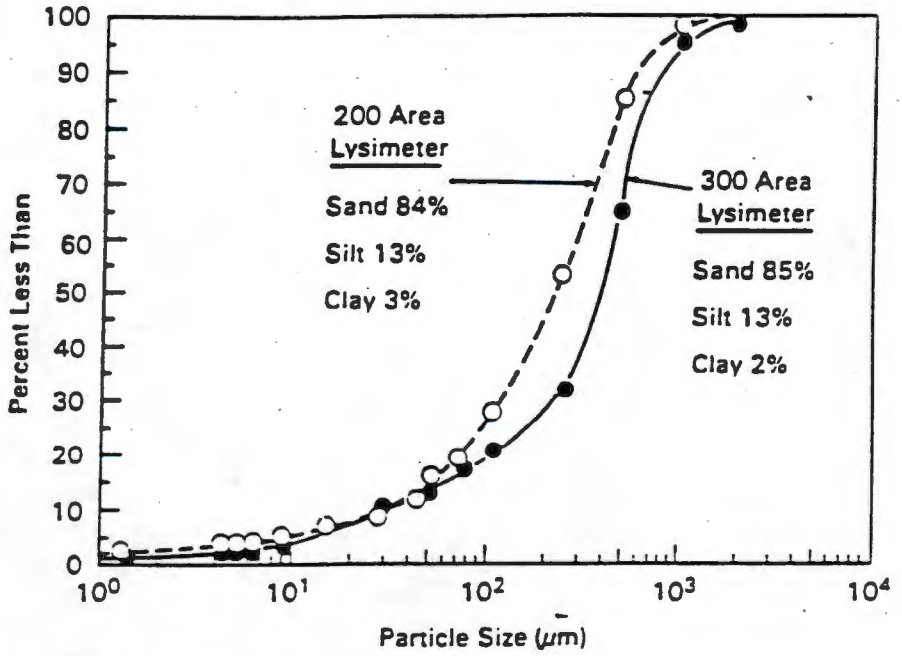
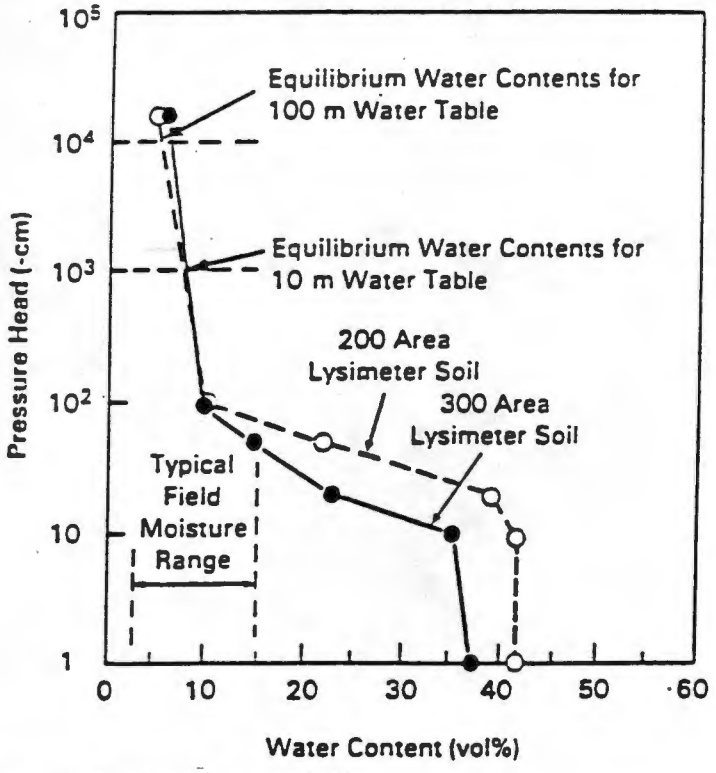


Figure 3-41. Conceptual Hydrogeologic Column for the Hanford Site.

9 2 1 2 7 5 1 3 9 7



a. Particle-Size Distribution



b. Water Retention Characteristics

Figure 3-42. Particle-Size Distribution and Water Retention Characteristics of Soils from Hanford Site Lysimeters (Gee and Heller 1985).

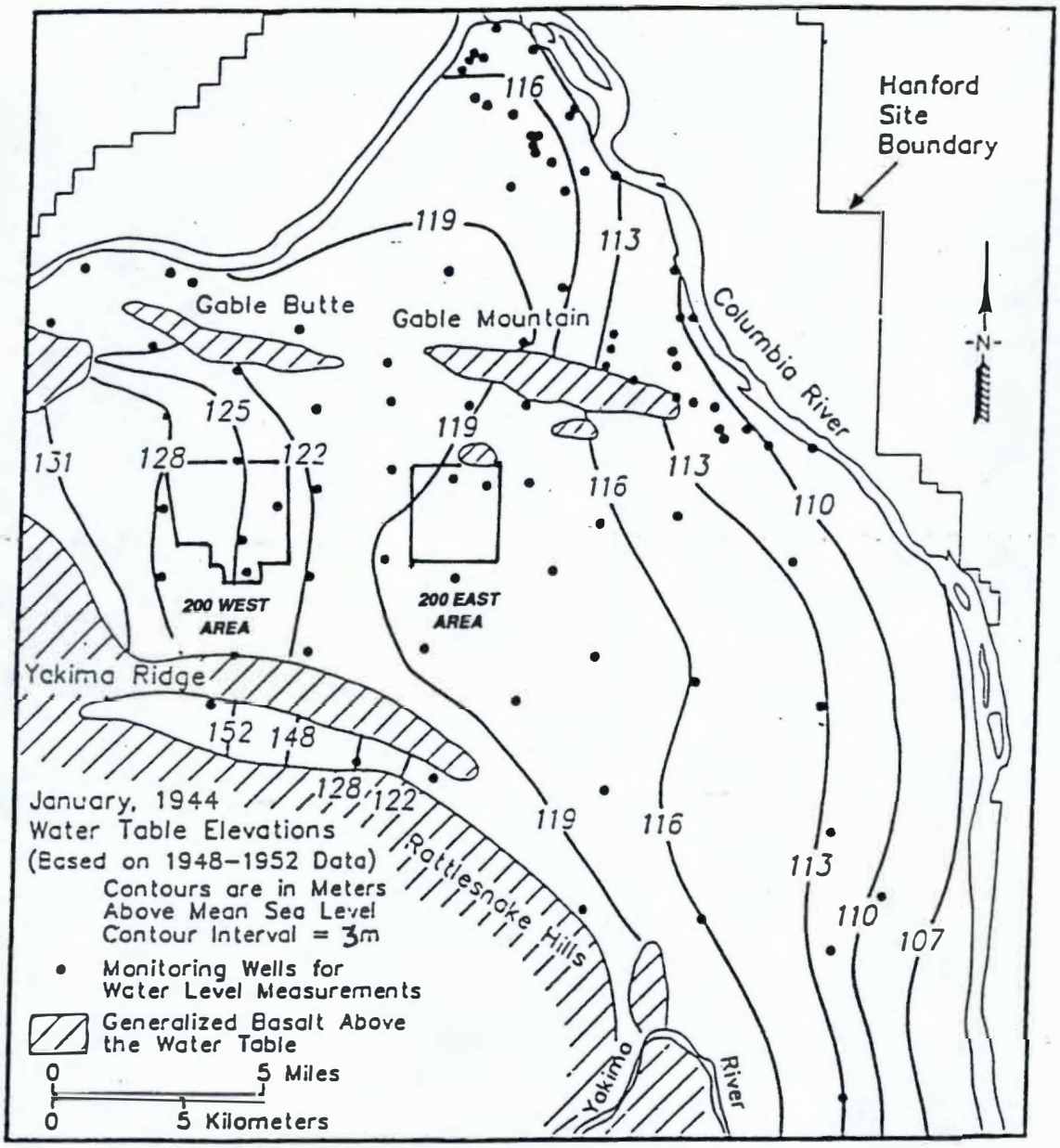


Figure 3-43. Hindcast Water Table Map of the Hanford Site, January 1944 (ERDA 1975).

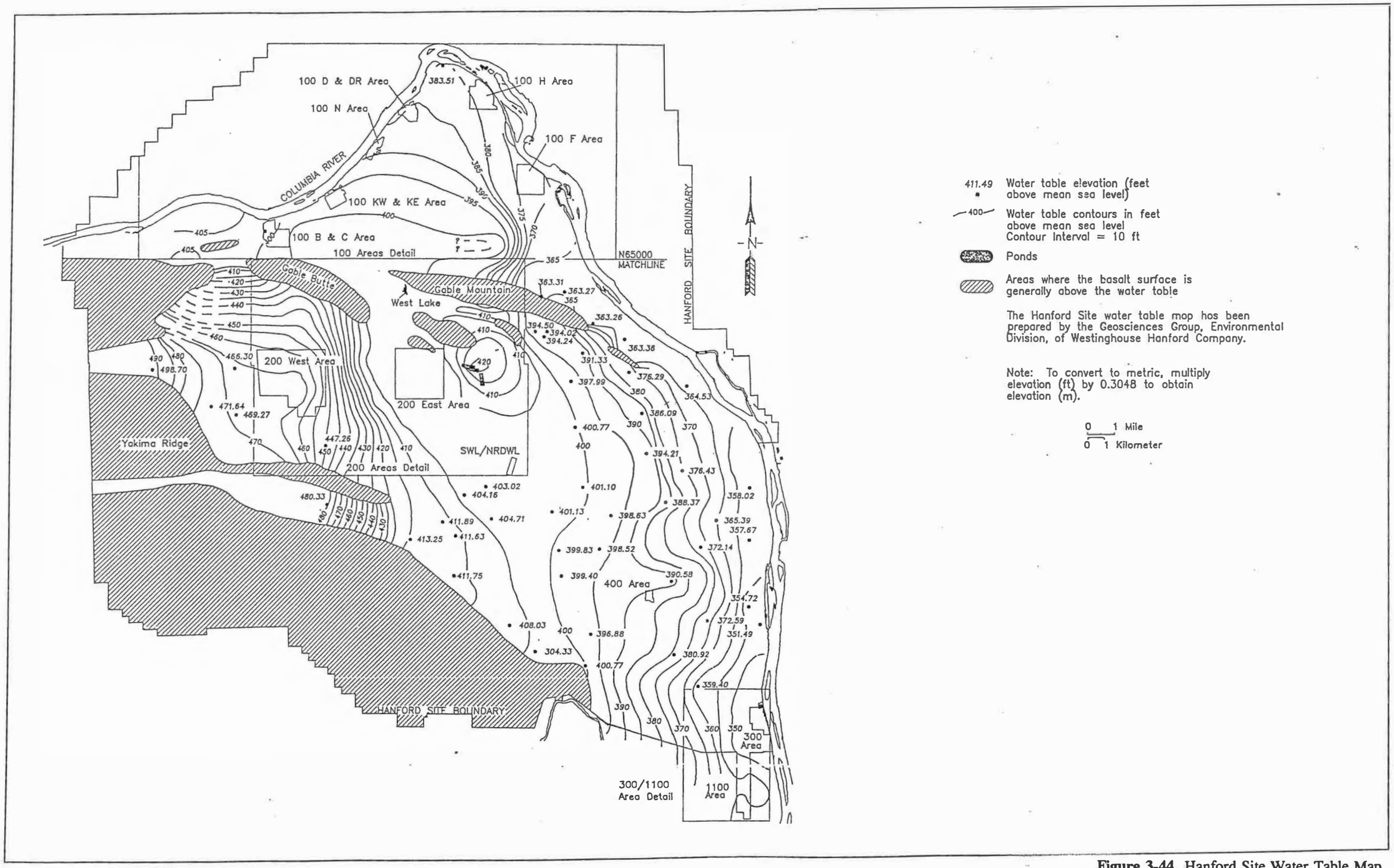


Figure 3-44. Hanford Site Water Table Map, June 1991 (Kasza et al. 1991).

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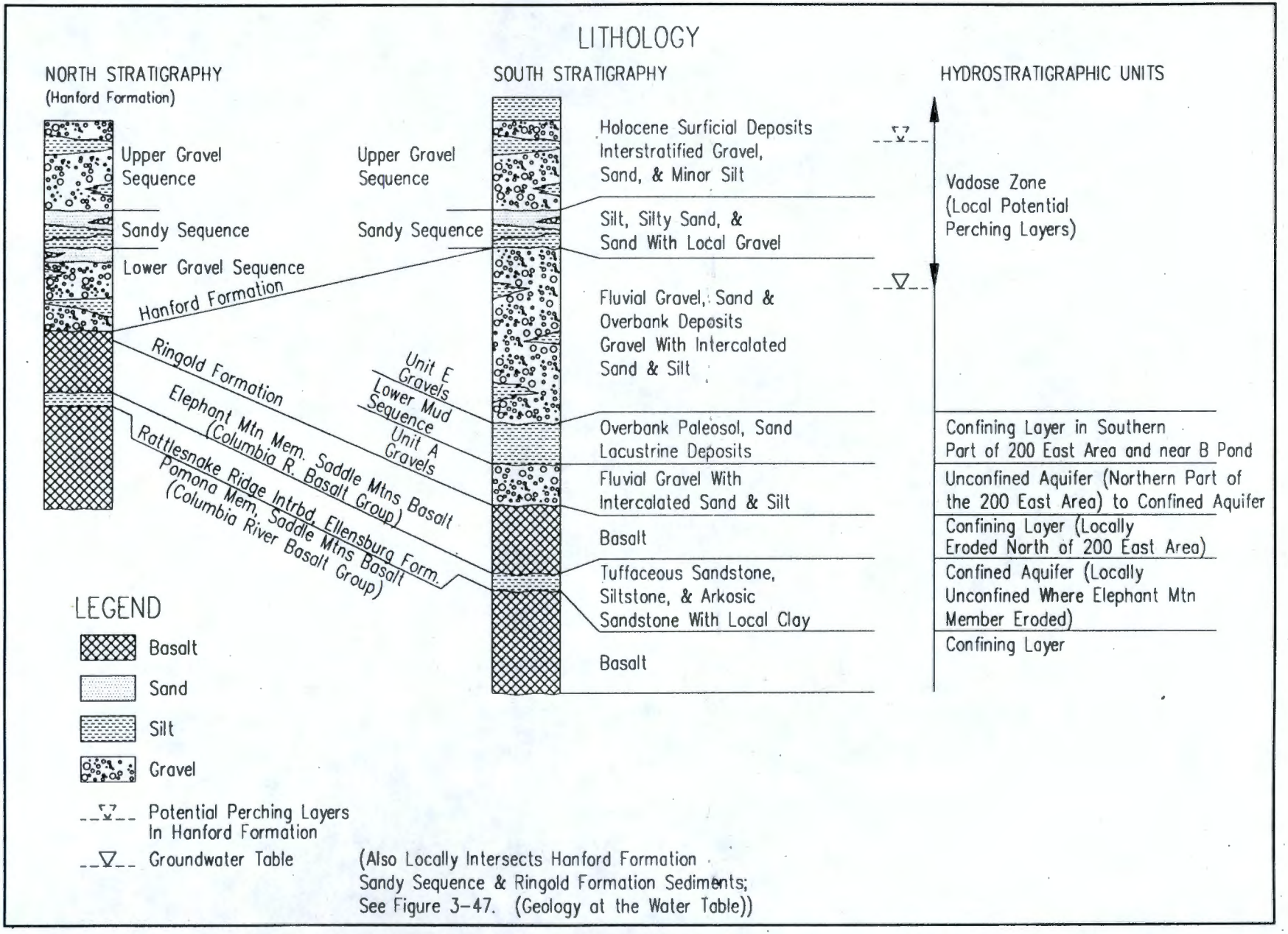

Figure 3-45. Conceptual Hydrogeologic Column for the 200 East Area (Lindsey et al. 1992; Connelly et al. 1992a; Delaney et al. 1991).

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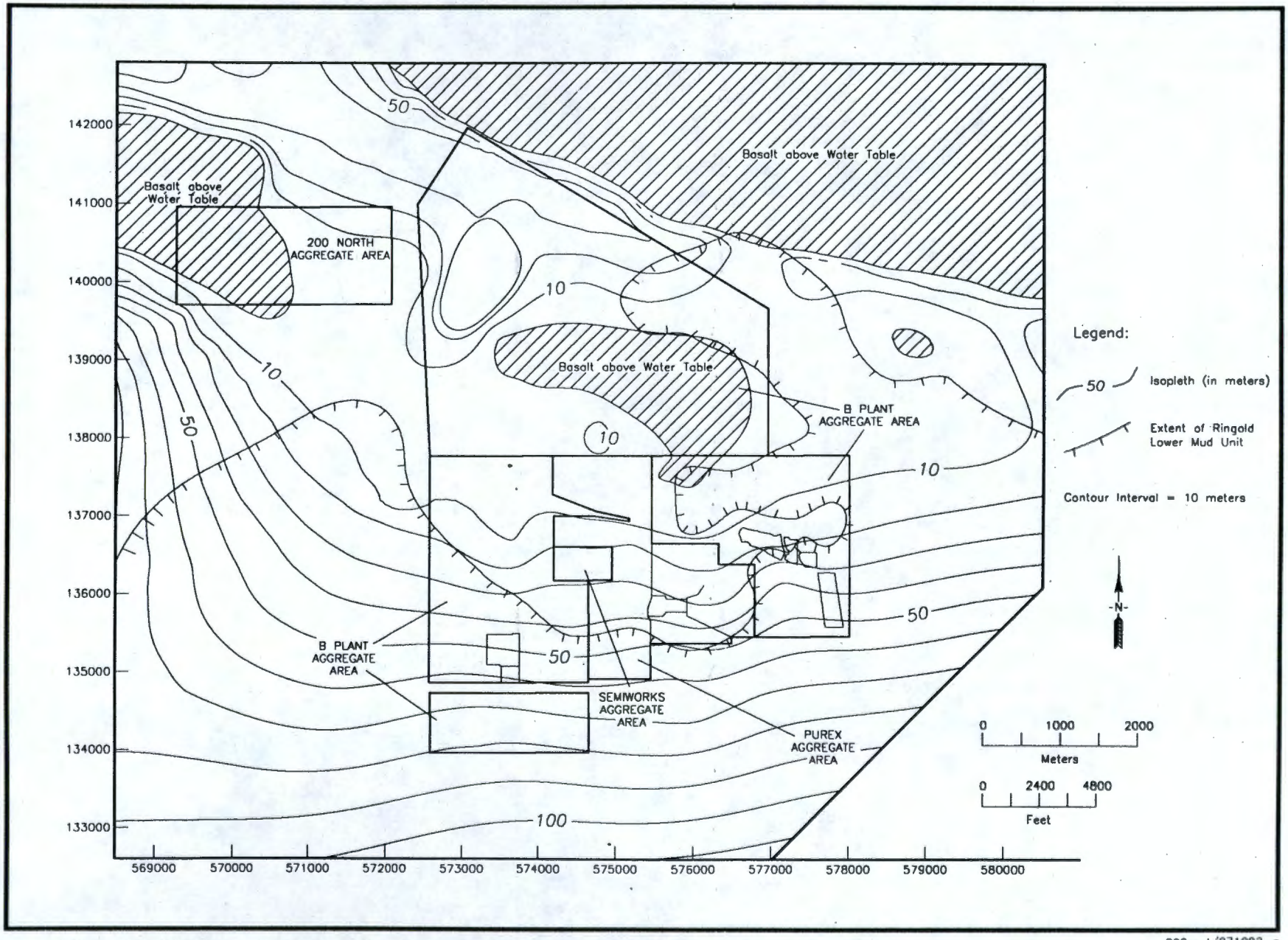

Figure 3-46. Isopach Map of the Uppermost Aquifer Saturated Zone in the 200 East Area (Connelly et al. 1992a).

9 2 1 2 7 5 1 4 0 3

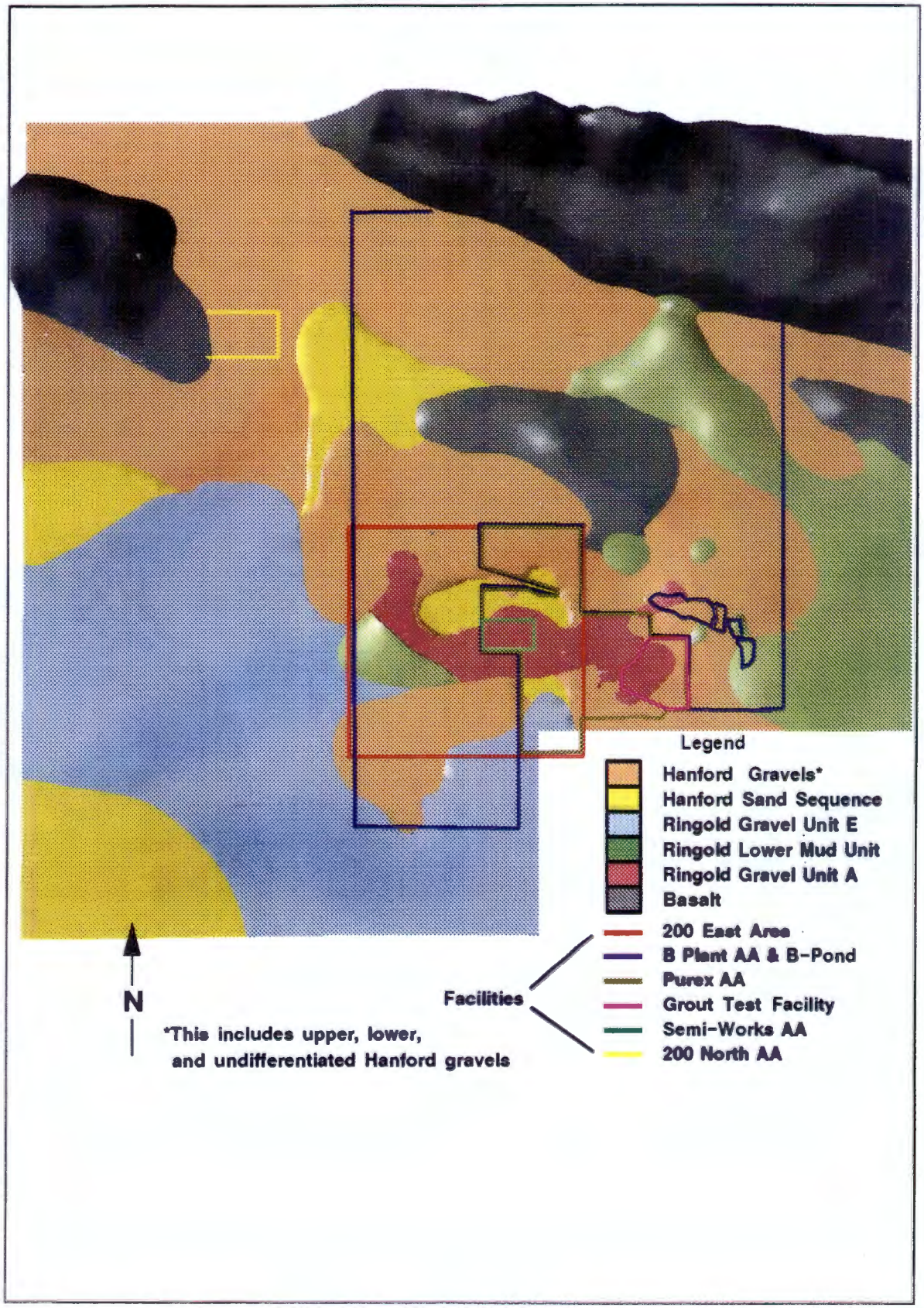

Figure 3-47. Geology of the Water Table for 1991 (Connelly et al. 1992a).

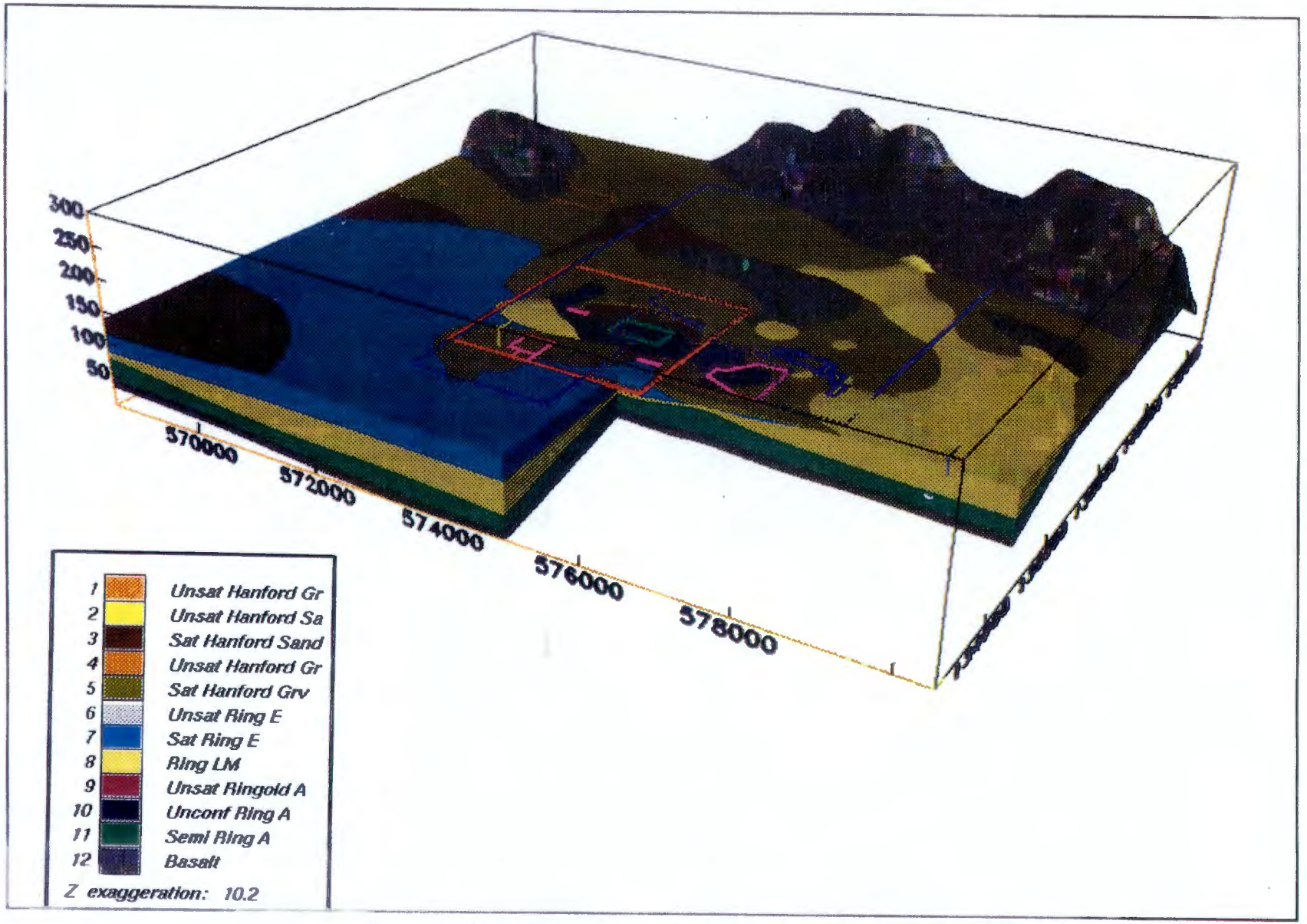

Figure 3-48. Uppermost Aquifer System (Connelly et al. 1992a).

9 2 1 2 7 5 1 4 0 5

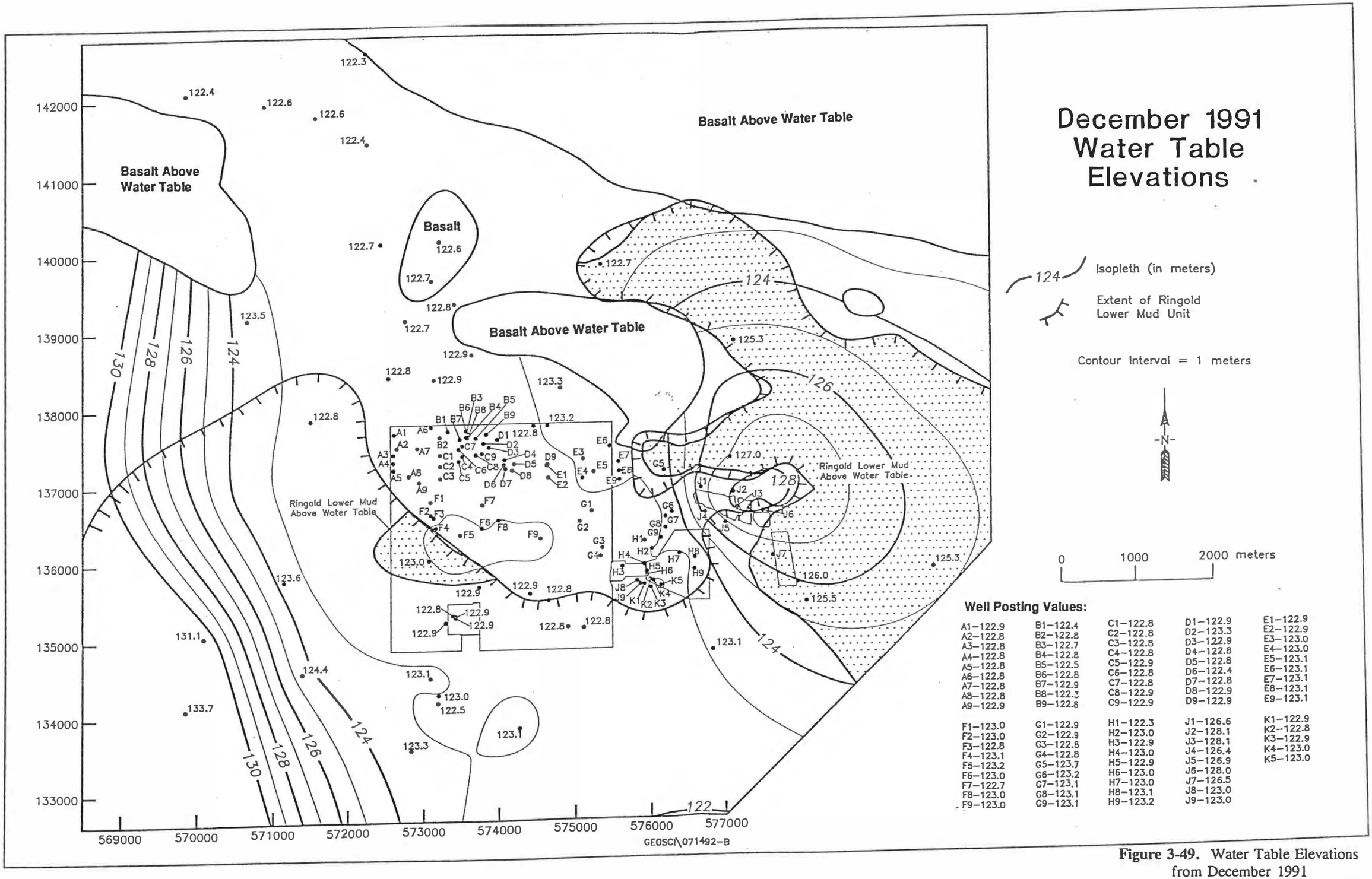

Figure 3-49. Water Table Elevations from December 1991 for the 200 East Area (Kasza et al. 1992).

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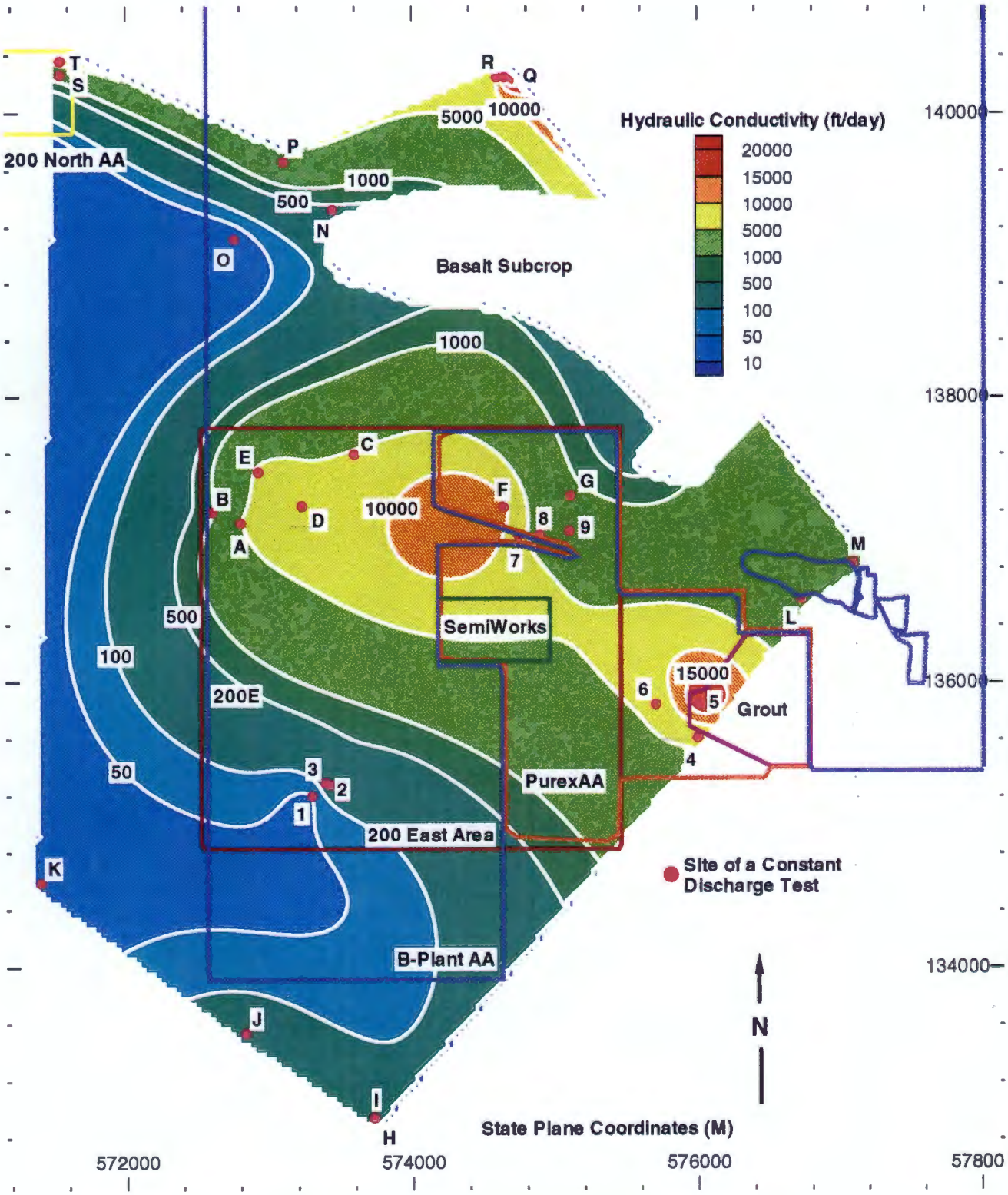

Figure 3-50. Hydraulic Conductivities of the Uppermost Aquifer in the 200 East Area (Connelly et al. 1992a).

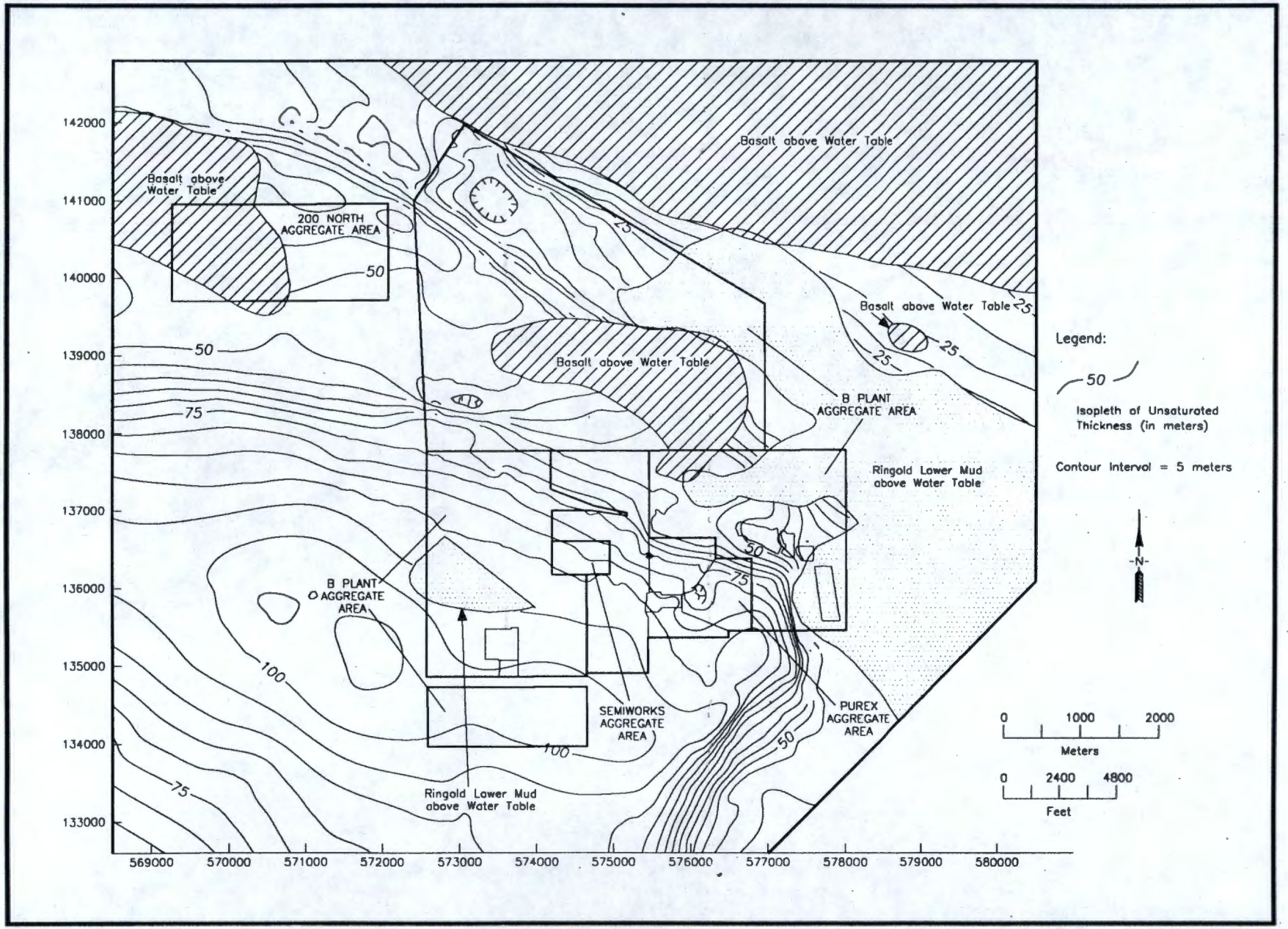

Figure 3-51. Isopach Map of the Vadose Zone in the 200 East Area (Connelly et al. 1992a).

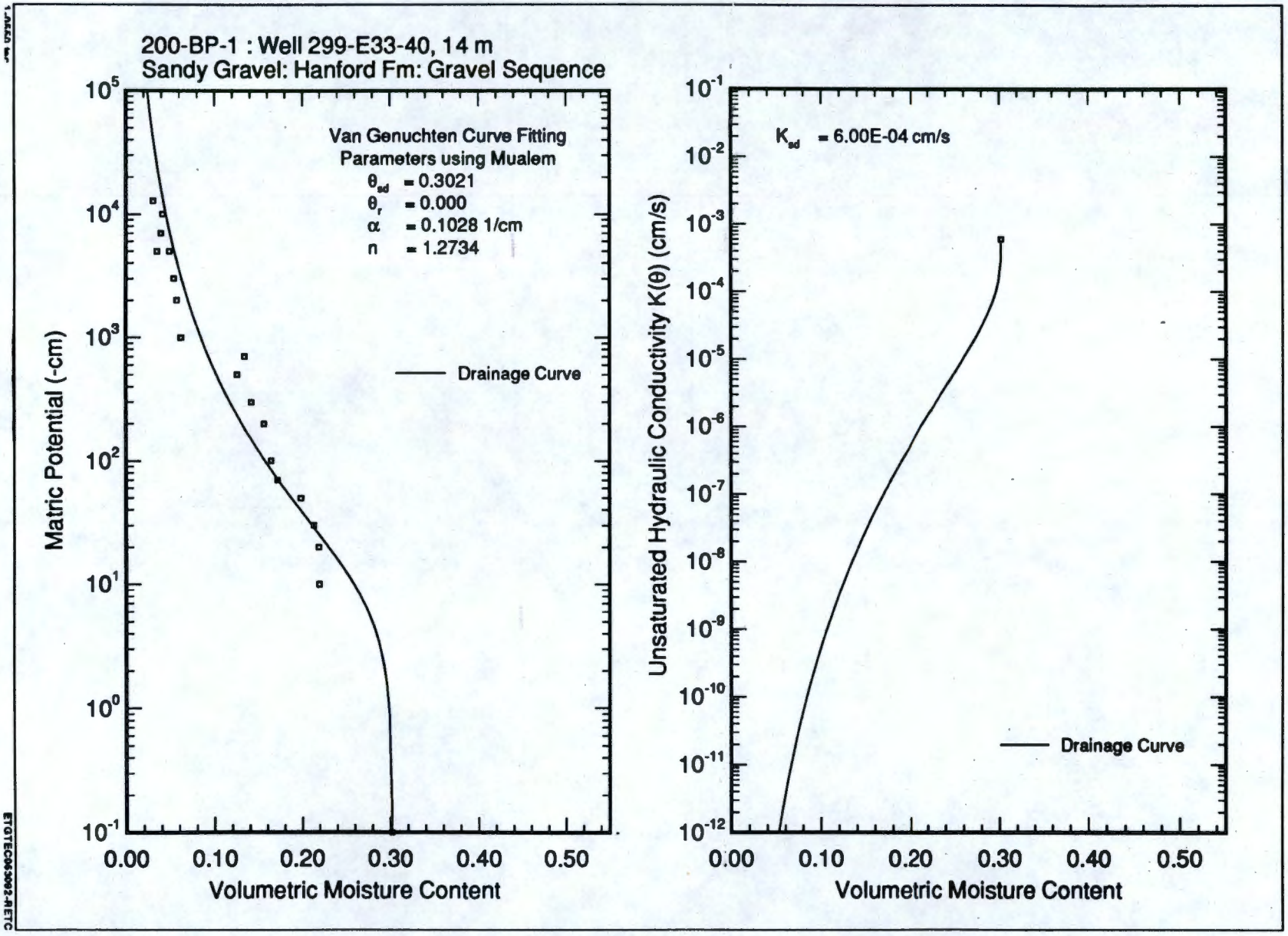

Figure 3-52. Wetting and Drying Curves with Matric Potential and Hydraulic Conductivity for Well 299-W18-21 (Connelly et al. 1992a).

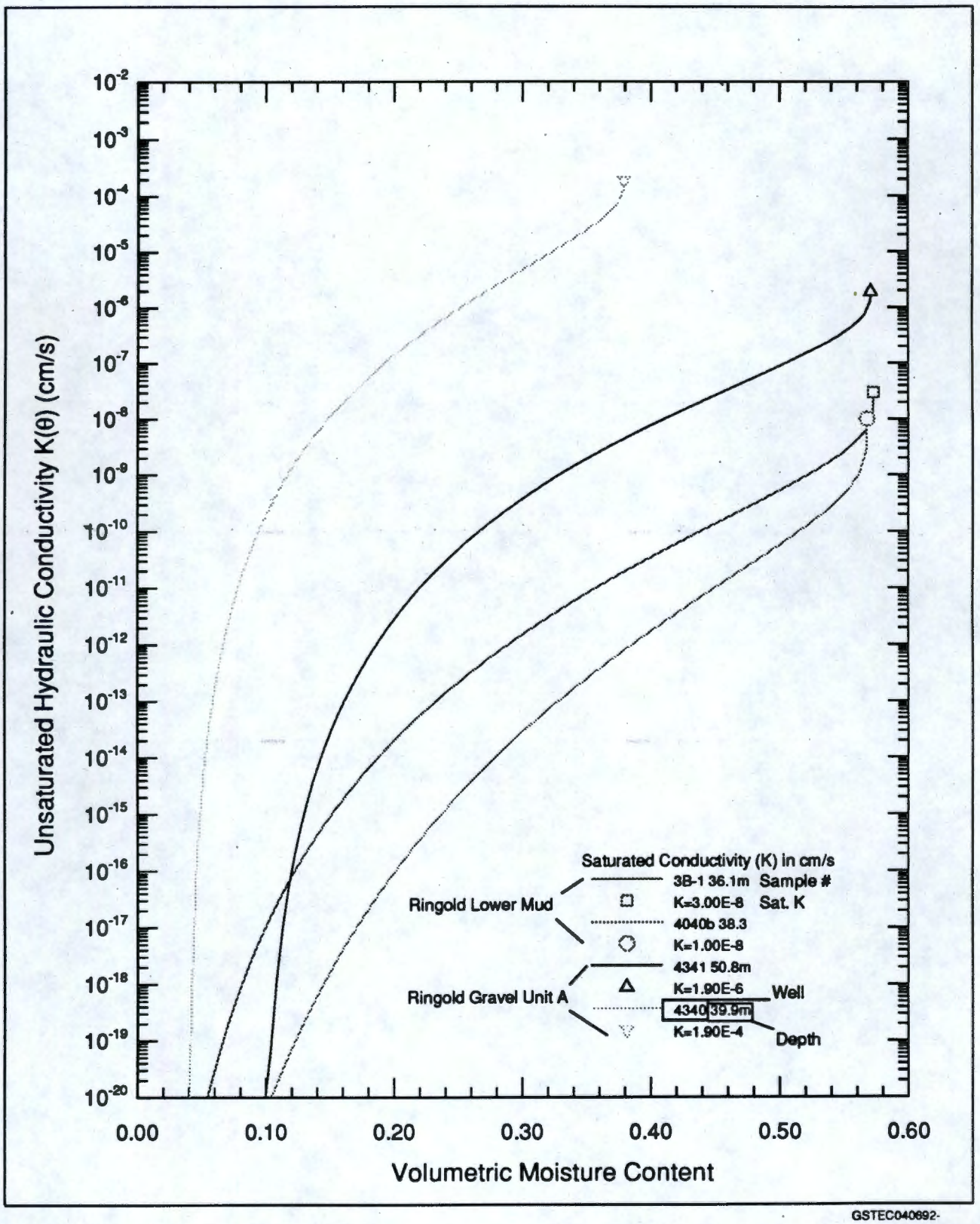

Figure 3-53. Ringold Unit A and Lower Mud Sequence Unsaturated Hydraulic Conductivity Curves for Drying Conditions (Connelly et al. 1992a).

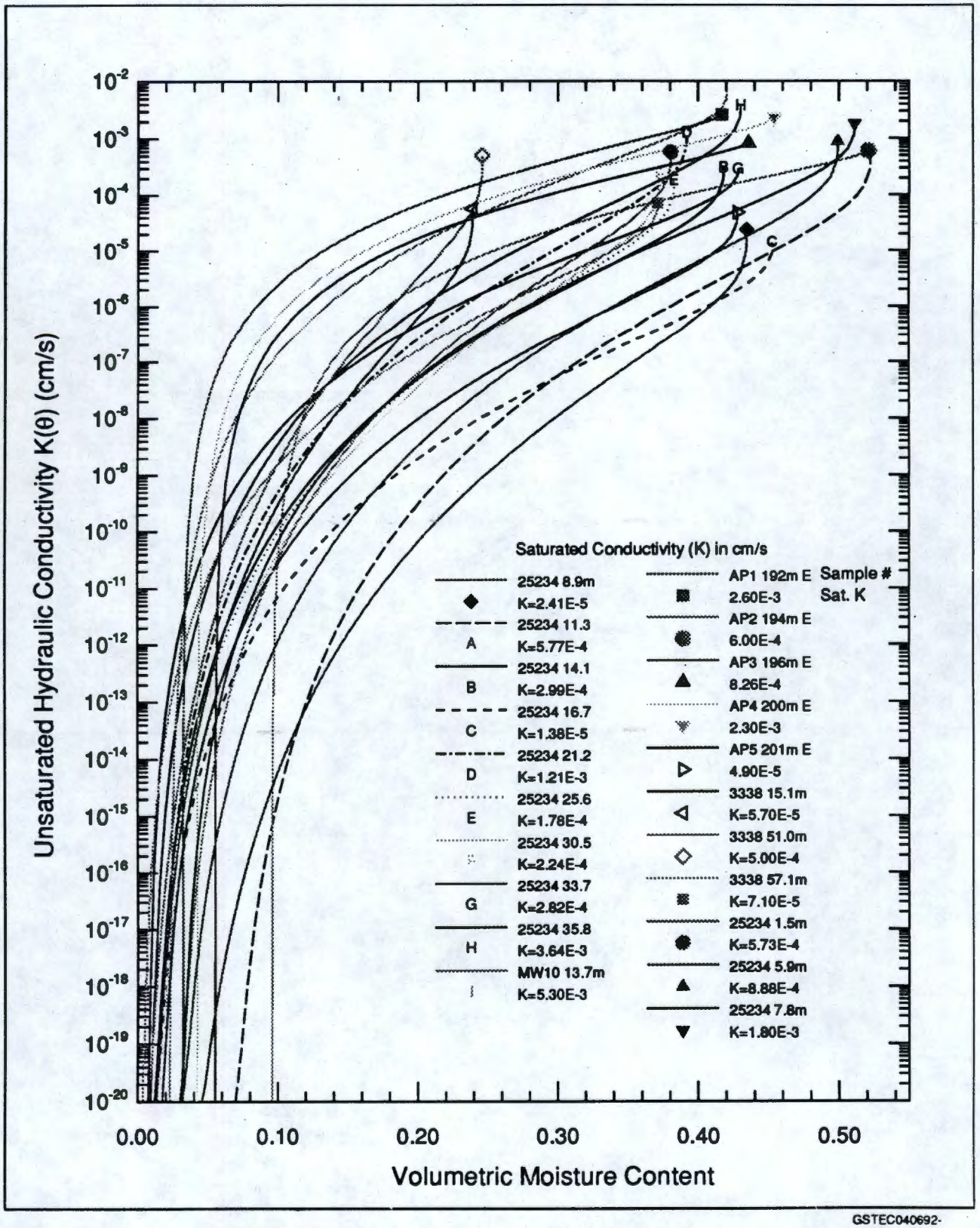

Figure 3-54. Hanford Formation Sandy Sequence Unsaturated Hydraulic Conductivity Curves for Drying Conditions--Drainage Set 1 (Connelly et al. 1992a).

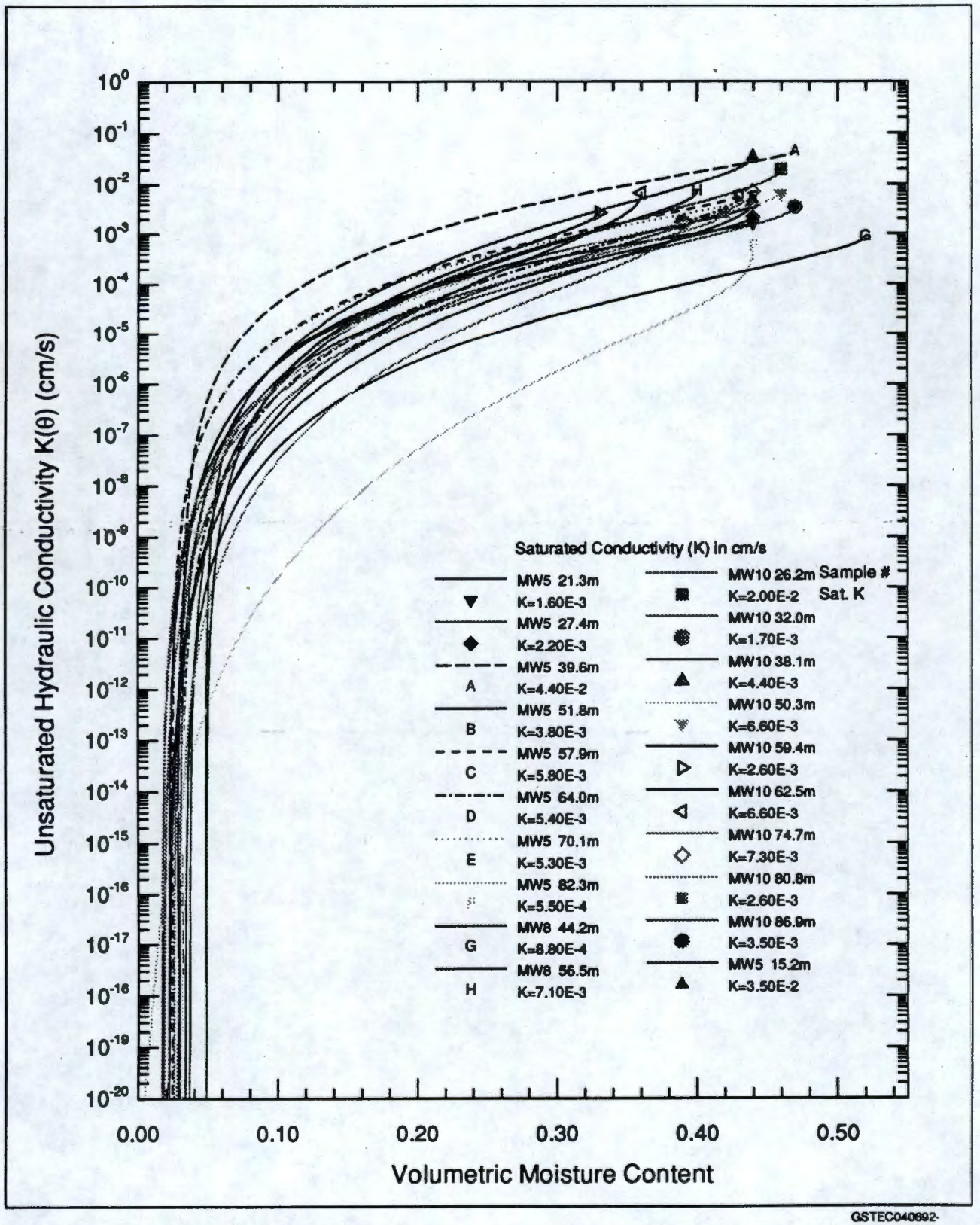

Figure 3-55. Hanford Formation Sandy Sequence Unsaturated Hydraulic Conductivity Curves for Drying Conditions--Drainage Set 2 (Connelly et al. 1992a).

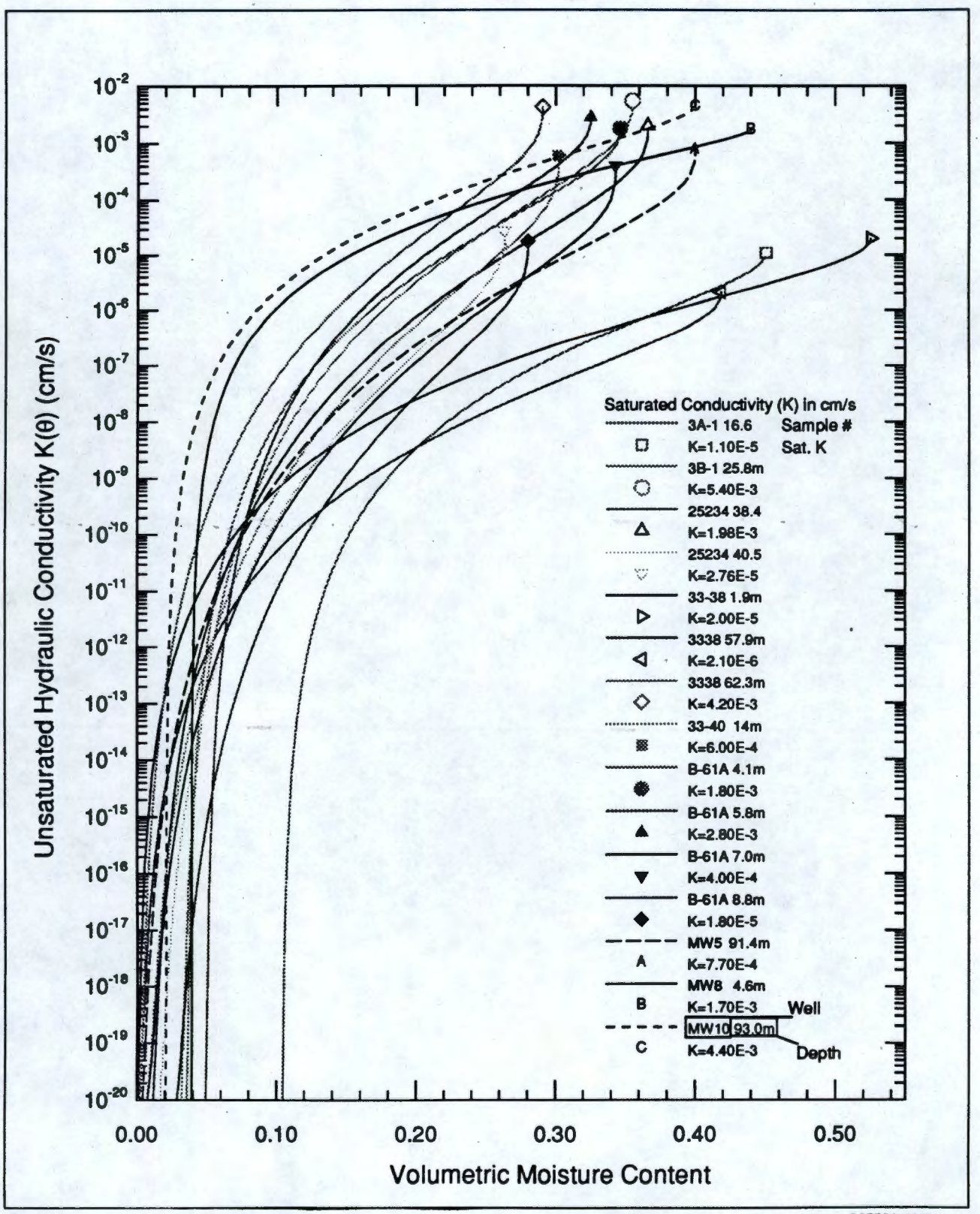

Figure 3-56. Hanford Formation Gravel Sequence Unsaturated Hydraulic Conductivity Curves for Drying Conditions (Connelly et al. 1992a).

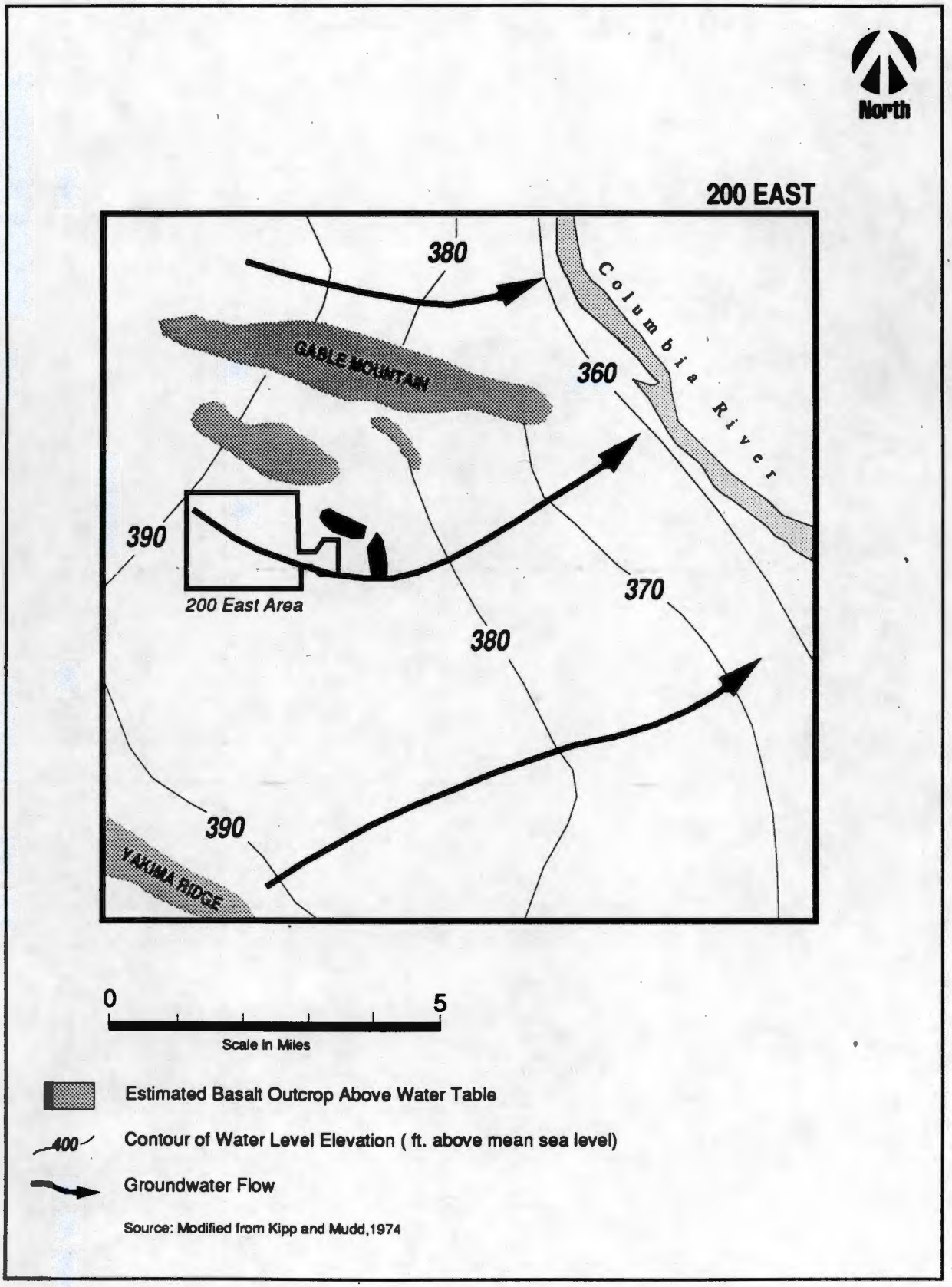

Figure 3-57. Water Table and Groundwater Flow in the Region of the 200 East Area for 1944.

9 2 1 2 7 5 1 4 1 3

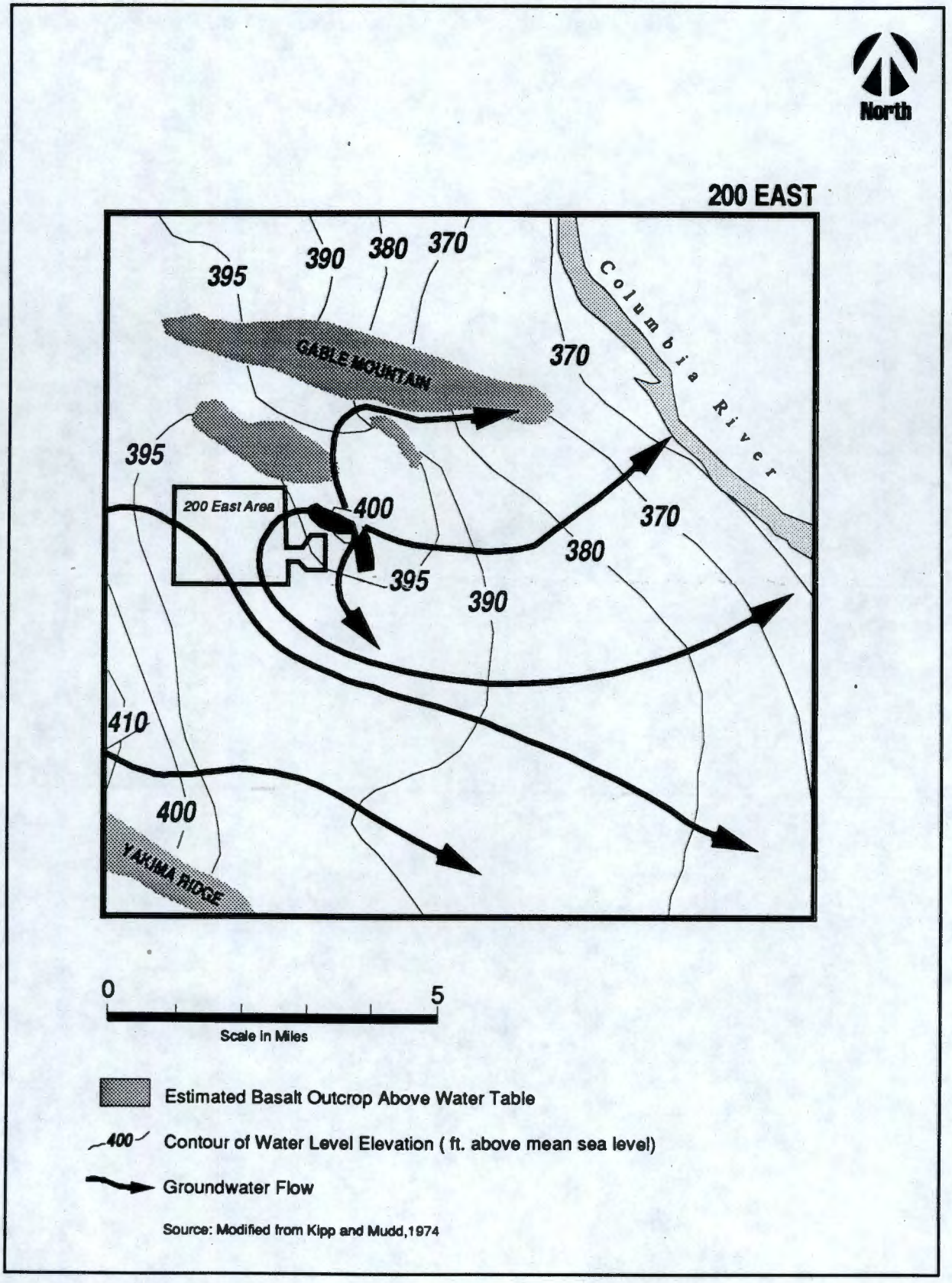

Figure 3-58. Water Table and Groundwater Flow in the Region of the 200 East Area for 1955.

9 2 1 2 7 5 1 4 1 4

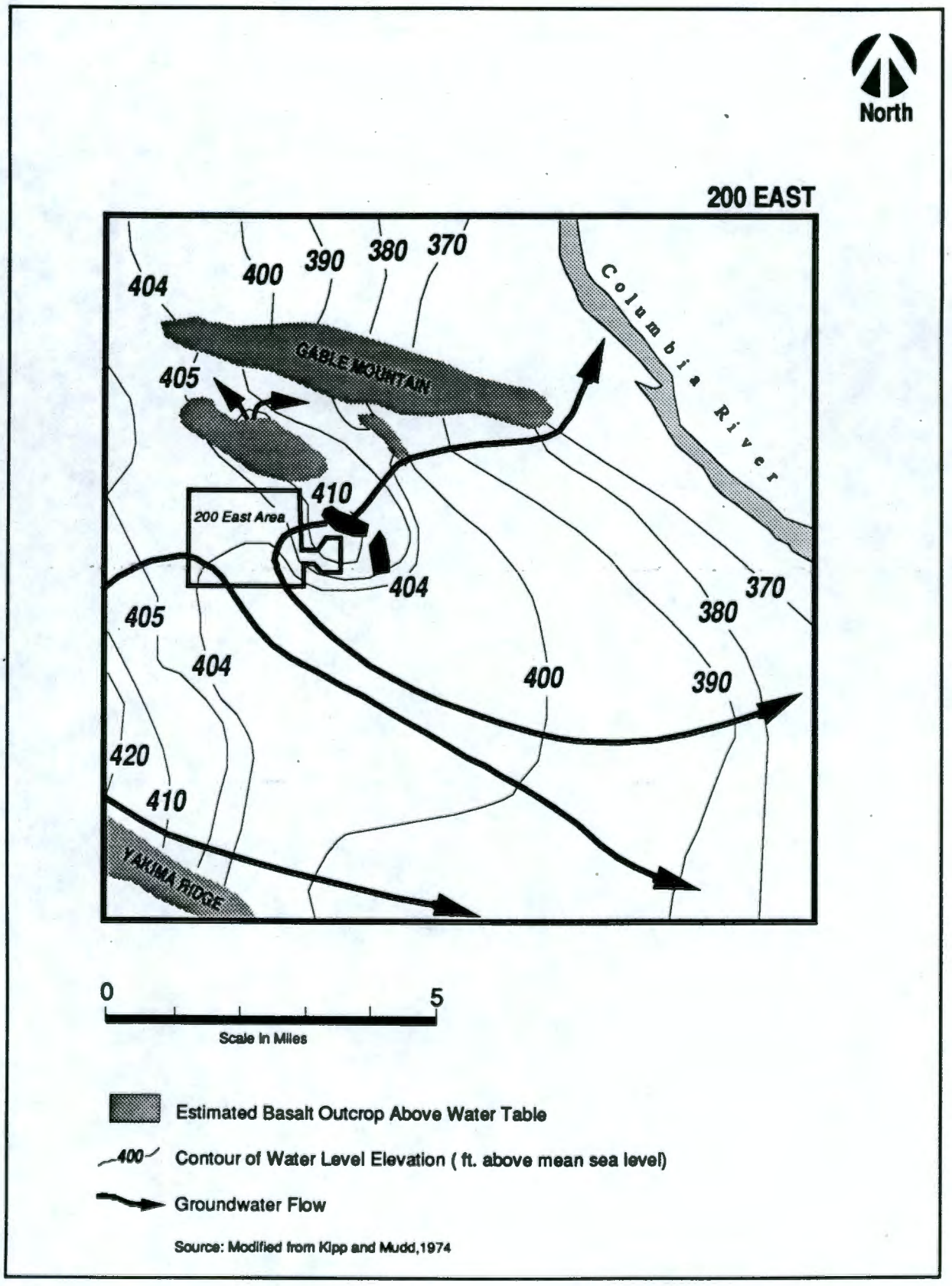

Figure 3-59. Water Table and Groundwater Flow in the Region of the 200 East Area for 1965.

9 2 1 2 7 5 1 4 1 5

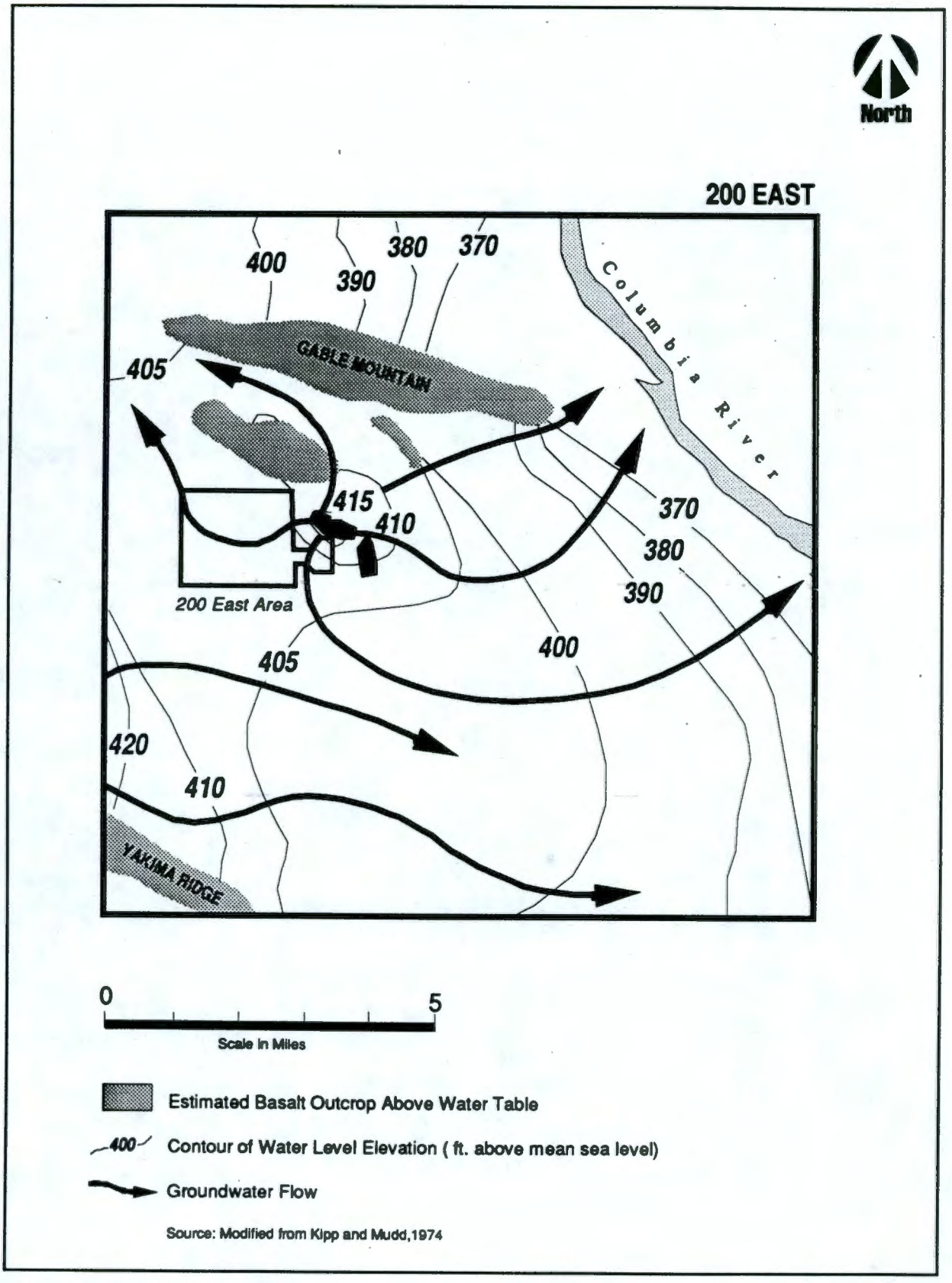

Figure 3-60. Water Table and Groundwater Flow in the Region of the 200 East Area for 1970.

9 2 1 2 7 5 1 4 1 6

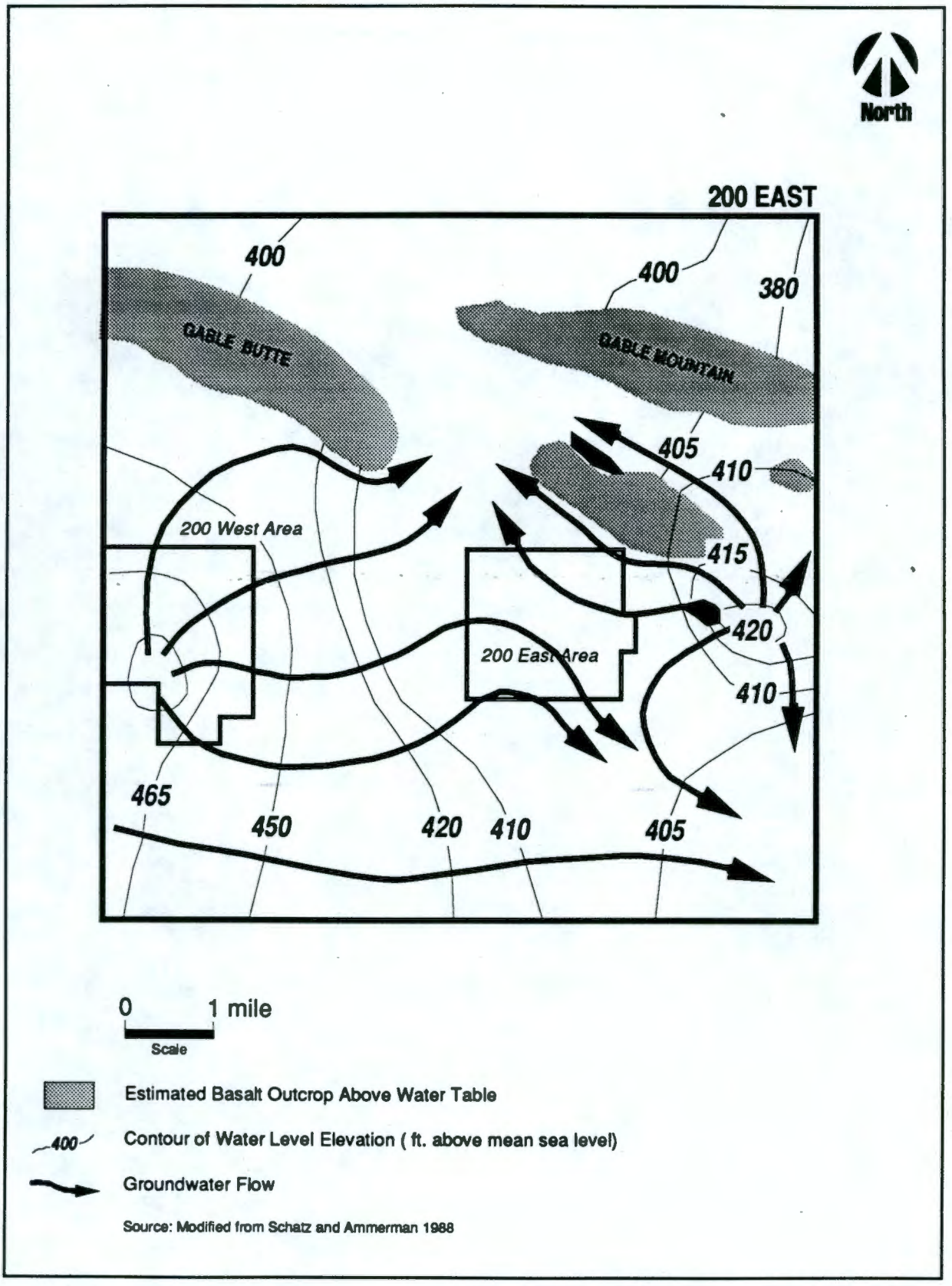

Figure 3-61. Water Table and Groundwater Flow in the Region of the 200 East Area for 1987.

9 2 1 2 7 5 1 4 1 7

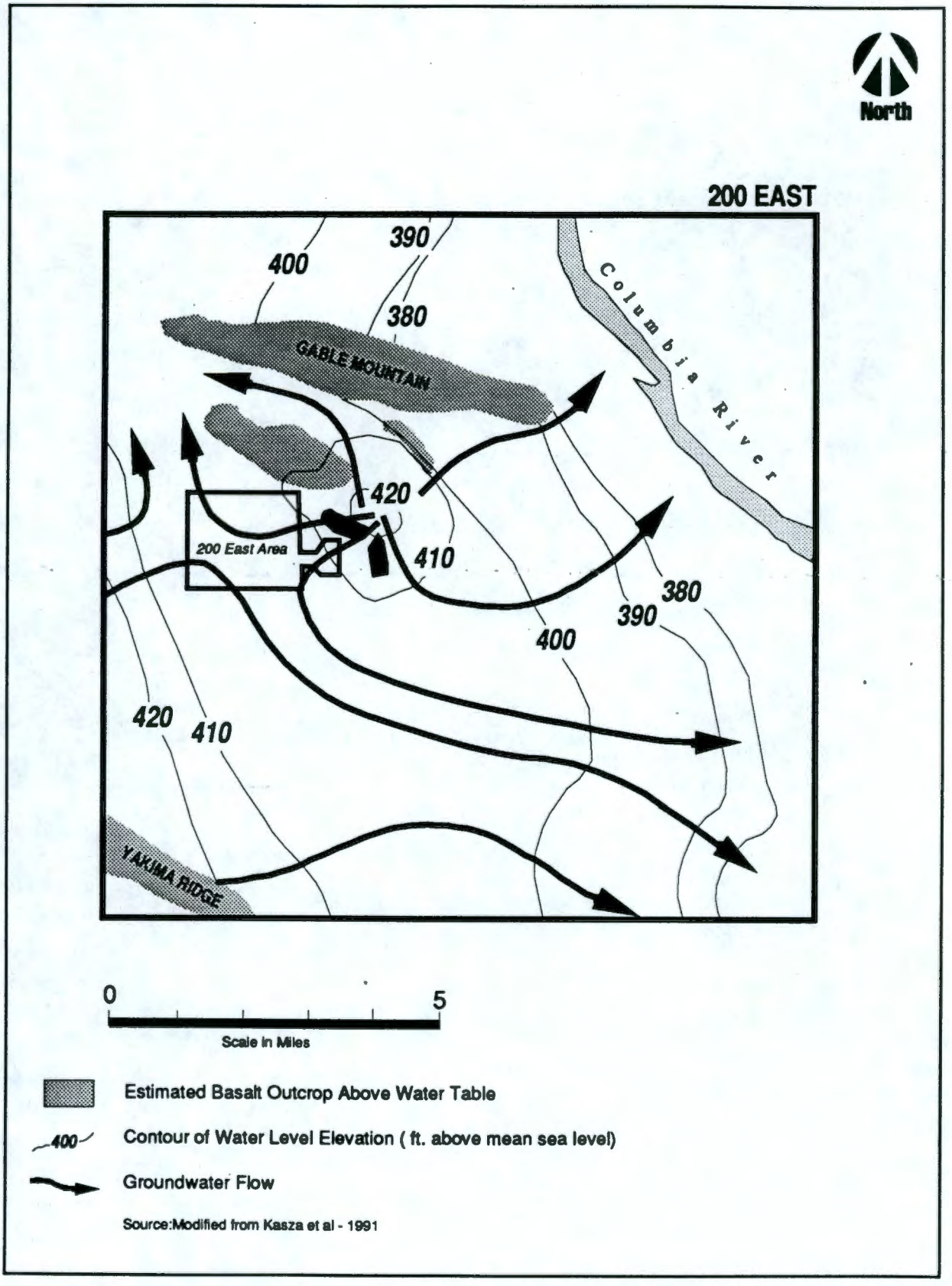

Figure 3-62. Water Table and Groundwater Flow in the Region of the 200 East Area for June 1991.

9 2 1 2 7 5 1 4 1 8

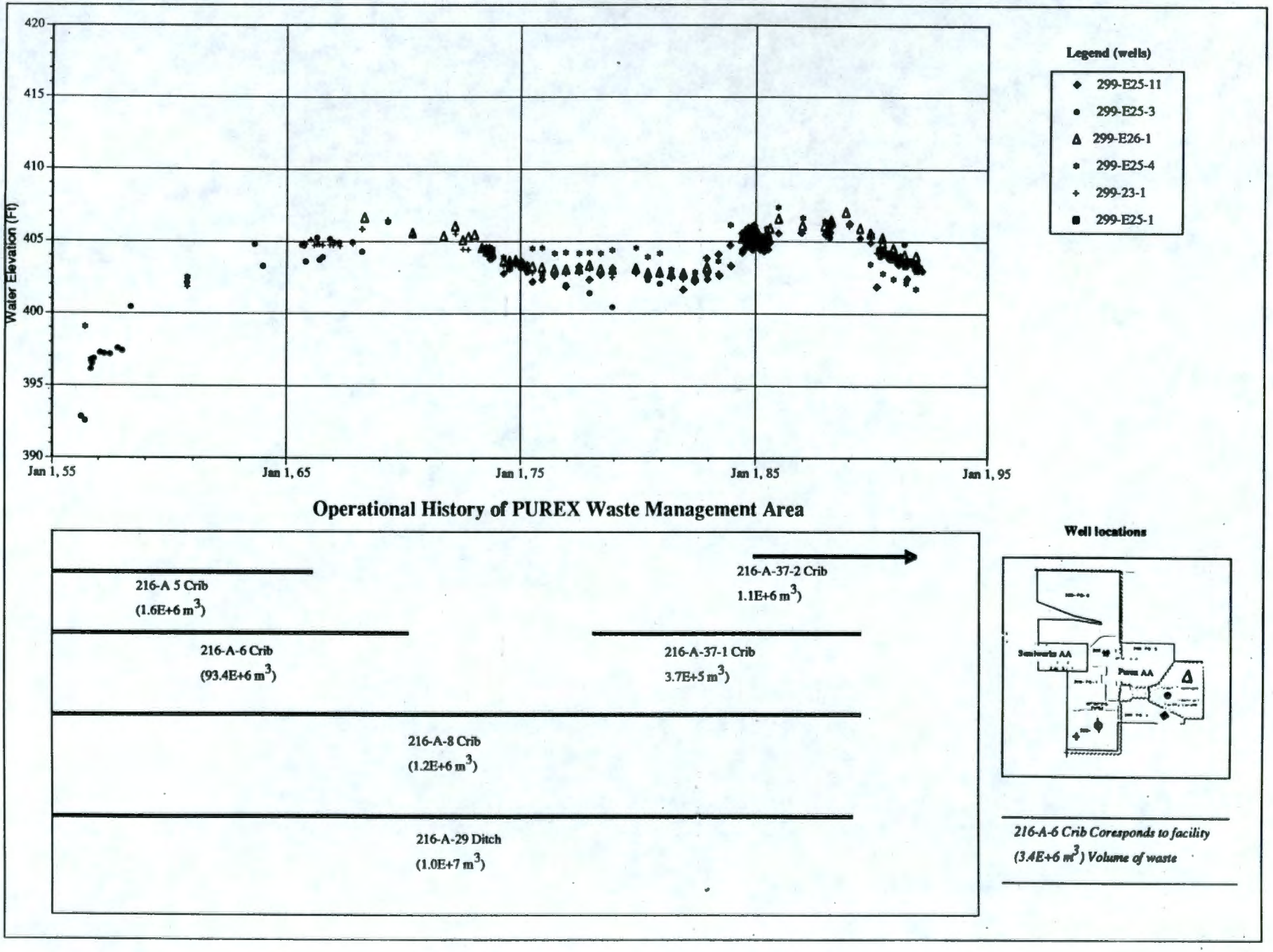

Figure 3-63. Well Hydrograph of the PUREX Plant Aggregate Area.

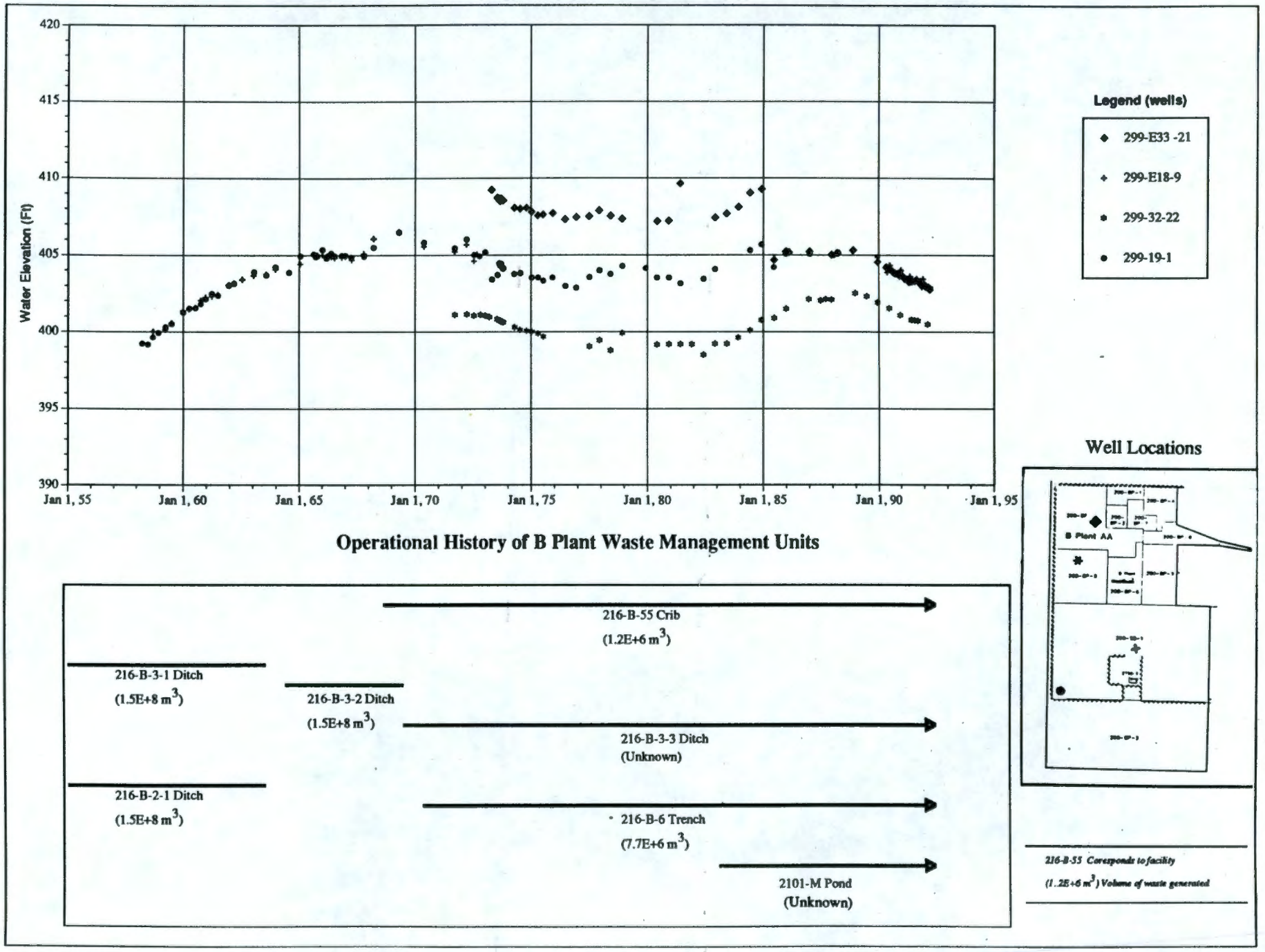

Figure 3-64. Well Hydrograph of the B Plant Aggregate Area (West of PUREX).

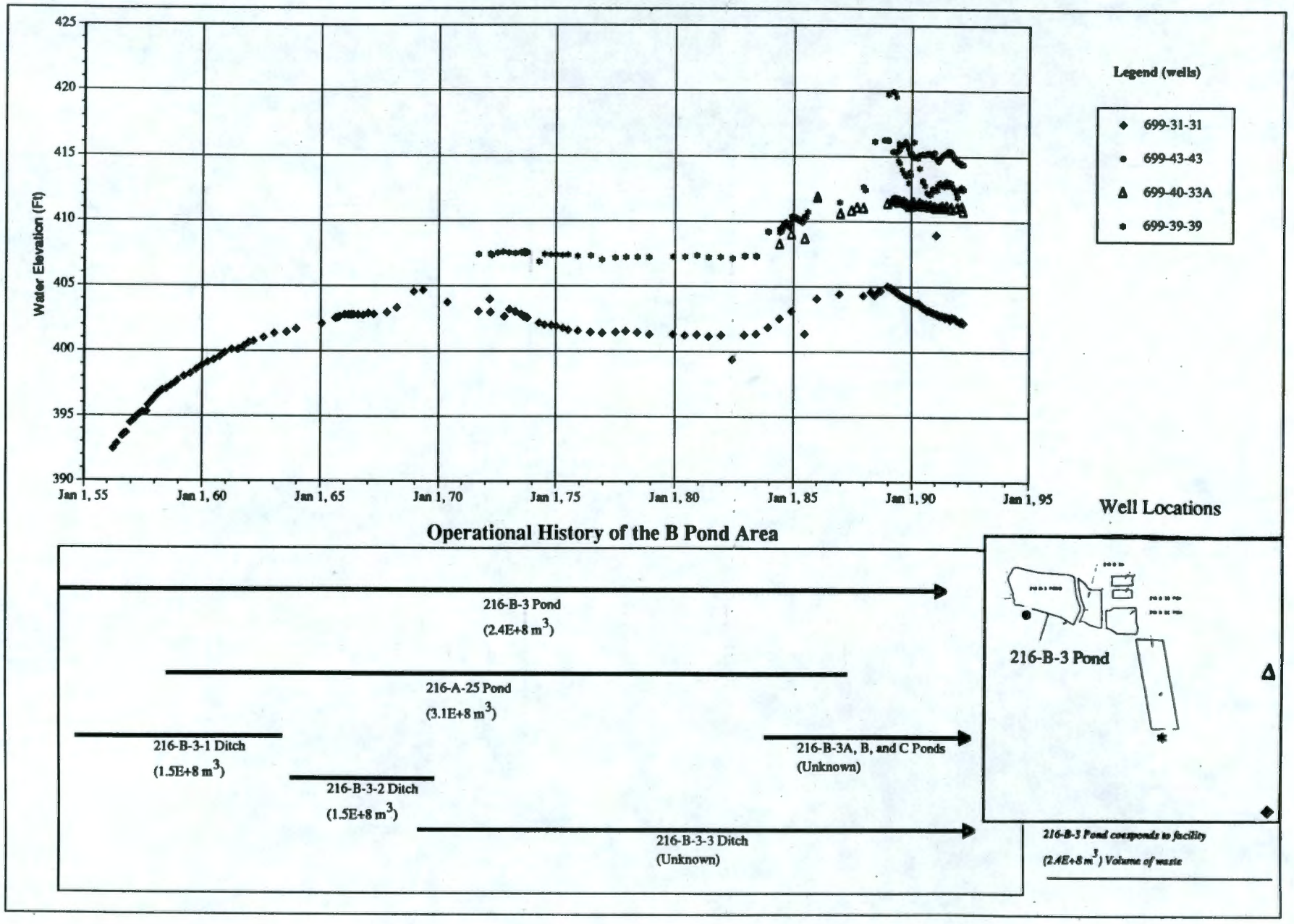

Figure 3-65. Well Hydrograph of the B Pond Area.

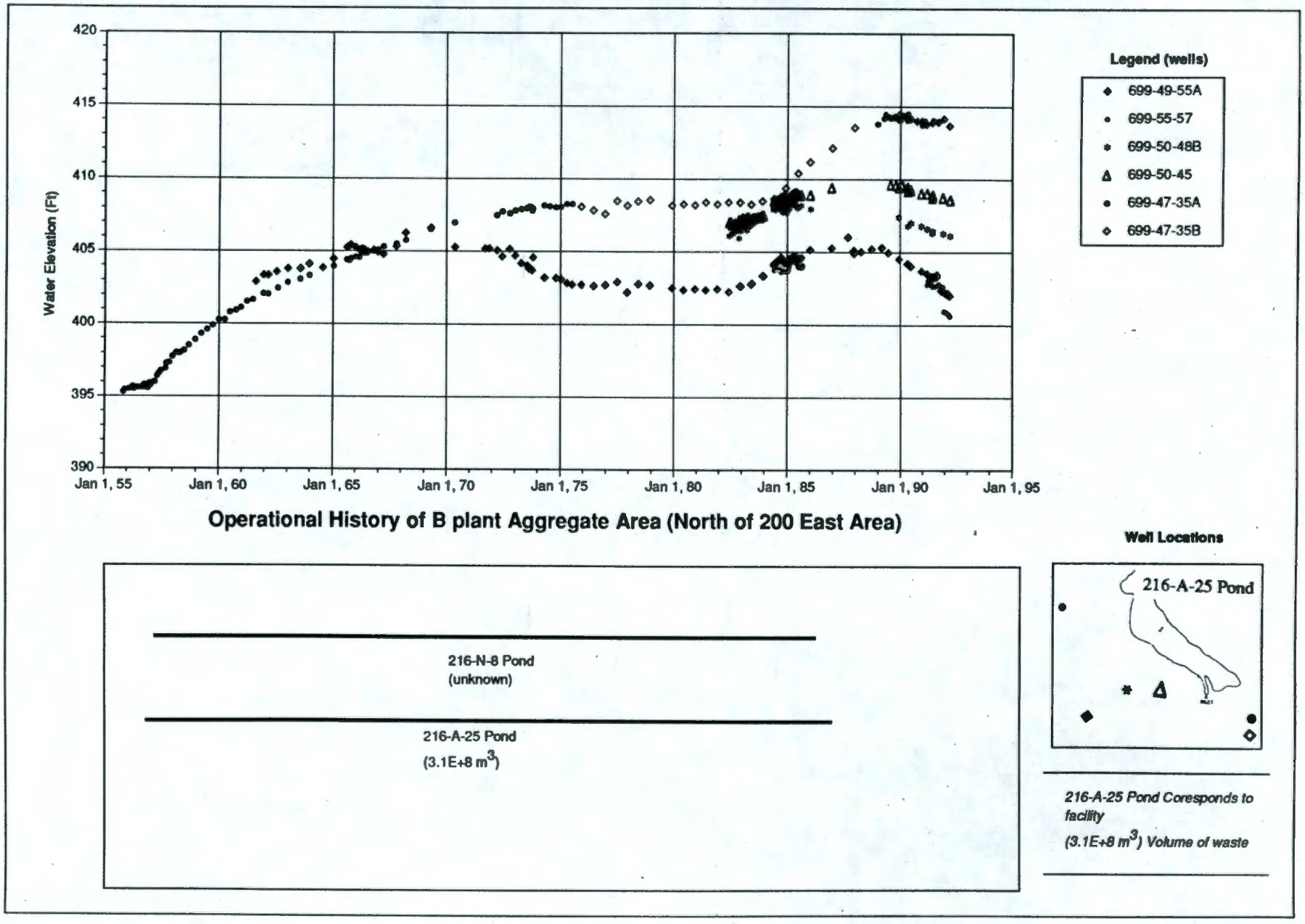

Figure 3-66. Well Hydrograph of the B Plant Aggregate Area (North of the 200 East Area).

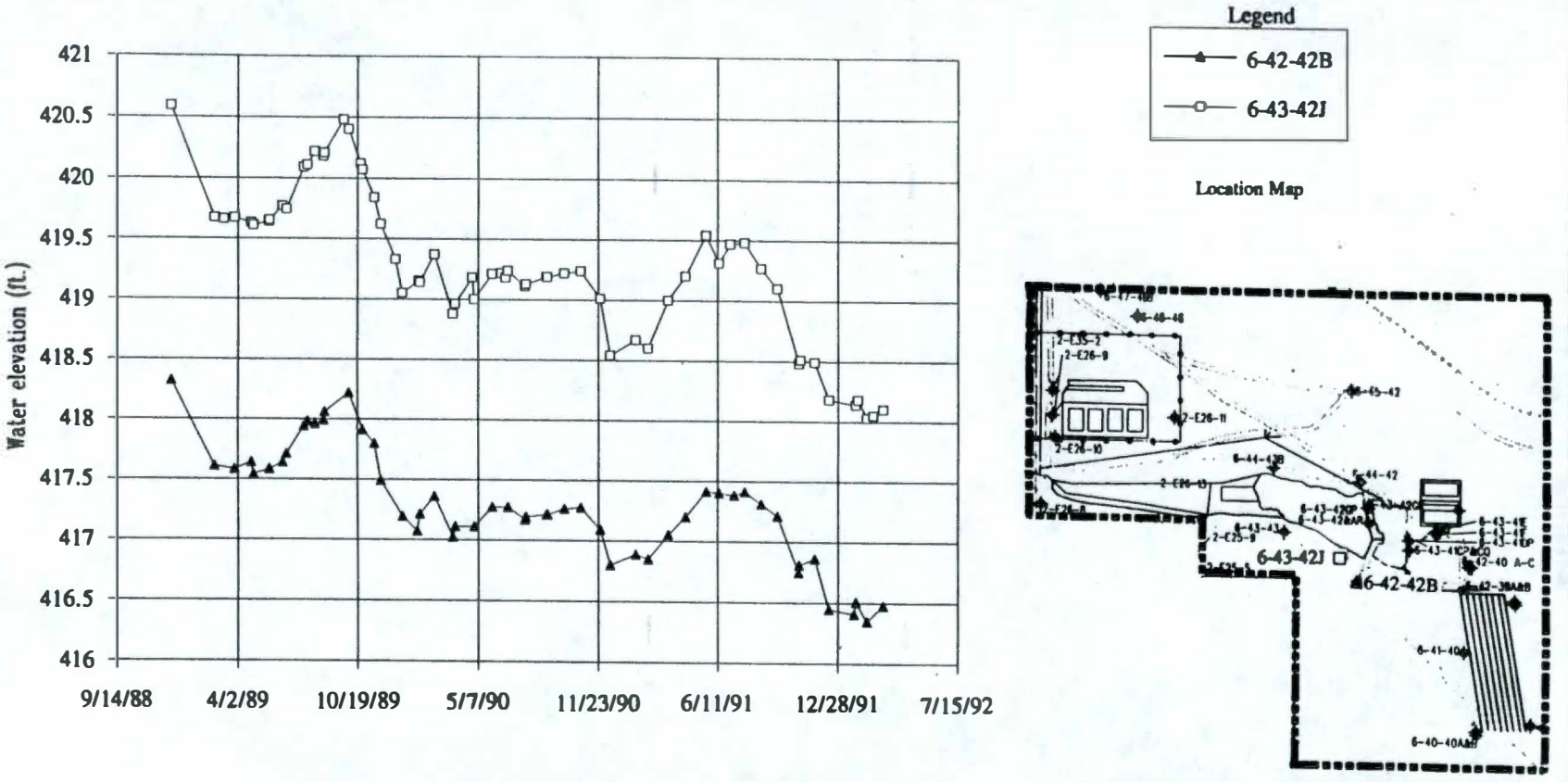

Figure 3-67. 600 Area Hydrograph Showing Declining Water Level.

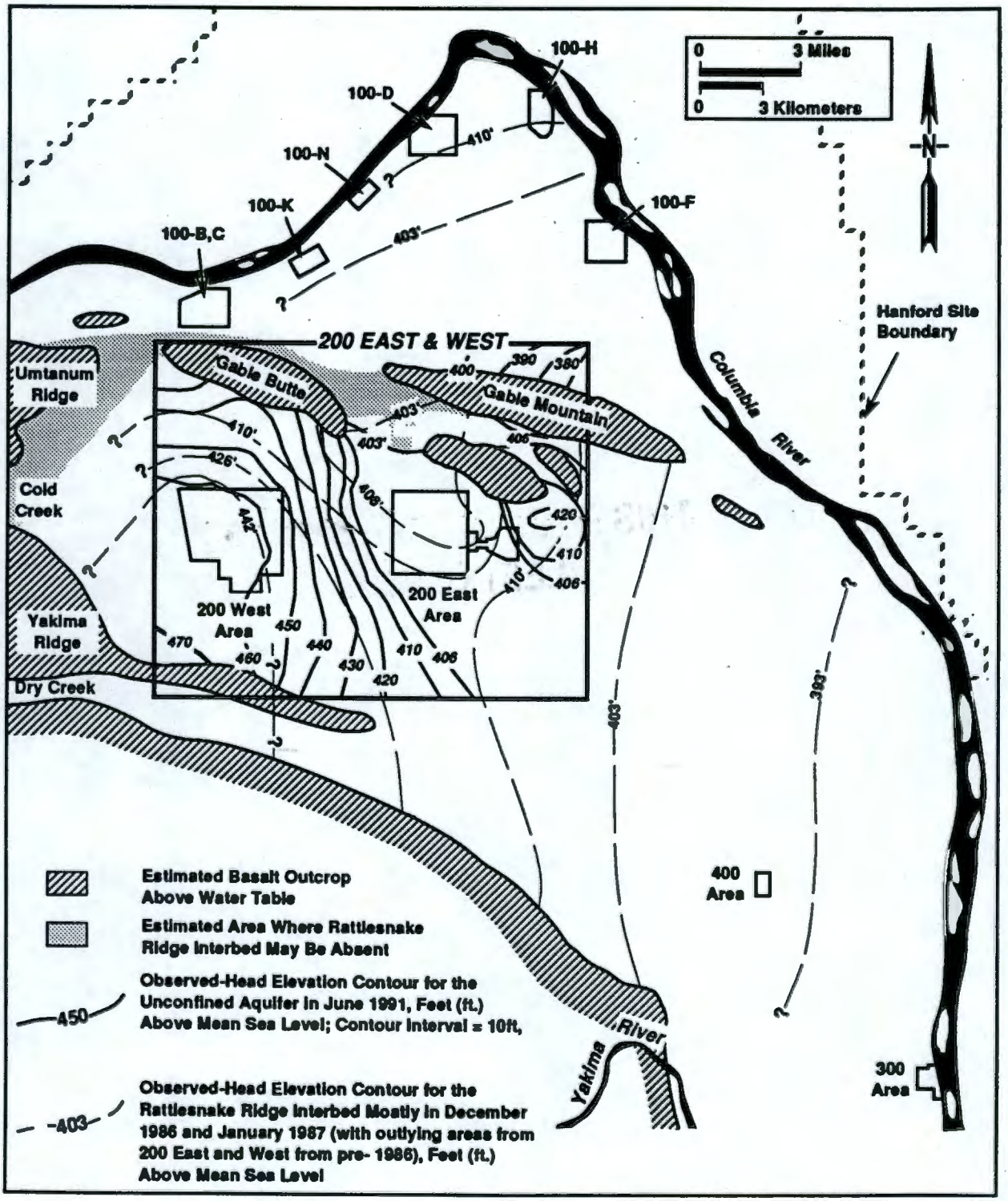

Figure 3-68. Potentiometric Surface Contour Map for the Unconfined and Rattlesnake Ridge Aquifers (Adapted from Kasza et al. 1991 and Jackson, 1992)

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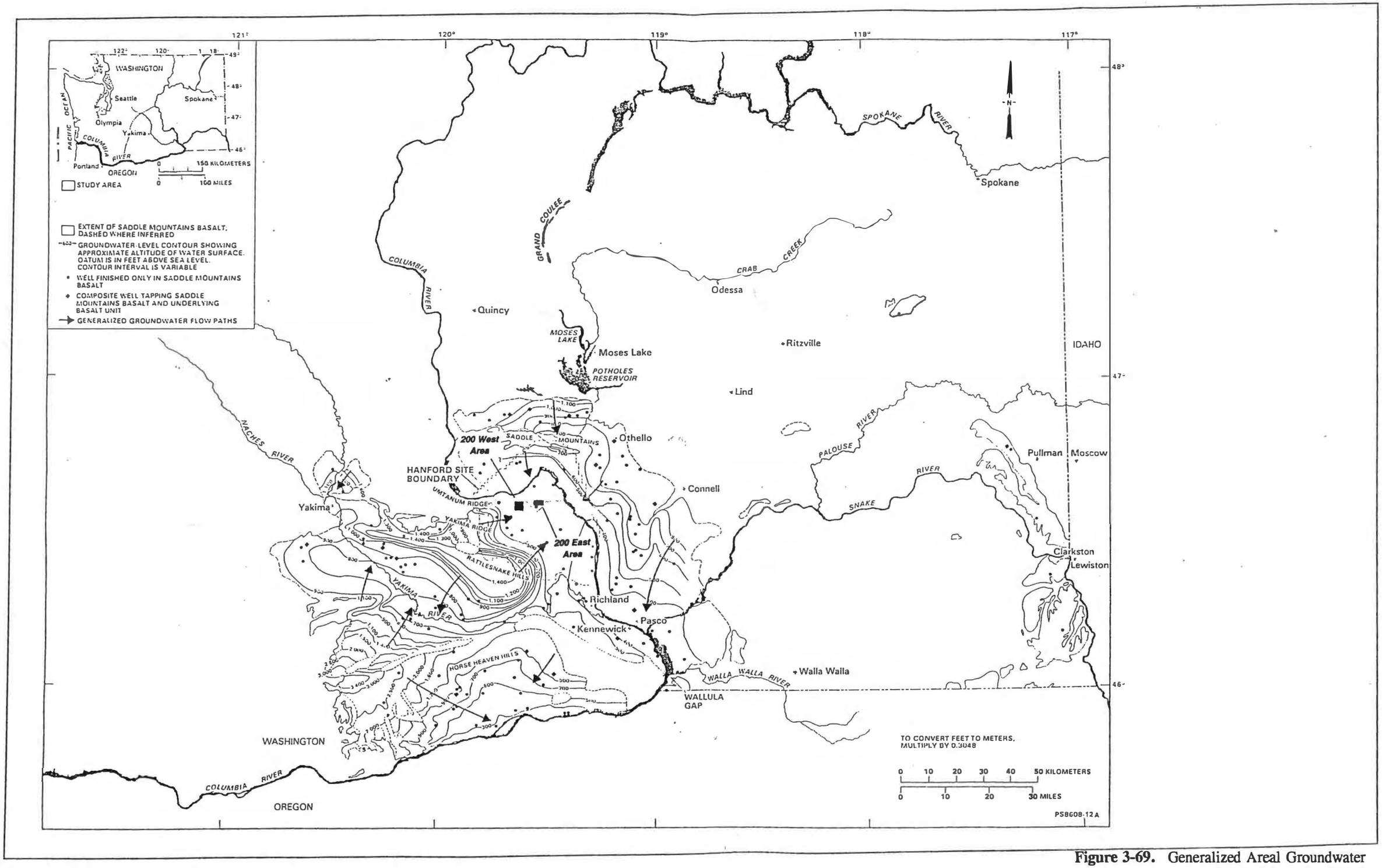
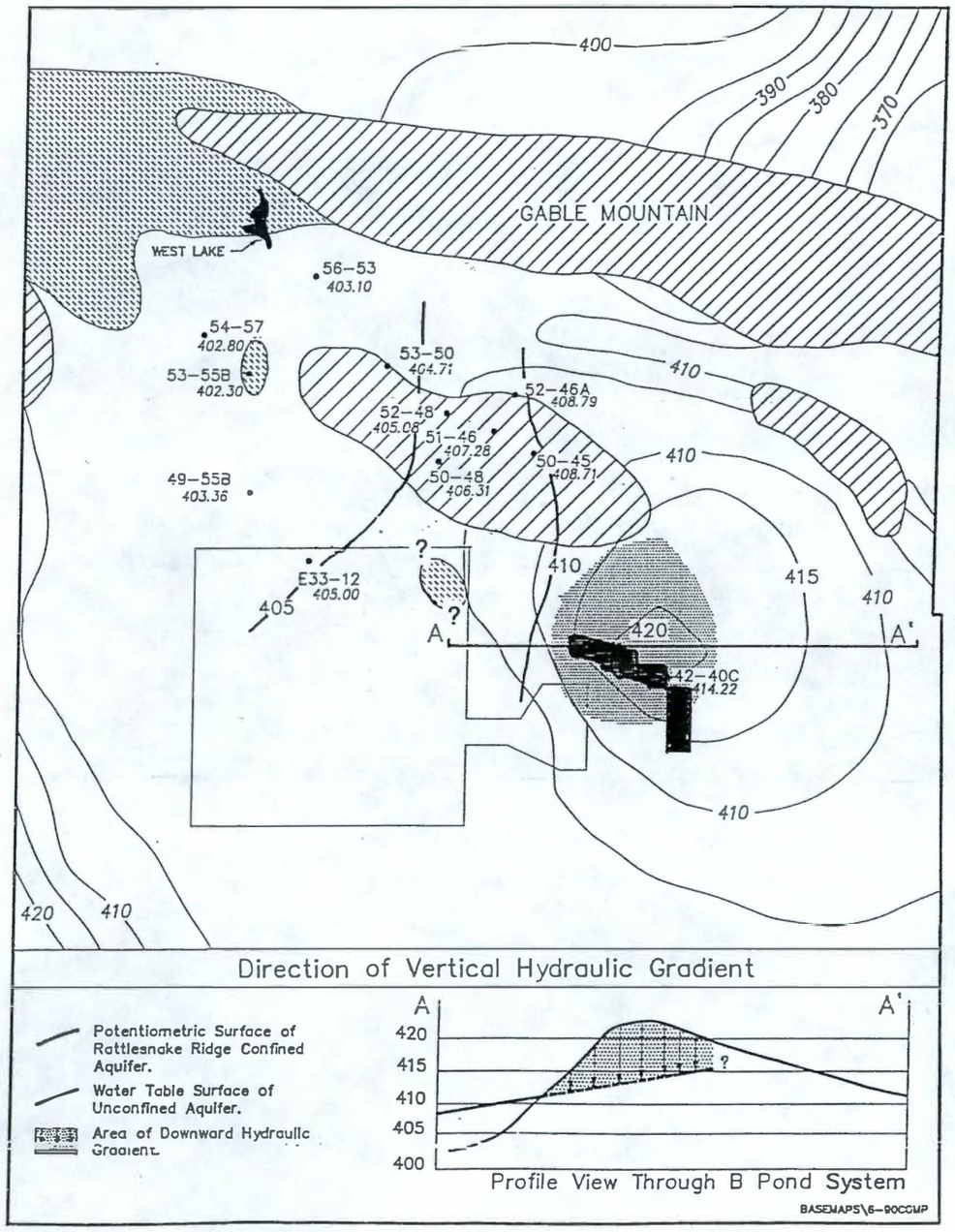


Figure 3-69. Generalized Areal Groundwater Flow Patterns in the Saddle Mountains Basalt within the Columbia Plateau (DOE 1988).

9 2 1 2 7 5 1 4 2 5



Potentiometric surface of the Rattlesnake Ridge confined aquifer in feet above mean sea level

Water table contours in feet above mean sea level

Areas of complete erosion of the Elephant Mountain Member (from RHO-RE-ST-12)

Area of downward hydraulic gradient

50-45 405 Wells in confined aquifer used to prepare map

Pond

Areas where the basalt surface is generally above the water table

T.13 N.
T.12 N.

The Rattlesnake Ridge aquifer, which is confined by the Elephant Mountain Member, is monitored quarterly in the eastern portion of 200 East Area. The June 1991 water level measurements in 12 wells completed in the Rattlesnake Ridge interbed were used to contour the potentiometric surface of the aquifer. Areal extent of downward hydraulic gradient from the unconfined aquifer to this confined aquifer is inferred from the water-table map and the contours of the potentiometric surface of the Rattlesnake Ridge. This area represents the zone in which downward flow might occur if a pathway is available due to complete erosion of the Elephant Mountain Member or sufficiently high hydraulic conductivity in the basalt. A profile view through the B Pond system shows the relationship between the unconfined water table and the potentiometric surface of the Rattlesnake Ridge confined aquifer.

The potentiometric surface of the Rattlesnake Ridge confined aquifer map has been prepared by the Geosciences Group, Environmental Division, Westinghouse Hanford Company.

Note: To convert to metric, multiply elevation (ft) by 0.3048 to obtain elevation (m).

-N-

0 1 Mile

0 1 Kilometer

Figure 3-70. Potentiometric Surface of the Rattlesnake Ridge Confined Aquifer and the Groundwater Level at the Unconfined Aquifer, Showing Area of Downward Hydraulic Gradient, June 1991 (Kasza et al. 1991 and Jackson 1992).

9 2 1 2 7 - 5 1 4 2 6

Table 3-1. Unconfined Aquifer Hydraulic Conductivities and Transmissivities for the Hanford Site.

Location	Interval Tested	Hydraulic Conductivity in m/s (ft/day)	Transmissivity in m^2/day (ft^2/day)
Hanford Site	Hanford Formation	1.8×10^{-3} to 7.2×10^{-2} (500-20,300)	1,300-55,200 (14,000-594,000)
	Ringold Formation (Unit E)	2.3×10^{-7} to 2.1×10^{-2} (0.06-600)	1.9-4,740 (20-51,000)
200 East Area	Unconfined Aquifer	5.3×10^{-5} to 4.0×10^{-3} (15-1,140)	0.08-62,300 (0.9-670,000)

Notes: Hanford Site data compiled from Newcomer et al. (1992b), Connelly et al. (1992b), Bjornstad (1990), Delaney et al. (1991), and Last et al. (1989).

200 East Area data compiled from Newcomer et al. (1992a), Connelly et al. (1992a), Swanson et al. (1992), Delaney et al. (1991), and Last et al. (1989).

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Table 3-2. Well Clusters and Associated Barometric Efficiency and Vertical Hydraulic Gradient Data (Connelly et al. 1992a).

Well Cluster	Barometric Efficiency	Maximum Vertical Hydraulic Gradient	Direction of Vertical Flow Component (During Max. Vertical Hydraulic Gradient)
299-E33-07 Uppermost aquifer	N/A	0.0050 ft/ft	↑
299-E33-40 Rattlesnake Ridge aquifer	25%		
699-49-55A Uppermost aquifer	N/A	0.0023 ft/ft	↑
699-49-55B Rattlesnake Ridge aquifer	22%		
699-49-57A Uppermost aquifer	N/A	0.0015 ft/ft	↑
699-49-57B Rattlesnake Ridge aquifer	19%		
699-50-53A Uppermost aquifer	N/A	0.0037 ft/ft	↑
699-50-53B Rattlesnake Ridge aquifer	15%		
699-55-57 Uppermost aquifer	N/A	0.0038 ft/ft	↑
699-54-57 Rattlesnake Ridge aquifer	15%		

Table 3-3. Endangered, Threatened, and Sensitive Plant Species Reported On or Near the Hanford Site.

Scientific Name	Common Name	Family	Washington State Status
Rorippa columbiae[a/] Suksd. ex Howell	Persistantsepal Yellowcress	Brassicaceae	Endangered
Artemesia campestris L ssp. *borealis* (Pall.) Hall & Clem. var. *wormskioldii*[a/] (Bess.) Cronq.	Northern Wormwood	Asteraceae	Endangered
Astragalus columbianus[a/] Barneby	Columbia Milk Vetch	Fabaceae	Threatened
Lomatium tuberosum[a/] Hoover	Hoover's Desert-Parsley	Apiaceae	Threatened
Astragalus arrectus Gray	Palouse Milk Vetch	Fabaceae	Sensitive
Collinsia sparsiflora Fisch.&Mey. var *bruciae* (Jones) Newsom	Few-Flowered Collinsia	Scrophulariaceae	Sensitive
Cryptantha interrupta (Greene)Pays.	Bristly Cryptantha	Boraginaceae	Sensitive
Cryptantha leucophaea Dougl. Pays	Gray Cryptantha	Boraginaceae	Sensitive
Erigeron piperianus Cronq.	Piper's Daisy	Asteraceae	Sensitive
Carex densa L.H. Bailey	Dense Sedge	Cyperaceae	Sensitive
Cyperus rivularis Kunth	Shining Flatsedge	Cyperaceae	Sensitive
Limosella acaulis Ses.&Moc.	Southern Mudwort	Scrophulariaceae	Sensitive
Lindernia anagallidea (Michx.)Pennell	False-pimpernel	Scrophulariaceae	Sensitive
Nicotiana attenuata Torr.	Coyote Tobacco	Solanaceae	Sensitive
Oenothera pygmaea Dougl.	Dwarf Evening-Primrose	Onagraceae	Sensitive

[a/] Indicates candidates on the 1991 Federal Register, Notice of Review.
Source: WHC (1992)

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Table 3-4. Federal and State Classifications of Animals That Could Occur on the 200 Areas Plateau.

Name	Status Federal	State
Peregrine Falcon (*Falco peregrinus*)	FE	SE
Sandhill Crane (*Grus canadensis*)		SE
Bald Eagle (*Haliaeetus leucocephalus*)	FT	ST
Ferruginous Hawk (*Buteo regalis*)	FC2	ST
Swainson's Hawk (*Buteo swainsoni*)	FC2	SC
Golden Eagle (*Aquila chrysaetos*)		SC
Burrowing Owl (*Athene cuniculuria*)		SC
Loggerhead Shrike (*Lanius ludovicianus*)		SC
Sage Sparrow (*Amphispiza belli*)		SC
Great Blue Heron (*Casmerodius albus*)		SM
Merlin (*Falco columbarius*)		SM
Prairie Falcon (*Falco mexicanus*)		SM
Long-billed Curlew (*Numenius americanus*)		SM
Striped Whipsnake (*Masticophis taeniatus*)		SC

FE - Federal Endangered
FT - Federal Threatened
FC2 - Federal Candidate
SE - State Endangered
ST - State Threatened
SC - State Candidate
SM - State Monitor
Source: WHC (1992)

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4.0 PRELIMINARY CONCEPTUAL SITE MODEL

Section 4.1 presents the chemical and radiological data that are available for the groundwater in the 200 East Groundwater Aggregate Area. These chemical and radiological data are evaluated in Sections 4.2 and 5.0 in order to qualitatively assess the potential impacts of the contamination to human health and to the environment. The quality and sufficiency of the existing data are assessed in Section 8.0. This information is also used to identify applicable or relevant and appropriate requirements (ARARs) (Section 6.0). Contaminant information is assessed in Section 7.0 to provide a basis for selecting technologies that can be implemented at the site.

Contaminants that are released into the environment at a waste management unit or unplanned release site may migrate from the point of release into other types of media. The potentially affected media in the 200 East Groundwater Aggregate Area include vadose zone soil, vadose zone moisture, vadose zone vapor, perched groundwater, perched zone soils, groundwater, aquifer materials, potable water supplies, surface water, sediment, surface soil, and vegetation. While the focus of this evaluation is groundwater quality, other media are included that potentially affect or contribute to groundwater contamination. The media that are affected at a specific site will depend upon the quantities, chemical and physical properties of the material that was released, and the subsequent contaminant migration history.

4.1 KNOWN AND SUSPECTED CONTAMINATION

Contaminants are identified in the groundwater underlying the 200 East Groundwater Aggregate Area. This section presents the nature and extent of groundwater contaminants, probable sources of these contaminants, and potential future migration. Section 4.1.1 discusses the areal distribution of each contaminant plume and identifies waste management units and other facilities the plume underlies. The intent is to identify those areas that may potentially contribute to the underlying and nearby groundwater contamination. Other potential upgradient historical source areas may have contributed to existing plumes, but need to be further evaluated with regard to historical groundwater flow conditions. Waste inventories associated with 200 East Groundwater Aggregate Area facilities are discussed in Section 2.0.

4.1.1 Results of Groundwater Quality Monitoring

The distribution of elevated chemical compounds in the groundwater at the 200 East Groundwater Aggregate Area is evaluated by groundwater monitoring. The five groundwater

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quality monitoring programs [Operational Groundwater Monitoring Network (OGWMN), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Pacific Northwest Laboratory (PNL) and Hanford Environmental Health Foundation (HEHF)] currently in operation at the Hanford Site collect the data used to evaluate the distribution of chemical compounds. These monitoring programs evaluate the groundwater quality by sampling selected wells for a variety of chemical compounds. Section 2.8 summarizes the monitoring well network and the chemical compounds analyzed for in each of these monitoring programs. Wells monitored in the network are identified in Tables 2-9, 2-10, 2-24, and 2-25. These tables identify each monitoring well, its screened interval, and the formation being monitored for each program.

Groundwater quality data collected for these monitoring programs are summarized in reports prepared by Connelly et al. (1992a); Last et al. (1991); Evans et al. (1990); DOE/RL (1991a); Serkowski and Jordan (1989); Schmidt et al. (1991); DOE/RL (1991b); Hoover and LeGore (1991); Evans et al. (1989); and Elder et al. (1989).

4.1.1.1 Groundwater Monitoring Data. The bulk of the groundwater quality data reported herein for the 200 East Groundwater Aggregate Area were compiled by Connelly et al. (1992a) from monitoring well samples conducted under the auspices of the five programs identified above between January 1, 1988 and April 1992. Due to a lack of laboratory capacity, chemical data for most chemical compounds and selected radionuclides were not collected between June 1990 and May 1991. Chemical and radionuclide data collected after April 1992 were not available from Westinghouse Hanford Company at the time this report was prepared. Groundwater contaminant plume maps were prepared by Connelly et al. (1992a) using sampling from January 1988 to December 1991 as discussed in Section 4.1.2.3.

Tables 2-9, 2-10, 2-24, and 2-25 identify for each monitoring well the screened interval, the formation that the well is screened, and where information is available whether the well is screened in the confined aquifer (Rattlesnake Ridge aquifer), or semiconfined or unconfined portions of the uppermost aquifer. Information identifying the aquifer screened by the well is not readily available. A detailed evaluation determining the aquifer in which wells are screened in has been started (Ledgerwood 1992). For the purposes of the 200 East Groundwater Aggregate Area Management Study Report, the aquifers in which the wells are screened were determined by comparing the wells' screened interval with available geologic data provided by Lindsey et al. (1992) and Connelly et al. (1992a).

Chemical compounds detected in the groundwater within the 200 East Groundwater Aggregate Area (January 1988 to April 1992) are listed on Table 4-1. This list was generated from data provided by Westinghouse Hanford and used by Connelly et al. (1992a) by searching the Hanford Site Groundwater Database for all contaminants detected within the

200 East Groundwater Aggregate Area wells from 1988 to 1992. For each constituent listed, this table identifies the well with the maximum average reported concentration and the maximum and minimum concentrations over this time period for that well. The number of detections and the number of samples less than the detection limit for that well are also listed. Table 4-1 also identifies for all monitoring wells the minimum reported detection limit, the total number of analyses conducted, and the total number of wells with detections.

Table 4-2 provides an initial, preliminary comparison of chemical data obtained from the shallow, unconfined portion of the uppermost aquifer system with sampling results from selected deeper nearby wells. The shallow wells are screened in the Hanford formation sands and gravels, and Ringold Formation gravels depending on their location (compare Plate 3 well locations with geologic units identified on Figure 3-47). The deeper wells include those screened in the deep portions of the unconfined aquifer, the semiconfined aquifer (areas where the Ringold unit A gravels are confined or partially confined by the Ringold lower mud sequence), and the uppermost confined aquifer (Rattlesnake Ridge aquifer). Deep and shallow wells compared in the text for groundwater contamination in a specific geographic area are grouped together on the table. The deeper wells were selected based on the availability of chemical information, spatial distribution across the area, reliability of well construction data, and proximity to shallow wells for comparison. Table 4-2 does not include an exhaustive list of all deep wells for which chemical data exists, nor additional shallow wells more distant from the deeper well locations. Additional detailed assessment of the vertical distribution of groundwater contamination will be completed on an area-specific or contaminant-specific basis as part of on-going and future groundwater assessment programs described in Chapter 8.0.

The criteria used to evaluate the groundwater quality data collected by the groundwater monitoring programs are based on maximum contaminant levels (MCLs) established by the U.S. Environmental Protection Agency (EPA) under the Safe Drinking Water Act; 4% of the derived concentration guide (DCG) as prescribed by DOE Order 5400.5; Washington State Groundwater Quality Standards (WAC 133-200) and the Washington State Model Toxics Control Act regulations (WAC 173-340). Contaminant plume maps were drawn for all contaminants detected in the 200 East Groundwater Aggregate Area since January 1, 1988 that exceeded at least one of these groundwater quality criteria (Connelly et al. 1992a).

4.1.1.2 Background Concentrations. Hoover and LeGore (1991) developed a program to determine background concentrations of naturally-occurring inorganic chemicals, water quality parameters, and radionuclides and radioactivity parameters. The results of the initial implementation of this program have been published (DOE/RL 1992d) and provide an estimate of baseline ("reasonable upper limit") levels ("provisional threshold values") against which contaminant concentrations can be compared (Table 4-3).

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The method used to determine these background levels included the following:

- Development of a conceptual model describing the geochemical changes which groundwater would undergo from the point of recharge through interactions with the rock and soil matrices

- Physical tests of groundwater-rock interactions using basalt and Ringold Formation sediments under both open- and closed-system conditions

- Development of data quality objectives, review of existing data, selection of a background study subset of wells which meet selection criteria (appropriate hydrostratigraphic regime, uncontaminated, completeness in charge balance, and consideration of well construction)

- Statistical interpretation of these data to check the fit of the data with a normal distribution: in most cases the sample size was too small to allow determination of a 95% confidence limit and the maximum recorded value was used for the provisional threshold value

- Interpretation of the results, revision of the conceptual model (accounting for possible effects from anthropomorphic influences), assessment of limitations, and recommendations for follow-up work.

The study found that the groundwater in the uppermost (unconfined) aquifer is dominantly an open-system regime (i.e., high hydraulic conductivity and susceptible to flushing by recharge waters) with modest basalt rock-water interactions leading to its compositional characteristics. This regime may however be more associated with the portion of the Hanford Site where the background study subset wells are located (mainly along the western and southwestern boundaries of the Hanford Site, near the Rattlesnake Hills) which could differ from the Hanford Site as a whole or the 200 Areas in particular where the study could not be conducted because of the presence of contamination. The study therefore recommends the extension of the study to new wells, both in other portions of the Hanford Site than were studied before as well as using newer construction, sampling, and analysis techniques to reduce the uncertainty of the background estimates and to characterize the processes going on in the aquifer.

4.1.1.3 Basis for Plume Evaluation. Plume maps provided by Connelly et al. (1992a) were developed by averaging detected concentration values at each well for chemical compounds identified in Table 4-1 and identifying those that exceeded groundwater quality criteria. This approach provides a gross indication of the extent of contamination for each constituent and sufficient data for contouring. Some of the plumes have areal extents that are indeterminant because they are essentially based on one well and surrounding well coverage

is inadequate to delineate the plume boundaries. The interpolation of these plume boundaries could be changed markedly with additional data. Plume maps discussed in this text are from Connelly et al. (1992a) and are based on sampling data from January 1988 to December 1991.

Interpretations of the groundwater contaminant plume configurations are dependent on the quality of the data. Limitations associated with the data used to compile contaminant plume maps are as follows:

- Monitoring well construction variations
- Differences in groundwater sampling and analyses procedures and methodologies (e.g., use of bailer rather than submersible pump)
- Monitoring well coverage variations and limitations
- Computer contouring routines and groundwater model interpretations.

These items may result in a change in the interpreted configuration of the plume map. In some cases the estimated areal extent of the plume may either be reduced or increased.

4.1.1.4 Chemical Compound Plume Evaluation. Thirteen individual plumes of chemical compounds were identified in the groundwater of the 200 East Groundwater Aggregate Area. Of these plumes, two (^{137}Cs and $^{239,240}Pu$) are contained within the 200 East Groundwater Aggregate Area fence boundary, and eleven plumes (chromium, nitrate, arsenic, ^{90}Sr, ^{60}Co, cyanide, gross alpha, gross beta, tritium, ^{99}Tc, and ^{129}I) extend beyond the boundary of the 200 East Groundwater Aggregate Area. The extent of the 13 plumes is discussed in this section. Section 4.1.2 discusses the various potential sources for these plumes.

The December 1991 water table elevation table map was used to evaluate the migration patterns of these plumes (Figure 3-49; Kasza et al. 1992). In addition, Connelly et al. (1992a) presented a map modified from Kasza et al. (1991) and Jackson (1992) which compares June 1991 water table elevations with the potentiometric surface of the Rattlesnake Ridge aquifer (Figure 3-70). This map provides a gross evaluation of areas with likely intercommunication where the hydraulic head indicates the potential for significant vertical flow from one aquifer to another.

4.1.1.5 Estimates of Areal Distribution of Contaminant Plumes. Estimates of areal extent for the 13 chemical compounds found at the 200 East Groundwater Aggregate Area were made from contaminant plume maps generated by Connelly et al. (1992a) (Figures 4-1 through 4-15). Additional Hanford site-wide maps of nitrate and tritium distributions are provided from Evans et al. (1990) for comparison (Figures 4-5 and 4-9). As discussed by

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Connelly et al. (1992a), the plumes delineated represent areas which must be addressed when considering the lowest regulatory cleanup levels. In some cases the detection limit is above the lowest regulatory levels; when this occurs, the contour is set at or slightly above the detection limit.

Table 4-4 provides the areal estimates for each plume. For the plume maps generated by Connelly et al. (1992a), a computer interpolated grid of concentration levels was obtained from the authors, and the areas and total mass were obtained by integration of the values. For cyanide and parts of tritium, nitrate, and ^{129}I plumes where only a graphical representation (map) was available, estimates of area were obtained by graphically measuring the plume on the map, and masses were estimated from the area and the average concentration within the plume. As discussed in Section 4.1.1.3, the areal distributions of plumes with limited well coverage were calculated by interpolating the chemical data between monitoring wells, based on the computer-generated contours. These areas include plumes defined by a positive detection in a single well and nondetections in adjacent wells. This calculation therefore represents an estimate of the actual extent of the plumes, and provides for a consistent basis for analysis. Multiple plumes or plumes with complex geometries are divided in the discussion by individual plumes or lobes.

4.1.1.6 Vertical Extent of Contamination. Limited data are available regarding the vertical extent of chemical and radionuclide contamination (Last et al. 1991; Connelly et al. 1992a). Three studies that evaluated the vertical extent are Eddy et al. (1978), Jensen (1987) and Graham et al. (1984). In 1976 Eddy et al. investigated the vertical extent of selected radionuclides in the uppermost aquifer. The bulk of this study was conducted southeast of the 200 East Groundwater Aggregate Area on selected 600 Area wells. Eddy et al. (1978) conclude that some contamination in the lower portion of the uppermost aquifer had occurred; however, concentrations of individual constituents appeared higher near the water table. Samples collected from Monitoring Well 699-31-31 contained concentrations of ^{106}Rb, tritium, and ^{60}Co at depths of up to 182 m (597 ft).

Jensen (1987) evaluated the intercommunication between the uppermost aquifer and Rattlesnake Ridge aquifer. The objective for Jensen's study was to determine the extent of intercommunication between the uppermost aquifer and the uppermost regionally extensive confined aquifer (Rattlesnake Ridge aquifer). Hydraulic head data collected during December 1986 was evaluated as part of this study. As discussed in Section 4.1.1.3, the extent of vertical plume migration was assessed by comparing water table elevations with the potentiometric surface of the Rattlesnake Ridge aquifer. The assessment included review of data reported by Connelly et al. (1992a), Kasza et al. (1991), and Jackson (1992). In addition, hydraulic intercommunication was discussed by Jensen (1987) and Graham et al. (1984). Jensen (1987) also compiled a map which compares the water table elevation with the potentiometric surface of the Rattlesnake Ridge aquifer. Data used to generate the water table and potentiometric surface were collected in December 1986. This map indicates that a

downward vertical gradient existed at that time over most of the 200 East Area and in the B Pond area. This downward gradient may have permitted contaminated waters within the uppermost aquifer system to discharge into the Rattlesnake Ridge aquifer.

Graham et al. (1984) also conducted an assessment of the intercommunication of the uppermost aquifer and Rattlesnake Ridge aquifer in the areas of the B Pond and Gable Mountain Pond. They evaluated the areas where the Elephant Mountain Basalt was eroded and estimated the potential for aquifer intercommunication based on groundwater chemistry and barometric pressure efficiencies. Graham et al. (1984) identified a downward gradient from the uppermost aquifer system to the Rattlesnake Ridge aquifer in the vicinities of Gable Mountain and the B Pond complex. In addition, they identified an area south and east of Gable Mountain Pond where groundwater chemical data indicated that aquifer intercommunication had occurred. They concluded that downward flow from the uppermost aquifer had probably occurred in the late 1960's and late 1970's when groundwater levels in the area were much higher. This downward flow apparently resulted in low levels of tritium and ^{129}I in the Rattlesnake Ridge aquifer in this area.

For each of the 13 contaminant plumes being evaluated, a nominal value of 10 m (33 ft) was chosen for the vertical extent of dissolved chemical constituents in the groundwater (Evans et al. 1990; Connelly et al. 1992a; and Last et al. 1991). Table 4-4 provides volume estimates for the quantity of contaminated water by each of the chemical compounds, based on this nominal thickness. Although this 10 m thickness does not account for the chemical constituents identified at greater depths, nor areas where the saturated aquifer may be thinner, this depth was selected to provide a preliminary estimate for the potential volume of the compound in the groundwater. Further characterization of the vertical extent of chemical constituents will be required to refine this thickness estimate, as discussed below.

4.1.1.7 Plumes of Chemical and Radionuclide Constituents. Thirteen chemical constituent plumes are presented for this investigation. The areal distribution and migration patterns of these plumes are discussed separately below.

It should be noted that the posted values on the plume maps (Figures 4-1 through 4-15) are based on a slightly earlier data set (January 1988 to December 1991) than the data in the tables and which are also used in the text (January 1988 to April 1992). The text therefore uses the most up-to-date information available; however, a check of the differences indicates that the overall plume distributions shown in the figures are still reasonably accurate.

4.1.1.7.1 Arsenic. Four distinct plumes of arsenic (plumes A, B, C, and D) were identified in the 200 East Area (Figure 4-1) based on analytical results of filtered samples. These plumes of dissolved arsenic cover a combined area of approximately 740,000 m^2 (7,900,000 ft^2) for concentrations equal to or greater than 10 μg/L. This bounding contour of 10 μg/L does not quite meet the potential MTCA criteria at 5 μg/L due to detection limits

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for the data set, but is below the MCL of 50 μg/L. In addition, the background concentration of arsenic at Hanford is reported by DOE/RL (1992) at 10 μg/L (Table 4-3). Therefore, some relatively low concentrations of arsenic for the plumes reported below may reflect levels at natural background levels (see Section 4.1.2.2.1).

Table 4-4 provides the areal distribution for plumes A, B, C, and D. Concentrations of arsenic range from below the detection limit (5 μg/L) to 56 μg/L (Monitoring Well 299-E25-17). Dissolved arsenic (filtered) ranges only up to 34 μg/L. Except for the one unfiltered sample, the MCL of 50 μg/L was not exceeded in the 200 East Area.

The highest average concentration of arsenic was found in plume C. This plume is located beneath the 216-A-6, 216-A-30, 216-A-37-1, 216-A-37-2, and 216-A-42 Cribs in the southern part of the PUREX Plant Aggregate Area. Seventeen wells were used to roughly define the areal extent of this plume, although control on the southeast side of the plume is poor because of inadequate well coverage. The water table elevation map (Figure 3-49) indicates that groundwater flow is predominantly toward the south.

Plume A is the northernmost plume. It is located beneath the northeastern corner of the 216-B-3 Pond. This plume is defined by one high concentration value of 13 μg/L. Six wells were used to delimit the areal distribution of plume A. This plume is associated with the groundwater mound located beneath the 216-B-3 Pond and, therefore, the plume should spread radially with the predominant direction of groundwater flow beneath the plume toward the northwest.

One higher concentration value of 10.4 μg/L dominates plume B (Figure 4-1). This plume is located west of the 216-B-3 Pond. Data were insufficient to define the shape and orientation of this plume. The water table elevation map (Figure 3-49) indicates a westerly flow for this plume.

Plume D (Figure 4-1) is defined by two wells which have yielded concentrations of 16.8 μg/L and 10.4 μg/L. Plume D is located in the southern part of the B Plant Aggregate Area just west of the 2101-M Building. Data were insufficient to define the shape and orientation of this plume. The water table elevation map indicates a southeasterly flow for this plume.

The mass of arsenic in groundwater within the 10 ppb contour line is estimated at approximately 22.8 kg (50 lb). This estimate is based on a vertical extent of 10 m (33 ft), a porosity of 0.2, and the computer interpolation of well averages.

An evaluation of the vertical extent of arsenic indicates that low levels of arsenic are found in the groundwater within the deep, unconfined and semiconfined portions of the uppermost aquifer and the confined aquifer. These arsenic concentrations ranged from 2.3 to

31 μg/L, below the MCL for arsenic. Table 4-2 lists arsenic concentrations for wells screened in different aquifers. The horizontal and vertical extent of arsenic concentrations in the deeper aquifers was not identified during this evaluation.

Arsenic concentrations measured in the deeper aquifers correspond to those areas where the uppermost aquifer is in hydraulic communication with the deeper aquifers. This occurs where the confining unit separating the uppermost aquifer from these deeper aquifers is absent. A vertical downward gradient appears to exist between the uppermost aquifer and the deeper aquifers within or adjacent to these areas.

Below unconfined portions of the uppermost aquifer, the highest average arsenic concentrations were measured in Well 299-E16-2 (31 μg/L), a well screened in the semiconfined portion of the uppermost aquifer. This well is located beneath Plume C, southwest of the 216-B-3 Pond System and southeast of Well 299-E25-17, the well with the maximum average arsenic concentrations (56 μg/L) (Table 4-1). Wells 299-E25-23 and 299-E25-24 are adjacent to Well 299-E16-2 and are screened within the shallow, unconfined portion of the uppermost aquifer. These wells had average arsenic concentrations of 17 to 24 μg/L.

Stratigraphic units within the semiconfined portion of the aquifer in this area have a southerly dip. North of this area the Hanford formation unconformably overlies the Ringold Formation. The Ringold Formation lower mud sequence, which creates the confining layer, is absent in this area. A vertical downward gradient is present in this area as evidenced by comparing the groundwater levels from the unconfined and semiconfined portions of the uppermost aquifer. Dissolved arsenic found in the unconfined portion of the aquifer would have the potential to migrate downward into the semiconfined portion in this area.

Arsenic concentrations were averaged for Well 699-42-40B at 5 μg/L. This well is screened in the semiconfined portion of the uppermost aquifer. This well is located immediately adjacent to the 216-B-3 Pond System in the area beneath plume B. Mounded groundwater present in the area may be providing a downward gradient, which has permitted dissolved arsenic to enter the semiconfined system.

One well, Well 699-47-50, screened in the Rattlesnake Ridge confined aquifer contained arsenic concentrations at 2.7 μg/L. This well is located just north of the area where a portion of the confining layer, the Elephant Mountain Basalt has been eroded. Thus, dissolved arsenic has the potential to migrate to the confined aquifer in this area. The horizontal hydraulic gradient in this area is toward the west.

Well 299-E33-40 contained low levels of arsenic (2.3 μg/L). This well is located at the northwestern end of the 200 East Area. The well is screened within the Rattlesnake

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Ridge aquifer. Improper well construction may have permitted the vertical migration of arsenic from the uppermost aquifer to this greater depth.

4.1.1.7.2 Chromium. Three areas of elevated concentrations of dissolved (filtered) chromium within the 200 East Area were identified as plumes A, B, and C (Figure 4-2). These plumes are distributed over an area of 120,000 m^2 (1,300,000 ft^2), based on chromium concentrations greater than or equal to the MCL of 50 μg/L. The contoured data on Figure 4-2 represent dissolved chromium concentrations based on analytical results of filtered samples. Results of unfiltered samples are not presented because they also reflect concentrations present in any suspended sediment and such values, therefore, are considered less representative. The reported background concentration for chromium in Hanford Site groundwater is reported to be below a detection limit of 30 μg/L (Table 4-3). The maximum average concentration in groundwater for unfiltered (total) chromium was 395 μg/L in Monitoring Well 699-40-40B and for filtered chromium was 65 μg/L in Well 299-E24-19 (Table 4-1). Well 699-40-40B is located at the south end of the 216-B-3 Pond System, and Well 299-E24-19 is located just south of the 241-A Tank Farm within plume C. Some of the elevated chromium levels may be contributed in past from chromium present in stainless steel used in newer wells, such as Well 699-40-40B although the effect is expected to be relatively minor compared to other potential sources.

Plume A is located in the B Plant Aggregate Area northwest of the 216-B-35 through -42 Cribs. The highest chromium concentration measured for plume A is 12 μg/L, which is below the MCL value of 50 μg/L. Plume A is defined by only one well, Well 299-E33-30. The water table elevation map (Figure 3-49) indicates a northerly flow for this plume.

Plume B lies beneath the southwest side of the 241-BX Tank Farm and the southeast side of the 216-B-35 through -42 Cribs. The highest average concentration measured for plume B is 51.2 μg/L from Well 299-E33-32. The shape and areal extent of plume B is poorly constrained. The water table elevation map indicates a northwesterly flow for this plume.

Plume C lies beneath the 241-A Tank Farm. The highest concentration measured for this plume is 65 μg/L from Well 299-E24-19. The shape and areal extent of plume C is poorly constrained. Groundwater flow in this area is uncertain as the plume is located near a groundwater divide. Flow is generally in a westerly direction with a probable southwesterly component according to the water table elevation map. Because of the plume's proximity to the groundwater divide, it may have a northwest component to its flow.

The mass of chromium in the 200 East Area is estimated at 13.5 kg (30 lb) (Table 4-4). This mass is based on the total areal distribution of the plumes as interpolated for the contour lines, a 10 m (33 ft) vertical extent, and a porosity of 20%.

Analytical data for dissolved chromium are relatively sparse for the deep, unconfined and semiconfined portions of the uppermost aquifers and the Rattlesnake Ridge aquifer (Table 2-2). Chromium concentrations detected within the deep unconfined portion of the uppermost aquifer ranges from below detection limits to 12.7 μg/L in well 299-E25-25. For the Rattlesnake Ridge aquifer, chromium concentrations are 9.80 and 20.8 for wells 699-49-578B and 699-49-55A, respectively. These concentrations generally are comparable to concentrations present in the shallow, unconfined portion of the uppermost aquifers which range from below detection limits to 26.4 μg/L.

The highest concentration of chromium identified in the deeper aquifers was measured in the semiconfined portion of the aquifer (Well 699-43-41E) near the 216-B-3 Pond. In this area, a downward gradient exists from the unconfined portion of the aquifer.

Chromium concentrations identified in the Rattlesnake Ridge aquifer ranged from 73.1 to 86.1 μg/L. These concentrations were measured in wells located north of the northwest end of the 200 East Area (Wells 699-47-50, 699-49-55b, 699-49-57B and 699-50-53). The head differential between the uppermost aquifer system and the Rattlesnake Ridge aquifer in this area is nearly equivalent, but with a slight upward gradient in places. This area is also characterized by an erosional window in the basalt that likely results in intercommunication between the Rattlesnake Ridge aquifer and the uppermost aquifer. The potentiometric surface in this area slopes toward the northwest and ultimately discharges into the West Lake area, where the Rattlesnake Ridge confined aquifer is absent.

One deep unconfined well (299-E25-25) contained detectable concentrations of chromium (30.5 μg/L). This well is located southwest of 216-B-3 Pond.

Well 299-E33-40 is screened within the Rattlesnake Ridge aquifer. Chromium concentrations in this well ranged up to 39 μg/L. This well was drilled across multiple aquifers, and it is possible that chromium may have entered the well during its construction or during the construction of nearby Well 299-E33-12 (Connelly et al. 1992a). However, recent increases in the concentration of chromium are not easily explained by this potential transport pathway.

The vertical extent of chromium in the various aquifers at the site has not been fully characterized. Additional characterization will be required in this area to better evaluate the distribution of chromium at the site.

4.1.1.7.3 Cyanide. One cyanide plume is present beneath the 200 East Area (Figure 4-3). The plume has an areal extent of 850,000 m^2 (9,200,000 ft^2) (Table 4-4). The highest average concentration of cyanide in this plume is 869 μg/L from Well 699-50-53A, which is the only well within the plume above the 200 μg/L (MCL) concentration. Groundwater flow in this area is toward the northwest.

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The mass of cyanide in the 200 East Area is estimated at 985 kg (2,170 lb) (Table 4-4). This mass is based on the total areal distribution of the plume as interpolated from the contour lines, a 10 m (33 ft) vertical extent, and a porosity of 20%.

The vertical extent of cyanide was evaluated by reviewing wells screened in the deep unconfined and semiconfined portions of the uppermost aquifer and in the Rattlesnake Ridge confined aquifer wells for the presence of cyanide. None of the wells had cyanide concentrations above the detection limit. Table 4-2 identifies the wells that were evaluated.

4.1.1.7.4 Nitrate. Elevated nitrate concentrations are widespread across the 200 East Area. Five plumes were delineated (plumes A, B, C, D, and E) (Figure 4-4). The areal distribution of nitrate for concentrations greater than or equal to the MCL of 45,000 μg/L (as nitrate) is estimated at 2,100,000 m^2 (23,000,000 ft^2). The maximum sample concentration of nitrate identified within the 200 East Area is 503,000 μg/L from Well 699-50-53A. The reported background concentration of nitrate for Hanford Site groundwater is 12,400 μg/L (Table 4-3). The concentrations of nitrate detected to the west of the 200 East Area are attributed to migration from the 200 West Area, as indicated in the 200 West AAMSR.

Plume A is located northeast of the 216-A-25 Pond. The highest average concentration of nitrate for this plume is 492,000 μg/L from Well 699-54-48. The shape and areal extent of this plume is poorly constrained due to a lack of wells. The water table elevation map (Figure 3-49) indicates that this plume is moving in a northwesterly direction.

Plume B is located north of the B Plant Aggregate Area. This plume contains Well 699-50-53A which has the highest average nitrate concentration of the 200 East Area wells with a concentration of 503,000 μg/L. The horizontal extent of this plume is not tightly constrained due to a lack of well coverage in this area. The water table elevation map indicates that this plume may be radially spread and flow in a generally northwest direction.

Plume C is located beneath the 241-AN, 241-AX, and 241-AY Tank Farms and the 216-A-10 Crib and 216-A-18 Trench. The highest average concentration in this plume is 142,000 μg/L for Well 299-E25-13. The southern extent of this plume is constrained by three wells, but the northern extent of the plume is poorly constrained. The 1990 groundwater map indicates that groundwater flow is toward the west in the vicinity of this plume.

Plume D is located in the southern portion of the PUREX Plant Aggregate Area beneath the 216-A-6, 216-A-30, 216-A-37-1, and 216-A-37-2 Cribs. The highest concentration of nitrate in plume D is 150,000 μg/L from Well 299-E25-20. Groundwater flow in plume D is toward the south.

Plume E is located in the PUREX Plant Aggregate Area beneath the 216-A-10, 216-A-36A, 216-A-36B, and 216-A-45 Cribs. A concentration of 244,000 μg/L is the maximum concentration for this plume. The areal extent of the plume is reasonably well constrained by four wells outside the plume's perimeter. The groundwater indicates that groundwater movement in this plume is toward the southeast.

Figure 4-5 shows the distribution of nitrate on the Hanford Site for 1989. This map shows a large plume is approaching the 200 East Area from the west. This northerly flow reflects groundwater flow in the vicinity of the 200 East Area, as some nitrate has moved from the 200 East Area toward the northwest and some has moved toward the southeast.

According to Thornton (1992), nitrate discharges associated with waste effluent appear to have significantly disturbed local reduction/oxidation (redox) conditions in the uppermost aquifer. The addition of large amounts of nitrate has resulted in the increased oxidation potential of the system. As a result, constituents that are more mobile under oxidizing conditions will be dissolved in the groundwater. Uranium and hexavalent chromium are examples of these constituents.

The mass of dissolved nitrate in the groundwater in the vicinity of the 200 East Area is estimated at 740,000 kg (1,630,000 lb). This estimate is based on computer integration of the distribution, a vertical extent of 10 m (33 ft), a porosity of 20%, and graphical adjustment for some portions of the plume (mainly from the 200 West Area).

The vertical extent of nitrate was evaluated by reviewing wells screened in the deep unconfined and semiconfined portions of the uppermost aquifer and in the Rattlesnake Ridge confined aquifer for the presence of nitrate. Table 4-2 provides a comparison of nitrate concentrations for these wells.

Chemical data from four wells screened in the deep, unconfined portion of the uppermost aquifer (299-E24-1, 299-E24-4, 299-E25-25 and 299-E26-5) were examined and compared for nitrate. These wells are located west to southwest of the B Pond complex. Average nitrate concentrations in these wells ranged from 756 to 155,000 μg/L.

Nitrate concentrations were examined in nine wells screened within the semiconfined portion of the uppermost aquifer (Table 4-2). Average nitrate concentrations in these wells ranged from 1,980 to 124,000 μg/L, which exceed the 45,000 μg/L MCL for nitrate. These wells are located west to southwest of the 216-B-3 Pond, within the general area of plumes C and D.

Two wells (699-47-50 and 699-52-46A) screened within the Rattlesnake Ridge confined aquifer contained average nitrate concentrations ranging from 3,560 to 6,470 μg/L. These wells are located north of the 200 East Area fence.

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A comparison of the Rattlesnake Ridge aquifer potentiometric surface and the uppermost aquifer water table indicates that the difference in hydraulic head is nearly zero. This suggests that presently vertical flow between aquifer is minor. During periods of a higher groundwater table, dissolved nitrate may have migrated downward into the Rattlesnake Ridge aquifer. This is supported by the presence of nitrates in the confined aquifer.

Elevated average concentrations of nitrate were identified in three wells (299-E17-6, 699-28-40 and 699-32-62) that may be completed across multiple aquifer zones. These wells pose a potential source for the vertical migration of chemical constituents.

4.1.1.7.5 Gross Alpha. Gross alpha measurements detected in the groundwater can be attributed to the presence of uranium and other high atomic number radionuclides such as plutonium and americium. Gross alpha analyses are run as a screening method for these isotopes. If elevated activity of gross alpha is measured, a more specific analysis can be conducted to identify the source for the gross alpha activity. Not all gross alpha contamination can be accounted for by specific radioisotopes due to the varying sensitivities of the analyses to specific radionuclides.

The gross alpha detections in the 200 East Area were divided into four plumes, plumes A, B, C and D (Figure 4-6). The areal extent of these plumes is estimated at 660,000 m^2 (7,100,000 ft^2) (Table 4-4) and is based on gross alpha concentrations greater than the MCL of 15 pCi/L. The reported background level of gross alpha for Hanford Site groundwater is 63 pCi/L although it may be only 5.79 pCi/L (Table 4-3).

Plume A is defined by one well, Well 699-55-57, and is located just east of the 200 North Aggregate Area. Because of poor well coverage in this area, this plume is poorly constrained. Groundwater flow in this area is toward the northwest.

Plume B is defined by one well, Well 699-52-54, and is located southeast of the 200 North Aggregate Area. Three wells, located north, west, and south of Well 699-52-54, indicate that this plume is not extensive. Groundwater flow in this area is toward the northwest.

Plume C is located beneath the 216-B-43 through -50 Cribs in the B Plant Aggregate Area. The highest average concentration in the plume is 30 pCi/L from Well 299-E33-7. The southern extent of the plume is fairly well constrained by eight wells, but the northern shape and extent of the plume is poorly constrained due to a lack of wells. The water table elevation map indicates that groundwater flow is toward the north in the vicinity of plume A.

Plume D is located beneath the 216-B-5 Reverse Well. Well 299-E28-24 has an average maximum concentration of 166 pCi/L and defines this plume. Groundwater movement at this location is toward the northwest according to the water table elevation map.

The activity of gross alpha was estimated at 0.03 Ci (Table 4-4). This estimate is based on the computer interpolated grid values; a 10 m (33 ft) vertical extent, and a porosity of 20%.

The vertical extent of gross alpha was evaluated by reviewing wells screened in the deep, unconfined and semiconfined portions of the uppermost aquifer and in the Rattlesnake Ridge confined aquifer for the presence of gross alpha. Table 4-2 identifies the wells that were evaluated. Gross alpha concentrations were identified in three wells screened in the deep, unconfined portion of the uppermost aquifer, eight wells in the semiconfined portions, and eleven wells in the Rattlesnake Ridge confined aquifer. In addition, six wells were identified that are possibly screened across more than one aquifer.

Wells identified in the deep, unconfined portion of the uppermost aquifer (Wells 299-E24-1, 299-E24-4, and 299-E25-25) had average gross alpha concentrations that ranged from 0.73 to 3.97 pCi/L. These wells are located in the southeast end of the 200 East Area.

Wells screened in the semiconfined portion of the uppermost aquifer had average gross alpha concentrations that ranged from 0.81 to 6.09 pCi/L (Table 4-2). These wells are located on the eastern half of 200 East Area and did not appear to correspond to the gross alpha plumes identified in the shallow, unconfined portion of the aquifer.

The eleven wells screened in the Rattlesnake Ridge confined aquifer had average gross alpha concentrations that ranged from 0.34 to 29.2 pCi/L, which exceeded the MCL for gross alpha. These wells are located in the area of plumes C and D, and in the areas across the 200 East Area where a downward vertical gradient from the unconfined aquifer was identified by Jensen (1987).

Six wells were identified as being screened across more than one aquifer. Average gross alpha concentrations ranging from 1.38 to 6.40 pCi/L were identified in these wells. These wells may create vertical conduits for contaminants to reach deeper aquifers.

4.1.1.7.6 Gross Beta. Gross beta levels can commonly be attributed to the presence of one or more of the following radionuclides in the groundwater: ^{60}Co, ^{90}Sr, ^{99}Tc, ^{106}Ru, ^{125}Sb, ^{137}Cs, ^{234}Th, ^{234}Pa, and ^{129}I. In most cases the gross beta activity in the 200 East Groundwater Aggregate Area plumes is derived from ^{99}Tc activity. Beta measurements are used as a screening tool, and if activity is identified, then a more specific analysis can be conducted to identify the sources. As discussed for gross alpha contamination in

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Section 4.1.1.6.5, not all gross beta contamination can be accounted for by specific radioisotopes due to varying sensitivities of the analyses to specific radionuclides.

The gross beta plume detections in the 200 East Groundwater Aggregate Area formed essentially six plumes, plumes A, B, C, D, E, and F (Figure 4-7). The combined areal extent of these plumes is 1,000,000 m^2 (10,800,000 ft^2). Gross beta levels used to define the areal extent of these plumes range from greater than or equal to 50 pCi/L to 2,760 pCi/L. The reported background concentration of gross beta for Hanford Site groundwater is 35.5 pCi/L (Table 4-3).

Plume A is the northernmost plume and is located in part beneath the 200 North Area. Well 699-55-57 defines this plume and has an average gross beta concentration of 890 pCi/L. The areal extent and shape of plume A is loosely constrained by wells to the east and north and poorly constrained due to a lack of wells to the south and west. Groundwater in the plume A area is flowing in a northerly direction according to the water table elevation map.

Plume B is located north of the 200 East Area beneath the 216-A-25 Pond and just north of an area where basalt extends above the water table. The highest average gross beta concentration in plume B is 558 pCi/L. Plume B is defined by five wells. The water table elevation map indicates a semiradial flow for groundwater from the 216-A-25 Pond to the east through northwest. As groundwater flows away from the 216-A-25 Pond, it is directed either towards the northwest or east.

Plume C extends to the north from the 200 East Area fence and lies beneath the 216-B-25 through -50 Cribs. Plume C has a maximum average concentration as high as 2,760 pCi/L from Well 699-50-53A. The plume is fairly well constrained by 24 wells. Groundwater flow in the plume C area is generally toward the northwest.

Plume D is located in the B Plant Aggregate Area beneath the 216-B-5 Reverse Well and the 216-B-9 Crib and Tile Field. The D plume is defined by the highest concentration of gross beta in the 200 East Groundwater Aggregate Area, 10,254 pCi/L from Well 299-E28-23. The water table elevation map indicates that groundwater flow in this plume is toward the northwest.

Plume E is located in the PUREX Plant Aggregate Area beneath the 216-A-10, 216-A-36, and 216-A-45 Cribs. The highest concentration in this plume is 937 pCi/L from Well 299-E17-15. Fourteen wells constrain the shape and areal extent of this plume. Groundwater flow in the plume E area is toward the southeast.

Plume F is located in the southern part of the B Plant Aggregate Area beneath the 216-B-20 through -36 Cribs. This plume is defined by one well, Well 299-E13-14. The

concentration in this well is 100 pCi/L. Groundwater flow in the plume F area is toward the east according to the water table elevation map.

The activity of gross beta is estimated at 5.2 Ci (Table 4-4). This estimate is based on the computer-interpolated grid values, a vertical extent of 10 m (33 ft), and a porosity range of 20%.

The vertical extent of gross beta was evaluated by reviewing wells screened in the deep, unconfined and semiconfined portions of the uppermost aquifer and wells in the Rattlesnake Ridge aquifer for the presence of gross beta. Table 4-2 identifies the wells that were evaluated. Gross beta concentrations were identified in three wells within the deep, unconfined portion of the uppermost aquifer, deeper uppermost unconfined wells, nine wells in the semiconfined portion, and thirteen wells in the Rattlesnake Ridge confined aquifer. In addition, six wells were identified that may be screened across more than one aquifer.

Wells identified in the deep, portion of the uppermost unconfined aquifer (Wells 299-E24-1, 299-E24-4, and 299-E25-25) had average gross beta concentrations that ranged from 5.2 to 44.6 pCi/L. These wells are located in the southeast end of the 200 East Area.

Wells screened in the semiconfined portion of the uppermost aquifer had gross beta concentrations that ranged from 4.39 to 148 pCi/L (Table 4-2). These wells are located on the central and eastern half of the 200 East Area. The highest concentration was identified in Well 299-E28-7, located southeast of the 216-B-5 Reverse Well. The 216-B-5 Reverse Well released liquid waste directly to the water table of the uppermost aquifer.

The thirteen wells screened in the Rattlesnake Ridge confined aquifer had gross beta concentrations that ranged from 6.1 to 287 pCi/L, which exceeds the MCL for gross beta. These wells are located in the area of plumes A and B, and in the areas across the 200 East Area where a downward vertical gradient from the uppermost unconfined aquifer was identified.

The highest average gross beta concentration in wells screened within the confined aquifer was measured in Well 299-E33-12. The maximum average concentration for this well is 286.9 pCi/L (Table 4-2). This maximum concentration is higher than gross beta concentrations in adjacent unconfined aquifer wells. Well 299-E33-12 was initially drilled across multiple aquifers, but has since been selectively sealed so that only the lower screened interval is being monitored. Connelly et al. (1992a) describe Well 299-E33-12 as having been drilled in the mid-1950's and having not been completed until 1982. The well created a hydraulic connection between the uppermost aquifer and the Rattlesnake Ridge aquifer. Dissolved contaminants in the uppermost aquifer were able to enter the deeper aquifer. A map comparing the vertical hydraulic gradient between the uppermost aquifer and the Rattlesnake Ridge aquifer was prepared by Jensen (1987) based on December 1986 data.

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This map indicates that within the area of this well a downward vertical gradient was present.

Connelly et al. (1992a) indicate that high-density salt waste discharged from the BY cribs may have migrated along the annular space of the well and entered the deeper aquifer. Elevated beta concentrations measured in this well may be due to this well being improperly sealed or from contamination that entered the confined aquifer during the time the well remained incomplete.

Six wells were identified as potentially being screened across more than one aquifer. Average gross beta concentrations that ranged from 7.88 to 33.2 pCi/L were identified in these wells. These wells require additional evaluation to ensure that they are not contributing to the vertical migration of chemical constituents.

4.1.1.7.7 Tritium. Elevated tritium concentrations have been observed in the groundwater in three plumes (above the MCL of 20,000 pCi/L) in the 200 East Area (Figure 4-8). The area covered by these plumes is 42,000,000 m^2 (452,000,000 ft^2). The highest tritium concentration is 4,270,000 pCi/L.

Plume A is located just north of the 216-B-3 Pond. This plume is defined by only two wells. Groundwater in this area is moving toward the northwest.

Plume B is located beneath the 216-B-3 Pond System. Like plume A, this plume contains two wells. Groundwater beneath this plume is moving toward the north.

Plume C covers a large area of elevated tritium concentrations extending from the western boundary of the 200 East Groundwater Aggregate Area across the central portion of the area to the southeast boundary (Figure 4-8). Four areas of higher concentrations (identified as C_1, C_2, C_3, and C_4 for this discussion) are contained within this plume. Plume C_1 has its highest concentrations beneath the 216-A-10, 216-A-36B, and 216-A-45 Cribs. The 4,270,000 pCi/L for Well 299-E24-11 is the highest tritium concentration in the 200 East Area. Groundwater movement beneath the 200 East Groundwater Aggregate Area is reflected in the shape of the C plume. The water table elevation map indicates groundwater is flowing toward the northeast in the C_2 plume area. The C_2 plume emanates from the 200 West Area, as indicated in the 200 West Groundwater AAMSR. The groundwater in the C_1 plume area is located along a groundwater divide. The water table elevation maps indicate that flow is mainly toward the southeast, but there may be some flow toward the northwest. The C_3 portion, as occurs for C_1, is located near a groundwater flow divide, although flow appears to occur to the southeast. The C_4 portion of the C plume extends toward the southeast and east beyond the area of Figure 4-8, and reaches the Columbia River, as shown

on Figure 4-9. The source of tritium in the C_4 plume is presumably from groundwater flow from the southeastern part of the 200 East Area. The area used to calculate the activity of plume C is approximately that which is included on Figure 4-8. Portions extending beyond the figure are excluded.

Figure 4-9 shows the distribution of tritium on the Hanford Site for 1989. This map shows a large plume approaching the 200 East Area from the west and also suggests that tritium has moved from the 200 East Area to the southeast. The source of tritium to the northwest of the 200 East Area probably is the result of northwesterly movement of groundwater in the northern portion of the 200 East Area.

The total activity of tritium present in the groundwater plumes in the 200 East Area is estimated at 16,400 Ci (Table 4-4). This estimate is based on the computer-interpolation of the plumes, graphical adjustments for some portions, an assumed 10 m (33 ft) depth, the computer-interpolation on a grid and a porosity of 20%.

The vertical extent of tritium was evaluated by reviewing wells screened in the deep, unconfined and semiconfined portions of the uppermost aquifer and wells in the Rattlesnake Ridge confined aquifer for the presence of tritium. Table 4-2 identifies the wells that were evaluated. Tritium concentrations were identified in three wells screened in the deep, unconfined portion of the uppermost unconfined aquifer, ten wells in the semiconfined position, and five wells in the Rattlesnake Ridge confined aquifer. In addition, three wells were identified that may be screened across more than one aquifer.

Wells identified in the deep unconfined portion of the uppermost aquifer (Wells 299-E24-1, 299-E24-4, and 299-E25-25) had average tritium concentrations that ranged from 300 to 3,710,000 pCi/L. These wells are located in the southeast end of the 200 East Area.

Wells screened in the semiconfined portion of the uppermost aquifer had average tritium concentrations that ranged from 170 to 4,270,000 pCi/L (Table 4-2). These wells are located on the eastern half of the 200 East Area and appear to correspond to the tritium plumes identified in the uppermost unconfined aquifer. Well 299-E24-11 had the highest average tritium concentrations. This well is located in the southeast quadrant of the 200 East Area, the area where the highest concentrations were measured in the uppermost unconfined aquifer.

The five wells screened in the Rattlesnake Ridge confined aquifer had average tritium concentrations that ranged from 146 to 2,610 pCi/L. These wells are located in the area of the tritium plume, and in the areas across the 200 East Area where a downward vertical gradient from the unconfined aquifer has been identified.

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Three wells were identified as potentially being screened across more than one aquifer. Average tritium concentrations ranging from 2,380 to 30,700 pCi/L were identified in these wells. These wells potentially create vertical conduits for contaminants to reach deeper aquifers. Well 299-E17-6 had the highest average tritium concentration for these wells.

4.1.1.7.8 Cobalt-60. One ^{60}Co plume is present beneath the 200 East Area (Figure 4-10). The plume of ^{60}Co greater than 100 pCi/L has an areal extent of 751,000 m^2 (8,100,000 ft^2). The 699-50-53A Well has a concentration of 474 pCi/L. The 4% Derived Concentration Guide (DCG) for ^{60}Co is j200 pCi/L. Groundwater flow in the plume is toward the northwest to north. No waste management units are located above this plume, so this plume presumably migrated to its present area from the south. The closest waste management units are the 216-B-43 through -50 Cribs.

The activity of ^{60}Co is estimated at 0.43 Ci (Table 4-4). This estimate is based on computer-interpolation of well values to a grid, an assumed vertical extent of 10 m (33 ft), and a porosity of 20%.

The vertical extent of ^{60}Co was evaluated by examining deep unconfined and semiconfined uppermost aquifer wells, and the Rattlesnake Ridge confined aquifer wells for the presence of ^{60}Co. Table 4-2 identifies the wells that were evaluated. Cobalt-60 concentrations were identified in one deeper uppermost unconfined well, five uppermost semiconfined wells, and one Rattlesnake Ridge confined well. Wells that are potentially screened across more than one aquifer were not identified.

Well 299-E24-4 is screened within the deeper portion of the uppermost aquifer. This well had average ^{60}Co concentrations of 1.32 pCi/L. An adjacent well in the upper portion of the uppermost aquifer had concentrations of 1.01 pCi/L. These wells are located in the southeast quadrant of the 200 East Area in an area of elevated concentrations of ^{60}Co.

Wells screened in the semiconfined portion of the uppermost aquifer had average ^{60}Co concentrations that ranged from 0.6 to 3.14 pCi/L (Table 4-2). These wells are located on the eastern half of the 200 East Area and appear to correspond with areas of elevated ^{60}Co concentrations identified in the uppermost unconfined portion of the shallow aquifer. This area corresponds to higher potentiometric heads within the unconfined portion of the uppermost aquifer with respect to the semiconfined portion.

One well, 299-E33-12, presently screened in the Rattlesnake Ridge confined aquifer had ^{60}Co concentrations of 10.5 pCi/L. This well is located in the northwestern quadrant of the 200 East Area. This well is present in an area where the potentiometric head of the uppermost aquifer was at one time higher than the hydraulic head in the Rattlesnake Ridge aquifer (Jensen 1987). As a result, groundwater from the uppermost aquifer may have flowed downward into the Rattlesnake Ridge aquifer. Connelly et al. (1992a) hypothesized

that high-density salt waste discharged from the BY cribs (Cribs 216-B-43 through 216-B-49) may have migrated vertically down this well and entered the deeper aquifer prior to completing a well seal to isolate the Rattlesnake Ridge aquifer in 1982. Either of these mechanisms may have contributed to the elevated ^{60}Co concentrations identified in the Rattlesnake Ridge aquifer.

4.1.1.7.9 Strontium-90. Four plumes of ^{90}Sr were identified for the 200 East Groundwater Aggregate Area (plumes A, B, C, and D) (Figure 4-11). These plumes cover a combined area of approximately 1,100,000 m^2 (11,800,000 ft^2). This areal estimate is based on dissolved ^{90}Sr concentrations of greater than 8 pCi/L, which is equivalent to the 4% DCG.

Plume A is centered just east of the 216-A-25 Pond. The highest average concentration of ^{90}Sr in this plume is 311 pCi/L from Well 699-53-48B. This plume is defined by three wells. Groundwater flow is toward the northwest.

Plume B is located beneath the 216-B-5 Reverse Well. This plume is defined by one well with a concentration of 5,150 pCi/L. Groundwater flow in the B plume area is toward the northwest.

Plume C is centered beneath the 241-A and 241-AW Tanks. Groundwater flow at this location appears to be toward the south-southeast. The flow direction in this area is difficult to discern due to the relatively flat groundwater levels and the no flow boundary created by groundwater moving radially from the B Pond area.

Plume D is located just south of plume C and is located beneath the 216-A-9 Cribs. This plume has a maximum concentration of 19 pCi/L. Except for its eastern side which has no well data, the shape and areal extent of this plume is controlled by eight wells. The groundwater flow is toward the southeast.

The activity of ^{90}Sr is estimated at 0.17 Ci (Table 4-4). This estimate is based on computer-interpolation of well values to a grid, an assumed vertical extent of 10 m (33 ft), and a porosity of 20%.

The vertical extent of ^{90}Sr was evaluated by examining reviewing wells screened in the deep unconfined and semiconfined portions of the uppermost aquifer, along with wells in the Rattlesnake Ridge confined aquifer for the presence of ^{90}Sr. Table 4-2 identifies the wells that were evaluated. Strontium-90 concentrations were identified in one well screened in the deep, unconfined portion of the uppermost aquifer, two wells in the semiconfined portion, and one well in the Rattlesnake Ridge confined aquifer.

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Well 299-E24-1 completed in the deep, unconfined uppermost aquifer had ^{90}Sr concentrations of 10.35 pCi/L. This well is located in the southeast quadrant of the 200 East Area.

Three wells screened in the semiconfined portion of the uppermost aquifer had ^{90}Sr concentrations that ranged from 0.29 to 75.6 pCi/L. These wells (699-42-40B, 299-E24-11 and 299-E28-7) are located at the 216-B-3 Pond System, in the southeast quadrant and the northwest quadrant of the 200 East Area. Wells 299-E28-7 and 299-E24-11 correspond to the plumes identified near the 216-B-5 Reverse Well (plume B) and the 216-A-9 Cribs (plume D), respectively.

One well, 699-54-57, was identified as being screened in the Rattlesnake Ridge aquifer. The ^{90}Sr concentration in this well was 0.37 pCi/L. Well 699-55-57, an adjacent shallow well located downgradient of Well 699-54-57, has no detections of ^{90}Sr. Well 699-54-57 is located in an area where the hydraulic heads are greater in the Rattlesnake Ridge aquifer than in the uppermost aquifer system, resulting in an upward gradient from the Rattlesnake Ridge aquifer. An erosional window is present in the Elephant Mountain Member Basalt east of Well 699-54-57, possibly resulting in aquifer intercommunication and the elevated concentrations of ^{90}Sr found in the Rattlesnake Ridge aquifer. The erosional window may have intercepted chemical compounds dissolved in the uppermost aquifer before they could have reached Well 699-55-57.

4.1.1.7.10 Technetium-99. Two distinct plumes of ^{99}Tc (plumes A and B) were identified in the 200 East Groundwater Aggregate Area (Figure 4-12). The estimated combined areal extent of these plumes is 1,500,000 m^2 (16,100,000 ft^2) (Table 4-4). This estimate is based on the areas delimited by ^{99}Tc concentrations greater than 900 pCi/L. Technetium-99 concentrations at the 200 East Groundwater Aggregate Area range from nondetections to 21,700 pCi/L. The 4% DCG for ^{99}Tc is 4,000 pCi/L.

The highest concentrations of ^{99}Tc are found in plume B, which is located north of the 200 East Area fence. The southern end of this plume is constrained by two wells with concentrations of 878 and 770 pCi/L. One well samples groundwater beneath the 216-B-43 through -50 Cribs. The rest of the plume is loosely constrained by five wells. Groundwater flow in this area is toward the northwest.

Plume A is defined by one well, Well 699-55-57. This well has an average ^{99}Tc concentration of 2,150 pCi/L and is located just east of the 200 North Area. Groundwater flow in this area is toward the northwest.

The activity of ^{99}Tc is estimated at 21.9 Ci (Table 4-4). This estimate is based on computer-interpolation of well values to a grid, an assumed vertical extent of 10 m (33 ft), and a porosity of 20%.

The vertical extent of ^{99}Tc was evaluated by reviewing wells screened in the deep, unconfined and semiconfined portions of the uppermost aquifer and in the Rattlesnake Ridge confined aquifer for the presence of ^{99}Tc. Table 4-2 identifies the wells that were evaluated. Technetium-99 concentrations were identified in one well screened in the deep, confined portion of the uppermost aquifer, two in the semiconfined portions, and six in the Rattlesnake Ridge confined aquifer.

Well 299-E25-25, which is screened in the deep, unconfined portion of the uppermost unconfined aquifer, had detection of Technetium-99 at 0.73 pCi/L. This well is located in the southeast quadrant of the 200 East Area.

Two wells screened in the semiconfined portion of the uppermost aquifer had ^{99}Tc concentrations that ranged from 28.9 to 92.4 pCi/L. These wells, 299-E28-1 and 299-E28-7, are located at the northwest quadrant of the 200 East Area. These wells correspond to the elevated ^{99}Tc concentrations identified near the 216-B-5 Reverse Well.

The ^{99}Tc concentration for six wells screened in the confined aquifer ranged from 4.84 to 705 pCi/L (Table 4-2). Wells in the shallow, unconfined portion of the uppermost aquifer adjacent to Wells 299-E33-12 and 699-54-57 have higher ^{99}Tc concentrations. These higher concentrations suggest that the uppermost aquifer may be the source for ^{99}Tc concentrations measured in the confined aquifer.

Higher ^{99}Tc concentrations were measured in Rattlesnake Ridge aquifer Wells 699-47-50 (153.4 pCi/L) and 699-42-40C (4.8 pCi/L) than in adjacent wells screened in the uppermost aquifer. The higher ^{99}Tc concentrations in the Rattlesnake Ridge aquifer at Well 699-47-50 probably reflect dissolved constituents that have entered the aquifer across a hydraulic connection (possibly fractures or erosionally thinned areas of the basalt) near the northeast corner of the 200 East Area and upgradient of this well. Adjacent uppermost aquifer wells, 299-E34-6 and 299-E34-5 are cross gradient of this erosional window and Well 699-47-50. Connelly et al. (1992a) indicate that in recent sampling events, concentrations of dissolved constituents have reduced in this well. They hypothesize that this concentration reduction may be associated with a reduction in the vertical hydraulic gradient between the uppermost aquifer and the Rattlesnake Ridge aquifer.

Well 699-42-40C had higher ^{99}Tc than adjacent wells located in the uppermost aquifer. This well is located in an area where a downward vertical hydraulic gradient is present as a result of aquifer recharge at the 216-B-3 Pond. Connelly et al. (1992a) hypothesize that since contaminant concentrations in this well have increased recently, the well may have an improper seal separating it from the uppermost aquifer system.

A slightly upward gradient from the Rattlesnake Ridge confined aquifer to the

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uppermost unconfined aquifer is probably responsible for preventing the higher concentrations of ^{99}Tc in the unconfined portion of the uppermost aquifer from entering the Rattlesnake Ridge confined aquifer (Wells 699-49-55B and 699-49-55A). Because of the low concentrations of ^{99}Tc in the confined aquifer and the slight differences in the potentiometric head, it is possible that the uppermost aquifer water containing dissolved ^{99}Tc may have once discharged into the Rattlesnake Ridge confined aquifer.

4.1.1.7.11 Iodine-129. The ^{129}I plume areas cover a combined area of 29,000,000 m^2 (312,000,000 ft^2) in the vicinity of the 200 East Area (Figure 4-13 and Table 4-4). This areal estimate is based on dissolved ^{129}I concentrations $\geq$ 1 pCi/L, whereas the 4% DCG is 20 pCi/L. The areal extent and shape of the central plume within the 200 East Area is defined by 33 wells. The highest concentrations of ^{129}I are beneath the 216-A-10 and 216-A-45 Cribs. The overall shape of the plume reflects groundwater flow. In the southwest part of the plume, groundwater flow is toward the east, while groundwater flow in the eastern part of the plume is toward the west. In part of the southeastern side of the plume, groundwater flow may be toward the southeast. This is supported by elevated concentrations of ^{129}I to the southeast of the 200 East Area (Figure 4-13). Groundwater flow in the rest of the plume is toward the northwest. Two additional plumes are identified on Figure 4-13, a plume to the west of the 200 East Area which originates from the 200 West Area, and a plume southeast of the 200 East Area.

The activity of ^{129}I is estimated at 0.24 Ci (Table 4-4). This estimate is based on computer-interpolation of well values to a grid, an assumed vertical extent of 10 m (33 ft), and a porosity of 20%. The ^{129}I concentrations shown in the westernmost portion of Figure 4-13 emanate from the 200 West Area, as indicated in the 200 West Groundwater AAMSR, and have to be removed from the estimate by a graphical method.

The vertical extent of ^{129}I was evaluated by examining deep unconfined and semiconfined uppermost aquifer wells, and the Rattlesnake Ridge confined aquifer wells for the presence of ^{129}I. Table 4-2 identifies the wells that were evaluated. Average ^{129}I concentrations were identified in two wells screened in the deep, unconfined portion of the uppermost aquifer, three wells in the semiconfined portion of the uppermost aquifer, and nine Rattlesnake Ridge confined aquifer wells. In addition to these wells, two wells, 699-28-40 and 699-32-62, were identified as potentially being screened across multiple aquifers.

Wells 299-E24-1 and 299-E25-25, which are screened in the uppermost aquifer, have average ^{129}I concentrations that ranged from 0.3 to 26.6 pCi/L. These wells are located in the southeast quadrant of the 200 East Area.

Three wells, screened in the semiconfined portion of the uppermost aquifer, had average ^{129}I concentrations that ranged from 0.01 to 2.6 pCi/L. These wells (299-E28-01,

299-E28-7 and 299-E16-2) are located at the southeast and northwest quadrants of the 200 East Area.

Nine wells are screened in the Rattlesnake Ridge confined aquifer with average concentrations that ranged from 0.0005 to 0.11 pCi/L (Table 4-2). Most of these wells appear to be located within the ^{129}I plume identified in the upper portion of the uppermost aquifer. The wells that are outside the ^{129}I plume are located north of the 200 East Area and within the 216-B-3 Pond System.

Two wells, 699-28-40 and 699-32-62, are identified as potentially being screened in multiple aquifers. Low levels of ^{129}I were detected in these wells. These values may represent an average concentration for the screened interval sampled. In addition, these wells potentially create a vertical conduit for contaminants to reach the deeper aquifers.

4.1.1.7.12 Cesium-137. One ^{137}Cs plume is present in the 200 East Groundwater Aggregate Area (Figure 4-14). The plume is defined by concentrations greater than 120 pCi/L, which is equivalent to the 4% DCG. This plume is defined by four wells, with the highest average ^{137}Cs concentration of 1,330 pCi/L in Well 299-E28-23. The 299-E28-23 Well samples groundwater near the 216-B-5 Reverse Well. Groundwater flow at this location is toward the northwest, and the areal extent of this plume is estimated at 22,000 m^2 (237,000 ft^2) (Table 4-4) greater than 120 pCi/L.

The total activity of ^{137}Cs is estimated at 0.014 Ci (Table 4-4). This estimate is based on the computer interpolation (actually extrapolation) of the plume, a porosity of 20% and a depth of 10 m (33 ft).

The vertical extent of ^{137}Cs was evaluated by examining wells screened in the deep, unconfined and semiconfined portions of the uppermost aquifer and wells in the Rattlesnake Ridge confined aquifer for the presence of ^{137}Cs. Table 4-2 identifies the wells that were evaluated. Average ^{137}Cs concentrations were identified in three wells in the semiconfined portion and one well screened across multiple aquifers. Cesium-137 was either not detected or not analyzed for in deep, unconfined portions of the uppermost aquifer and in confined wells (Table 4-2).

Wells 699-42-40A and 699-42-40B located near the 216-B-3 Pond System and Well 299-E28-7 located near the 216-B-5 Reverse Well were screened in the semiconfined portion of the uppermost aquifer. These wells had concentrations that ranged from 0.11 to 3.75 pCi/L (Table 4-2).

Well 299-E17-6 was potentially screened across multiple aquifers. Low levels of ^{137}Cs were detected in this well (4.58 pCi/L). This well is located in the southeast quadrant of the 200 East Area.

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4.1.1.7.13 Plutonium-239/240. One $^{239/240}Pu$ plume is present in the 200 East Groundwater Aggregate Area (Figure 4-15). The plume is defined by concentrations of greater than 1 pCi/L, which is similar to the 4% DCG of 1.2 pCi/L. This plume is defined by three wells. The highest $^{239/240}Pu$ (73.9 pCi/L) was detected in Well 299-E28-23. The 299-E28-23 Well samples groundwater near the 216-B-5 Reverse Well. Groundwater flow at this location is toward the northwest. The areal extent of this plume is estimated at 19,000 m^2 (205,000 ft^2) (Table 4-4).

The total activity of $^{239/240}Pu$ is estimated at 0.0006 (Table 4-4). This estimate is based on an average concentration of 73.9 pCi/L (the one well with data), a porosity of 20%, and a depth of 10 m (33 ft).

The vertical extent of $^{239/240}Pu$ was evaluated by examining wells screened in the deep, unconfined and portions of the semiconfined uppermost aquifer and wells in the Rattlesnake Ridge confined aquifer for the presence of $^{239/240}Pu$. Table 4-2 identifies the wells that were evaluated. Plutonium-239/240 concentrations were identified in two wells in the semiconfined portion of the uppermost aquifer. Plutonium-239/240 was either not detected or not analyzed for in deep uppermost unconfined and confined wells (Table 4-2).

Wells screened in the semiconfined portion of the uppermost aquifer, Wells 299-E28-1 and 299-E28-7, had concentrations that ranged from 0.02 to 0.05 pCi/L (Table 4-2). These wells are located in the northeast quadrant of the 200 East Area near the 216-B-5 Reverse Well. Detection of $^{239/240}Pu$ was not made in adjacent Well 299-E28-5 screened in the shallow, unconfined portion of the uppermost aquifer.

4.1.2 Known Releases from 200 East Area and 200 North Area Facilities

This section correlates contaminants identified in the groundwater to known releases from waste management units in the 200 East and 200 North Areas. The discussion is divided into identification of the factors that have contributed to the presence of contaminants in the groundwater followed by a discussion of individual contaminants.

4.1.2.1 Factors Contributing to Groundwater Contamination. Factors that have led to the observed groundwater contamination include: operation processes at the four plants in the 200 East and 200 North Areas that generated waste streams; content, quantity, and areal extent of disposed wastes; and mobility of each contaminant in the vadose zone. This list is not intended to be exhaustive.

4.1.2.1.1 Plant Operations and Waste Generation. Table 4-4 summarizes the waste streams from the various plant operations in the 200 East and 200 North Areas which were disposed to waste management units that potentially contributed contaminants to groundwater.

It also indicates the period of disposal. Operations and waste generation for each of the plants in the 200 East and 200 North Areas are described in Section 2.4. That discussion includes a summary of the waste-producing processes (Table 2-6) and identification of waste-management units where process wastes were disposed.

4.1.2.1.2 Sources of Groundwater Contaminants. Disposal of waste to waste management units potentially contributing contaminants to groundwater is identified below for the primary contaminants of concern in the groundwater. Waste disposal and storage is discussed in Section 2.3 by waste management unit. Tables 2-5 and 2-6 identify known inventories for specific waste management units that potentially have contributed contaminants to groundwater. Inventories are presented as a general guide to contaminants present, although the data presented in these tables must be viewed as incomplete. The dates of operation for these waste management units are shown on Table 2-4. This information is reformatted in this section to help identify potential sources for contaminant plumes identified in the groundwater. Where possible, contaminant plumes are related back to probable release sources in Sections 4.1.2.2 and 4.1.2.3.

4.1.2.1.3 Mobility of Contaminants Released to the Vadose Zone. Calculations were performed for waste management units in all of the 200 East and 200 North Areas source reports based on liquid waste discharge volumes and soil pore capacities. Waste management units receiving sufficient discharge for liquids to reach the water table by this calculation are identified in Section 2.3 as potentially contributing contaminants to the groundwater. This section discusses the potential for contaminants in these units to migrate to the uppermost aquifer.

The major processes affecting transport of chemicals discharged to the vadose zone include: precipitation/dissolution, adsorption/desorption, filtration of colloids and suspended particles, and diffusion into micropores within mineral grains (Serne and Wood 1990). The precipitation/dissolution and adsorption/desorption are considered the most important. Factors that affect the migration of contaminants in the vadose zone are summarized below:

- Ionic state--cations are more strongly sorbed than anions and nonionized solutions are more weakly sorbed.

- Valence state--generally, multivalent ions are more strongly sorbed than univalent ions.

- Particle size of contaminant--deposition of the contamination increases with increasing particle size.

- Soil grain size--sorption increases as soil (sorbent) particle size decreases. Filtration and ion exchange also increase with decreased soil grain size.

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- pH and redox potential--the chemical species of a contaminant is dependent on these conditions, both in the waste and in the soil.

- Soil mineralogy--mineralogy affects the abundance of sorption sites as well as the availability of ions for precipitation.

- Waste stream constituents--sorption may be decreased if competing chemicals in the waste interfere, and complexing of inorganics with organics in the waste stream may increase the mobility of inorganics.

- Volume of discharge--hydrostatic forces are the primary driving force for contaminant migration, so that discharges that maintain saturated conditions in the vadose zone result in more rapid downward migration.

- Lithology--variations of the soil stratigraphy with depth, such as the presence of low-permeability layers, may increase the flowpath length of contaminant migration and slow its rate of descent.

- Monitoring wells--poorly sealed monitoring wells may provide a conduit by which contaminants may flow through the vadose zone to the groundwater.

Further discussion of contaminant mobility and transport is contained in Section 4.2.2 below. The potential for migration to the unconfined aquifer for each contaminant detected in the groundwater is discussed below in Sections 4.1.2.2 and 4.1.2.3.

4.1.2.2 Source and Mobility of Chemicals Released to Vadose Zone. Groundwater monitoring has detected numerous chemicals present in the groundwater of the 200 East and 200 North Areas (Table 4-1). Section 4.1.1 describes the plumes for the chemicals with the most significant concentrations. The probable source and mobility in the vadose zone of each of these chemicals with identified groundwater plumes are discussed below, beginning with inorganic and then organic compounds. Other inorganic and organic compounds detected in groundwater but not shown on plume maps are also discussed.

4.1.2.2.1 Inorganic Compounds. Inorganic compounds for which plumes in the groundwater are described include: arsenic, chromium, cyanide, and nitrate. Other inorganic compounds detected are listed in Table 4-1.

Arsenic. Arsenic was not reported in inventories of chemical wastes discharged to waste management units for disposal, as presented in Table 2-6. Even so, arsenic is reported as a chemical disposed of to the PUREX Plant and to the B Plant. Arsenic is also reported to have been used in the separation and recovery process at U Plant. Some of the waste from this process was disposed of in the 216-B Cribs. Alternatively, lowering of the vadose

zone pH and groundwater pH through release of acidic waste may alter iron oxide (e.g., iron hydroxide) to ionic iron (ferric iron), thereby mobilizing other metal ions such as arsenic that were adsorbed to the iron oxide. In addition, a lower pH may reduce arsenic to a lower valence state, thus making it less likely to adsorb to iron oxide.

Plume A (Figure 4-1) underlies the 216-B-3 Pond. The 216-B-3 Pond may also have contributed to plume B. Plume C would appear to have formed from discharges to the 216-A-37-1, 216-A-37-2, and 216-A-30 Cribs. The source of arsenic for plume D may be the 2101-M Pond. The pond may have received waste from the Basalt Waste Isolation Project laboratories, however, arsenic is reportedly not known to have been included with the wastes discharged (DOE/RL 1991f).

Arsenic exists as a negative ion in most soil conditions or as an oxide in slightly oxidizing to slightly reducing conditions (Dragun 1988). It is expected that arsenic in Hanford soils is a monovalent or divalent anion under most site conditions and therefore has a moderate to high mobility (Dragun 1988).

Concentrations of arsenic detected in a groundwater sampling from the 200 East Groundwater Aggregate Area may reflect background concentrations (DOE/RL 1991f), although the plausibility of this source has not been demonstrated. DOE/RL (1992d) presents a 10 μg/L background concentration for arsenic, as listed on Table 4-3.

Chromium. Chromium was not reported in inventories of chemical wastes discharged to waste management units for disposal, but sodium dichromate is reported at the PUREX Plant as 110 kg (242 lb) released to 216-A-4 Crib, 300 kg (660 lb) released to 216-A-21 Crib, 200 kg (440 lb) released to 216-A-27 Crib, at the B Plant as 100 kg (220 lb) released to 216-B-10A Crib, and 100 kg (220 lb) released to 216-B-5 Reverse Well (Table 2-6). In addition to these inventories, chromium may be associated with some of the process waste streams discharged to other units. Chromate waste was produced by the Semi-Works Plant and waste streams from Semi-Works were disposed of in the Semi-Works Aggregate Area. Chromium is stable in the dissolved form under oxidizing conditions as hexavalent chromium which is more mobile. Within the 200 East Area chromium concentrations are largely below the detection limits despite the presence of oxidizing conditions. Thornton (1992) indicates that this suggests waste streams from the 200 East Area were "essentially absent of hexavalent chromium." Besides release as sodium dichromate, chromium in the waste stream may have originated as a by-product of the separation processes or through dissolution of the walls of stainless steel process equipment by the strong acid solutions.

The source of chromium in plume A (Figure 4-2) is uncertain. The closest likely sources are the 216-B-35 through -42 Cribs. These cribs are the probable source for plume B as well. Plume C underlies the PUREX tank farms.

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Chromium is mobile under oxidizing conditions (in its hexavalent state), but relatively immobile under more reducing conditions. Hexavalent chromium exists as a monovalent (pH <6) or divalent (pH >6) anion and has a high mobility in soil types present at the site, while trivalent chromium has low mobility (Dragun 1988).

Cyanide. Inventories (Table 2-6) indicate that cyanide was disposed in the form of ferrocyanide to 13 cribs and 12 trenches in the B Plant Aggregate Area. A total of 73,800 kg (162,000 lb) is shown for the cribs and trenches. In addition to the ferrocyanide reported in Table 2-6, cyanide and ferric cyanide are reported as being disposed within the PUREX Plant Aggregate Area. Ferrocyanide was used to enhance precipitation of long-lived radionuclides before the supernatant was discharged to the ground.

The cyanide plume is not beneath any waste management units (Figure 4-3). The plume may have migrated to its present position from beneath the 216-B-43 through -50 Cribs. These cribs had ferrocyanide released to them.

The chemical form of cyanide present in the subsurface is believed to be ferrocyanide based on its known form of release to the vadose zone and limited laboratory studies using a special ion chromatography method (Last et al. 1991). Ferrocyanide, which is neutral, likely is very mobile in the soil and groundwater. Cyanide also is expected to have high mobility as an anion where it exists as a free ion.

Nitrate. The chemical waste inventory (Table 2-6) indicates that nitrate was discharged in many forms to waste management units that potentially contributed contaminants to groundwater. Release of nitrate to these units is reported at 32,800,000 kg (72,000,000 lb) with the largest component discharged at B Plant. Other forms of nitrate discharged include aluminum nitrate 5,000 kg (11,000 lb), ammonium nitrate 2,600,000 kg (5,720,000 lb), and nitric acid 27,000 kg (59,000 lb). Nitrate discharge is associated with most of the units in Table 2-6. The nitrate plume in groundwater is estimated to represent 740,000 kg (1,630,000 lb).

Disposal of nitrate has been widespread, and the plumes may reflect contributions from many sources (Figure 4-4). Plume A is associated with the 216-A-25 Pond. Plume B does not currently underlie any waste management units, but a likely source of nitrate would have been the 216-B-43 through -50 Cribs. Possible contributors to plume C are the 216-A-10 Crib or the 216-A-18 Trench. Plume D underlies the 216-A-9 Crib. Plumes E and F are associated with several cribs that may have been nitrate sources (216-A-5, 216-A-10, 216-A-4, 216-A-21, 216-A-27, 216-A-36A, 216-A-36B, 216-A-45 Cribs).

Nitrate exists as a negative ion and is readily soluble in water, so virtually no sorption is expected to occur in Hanford soils (Serne and Wood 1990; Evans et al. 1990). Nitrate

degrades through natural (biological) processes to ammonia, thereby resulting in reduced concentrations with time.

Other Inorganics. Other inorganics detected during groundwater monitoring are listed on Table 4-1. Chemical inventories (Table 2-6) include records for discharge of some of these inorganics as compounds, although this record is not considered to be complete. Aluminum was disposed of in the form of aluminum nitrate to the 216-B-5 Reverse Well in B Plant. A total of 5,000 kg (11,000 lb) of aluminum nitrate was discharged to the well. Aluminum discharge at B Plant also is reported in the form of sodium aluminate to the 216-B-36 and 216-B-40 Trenches at a quantity of 44,000 kg (96,800 lb). Iron was discharged in the form of 73,800 kg (162,000 lb) of ferrocyanide to the majority of the cribs and trenches at B Plant. The inventory data in Table 2-6 indicates that 374,000 kg (823,000 lb) of fluoride was disposed of to six waste management units at B Plant with 240,000 kg (528,000 lb) attributed to the 216-B-7A and B Cribs. Process waste that was disposed of in the 200 East Area included a large number of different metals for which no inventory data were available.

The cation exchange capacity of the Hanford Site soils is low due to its coarse nature and low organic content. Thus, sorption through cation exchange of ionic metals is expected to be relatively low. The complex chemistry of the waste discharged at 200 East Area included many metal compounds and many other elements and compounds that likely altered the mobility of each metal. In general, the soil types present in the vadose zone at the site and natural soil conditions suggest that metals with anticipated high mobilities include selenium, metals with anticipated moderate or moderate to high mobilities include barium, cadmium, copper, iron, manganese, silver, and zinc, and metals with anticipated low mobilities include aluminum and mercury (Krauskopf 1979; Matthess 1982; Dragun 1988). However, changes to the pH and redox potential, as has happened in many cases, and the very complex chemistry of the waste could greatly affect predicted mobilities.

4.1.2.2.2 Organic Compounds. There are no organic compounds for which plumes in the groundwater are described. Organic compounds detected are listed in Table 4-1.

Carbon Tetrachloride (CCl_4). Carbon tetrachloride was used in the PUREX Aggregate Area in the 202-A Building Analytical Laboratory. It is identified as being part of the waste stream from PUREX that was disposed of in the B Plant. Carbon tetrachloride is not included in the chemical waste inventory (Table 2-6).

Carbon tetrachloride is a DNAPL, meaning that it sinks in water and has a low solubility. Mechanisms for transport through the vadose zone to the unconfined aquifer include gravity-driven liquid phase descent, aqueous phase transport (dissolved or as an emulsion in water), and density-driven vapor phase flow (Last et al. 1991). If carbon tetrachloride has been present at the water table in sufficient quantity, then it may have

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continued to sink through the aquifer as a separate phase until it reached a low permeability zone. In addition, because carbon tetrachloride has a low dielectric constant, it can increase the permeability of subsurface materials, thereby strongly influencing its migration pathways and permitting it to migrate vertically.

Chloroform. Chloroform is not included in the inventory for chemical waste (Table 2-6). Chloroform is reported to have been used in B Plant processes and is listed as being disposed of within the PUREX and B Plant areas.

Chloroform is probably a degradation product of carbon tetrachloride either through radiolytic processes prior to disposal or through natural transformation processes (i.e., microbial degradation) in the subsurface (Evans et al. 1990). Chloroform is a DNAPL and, as such, is expected to migrate by similar means as described for carbon tetrachloride.

Trichloroethylene. Trichloroethylene is not included in the inventory for chemical waste discharged to waste management units potentially contributing contaminants to groundwater (Table 2-6).

Other Organic Compounds. Other organic compounds detected in groundwater are listed in Table 4-1. These compounds likely were included in the waste discharged to the waste management units from peripheral activities to the main process operations. The compounds 1,2-dichloroethane, 1,1,1-trichloroethane, tetrachloroethylene, and bis(2-ethylhexyl) phthalate are all DNAPLs and, as such, are expected to migrate by similar means as described for carbon tetrachloride. Bis(2-ethylhexyl)phthalate is a common laboratory contaminant and may be a spurious detection. Toluene is a light nonaqueous phase liquid with low solubility in water that may be transported by gravity-driven liquid phase descent or by aqueous phase transport (dissolved or as an emulsion in water). If liquid-phase descent has occurred, toluene will pool above the water table. DDT is practically insoluble in water, but may be dissolved in another solvent that has migrated to the groundwater.

4.1.2.3 Source and Mobility of Radionuclides Released to Groundwater. Groundwater monitoring also has detected numerous radionuclides present in the groundwater of the 200 East and 200 North Areas (Table 4-1). Section 4.1.1 describes the plumes for the radionuclides with the most significant concentrations. Plume maps include gross alpha, gross beta, ^{60}Co, ^{137}Cs, ^{90}Sr, tritium, ^{99}Tc, ^{129}I, uranium, and $^{239,240}Pu$. The probable source and mobility in the vadose zone of each of these radionuclides chemicals with identified groundwater plumes are discussed below. Other radionuclides detected in groundwater but not shown on plume maps are also discussed. These include: ^{14}C, ^{63}Ni, ^{106}Ru, radium, and ^{241}Am.

4.1.2.3.1 Gross Alpha. The radiological waste inventory (Table 2-5) includes gross alpha values as an indicator of radionuclide releases. Most of the waste management units

that potentially contributed contaminants to the groundwater in the PUREX, B Plant, and 200 North Aggregate Areas include alpha in their waste inventory. Alpha is not included in the waste inventory of the Semi-Works Aggregate Area. The alpha for PUREX units is 81 Ci with 28.1 Ci attributed to the 216-A-10 Crib. The alpha for B Plant is 887 Ci with 264 Ci attributed to the 216-B-7A and B Cribs and 262 Ci attributed to the 216-B-5 Reverse Well. The reported alpha for the 200 North Aggregate Area is 0.184 Ci. The contaminant plumes described in 4.1.1.7.5 represent roughly 0.03 Ci in groundwater.

Plume A (Figure 4-6) is partially located beneath the 216-B-43 through -50 Cribs. These cribs are a likely source of alpha emitters. The most likely source for plume B is the 216-B-5 Reverse Well.

Gross alpha primarily is an indicator of uranium and other high atomic number radionuclides such as plutonium and americium. Thus, alpha detections primarily are dependent on the migration potential and concentrations of uranium, plutonium, and americium.

4.1.2.3.2 Gross Beta. The radiological waste inventory (Table 2-5) includes gross beta values as an indicator of radionuclide releases. Most of the waste management units that potentially contributed contaminants to the groundwater in PUREX, B Plant, and 200 North aggregate areas include beta in their waste inventory. Beta is not included in the waste inventory for the Semi-Works Aggregate Area. The beta for PUREX units is 7,611 Ci with 3,630 Ci attributed to the 216-A-36A Crib, 1,360 Ci attributed to the 216-A-36B Crib and 1,110 Ci attributed to the 216-A-8 Crib. The beta for B Plant is 40,500 Ci with 4,490 Ci attributed to the 216-B-7A and B Cribs. The beta for the 200 North Aggregate Area is 2.168 Ci. Beta levels can be attributed to uranium fission products including ^{60}Co, ^{90}Sr, ^{99}Tc, ^{106}Ru, ^{125}Sb, ^{137}Cs, ^{234}Th, and ^{234}Pa, and to a lesser extent, ^{129}I. Some shorter-lived beta emitters, such as ^{131}I, may also have contributed initially, but have since decayed significantly. The contaminant plume described in Section 4.1.1.7.6 represents roughly 5.15 Ci in the groundwater.

Plume A (Figure 4-7) is located partially beneath the 200 North Area. The source of this plume may be from waste disposal at the 200 North Area or from upgradient sources. Plume B is located partially beneath the 216-A-25 Pond, and the pond is a likely contributor to the plume. Plume C is for the most part downgradient from 200 East sources of contamination, but its southern boundary is beneath the 216-B-35 through -42 Cribs. These cribs are likely sources for contributing to plume C. The source of plume D is the 216-B-5 Reverse Well. The 216-A-10, 216-A-36, and 216-A-45 Cribs are likely contributors to plume E. The 216-B-20 through 216-B-36 Trenches are the likely contributors to plume F.

Gross beta is an indicator of many radionuclides and does not have a migration potential of its own.

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4.1.2.3.3 Tritium. Tritium (^3H) is reported in the radiological inventory for waste management units for all but the 200 North Aggregate Area (Table 2-5). Tritium was present in many of the waste streams discharged to the soil column in 200 East Area (Evans et al. 1990). A total of 32,521 Ci is reported in Table 2-5 with 18,500 Ci attributed to the 216-A-10 Crib and 4,000 Ci attributed to the 216-A-9 Crib. Concentrations of tritium detected in groundwater indicate 16,420 Ci are present in the groundwater.

Plumes A and B (Figure 4-8) are probably the result of discharges to the 216-B-3 Pond. Plume C reflects migration of tritium into the 200 East Area from the 200 West Area and contributions from various waste management units in the PUREX Plant Aggregate Area.

Tritium (^3H), as a constituent of tritiated water, closely resembles ordinary water in its structure (although is 11% heavier) and it travels unretarded along with water. The half life for tritium is 12.3 years.

4.1.2.3.4 Carbon-14. Carbon-14 is not included in the inventory for radiological waste (Table 2-5). Carbon-14 is a fission product and likely was associated with process waste from reactor fuel reprocessing. Carbon is listed as an impurity in uranium metal that may have been present in small quantities throughout the separation precesses. Carbon exists primarily in the form of carbon dioxide, which is readily soluble in water. Thus, carbon migrates unretarded with water. The half life for ^{14}C is 5,730 years.

4.1.2.3.5 Cobalt-60. Cobalt-60 is reported in the radiological inventory for waste management units for all but the 200 North Aggregate Area (Table 2-5), although cobalt is presumed to have been present in the waste at 200 North due to the presence of irradiated uranium. Cobalt-60 is a fission product and likely was associated with precess waste from reactor fuel reprocessing. Cobalt is listed as an impurity in uranium metal that may have been present in small quantities throughout the separation processes. The inventory in Table 2-5 shows a total of 7.8 Ci released to units that potentially contributed contaminants to the groundwater. The largest release was 3.32 Ci to the 216-A-5 Crib. The contaminant plume described in Section 4.1.1.7.8 represents 0.43 Ci. The ^{60}Co plume (Figure 4-10) is not located beneath any waste management units. The plume is located downgradient from the 216-B-43 through -50 Cribs. These cribs are the closest units that may have contributed to the plume.

Cobalt exists primarily as a divalent cation up to a pH of approximately 9.5 that forms complexes with common anions (chloride, nitrate, hydroxide, and sulfate) to form mostly neutral or anionic species (Serne and Wood 1990). At a pH of 9 or less, which includes conditions present in the vadose zone, cobalt should sorb via cation exchange if it does not react with other anions to form anionic or neutral species. The formation of anionic and neutral complexes, as well as the formation of colloids, can result in a moderate to high

mobility for cobalt (Serne and Wood 1990). Thus, some cobalt is expected to have sorbed to vadose zone soil through cation exchange, but that anionic and neutral species have allowed some migration to the unconfined aquifer. The half life for ^{60}Co is 5.3 years.

4.1.2.3.6 Nickel-63. Nickel-63 is not included in the inventory for radiological waste (Table 2-5). Nickel-63 is a fission product and likely was associated with process waste from reactor fuel reprocessing. The half life for ^{63}Ni is 100.1 years.

Nickel mobility exists primarily as a cation in the soil types at the site and is expected to have a high mobility due to the low cation exchange capacity. Nickel may have formed complexes in the waste stream that are less mobile.

4.1.2.3.7 Strontium-90. Strontium-90 is reported in the radiological inventory of Table 2-5 for most of the waste management units. The inventory in Table 2-5 shows a total of 13,300 Ci released to units that potentially contributed contaminants to the groundwater. The largest release was 2,200 Ci to the 216-B-7A and B Cribs. As discussed below, releases of ^{90}Sr (and ^{137}Cs) are also suspected for the BY Cribs (Cribs 216-B-43 through 216-B-50). The contaminant plumes described in Section 4.1.1.7.9 represent 0.17 Ci.

Plume A (Figure 4-11) is associated with the 216-A-25 Pond. The source of contaminants for plume B is the 216-B-5 Reverse Well. The 216-A-4, 216-A-5, 216-A-10, 216-A-21, 216-A-27, 216-A-36A, 216-A-36B, and 216-A-45 Cribs are all potential contributors to plumes C and D.

Strontium exists as a divalent cation throughout the potential range of groundwater pH in the absence of complexing anions and organic ligands. Strontium sorbs by ion exchange as a cation, with the degree of sorption in Hanford soil dependent on the types and concentrations of other cations in solution that can compete successfully for sorption sites (Serne and Wood 1990). Strontium may also precipitate as phosphate complexes. However, numerous organic anions react with strontium to form soluble organic complexes, which increases strontium mobility when present in the waste stream, and strontium is very mobile under acid conditions (Serne and Wood 1990). Thus, strontium commonly will be moderately sorbed or precipitated, but may be much more mobile in soil and groundwater where significant cationic competition for sorption sites occurs (e.g., high calcium conditions or high salt wastes), where significant organics are present in the waste, or where conditions are highly acidic. The half life for ^{90}Sr is 28.5 years.

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Evidence for vertical migration for ^{90}Sr and ^{137}Cs as a density plume associated with high-salt wastes from the 216-BY Cribs was presented by Smith (1980). During this study Smith (1990) cited gamma logging and groundwater sampling results from deep wells north and south of the 241-B-361 Settling Tank. These wells included wells 299-E-28-7, and 299-E28-23 through 299-E28-25. The wells were screened in the deep unconfined portion of the uppermost aquifer near the basalt surface (Plate 1A and Plate 2). Results cited by Smith (1990) indicated that low-level gamma activity and ^{137}Cs concentrations were present near the basalt surface south and east of the BY Cribs and the 216-B-5 Reverse Well. Smith (1990) attributed the likely source of the contamination to the 216-BY Cribs where relatively large quantities of high-salt ^{90}Sr and ^{137}Cs wastes discharged.

Transport of ^{90}Sr and ^{137}Cs contaminants as a gravity-driven density flow would resemble the DNAPL transport mechanism described in Section 4.1.2.2.2 for carbon tetrachloride in an aquifer, given a sufficient waste quantity to sink through the saturated zone to a low-permeability layer or the basalt surface. The southward slope of the basalt surface toward the axis of the Cold Creed syncline would also tend to promote spreading of the density flow. Additional deep well exploration in this area and to the southeast is needed to more-completely assess the condition and to substatiate the presence of these contaminants as a density plume.

4.1.2.3.8 Technetium-99. Technetium-99 is not included in the inventory for radiological waste (Table 2-5). Technetium-99 is a fission product and likely was associated with process waste from reactor fuel reprocessing. Fission products are associated with numerous operations processes. The plumes described in Section 4.1.1.7.10 indicate that 21.9 Ci are present in the 200 East Area groundwater.

Plume A (Figure 4-12) is associated with the 200 North Area. Plume B is downgradient from the 200 East Area except for the southern portion of the plume which underlies the 216-B-43 through -50 Cribs.

Technetium exists as a negative ion in oxidizing environments and in soil types present at Hanford, and thereby, does not readily complex with other chemical species (Serne and Wood 1990). Consequently, technetium is considered nonsorbing in the Hanford soil environment. These conditions result in a high mobility for technetium in Hanford soils. Sorption may occur in soils that contain considerable organic matter, which tends to sorb anionic species, and the valence state may be reduced to the +4 state, causing precipitation or sorption. However, organic soils are not present at the site. The half life for ^{99}Tc is 213,000 years.

4.1.2.3.9 Ruthenium-106. Ruthenium is included in the inventory for radiological waste (Table 2-5) for most of the waste management units in the PUREX, Semi-Works, and 200 North areas and for some of the units in the B Plant area. The inventory in Table 2-5

shows a total of 5.5 Ci released to the units that potentially contributed contaminants to the groundwater. The largest release was 3.17 Ci to 216-A-36B Crib. Ruthenium-106 is a fission product and likely was associated with process waste from reactor fuel reprocessing. Ruthenium is a primary contaminant in purified plutonium and uranium streams.

Ruthenium exists primarily in the +3 and +4 oxidation states and complexes readily with common anions to form a variety of anions or cations, depending on chemical conditions (Serne and Wood 1990). Mobility of ruthenium is greatly increased in the presence of nitrite and nitrate (Serne and Wood 1990), which results in a generally high mobility in the areas of nitrate releases. The half life for ^{106}Ru is 1.0 years.

4.1.2.3.10 Iodine-129. Iodine-129 is reported in the waste inventory for the 216-A-10, 216-A-36B, 216-A-37-1, and 216-A-45 Cribs in the PUREX Aggregate Area. A total of 0.131 Ci are reported for these cribs with 0.107 Ci attributed to the 216-A-10 Crib. Iodine-129 is a fission product and likely was associated with process waste from fuel reprocessing. The plume described in Section 4.1.1.7.11 indicates that 0.24 Ci are present.

The ^{129}I plume lies beneath a large part of the 200 East Area (Figure 4-13). The highest concentrations appear to be from the contributions of the 216-A-10 and 216-A-45 Cribs.

Iodine exists as a negative ion in oxidizing environments and in soil types present at Hanford, and thereby, does not readily complex with other chemical species (Serne and Wood 1990). Consequently, iodine is considered nonsorbing in the Hanford soil environment. Sorption may occur in soils that contain considerable organic matter, which tends to sorb anionic species, but such soils are not present at the site. The half life for ^{129}I is 1.6×10^7 years.

4.1.2.3.11 Cesium-137. Cesium-137 is reported in the radiological inventory of Table 2-5 for most of the waste management units. The inventory in Table 2-5 shows a total of 11,599 Ci released to units that potentially contributed contaminants to the groundwater. The largest releases were 1,570 Ci to the 216-B-30 Trench and 1,350 Ci to the 216-B-37 Trench. The plume described in Section 4.1.1.7.12 is estimated to contain 0.014 Ci ^{137}Cs. The plume (Figure 4-14) appears to be related to releases to the 216-B-5 Reverse Well.

Cesium exists as a monovalent cation within the range of soil and groundwater pH at Hanford and shows no tendency to complex with inorganic or organic ligands, no tendency to polymerize, nor a tendency to form colloids (Serne and Wood 1990). Consequently, cesium is expected to sorb primarily by ion exchange, with the degree of sorption dependent on the concentrations of other cations that can compete for sorption sites. Cesium is very mobile under acid conditions (pH <3). The half life for ^{137}Cs is 30 years.

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As discussed for ^{90}Sr on Section 4.1.2.3.7, relatively low concentrations of ^{137}Cs and gamma radiation were detected in groundwater samples from the deep, unconfined portion of the uppermost aquifer, near the basalt contact (Smith 1980). These detections from near the basalt contact may indicate downward migration by density driven flow of high-salt liquids originating from historic discharges to the BY Cribs (Cribs 216-B-43 through 216-B-50).

4.1.2.3.12 Radium. Radium is not included in the inventory for radiological waste (Table 2-5). Radium is a decay product of uranium and likely was associated with waste for which uranium was identified.

4.1.2.3.13 Uranium. Uranium (^{238}U and total U) is reported in the radiological inventory for most of the waste management units (Table 2-5). The inventory in Table 2-5 shows 30.89 Ci for total uranium released to units that potentially contributed contaminants to the groundwater. The largest releases were 13 Ci to the 216-A-19 Trench and 6.96 Ci to 216-B-12 Crib.

Serne and Wood (1990) report that under oxidizing conditions that exist at Hanford, dissolved uranium is predicted to exist as a cation up to a pH of approximately 6, as a neutral hydroxide species from a pH of approximately 6 to 8, and as an anionic carbonate above a pH of 8. This suggests that uranium would sorb via cation exchange under acid conditions and sorb very poorly under neutral and basic conditions. However, strong evidence suggests that a uranium phosphate has precipitated beneath the cribs because of the high phosphate content in the waste streams (Serne and Wood 1990). Data compiled in the U Plant AAMSR indicate that uranium (^{238}U) has reacted with the soil where it has been discharged to form carbonate-phosphate compounds in the upper portions of the vadose zone, with little uranium normally reaching the unconfined aquifer. The half life for ^{238}U is 4.5×10^9 years.

Remobilization of uranium through acidic discharge is shown by events related to the 216-U-1 and 216-U-2 Cribs (Baker et al. 1988), which had received some 0.7 Ci of uranium between 1951 and 1967 that apparently precipitated in the soil. Acidic decontamination wastes, which were discharged to the cribs toward the end of their service life, had partially dissolved the sorbed uranium beneath the cribs but was of insufficient volume to transport the dissolved uranium to the groundwater. In 1984, a new crib (216-U-16) was installed south of the 216-U-1 and 216-U-2 Cribs. Liquid discharges to 216-U-16 Crib were sufficient to form a perched zone above a caliche layer that by 1985 migrated under the 216-U-1 and 216-U-2 Cribs. This additional discharge mixed with the uranium-bearing fluid and uranium migrated downward with the liquid discharge to the unconfined aquifer. This was observed in a nearby monitoring well, as uranium concentrations rose from 166 pCi/L to about 72,000 pCi/L over a short period. A pump and treat remediation of the groundwater followed.

4.1.2.3.14 Plutonium-238/239/240/241. Plutonium-238 is reported for three waste management units in Table 2-5: 216-A-10 Crib, 216-A-45 Crib, and the 216-B-3 Pond. The inventory in Table 2-5 shows a total of 0.338 Ci released to the three cribs with 0.329 Ci attributed to the 216-A-10 Crib. Plutonium-239 is reported for the majority of the waste management units in Table 2-5. The inventory in Table 2-5 shows a total of 952 Ci released with 373 Ci attributed to the 216-A-37-2 Crib, 246 Ci attributed to the 216-B-7A and 216-B-7B Cribs, and 244 Ci attributed to the 216-B-5 Reverse Well. Plutonium-240 is reported for the majority of the waste management units in Table 2-5. The inventory in Table 2-5 shows a total of 156 Ci released with 66.2 Ci attributed to the 216-B-7A and 216-B-7B Crib and 65.7 Ci attributed to the 216-B-5 Reverse Well. Plutonium-241 is reported for three waste management units in Table 2-5: 216-A-10 Crib, 216-A-36B Crib, and 216-A-45 Crib. The inventory in Table 2-5 shows that the 43.5 Ci were released to the three cribs with 42.3 Ci attributed to the 216-A-10 Crib. The inventory in Table 2-5 shows 11,467 g (25.3 lb) of plutonium released to waste management units that may have contributed contaminants to the groundwater with 4,300 g (9.5 lb) attributed to the 216-B-7A and 216-B-7B Cribs and 4,270 g (9.4 lb) attributed to the 216-B-5 Reverse Well.

The plume described in Section 4.1.1.7.13 contains an estimated 0.00056 Ci of plutonium. The source of this plume appears to be the 216-B-5 Reverse Well.

As described by Nishita et al. (1979), sorption of ^{239}Pu (and ^{241}Am) is greatest is calcareous soils between pH of 2 and 8, with high solubility below pH 2 and low to moderate solubility above pH 8. Below pH 2, TRUs are primarily in the ionic forms. Between a pH 2 and 8, low solubility indicates rapid hydrolysis, polymerization, and colloid and aggregate formation of TRUs. The solubilities mimic the pH solubility curves for aluminum, iron, and manganese, indicating that the insoluble hydrous oxides of these metals provide sorption sites for the TRUs. Nishita et al. (1979) also note that the presence of complexing or chelating agents, such as nitrate and organics (both of which are present in 200 East Area liquid discharges), increase the solubility of TRUs and are the likely mechanism for some transport of TRUs to the groundwater. Serne and Wood (1990) indicate that the maximum ^{239}Pu sorption occurs at the site in the pH range of 4 to 8.5. Price et al. (1979) indicate that most of the ^{239}Pu is retained in the top 15 m (49 ft) of the vadose zone beneath the 216-Z-1A Crib, with a maximum depth penetration of 30 m (98 ft), due to silicate hydrolysis reactions between the acidic waste liquid and the sediments and precipitation by plutonium-carbonate complexes. Price and Ames (1975) also show that ^{239}Pu at the 216-U-9 and 216-Z-1A Cribs decreases sharply in concentration in the top 9 m (30 ft), including apparent filtering of small plutonium oxide particles in the soil close to the discharge outlet. The half life of ^{239}Pu is 24,400 years.

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4.1.2.3.15 Americium-241. Americium-241 is reported in the radiological inventory for waste management units for the PUREX and B Plant areas (Table 2-5), although americium is presumed to have been present in the processes at all four 200 East Groundwater Area plants due to the presence of irradiated uranium. The values presented in Table 2-5 indicate a total of 5.3 Ci of americium for units at PUREX and B Plant.

Sorption of americium through ion exchange and physical sorption (polymerization and precipitation) to the soil is favored because the predicted ionic state of americium is cationic within the normal soil pH range (Serne and Wood 1990). Numerous organic anions react with americium to form soluble organic complexes, which increases americium mobility when present in the waste stream (Serne and Wood 1990). Americium is very mobile under acid conditions (pH of 1 to 3) and, thus, may be remobilized by acidic releases (Nishita et al. 1979). Price et al. (1979) observed that americium has the same distribution pattern as plutonium in the soil beneath the 216-Z-1A Crib and concluded that americium likely behaves the same as plutonium in the vadose zone. The half life for ^{241}Am is 432 years.

4.1.3 Potential Future Contaminant Plumes

4.1.3.1 Anticipated Changes in Groundwater Flow. Artificial recharge to the unconfined aquifer in the separation areas has dramatically altered the shallow groundwater flow. Before 1944 groundwater within the upper unconfined aquifer flowed generally in a west to east trend across the Hanford Site and the 200 West Area, as discussed in Section 3.5.2. Local groundwater mounding due to artificial recharge, primarily in the vicinity of the 216-B-3 Pond (within the 200 East Area) and the 216-U-10 Pond (within the 200 West Area), has significantly altered the dynamics of this system. Mounding of the water table has caused radial horizontal flow, steepened horizontal hydraulic gradients, and localized downward vertical gradients. As the patterns of artificial recharge have changed, so have the patterns of groundwater flow. This section addresses future groundwater flow patterns that may occur based on anticipated artificial recharge and its overprint on the natural flow regime.

4.1.3.1.1 Existing Conditions. Currently, groundwater flow within the 200 East Area radiates away from 216-B-3 Pond initially, then trends primarily to the east and southeast toward the Columbia River, with a smaller portion directed to the northeast and Gable Gap. Groundwater flow within the 200 West Area trends northeast and east towards the 200 East Area and Gable Gap, with a small component trending to the northwest and the gap west of Gable Butte (Figure 4-16 and Section 3.5.2). Eastward flow from 200 West Area and westward flow from B Pond converge in an area underlying the western portion of the 200 East Area and divide into northern and southern components of flow. The flow ridgeline that divides north from south in this convergence zone approximately bisects the fenced area of the 200 East Area in an east-west direction. Groundwater north of this

ridgeline flows north to Gable Gap, and groundwater south of this ridgeline flows southeastward toward the Columbia River (Figure 4-16).

The configuration of past and present contaminant plumes discussed in Section 4.1.2 provides insight on flow paths from the 200 West Area. Tritium and nitrate, both common components of the waste streams contributing to artificial recharge, are good tracers for defining groundwater flow directions. The tritium plume for the 200 East Groundwater Aggregate Area extends to the southeast and then to the east across a large area, ultimately reaching the Columbia River, as well as to the northwest and apparently through Gable Gap (Figures 4-8 and 4-9). Nitrate has a similarly shaped plume that extends over much of the same area as tritium (Figures 4-4 and 4-5). These trends agree with the flow paths indicated by historical and present potentiometric surfaces (Figures 3-57 to 3-62).

4.1.3.1.2 Future Artificial Recharge. Artificial recharge in the 200 East Groundwater Aggregate Area peaked and remained fairly constant from the 1950's through the 1980's. Mounding of the water table in the area of 216-B-3 Pond appears to have peaked in the mid-1980's following restart of the 202-A Building operations in 1983 and decommissioning of the Gable Mountain Pond (216-A-25) in 1987. Discharge to the 216-B-3 Pond System from sources within the 200 East Area is not expected to decrease substantially until 1994 and 1995, at which time recharge will be shifted to new facilities.

Two SALDS facilities for disposal of treated and untreated wastewater are planned for the 200 Areas. Project C-018H (242-A Evaporator/PUREX Plant Condensate Treatment Facility) is planned for construction to the north of the 200 West Area (see Section 2.7). Tri-Party Agreement milestone M-17-14 (Ecology et al. 1991) indicates that discharge of treated effluent to the soil column will be initiated in October 1994. Project W-049H (200 Area Treated Effluent Disposal Facility) is planned for construction to the east or north of 216-B-3 Pond, with a location nearly 1 km to the east being the preferred location (see Section 2.7). Tri-Party Agreement milestone M-17-08 indicates that operation of this second SALDS will be initiated in June 1995. This shift in discharge areas from current practice will affect future groundwater flow underlying both the 200 West and East Groundwater Aggregate Areas. Discharge to the two SALDS will continue for an indefinite period, but eventually all artificial recharge will be discontinued and the area will revert to essentially natural flow conditions.

4.1.3.1.3 Anticipated Gradient and Flow Changes. The decrease in artificial recharge to the 200 East Groundwater Aggregate Area and its ultimate termination will alter current groundwater flow directions and gradients. Current groundwater flow directions are shown on Figure 4-16, as based on the 1991 water table contour map (Figure 3-49). The current groundwater flow conditions are expected to remain essentially the same until discharge is shifted to the two SALDS facilities in 200 West and 200 East Areas in 1994 and 1995. A

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shift from current discharge to discharge at the SALDS facilities should have the following anticipated effects on groundwater flow and contaminant transport:

- The potentiometric surface of the water table underlying the 200 East Area currently has low relief and a shallow gradient with the exception of the mounding beneath 216-B-3 Pond. The transfer of discharge of a similar rate to the Project W-049H SALDS facility to the preferred location east of 216-B-3 Pond will result in formation of a similar water table mound that is simply shifted slightly in location. The shift in mounding to the east can be expected to lower the water table by an estimated 2 to 4 m (6 to 12 ft) in the area underlying 216-B-3 Pond and by an estimated zero to 2 m (zero to 6 ft) in the area to the west, depending on the proximity of any location to the current mound apex. These estimates are made by shifting the current mound to the new locus of discharge.

- Horizontal groundwater gradients will undergo a very slight change due to the shift in the location of mounding. Westward gradients induced by the present mounding will be reduced slightly, thereby resulting in a moderate reduction in the westward-directed flow that occurs in the eastern portion of the 200 Groundwater East Aggregate Area. The current gradient of approximately 0.003 the western flank of the mound could be reduced to about 0.002 following the shift (gradients decrease sharply with increasing distance from the apex of the mound). Reduction of the gradient in the area underlying 216-B-3 Pond and the PUREX Plant will cause a slight shift to the east in the location of the confluence of eastward- and westward-directed flow. The result of this shift will be a slight reduction in the area underlain by flow to the northeast toward Gable Gap and a corresponding increase in area with flow toward the southeast.

- Shifting of discharge in the 200 West Area to the Project C-018H SALDS on the area's north side will have a minor effect on flow in the 200 East Groundwater Aggregate Area. It is possible that the shifting of discharge and resultant water table mounding to the north may slightly increase flow through Gable Gap from the 200 West Area, thereby causing a slight reduction of flow through the gap from 200 East Groundwater Aggregate Area.

- The downward vertical gradient within the unconfined aquifer in the eastern 200 East Groundwater Aggregate Area also can be expected to be slightly reduced due the lowering of the head. A reduction in the downward vertical gradient between the unconfined and confined aquifers in the area of 216-B-3 Pond also will occur.

- Changes to groundwater flow velocities are not expected to be significant due to the very minor changes anticipated for hydraulic gradients. A small reduction in the rate proportional with the gradient reduction is expected for westward-directed flow in the eastern portion of the 200 East Groundwater Aggregate Area. Incremental reductions

in downward flow in the same area will also correspond to slightly decreased downward hydraulic gradients.

- Besides the shift in the location of discharge to the Project W-049H SALDS and its resultant mounding, thereby causing minor changes to groundwater conditions as described above, the overall configuration of groundwater flow will not be greatly affected. Recharge from irrigation has caused groundwater levels to rise approximately 15 m (50 ft) within the upper Cold Creek valley west of the 200 West Area since 1944 (Graham et al. 1984). Groundwater levels across the 200 Areas Plateau have also risen in response to this recharge and will remain at elevated levels compared to pre-Hanford site activity as long as the groundwater recharge to the west is maintained.

Eventually, all wastewater discharges to waste management units within both the 200 West and 200 East Areas will be eliminated. This elimination of wastewater recharge to the unconfined aquifer will cause the dynamics of the unconfined aquifer to approach pre-Hanford conditions, albeit with a higher water table, as discussed above. Termination of all artificial recharge in the 200 Areas at some point in the future will likely result in the following additional changes:

- All mounding due to artificial recharge will dissipate and the dominant horizontal flow direction will revert to east-southeast across the 200 East Groundwater Aggregate Area (Figure 4-18). No groundwater from the 200 East Area is anticipated to flow through Gable Gap once mounding in the 200 East Area dissipates, although some flow of groundwater through the gap (originating from other areas) likely will continue at a reduced rate. As shown by Freshley and Graham (1988), an increased rate of natural recharge through greater infiltration of precipitation could cause all flow from the 200 Areas to be directed through Gable Gap. However, observations of present conditions do not support this alternative as a likely scenario.

- Horizontal hydraulic gradients within the 200 East Groundwater Aggregate Area will be reduced due to elimination of mounding. An area of very low hydraulic gradients will remain underlying the western portion of 200 East Groundwater Aggregate Area, but the overall gradient between the site and the Columbia River is expected to stabilize to a gradient below 0.001.

- Downward vertical gradients between aquifers will be essentially eliminated. The only current area of significant downward gradients, which occurs in the area of 216-B-3 Pond and which will soon shift to beneath the Project W-049H SALDS, will eventually return to natural conditions. The vertical gradient between the unconfined aquifer and the confined basalt aquifers likely will revert to pre-Hanford Site conditions of an upward vertical gradient once mounding is gone, but not at the same magnitude as

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previously due to the higher water table that will be maintained by continued artificial recharge from irrigation to the west in upper Cold Creek valley.

- The decrease of horizontal gradient values will result in a proportional decrease in the rate of groundwater flow (and contaminant transport) from the 200 East Groundwater Aggregate Area.

4.1.3.2 Anticipated Releases from Vadose Zone. Potential future releases to the groundwater from the vadose zone include continued downward migration of previously released contaminants, leaching of sorbed or precipitated contaminants from the soil by water discharged through active units or by infiltrating precipitation, and contaminants entrained in discharge to currently active waste management units. It is possible that none of these modes will greatly affect present contaminant plumes, although some additional contribution of contaminants to the unconfined aquifer can be expected.

Gross gamma geophysical logging has not provided evidence that downward migration of radionuclides is ongoing in the vadose zone (spectral gross gamma logging may provide more definitive data in the future). However, slow draining of soil underlying waste management units that were recently closed may contribute some small amount of additional contaminants to the groundwater.

Leaching of sorbed or precipitated contaminants may occur at locations where water flows through contaminated soil zones. Such occurrences due to natural infiltration are probably negligible due to the very low rate for the site. Leaching of contaminants from the soil may occur in areas of continued artificial recharge. Remobilization of contaminants is not likely to be significant unless the waste discharged significantly alters the chemical conditions (e.g., a significant change to the pH).

The *Liquid Effluent Study Final Project Report* (WHC 1990b) documents the history and characteristics of current liquid discharges. The report includes discussion of twelve waste management units in the 200 East Area, seven of which were active at that time: 216-A-29 Ditch, 216-A-30 Crib, 216-A-37-2 Crib, 216-B-3 Pond System, 216-B-55 Crib, 216-B-62 Ditch, and 216-B-63 Trench. 216-A-8 Crib, which also is discussed, presently is inactive but may be put in service again in the near future. Discharges for these units were listed in a range of 114 m^3/month (216-A-8 Crib) to 4,590,000 m^3/month (216-B-3 Pond System). Calculated travel times for liquid discharge to reach the groundwater range from 25 days (216-B-63 Trench) to 417 days (216-A-29 Ditch). Most of these discharges contained low concentrations of metals and radionuclides, with some containing organic compounds such as acetone. The *Liquid Effluent Study Final Project Report* (WHC 1990b) states that in most cases a negligible impact to the groundwater is expected from future discharges. The largest impact anticipated is the impact on groundwater flow that will result from continued discharge to the 216-B-3 Pond System in the short term. Mounding in the pond area will

maintain hydraulic gradients that result in higher rates of groundwater flow than would occur under natural conditions. Discharges have been reduced significantly since the issuance of the *Liquid Effluent Study Final Project Report* (WHC 1990b) due to restrictions imposed in TPA Milestone M-17.

4.1.3.3 Projected Contaminant Plumes. Projected groundwater flow paths are presented in Section 4.1.3.1 for periods following cessation of artificial recharge to the 200 West and 200 East Areas (Figures 4-17 and 4-18). These flow paths can be used for estimating the trend of future contaminant plume migration. Section 4.1.3.2 indicates that no significant sources are anticipated for contaminants in the groundwater that will significantly affect the contaminant plumes presented in Section 4.1. Therefore, groundwater flow paths presented in Figures 4-17 and 4-18 can be applied to present contaminant plumes to project future trends in migration.

In general, the most significant change to contaminant migration will not occur in the near future when discharge is shifted to the two SALDS, but rather when all artificial discharge ceases and the water table mound in the 200 East Area has dissipated. When that has occurred and groundwater flow dynamics again approach the pre-Hanford conditions (Figure 4-18), contaminant transport by advection will occur along a generally eastern to southeasterly trend with rates only slightly reduced from present rates. Contaminant transport from the 200 East Groundwater Aggregate Area through Gable Gap will cease.

The projected effect of future contaminant transport by advection with groundwater flow is discussed below for each contaminant plume presented in Section 4.1 (Figures 4-1 to 4-15).

4.1.3.3.1 Arsenic. The arsenic plumes represent relatively small areas of elevated contamination without clear evidence of current plume migration (Figure 4-1). In the near future, plumes C and D will continue to be directed along flowpaths to the southeast. Plumes A and B likely will be directed to the northwest. In the long term, plume migration will be directed along flowpaths to the east and southeast.

4.1.3.3.2 Chromium. Three locations of elevated chromium concentrations (greater than 50 μg/L) occur over limited areas and without clear evidence of current plume migration (Figure 4-2). In the near future, plumes A and B likely will continue to be directed to the northwest and plume C may be shifted from the southeast to the northwest. In the long term, all three plumes will be directed to the east and southeast.

4.1.3.3.3 Cyanide. Elevated levels of cyanide (greater than 200 μg/L) are observed in only one location (Figure 4-3). Current and near future groundwater flow directions will result in a northwestward transport of cyanide. In the long term, the cyanide plume will be directed to the southeast.

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4.1.3.3.4 Nitrate. As shown on Figures 4-4 and 4-5, elevated levels of nitrate are widespread in the 200 East Groundwater Aggregate Area with several areas having concentrations greater than 45,000 μg/L and with apparent discharge of nitrate to the Columbia River. Most of the plume extends southeast and east from the source areas, but a component apparently has migrated to the northwest through Gable Gap. Current and near future groundwater flow directions will result in continued migration with only minor shifting in the near future of some nitrate transport from the northwest to the southeast. In the long term, nitrate contaminant transport will be shifted almost entirely to the east and southeast, while transport of nitrate that has already reached the Gable Gap area will continue northward, but its source will be cut off by the change in groundwater flow. Flow of nitrate into the Columbia River will continue, although concentrations are expected to diminish with time as releases of nitrate to the groundwater are reduced.

4.1.3.3.5 Gross Alpha. Gross alpha is an indicator of uranium, plutonium, americium, and other high atomic number radionuclides. As such, it will follow the migration patterns of these radionuclides.

4.1.3.3.6 Gross Beta. Gross beta is an indicator of many of the fission product radionuclides. As such, it will follow the migration patterns of those radionuclides.

4.1.3.3.7 Tritium. As shown on Figures 4-8 and 4-9, elevated levels of tritium, like nitrate, are widespread in the 200 East Groundwater Aggregate Area with great areas having concentrations greater than 20,000 pCi/L and with apparent flow of tritium into the Columbia River. Most of the plume extends southeast and east from the source areas, but a component with lower concentrations apparently has migrated to the northwest through Gable Gap. Current and near future groundwater flow directions will result in continued migration in the same directions with only minor shifting in the near future of some tritium transport from the northwest to the southeast. In the long term, tritium contaminant transport will be shifted almost entirely to the east and southeast, while transport of tritium that has already reached the Gable Gap area will continue northward, but its source will be cut off by the change in groundwater flow. Flow of tritium into the Columbia River will continue, although concentrations are expected to diminish with time as releases of tritium to the groundwater are reduced and released amounts continue to decay.

4.1.3.3.8 Cobalt-60. The ^{60}Co plume, as shown on Figure 4-10, will continue to be directed to the northeast in the present and near future. In the long term, the direction of transport will be reversed to the southeast.

4.1.3.3.9 Strontium-90. Currently, plumes A and B of ^{90}Sr (Figure 4-11) are being directed to the northwest by groundwater flow, with plumes C and D being directed to the southeast. In the near future, plume B might possibly be redirected to the southeast. In the long term, all plumes are expected to be directed to the east and southeast.

4.1.3.3.10 Technetium-99. Plumes A and B of ^{99}Tc (Figure 4-12) are being directed to the northwest by present groundwater flow and this can be expected to continue in the near future. In the long term, the direction of transport flow for both plumes will be redirected to the east-southeast.

4.1.3.3.11 Iodine-129. The ^{129}I plume, as shown on Figure 4-13, underlies the center of 200 East Area and currently is divided by bifurcating groundwater flow into transport to the northwest and southeast. Transport in the near future will be similar, but with a slightly larger component expected to be directed to the southeast. In the long term, all transport is expected to be directed to the east-southeast.

4.1.3.3.12 Cesium-137. The ^{137}Cs plume shown on Figure 4-14 indicates a limited area of elevated concentrations above 120 pCi/L in the central portion of the 200 East Area. Current contaminant transport appears to be to the northeast and this is likely to continue in the near future. However, contaminant transport in the long term is expected to be directed to the east-southeast.

4.1.3.3.13 Plutonium-239/240. The $^{239/240}Pu$ plume shown on Figure 4-15 indicates a limited area of elevated concentrations above 1 pCi/L in the central portion of the 200 East Area. Current contaminant transport appears to be to the northeast and this is likely to continue in the near future. However, contaminant transport in the long term is expected to be directed to the east-southeast.

4.1.4 Interactions of Study Area Groundwater with Other Areas

As discussed above, groundwater flow from the 200 East Area has resulted in contaminant transport through advection in the unconfined aquifer. The transport has occurred primarily to the east-southeast and to the northwest. Nitrate and tritium, which have been discharged in large quantities and also are very mobile in groundwater, form the largest plumes and have traveled the longest distance. Both nitrate and tritium have been advected to the east-southeast from the 200 East Area and have been discharged to some degree to the Columbia River. Nitrate and tritium also have been transported northward to the area of Gable Gap, but these and other contaminants do not appear to have travelled a long distance through the gap (at least in high concentrations) and are unlikely to have impacted groundwater in the 100 Area or the Columbia River.

Figure 4-16 illustrates flowpaths for present conditions. The flowpaths indicate that migration of mobile contaminants is divided to the east-southeast and to the northwest.

Qualitatively estimated near-future migration during operation of the SALDS (following closure of all existing 200 Areas liquid waste disposal units) indicates that these contaminants

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will continue along similar migration paths to the present, but with slightly increased transport to the east-southeast due to a shift of discharge and mounding to the east (Figure 4-17).

Estimated groundwater flow in the future (also qualitative), when all artificial recharge has ceased and related mounding has dissipated, will result in flow from both 200 Areas to trend to the east-southeast (Figure 4-18). At such a time, mobile contaminants advected from the 200 East Area will be transported eastward and southeastward toward the Columbia River, while contaminant transport to the northwest will have ceased. Mobile contaminants advected from the 200 West Area also will be transported eastward and southeastward where they may commingle with contaminants from the 200 East Area.

4.2 POTENTIAL IMPACTS TO HUMAN HEALTH

This preliminary assessment is intended to provide a qualitative evaluation of potential human health and environmental hazards associated with the known and suspected contaminants in the 200 East Groundwater Aggregate Area. The assessment includes a discussion of potential transport pathways, develops a conceptual model of human exposure based on these pathways, and presents the physical, radiological, and toxicological characteristics of the known or suspected contaminants.

The primary transport pathway addressed in this section is migration of contaminants from waste management units and unplanned releases to groundwater, transport within groundwater, and transport from groundwater to surface water. Other transport pathways that could potentially lead to exposures to human or environmental receptors (e.g., airborne dust transport) were discussed in the AAMSRs for the individual source areas within the 200 East Area boundary.

It is important to note that these evaluations do not attempt to quantify potential human health risks associated with exposure to 200 East Groundwater Aggregate Area contaminants. Such a risk assessment cannot be performed until additional characterization data are acquired. Risk assessments will be performed in accordance with the *Hanford Site Baseline Risk Assessment Methodology* (DOE/RL 1991d) which was prepared in response to the M-29 milestone. This document incorporates the requirements established in the *Risk Assessment Guidance for Superfund* (EPA 1989b) and the *EPA Region 10 Supplemental Risk Assessment Guidance for Superfund* (EPA 1991).

4.2.1 Release Mechanisms

Waste management units and unplanned releases can be divided into two general categories based on the nature of the waste release: (1) units where waste was discharged directly to the environment; and (2) units where waste was disposed of inside a containment structure and must bypass an engineered barrier to reach the environment.

In the first group are those waste management units where release of wastes to the soil column was an integral part of the waste disposal strategy. Included in this group are tile fields, ditches, french drains, seepage basins, cribs, reverse wells, septic system drain fields, and some disposal trenches. Also in this group are unplanned releases that involved waste material contacting soil. For these types of waste management units, if discharges to the unit contained chemicals of concern, it can be assumed that soils underlying the waste management unit may contain some of the chemical being disposed of. The first task in developing a conceptual model for these units is to determine whether chemicals of concern are retained in soil near the waste management unit, or are likely to migrate to the underlying aquifer and then to receptor points such as drinking water wells or surface water bodies. Factors affecting migration of chemicals away from the point of release will be discussed in the following section.

In the second group are waste management units that were intended to act as a barrier to environmental releases. Included in this group are burial grounds containing drums or other containers, vaults and caissons, storage and treatment tanks, cribs with membrane liners, retention basins, waste transfer facilities, and unplanned releases that occurred within containment structures. Waste management units that received only dry waste can also be included in this category, since the potential for wastes to migrate to soils outside of the unit is low due to the negligible natural recharge rate at the Hanford Site. However, early disposal records (prior to about 1968) are incomplete; therefore, it is possible that some liquid wastes may have been disposed to these units. For these waste management units, the first consideration to be addressed in developing a conceptual model is the integrity of the containment structure.

The ability of this report to evaluate the efficacy of engineered barriers is limited by the lack of vadose zone and subsurface soil sampling data for many waste management units. Indication of radioactive waste releases is provided by gamma logging of boreholes; however, the usefulness of these data is limited by methodological problems, and this information also is not available for all waste management units. Available sampling information and gamma logs for the waste management units and unplanned releases are summarized in Section 4.1 of each individual source AAMSR.

The efficacy and integrity of concrete liners (e.g., retention basins), and concrete and steel tanks and vaults have not been determined for all units of this type. Certain single-shell

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tanks within the B Plant and PUREX Plant Aggregate Areas have been classified as assumed or confirmed leakers based on historical inventory information and/or the results of gamma logging of boreholes. The potential for releases to groundwater is expected to be low for waste management units that received only dry wastes such as contaminated dirt, decommissioning wastes (e.g., the 218-C-9 Burial Ground) and process equipment.

4.2.2 Transport Pathways

Transport pathways expected to affect contaminants in the 200 East Groundwater Aggregate Area are summarized in this section, including the following:

- Drainage and leaching of bulk fluids and dissolved contaminants from soil to perched water and groundwater
- Transport in the groundwater
- Vapor transport in the subsurface
- Migration between groundwater and surface water.

4.2.2.1 Transport from Soils to Perched Water and Groundwater. Soil is the initial receiving medium for waste discharges in the 200 East Groundwater Aggregate Area, whether the release is directly to soil or through failure of a containment system. Several factors determine whether chemicals that are introduced into the vadose zone will reach a perched water zone or the unconfined portion of the uppermost aquifer, which lies at depths of approximately 60 to 90 m (200 to 290 ft) below ground surface in the 200 East Area. These factors are discussed in the following sections.

4.2.2.1.1 Depth of Release. Waste management units that released wastes at a greater depth below the surface are more likely to contaminate groundwater than waste management units where the release was shallow. Units designed to release wastes below the surface include french drains, cribs, and reverse wells. The deepest units located in the 200 East Area are five reverse wells within the B Plant Aggregate Area, which discharged radioactive liquid wastes slightly above or below the water table. Because of this proximity to the water table, reverse wells are known or presumed to have contributed contaminants to the groundwater.

4.2.2.1.2 Liquid Volume or Recharge Rate. The primary mechanism leading to migration of waste constituents to the water table is distillation from infiltrating soil pore water. In the absence of natural recharge, chemicals migrate by the generally slower mechanism of molecular diffusion. In the 200 East Groundwater Aggregate Area, the primary sources of recharge are precipitation and waste management units that discharge

liquid waste to the soil column. As discussed in Section 3.5.1.2, estimates of natural precipitation recharge range from zero to 10 cm/yr (4 in./yr), primarily depending on surface soil type, vegetation, and topography. Gravelly surface soils with no or minor shallow-rooted vegetation appear to facilitate precipitation recharge. One modeling study (Smoot et al. 1989) indicated that some radionuclide (^{137}Cs and ^{106}Ru) transport can occur with as little as 5 cm/yr (2 in./yr) of natural recharge. However, other researchers (Routson and Johnson 1990) conclude that no net precipitation recharge occurs in the 200 Areas, particularly at waste management units that are capped with fine-grained soils or impermeable covers.

With respect to artificial recharge, as discussed in Section 2.3, waste management units (e.g., the 216-B-12 Crib, 216-A-6 Crib, and 216-C-1 Crib) were identified in which the known volume of liquid waste discharged exceeded the total estimated soil pore volume present below the footprint of the facility. In these cases, the moisture content of soil below the waste management units likely approached saturation during the period of use of these facilities. Because unsaturated hydraulic conductivity is maximized at water contents near saturation, the volume of liquid wastewater historically discharged to the waste management units identified in Table 2-1 probably enhanced fluid migration in the vadose zone beneath these units.

Contaminants that are not initially transported to the water table by downward water flow may be mobilized at a later date if an additional large volume of liquid is added to the waste management unit. In addition, liquids discharged to one unit could mobilize wastes discharged to an adjacent unit if lateral migration takes place within the vadose zone. An example of this process occurred at the 216-U-16 Crib in the U Plant Aggregate Area where lateral migration of waste above a caliche layer mixed with and transported acidic waste beneath the 216-U-1 and 216-U-2 Cribs in the 200 West Area that had remobilized previously sorbed or precipitated radionuclides. At present, artificial recharge within the 200 East Groundwater Aggregate Area is limited to septic wastewaters, cooling waters, and other noncontact wastewaters. The potential interactions between these discharges and adjacent waste management units generally have not been characterized.

4.2.2.1.3 Soil Moisture Transport Properties. As discussed in Section 3.5.2, moisture flux in the vadose zone is dependent on hydraulic conductivity as well as gradients of moisture content or matrix suction. Higher unsaturated hydraulic conductivities are associated with higher moisture contents. However, higher unsaturated hydraulic conductivities may be associated with fine-grained soils compared to coarse-grained soils at low moisture contents. Due to the highly stratified nature of Hanford Site vadose zone soils and the moisture content dependence of unsaturated hydraulic conductivity, lateral spreading is expected. Lateral spreading commonly occurs at any interface within the vadose zone between fine- and course-grained soils. This lateral spreading may substantially reduce the potential for contaminant migration to the uppermost aquifer.

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Conditions leading to the accumulation of soil moisture or liquid waste in soil zones above the water table (perched water zones) are discussed in Section 3.5.1.1.2. The presence of perching layers beneath waste management units where liquid wastes were released may have led to lateral migration of contaminants away from the point of release.

Rapid transport of contaminants to the subsurface may occur if contaminants are able to migrate along the casing of an improperly sealed monitoring well or borehole.

4.2.2.1.4 Retardation. The rate at which contaminants will be transported through unsaturated soils depends on a number of characteristics of the chemical, the waste, and the soil matrix. In general, chemicals that have low solubilities in the leaching fluid or strongly sorb to soils will be retarded in their migration velocity compared to the movement of soil pore water. Studies have been conducted of soil parameters affecting waste migration at the Hanford Site to attempt to identify the factors that control migration of radionuclides and other chemicals. Recent studies of soil sorption applicable to the Hanford Site are summarized by Cantrell and Serne (1992), Ames and Serne (1991), and Serne and Wood (1990). Some of the processes that have been shown to control the rate of transport are the following:

- **Adsorption to Soils.** Most contaminants are chemically attracted to some degree to the solid components of the soil matrix. For organic compounds, the adsorption is generally to the organic fraction of the soil, although in extremely low-organic soils, adsorption to inorganic components may be of greater importance. Soil components contributing to adsorption of inorganic compounds include clays, organic matter, and iron and aluminum oxyhydroxides. In general, surface and Hanford formation soils are characterized as sandy or gravelly with very low organic content (<0.1%) and low clay content (<12%) (Tallman et al. 1981). Thus, site-specific adsorption factors are likely to be lower, and rate of transport higher, than the average for soils nationwide.

- **Filtration.** Filtration of suspended particulates by fine-grained sediments was suggested as a mechanism for concentration of plutonium in certain sedimentary layers at the 216-Z-1A Tile Field in the 200 West Area. This finding suggests that migration of suspended particulates may be an important mechanism of transport for chemicals of low solubility. Particulates in the colloid size range may pass through even fine-grained soils.

- **Solubility.** The migration of some chemicals from the point of release is controlled by the rate of dissolution of the chemical from a separate phase. The concentration of such chemicals in the pore water will be extremely

low, even if they are poorly sorbed to soils. An example cited by Serne and Wood (1990) is the low rate dissolution of plutonium oxide, which appears to be the limiting factor controlling the release of plutonium from waste materials at neutral and basic pH.

- **Organic Content of Waste.** Waste liquids containing high concentrations of certain organic compounds can alter the rate of transport of the waste constituents through soils. A liquid with a low dielectric constant, such as carbon tetrachloride, can cause clays within the soil to shrink, which will increase the permeability of the soil by creating cracks and fissures (DOE/RL 1991c). In addition, the complexing of many inorganic compounds with organic compounds in the waste stream can greatly increase the mobility of the compounds (see Section 4.2.2.1.5).

- **Ionic Strength of Waste.** For some inorganics, the dominant mechanism leading to desorption from the soil matrix is ion exchange. Leachant having high ionic strength (high salt content) can bias the sorption equilibrium toward desorption, leading to higher concentrations of the chemical in the soil pore water. Wastes within the 200 East Aggregate Area that can be considered of high ionic strength include any releases from the PUREX and B Plant Aggregate Area tanks, and liquid coating wastes from the REDOX and PUREX pilot process condensates.

- **Waste pH.** The pH of a leachant has a strong effect on inorganic contaminant transport. Acidic leachates tend to increase migration both by increasing the solubility of precipitates and by changing the distribution of charged species in solution. The exact impact of acidic or basic wastes will depend on whether the chemical is normally in cationic, anionic, or neutral form, and the form that it takes at the new pH. Cationic species tend to be more strongly adsorbed to soils than neutral or anionic species. The extent to which addition of acidic leachate will cause a contaminant to migrate will also depend on the buffering or neutralizing capacity of the soil, which is correlated with the calcium carbonate ($CaCO_3$) content of the soil and the extent of reaction of acidic wastes with soil silicates (Price et al. 1979). The soils in the Hanford formation generally have carbonate contents in the range of 0.1 to 5%. Higher carbonate contents (20 to 30%) are observed within the Plio-Pleistocene caliche layer. Once a waste liquid has been neutralized, the dissolved constituents may reprecipitate or become readsorbed to the soil.

Observations of pH impacts on waste transport at the Hanford Site include the following:

- Mobilization of plutonium and americium isotopes beneath the 216-Z-1A Tile Field in the 200 West Area by acid liquid waste depended on a combination of pH effects and complexation by organic components of the waste. These processes were implicated in migration of the radionuclides to a depth of 30 m (100 ft) below the bottom of the crib

- Leaching of americium from 216-Z-9 Trench sediments, in the same vicinity, was found to be solubility controlled and correlated to solution pH (Rai et al. 1981).

4.2.2.1.5 Complexation and Cosolvation. Certain materials disposed of within the 200 East Groundwater Aggregate Area are known to form complexes with inorganic ions, which can enhance the solubility and mobility of the inorganic species. Tributyl phosphate, dibutyl phosphate, EDTA and HEDTA are the primary organic complexing agents disposed of in the 200 East Area. However, these compounds were not analyzed for or not detected (tributyl phosphate) in groundwater in the 200 East Area.

Cyanide ions can form complexes with many metal cations, but formation of such complexes reduces the mobility of cyanide compounds compared to the mobility of the free ion, but commonly increases the mobility of the metal.

The presence in leachate of high levels of water-miscible organic solvents can mobilize strongly sorbed organic compounds by the process of cosolvation, and may also impact mobility of inorganic contaminants. Laboratory studies cited by Price et al. (1979) indicate that the presence of organic wastes reduced sorption of ^{239}Pu to Hanford Site soils. Although water-miscible solvents such as acetone were detected in 200 East Area groundwater at relatively low (ppb) levels, there is no indication that sufficient volumes were disposed of in waste management units to lead to significant cosolvent effects.

4.2.2.1.6 Contaminant Loss Mechanisms. Processes that can lead to loss of chemicals from soils and thus decrease the amount of chemical available for leaching to groundwater include the following:

- **Radioactive Decay.** Radioactivity of radionuclides decays over time and generally decreases the quantities and impacts from radioactive isotopes. However, for some radioactive decay chains, in-growth of daughter products can temporarily lead to a net increase in radioactive emissions over time.

- **Biotransformation.** Microorganisms in the soil may degrade organic chemicals such as acetone and inorganic chemicals such as nitrate.

- **Chemical Transformation.** Hydrolysis, oxidation, reduction, radiolytic degradation, and other chemical reactions are possible degradation mechanisms for contaminants.

- **Vegetative Uptake.** Vegetation may remove chemicals from the soil, bring them to the surface, and at the same time thereby introduce them to the food web.

- **Volatilization.** Organic chemicals and volatile radionuclides can partition into the soil vapor phase. Some elements (mainly fission products such as iodine, ruthenium, cerium, and antimony) are referred to as "semivolatiles" because they have a lesser tendency to volatilize.

4.2.2.2 Transport in Groundwater. The primary mode of contaminant migration in the 200 East Area groundwater is advective transport of dissolved chemicals. Other processes that could lead to migration of contaminants in groundwater include transport of suspended particulates, diffusion, density-driven flow of high-salt liquids (e.g., perhaps from the BY cribs), and bulk flow of dense nonaqueous phase liquids (DNAPLs). The presence of fine-grained silt layers in the unsaturated zone will generally prevent particulates larger than the colloid size range from reaching groundwater. In low hydraulic conductivity materials (e.g., clays) diffusion may be a significant transport mechanism.

The transport of dissolved contaminants in the saturated zone is affected by the groundwater flow rates and flow paths, retardation of contaminants, and contaminant loss mechanisms. The impact of each of these factors is discussed below.

4.2.2.2.1 Hydrologic Factors. Local and regional flow patterns at the 200 East Area and Hanford Site are described in Section 3.5. Based on this information and the plume distributions described in Section 4.1, the primary directions of transport from most of the 200 East Area are east to southeast, toward the Columbia River and north, through Gable Gap. Artificial recharge from disposal of liquid wastes and reactor cooling waters has led to mounding of groundwater beneath the 200 Areas. The effect of the mounding is that a greater fraction of the groundwater flow from the northern part of the 200 East Area is diverted northward toward Gable Gap.

Variations in horizontal hydraulic conductivity across the Hanford Site impact the travel time of contaminants to offsite receptors. As discussed in Section 3.5, the uppermost aquifer in the 200 East Area lies partially within the more permeable Hanford formation while in the 200 West Area, the uppermost aquifer lies within the generally less permeable Ringold Formation, Thus, the rate of contaminant transport is generally faster in the 200 East Area than in the 200 West Area (Freshley and Graham 1988). The zone of higher permeability strata which crosses the 200 East Area from northwest to southeast appears to act as a preferential flow path for contaminant transport. As discussed in Section 4.1, this flow

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pattern can be discerned in the contours of the tritium plume which extends in a southwestern direction from the 200 East Area.

The potential for transport of contaminants from the uppermost aquifer to migrate to the confined aquifer and the regional basalt aquifer depends on the existence of downward vertical gradients. As discussed in Section 3.5, hydrologic studies suggest that downward gradients are present in some areas of the Hanford Site due to groundwater mounding beneath wastewater disposal facilities. Vertical gradients are downward to negligible across the 200 East Area; thus, some downward transport of mobile dissolved constituents is likely. Certain highly mobile contaminants have been detected in wells screened within the confined aquifer (e.g., tritium, uranium, technetium).

4.2.2.2.2 Retardation in Groundwater. Mechanisms leading to retardation of contaminants on aquifer solid materials are generally the same as those occurring in the unsaturated zone, which are described in Section 4.2.2.1.4. Physical/chemical mechanisms causing a contaminant to be retarded in its migration relative to the groundwater include adsorption, ion exchange, precipitation, and chemical reaction with aquifer solids.

The geochemical environment of the saturated zone may differ from that of the vadose zone particularly in terms of its redox potential, pH, and soil-water ionic composition. In addition, introduction of concentrated waste solutions into the saturated zone may alter significantly the rate of transport of contaminants compared to their behavior in dilute solutions. Potential impacts of concentrated wastes on contaminant mobility include the following:

- Bacterial metabolism of waste materials that can act as substrates for microbial growth (e.g., biodegradable organic compounds, nitrate, sulfate) can create localized areas of anoxic, low Eh conditions in the groundwater. Some inorganic species (e.g., arsenic, heavy metals) are more mobile under these conditions. Ames and Serne (1991) concluded, however, that the persistence of nitrate in Hanford Site groundwater indicates that biotransformation of nitrate is not a significant process.

- High concentrations of chloride or other ionic species can affect the binding properties of clay surfaces and metal hydroxides, altering the sorption of contaminants to soil materials.

- Anionic contaminants, e.g., chloride (Cl^-) and fluoride (Fl^-), can migrate through clay soils at a velocity greater than the average rate of groundwater movement. This phenomenon, known as anion exclusion, is due to repulsion between the contaminant anions and negatively charged soil surfaces (Dragun 1988).

- Alteration in groundwater pH due to introduction of acidic or basic wastes into the aquifer can modify contaminant mobility both by affecting the ionic form of the contaminant and by changing the binding characteristics of soil adsorptive surfaces (i.e., metal oxides, clay minerals, and soil organic matter) (Dragun 1988).

4.2.2.2.3 Contaminant Loss Mechanisms. Processes leading to loss of contaminants from groundwater are generally the same as those affecting contaminants in the vadose zone: radioactive, chemical, and biological decay. Contaminant losses from volatilization are expected to occur primarily in near-surface soils, and this loss mechanism is likely to be less important once contaminants reach the water table.

4.2.2.4 Vapor Transport in the Subsurface. Migration of chemical vapors in the unsaturated zone pore spaces was suggested as an important transport pathway for carbon tetrachloride and other volatile organics in the 200 West Area (DOE/RL 1991c). Lateral migration of vapors like carbon tetrachloride vapors above or below the Plio-Pleistocene caliche layer due to density-driven migration and diffusion was proposed as a potential explanation for detection of this chemical at locations distant from known disposal locations. Equilibration of these vapors with infiltrating wastewater or natural recharge can then provide a source of contamination of perched water or groundwater. Due to the slope of the Plio-Pleistocene layer, vapor transport can lead to migration of contaminants in directions opposite to the regional groundwater flow direction (DOE/RL 1991c).

Although numerous volatile organic compounds have been detected sporadically in groundwater in the 200 East Area (see Section 4.1), there is no indication that high concentrations of these chemicals are present in the subsurface. Therefore, the importance of vapor transport in the 200 East Area has not been determined.

4.2.2.5 Transport from Groundwater to Surface Water. The only naturally occurring surface water body in the 200 East Area vicinity is West Lake, a pond near Gable Gap, some distance away from contaminant plumes. Man-made surface water bodies (e.g., ditches and ponds) are present, but these are not in hydraulic contact with the underlying aquifer. Thus, no transport of contaminants from groundwater to these surface waters is anticipated.

Transport of contaminants to surface water bodies outside of the 200 East Groundwater Aggregate Area via groundwater discharge is the primary pathway of potential concern for the 200 East Area. Flow from the unconfined portions of the uppermost aquifer is into the Columbia River, either via springs near the river or by direct flow into the river. As discussed above, groundwater from the 200 East Area may reach the river either to the north, via Gable Gap, or to the east and southeast. Discharge of water with potential contaminants is also possible from the Rattlesnake Ridge aquifer at discharge points to the

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Yakima River, and indirectly to the Columbia River via localized upward gradients to the unconfined system. Groundwater flow is discussed in Section 3.5.2.

A number of studies attempt to estimate the time required for contaminants to travel in groundwater from the 200 Areas to the Columbia River. Freshley and Graham (1988) summarize the results of many of these studies as well as the methodology and assumptions used to obtain the estimates. Methods used to derive time of travel estimates include use of plume monitoring data, flow tracer studies, extrapolation of local hydrologic measurements, and groundwater modeling. Based on historical plume configurations of tritium, the most mobile contaminant present in the 200 East Area groundwater, the 30 pCi/L tritium plume reached the river around 1976 to 1979 (Freshley and Graham 1988). Estimates of the time required for tritium from the PUREX cribs to reach the river range from to 13 to 23 years. Time of travel estimates vary due to differing methods used to derive the estimates (i.e., based on monitoring data or flow modeling), the assumed release date, the starting location and the flow path that the contaminant takes to the river. For estimates obtained from modeling, time of travel depends on assumptions incorporated into the model about future hydrologic gradients and recharge conditions.

4.2.3 Conceptual Model

Figure 4-19 presents a graphical summary of the contaminant sources, release mechanisms, and 200 East Area/Hanford Site physical characteristics that could potentially affect the generation, transport, and impact of contaminants in the 200 East Area groundwater on humans and biota (conceptual model).

Sources of potential environmental contamination were summarized in Section 2.0. Some of the major sources of wastes include: stack emissions and drainage, PUREX and REDOX process wastes, critical mass laboratory wastes, analytical laboratory wastes, sanitary waste and sewage, process feed materials, contaminated equipment or waste material that was spilled during transit or disposed of in the burial grounds, and decommissioning debris from Semi-Works.

Contaminants from these and other sources have been disposed of at the PUREX, B Plant and Semi-Works waste management units. The units include ponds, ditches, retention basins, single-shelled tanks, settling tanks, tank farms, trenches, cribs, french drains, reverse wells, diversion boxes, catch tanks, valve pits, septic tanks and drain fields, vaults, WESF Storage Pool, burial grounds, and the various unplanned releases that have occurred within the 200 East Area. Releases from these disposal activities and resulting contamination of the aquifer beneath the 200 East Area are described in Sections 2.0 and 4.1.

The focus of the 200 East Area groundwater conceptual model is on the migration of contaminants from the waste management units and unplanned releases to groundwater, transport within the groundwater, and transport from groundwater to surface water. Other release mechanisms that may have transported contamination to potentially affected surface media are addressed in the source area AAMSRs.

Many waste management units discharge their waste effluents directly to the near surface (vadose zone) soils. The trenches are potential release points via leaching or drainage of the liquid portion of the disposed materials. The cribs provide seepage discharge and similarly the french drains, reverse wells, and septic system drain fields directly inject their effluents into the subsurface sediments. The unplanned releases have mainly impacted surface soils, with the exception of tank leaks, which generally release wastes to the shallow subsurface.

The primary mechanism of vertical contaminant migration is the downward movement of water from the surface through the vadose zone to the unconfined aquifer. The contaminants generally move as a dissolved phase in the water, and their rate of migration is controlled both by water movement rates and by adsorption and desorption reactions involving the surrounding sediments. Other transport pathways that may be significant are vapor transport (for volatile organics) and diffusion (for fine-grained soils). Some contaminants are strongly sorbed on sediments and their downward movement through the stratigraphic column is greatly retarded. Significant lateral migration of contaminants is restricted to perched water zones and to the unconfined aquifer, where water is moving laterally. Again adsorption and desorption reactions may greatly retard lateral contaminant migration. Contaminants that were introduced to the soil column outside of the aggregate area may migrate into the area in the aquifer through advection by groundwater flow. As another potential mechanism of vertical contaminant migration, bad well seals may promote downward movement of chemical constituents within the uppermost aquifer and between the uppermost and Rattlesnake Ridge aquifers. Contamination promoted by suspected bad well seals is discussed in Section 4.1.1.

Once contaminants reach the uppermost unconfined aquifer, their primary mode of continued migration is by advective transport as dissolved chemicals. If sufficient volumes of nonmiscible organic solvents are present, they may migrate via bulk flow either above or below the water table; however, there is no indication that such separate phase organic layers are present in 200 East Area groundwater.

Humans (offsite and onsite) and other biota (plants and animals) can be exposed to groundwater contaminants as a result of withdrawal and use of contaminated groundwater obtained from wells, or as a result of withdrawal and use of surface water that has been contaminated by groundwater migration and discharge to surface water. There are four

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general routes by which direct or indirect exposure to contaminants in groundwater can occur at a waste site:

- Inhalation of airborne volatiles or fugitive dusts from surface soils contaminated through irrigation with ground or surface water
- Ingestion of water, fugitive dust, surface soils, agricultural products, or other biota (either directly or through the food chain)
- Direct contact with waterborne contaminants or contaminated surface soils
- Direct radiation by waterborne contaminants, surface soils, or fugitive dusts.

4.2.4 Characteristics of Contaminants

Table 4-6 is a list of radioactive and nonradioactive chemical substances that represent candidate contaminants of potential concern for the 200 East Groundwater Aggregate Area. Chemicals on this list were identified from the following sources:

- Chemicals detected in groundwater within the 200 East Groundwater Aggregate Area, as reported in Connelly et al. (1992a) and the Westinghouse Hanford groundwater data base.
- Chemicals reported in waste disposal inventories for those PUREX, B Plant and Semi-Works Aggregate Area waste management units which were determined to be potential sources of release to groundwater, based on release volume and soil pore water capacity.
- Chemicals reported in the TRAC inventory system for those single-shell tanks that were determined to be confirmed or assumed leakers based on evaluation of gamma logs or other data.

This table also includes daughters of long-lived parent radionuclides, whether or not the daughter species have been detected or reported.

Given the large number of candidate chemicals of concern identified from the above sources, it is appropriate to focus this assessment on those contaminants that pose the greatest risk to human health or the environment. Table 4-7 lists the contaminants of concern for the 200 East Groundwater Aggregate Area. This list was developed from Table 4-6 and includes only those contaminants which meet the following criteria:

- Radionuclides with a half-life greater than one year

- Radionuclides with a half-life of less than one year and are part of a long-lived decay chain that would result in the building up of the short-lived radionuclide activity to a level of 1% or greater of the parent radionuclide's activity within the time period of interest

- Chemicals that are known or suspected chemical carcinogens or that have a U.S. Environmental Protection Agency (EPA) noncarcinogenic toxicity factor. In addition, chemicals with known chronic toxicity but no toxicity factors are included. These chemicals include:

  - Dibutyl phosphate

  - Lead

  - Selenium

  - Tributyl phosphate

  - Uranium.

The following characteristics will be discussed for the contaminants listed in Table 4-6:

- Detection of contaminants in environmental media

- Historical association with plant activities

- Mobility

- Persistence

- Toxicity

- Bioaccumulation.

4.2.4.1 Detection of Contaminants in Environmental Media. Chemicals detected in groundwater samples collected from 200 East Area monitoring wells between 1988 and 1992 are summarized in Table 4-1. A list of chemicals that were analyzed for but not detected in these wells is provided in Table A-3 of Appendix A. It should be noted that groundwater is

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routinely tested for only a limited number of radionuclides; this limitation is discussed as a data gap in Section 8.0.

4.2.4.2 Historical Association with Source Area Activities. Potential sources of contamination to the 200 East Area groundwater were identified in Section 2.0, including waste management units used for disposal of liquid waste (cribs, trenches, tile fields, french drains, septic fields, reverse wells), leaking tanks, and other unplanned releases. Chemicals that were known or suspected components of the waste streams entering these units are potential groundwater contaminants. Known or suspected constituents of the waste streams were identified in the PUREX, B Plant, Semi-Works, and 200 North AAMSRs based on waste inventories and process information. Waste inventories are summarized in Tables 2-5 and 2-6 for those waste management units that are considered likely to have impacted groundwater, based on the volume of liquid waste released to the subsurface. Constituents of single-shell tanks that are assumed or suspected leakers and thus are potential contributors to groundwater contamination are summarized in Tables 2-2, 2-3, and 2-4.

It should be noted that the WIDS system does not report all TRU elements and fission products that are likely to occur in radioactive waste streams within the 200 East Area. Thus, it is likely that additional radionuclides were disposed to 200 East Groundwater Aggregate Areas that are not included in the waste inventories. Additionally, only those nonradioactive chemicals that were present in large quantities in the waste were reported (e.g., nitrates, carbon tetrachloride).

Nonradioactive chemicals reportedly released into the 200 East Groundwater Aggregate Area waste management units in large volumes include nitric acid, various metallic nitrates, sodium aluminate, sodium nitrate, kerosene, tributyl phosphate, sodium, ammonium nitrate, sulfates, and ammonium carbonate.

4.2.4.3 Mobility. Since most wastes within the 200 East Groundwater Aggregate Area were released directly to subsurface soils via injection, infiltration, or burial, the mobility of wastes in the subsurface will determine the potential for future exposures. The mobility in the subsurface of the chemicals listed in Table 4-6 varies widely and depends on site-specific factors as well as the intrinsic properties of the chemical. Much of the site-specific information needed to characterize mobility is not available and must be obtained during the RI/FS process. However, it is possible to make general statements about the relative mobility of the candidate chemicals of concern.

The mobility of radionuclides and other inorganic elements in groundwater depends on the chemical form and charge of the element or molecule, which in turn depends on site-related factors such as the pH, redox state, and ionic composition of the groundwater. Cationic species (e.g., Cd^{2+}, Pu^{4+}) generally are retarded in their migration relative to groundwater to a greater extent than anionic species such as nitrate (NO3-). The presence in

groundwater of complexing or chelating agents can increase the mobility of metals by forming neutral or negatively charged compounds.

The chemical properties of radionuclides are essentially identical to the nonradioactive form of the element; thus, discussions of the chemical properties affecting the transport of contaminants can apply to both radionuclides and nonradioactive chemicals.

A soil-water distribution coefficient (K_d) can be used to predict mobility of inorganic chemicals in the subsurface. Table 4-8 summarizes soil-water distribution coefficients that have been developed for many of the candidate inorganic chemicals of concern. As discussed above, the pH and ionic strength of the leaching medium have an impact on the adsorption of inorganics to soil; thus, the listed K_ds are valid only for a limited range of pH and waste composition. In addition, soil sorption of inorganics is highly dependent on the mineral composition of the soil, the ionic composition of the soil pore water, and other site-specific factors. Thus, a high degree of uncertainty is involved with use of K_ds that have not been verified by experimentation with site soils.

Cantrell and Serne (1992) performed a literature review and identified probable K_ds and ranges of K_ds for 10 substances [tritium, Cs, Sr, Co, Bi, UO_2, Pu, TcO_4^-, cyanide (HCN) and phosphate] for use in Hanford investigations.

Serne and Wood (1990) recommended K_d values for use with Hanford waste assessments for a limited number of important radionuclides (Am, Cs, Co, Cu, I, Pu, Ru, Sr, and tritium) based on soil column or batch desorption studies, and proposed conservative average values for a more extensive list of elements based on a review of the literature. A K_d of <1 is recommended for Am, Cs, Pu, and Sr under acidic conditions.

Strenge and Peterson (1989) developed default K_d values for a large number of elements for use in the Multimedia Environmental Pollution Assessment System (MEPAS), a computerized waste management unit evaluation system. The K_d values were based on findings in the scientific literature, and include nonsite-specific as well as Hanford Site values. Values are provided for nine sets of environmental conditions: three ranges of waste pH and three ranges of soil adsorbent material (sum of percent clay, organic material, and metal hydrous oxides). The values presented in Table 4-8 are for conditions of neutral waste pH and less than 10% adsorbent material, which is likely to be most representative of Hanford Site soils.

The mobility of inorganic species in soil can be divided roughly into three mobility classes, using site-specific values (Cantrell and Serne 1992 or Serne and Wood 1990) where available and conservative default values otherwise: highly mobile ($K_d<5$), moderately mobile ($5<K_d<100$), and low mobility ($K_d>100$). The mobility classes for the candidate chemicals of concern are as follows:

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High Mobility (K_d < 5)

Antimony	Iodine	Silica
Arsenic	Lithium	Sodium
Boron	Neptunium	Sulfate
Carbon (as $^{14}CO_p$)	Nitrate	Technetium
Chloride	Palladium	Thallium
Chromium (VI)	Potassium	Tritium
Cyanide (free ion)	Protactinium	Uranium
Fluoride	Selenium	

Moderate Mobility (5 <K_d < 100)

Barium	Copper	Magnesium
Beryllium	Europium	Manganese
Cadmium	Iron	Nickel
Calcium	Lanthanum	Niobium
Cerium	Lead	Phosphate
Polonium	Samarium	Tin
Promethium	Silver	Vanadium
Radium	Strontium	Zinc
Ruthenium	Thorium	Zirconium

Low Mobility (K_d > 100)

Actinium	Cesium	Plutonium
Aluminum	cobalt	Yttrium
Americium	Curium	
Bismuth	Mercury	

Note that the environmental mobility of radionuclides may be determined by the adsorption characteristics of either the parent or daughter species in a decay chain. For example, a contaminant that is itself immobile in the subsurface could be detected at some distance from the source due to its production from a mobile parent species.

The tendency of organic compounds to adsorb to the organic fraction of soils is indicated by the soil organic matter partition coefficient, Koc. Partition coefficients for the

candidate organic chemicals of potential concern are listed in Table 4-9. Chemicals with low Koc values are weakly adsorbed by soils and will tend to migrate in the subsurface, although their rate of travel will be retarded somewhat relative to the pore water or groundwater flow. Soils at the Hanford Site have very little organic carbon content and thus sorption to the inorganic fraction of soils may dominate over sorption to soil organic matter. Mobility of organic chemicals in the subsurface can be roughly estimated by the equation:

$$K_d = K_{oc} * f_{oc}$$

where f_{oc} is the organic carbon content of the aquifer solids, which is generally less than 0.1% in Hanford soils.

4.2.4.4 Persistence. Once released to environmental media, the concentration of a chemical may decrease because of biological or chemical transformation, radioactive decay, or the intermediate transfer processes discussed above that remove the chemical from the medium (e.g., volatilization to air). Radiological, chemical, and biological decay processes affecting the persistence of the candidate contaminants of potential concern are discussed below.

The persistence of radionuclides depends primarily on their half-lives. A comparison of the half-lives and specific activities for the candidate radionuclides of potential concern is presented in Table 4-10. The specific activity is the decay rate per unit mass, and is inversely proportional to the half-life of the radionuclide. Half-lives for the radionuclides listed in Table 4-10 range from fractions of a second to over one billion years. Also listed are the decay mechanisms of primary concern for the radionuclide. Note that radionuclides often undergo several decay steps in quick succession, (e.g., an alpha decay followed by release of one or more gamma rays). The daughter products of these decays are often themselves radioactive.

Nonradioactive inorganic chemicals detected at the site are generally persistent in the environment, although they may decline in concentration due to transport processes or change their chemical form due to chemical or biological reactions. Nitrate and sulfate undergo chemical and biological transformations that may lead to their loss to the atmosphere (as N_2 and H_2S) or incorporation into living organisms, depending on the redox environment and microbiological communities present in the medium.

Biotransformation rates for organics vary widely and are highly dependent on site-specific factors such as soil moisture, redox conditions, and the presence of nutrients and of organisms capable of degrading the compound. Ketones, such as acetone and MIBK, are easily degraded by microorganisms in soil and thus would tend not to persist. Chlorinated solvents (e.g., carbon tetrachloride) may undergo slow biotransformation in the subsurface under appropriate conditions of soil redox state and nutrient availability. Volatile aromatics

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such as toluene are generally intermediate in their biodegradability between these two example groups.

4.2.4.5 Toxicity. Contaminants may be of potential concern for impacts to human health if they are known or suspected to have carcinogenic properties, or if they have adverse noncarcinogenic human health effects. The toxicity characteristics of the candidate contaminants of potential concern are summarized below.

4.2.4.5.1 Radionuclides. All radionuclides are classified by EPA as known human carcinogens based on their property of emitting ionizing radiation and on the evidence provided by epidemiological studies of radiation-induced cancers in humans. Noncarcinogenic health effects associated with radiation exposure include genetic and teratogenic effects; however, these effects generally occur at higher exposure levels than those required to induce cancer. Thus, the carcinogenic effect of radionuclides is the primary identified health concern for these chemicals.

Risks associated with radionuclides differ for various routes of exposure depending on the type of ionizing radiation emitted. Nuclides that emit alpha or beta particles are hazardous primarily if the materials are inhaled or ingested, since these particles expend their energy within a short distance after penetrating body tissues. Gamma-emitting radioisotopes are of concern as both external and internal hazards. A fourth mode of radioactive decay, neutron emission, is generally not of major health concern, since this mode of decay is much less frequent than other decay processes. In addition to the mode of radioactive decay, the degree of hazard from a particular radionuclide depends on the rate at which particles or gamma radiation are released from the material.

Excess cancer risks for exposure to radionuclides by inhaling air, drinking water, ingesting soil, and by external irradiation are shown in Table 4-11 for the radionuclides of potential concern. The unit risk values represent the increase in probability of cancer to an individual exposed for a lifetime to a radionuclide at a level of 1 pCi/m^3 in air, 1 pCi/L in drinking water, 1 pCi/g in ingested soil, or to external radiation from soil having a radionuclide content of 1 pCi/g.

For those radionuclides without slope factors, the *Hanford Site Baseline Risk Assessment Methodology* (DOE/RL 1991d) proposes to use the dose conversion factors developed by the International Commission on Radiological Protection to calculate a risk value. For those radionuclides without slope factors, the document proposes to consult the EPA Region 10 risk assessment staff or the EPA Office of Radiation Programs to request the development of a slope factor. Any Hanford Site risk assessments will be performed in accordance with the *Hanford Site Baseline Risk Assessment Methodology* document (DOE/RL 1991d) which includes the guidance established in the *Risk Assessment Guidance for*

Superfund (EPA 1989b) and the *EPA Region 10 Supplemental Risk Assessment Guidance for Superfund* (EPA 1991).

The unit risk factors for different radionuclides are roughly proportional to their specific activities, but also incorporate factors to account for distribution of each radionuclide within various body organs, the type of radiation emitted, and the length of time that the nuclide is retained in the organs.

Based on the factors listed in Table 4-11 the highest risk for ingestion of water containing 1 pCi/L of a radionuclide is from the transuranic isotopes ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, ^{243}Am, and ^{237}Np, and the fission products ^{210}Po, ^{210}Pb, and ^{227}Ac. The highest risk from inhalation of 1 pCi/m^3 in air is from alpha emitters (e.g., ^{238}U, ^{241}Am, ^{238}Pu, ^{227}Ac). The highest risks from ingestion of soil at 1 pCi/g are for ^{227}Ac, ^{241}Am, ^{243}Am, ^{238}Pu, ^{244}Cm, and ^{243}Cm. The highest risk from external exposure to a surface contaminated at 1 pCi/g is from ^{60}Co, ^{137m}Ba (a daughter product of ^{137}Cs), ^{134}Cs, ^{214}Bi, ^{214}Pb, and ^{154}Eu.

The standard EPA risk assessment methodology assumes that the probability of a carcinogenic effect increases linearly with dose at low dose levels, i.e., there is no threshold for carcinogenic response. The EPA methodology also assumes that the combined effect of exposure to multiple carcinogens is additive without regard to target organ or cancer mechanism. However, the additive risk from chemical carcinogens and radionuclides should be computed separately (EPA 1989b).

4.2.4.5.2 Hazardous Chemicals. Carcinogenic and noncarcinogenic health effects associated with the candidate chemicals of potential concern are summarized in Table 4-12. EPA has not derived toxicity criteria for many of these chemicals. Many of the chemicals that lack toxicity criteria have negligible toxicity or are necessary nutrients in the human diet. However; several of the chemicals have known toxic effects but no toxicity criterion is presently available. In some instances the criteria have been withdrawn by EPA pending review of the toxicological data and will be reissued at a future date. Chemicals with known chronic toxicity for which toxicity factors are presently not available include the following:

- Lead
- Selenium
- Uranium
- Tributyl phosphate.

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4.2.4.6 Bioaccumulation potential. Contaminants may be of concern for exposure if they have a tendency to accumulate in plant or animal tissues at levels higher than those in the surrounding medium (bioaccumulation) or if their levels increase at higher trophic levels in the food chain (biomagnification). Contaminants may be bioaccumulated because of element-specific uptake mechanisms (e.g., incorporation of strontium into bone) or by passive partitioning into body tissue (e.g., concentration of organic chemicals in fatty tissues).

9 2 1 2 7 3 5 1 4 9 8

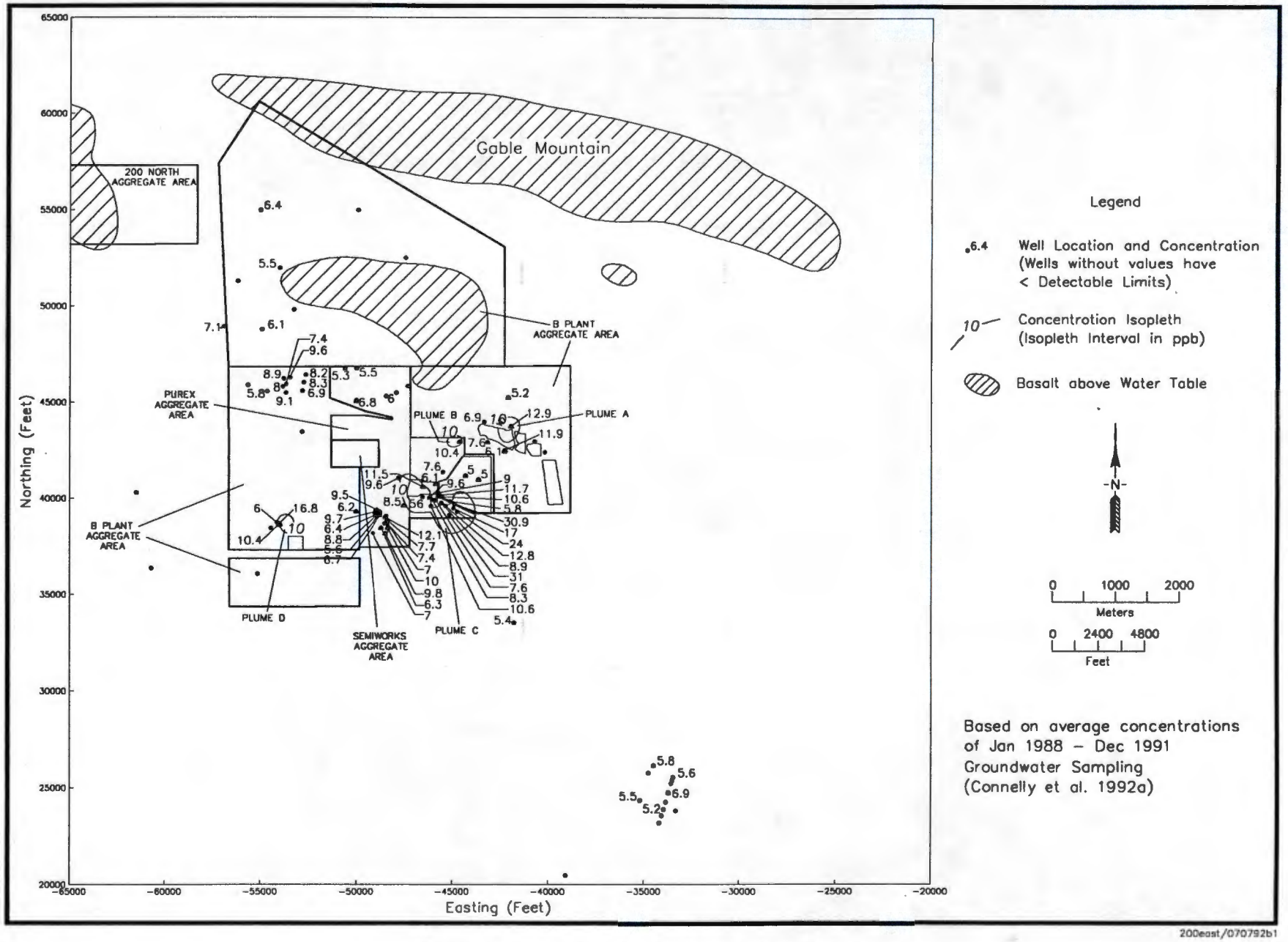

Figure 4-1. Arsenic Groundwater Plume Map.

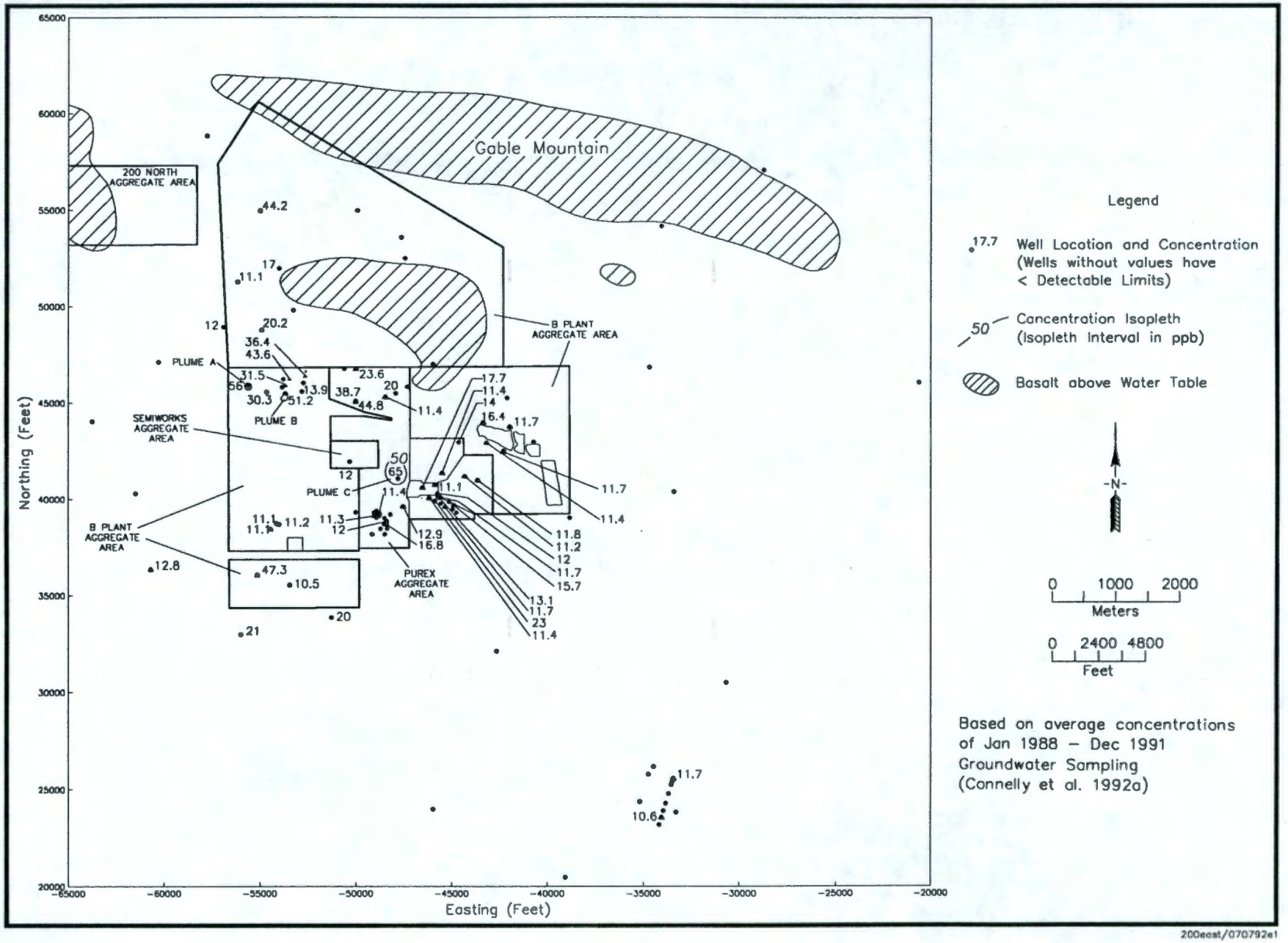

Figure 4-2. Chromium Groundwater Plume Map.

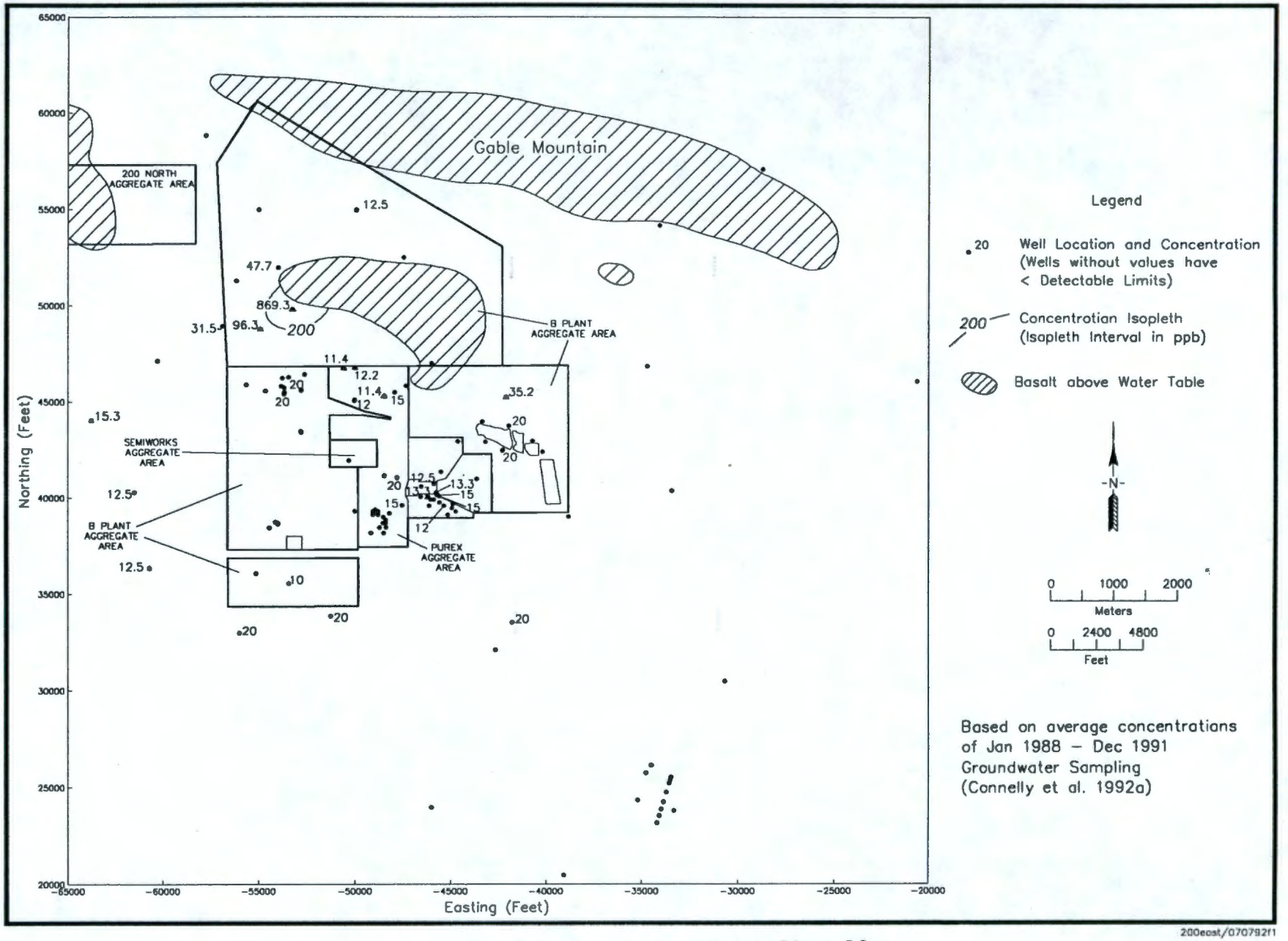

Figure 4-3. Cyanide Groundwater Plume Map.

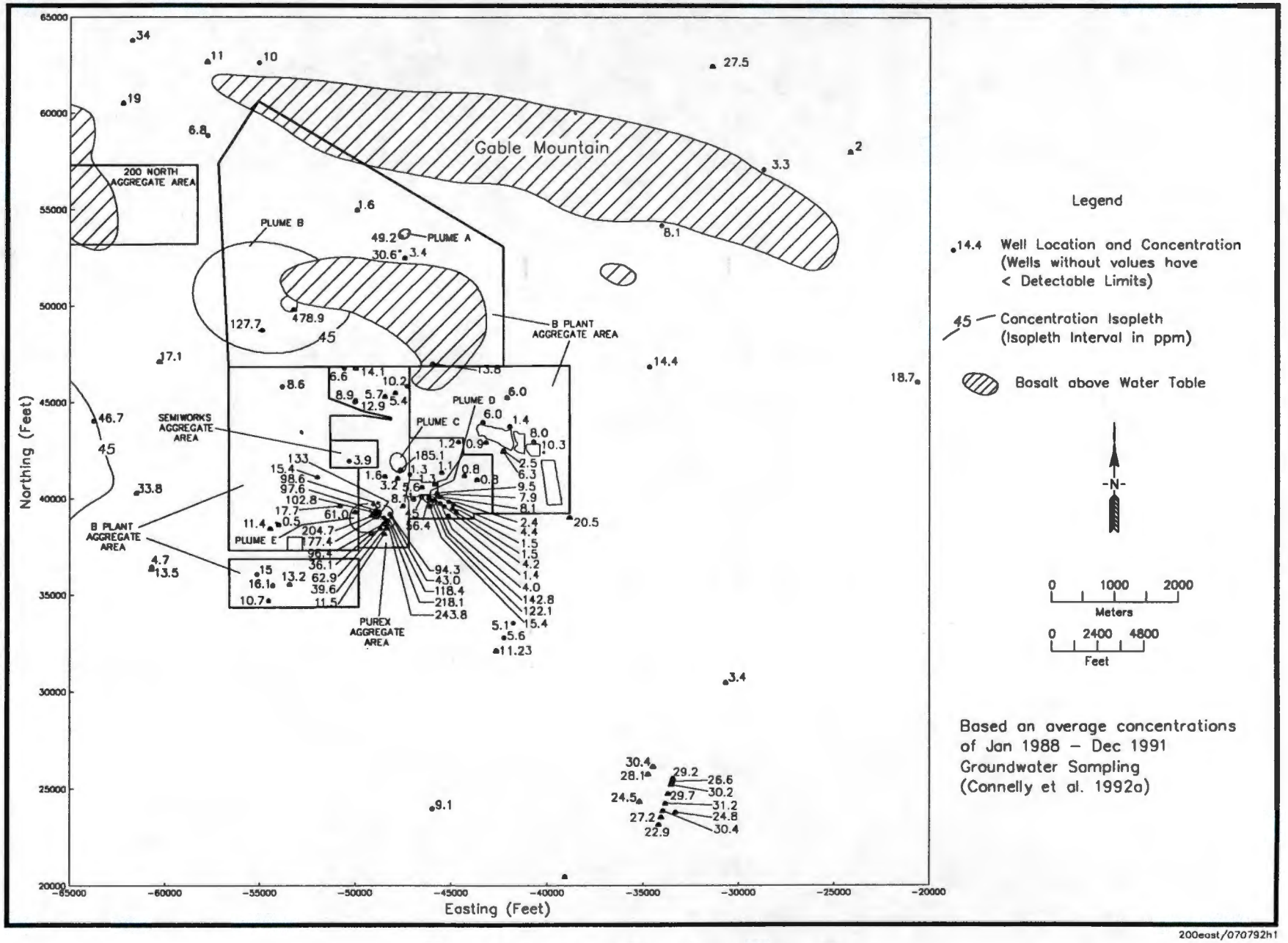

Figure 4-4. Nitrate Groundwater Plume Map.

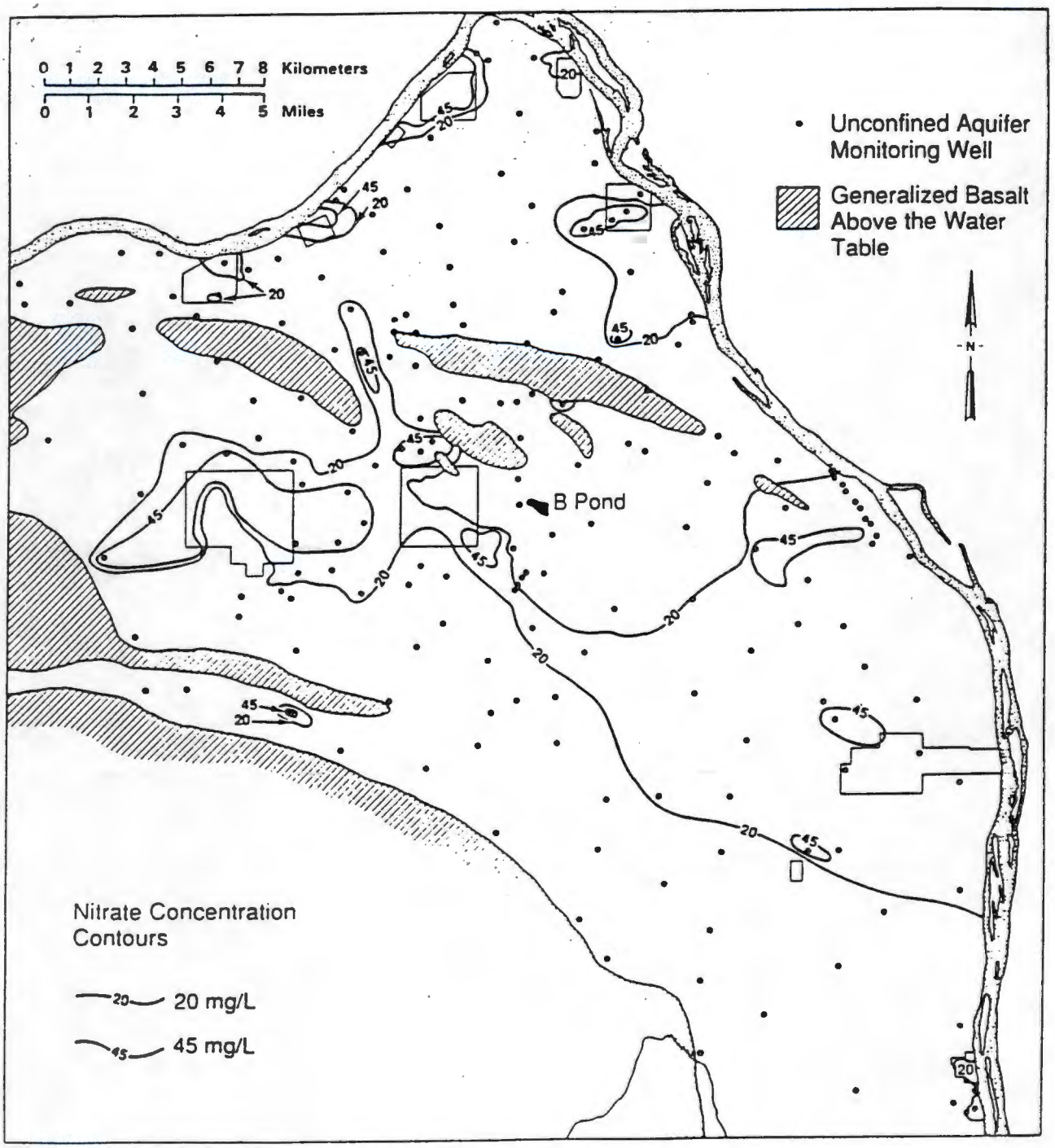

Figure 4-5. Distribution of Nitrate on the Hanford Site for 1989 (Evans et al. 1990).

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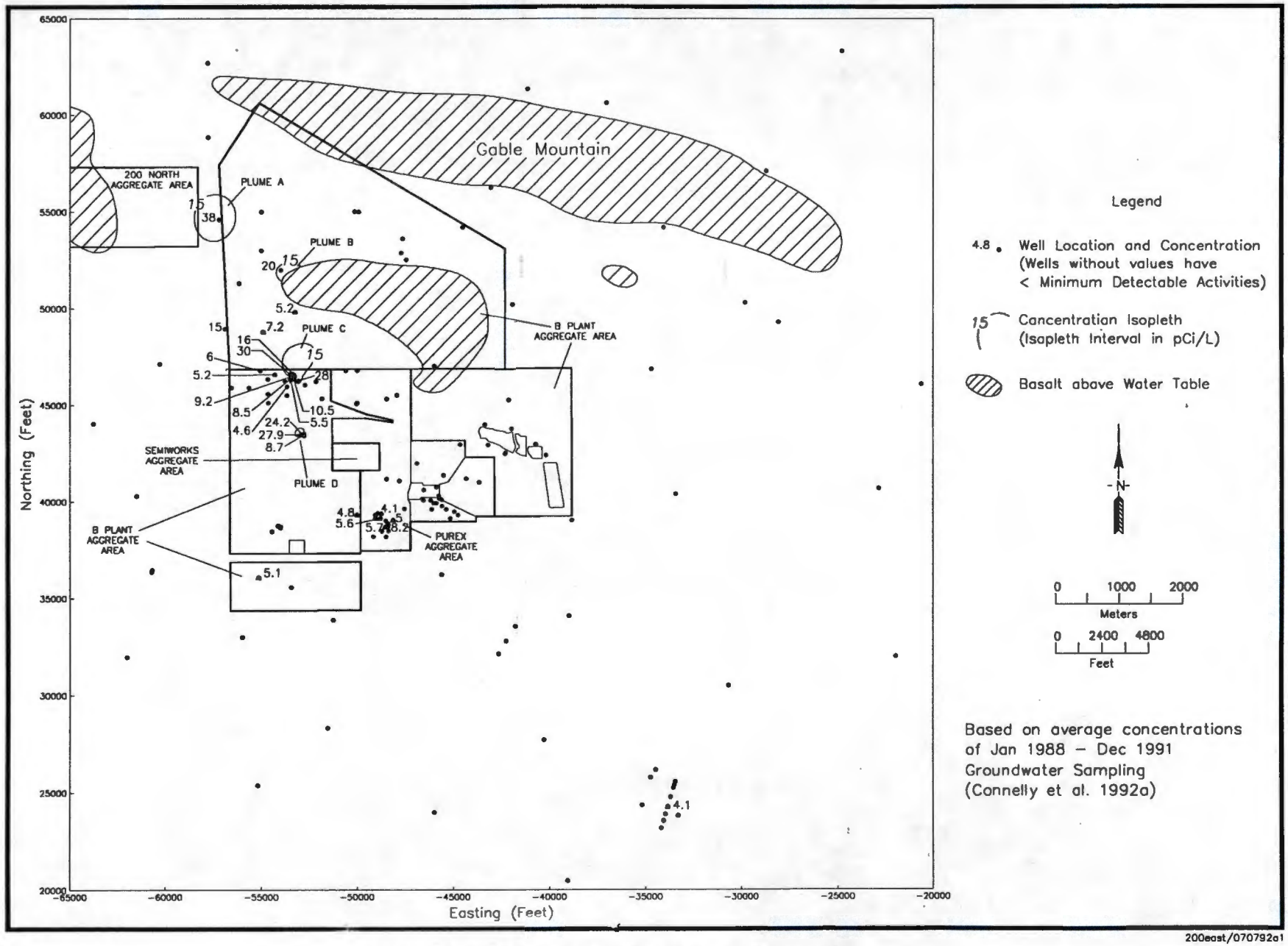


Figure 4-6. Gross Alpha Groundwater Plume Map.

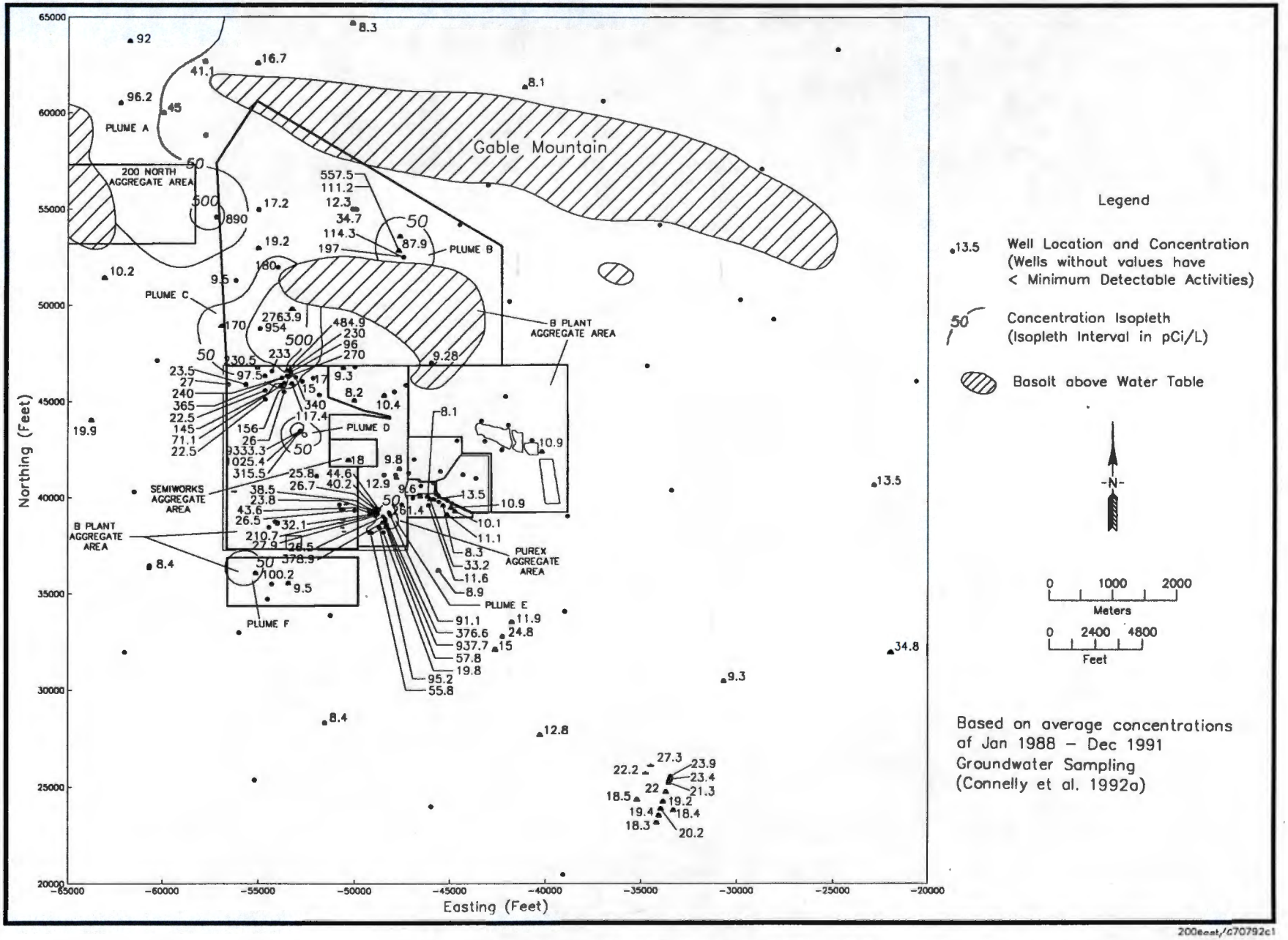


Figure 4-7. Gross Beta Groundwater Plume Map.

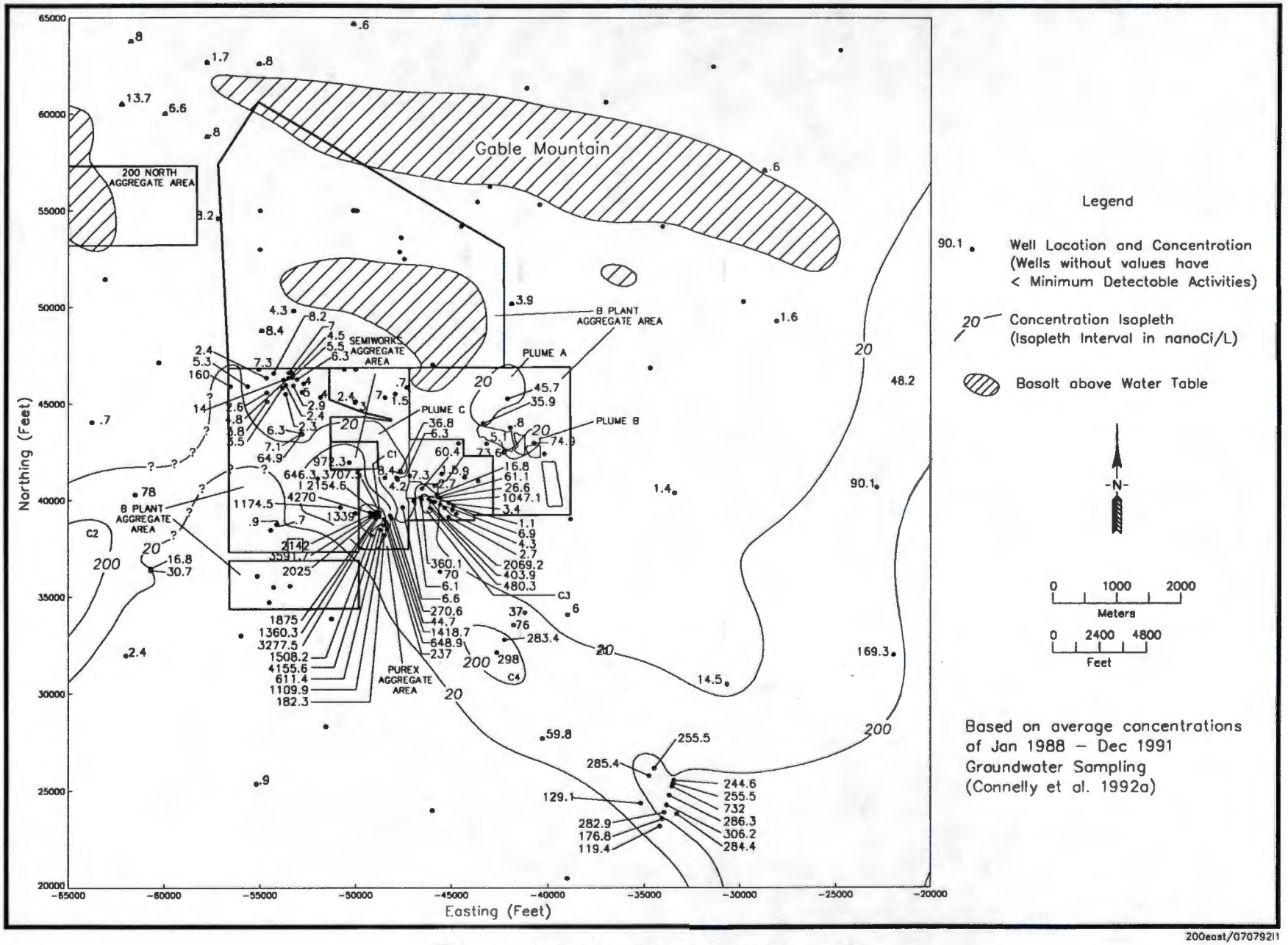


Figure 4-8. Tritium Groundwater Plume Map.

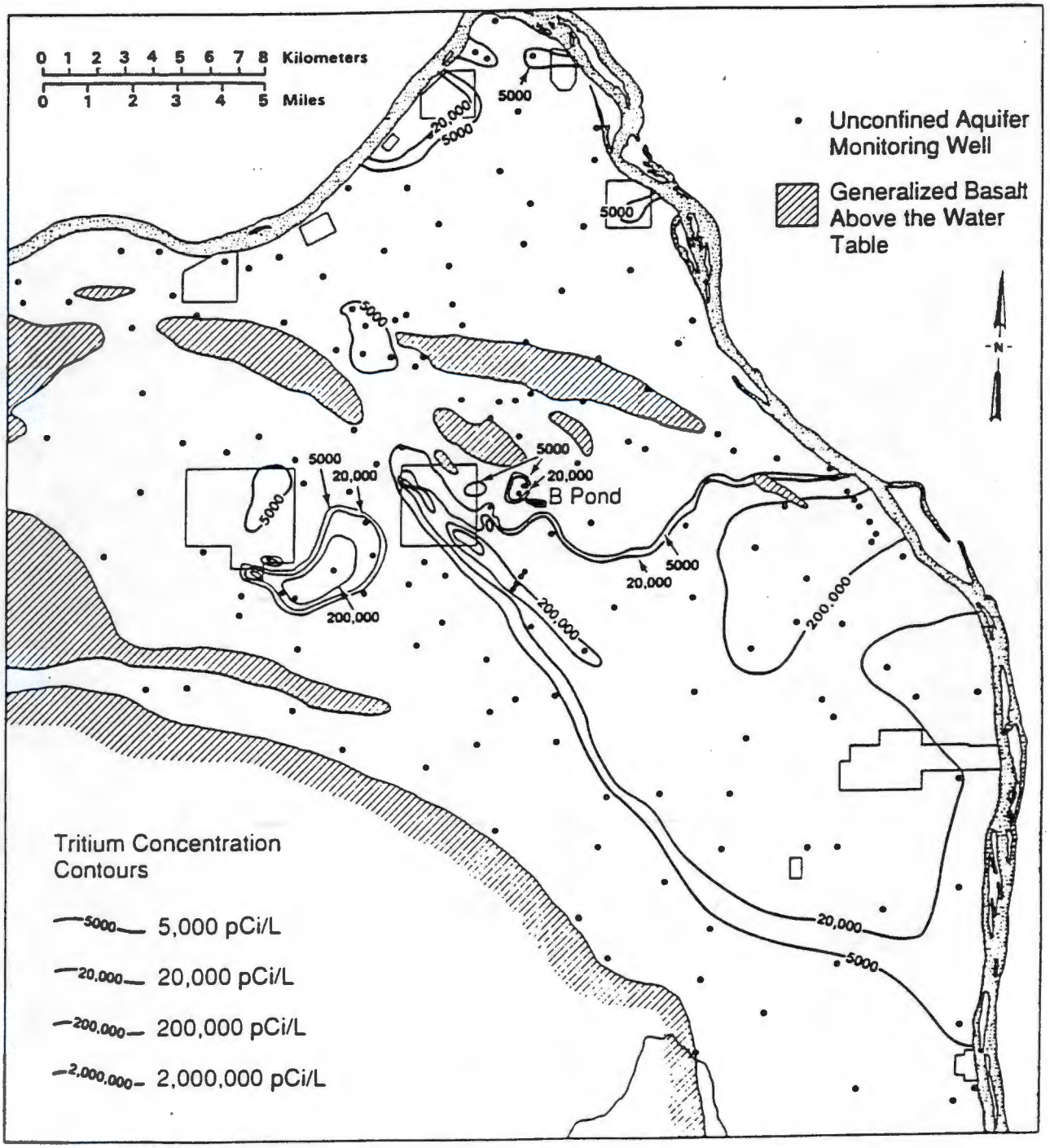


Figure 4-9. Distribution of Tritium on the Hanford Site for 1989 (Evans et al. 1990).

9 2 1 2 7 5 1 5 0 7

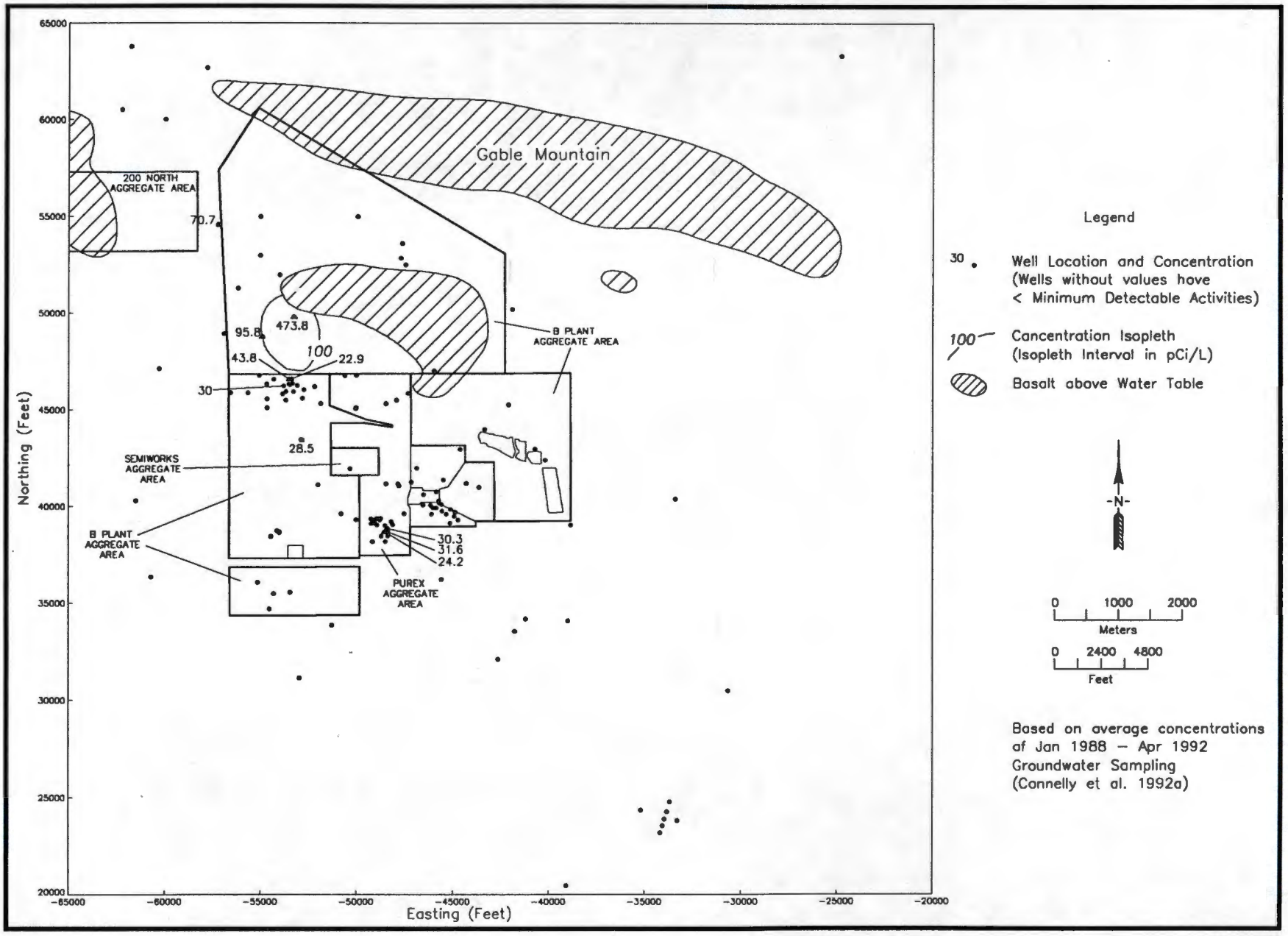


Figure 4-10. Cobalt-60 Groundwater Plume Map.

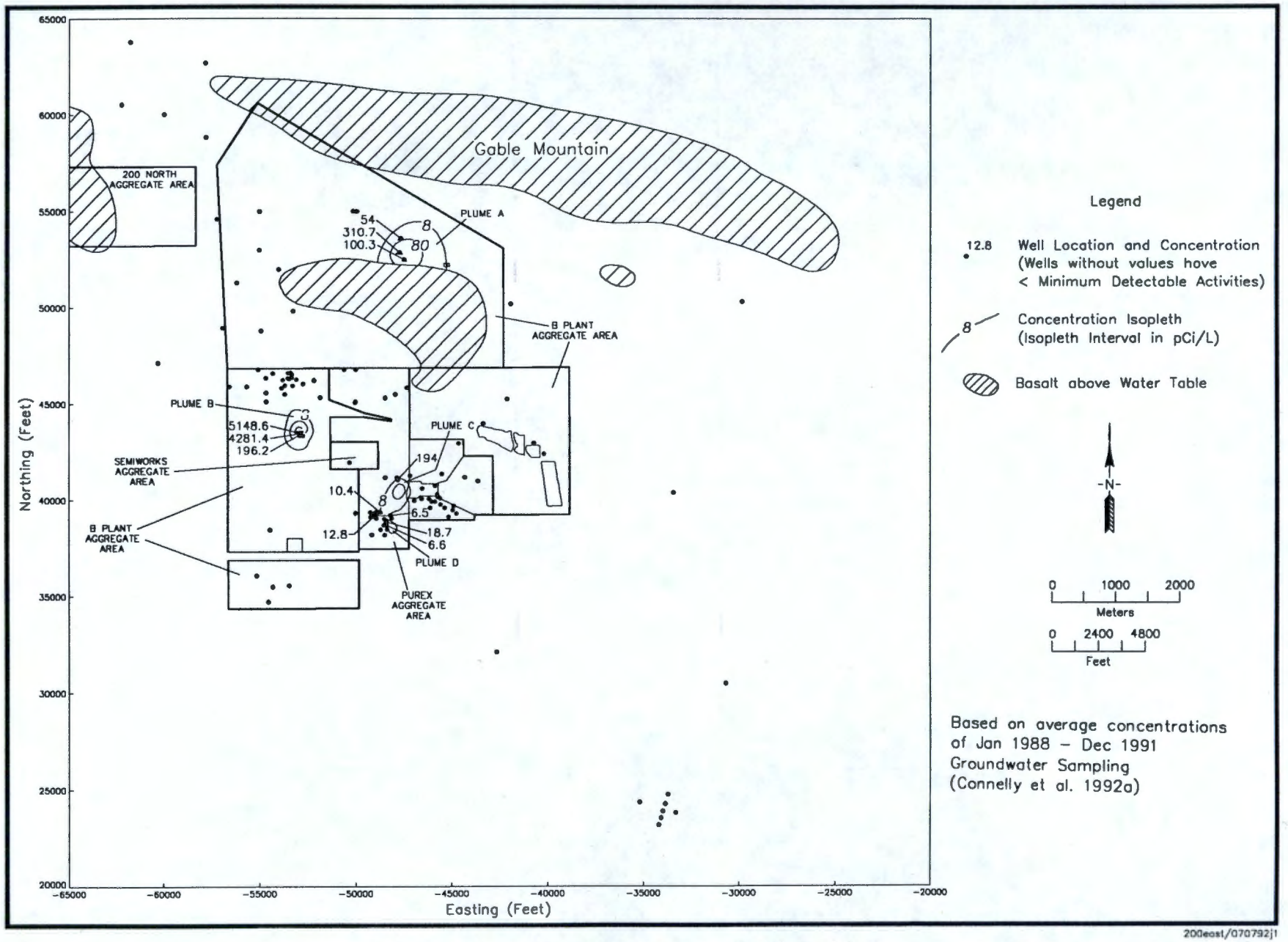


Figure 4-11. Strontium-90 Groundwater Plume Map.

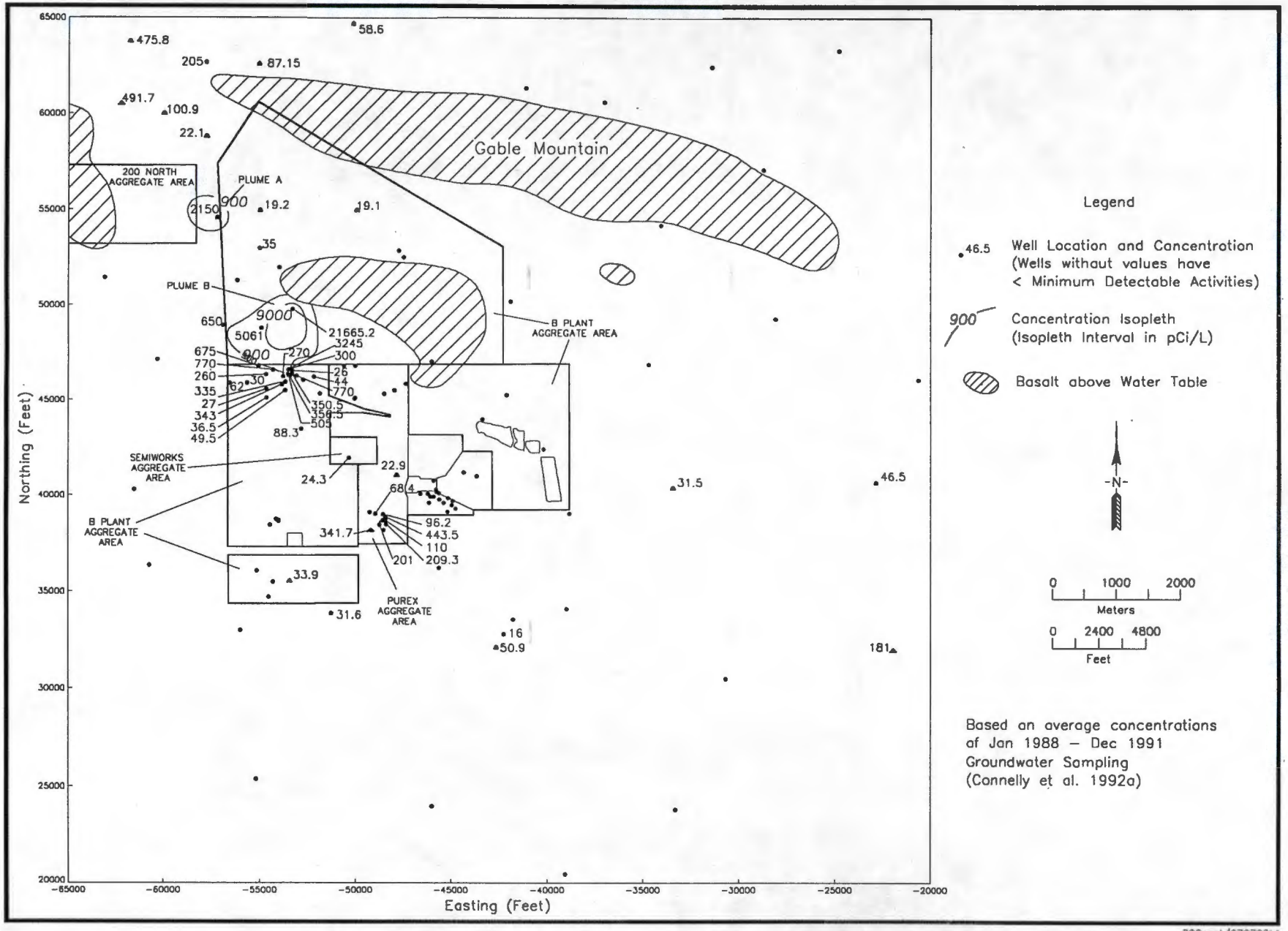


Figure 4-12. Technetium-99 Groundwater Plume Map.

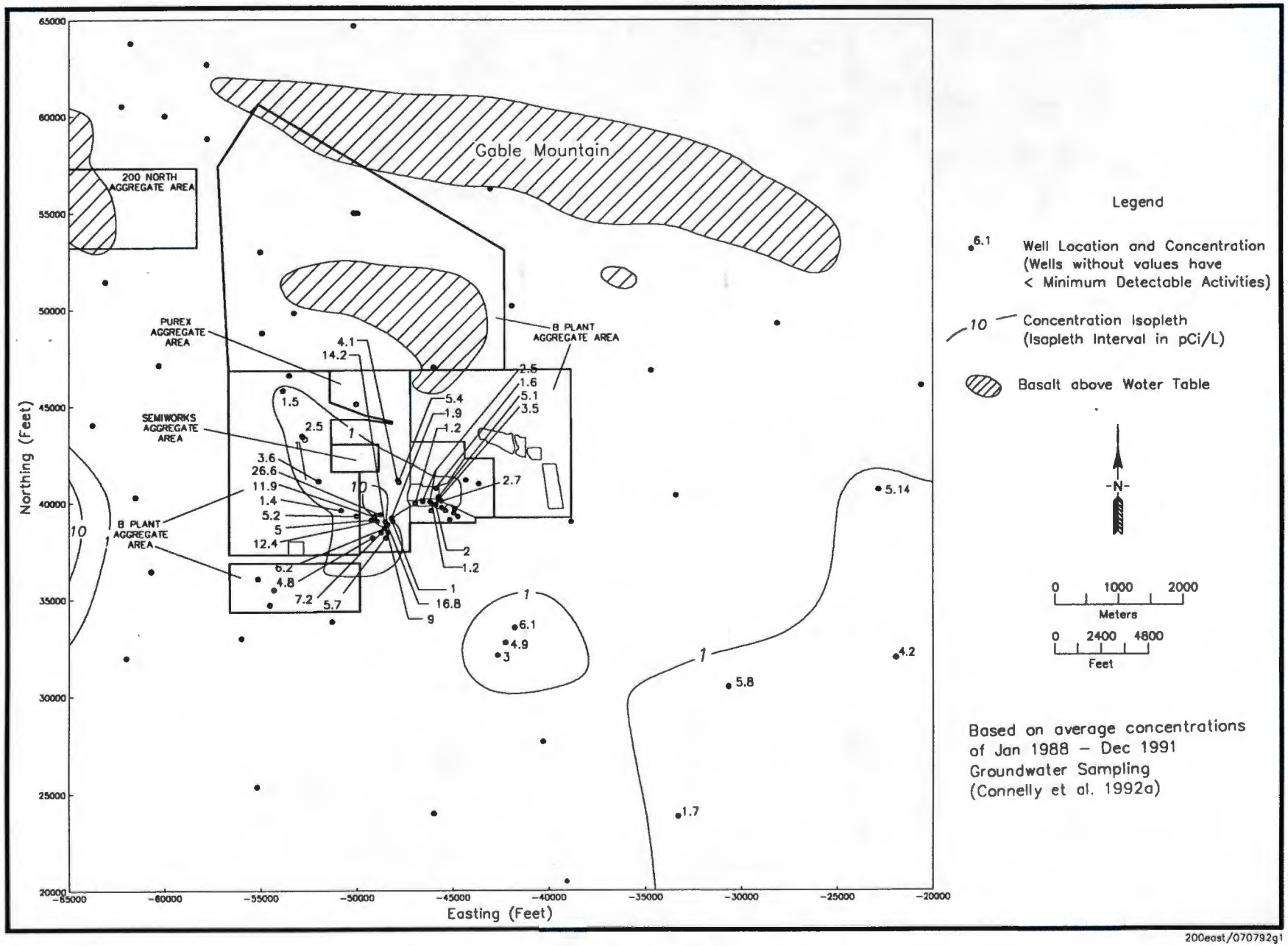


Figure 4-13. Iodine-129 Groundwater Plume Map.

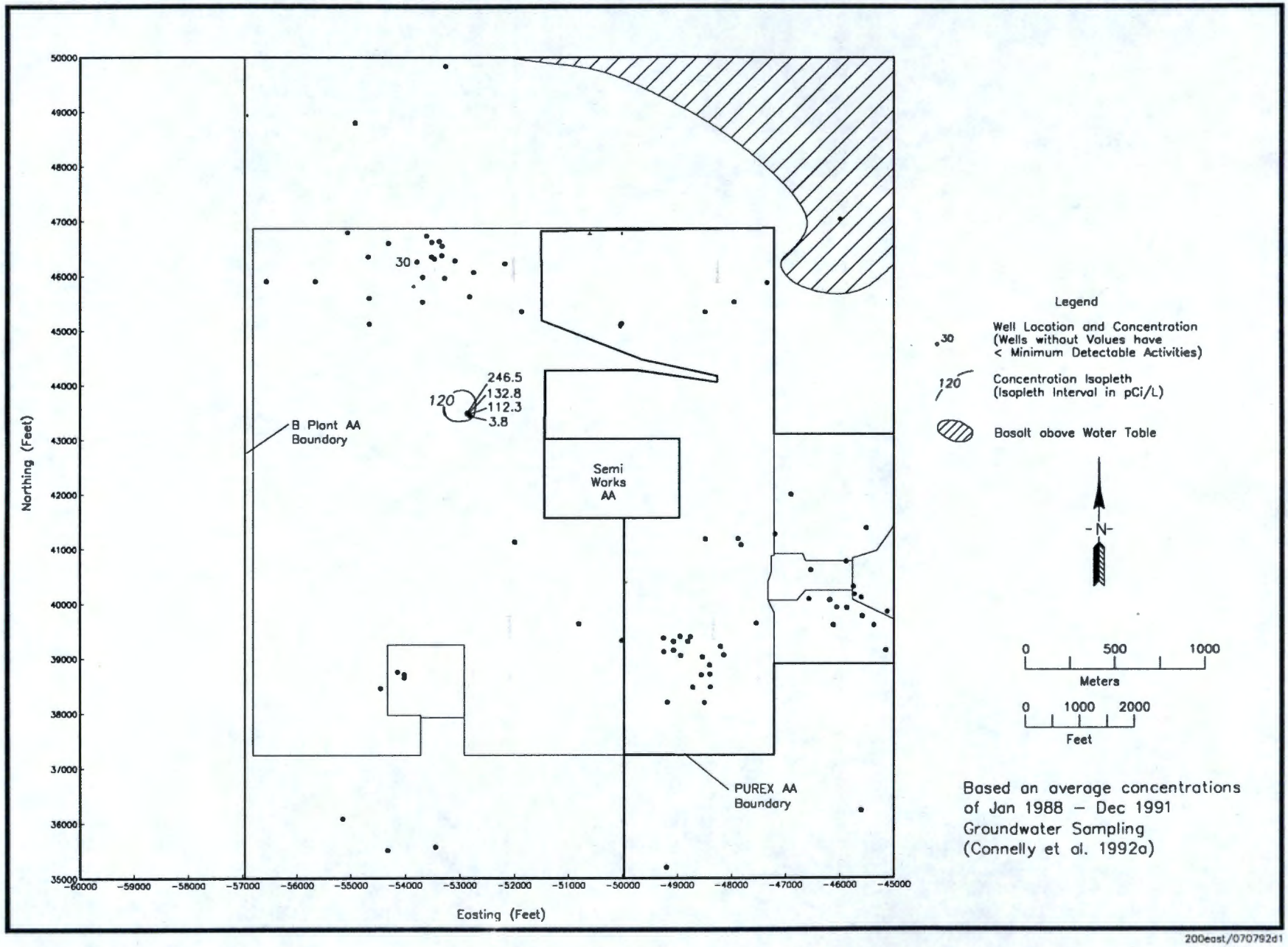
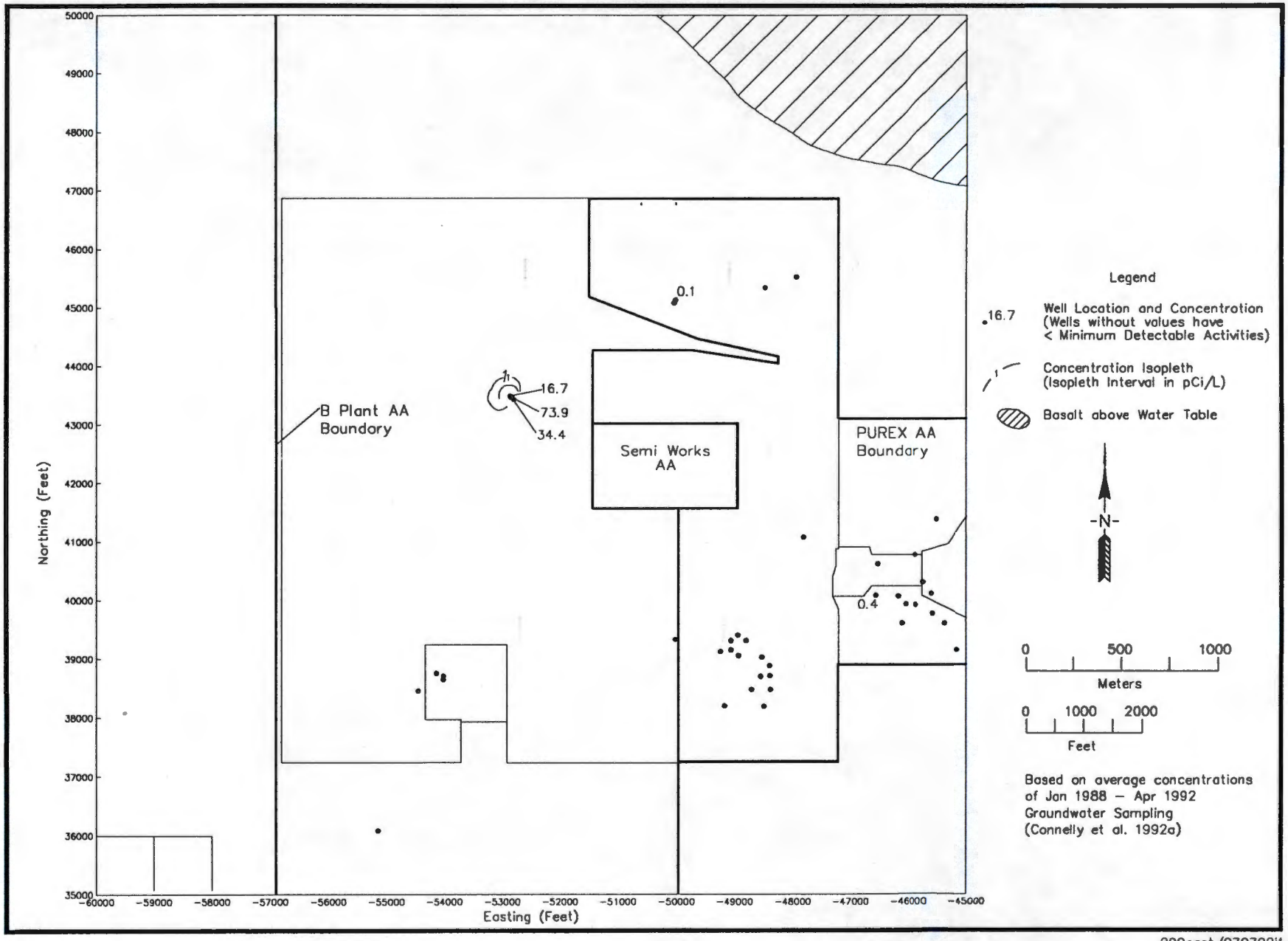


Figure 4-14. Cesium-137 Groundwater Plume Map.



200east/07079211

Figure 4-15. Plutonium-239/240 Groundwater Plume Map.

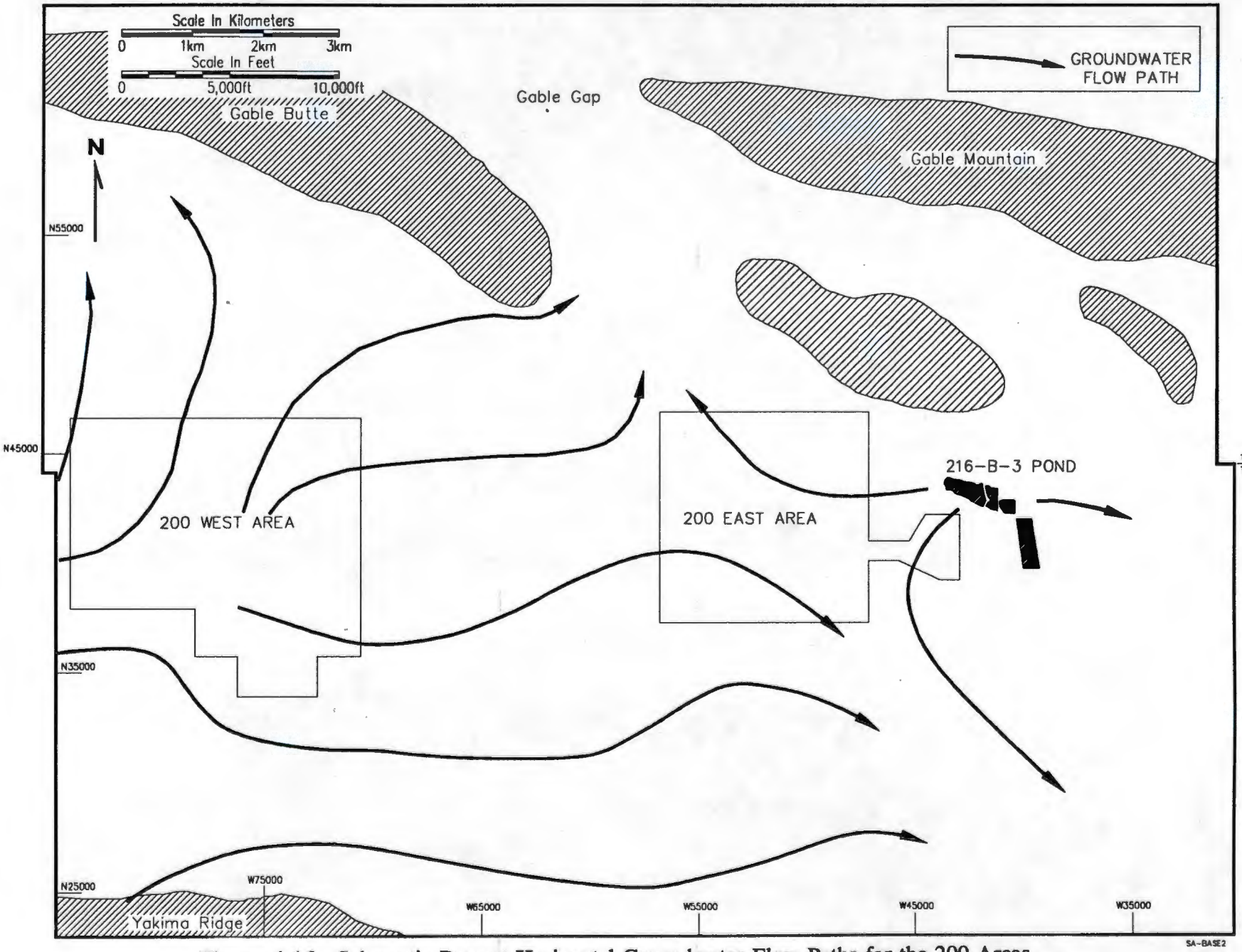


Figure 4-16. Schematic Present Horizontal Groundwater Flow Paths for the 200 Areas.

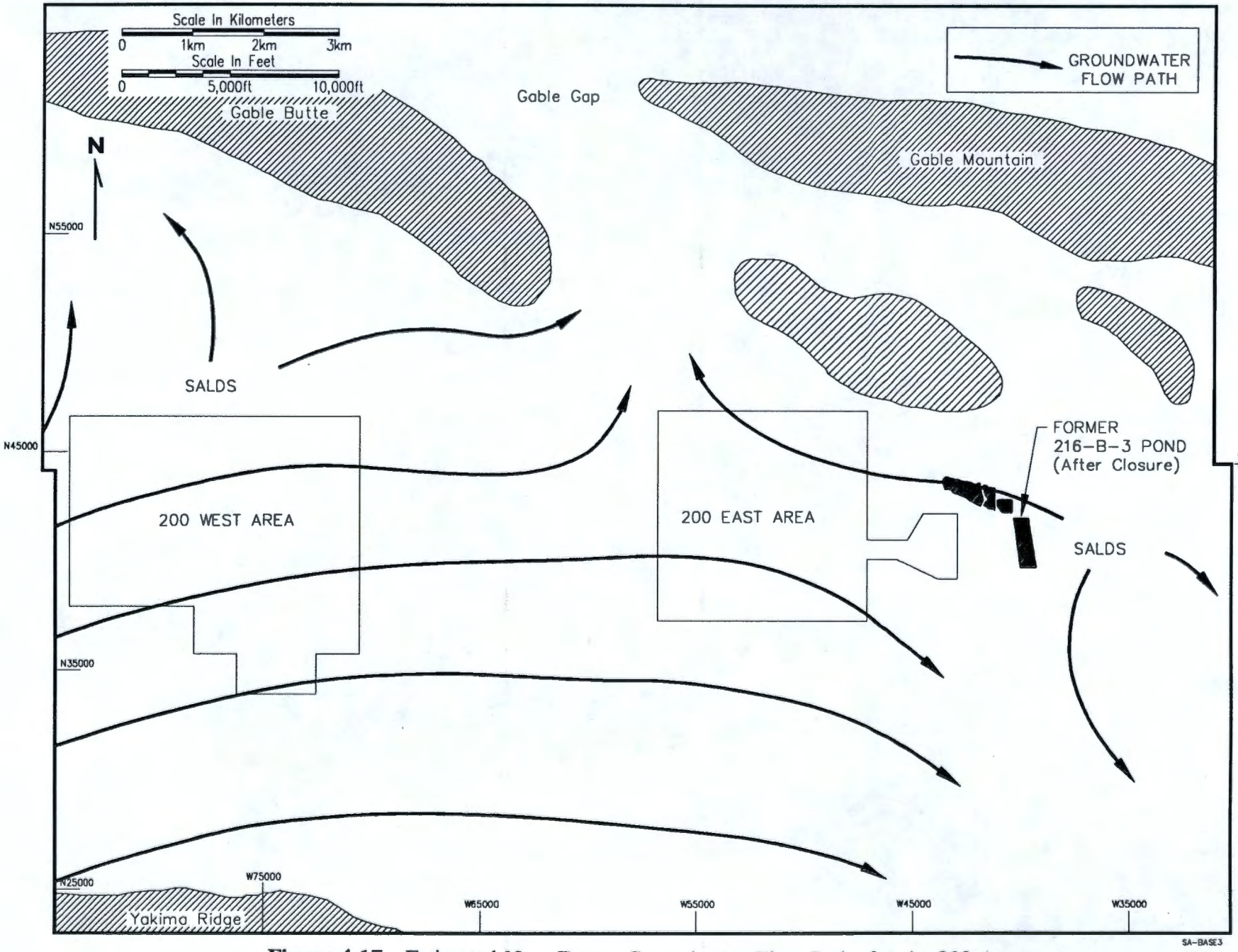


Figure 4-17. Estimated Near-Future Groundwater Flow Paths for the 200 Areas.

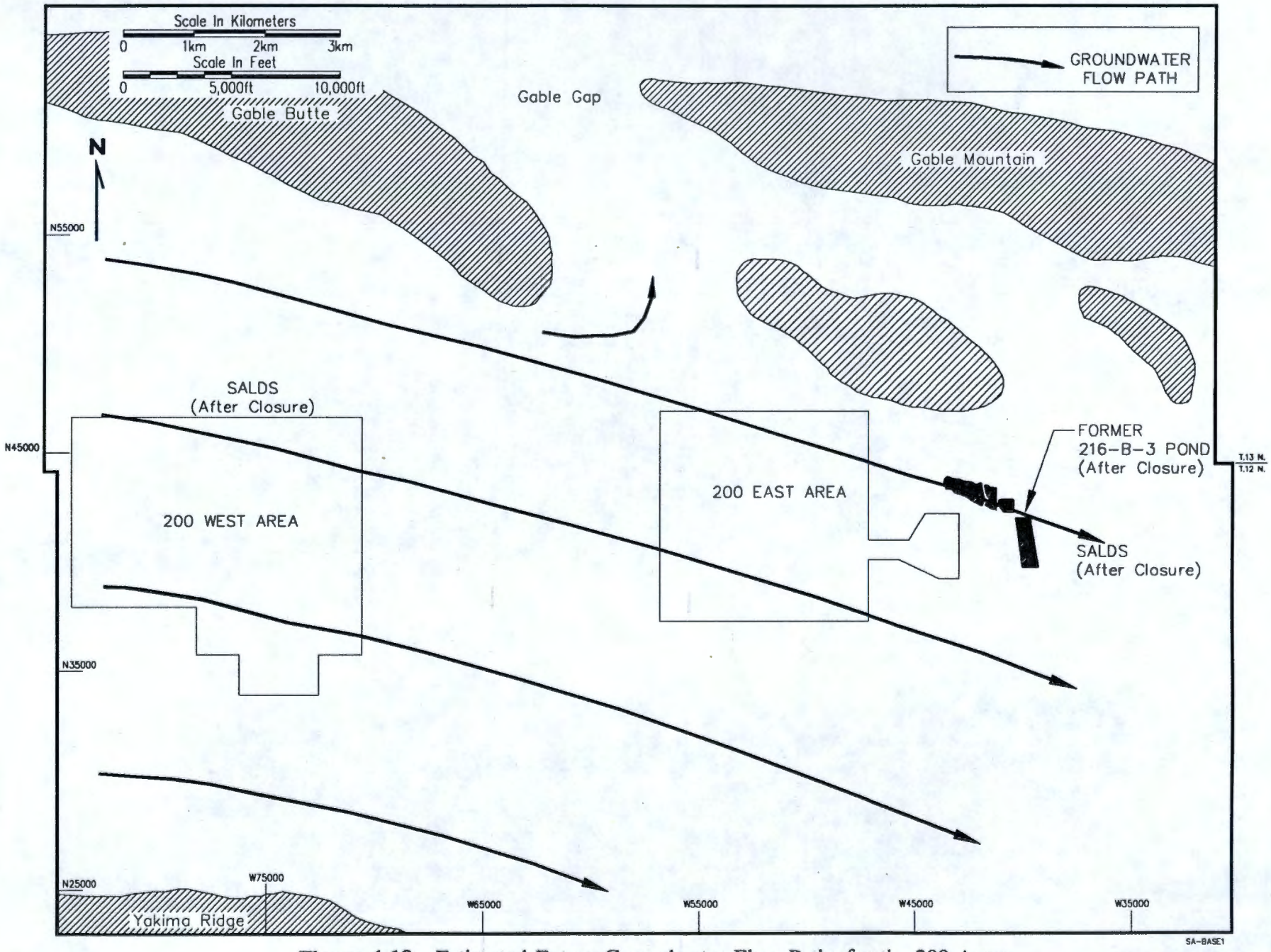


Figure 4-18. Estimated Future Groundwater Flow Paths for the 200 Areas.

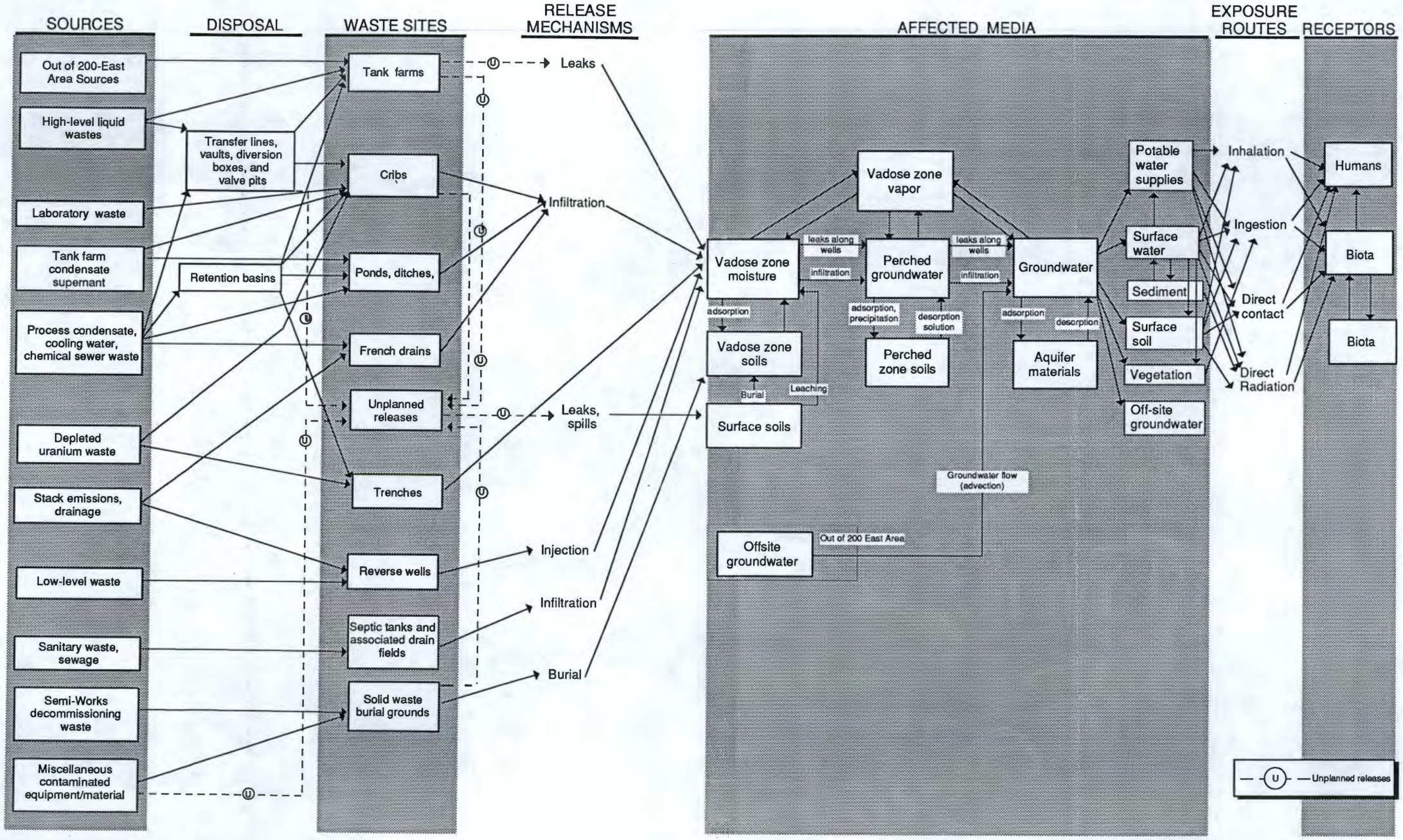


Figure 4-19. Conceptual Model of the 200 East Groundwater Aggregate Area.

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Table 4-1. Average Reported Constituent Concentrations/Maximums and Minimums--200 East Groundwater Aggregate Area (January 1988 to April 1992).

Constituent	Well-Specific Data						All Wells		
	Well Number	Average of Reported Values	Maximum of Detections	Minimum of Detec-tions	Number of Detections	Number of < D.L.	Minimum Reported D.L.	Total Number of Analyses	Total Number of Wells with Detections
ORGANIC COMPOUNDS (µg/L)									
Carbon Tetrachloride[a/]	2-E27-8	4.48	0.8	0.8	1	7	1	667	7
Chloroform[a/]	2-E18-3	8.33	25	25	1	5	0.5	670	10
Methylene Chloride[a/]	2-E17-16	1286.00	6400	6400	1	4	1	672	48
1,1-Dichloroethane[a/]	6-24-33	5.26	2.2	1.1	5	5	1	638	5
1,2-Dichloroethane[a/]	6-24-34C	4.04	0.5	0.5	1	11	0.5	621	1
Cis-1,2-Dichloroethylene	6-24-34A	1.23	1.7	1.7	1	2	1	20	2
Trans-1,2 Dichloroethylene[a/]	6-24-34A	4.73	2	2	1	10	1	637	2
1,1,1-Trichloroethane[a/]	6-23-34	39.47	60	30	15	0	0.5	671	11
1,1,2-Trichloroethane[a/]	6-24-34C	2.10	0.6	0.6	1	12	0.2	665	1
Trichloroethylene[a/]	6-31-31P	12.00	12	12	1	0	0.5	670	8
Tetrachloroethylene[a/]	6-24-34B	8.19	11	6.3	12	0	0.5	665	10
Pyrene	2-E33-3	8.50	13	13	1	1	3	83	1
Styrene	2-E25-23	9.50	14	5	2	0	4	95	2
Toluene	2-E23-1	30.00	30	30	1	0	2	603	10
2,4-Dinitrotoluene	2-E33-3	8.67	11	11	1	2	5	145	1

Table 4-1. Average Reported Constituent Concentrations/Maximums and Minimums--200 East Groundwater Aggregate Area (January 1988 to April 1992). Page 2 of 9

Constituent	Well-Specific Data						All Wells		
	Well Number	Average of Reported Values	Maximum of Detections	Minimum of Detec-tions	Number of Detections	Number of < D.L.	Minimum Reported D.L.	Total Number of Analyses	Total Number of Wells with Detections
Phenol[a/]	2-E35-2	12.25	8	8	1	3	1	802	5
2,3,4,6-Tetrachlorophenol	6-40-40B	10.00	10	10	1	0	10	209	1
2,4-Dichlorophenol	2-E17-16	18.00	26	26	1	1	5	245	1
2,4-Dimethylphenol	2-E17-18	20.00	20	20	1	0	5	187	2
2,4-Dinitrophenol	6-42-41	120.00	120	120	1	0	10	246	2
2-Chlorophenol	2-E33-3	15.33	22	14	2	1	2	247	2
O-Nitrophenol	6-42-41	28.00	28	28	1	0	5	186	2
Pentachlorophenol	2-E33-29	66.67	50	50	1	5	4	322	1
Acetone	2-E28-7	140.00	140	140	1	0	1	457	25
Methyl Ethyl Ketone	2-E33-29	37.00	10	10	1	9	5	611	4
4-Methyl-2-Pentanone	2-E33-5	11.00	11	11	1	0	1	155	2
Cyclohexanone	6-50-53B	4.00	4	4	1	0	4	1	1
Aldrin	2-E25-33	0.74	1.8	1.7	2	3	0.05	312	5
DDD	2-E25-33	0.17	0.3	0.23	2	3	0.1	312	4
DDT	2-E34-8	2.50	5	4.8	2	2	0.1	313	5
Dieldrin	2-E34-8	1.63	4.8	4.8	1	2	0.05	312	5
Endrin	2-E34-8	2.30	4.6	4.4	2	2	0.1	654	5
Endrin Aldehyde	2-E25-32P	0.33	0.6	0.6	1	2	0.2	211	4
Gamma-BHC	2-E34-8	0.67	1.9	1.9	1	2	0.05	653	5

Table 4-1. Average Reported Constituent Concentrations/Maximums and Minimums--200 East Groundwater Aggregate Area (January 1988 to April 1992).

Constituent	Well-Specific Data						All Wells		
	Well Number	Average of Reported Values	Maximum of Detections	Minimum of Detec-tions	Number of Detections	Number of < D.L.	Minimum Reported D.L.	Total Number of Analyses	Total Number of Wells with Detections
Heptachlor	2-E34-8	0.63	1.8	1.8	1	2	0.05	312	5
Bis(2-ethylhexyl) Phthalate	2-E32-5	56.00	56	56	1	0	1	151	13
Diethyl Ether	2-E34-5	10.00	10	10	1	0	9	3	3
Dimethoate	2-E25-31	5242.75	20600	349	2	2	0.48	99	4
Ethyl Cyanide	2-E25-32P	5003.00	7	7	1	3	5	152	1
P-Chloro-m-Cresol	2-E33-3	14.67	21	13	2	1	5	247	2
Phorate	6-43-42J	11.00	11	11	1	0	2	62	2
Trichloromonofluoromethane	2-E17-17	10.75	13	13	1	3	5	244	2
Triethyleneglycol	2-E33-35	10.00	10	10	1	0	10	1	1
Unknown	2-E25-31	841.60	4100	14	5	0	1	41	31
Unknown Aliphatic Hydrocarbon	2-E32-4	6.00	6	6	1	0	2	2	2
Unknown Halogenated Hydrocarbon	2-E25-32P	14.00	14	14	1	0	14	1	1
CONVENTIONAL CONSTITUENTS (μg/L)									
Ammonium Ion	6-49-55A	1109.40	1490	800	5	0	50	664	45
Bromide	2-E25-25	861.54	200	200	1	12	500	827	4
Chloride	2-E28-24	193000.00	193000	193000	1	0	430	1033	217
Fluoride[a/]	2-E28-24	2200.00	2200	2200	1	0	100	1174	175

Table 4-1. Average Reported Constituent Concentrations/Maximums and Minimums--200 East Groundwater Aggregate Area (January 1988 to April 1992).

Constituent	Well-Specific Data						All Wells		
	Well Number	Average of Reported Values	Maximum of Detections	Minimum of Detec-tions	Number of Detections	Number of < D.L.	Minimum Reported D.L.	Total Number of Analyses	Total Number of Wells with Detections
RADIONUCLIDES (pCi/L)									
Gross Alpha[a/]	2-E28-24	166.80	1250	0.34	5	3	-0.774	1648	242
Gross Beta	2-E28-23	10254.44	12900	7660	9	0	-2.65	1945	273
Tritium	2-E24-11	4270000.00	8070000	2250000	7	0	-371	1671	233
Beryllium-7	6-50-42	222.00	222	222	1	0	-242	85	5
Carbon-14	2-E24-1	38.26	58.8	27.9	5	0	-2.52	33	5
Potassium-40	2-E33-35	240.35	469	469	1	1	4.13	87	45
Cobalt-60	6-50-53A	473.78	532	352	9	0	-13.7	1046	86
Zinc-65	2-E13-14	7.46	7.46	7.46	1	0	-17.9	87	4
Strontium-90	2-E28-25	5148.57	6270	3150	7	0	-3.67	845	45
Zirconium/Niobium-95	6-36-46R	81.40	81.4	81.4	1	0	-32	87	2
Technetium-99	6-50-53A	21665.17	32700	391	6	0	-11.2	546	129
Ruthenium-106	2-E17-15	300.63	885	87.2	4	2	-96.9	978	37
Antimony-125	2-E34-8	7.89	11.9	10.9	2	1	-48.1	153	15
Iodine-129[a/]	6-35-70	30.05	87.8	10.3	7	0	-0.409	298	110
Cesium-134	2-E17-1	3.65	3.65	3.65	1	0	-7.42	87	3
Cesium-137	2-E28-23	1328.40	1800	844	10	0	-9.94	1047	46
Cerium/Praseodymium-144	2-E34-2	28.65	34.7	34.7	1	1	-39.1	87	2
Europium-154	6-36-46R	12.20	12.2	12.2	1	0	-38.1	87	11
Europium-155	2-E27-16	9.35	9.35	9.35	1	0	-13.4	97	4

Table 4-1. Average Reported Constituent Concentrations/Maximums and Minimums--200 East Groundwater Aggregate Area (January 1988 to April 1992).

Constituent	Well-Specific Data						All Wells		
	Well Number	Average of Reported Values	Maximum of Detections	Minimum of Detec-tions	Number of Detections	Number of < D.L.	Minimum Reported D.L.	Total Number of Analyses	Total Number of Wells with Detections
Lead-212	2-E33-35	12.60	12.6	12.6	1	0	9.56	4	4
Radium	2-E25-17	1.65	1.65	1.65	1	0	-0.094	667	108
Uranium	2-E28-26	21.23	28.5	15.9	6	0	0.0132	363	123
Uranium-234	2-E28-21	33.07	70.8	12	3	0	0.0645	72	10
Uranium-235	2-E28-21	1.57	3.21	0.554	3	0	-0.00785	72	9
Uranium-238	2-E28-21	31.40	67.2	11.7	3	0	0.0769	72	10
Plutonium-238	2-E28-23	0.36	2.13	0.0407	7	0	-0.0167	254	6
Plutonium-239/40	2-E28-23	73.86	449	7.21	7	0	-0.00938	255	19
Americium-241	2-E33-35	0.04	0.085	0.085	1	1	-0.00708	55	11
INORGANIC COMPOUNDS (µg/L)									
Aluminum	2-E16-2	11195.00	14000	8390	2	0	150	551	50
Aluminum, filtered	6-40-33A	485.00	485	485	1	0	150	659	26
Antimony	2-E33-31	129.75	19	19	1	3	100	789	20
Antimony	2-E33-32	129.75	19	19	1	3	100	789	20
Antimony, filtered	2-E33-28	114.88	19	19	1	7	100	745	21
Arsenic	2-E25-17	56.00	56	56	1	0	2	856	127
Arsenic, filtered	2-E25-30P	23.68	34	15	4	0	2	772	119
Barium	2-E25-17	343.00	343	343	1	0	6	932	162
Barium, filtered	6-40-39	113.20	120	108	5	0	6	841	169

Table 4-1. Average Reported Constituent Concentrations/Maximums and Minimums--200 East Groundwater Aggregate Area (January 1988 to April 1992).

Constituent	Well-Specific Data						All Wells		
	Well Number	Average of Reported Values	Maximum of Detections	Minimum of Detec-tions	Number of Detections	Number of < D.L.	Minimum Reported D.L.	Total Number of Analyses	Total Number of Wells with Detections
Beryllium	2-E32-4	4.75	10	10	1	11	1	790	5
Beryllium, filtered	2-E27-10	5.33	7	7	1	5	1	746	8
Boron	2-E32-5	182.00	182	182	1	0	10	424	111
Boron, filtered	2-E32-5	168.00	168	168	1	0	10	456	128
Cadmium	2-E25-17	211.00	211	211	1	0	2	811	22
Cadmium, filtered	2-E17-14	4.22	12	4	2	7	2	754	18
Cadmium, filtered	2-E17-15	4.22	6	6	1	8	2	754	18
Calcium	2-E28-12	80700.00	80700	80700	1	0	11000	970	169
Calcium, filtered	6-50-53A	240666.67	254000	222000	9	0	10600	879	172
Chromium	6-40-40B	395.00	770	770	1	1	3	986	123
Chromium, filtered	2-E24-19	65.00	65	65	1	0	3	771	52
Cobalt	2-E25-17	30.00	30	30	1	0	4	628	4
Copper	2-E17-17	92.70	798	11	5	5	7	837	82
Copper, filtered	2-E33-34	26.00	32	32	1	1	7	759	28
Cyanide	6-50-53A	869.33	1690	422	15	0	5	497	9
Hydrazine[a/]	2-E25-17	38.00	38	38	1	0	30	249	2
Iron	2-E25-17	592000.00	592000	592000	1	0	20	1016	165
Iron, filtered	6-54-34	3370.00	3370	3370	1	0	20	816	120
Lead	2-E25-17	52.00	52	52	1	0	2	761	68
Lead, filtered	2-E33-28	6.56	16	8	2	7	2	724	20

Table 4-1. Average Reported Constituent Concentrations/Maximums and Minimums--200 East Groundwater Aggregate Area (January 1988 to April 1992).

Constituent	Well-Specific Data						All Wells		
	Well Number	Average of Reported Values	Maximum of Detections	Minimum of Detec-tions	Number of Detections	Number of < D.L.	Minimum Reported D.L.	Total Number of Analyses	Total Number of Wells with Detections
Lithium	2-E16-2	19.00	19	19	1	0	10	341	9
Lithium, filtered	6-40-33A	16.00	16	16	1	0	10	372	8
Magnesium	6-50-53A	89900.00	89900	89900	1	0	870	981	169
Magnesium, filtered	6-50-53A	67388.89	71100	63000	9	0	2880	877	172
Manganese	2-E25-17	6240.00	6240	6240	1	0	2	918	142
Manganese, filtered	6-52-57	295.00	295	295	1	0	2	768	79
Mercury	2-E27-15	0.44	0.92	0.92	1	2	0.1	736	2
Mercury, filtered	2-E27-15	0.21	0.23	0.23	1	2	0.1	702	3
Nickel	6-50-53A	590.00	590	590	1	0	7	953	108
Nickel, filtered	2-E24-19	60.00	60	60	1	0	7	769	43
Nitrate[a/]	6-50-53A	503215.59	625000	665	17	0	200	1887	239
Nitrite	6-26-35C	1080.00	1400	1400	1	4	200	688	2
Phosphate	2-E25-30P	9465.71	24500	1100	7	0	400	991	4
Potassium	6-50-53A	16800.00	16800	16800	1	0	2190	1004	168
Potassium, filtered	6-50-53A	14522.22	15400	13500	9	0	2380	886	172
Selenium	6-50-53A	33.00	33	33	1	0	1	765	34
Selenium, filtered	6-50-53A	23.50	27	19	4	0	1	735	28
Silicon	2-E25-17	73600.00	73600	73600	1	0	3830	437	112
Silicon, filtered	2-E25-23	31600.00	31600	31600	2	0	836	470	129
Silver	2-E33-10	12.50	15	15	1	1	4	806	2

Table 4-1. Average Reported Constituent Concentrations/Maximums and Minimums--200 East Groundwater Aggregate Area (January 1988 to April 1992).

Constituent	Well-Specific Data						All Wells		
	Well Number	Average of Reported Values	Maximum of Detections	Minimum of Detec-tions	Number of Detections	Number of < D.L.	Minimum Reported D.L.	Total Number of Analyses	Total Number of Wells with Detections
Silver, filtered	6-24-34A	12.13	27	27	1	7	4	748	1
Sodium	2-E25-30P	88042.86	107000	66400	7	0	3540	961	168
Sodium, filtered	2-E25-30P	74900.00	91600	62600	7	0	3770	880	171
Strontium	2-E17-14	388.00	488	313	8	0	78	604	116
Strontium, filtered	6-50-53A	1009.00	1150	944	9	0	81	744	146
Sulfate	6-50-53A	404818.18	434000	386000	11	0	500	1043	215
Thallium	6-49-57A	50.00	50	50	1	0	5	154	1
Thallium, filtered	6-49-57A	50.00	50	50	1	0	5	137	1
Titanium	2-E16-2	1120.00	1120	1120	1	0	60	340	10
Total Carbon	6-24-34B	56560.83	91000	65	6	0	18	651	160
Uranium, chemical	2-E28-18	38.01	58.5	9.06	15	0	-313	337	110
Vanadium	2-E25-17	656.00	656	656	1	0	5	921	143
Vanadium, filtered	2-E25-23	135.40	145	123	5	0	5	837	152
Zinc	6-40-40B	547.00	1000	94	2	0	3	914	149
Zinc, filtered	6-54-34	358.00	358	358	1	0	3	811	122
MISCELLANEOUS									
Total Dissolved Solids (ppb)	2-E25-35	444000.00	444000	444000	1	0	130	86	51
Total Organic Carbon (ppb)	2-E25-31	1550.00	3790	1000	13	16	133	1652	46
Total Organic Halogen (ppb)	2-E17-14	2416.84	19300	10	5	20	-5.8	2082	90
COD (ppb)	6-43-41E	101.00	178	24	2	0	[illegible]	3	2

Table 4-1. Average Reported Constituent Concentrations/Maximums and Minimums--200 East Groundwater Aggregate Area (January 1988 to April 1992).

Constituent	Well-Specific Data						All Wells		
	Well Number	Average of Reported Values	Maximum of Detections	Minimum of Detec-tions	Number of Detections	Number of < D.L.	Minimum Reported D.L.	Total Number of Analyses	Total Number of Wells with Detections
Alkalinity (ppb)	6-23-34	219885.38	593000	250	13	0	66	307	93
pH, Field Measurement (pH)	6-50-48B	9.98	9.98	9.98	1	0	7	2140	245
Conductivity, Laboratory (μmho/cm)	2-E25-13	1490.00	1490	1490	1	0	142	1115	157
Specific Conductance (μmho/cm)	6-50-53A	1459.75	1621	1295	4	0	80	2228	245
Turbidity (NTU)	2-E16-2	200.00	200	200	1	0	0.1	545	135
Turbidity (NTU)	2-E25-17	200.00	200	200	1	0	0.1	545	135
Turbidity (NTU)	2-E25-6	200.00	200	200	1	0	0.1	545	135
Coliform (Membrane Filter) (ppb)	2-E33-30	2.75	8	8	1	3	1	154	4
Coliform Bacteria (MPN)	2-E25-29P	268.22	2400	2400	1	8	1	505	12

Notes:

a/ Chemical data combined from two chemical constituent data codes or from more than one analytical method. Chemical constituent data codes from Hanford Site Groundwater Database provided by WHC.

b/ No minimum detection limit for reported constituent.

μg/L Micrograms per liter

pCi/L Picocuries per liter

Average reported value for some constituents exceeds the maximum detection. This is the result of the reported detection level(s) for the well exceeding the detection result.

D.L. Detection Limit

Table 4-2. Comparison of Average Reported Concentrations of Selected Chemical Constituents for the Unconfined and Confined Aquifers (January 1988 to April 1992).

	Radionuclides (pCi/L)									Inorganic Compounds (μg/L)			
Well Aquifer	Gross Alpha	Gross Beta	Tritium	^{60}Co	^{90}Sr	^{99}Tc	^{129}I	^{137}Cs	$^{239/240}Pu$	Arsenic	Chromium	Cyanide	Nitrate
2-E26-8 Confined	0.34[a]	9.37	ND	–	ND	ND	ND	–	–	–	–	–	ND
2-E26-4 Unconfined	3.52	6.23	23487.50	–	0.46	–	1.27	–	–	–	–	–	2144.58[a]
2-E33-12 Confined[b]	29.15	286.90	497.50	10.48	ND	704.97	–	ND	–	–	–	–	ND
2-E33-13 Unconfined	28.00	340.00	6300.00	ND	ND	770.00	–	ND	–	–	–	–	–
2-E33-39 Unconfined	–	–	–	–	–	–	–	–	–	8.20	3.70	ND	–
2-E33-3 Unconfined	9.20	177.15	4066.00	13.76	ND	57.75	2.39	ND	0.04	10.00	ND	12.33	40776.35
6-42-40C Confined	3.11	11.58	2612.50	–	0.59	4.84	0.11	–	–	–	–	–	ND
6-42-40A Unconfined	0.81	4.29	169.78	-2.38[a]	ND	–	–	0.11[a]	ND	ND	ND	ND	1920[a]
6-42-40B Unconfined	1.10	10.88	573.84	1.01[a]	0.29[a]	ND	–	0.72[a]	–	5.00	–	ND	ND
6-43-41E Unconfined	2.82	6.20	74910.73	ND	ND	–	–	ND	ND	ND	–	ND	7980.00
6-47-50 Confined	2.19	7.68	230.83[a]	ND	1.07	153.43	0.01	ND	ND	2.70	–	ND	6472.86
2-E34-6 Unconfined	2.43	9.29	315.63	1.60[a]	0.01[a]	2.36	–	ND	ND	5.29	–	ND	6600.00
2-E34-5 Unconfined	3.09	7.28	208.39	ND	0.09	ND	–	ND	ND	5.53	9.44	ND	14125.00

Table 4-2. Comparison of Average Reported Concentrations of Selected Chemical Constituents for the Unconfined and Confined Aquifers (January 1988 to April 1992).

	Radionuclides (pCi/L)									Inorganic Compounds (μg/L)			
Well Aquifer	Gross Alpha	Gross Beta	Tritium	^{60}Co	^{90}Sr	^{99}Tc	^{129}I	^{137}Cs	$^{239/240}Pu$	Arsenic	Chromium	Cyanide	Nitrate
6-49-55B Confined	2.68	6.08	ND	ND	ND	13.14	ND	ND	–	ND	20.80	ND	ND
6-49-55A Unconfined	6.35	929.82	8443.64	95.78	ND	5061.00	0.06	ND	–	6.10	8.70	96.32	138083.81
6-49-57B Confined	2.90	ND	–	ND	ND	ND	–	ND	–	ND	9.80	ND	–
6-49-57A Unconfined	15.00	170.00	–	ND	ND	650.00	–	ND	–	7.10	26.4	31.50	–
6-50-45 Confined	1.95	6.31	ND	–	ND	ND	-0.02[a]	–	–	–	–	–	ND
6-50-42 Unconfined	1.20	6.02	3947.14	ND	ND	ND	0.32	ND	ND	–	–	–	5000.00
6-50-48B Confined	ND	12.00	ND	–	ND	5.30	-0.0002[a]	–	–	–	–	–	ND
6-51-46 Confined	ND	17.66	ND	–	ND	ND	0.0005[a]	–	–	–	–	–	ND
6-52-46A Confined	1.92	8.76	677.24	–	ND	ND	-0.01[a]	–	–	–	–	–	3560.00
6-52-48 Confined	0.97[a]	10.09	ND	–	ND	ND	0.01[a]	–	–	–	–	–	ND
6-53-47A Unconfined	1.59	114.32	–	1.18[a]	59.69	2.59	–	1.48[a]	ND	ND	–	ND	3445.00
6-53-47B Unconfined	4.31	197.00	ND	1.39[a]	100.30	–	–	ND	–	–	–	–	30600.00
6-53-50 Confined	0.82	6.31	ND	–	ND	ND	0.04[a]	–	–	–	–	–	ND
6-54-49 Unconfined	1.00	48.48	ND	–	22.44	–	–	–	–	–	–	–	4950.00

Table 4-2. Comparison of Average Reported Concentrations of Selected Chemical Constituents for the Unconfined and Confined Aquifers (January 1988 to April 1992).

	Radionuclides (pCi/L)									Inorganic Compounds (μg/L)			
Well Aquifer	Gross Alpha	Gross Beta	Tritium	^{60}Co	^{90}Sr	^{99}Tc	^{129}I	^{137}Cs	$^{239/240}Pu$	Arsenic	Chromium	Cyanide	Nitrate
6-50-53B Confined	3.20	7.00	–	ND	ND	ND	–	ND	–	ND	–	ND	–
6-50-53A Confined	4.92[a]	2763.89	4314.00	473.78	ND	21665.17	0.15	ND	–	2.90	10.00	869.33	503215.59
6-54-57 Confined	1.97[a]	9.67	146.40[a]	ND	0.37[a]	20.16	ND	ND	–	–	–	–	ND
6-55-57 Unconfined	38.00	890.00	8200.00	70.65	ND	2150.00	–	ND	–	–	–	–	–
6-56-53 Confined	ND	11.55	ND	–	ND	ND	0.03	–	–	–	–	–	ND
2-E28-1 Semi-confined to Confined	–	–	6636.67	ND	ND	28.90	2.55	ND	0.05	–	–	–	4825.00
2-E28-7 Semi-confined to Confined	1.94	148.00	7142.50	2.29[a]	75.59	92.43	1.04	3.75	0.02	ND	–	ND	7576.00
2-E28-5 Shallow Unconfined	–	–	2180.00	–	–	–	–	–	–	–	–	–	3100.00
2-E16-2 Semi-confined to Confined	2.29[a]	11.09	2705.11	0.60[a]	ND	ND	0.17	ND	ND	31.00	–	ND	2403.68[a]
2-E25-23 Shallow Unconfined	0.57[a]	10.08	259.83[a]	ND	ND	2.14	0.06	ND	ND	24.00	ND	ND	1998.00[a]
2-E25-24 Shallow Unconfined	0.97[a]	10.85	418.14	0.07[a]	ND	ND	ND	ND	ND	17.00	ND	ND	1958.46[a]

Table 4-2. Comparison of Average Reported Concentrations of Selected Chemical Constituents for the Unconfined and Confined Aquifers (January 1988 to April 1992).

	Radionuclides (pCi/L)									Inorganic Compounds (μg/L)			
Well Aquifer	Gross Alpha	Gross Beta	Tritium	^{60}Co	^{90}Sr	^{99}Tc	^{129}I	^{137}Cs	$^{239/240}Pu$	Arsenic	Chromium	Cyanide	Nitrate
2-E24-11 Semi-confined to Confined	–	23.77	4270000.00	ND	1.08	–	–	ND	–	–	–	–	123573.60
2-E24-12 Shallow Unconfined	5.67	261.40	270591.67	4.94[a]	6.46	–	1.91	ND	–	–	–	ND	111676.92
6-34-41B Semi-confined to Confined	–	–	36971.43	3.14[a]	–	–	–	ND	–	–	–	–	5745.89
6-33-42 Shallow Unconfined	3.29	24.80	283375.00	–	–	16.00	4.90	–	–	–	–	–	22585.71
6-34-42 Shallow Unconfined	3.29	11.90	75850.00	7.00	–	13.73	6.13	0.43	–	5.35	–	ND	8305.00
6-26-35C Semi-confined to Confined	1.67	20.96	52450.00	–	–	–	–	–	–	ND	–	ND	21342.86
6-26-35A Shallow Unconfined	2.09	22.22	285400.00	–	–	–	–	–	–	5.00[a]	–	ND	28112.50
6-60-57 Semi-confined to Confined	–	6.47	370.43	–	–	–	ND	–	–	–	–	ND	2574.29
6-59-58 Shallow Unconfined	ND	7.20	754.50	–	ND	22.10	ND	–	–	–	–	ND	3366.67

Table 4-2. Comparison of Average Reported Concentrations of Selected Chemical Constituents for the Unconfined and Confined Aquifers (January 1988 to April 1992).

	Radionuclides (pCi/L)									Inorganic Compounds (μg/L)			
Well Aquifer	Gross Alpha	Gross Beta	Tritium	^{60}Co	^{90}Sr	^{99}Tc	^{129}I	^{137}Cs	$^{239/240}Pu$	Arsenic	Chromium	Cyanide	Nitrate
6-54-45A Semi-confined to Confined	6.09	7.78	ND	–	–	–	–	–	–	–	–	–	ND
6-55-40 Shallow Unconfined	–	–	203.59[a]	–	–	–	–	–	–	–	–	–	7000.00
6-54-48 Shallow Unconfined	1.51	87.91	ND	ND	54.04	–	–	ND	–	–	–	–	492000.00
2-E24-1 Deep Unconfined	3.97	44.64	3707500.00	ND	10.35	–	26.60	ND	–	–	–	–	154505.89
2-E24-16 Shallow Unconfined	3.40	40.23	1875000.47	2.68	–	–	–	-0.16[a]	ND	8.91	–	ND	96557.14
2-E24-4 Deep Unconfined	0.73	5.26	8361.43	1.32[a]	ND	–	–	ND	–	–	ND	ND	2360.20[a]
2-E24-13 Shallow Unconfined	–	6.59	6273.33	1.01	ND	–	4.07	ND	–	–	–	–	2860.00
2-E25-25 Deep Unconfined	0.86[a]	5.20	300.62	ND	ND	0.73[a]	0.32	ND	ND	5.07	30.52	ND	756.31
2-E26-5 Deep Unconfined	–	–	–	–	–	–	–	–	–	8.00	ND	ND	1490.00
6-28-52A[c]	2.30	8.41	ND	–	–	–	–	–	–	–	–	–	ND
2-E17-6[c]	1.38	33.22	30713.36	ND	ND	ND	ND	4.58	–	ND	ND	ND	24240.00

Table 4-2. Comparison of Average Reported Concentrations of Selected Chemical Constituents for the Unconfined and Confined Aquifers (January 1988 to April 1992). Page 6 of 6

	Radionuclides (pCi/L)									Inorganic Compounds (μg/L)			
Well Aquifer	Gross Alpha	Gross Beta	Tritium	^{60}Co	^{90}Sr	^{99}Tc	^{129}I	^{137}Cs	$^{239/240}Pu$	Arsenic	Chromium	Cyanide	Nitrate
2-E33-40[c/]	6.40	20.00[a/]	ND	ND	ND	3.20	–	ND	–	2.30	39.00	ND	–
6-28-40[c/]	3.55	12.83	59816.67	–	–	–	0.17	–	–	–	–	–	16350.00
6-32-62[c/]	1.94	7.28	2383.33	–	–	–	0.04	–	–	–	–	–	26450.00

Confined Aquifer: Rattlesnake Ridge interbed.
Semiconfined to Confined Aquifer: Ringold unit A gravels beneath Ringold lower mud sequence.

μg/L Micrograms per liter.
pCi/L Picocuries per liter.
ND All reported values below reported detection limit for well.
a/ Average reported value exceeds the maximum detection limit for constituent in listed well.
b/ Originally open borehole into Rattlesnake Ridge interbed. Grouted in 1982 to isolate screened interval in Rattlesnake Ridge interbed, but poor well seal currently suspected.
c/ Screened interval across multiple aquifers or hydrostratigraphic units.
"--" No information available.

Table 4-3. Background Concentrations in Hanford Site Groundwater
(source: DOE/RL 1992d)

Constituent	Background Concentration	Units
Inorganics		
Aluminum	<200 1/	ppb (μg/L)
Ammonium	120	ppb (μg/L)
Arsenic	10	ppb (μg/L)
Barium	68.5	ppb (μg/L)
Beryllium	<5 1/	ppb (μg/L)
Bismuth	<5 1/	ppb (μg/L)
Boron	<100 1/	ppb (μg/L)
Cadmium	<10 1/	ppb (μg/L)
Calcium	63,600	ppb (μg/L)
Chloride: low 2/ high 2/	8,690 28,500	ppb (μg/L) ppb (μg/L)
Chromium	<30 1/	ppb (μg/L)
Copper	<30 1/	ppb (μg/L)
Fluoride	1,340 (775 3/)	ppb (μg/L)
Iron: low 2/ mid 2/ high 2/	86 291 818	ppb (μg/L) ppb (μg/L) ppb (μg/L)
Lead	<5 1/	ppb (μg/L)
Magnesium	16,480	ppb (μg/L)
Manganese: low 2/ high 2/	24.5 163.5	ppb (μg/L) ppb (μg/L)
Mercury	<0.1 1/	ppb (μg/L)
Nickel	<30 1/	ppb (μg/L)
Nitrate	12,400	ppb (μg/L)
Phosphate	<1,000 1/	ppb (μg/L)
Potassium	7,975	ppb (μg/L)
Selenium	<5 1/	ppb (μg/L)
Silicon	26,500	ppb (μg/L)

9 2 1 2 7 5 1 5 3 3

Table 4-3. Background Concentrations in Hanford Site Groundwater
(source: DOE/RL 1992d)

Constituent	Background Concentration	Units
Silver	<10 1/	ppb (μg/L)
Sodium	33,500	ppb (μg/L)
Strontium	264.1	ppb (μg/L)
Sulfate	90,500	ppb (μg/L)
Vanadium	15	ppb (μg/L)
Zinc: low 2/ high 2/	<50 1/ 673	ppb (μg/L) ppb (μg/L)
Parameters		
Alkalinity (field) (lab)	215,000 210,000	ppb (μg/L) ppb (μg/L)
pH (field) (lab)	6.90 - 8.24 7.25 - 8.25	pH units pH units
TOC	2,610 (1,610 3/)	ppb (μg/L)
Conductivity (field) (lab)	539 530	μmho/cm μmho/cm
TOX	60.8 (37.6 3/)	[ppb (μg/L)]
Carbon (total)	50,100	ppb (μg/L)
Radionuclides/Radioactivity Parameters		
Gross alpha	63 (5.79 3/)	pCi/L
Gross beta	35.5 (12.62 3/)	pCi/L
Radium	0.23	pCi/L
Uranium	3.43	pCi/L

Background concentrations are "Provisional Threshold Values" from Table 5-9 of DOE/RL 1992d.

1/ Detection limit.
2/ Low, mid, high refer to separate concentration groupings which appeared in the sample population but apparently cannot be identified spatially on the Hanford Site.
3/ Reanalysis of background with potential outliers removed.

9 2 1 2 7 5 1 5 3 4

Table 4-4. Estimated Areas, Volumes, and Masses of Plumes, 200 East Groundwater Aggregate Area

Inorganic and Organic Compounds:						Groundwater Volume (m^3) Porosity (n) =			
Chemical Compound	Plume	Max. Conc. (μg/L)	Monitoring Well	Bounding Contour Interval (μg/L)	Area (m^2)	n = 0.1	n = 0.2	n = 0.3	Mass (kg)
Arsenic	A	13	699-44-42						
	B	10	699-43-45						
	C	24	299-E25-30P						
	D	12	299-E18-3						
				10	740,000	740,000	1,500,000	2,200,000	22.8
Chromium	A	56	299-E33-30						
	B	51	299-E33-32						
	C	65	299-E24-19						
				50	120,000	120,000	240,000	360,000	13.5
Cyanide		869	699-50-53A	200	850,000	850,000	1,700,000	2,550,000	985
Nitrate	A	492,000	699-54-48						
	B	503,000	699-50-53A						
	C	142,000	299-E25-13						
	D	150,000	299-E25-20						
	E	244,000	299-E17-15						
				45,000	2,100,000	2,100,000	4,300,000	6,400,000	740,000

Table 4-4. Estimated Areas, Volumes, and Masses of Plumes, 200 East Groundwater Aggregate Area

Radionuclides:

Chemical Compound	Plume	Max. Activity (pCi/L)	Monitoring Well	Bounding Contour Interval (pCi/L)	Area (m^2)	Groundwater Volume (m^3) Porosity (n) = n = 0.1	n = 0.2	n = 0.3	Activity (Ci)
Gross Alpha	A	38	699-55-57						
	B	20	699-52-54						
	C	30	299-E33-7						
	D	166	299-E28-24						
				15	660,000	660,000	1,300,000	2,000,000	0.03
Gross Beta	A	890	699-55-57						
	B	558	699-53-48B						
	C	2,760	699-50-53A						
	D	10,300	299-E28-23						
	E	937	299-E17-15						
	F	100	299-E13-14						
				50	1,000,000	1,100,000	2,300,000	3,400,000	5.2
Tritium	A	45,700	699-45-42						
	B	74,900	699-43-41E						
	C1	4,270,000	299-E24-11						
	C2	1,130,000	699-35-66						
	C3	2,069,200	299-E25-19						
	C4	298,000	699-32-43						
				20,000	42,000,000	42,000,000	85,000,000	130,000,000	16,400
Co-60		474	699-50-53A	100	750,000	750,000	1,500,000	2,200,000	0.43

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Table 4-4. Estimated Areas, Volumes, and Masses of Plumes, 200 East Groundwater Aggregate Area

Radionuclides:						Groundwater Volume (m^3) Porosity (n) =			
Chemical Compound	Plume	Max. Activity (pCi/L)	Monitoring Well	Bounding Contour Interval (pCi/L)	Area (m^2)	n = 0.1	n = 0.2	n = 0.3	Activity (Ci)
Sr-90	A	311	699-53-48B						
	B	5150	299-E28-25						
	C	194	299-E24-19						
	D	19	299-E17-14						
				8	1,100,000	1,100,000	2,100,000	3,200,000	0.17
Tc-99	A	2150	699-55-57						
	B	21700	699-50-53A						
				900	1,500,000	1,500,000	2,900,000	4,400,000	21.9
I-129		26.6	299-E24-1	1	29,000,000	29,000,000	58,000,000	87,000,000	0.24
Cs-137		1330	299-E28-23	120	22,000	22,000	44,000	66,000	0.014
Pu-239/240		73.9	299-E28-23	1	19,000	19,000	37,000	56,000	0.0006

Table 4-5. Summary of Waste-Producing Processes Potentially Contributing Contaminants to Groundwater Beneath the 200 East Area.

Process	Waste Generated	Major Chemical Constituents	Waste Disposal Methods	Waste Management Units Potentially Affecting Groundwater	Years In Service
U Plant Aggregate Area					
Uranium recovery	Process waste	Nitric acid, bismuth phosphate, NAOH	Crib, french drain, pond, ditch	216-U-1, 216-U-2, 216-U-10	1952 - 1958
	Wastewater	Nitrates	Crib, french drain, pond, ditch	216-U-1, 216-U-2, 216-U-10	1952 - 1958
UO_3 conversion	Wastewater	Nitrates	Pond, crib, ditch	216-U-10, 216-U-1, 216-U-2, 216-U-12	1944 - present
Solvent treatment	Spent solvents	Tributyl phosphate, normal paraffin hydrocarbons	Crib	various	1952 - 1958
	Carbonate scrub solution	Carbonate, tributyl phosphate, normal paraffin hydrocarbons	Crib	various	1952 - 1958
Analytical laboratory	Laboratory process waste	Unknown	Reverse well, french drain	216-U-4	1947 - 1972
	Used or discarded reagents	Unknown	Reverse well, french drain	216-U-4	1947 - 1972
	Wastewater	Unknown	Reverse well, french drain	216-U-4	1947 - 1972

Table 4-5. Summary of Waste-Producing Processes Potentially Contributing Contaminants to Groundwater Beneath the 200 East Area.

Process	Waste Generated	Major Chemical Constituents	Waste Disposal Methods	Waste Management Units Potentially Affecting Groundwater	Years In Service
Tank farm condensate	Wastewater	Unknown	French drain	None	1954 - 1957
		Z Plant Aggregate Area			
Plutonium Finishing Plant (PFP)	Process waste	Nitric acid, nitrate salts, fluoride	Cribs until 1973, tanks after 1973	216-Z-3, 216-Z-12	1949 - 1973
	Wastewater	Sodium, fluoride, sulfate	Ponds, ditches, seepage basin	216-U-10, 216-Z-21	1949 - 1973
RECUPLEX	Aqueous process waste	Nitric acid, fluorides, nitrates, phosphate	Ditch, pond	216-U-10	1955 - 1962
	Organic solvent waste	CCl_4, TBP, DBBP	Trench	216-Z-9	1955 - 1962
	Spent silica gel	Silica gel, Pu	French drain	216-Z-8	1955 - 1962
Plutonium Reclamation Facility (PRF)	Aqueous process waste	Nitric acid, fluorides, nitrates, phosphate	Crib, tile field	216-Z-1, 216-Z-2, 216-Z-1A, 216-Z-18	1964 - 1978 1984 - 1991
	Organic process waste	CCl_4, TBP, DBBP	Crib, tile field	216-Z-1, 216-Z-2, 216-Z-1A, 216-Z-18	1964 - 1978
Americium recovery	Spent ion exchange resin	^{241}Am, resin	Ditches, pond	216-U-10	1964 - 1976
Analytical laboratory	Laboratory process wastes	Unknown	Crib	216-Z-3, 216-Z-12	1955? - present
	Used or discarded reagents	Unknown	Crib	216-Z-3, 216-Z-12	1955 - present

Table 4-5. Summary of Waste-Producing Processes Potentially Contributing Contaminants to Groundwater Beneath the 200 East Area.

Process	Waste Generated	Major Chemical Constituents	Waste Disposal Methods	Waste Management Units Potentially Affecting Groundwater	Years In Service
	Wastewater	Sanitary and lab water	Crib	216-Z-3, 216-Z-12	1955 - present
Plutonium Isolation Facility (PIF)	Process waste	Nitric acid	Trench, crib, reverse well	216-Z-5, 216-Z-7 216-Z-10	1945 - 1949
	Wastewater	Unknown			
S Plant Aggregate Area					
Feed preparation	Jacket dissolution	Fission products, jacket constituents (alloy) sodium hydroxide, sodium aluminate	Tank	None	1951 - 1967
	Slug dissolution	Sodium hydroxide, ferrous sulfamate, zirconium, niobium	Tank	None	1951 - 1967
Extraction cycles	Aqueous process waste	Sodium aluminate, fission products, sodium hydroxide	Crib	Various	1951 - 1967
	Organic process waste	Hexone	Crib	Various	1951 - 1967
Solvent recovery	Aqueous waste	Sodium hydroxide, sodium carbonate	Crib	Various	1951 - 1967

Table 4-5. Summary of Waste-Producing Processes Potentially Contributing Contaminants to Groundwater Beneath the 200 East Area.

Process	Waste Generated	Major Chemical Constituents	Waste Disposal Methods	Waste Management Units Potentially Affecting Groundwater	Years In Service
Analytical laboratory	Laboratory waste	Sodium hydroxide, organics, fission products	Tank	None	1951 - present
T Plant Aggregate Area					
Bismuth phosphate	Process waste	Nitric acid	Tank, crib, trench	Various	1944 - 1956
	Aqueous process waste	Phosphoric acid, nitrate solution, uranium, plutonium	Tank, crib, trench	Various	1944 - 1956
Lanthanum fluoride	Process waste	Plutonium, sodium bismuthate, phosphoric acid, nitric acid, hydrogen fluoride, lanthanum salts	Tank, crib, trench	Various	1944 - 1956
	Aqueous process waste	Plutonium, sodium bismuthate, phosphoric acid, nitric acid, hydrogen fluoride, lanthanum salts	Tank, crib, trench	Various	1944 - 1956
"Hot" Semi-Works	Aqueous process waste	Ammonium silico-fluoride	Tank, crib, trench	Various	1944 - 1956
Decontamination and equipment refurbishment	Wastewater	Bismuth phosphate	Crib	216-T-28	1944 - 1956

Table 4-5. Summary of Waste-Producing Processes Potentially Contributing Contaminants to Groundwater Beneath the 200 East Area.

Process	Waste Generated	Major Chemical Constituents	Waste Disposal Methods	Waste Management Units Potentially Affecting Groundwater	Years In Service
Containment Systems Test Facility (CSTF)	NA	NA	NA	NA	NA
Analytical laboratory	Aqueous process waste	Sodium, lithium, sodium iodine	Crib	216-T-28	1944 - 1956
Analytical laboratory	Aqueous process waste	Cesium, manganese, zinc, lithium, sulfate, iodine and hydrogen iodine	Crib	216-T-28	1944 - 1956

NA = No information available.

Table 4-6. Candidate Contaminants of Potential Concern for the 200 East Groundwater Aggregate Area

TRANSURANICS

Americium-241
Americium-242*
Americium-242m
Americium-243
Curium-242*
Curium-244
Curium-245
Neptunium-237
Neptunium-239
Plutonium-238
Plutonium-239
Plutonium-240
Plutonium-241

URANIUM

Uranium (total)
Uranium-233
Uranium-234
Uranium-235
Uranium-236
Uranium-238

FISSION PRODUCTS

Actinium-225
Actinium-227
Antimony-125
Antimony-126
Antimony-126m
Astatine-217*
Barium-133
Barium-137m
Bismuth-210
Bismuth-211
Bismuth-213
Bismuth-214
Carbon-14
Cerium,-144
Cesium-134
Cesium-135
Cesium-137
Cobalt-60
Europium-154
Francium-221
Francium-223*
Iodine-129
Krypton-85
Lead-209
Lead-210
Lead-211
Lead-214
Nickel-59
Nickel-63
Polonium-214
Polonium-215*
Polonium-218
Potassium-40
Protactinium-231
Protactinium-233*
Protactinium-234*
Niobium-93m
Niobium-95*
Niobium-95m*
Palladium-107*
Polonium-210
Polonium-211*
Polonium-213*
Protactinium-234m*
Radium-223
Radium-225
Radium-226
Radium-228
Radon-219*
Radon-222
Rhodium-106
Ruthenium-106
Samarium-151
Selenium-79
Silver-110*
Silver-110m*
Strontium-89*
Strontium-90
Technetium-99
Thallium-207
Thorium-227
Thorium-229
Thorium-230
Thorium-231
Thorium-232
Thorium-234
Tin-126*
Tritium
Yttrium-90
Zirconium-93
Zirconium-95*

METALS

Aluminum
Barium
Beryllium
Cadmium
Chromium
Copper
Iron
Lead
Lithium
Magnesium
Manganese
Mercury
Nickel
Radium
Silver
Strontium
Titanium
Uranium
Vanadium
Zinc

OTHER INORGANICS

Ammonia
Ammonium nitrate
Arsenic
Boron
Calcium
Chloride
Cyanide
Ferrocyanide
Fluoride
Hydrofluoric acid
Nitrate
Nitrite
Nitric acid
Phosphate
Potassium
Selenium
Silica
Sodium
Sodium nitrite
Sodium aluminate
Sodium dichromate
Sodium metasilicate
Sodium hydroxide
Sodium nitrate
Sulfate
Sulfuric acid

VOLATILE ORGANICS

Acetone
Carbon tetrachloride
Chloroform
Dibutyl phosphate
1,2-Dichloroethane
Methylene chloride
Methyl isobutyl ketone (MIBK)
Methyl isopropyl ketone
Tetrachloroethylene
Toluene
Tributyl phosphate
1,1,1-Trichloroethane
Trichloroethylene
Xylenes

SEMIVOLATILE ORGANICS

Bis(2-ethylhexyl) phthalate
DDT
Dibutyl butyl phosphonate
Methyl isobutyl carbinol
n-Nitrosodimethylamine
Sodium oxalate

* The radionuclide has a half-life of < 1 year and, if it a daughter product, the parent has a half-life of < 1 year, and the buildup of the short-lived daughter would result in an activity of < 1% of the parent radionuclide's initial activity.

9 2 1 2 7 5 1 5 4 3

Table 4-7. Chemicals of Potential Concern for the 200 East Groundwater Aggregate Area.

TRANSURANICS	FISSION PRODUCTS (cont.)	OTHER INORGANICS	SEMIVOLATILE ORGANICS
Americium-241	Polonium-210	Ammonia	Aldrin
Americium-242m	Polonium-214	Ammonium carbonate	gamma-BHC
Americium-243	Polonium-218	Ammonium nitrate	Bis(2-ethylhexyl) phthalate
Curium-244	Potassium-40	Arsenic	Butyl phosphate
Curium-245	Promethium-147	Boron	p-Chloro-m-cresol
Neptunium-237	Protactinium-231	Cyanide	2-Chlorophenol
Neptunium-239	Radium-223	Ferrocyanide	DDD
Plutonium-238	Radium-225	Fluoride	DDT
Plutonium-239	Radium-226	Hydrofluoric acid	Dibutyl phosphate
Plutonium-240	Radium-228	Nitrate	2,4-Dichlorophenol
Plutonium-241	Radon-222	Nitrite	Dieldrin
	Rhodium-106	Nitric acid	Dimethoate
URANIUM	Ruthenium-106	Selenium	2,4-Dimethylphenol
	Samarium-151	Sodium dichromate	2,4-Dinitrophenol
Uranium (total)	Selenium-79		2,4-Dinitrotoluene
Uranium-233	Strontium-90	VOLATILE ORGANICS	Endrin
Uranium-234	Technetium-99		Heptachlor
Uranium-235	Thallium-207	Acetone	Hydrazine
Uranium-236	Thorium-227	Carbon tetrachloride	Pentachlorophenol
Uranium-238	Thorium-229	Chloroform	Phenol
	Thorium-230	Cyclohexanone	Pyrene
FISSION PRODUCTS	Thorium-231	1,1-Dichloroethane	2,3,4,5-Tetrachlorophenol
	Thorium-234	1,2-Dichloroethane	Tributyl phosphate
Actinium-225	Tritium	cis-1,2-Dichloroethene	
Actinium-227	Yttrium-90	trans-1,2-Dichloroethene	
Antimony-125	Zirconium-93	Methylene chloride	
Antimony-126		Methyl ethyl ketone (MEK)	
Antimony-126m	METALS	Methyl isobutyl ketone (MIBK)	
Barium-137m		Styrene	
Bismuth-210	Antimony	Tetrachloroethylene	
Bismuth-211	Barium	Toluene	
Bismuth-213	Beryllium	1,1,1-Trichloroethane	
Bismuth-214	Cadmium	1,1,2-Trichloroethane	
Carbon-14	Chromium	Trichloroethylene	
Cesium-134	Copper	Trichloromonofluoromethane	
Cesium-135	Lead		
Cesium-137	Manganese		
Cobalt-60	Mercury		
Europium-154	Nickel		
Europium-155	Silver		
Francium-221	Thallium		
Iodine-129	Titanium		
Lead-209	Uranium		
Lead-210	Vanadium		
Lead-211	Zinc		
Lead-214			
Nickel-63			
Niobium-93m			

9 2 1 2 7 5 1 5 4 4

Table 4-8. Soil-Water Distribution Coefficients (K_d) for Candidate Radionuclides[a/] and Inorganics of Potential Concern for the 200 East Groundwater Aggregate Area. Page 1 of 3

Element or Chemical	Range of K_{ds} for Hanford Site Cantrell and Serne 1992 (Serne and Wood 1990) in mL/g	Probable K_d[b/] Cantrell and Serne 1992 (Serne and Wood 1990) in mL/g	MEPAS Default K_d pH 6-9[c/] (Strenge and Peterson 1989) in mL/g	Mobility Class
Actinium	–	–	228	Low
Aluminum	–	–	35,300	Low
Americium	(100 to 1,000) (<1 at pH 1-3)	(100)	82	Low
Ammonia	–	–	–	NA
Antimony	–	–	2	High
Arsenic	–	(0)	5.86	High
Barium	–	(50)	530	Moderate
Beryllium	–	–	70	Moderate
Bismuth	500-19,000	1,000	–	Low
Boron	–	–	0.19	High
Cadmium	–	(15)	14.9	Moderate
Calcium	–	(10)	70	Moderate
Carbon (^{14}C)	–	–	0	High
Cesium	500 to 1,000 (1 to 200 (acidic waste))	500	51	Low
Chloride	<1	0	–	High
Chromium (VI)	–	0	16.8	Moderate -High
Cobalt	1,000 to 10,000	2,000	1.9	Low
Copper	–	(15)	41.9	Moderate
Cyanide ion[e/]	–	0.1	–	High[d/]
Curium	(100 to >2,000)	(100)	82	Low
Europium	–	(50)	228	Moderate
Fluoride	–	–	0	High
Francium	–	–	–	NA
Iodine	(<1)	0	0	High
Iron	–	(20)	15	Moderate
Krypton	–	–	0	High

9 2 1 2 7 5 1 5 4 5

Table 4-8. Soil-Water Distribution Coefficients (K_d) for Candidate Radionuclides[a/] and Inorganics of Potential Concern for the 200 East Groundwater Aggregate Area. Page 2 of 3

Element or Chemical	Range of K_{ds} for Hanford Site Cantrell and Serne 1992 (Serne and Wood 1990) in mL/g	Probable K_d[b/] Cantrell and Serne 1992 (Serne and Wood 1990) in mL/g	MEPAS Default K_d pH 6-9[c/] (Strenge and Peterson 1989) in mL/g	Mobility Class
Lead	–	(30)	234	Moderate
Lithium	–	–	0	High
Magnesium	–	–	70	Moderate
Manganese	–	(20)	16.5	Moderate
Mercury	–	–	322	Low
Neptunium	(<1 to 5)	(3)	3	High
Nickel	–	(15)	12.2	Moderate
Nitrate/nitric acid	–	–	0	High
Niobium	–	–	50	Moderate
Phosphate	20 to 100	50	50	Moderate
Plutonium	(100 to 1,000) (< 1 at pH 1 to 3)	(100)	10	Low
Polonium	–	–	5.9	Moderate
Potassium	–	–	0	High
Protactinium	–	–	0	High
Radium	–	(20)	24.3	Moderate
Radon	–	–	–	NA
Rhodium	–	–	–	NA
Ruthenium	(20 to 700) (<2 at >1 M nitrate)	–	274	Low-Moderate
Samarium	–	(50)	228	Moderate
Selenium	–	(0)	5.91	High
Silica	–	–	5.0	High
Silver	–	(20)	0.4	Moderate
Sodium	–	(3)	0	High
Strontium	5 to 100 0 to 20 (acidic conditions) (200 to 500 (w/phosphate or oxalate))	20	24.3	Moderate

9 2 1 2 7 5 1 5 4 6

Table 4-8. Soil-Water Distribution Coefficients (K_d) for Candidate Radionuclides[a/] and Inorganics of Potential Concern for the 200 East Groundwater Aggregate Area. Page 3 of 3

Element or Chemical	Range of K_{ds} for Hanford Site Cantrell and Serne 1992 (Serne and Wood 1990) in mL/g	Probable K_d[b/] Cantrell and Serne 1992 (Serne and Wood 1990) in mL/g	MEPAS Default K_d pH 6-9[c/] (Strenge and Peterson 1989) in mL/g	Mobility Class
Sulfate	–	(0)	0	High
Technetium	0 to 1	0	3	High
Thallium	–	–	0	High
Thorium	–	(50)	100	Moderate
Titanium	–	–	–	NA
Tritium	0	0	0	High
Uranium	0 to 3	1	0	High
Vanadium	–	–	50	Moderate
Yttrium	–	–	278	Low
Zinc	–	(15)	12.7	Moderate
Zirconium	–	(30)	50	Moderate

a/ Radionuclides with half-lives of greater than one year or short-lived products of long-lived precursors.
b/ Average K_ds for low salt and organic solutions with neutral pH.
c/ Default values for pH 6-9 and soil content of [clay + organic matter + metal oxyhydroxides] < 10% (Strenge and Peterson 1989).
d/ Mobility classes are defined as: High ($K_d < 5$); Moderate ($5 < K_d < 100$); Low ($K_d > 100$).
e/ Cyanide mobility is highly dependent on identity of complexing agent. Simple cyanides (e.g., HCN) are more mobile than complex (e.g., metallic) cyanides.
– Value was not provided for this element in this reference.
NA K_d value was not provided from sources cited in this table.

9 2 1 2 7 5 1 5 4 7

Table 4-9. Physical/Chemical Properties of Candidate Organic Compounds of Potential Concern for the 200 East Groundwater Aggregate Area.

Compound	Molecular Weight in g/mole	Water Solubility in mg/L	Vapor Pressure in mm Hg	Henry's Law Constant in atm-m^3/mole	Soil/Organic Matter Partition Coef. K_{oc} in mL/g
Acetone	58.0	miscible	270	2.1×10^{-5}	2.2
Aldrin	365	0.18	6.0×10^{-6}	1.6×10^{-5}	96,000
gamma-BHC	290.8	7.8	1.6×10^{-4}	7.8×10^{-6}	1,100
Bis(2-ethylhexyl) phthalate	391.0	0.40	2.0×10^{-7}	4.4×10^{-7}	87,000
Carbon tetrachloride	154.0	758	90	2.4×10^{-2}	110
Chloroform (trichloromethane)	119	8,200	150	2.9×10^{-3}	31
p-Chloro-m-cresol	142.6	3,900	0.008	4.3×10^{-7}	780
2-Chlorophenol	128.6	29,000	1.8	1.0×10^{-5}	73
Cyclohexanone	98.2	50,000	4.5	1.3×10^{-5}	4
DDD	320	0.1	1.9×10^{-6}	8.0×10^{-6}	770,000
DDT	354.5	0.005	5.5×10^{-6}	5.1×10^{-4}	240,000
Dibutyl phosphate	210.2	"insoluble"[a]	1[a]		
1,1-Dichloroethane	98.96	5,500	180	4.3×10^{-3}	30
1,2-Dichloroethane	98.96	8,500	64	9.8×10^{-4}	14
cis/trans-1,2-Dichloroethene	96.94	6,300	320	6.6×10^{-3}	59
2,4-Dichlorophenol	163	4,600	0.059	2.8×10^{-6}	380
Dieldrin	381	0.19	1.8×10^{-7}	4.6×10^{-7}	1,700
Diethyl ether	74.12[a]	8,000[a]	440[a]	1.35×10^{-3}[a]	73[a]
Dimethoate	229.3	> 5,000[a]	1.6×10^{-6}[a]	2.9×10^{-7}[a]	17[a]

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Table 4-9. Physical/Chemical Properties of Candidate Organic Compounds of Potential Concern for the 200 East Groundwater Aggregate Area.

Compound	Molecular Weight in g/mole	Water Solubility in mg/L	Vapor Pressure in mm Hg	Henry's Law Constant in atm-m^3/mole	Soil/Organic Matter Partition Coef. K_{oc} in mL/g
2,4-Dimethylphenol	122.2	590	0.026	1.8×10^{-5}	96
2,4-Dinitrophenol	184.1	5,600	1.5×10^{-5}	6.5×10^{-10}	17
2,4-Dinitrotoluene	182.1	2,400	0.0051	5.1×10^{-6}	45
EDTA	292.2	61,000	1.4×10^{-8}	3.0×10^{-7}	0.73
Endrin	380.9	0.20	2.7×10^{-7}	1.0×10^{-6}	11,000
Endrin aldehyde	380.89	0.25[a]	2×10^{-7}[a]	2.9×10^{-9}[a]	8,500 to 45,000[a]
Ethyl cyanide	55.08	118,000[a]	40[a]	3.7×10^{-5}[a]	1.2[a]
HEDTA	278.3	"soluble"[a]			
Heptachlor	373.5	0.056	3.0×10^{-4}	2.9×10^{-3}	6,000
Hydrazine	32.05	300,000	14	2.0×10^{-6}	0.0053
Methylene chloride	84.9	20,000	360	2×10^{-3}	8.8
Methyl ethyl ketone	72.1	270,000	78	2.7×10^{-5}	4.5
Methyl isobutyl ketone	100.2	19,000	6.0	4.2×10^{-5}	19
o-Nitrophenol	139.1	16,000[b]	2.2[b]	3.0×10^{-4}[b]	50[b]
Normal paraffin hydrocarbons		"insoluble"[a]			
Pentachlorophenol	266.0	14	1.1×10^{-4}	2.8×10^{-6}	53,000
Phenol	94.1	93,000	0.34	4.5×10^{-7}	14
Phorate	260.4		8.4×10^{-4}		
Pyrene	202.3	0.13	2.5×10^{-6}	5.0×10^{-6}	38,000

WHC(200E-3)/9-22-92/03043T.1

Table 4-9. Physical/Chemical Properties of Candidate Organic Compounds of Potential Concern for the 200 East Groundwater Aggregate Area.

Compound	Molecular Weight in g/mole	Water Solubility in mg/L	Vapor Pressure in mm Hg	Henry's Law Constant in atm-m^3/mole	Soil/Organic Matter Partition Coef. K_{oc} in mL/g
Styrene	104.2	320	100	4.7×10^{-3}	550
2,3,4,6-Tetrachlorophenol	231.89	1,000	9.1×10^{-4}	3.1×10^{-7}	17,000
Tetrachloroethylene	165.85	150	18	2.6×10^{-2}	360
Toluene	92.2	1,550	28.4	6.4×10^{-3}	300
Tributyl phosphate	266.3	280	15	1.9×10^{-2}	6,000
Tributyl phosphonate					
1,1,1-Trichloroethane	133.4	1,500	120	1.4×10^{-2}	150
1,1,2-Trichloroethane	133.4	4,500	30	1.2×10^{-3}	56
Trichloroethylene	131.3	1,100	58	9.1×10^{-3}	130
Trichloromonofluoromethane	137.4	1,100	670	0.11	160
Triethylene glycol	150.18	1.4×10^{6}	8.7×10^{-4}	1.3×10^{-10}	0.0051

Sources: Strenge and Peterson 1989, except as noted in footnotes.

a/ Values listed in Hazardous Substance Data Base (HSDB), National Library of Medicine database (HSDB 1991).

b/ Data for o-nitrophenol was not located, values for p-nitrophenol are listed.

Blank indicates value not available from above sources.

Table 4-10. Radiological Properties of Candidate Radionclides of Potential Concern for the 200 East Groundwater Aggregate Area. Page 1 of 3

Radionuclide	Half-Life	Specific Activity[a/] in Ci/g	Radiation of Concern[b/]
^{225}Ac	10 day	5.8×10^{4}	α
^{227}Ac	21.8 yr	7.2×10^{1}	β, α
^{110}Ag	24.6 sec	4.2×10^{9}	β
^{110m}Ag	249.85 day	4.7×10^{3}	β, γ
^{241}Am	432 yr	3.4×10^{0}	α
^{242}Am	16 hr	8.1×10^{5}	β
^{242m}Am	152 yr	9.7×10^{0}	α
^{243}Am	7,380 yr	2.0×10^{-1}	α
^{217}At	0.032 sec	1.6×10^{12}	α
^{133}Ba	10.5 yr	2.5×10^{2}	γ [c/]
^{137m}Ba	2.6 min	5.3×10^{8}	γ
^{210}Bi	5.01 day	1.2×10^{5}	β
^{211}Bi	2.13 min	4.2×10^{8}	α, β
^{213}Bi	45.6 min	1.9×10^{7}	β, α
^{214}Bi	19.9 min	4.4×10^{7}	β, γ
^{14}C	5,730 yr	4.5×10^{0}	β
^{242}Cm	163.2 day	3.3×10^{3}	α
^{244}Cm	18.1 yr	8.1×10^{1}	α
^{245}Cm	8,500 yr	1.7×10^{-1}	α, γ
^{60}Co	5.3 yr	1.1×10^{3}	γ
^{134}Cs	2.06 yr	1.3×10^{3}	γ
^{135}Cs	2.3×10^{6} yr	1.2×10^{-3}	β
^{137}Cs	30 yr	8.7×10^{1}	γ [c/]
^{154}Eu	8.8 yr	2.7×10^{2}	β, γ [c/]
^{221}Fr	4.8 min	1.8×10^{8}	α
^{223}Fr	21.8 min	3.9×10^{7}	β
^{3}H	12.3 yr	9.7×10^{3}	β
^{129}I	1.6×10^{7} yr	1.7×10^{-4}	β
^{40}K	1.3×10^{9} yr	6.7×10^{-6}	β, γ [c/]
^{85}Kr	10.7 yr	3.9×10^{2}	β
^{93m}Nb	14.6 yr	2.8×10^{2}	γ [c/]
^{95}Nb	34.97 day	3.9×10^{4}	β, γ
^{95m}Nb	90 hr	3.7×10^{5}	γ [c/]
^{59}Ni	75,000 yr	7.6×10^{4}	γ [c/]
^{63}Ni	100.1 yr	6.2×10^{1}	β
^{237}Np	2.14×10^{6} yr	7.0×10^{-4}	α, γ

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Table 4-10. Radiological Properties of Candidate Radionclides of Potential Concern for the 200 East Groundwater Aggregate Area. Page 2 of 3

Radionuclide	Half-Life	Specific Activity[a] in Ci/g	Radiation of Concern[b]
^{239}Np	2.35 day	2.3×10^{5}	β
^{231}Pa	32,800 yr	4.7×10^{-2}	α
^{233}Pa	27 day	2.1×10^{4}	β, γ[c]
^{234}Pa	6.8 hr	2.0×10^{-6}	β
^{234m}Pa	1.17 min	6.9×10^{8}	β
^{209}Pb	3.25 hr	4.5×10^{6}	β
^{210}Pb	22.3 yr	7.6×10^{1}	β
^{211}Pb	36.1 min	2.5×10^{7}	β
^{214}Pb	26.8 min	3.3×10^{7}	β, γ[c]
^{107}Pd	6.5×10^{6} yr	5.1×10^{-4}	β
^{210}Po	128 day	4.9×10^{3}	α
^{211}Po	0.52 sec	1.0×10^{11}	α, γ
^{213}Po	4.2×10^{-6} sec	1.3×10^{16}	α
^{214}Po	6×10^{-5} sec	8.8×10^{14}	α
^{215}Po	7.8×10^{-4} sec	2.9×10^{13}	α
^{218}Po	3.05 min	2.8×10^{8}	α
^{238}Pu	87.7 yr	1.7×10^{1}	α
^{239}Pu	24,400 yr	6.2×10^{-2}	α
^{240}Pu	6,560 yr	2.3×10^{-1}	α
^{241}Pu	14.4 yr	1.0×10^{2}	β
^{223}Ra	11.43 day	5.1×10^{4}	α
^{225}Ra	14.8 day	3.9×10^{4}	β
^{226}Ra	1,600 yr	9.9×10^{-1}	α
^{228}Ra	5.75 yr	2.3×10^{2}	β
^{187}Re	5×10^{10} yr	3.8×10^{8}	β
^{106}Rh	30 sec	3.5×10^{9}	β, γ
^{219}Rn	4.0 sec	1.3×10^{10}	α
^{222}Rn	3.8 day	1.5×10^{5}	α, γ
^{106}Ru	1.0 yr	3.4×10^{3}	β, γ[c]
^{126}Sb	12.4 day	8.4×10^{4}	β, γ[c]
^{126m}Sb	19 min	7.85×10^{7}	β, γ[c]
^{79}Se	<65,000 yr	7.0×10^{-2}	β
^{151}Sm	90 yr	2.6×10^{1}	β
^{126}Sn	1×10^{5} yr	2.8×10^{-2}	γ
^{89}Sr	50.55 day	2.9×10^{4}	β, γ[c]
^{90}Sr	28.5 yr	1.4×10^{2}	β
^{99}Tc	213,000 yr	1.7×10^{-2}	β

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Table 4-10. Radiological Properties of Candidate Radionclides of Potential Concern for the 200 East Groundwater Aggregate Area. Page 3 of 3

Radionuclide	Half-Life	Specific Activity[a/] in Ci/g	Radiation of Concern[b/]
^{227}Th	18.7 day	3.1×10^{4}	α
^{229}Th	7,340 yr	2.1×10^{-1}	α
^{230}Th	77,000 yr	2.1×10^{-2}	α
^{231}Th	25.5 hr	5.3×10^{5}	β
^{232}Th	1.4×10^{10} yr	1.1×10^{-7}	α
^{234}Th	24.1 day	2.3×10^{-4}	β
^{207}Tl	4.77 min	1.9×10^{8}	β, γ
^{233}U	159,000 yr	9.7×10^{-3}	α
^{234}U	244,500 yr	6.2×10^{-3}	α
^{235}U	7.0×10^{8} yr	2.2×10^{-6}	α, γ
^{236}U	2.3×10^{7} yr	6.5×10^{-5}	α
^{238}U	4.5×10^{9} yr	3.4×10^{-7}	α
^{90}Y	6.41 hr	5.4×10^{5}	β
^{95}Zr	64 day	2.1×10^{4}	β

a/ Source: DOE 1990.
b/ α - alpha decay; β - negative beta decay; γ - release of gamma rays.
c/ Gamma radiation due to daughter product activity.

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Table 4-11. Relative Risks for Radionuclides of Potential Concern for the 200 East Groundwater Aggregate Area. Page 1 of 3

Radionuclide	Half-Life[a/]	Air Unit Risk[b/] in $(pCi/m^3)^{-1}$	Drinking Water Unit Risk[c/] in $(pCi/L)^{-1}$	Soil Ingestion Unit Risk[d/] in $(pCi/g)^{-1}$	External Exposure Unit Risk[e/] in $(pCi/g)^{-1}$
^{225}Ac	10 day	1.2×10^{-3}	8.7×10^{-7}	4.6×10^{-8}	9.4×10^{-6}
^{227}Ac	21.8 yr	4.2×10^{-2}	1.8×10^{-5}	9.5×10^{-7}	1.3×10^{-7}
^{241}Am	433 yr	2.1×10^{-2}	1.6×10^{-5}	8.4×10^{-7}	1.6×10^{-5}
^{242m}Am	152 yr	NA	NA	NA	NA
^{243}Am	7,380 yr	2.1×10^{-2}	1.5×10^{-5}	8.1×10^{-7}	3.6×10^{-5}
^{133}Ba	10.5 yr	NA	NA	NA	NA
^{137m}Ba	2.6 min	3×10^{-10}	1.2×10^{-10}	6.5×10^{-12}	3.4×10^{-4}
^{210}Bi	5.01 day	4.1×10^{-5}	9.7×10^{-8}	5.1×10^{-9}	0
^{211}Bi	2.13 min	9.7×10^{-8}	6.1×10^{-10}	3.2×10^{-11}	2.8×10^{-5}
^{213}Bi	45.6 min	1.6×10^{-7}	1.2×10^{-8}	6.2×10^{-10}	8.1×10^{-5}
^{214}Bi	19.9 min	1.1×10^{-6}	7.2×10^{-9}	3.8×10^{-10}	8.0×10^{-4}
^{14}C	5,730 yr	3.2×10^{-9}	4.7×10^{-8}	2.5×10^{-9}	0
^{244}Cm	18.1 yr	1.4×10^{-2}	1.0×10^{-5}	5.4×10^{-7}	5.9×10^{-7}
^{245}Cm	8,500 yr	NA	NA	NA	NA
^{60}Co	5.3 yr	8.1×10^{-5}	7.8×10^{-7}	4.1×10^{-8}	1.3×10^{-3}
^{134}Cs	2.06 yr	1.4×10^{-5}	2.1×10^{-6}	1.1×10^{-7}	8.9×10^{-4}
^{135}Cs	2.3×10^{6} yr	1.4×10^{-6}	2.1×10^{-7}	1.1×10^{-8}	0
^{137}Cs	30 yr	9.6×10^{-6}	1.4×10^{-6}	7.6×10^{-8}	0
^{154}Eu	8.8 yr	7.2×10^{-5}	1.5×10^{-7}	8.1×10^{-9}	6.8×10^{-4}
^{221}Fr	4.8 min	4.7×10^{-7}	3.0×10^{-9}	1.6×10^{-10}	1.9×10^{-5}
^{3}H	12.3 yr	4.0×10^{-8}	2.8×10^{-9}	1.5×10^{-10}	0
^{129}I	1.6×10^{7} yr	6.1×10^{-5}	9.6×10^{-6}	5.1×10^{-7}	1.5×10^{-5}
^{40}K	1.3×10^{9} yr	4.0×10^{-6}	5.7×10^{-7}	3.0×10^{-8}	7.8×10^{-5}
^{85}Kr	10.7 yr	NA	NA	NA	NA
^{93m}Nb	14.6 yr	NA	NA	NA	NA
^{59}Ni	75,000 yr	3.5×10^{-7}	4.4×10^{-9}	2.3×10^{-10}	3.4×10^{-7}
^{63}Ni	100.1 yr	8.7×10^{-7}	1.2×10^{-8}	6.2×10^{-10}	0
^{237}Np	2.14×10^{6} yr	1.8×10^{-2}	1.4×10^{-5}	7.3×10^{-7}	1.8×10^{-5}
^{239}Np	2.35 day	7.7×10^{-7}	4.8×10^{-8}	2.5×10^{-9}	1.1×10^{-4}
^{231}Pa	32,800 yr	2.0×10^{-2}	9.7×10^{-6}	5.1×10^{-7}	2.0×10^{-5}
^{209}Pb	3.25 hr	3.6×10^{-8}	4.3×10^{-9}	2.3×10^{-10}	0
^{210}Pb	22.3 yr	8.7×10^{-4}	3.4×10^{-5}	1.8×10^{-6}	1.8×10^{-6}
^{211}Pb	36.1 min	1.5×10^{-6}	9.2×10^{-9}	4.9×10^{-10}	2.9×10^{-5}

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Table 4-11. Relative Risks for Radionuclides of Potential Concern for the 200 East Groundwater Aggregate Area.

Radionuclide	Half-Life[a/]	Air Unit Risk[b/] in $(pCi/m^3)^{-1}$	Drinking Water Unit Risk[c/] in $(pCi/L)^{-1}$	Soil Ingestion Unit Risk[d/] in $(pCi/g)^{-1}$	External Exposure Unit Risk[e/] in $(pCi/g)^{-1}$
^{214}Pb	26.8 min	1.5×10^{-6}	9.2×10^{-9}	4.9×10^{-10}	1.5×10^{-4}
^{210}Po	128 day	8.7×10^{-4}	3.4×10^{-5}	1.8×10^{-6}	1.8×10^{-6}
^{214}Po	6×10^{-5} sec	1.4×10^{-13}	5.1×10^{-16}	2.7×10^{-17}	4.7×10^{-8}
^{215}Po	7.8×10^{-4} sec	2.9×10^{-12}	1.4×10^{-14}	7.6×10^{-16}	8.7×10^{-8}
^{218}Po	3.05 min	3.0×10^{-7}	1.4×10^{-9}	7.6×10^{-11}	0
^{238}Pu	87.7 yr	2.1×10^{-2}	1.4×10^{-5}	7.6×10^{-7}	5.9×10^{-7}
^{239}Pu	24,400 yr	2.6×10^{-2}	1.6×10^{-5}	8.4×10^{-8}	2.6×10^{-7}
^{239}Pu oxide	24,400 yr	2.6×10^{-2}	1.6×10^{-6}	8.4×10^{-8}	2.6×10^{-7}
^{240}Pu	6,560 yr	2.1×10^{-2}	1.6×10^{-5}	8.4×10^{-8}	5.9×10^{-7}
^{240}Pu oxide	6,560 yr	2.1×10^{-2}	1.6×10^{-6}	8.4×10^{-8}	5.9×10^{-7}
^{241}Pu	14.4 yr	1.5×10^{-4}	2.5×10^{-7}	1.3×10^{-8}	0
^{223}Ra	11.4 day	1.6×10^{-3}	4.1×10^{-6}	2.2×10^{-7}	8.4×10^{-5}
^{225}Ra	14.8 day	8.2×10^{-4}	3.4×10^{-6}	1.8×10^{-7}	8.0×10^{-6}
^{226}Ra	1,600 yr	1.5×10^{-3}	6.1×10^{-6}	3.2×10^{-7}	4.1×10^{-6}
^{228}Ra	5.75 yr	3.4×10^{-4}	5.1×10^{-6}	2.7×10^{-7}	5.6×10^{-13}
^{106}Rh	30 sec	NA	NA	NA	NA
^{222}Rn	3.8 day	3.7×10^{-7}	NA	NA	2.2×10^{-7}
^{106}Ru	1.0 yr	2.3×10^{-4}	4.9×10^{-7}	2.6×10^{-8}	0
^{125}Sb	2.73 yr	NA	NA	NA	NA
^{126m}Sb	19 min	NA	NA	NA	NA
^{79}Se	<65,000 yr	NA	NA	NA	NA
^{151}Sm	90 yr	NA	NA	NA	NA
^{90}Sr	28.5 yr	2.8×10^{-5}	1.7×10^{-6}	8.9×10^{-8}	0
^{99}Tc	213,000 yr	4.2×10^{-6}	6.6×10^{-8}	3.5×10^{-9}	3.4×10^{-10}
^{227}Th	18.72 day	2.5×10^{-3}	2.5×10^{-7}	1.3×10^{-8}	6.6×10^{-6}
^{229}Th	7,340 yr	3.9×10^{-2}	2.0×10^{-6}	1.1×10^{-7}	5.8×10^{-5}
^{230}Th	77,000 yr	1.6×10^{-2}	1.2×10^{-6}	6.5×10^{-8}	5.9×10^{-7}
^{231}Th	25.5 hr	2.5×10^{-7}	2.0×10^{-8}	1.1×10^{-9}	1.1×10^{-5}
^{232}Th	1.4×10^{10} yr	1.6×10^{-2}	1.1×10^{-6}	5.9×10^{-8}	4.5×10^{-7}
^{234}Th	24.1 day	1.6×10^{-5}	2.0×10^{-7}	1.1×10^{-8}	5.6×10^{-6}
^{207}Tl	4.77 min	2.3×10^{-9}	6.6×10^{-10}	3.5×10^{-11}	1.2×10^{-6}
^{233}U	159,000 yr	1.4×10^{-2}	7.2×10^{-6}	3.8×10^{-7}	3.2×10^{-7}
^{234}U	244,500 yr	1.4×10^{-2}	7.2×10^{-6}	3.8×10^{-7}	5.6×10^{-7}
^{235}U	7.0×10^{8} yr	1.3×10^{-2}	6.6×10^{-6}	3.5×10^{-7}	9.7×10^{-5}

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Table 4-11. Relative Risks for Radionuclides of Potential Concern for the 200 East Groundwater Aggregate Area.

Radionuclide	Half-Life[a/]	Air Unit Risk[b/] in $(pCi/m^3)^{-1}$	Drinking Water Unit Risk[c/] in $(pCi/L)^{-1}$	Soil Ingestion Unit Risk[d/] in $(pCi/g)^{-1}$	External Exposure Unit Risk[e/] in $(pCi/g)^{-1}$
^{236}U	2.3×10^7 yr	NA	NA	NA	NA
^{238}U	4.5×10^9 yr	1.2×10^{-2}	6.6×10^{-6}	3.5×10^{-7}	4.5×10^{-7}
^{90}Y	64.1 hr	2.8×10^{-6}	1.6×10^{-7}	8.6×10^{-9}	0
^{93}Zr	1.53×10^6 yr	NA	NA	NA	NA

a/ Source: DOE 1990
b/ Excess cancer risk associated with lifetime exposure to 1 pCi/m^3 (10^{-12} Ci) per day in air (EPA 1991a).
c/ Excess cancer risk associated with lifetime exposure to 1 pCi (10^{-12} Ci) per day in drinking water (EPA 1991a).
d/ Excess cancer risk associated with lifetime exposure to 1 pCi/g (10^{-12} Ci/g) per day in soil (EPA 1991a).
e/ Excess cancer risk associated with lifetime exposure to surface soils containing 1 pCi/g of gamma-emitting radionuclides (EPA 1991a).

NA No information available.

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Table 4-12. Potential Chronic Health Effects of Candidate Chemicals of Potential Concern for the 200 East Groundwater Aggregate Area. Page 1 of 3

Chemical	Tumor Site Inhalation Route; Oral Route [Weight of Evidence Group[a/]]	Noncarcinogenic Chronic Health Effects Inhalation Route; Oral Route
INORGANIC CHEMICALS		
Aluminum	--	--
Ammonia	--	decreased pulmonary function, degrades odor; taste of water
Ammonium nitrate	(see ammonia and nitrate)	(see ammonia and nitrate)
Arsenic	respiratory tract [A]; skin [a]	NA; keratosis, hyperpigmentation
Barium	--	fetotoxicity; increased blood pressure
Beryllium	lung [B2]; total tumors [B2]	none observed
Boron	--	NA; testicular lesions
Cadmium	respiratory tract [B1]; NA	cancer; renal damage
Calcium	--	--
Chloride	--	--
Chromium	lung [A] - Cr(VI) only; NA	Nasal mucosa atrophy (Cr (III) and (VI)); hepatotoxicity (Cr (III))
Copper	--	NA; gastrointestinal irritation
Cyanide	--	NA; weight loss, thyroid effects, myelin degeneration
Ferrocyanide	(see cyanide)	(see cyanide)
Fluoride	--	NA; dental fluorosis at high levels
Iron	--	--
Lead	[B2][c/]; [B2]	central nervous system (CNS) effects[c/]; CNS effects
Lithium	--	--
Magnesium	--	--
Manganese	--	respiratory, psychomotor symptoms; no effect
Mercury	--	neurotoxicity; kidney effects
Nickel	respiratory tract [A]; NA	cancer; reduced weight gain
Nitrate/Nitrite	--	NA; methemoglobinemia in infants[d/]

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Table 4-12. Potential Chronic Health Effects of Candidate Chemicals of Potential Concern for the 200 East Groundwater Aggregate Area. Page 2 of 3

Chemical	Tumor Site Inhalation Route; Oral Route [Weight of Evidence Group[a/]]	Noncarcinogenic Chronic Health Effects Inhalation Route; Oral Route
Nitric acid	(see nitrate)	(see nitrate)
Phosphate	--	--
Potassium	--	--
Selenium	--	--
Silica	--	--
Silver	--	NA; argyria
Sodium	--	--
Sodium aluminate	(see sodium and aluminum)	(see sodium and aluminum)
Sodium dichromate	(see sodium and chromium(VI))	(see sodium and chromium(VI))
Sodium metasilicate	(see sodium and silica)	(see sodium and silica)
Sodium hydroxide	--	--
Sodium nitrate	(see sodium and nitrate)	(see sodium and nitrate)
Sodium nitrite	(see sodium and nitrite)	(see sodium and nitrite)
Sulfate	--	--
Sulfuric acid	--	respiratory; NA
Strontium	--	--
Titanium	--	--
Uranium (soluble salts)	--	NA; body weight loss, nephrotoxicity
Vanadium	--	NA; none observed
Zinc	--	NA; anemia
	--	--
ORGANIC CHEMICALS	--	--
Acetone	--	NA; kidney and liver effects
Bis(2-ethylhexyl)phthalate	NA [B2]; liver [B2]	NA; increased liver weight
Carbon tetrachloride	liver [B2]; liver [B2]	NA; liver lesions
Chloroform	liver [B2]; kidney [B2]	NA; liver lesions
DDT	liver [B2]; liver [B2]	NA; liver lesions
Dibutyl butyl phosphonate	--	--
Dibutyl phosphate	--	NA; respiratory irritation[b/]

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Table 4-12. Potential Chronic Health Effects of Candidate Chemicals of Potential Concern for the 200 East Groundwater Aggregate Area.

Chemical	Tumor Site Inhalation Route; Oral Route [Weight of Evidence Group[a/]]	Noncarcinogenic Chronic Health Effects Inhalation Route; Oral Route
1,2-Dichloroethane	circulatory system [B2]; circulatory system [B2]	--
Methylene chloride	lung, liver [B2]; liver [B2]	NA; liver toxicity
Methyl isobutyl carbinol	--	--
Methyl isobutyl ketone (MIBK, "Hexone")	--	liver and kidney effects; liver and kidney effects
Methyl isopropyl ketone	--	--
n-Nitrosodimethylamine	liver [B2]; liver [B2]	--
Sodium oxalate	--	--
Tetrachloroethene	leukemia, liver [B2]; liver [B2]	NA; hepatotoxicity
Toluene	--	CNS effects, eye irritation; change in liver and kidney weights
Tributyl phosphate	--	respiratory irritant; kidney damage[b/]
1,1,1-Trichloroethane	--	liver toxicity; liver toxicity
Trichloroethylene	lung [B2]; liver [B2]	--

a/ Weight of Evidence Groups for carcinogens: A - Human carcinogen (sufficient evidence of carcinogenicity in humans); B -Probable Human Carcinogen (B1 - limited evidence of carcinogenicity in humans; B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of data in humans); C - Possible Human Carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of human data); D - Not Classifiable as to Human Carcinogenicity (inadequate or no evidence).
b/ Verified toxicity information was not available from EPA 1991 or 1992. Toxicity information was obtained from EPA Registry of Toxic Effects of Chemical Systems (RTECS). A blank space means that no information was available from the above sources.
c/ Lead is considered by EPA to have both neurotoxic and carcinogenic effects; however, no toxicity criteria are available for lead at the present time.
d/ Toxic effect is considered to occur from exposure to nitrite; nitrate can be converted to nitrite in the body by intestinal bacteria.
e/ Toxic effect of untritiated naphthylamine.
NA No information available.

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5.0 GROUNDWATER CONTAMINANT SCREENING AND PRIORITIZATION

This preliminary qualitative evaluation of groundwater contaminants is intended to provide input to the 200 East Area recommendation process (Section 9.0). That process requires evaluation of groundwater contaminants and contaminant plumes in the context of their near and long-term significance to human health and the environment.

The approach that has been taken in this evaluation of 200 East Area groundwater contaminants is as follows:

- Contaminants of potential concern are identified within the 200 East Area. As discussed in Section 4.2, contaminants of potential concern were selected from the list of candidate contaminants of potential concern presented in Table 4-6. The subset of those contaminants that were detected in the unconfined aquifer beneath the 200 East Area during 1988 through 1992 are listed in Table 5-1.

- Relative-significance rankings are developed for the currently measured groundwater contaminant concentrations, and the contaminant concentrations projected to occur offsite following transport within the Hanford unconfined aquifer.

- The relative-significance rankings for collocated contaminants are combined, as appropriate, to construct overall significance rankings for contaminant plumes or portions of plumes within the groundwater. These overall rankings are used, in conjunction with other factors, to identify regions of the contaminated aquifer for the review and possible redefinition of groundwater operable units.

In the data evaluation process presented in Section 9.0, "higher" priority sites are evaluated for the potential implementation of an interim remedial measure (IRM). "Lower" priority sites are evaluated to determine what type of additional investigation is necessary to establish a final remedy. Further detail is presented in Section 9.0.

The data used for this evaluation of contaminant significance based on human health considerations are presented in the earlier sections of this report. The types of data that have been assessed include site histories and physical descriptions (Section 2.0), descriptions of the physical environment of the study area (Section 3.0) and a summary of the available chemical and radiological data for the 200 East Area aquifer (Section 4.0).

The quality and sufficiency of these data are assessed in Section 8.0. This information is also used to identify applicable or relevant and appropriate requirements (ARARs) (Section 6.0).

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5.1 CONCEPTUAL FRAMEWORK FOR RISK-BASED SCREENING

The range of potential human health exposure pathways associated with the 200 East Area groundwater was summarized in Section 4.2. The U.S. Environmental Protection Agency (EPA; 1989a) considers a human exposure pathway to consist of four elements: (1) a source and mechanism for contaminant release; (2) a retention or transport medium (or media); (3) a point of potential human contact; and (4) an exposure route (e.g., ingestion) at the contact point. The probability of the existence of a particular pathway is dependent upon the physical and institutional controls affecting site access and use. In the absence of site access controls and other land use restrictions, the identified potential exposure pathways can all occur. For example, it can be hypothesized that an individual may establish a residence within the boundaries of the Hanford Site, drill a well and withdraw contaminated water for drinking water and crop irrigation. However, within the five- to ten-year period of interest associated with identification and prioritization of remedial actions associated with the 200 East Area, unrestricted access and ability to drill a well have a negligible probability of occurrence. Until future land use of the Hanford Site is defined, U.S. Department of Energy (DOE) policy is that the Hanford Site will remain under DOE management, which includes control over beneficial use of the land and any uses of groundwater at least until the year 2018 as agreed upon in the Tri-Party Agreement.

Public exposure to groundwater contaminants can also occur following contaminant transport through the unconfined aquifer to offsite locations. The distances separating current 200 East Area groundwater plumes from offsite locations are significant.

To provide input to the prioritization of remediation actions for the 200 East Area, groundwater contaminants were evaluated on the basis of: (1) their currently measured levels and (2) their theoretical levels estimated to occur offsite following transport through the unconfined aquifer. It is important to note that this contaminant screening process does not evaluate potential risks associated with the Hanford Site and potential exposure to contaminated groundwater. Rather, the screening, on a consistent semiquantitative basis, evaluates the various contaminants in the aquifer and potential future contaminant concentrations offsite, for their relative intrinsic significance to human health. This screening process does not consider, nor suggest for consideration, any specific scenario for exposure to groundwater contaminants. Formal quantitative evaluations of potential human health risks will ultimately be conducted in accordance with the M-29 milestone report, *Hanford Site Baseline Risk Assessment Methodology* (DOE/RL 1991d).

5.2 SCREENING PROCESS

The objective of the 200 East Area groundwater contaminant screening process is to provide risk-based input to the process of: (1) establishing groundwater remedial action

priorities; and (2) defining groundwater "operable units" that focus and ensure the effectiveness of remedial actions. This risk-based input consists of relative-significance rankings developed for the currently measured groundwater contaminant concentrations, and the contaminant concentrations projected to occur offsite following transport within the Hanford unconfined aquifer.

The Multimedia Environmental Pollutant Assessment System (MEPAS), developed by the Pacific Northwest Laboratory (PNL), was used to calculate semiquantitative indices of contaminant relative-risk significance. These relative-risk indices integrate the various contaminant characteristics (toxicity, mobility, persistence, quantity, etc.) into a single prioritization value, thereby providing comprehensive input to the recommendation process. The MEPAS computer software is an enhanced version of the Remedial Action Priority System (RAPS) (Whelan et al. 1987).

5.2.1 Multimedia Environmental Pollutant Assessment System

The MEPAS is a computer-based system that uses empirical, analytical, and semi-analytical mathematical algorithms and pathway analyses to estimate the following processes:

- Potential release of contaminants into the environment
- Transport of contaminants through and between four major environmental transport elements: groundwater, surface water, overland flow, and atmospheric
- Exposure to surrounding human populations (i.e., food chain considerations, inhalation, ingestion, dermal contact, and external dose)
- Human health effects associated with exposure to chemicals and radionuclides.

Detailed descriptions of the MEPAS formulations are given in Droppo et al. (1989) and Whelan et al. (1987). MEPAS was developed to calculate semiquantitative indices of health risks associated with long-term (hundreds to thousands of years) environmental conditions resulting from the release of contaminants from a hazardous waste site. Potential health impacts are evaluated for multiple, sequential 70-yr exposure increments, with average concentrations defined for each increment.

The MEPAS groundwater component computes (or takes as input) contaminant concentrations at wells and calculates solute fluxes from the groundwater environment to the surface water environment. The groundwater pathway solution algorithms are based on Green's functions (Whelan et al. 1987).

The MEPAS is capable of addressing nontidal rivers and wetlands. A three-dimensional, steady-state, vertically integrated mass balance equation for contaminant transport in a river environment (where longitudinal advection dominates longitudinal dispersion) forms the basis for the river water solution algorithm (Codell et al. 1982). Contaminants released into a river are transported through the system by the processes of advection and dispersion, with dispersion being considered in both the lateral and vertical directions.

Overland flow is that portion of precipitation that ultimately appears as flowing water on the ground surface. The driving mechanism transporting contaminants through the overland pathway is this overland flow. Estimation techniques for the overland pathway are based on the curve number technique of the U.S. Department of Agriculture's Soil Conservation Service (SCS 1972, 1982). The overland transport pathway can interact with the surface water pathway or directly supply the exposure component with contaminant levels.

The MEPAS atmospheric component considers release mechanisms and characteristics, dilution and transport, washout by cloud droplets and precipitation, and deposition on the underlying surface cover. The prediction of contaminant movement through the atmospheric pathway therefore involves modeling components that address atmospheric suspension/emission, transport, diffusion, and deposition. Contaminant transport is assumed to occur fast enough to allow chemical transformations to be neglected. Atmospheric transport and dispersion are computed in terms of sector-averaged values using Gaussian dispersion principles. Deposition is calculated as the sum of wet and dry deposition.

The results from each of the four transport pathways are used in the exposure assessment component of MEPAS to calculate the hazard potential for each contaminant. The exposure assessment component considers potential exposure of the surrounding population through the following exposure routes:

- Dermal contact with chemicals
- External dose from radiation
- Inhalation of airborne contaminants
- Ingestion of contaminated drinking water, soil, crops, animal products, and aquatic foods.

Based on the air, water, and soil contaminant levels provided by the transport pathway analyses, an estimate is made of the average daily human exposure to each contaminant. The daily exposure rate is next converted to an average individual relative health risk index (RRI) using mathematical models for radionuclides, carcinogenic chemicals, and noncarcinogenic

chemicals. Some chemicals have both carcinogenic and toxic effects and are therefore considered in both categories. The RRI indicates the level of potential health impact to an average member of the exposed population. For radionuclides, the RRI is based on cancer risk estimates of the National Academy of Sciences Committee on Biological Effects of Ionizing Radiation (NAS 1980). The risks from chemical carcinogens are based on cancer potency factors defined by the EPA (1982). For noncarcinogens, RRIs represent the ratio of estimated dose to reference dose multiplied by 1×10^{-6}. Due to their chemical nature, constituents such as 1,1-dichloroethane, beryllium, cadmium, chromium, and nickel are considered both as carcinogens and toxic noncarcinogens.

The MEPAS also provides a database of standardized values for many nonsite-specific parameters, including all chemical-specific values and the soil-water distribution coefficient (K_d) (Strenge and Peterson 1989). The values contained in this database were used in the relative-risk computations, with a few exceptions. The Cancer Potency Factors (CPF) for carcinogenic chemicals and the Reference Doses (RfD) for noncarcinogenic chemicals are often updated by EPA. Due to these updates, the values in the MEPAS database were reviewed and the following changes were made:

- **1,1,1-Trichloroethane.** The MEPAS database classifies this chemical as a carcinogen, however, EPA does not. Therefore, the chemical was flagged as a noncarcinogen in the MEPAS database.

- **Trichloroethylene.** The EPA retracted the oral CPF, so the MEPAS database does not present a value for this parameter. However, the *Health Effects Assessment Summary Tables* (HEAST) provide a value of 1.7E-02 $(mg/kg/day)^{-1}$, which was entered into the database.

- **Lead.** The EPA has retracted the RfDs for lead which, therefore, should not be used in this assessment. While the MEPAS database currently includes the old values, the relative risk from this chemical is discussed qualitatively.

- **Uranium.** The oral and inhalation RfDs in MEPAS are based on an inhalation Threshold Limit Value (TLV) based on negative findings in an occupational study. This value is questionable and was not used. However, a proposed maximum contaminant level (MCL) has been derived, based on an RfD of 3.0E-03 mg/kg/day (Federal Register, Vol. 56, No. 138, Thursday, July 18, 1991). This value has instead been used for the oral toxicity value of uranium.

- **Aluminum, boron, cobalt, magnesium, sulfate, zinc, and diethyl ether.** The oral and inhalation RfDs in MEPAS are based on an inhalation TLV, based on negative findings in an occupational study. Since the EPA has not developed exposure criteria for the chemicals, the relative risk will not be quantified.

As described in Section 4.2.4.3, the soil-water distribution coefficient, K_d, is used to predict the mobility of inorganic contaminants in groundwater. The default K_d values contained in the MEPAS data libraries were not used in the ranking of groundwater contaminants. Instead, the values for K_d contained in column three of Table 4-7 were used with preference given to values provided by Cantrell and Serne (1992) when available.

5.2.2 Evaluation of Current Plumes

For the evaluation of current concentrations of groundwater contaminants, unit concentrations (i.e., 1 pCi/mL, 1 g/mL) of the contaminants listed in Table 5-1 were input to MEPAS. These represent the subset of contaminants of potential concern from Table 4-6 that were detected in samples of 200 East Area groundwater collected during 1989 and 1990. Contaminants of potential concern that were not detected, or were only detected in a single sample during this period, are not included. For each of the contaminant unit concentrations, MEPAS calculated unit RRI values. The unit RRI values represent semiquantitative measures of relative human health risk, normalized to a level of 10^{-6}.

The calculated unit RRI values are combined with the Geographical Information System (GIS) database of measured 200 East Area groundwater concentrations for the individual contaminants, resulting in a GIS database of contaminant RRI values. Contaminant RRI data for both chemical and radiological carcinogens are combined to produce total RRI values for the unconfined aquifer and plotted to allow visual identification and ranking. Noncarcinogenic contaminant RRI values are summed and plotted separately.

5.2.3 Potential Future Offsite Contaminant Levels

The second screening evaluation examined potential future offsite concentrations of contaminants that may result from 200 East Area groundwater contaminant transport and discharge into the Columbia River. The calculations were based on present measured concentrations and plume volumes that were combined to estimate the inventory of contaminants within the unconfined aquifer. These calculations could only be performed for contaminants with sufficient detection data to enable estimation of plume volume and contaminant inventory. The contaminants addressed in this second screening evaluation were ^{137}Cs, ^{60}Co, ^{129}I, $^{239/240}Pu$, ^{90}Sr, ^{99}Tc, ^{3}H, arsenic, chromium, cyanide, and nitrate.

The MEPAS was used to calculate contaminant transport within the aquifer and discharge into the river, as described in Section 5.2.1. The resulting RRI values, based on potential offsite concentrations, provide a secondary relative ranking of 200 East Area groundwater contaminants.

5.3 SUMMARY OF SCREENING RESULTS

As described in the preceding sections, the MEPAS computer code was used to evaluate the contaminants detected in groundwater beneath the 200 East Area, and generate relative significance rankings for (1) the currently measured contaminant concentrations and (2) contaminant concentrations projected to occur offsite following transport within the Hanford unconfined aquifer. While these relative significance rankings are based on human health risk considerations, the screening process did not evaluate potential risks associated with the Hanford Site or potential exposure to contaminated groundwater. Rather, the screening process provided a consistent semiquantitative evaluation of the various contaminants for their relative intrinsic significance to human health.

The ranking values described in the sections that follow provide risk-related bases for prioritizing plume-specific or contaminant-specific remedial actions. The role of these risk-related values in the overall recommendation process is described in Section 9.0.

5.3.1 Current Plumes

The unit RRI values for the evaluation of current plumes, calculated as described in Section 5.2.2, are listed in Table 5-2. The unit RRI values were multiplied by the concentration in the groundwater at a well (and by a constant to adjust units) to give the RRI for that constituent at that point. The maximum value of this constituent RRI value in the 200 East Area is also shown in Table 5-2. The RRI values are also serially ranked in Table 5-2 for radiological and chemical carcinogens combined and chemical noncarcinogens separately. Carcinogens were ranked from 1 (for highest RRI) to 23 (for lowest). Noncarcinogens were ranked from 1 (for highest RRI) to 24 (for lowest RRI). Some ranks were repeated because of ties, where RRI values are essentially the same (i.e., within 10%). Also, some contaminants were ranked as "L," since the unit RRI was computed by MEPAS to be zero. The contaminants for which an "L" ranking was applied are those that are chemical carcinogens by the inhalation exposure pathway only and are not volatile (i.e., beryllium, cadmium, and chromium). Also, some detections were considered questionable and were therefore not ranked, as indicated on Table 5-2 by the notation "NR." The highest ranked radionuclide, chemical carcinogen, and chemical noncarcinogen are ^{90}Sr, arsenic, and cyanide, respectively.

The calculated constituent RRI values have been combined for chemical and radiological carcinogens and separately for chemical noncarcinogens to produce a total carcinogenic contaminant RRI and a total noncarcinogenic contaminant RRI for each well. The total RRI values were then contoured and plotted to allow visual identification and ranking. Plates 4 and 5 depict contours of the carcinogenic RRI and the noncarcinogenic RRI for the 200 East Area, respectively.

The carcinogenic RRI plume depicted in Plate 4 exhibits an area of high RRI values, generally greater than about 300 with three separate areas above 1,000. This region of high carcinogenic RRI snakes through the 200 East Area, starting north of the northwest corner of the 200 East Area (with the highest levels, an area with values greater than 3,000), moving southeast through the 200 East Area to the southeast corner of the 200 East Area, with two knots of high RRI values (>1,000) along this section. The 300 contour continues from this corner northeast to the 216-B-3 Pond System.

This feature can be explained by the distribution of contamination, mainly radionuclides, in the 200 East Area. The highest area, north of the 200 East northern fence, represents the high levels of ^{99}Tc (plume B on Figure 4-12) and ^{60}Co (Figure 4-10) which are found in this area. The next knot, in the northwest quadrant of the 200 East Area, is due to the contamination around the 216-B-5 Reverse Well, including ^{90}Sr (Figure 4-11, plume B), ^{137}Cs (Figure 4-14), and ^{239,240}Pu (Figure 4-15). The third knot, in the southeast quadrant of the 200 East Area, is mainly due to tritium (Figure 4-8), but with contributions from ^{90}Sr (Figure 4-11, plumes C and D), and ^{99}Tc. The approximately 300 contour shows some of the features of the tritium plume (Figure 4-8), including a branch to the southwest which appears to be emanating from the 200 West Area. An isolated area some distance to the southeast (highest at Well 699-25-348) is due to detections of the carcinogens trichloroethylene and tetrachloroethylene near the Central Landfill. There are also a few other isolated locations (wells) with high RRI values (>1,000) which are not indicated as within a 1,000 contour because of the smoothing associated with the contouring process. These include Well 699-53-48B, northeast of Gable Mountain Pond, which has high ^{90}Sr levels and Well 699-55-57, near the 200 North Aggregate Area, with ^{99}Tc.

The noncarcinogenic RRI plume map, Plate 5, shows the highest area (within the only 100 contour) to the northwest of the 200 East Area, in the same place as one of the highest levels of carcinogenic RRI. This high-RRI area is mainly due to the nitrate plume (Figure 4-4, plume B) and cyanide plume (Figure 4-3). Lower levels emanate from this center, mainly in two directions: to the southwest and east as outlined by the 3 contour. These generally high areas appear to be attributable to several metals, mainly antimony, and chromium. An area in the southeast corner of the 200 East Area is mainly due again to nitrate (Figure 4-4, plume E). An isolated area of especially high levels, at the southeast edge of the map, are attributable to detections of 1,1,1-trichloroethane near the Central Landfill.

5.3.2 Potential Future Offsite Contaminant Levels

The RRI values for the evaluation of potential future offsite contaminant levels were calculated as described in Section 5.2.3. The input parameters used for the evaluation are provided in Appendix A. The results of these computations are listed in Table 5-3 for each contaminant of concern evaluated. The RRIs were only computed for contaminants of concern with known groundwater plumes as described in Section 4.2 and listed in Table 5-3.

The RRI values are also ranked on Table 5-3 from 1 for highest to 4 for lowest (3 for noncarcinogens). Several contaminants resulted in RRI values of zero, based on their low mobility characteristics (these are noted in Table 5-2 by a ranking of "L"). The RRI values for the remaining contaminants ranged from 1E-12 to 3E-09, with chromium, nitrate, and ^{99}Tc ranking the highest.

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Table 5-1. Contaminants Evaluated Based on Current Plume Contaminant Levels.

Radionuclides	Inorganics	Organics
Americium-241	Aluminum	1,1,1-Trichloroethane
Antimony-125	Antimony	1,1,2-Trichloroethane
Beryllium-7	Arsenic	1,1-Dichloroethane
Carbon-14	Barium	1,2-Dicholorethane
Cerium-144	Beryllium	1,2-Dichloroethylene
Cesium-134	Boron	2,3,4,6-Tetrachlorophenol
Cesium-137	Cadmium	2,4-Dichlorophenol
Cobalt-60	Chromium	2,4-Dimethylphenol
Europium-154	Cobalt	2,4-Dinitrophenol
Europium-155	Copper	2,4-Dinitrotoluene
Iodine-129	Cyanide	2-Chlorophenol
Lead-212	Fluoride	4-Methyl-2-Pentanone
Niobium-95	Iron	Acetone
Plutonium-238	Lead	Aldrin
Plutonium-239/240	Lithium	Bis(2-ethylhexyl)phthalate
Potassium-40	Magnesium	Carbon tetrachloride
Radium-226)	Mangenese	Chloroform
Ruthenium-106	Mercury	Cyclohexanone
Strontium-90	Nickel	DDD
Technetium-99	Nitrate/Nitrite	DDT
Tritium	Phosphate	Dieldrin
Uranium-234	Potassium	Diethyl ether
Uranium-235	Selenium	Endrin
Uranium-238	Silver	Gamma-BHC
Zinc-65	Sodium	Heptachlor
	Strontium	Hydrazine
	Sulfate	Methyl ethyl ketone
	Thallium	Methylene chloride
	Uranium	p-Chloro-m-cresol
	Vanadium	Pentachlorophenol
	Zinc	Phenol
		Pyrene
		Styrene
		Tetrachloroethylene
		Toluene
		Trichloroethylene
		Trichloromonofluoromethane
		Triethylene glycol

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Table 5-2. Unit RRIs Computed for Current Plume Contaminant Levels.

Constituents	Unit RRI	Groundwater Concentration	RRI	Ranking
Radionuclides				**Carcinogens**
Americium-241	1.0E-01	4.0E-02	4.0E+00	21
Antimony-125	7.0E-05	7.9E+00	5.5E-01	23
Beryllium-7	2.4E-06	2.2E+02	5.3E-01	NR[b]
Carbon-14	5.5E-04	3.8E+01	2.1E+01	16
Cerium-144	4.4E-04	2.9E+01	1.3E+01	NR
Cesium-134	3.1E-04	3.7E+00	1.1E+01	17
Cesium-137	2.1E-03	1.3E+03	2.8E+03	5
Cobalt-60	6.4E-04	4.7E+02	3.0E+02	10
Europium-154	2.2E-04	1.2E+01	2.7E+00	NR
Europium-155	3.5E-05	9.4E+00	3.3E-01	NR
Iodine-129	1.5E-02	3.0E+01	4.5E+02	7[a]
Lead-212	2.9E-04	1.3E+01	3.7E+00	NR
Niobium-95	5.1E-05	8.1E+01	4.2E+00	NR
Plutonium-238	8.7E-02	3.6E-01	3.1E+01	15
Plutonium-239/240	8.7E-02	7.4E+01	7.2E+03	3
Potassium-40	2.0E-03	2.4E+02	4.8E+02	7[a]
Radium (as Ra-226)	3.6E-02	1.7E+00	5.9E+01	14
Ruthenium-106	5.9E-04	3.0E+02	1.8E+02	12[a]
Strontium-90	7.0E-03	5.1E+03	3.6E+04	1
Technetium-99	5.8E-04	2.2E+04	1.3E+04	2
Tritium	1.3E-06	4.3E+06	5.6E+03	4
Uranium-234	6.1E-03	3.3E+01	2.0E+02	11
Uranium-235	5.9E-03	1.6E+00	9.3E+00	18[a]
Uranium-238	5.6E-03	3.1E+01	1.8E+02	12[a]
Zinc-65	1.7E-03	7.5E+00	1.3E+01	NR
Chemical Carcinogens				
1,1,2-Trichloroethane	4.9E+03	2.1E+00	1.0E+01	NR
1,1-Dichloroethane	8.9E+04	5.3E+00	4.7E+02	7[a]
1,2-Dichloroethane	1.0E+04	4.0E+00	4.0E+01	NR
cis-1,2-Dichloroethylene	3.3E+00	1.2E+00	4.0E-03	NR
trans-1,2-Dichloroethylene	3.3E+00	4.7E+00	1.6E-02	NR
2,4-Dinitrotoluene	1.5E+05	8.7E+00	1.3E+03	NR
Aldrin	3.7E+06	7.4E-01	2.7E+03	NR
Arsenic	9.3E+04	2.4E+01	2.2E+03	6
Beryllium	0.0E+00	5.3E+00	0.0E+00	L[c]
Bis(2-ethylhexyl)phthalate	3.1E+06	5.6E+01	1.7E+05	NR
Cadmium	0.0E+00	4.2E+00	0.0E+00	L
Carbon tetrachloride	8.0E+03	4.5E+00	3.6E+01	NR
Chloroform	1.1E+03	8.3E+00	9.1E+00	18[a]
Chromium	0.0E+00	6.5E+01	0.0E+00	L

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Table 5-2. Unit RRIs Computed for Current Plume Contaminant Levels.

Constituents	Unit RRI	Groundwater Concentration	RRI	Ranking
Chemical Carcinogens (continued)				**Carcinogens (continued)**
DDD	1.7E+04	1.7E-01	2.9E+00	NR
DDT	3.9E+04	2.5E+00	9.8E+01	NR
Dieldrin	2.1E+06	1.6E+00	3.4E+03	NR
Heptachlor	3.6E+05	6.3E-01	2.3E+02	NR
Hydrazine	7.8E+07	3.8E+01	3.0E+06	NR
Methylene chloride	3.8E+02	1.3E+03	4.9E+02	NR
Nickel	0.0E+00	6.0E+01	0.0E+00	L
Tetrachloroethylene	3.8E+02	8.2E+00	3.1E+00	22
Trichloroethylene	8.4E+02	1.2E+01	1.0E+01	18[a/]
Chemical Noncarcinogens				**Noncarcinogens**
1,1,1-Trichlorethane	3.4E+09	4.0E+01	1.3E+02	2
1,1-Dichloroethane	9.1E+04	5.3E+00	4.8E-04	24
2,3,4,6-Tetrachlorophenol	1.4E+06	1.0E+01	1.4E-02	NR
2,4-Dichlorophenol	3.2E+07	1.8E+01	5.8E-01	NR
2,4-Dimethylphenol	5.1E+06	2.0E+01	1.0E-01	NR
2,4-Dinitrophenol	1.9E+08	1.2E+02	2.3E+01	NR
2-Chlorophenol	3.4E+07	1.5E+01	5.2E-01	12[a/]
4-Methyl-2-pentanone	1.7E+07	1.1E+01	1.9E-01	NR
Acetone	1.1E+06	1.4E+02	1.5E-01	NR
Antimony	1.3E+08	1.1E+02	1.5E+01	5[a/]
Barium	9.3E+05	1.1E+02	1.1E-01	16
Beryllium	1.9E+11	5.3E+00	1.0E+03	NR
Cadmium	3.0E+08	4.2E+00	1.3E+00	8
Chromium	1.0E+07	6.5E+01	6.5E-01	10[a/]
Copper	3.4E+06	2.6E+01	8.8E-02	17
Cyanide	1.7E+08	8.7E+02	1.5E+02	1
Cyclohexanone	1.5E+05	4.0E+00	6.0E-04	NR
Endrin	1.2E+08	2.3E+00	2.8E-01	NR
Fluoride	1.6E+06	2.2E+03	3.5E+00	7
Gamma-BHC	2.8E+08	6.7E-01	1.9E-01	NR
Iron	4.6E+04	3.4E+03	1.6E-01	15
Lithium	4.7E+04	1.6E+01	7.5E-04	23
Manganese	2.5E+05	3.0E+02	7.4E-02	18[a/]
Mercury	1.6E+09	2.1E-01	3.4E-01	NR
Methyl ethyl ketone	6.4E+06	3.7E+01	2.4E-01	NR
Nickel	3.3E+06	6.0E+01	2.0E-01	14
Nitrate	4.4E+04	5.0E+05	2.2E+01	4
p-Chloro-m-cresol	3.1E+06	1.5E+01	4.6E-02	20

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Table 5-2. Unit RRIs Computed for Current Plume Contaminant Levels.

Constituents	Unit RRI	Groundwater Concentration	RRI	Ranking
Chemical Noncarcinogens (continued)				**Noncarcinogens (continued)**
Pentachlorophenol	6.3E+09	6.7E+01	4.2E+02	NR
Phenol	6.4E+05	1.2E+01	7.9E-03	NR
Potassium	4.3E+02	1.5E+04	6.2E-03	22
Pyrene	1.9E+06	8.5E+00	1.6E-02	NR
Selenium	2.0E+09	2.4E+01	4.7E+01	3
Silver	7.7E+07	1.2E+01	9.3E-01	NR
Sodium	9.7E+02	7.5E+04	7.3E-02	18[a/]
Strontium	6.3E+05	1.0E+03	6.4E-01	10[a/]
Styrene	1.5E+09	9.5E+00	1.4E+01	5[a/]
Thallium	4.2E+09	5.0E+01	2.1E+02	NR
Toluene	3.8E+05	3.0E+01	1.1E-02	21
Trichloromonofluoromethane	1.9E+05	1.1E+01	2.1E-03	NR
Triethylene glycol	8.9E+07	1.0E+01	8.9E-01	NR
Uranium (chemical)	1.5E+07	3.8E+01	5.7E-01	12[a/]
Vanadium	7.2E+06	1.4E+02	9.7E-01	9

a/ Some rankings are repeated due to a tie in maximum relative risk index (less than 10% difference).
b/ NR = Not ranked because of questionable detection.
c/ L = Lower than was calculable by MEPAS.

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Table 5-3. Contaminants Evaluated for Future Offsite Plume Contaminant Levels.

Constituent	RRI	Ranking
Radionuclides		**Carcinogens**
Cesium-137	0.0E+00	L[a/]
Cobalt-60	0.0E+00	L
Iodine-129	2.1E-11	3
Plutonium-239/240	0.0E+00	L
Strontium-90	0.0E+00	L
Technetium-99	1.1E-10	1
Tritium	1.3E-12	4
Chemical Carcinogens		
Arsenic	3.3E-11	2
Chromium	0.0E+00	L
Chemical Noncarcinogens		**Noncarcinogens**
Chromium	2.7E-09	1
Cyanide	5.8E-18	3
Nitrate	3.0E-10	2

a/ L = Lower than was calculable by MEPAS.

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6.0 POTENTIALLY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

6.1 INTRODUCTION

The Superfund Amendments and Reauthorization Act (SARA) of 1986 amended the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to require that all applicable or relevant and appropriate requirements (ARARs) be employed during implementation of a hazardous waste site cleanup. "Applicable" requirements are defined by the U.S. Environmental Protection Agency (EPA) in "CERCLA Compliance with Other Laws Manual" (OSWER Directive 9234.1-01, August 8, 1988) as:

> cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

A separate set of "relevant and appropriate" requirements that must be evaluated include:

> cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

"To-be-Considered Materials" (TBCs) are nonpromulgated advisories or guidance issued by federal or state governments that are not legally binding and do not have the status of potential ARARs. However, in many circumstances, TBCs will be considered along with potential ARARs and may be used in determining the necessary level of cleanup for protection of health or the environment.

The following sections identify potential ARARs to be used in developing and assessing various remedial action alternatives at the 200 East Groundwater Aggregate Area. Specific requirements pertaining to hazardous and radiological waste management, remediation of contaminated soils, surface water protection, and air quality will be discussed.

The potential ARARs focus on federal or state statutes, regulations, criteria, and guidelines. The specific types of potential ARARs evaluated include the following:

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- Contaminant-specific
- Location-specific
- Action-specific.

Potential contaminant-specific ARARs are usually health or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical contaminant values that are generally recognized by the regulatory agencies as allowable to protect human health and the environment. In the case of the 200 East Groundwater Aggregate Area, potential contaminant-specific ARARs address chemical constituents and/or radionuclides. The potential contaminant-specific ARARs that were evaluated for the 200 East Groundwater Aggregate Area are discussed in Section 6.2.

Potential location-specific ARARs are restrictions placed on the concentration of hazardous substances, or the conduct of activities, solely because they occur in specific locations. The potential location-specific ARARs that were evaluated for the 200 East Groundwater Aggregate Area are discussed in Section 6.3.

Potential action-specific ARARs apply to particular remediation methods and technologies, and are evaluated during the detailed screening and evaluation of remediation alternatives. The potential action-specific ARARs that were evaluated for the 200 East Groundwater Aggregate Area are discussed in Section 6.4.

The TBC requirements are other federal and state criteria, advisories, and regulatory guidance that are not promulgated regulations, but are to be considered in evaluating alternatives. Potential TBCs include U.S. Department of Energy (DOE) Orders that carry out authority granted under the Atomic Energy Act. All DOE Orders are potentially applicable to operations at the 200 East Groundwater Aggregate Area. Specific potential TBC requirements are discussed in Section 6.5.

Potential contaminant- and location-specific ARARs will be refined during the aggregate area management study (AAMS) process. Potential action-specific ARARs are briefly discussed in this section, and will be further evaluated upon final selection of remedial alternatives. The points at which these potential ARARs must be achieved and the timing of the ARARs evaluations are discussed in Sections 6.6 and 6.7, respectively.

6.2 CONTAMINANT-SPECIFIC REQUIREMENTS

A contaminant-specific requirement sets concentration limits in various environmental media for specific hazardous substances, pollutants, or contaminants. Based on available

information, some of the currently known or suspected contaminants that may be present in the 200 East Groundwater Aggregate Area are outlined in Table 4-6. The currently identified potential federal and state contaminant-specific ARARs are summarized below.

6.2.1 Federal Requirements

Federal contaminant-specific requirements are specified in several statutes, codified in the U.S. Code (USC), and promulgated in the Code of Federal Regulations (CFR), as follows:

- **Safe Drinking Water Act (42 U.S.C. 30.0 (f)).** Drinking water criteria are established by EPA pursuant to the federal Safe Drinking Water Act (SDWA) (42 U.S.C. 30.0 (f)) and are promulgated in 40 CFR Parts 141 and 143. These regulations present water quality standards (contaminant levels) for water used for drinking, cooking, bathing, and similar uses. Maximum contaminant levels (MCLs) are enforceable for public water systems, usually at the point of water usage. Secondary maximum contaminant levels (SMCLs) are established for contaminants in drinking water that may adversely affect odor, color, or public welfare. Maximum contaminant level goals (MCLGs) are non-enforceable, health-based goals that do not take cost or feasibility into account. The EPA may consider MCLGs where multiple exposure pathways exist, highly sensitive populations are involved, or a greater degree of protection is otherwise required.

  Currently, the EPA applies MCLs as potential ARARs for groundwater contaminants at CERCLA sites where groundwater could be used as a drinking water source. The federal MCLs and SMCLs are presented in Table 6-1 for the potential contaminants of interest. The MCLGs have not been included as potential ARARs because they are not enforceable, their application would be subject to negotiation with the agencies, and their application would depend on the remedial alternatives being considered.

- **Resource Conservation and Recovery Act (42 U.S.C. 6901, 40 CFR 260 to 271).** The Resource Conservation and Recovery Act (RCRA) addresses the generation and transportation of hazardous waste, and waste management activities at facilities that treat, store, or dispose of hazardous wastes. Subtitle C of RCRA (Hazardous Waste Management) mandates the creation of a cradle-to-grave management and permitting system for hazardous wastes. The RCRA defines hazardous wastes (40 CFR 261) as "solid wastes" (even though the waste is often liquid in physical form) that may cause or significantly contribute to an increase in mortality or serious illness; or that

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poses a substantial hazard to human health or the environment when improperly managed. In Washington State, RCRA is implemented by EPA and the authorized state agency, the Washington State Department of Ecology (Ecology).

The CERCLA sections 121 (d) and 121 (e) respectively require that CERCLA activities, including remedial actions, comply with substantive requirements and not administrative requirements such as permitting. Therefore, hazardous waste activities conducted on site at the 200 East Groundwater Aggregate Area will comply with the substantive requirements of RCRA, and not the permitting requirements of RCRA, which are deemed to be potential ARARs.

Two key potential contaminant-specific ARARs have been adopted under the federal hazardous waste regulations: the Toxicity Characteristic Leaching Procedure (TCLP) designation limits promulgated under 40 CFR Part 261; and the hazardous waste land disposal restrictions (LDRs) for constituent concentrations promulgated under 40 CFR Part 268.

The TCLP designation limits define when a waste is hazardous, and are used to determine when more stringent management standards apply than would be applied to typical solid wastes. Thus, the TCLP potential contaminant-specific ARARs can be used to determine when RCRA waste management standards may be required. The TCLP limits are presented in Table 6-1.

The LDRs are numerical limits derived by EPA by reviewing available technologies for treating hazardous wastes. Until a prohibited waste can meet the numerical limits, it can be prohibited from land disposal. Two sets of limits have been promulgated: limits for constituent concentrations in waste extract, which use the TCLP test to obtain a leached sample of the waste; and limits for constituent concentrations in waste, which address the total contaminant concentration in the waste. The latter concentrations are generally applied to wastewaters (e.g., groundwater, leachate). Applicability to CERCLA actions is based on determinations of waste "placement/disposal" during a remediation action. According to OSWER Directive 9347.3-05FS, EPA concludes that Congress did not intend in situ consolidation, remediations, or improvement of structural stability to constitute placement or disposal. The land disposal numerical limits can be used to determine if generated cleanup wastes can be redisposed of onsite without further treatment, or must be subject to certain treatment practices prior to land disposal. The LDR limits are presented in Table 6-1 (see Section 6.4.1 for a further discussion on applying the land disposal restriction limits).

- **Clean Air Act (42 U.S.C. 7401).** The Clean Air Act (42 U.S.C. 7401) establishes National Primary and Secondary Ambient Air Quality Standards (NAAQS) (40 CFR Part 50), National Emission Standards for Hazardous Air Pollutants (NESHAP)(40 CFR Part 61), and New Source Performance Standards (NSPS)(40 CFR Part 60). These standards would not, in most cases, be potential contaminant-specific ARARs for the 200 East Groundwater Aggregate Area. However, it is possible that unique circumstances, or instances where groundwater remediation alternatives result in emissions to air, could require consideration of air quality standards as potential contaminant-specific ARARs. The applicability or relevance and appropriateness of potential air quality ARARs in such situations would be subject to negotiation with the agencies and may depend on the remedial alternatives being considered.

  In general, new and modified stationary sources of air emissions must undergo a pre-construction review to determine whether the construction or modification of any source, such as a CERCLA remedial program, would interfere with attaining or maintaining NAAQS or fail to meet other new source review requirements including NESHAP and NSPS. However, the process applies only to "major" sources of air emissions (defined as emissions of 250 tons/yr). The 200 East Groundwater Aggregate Area would not constitute a major source.

  Section 112 of the Clean Air Act directs EPA to establish standards at the level that provides an ample margin of safety to protect the public health from hazardous air pollutants. The NESHAP standards for radionuclides are directly applicable to DOE facilities under Subpart H of Section 112 that establishes a 10 mrem/yr standard for total exposure to an offsite receptor. Further, if the maximum individual dose during remediation exceeds 1% of the NESHAP standard (0.1 mrem/yr), a report meeting the substantive requirements of an application for approval of construction must be prepared.

6.2.2 State of Washington Requirements

Potential state contaminant-specific requirements are specified in several statutes, codified in the Revised Code of Washington (RCW) and promulgated in the Washington Administrative Code (WAC).

- **Water Quality Standards.** Washington State has adopted various numerical standards under the state Water Pollution Control Act (Chapter 90.48 RCW)

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related to surface and groundwater contaminants. These are included principally in the following regulations:

- **Public Water Supplies (Chapter 248-54 WAC).** This regulation establishes drinking water standards for public water supplies. The standards essentially parallel the federal drinking water standards (40 CFR Parts 141 and 143).

- **Water Quality Standards for Ground Waters of the State of Washington (RCW 90.44, Chapter 173-200 WAC).** This regulation establishes contaminant standards for protecting existing and future beneficial uses of groundwater through the reduction or elimination of the discharge of contaminants to the state's groundwater.

The state drinking water quality standards would be evaluated as potential ARARs in essentially the same manner as the federal drinking water standards would be considered. Because the numerical standards are identical for both federal and state contaminants, the state drinking water standards are already addressed in Table 6-1 under the federal MCL and SMCL columns.

The state groundwater standards are not applicable to cleanup actions approved by Ecology under Washington's Model Toxics Control Act (MTCA) or by EPA under CERCLA [(WAC 173-200-010(3)(c)]. Groundwater cleanup standards are to be developed under MTCA procedures (see Section 6.2.2.2 for a discussion of these procedures). Nevertheless, the state groundwater standards may be considered relevant and appropriate as potential ARARs for contaminants in groundwater (e.g., where no other potential ARARs exist for particular constituents) and for selected remedial actions that could result in discharges to groundwater (e.g., if treated wastewaters are discharged to the soil column). Determining ARARs for treated discharges would depend on the type of remediation performed and would have to be established on a case-by-case basis as remedial actions are defined.

- **Model Toxics Control Act (RCW 70.105D, Chapter 173-340 WAC).** The MTCA (RCW 70.105D, Chapter 173-340 WAC) (Ecology 1991b) authorized Ecology to adopt cleanup standards for remedial actions at hazardous waste sites. These regulations are considered potential ARARs for soil, groundwater, and surface water cleanup actions. The processes for identifying, investigating, and cleaning up hazardous waste sites are defined and cleanup standards are set for groundwater, soil, surface water, and air in Chapter 173-340 WAC.

Under MTCA regulations, cleanup standards may be established by one of three methods:

- Method A may be used if a routine cleanup action, as defined in WAC 173-340-200, is being conducted at the site or relatively few hazardous substances are involved for which cleanup standards have been specified by Tables 1, 2, or 3 of WAC 173-340-720 through 173-340-745.

- Under Method B, a risk level of 10^{-6} is established and a risk calculation based on contaminants present is determined.

- Method C cleanup standards represent concentrations that are protective of human health and the environment for specified site uses. Method C cleanup standards may be established where it can be demonstrated that such standards comply with applicable state and federal laws, that all practical methods of treatment are used, that institutional controls are implemented, and that one of the following conditions exist: (1) Method A or Method B standards are below background concentrations; (2) Method A or Method B results in a significantly greater threat to human health or the environment; (3) Method A or Method B standards are below technically possible concentrations; or (4) the site is defined as an industrial site for purposes of remediation.

Table 1 of Method A addresses groundwater and is considered to be a potential ARAR for the 200 East Groundwater Aggregate Area. Table 2 of Method A is intended for nonindustrial site soil cleanups and Table 3 of Method A is intended for industrial site soil cleanups. Since soil cleanup is being addressed in other source unit aggregate area management study reports (AAMSRs), Table 6-1 presents as potential ARARs only the cleanup standards from Table 1 of Method A for preliminary contaminants of concern.

In addition to Method A, Method B and Method C cleanup standards may also be considered potential ARARs for the 200 East Groundwater Aggregate Area. Method B and Method C cleanup standards can be calculated on a case-by-case basis in concert with Ecology. Method B and Method C should be used where Method A standards do not exist or cannot be met, or where routine cleanup actions cannot be implemented at a specific contaminated site.

- **State Hazardous Waste Management Act and Dangerous Waste Regulations (Chapter 173-303 WAC).** The state of Washington is a RCRA-authorized state for hazardous waste management, and has developed state-

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specific hazardous waste regulations under the authority of the State Hazardous Waste Management Act. Generally, state hazardous waste regulations (WAC 173-303) parallel the federal regulations. The state definition of a hazardous waste incorporates the EPA designation of hazardous waste that is based on the compound being specifically listed as hazardous, or on the waste exhibiting the properties of reactivity, ignitability, corrosivity, or toxicity as determined by the TCLP.

In addition, Washington State identifies other waste as hazardous. Three unique criteria are established: toxic dangerous waste; persistent dangerous waste; and carcinogenic dangerous waste. These additional designation criteria may be imposed by Ecology as potential ARARs, for purposes of determining acceptable cleanup standards and appropriate waste management standards.

- **Washington State Air Quality Requirements.** Washington State air quality standards would not, in most cases, be potential contaminant-specific ARARs for the 200 East Groundwater Aggregate Area. However, it is possible that unique circumstances, or instances where groundwater remediation alternatives result in emissions to air, could require consideration of air quality standards as potential contaminant-specific ARARs. The applicability or relevance and appropriateness of potential air quality ARARs in such situations would be subject to negotiation with the agencies and may depend on the remedial alternatives being considered.

  Ambient Air Quality Standards and Emission Limits for Radionuclides (Chapter 173-480 WAC), implemented by Ecology, specify maximum accumulated dose limits to members of the public. Monitoring and Enforcement of Air Quality and Emission Standards for Radionuclides (WAC 246-247), implemented by the Washington Department of Health (Health), adopt the Ecology standards for maximum accumulated dose limits to members of the public. Controls for New Sources of Toxic Air Pollutants (Chapter 173-460 WAC), implemented by Ecology, establish allowable acceptable source impact levels (ASILs) for hundreds of organic and inorganic compounds. Ecology's ASILs may be potential ARARs for cleanup activities that could affect air, but they would have to be established on a case-by-case basis as remedial actions are defined.

6.2.3 Surface Water Quality Standards

This section describes federal and state contaminant-specific requirements that generally apply only to surface water contaminants. These standards are discussed because the agencies may rely on them as potential ARARs if the following:

- 200 East Groundwater Aggregate Area groundwater is discharging or will be discharged to surface waters (e.g., Columbia River)

- No other potential contaminant-specific ARARs for protection of human consumption are readily identifiable from groundwater requirements for particular contaminants.

The applicability or relevance and appropriateness of potential surface water ARARs will be subject to negotiation with the agencies and may depend on the remedial alternatives being considered.

- **Clean Water Act.** Federal Water Quality Criteria (FWQC) are developed under the authority of the Clean Water Act to assist the states in protecting surface water quality. Different FWQC are derived for protection of human health and protection of aquatic life. The human health FWQC are subdivided according to how people are expected to use the water: drinking the water and consuming aquatic organisms (e.g., fish, clams) living in the water; or consuming the organisms and not drinking the water. The aquatic life FWQC are subdivided into saltwater and freshwater, and further subdivided into criteria for protecting against acute and chronic effects in aquatic organisms.

  Section 121(d)(2)(B)(i) of SARA states that the designated or potential use of the surface or groundwater, the environmental media affected, the purposes for which the criteria were developed, and the latest available information must be considered when determining whether or not water quality criteria under the Clean Water Act are relevant and appropriate under the circumstances of a release or threatened release. Thus, although the FWQC may be considered as potential ARARs at the 200 East Groundwater Aggregate Area, they will likely be subject to negotiation with the agencies and may depend on the remedial alternatives being considered.

- **National Pollutant Discharge Elimination System and Water Quality Standards (RCW 90.48, WAC 173-220, and 40 CFR 122).** National Pollutant Discharge Elimination System (NPDES) regulations govern point source discharges into navigable waters. Limits on the concentrations of contaminants and volumetric flowrates that may be discharged are determined

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on a case-by-case basis and permitted under this program. In addition, NPDES regulations establish water quality standards for discharges from various industrial classifications. The EPA currently implements this program in Washington State for federal facilities; however, assumption of the NPDES program by the state is likely within five years. Although no point source discharges have been identified for 200 East Groundwater Aggregate Area remedial actions at this time, the agencies may evaluate contaminant-specific limits under the NPDES program as potential ARARs when remediation alternatives are developed. These potential ARARs will have to be negotiated on a case-by-case basis.

- **Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201 WAC and Proposed Chapter 173-201A WAC).** Ecology has adopted numerical ambient water quality criteria for six conventional pollutant parameters (defined at WAC 173-201-025): (1) fecal coliform bacteria; (2) dissolved oxygen; (3) total dissolved gas; (4) temperature; (5) pH; and (6) turbidity. In addition, toxic, radioactive, or deleterious material concentrations are required to be below those of public health significance or which may cause acute or chronic toxic conditions to the aquatic environment or which may adversely affect any water use. The current Chapter 173-201 WAC has promulgated numerical water quality criteria for a limited number of compounds; these criteria generally are identical to the FWQC. Ecology has initiated rulemaking to expand and incorporate the remaining FWQC numerical criteria for toxic chemicals. Currently, only the current Chapter 173-201 WAC could be considered a potential ARAR; the proposed Chapter 173-201A WAC could only be a potential TBC. Since the FWQC and promulgated state water quality criteria are essentially identical, the state standards are already addressed by the FWQC.

  Under the state Water Quality Standards, the criteria and classifications do not apply inside an authorized mixing zone surrounding a wastewater discharge. Ecology is presently developing additional guidance and regulations for defining mixing zones; in the past, Ecology has generally followed guidelines contained in "Criteria for Sewage Works Design." Although water quality standards can be exceeded inside a mixing zone, state regulations will not permit discharges that cause mortalities of fish or shellfish within the zone or that diminish aesthetic values.

6.3 LOCATION-SPECIFIC REQUIREMENTS

Potential location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they are in specific locations. Some examples of special locations include floodplains, wetlands, historic places, and sensitive ecosystems or habitats.

Table 6-2 lists various location-specific standards and indicates which of these may be potential ARARs. Potential ARARs have been identified as follows:

- **Floodplains.** Requirements for protecting floodplains are not necessarily potential ARARs for the 200 East Groundwater Aggregate Area as there are none in the 200 East Area or vicinity (see Section 3.3.3). However, remedial actions selected for cleanup may require projects in or near floodplains (e.g., construction of a treatment facility outfall at the Columbia River). In such cases, location-specific floodplain requirements may be potential ARARs.

- **Wetlands, Shorelines, and Rivers and Streams.** Requirements related to wetlands, shorelines, and rivers and streams are not necessarily potential ARARs for the 200 East Groundwater Aggregate Area. However, remedial actions selected for cleanup may require projects on a shoreline or wetland, or discharges to wetlands, rivers, or streams (e.g., construction of a treatment facility outfall at the Columbia River). In such cases, location-specific shoreline and wetlands requirements may be potential ARARs.

- **Threatened and Endangered Species Habitats.** As discussed in Section 3.6, various threatened and endangered species (e.g., American peregrine falcon, bald eagle, white pelican, and sandhill crane) inhabit portions of the Hanford Site and may occur in the 200 East Groundwater Aggregate Area. Therefore, critical habitat protection for these species may constitute potential ARARs.

- **Wild and Scenic Rivers.** The Columbia River Hanford Reach is currently undergoing study pursuant to the federal Wild and Scenic Rivers Act. Pending results of this study, actions that may impact the Hanford Reach may be restricted. This requirement would not necessarily be an ARAR for the 200 East Groundwater Aggregate Area. However, Wild and Scenic Rivers Act requirements may be ARARs for actions taken as a result of 200 East Groundwater Aggregate Area cleanup efforts that could affect the Hanford Reach.

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6.4 ACTION-SPECIFIC REQUIREMENTS

Potential action-specific ARARs are requirements that are triggered by specific remedial actions at the site. These remedial actions will not be fully defined until a remedial approach has been selected. However, the universe of potential action-specific ARARs defined by a preliminary screening of potential remedial action alternatives will help focus the selection process. Potential action-specific ARARs are outlined below. (Note that potential contaminant- and location-specific ARARs discussed above will also include provisions for potential action-specific ARARs to be applied once the remedial action is selected.)

6.4.1 Federal Requirements

- **Comprehensive Environmental Response, Compensation, and Liability Act (40 CFR 300).** The CERCLA (including SARA) and regulations adopted pursuant to CERCLA, as contained in the National Contingency Plan (40 CFR 300), include selection criteria for remedial actions. Under the criteria, onsite treatment options are more highly favored when available. Emphasis is placed on alternatives that permanently treat or immobilize contamination. Selected alternatives must be protective of human health and the environment, which implies that federal and state ARARs be met. However, a remedy may be selected that does not meet all ARARs if the requirement is technically impractical, if its implementation would produce a greater risk to human health or the environment, if an equivalent level of protection can otherwise be provided, if state standards are inconsistently applied, or if the remedy is only part of a complete remedial action which attains potential ARARs.

  The CERCLA gives state cleanup standards essentially equal importance as federal standards in guiding cleanup measures in cases where state standards are more stringent. State standards pertain only if they are generally applicable, passed through formal means, adopted on the basis of hydrologic, geologic, or other pertinent considerations, and do not preclude the option of land disposal by a state-wide ban. Most importantly, CERCLA provides that cleanup of a site must ensure that public health and the environment are protected. Selected remedies should meet all ARARs, but issues such as cost-effectiveness must be weighed in the selection process.

- **Resource Conservation and Recovery Act (42 U.S.C. 6901, 40 CFR 260 to 271).** The RCRA (42 U.S.C. 6901), and regulations adopted pursuant to RCRA, describe numerous action-specific requirements that may be potential ARARs for cleanup activities. The primary regulations are promulgated under

40 CFR Parts 262 (standards for generators), 264, and 265 (standards for owners and operators of hazardous waste treatment, storage, and disposal facilities), and include such action-specific requirements as follows:

- Packaging, labeling, placarding, and manifesting of offsite waste shipments

- Inspecting waste management areas to ensure proper performance and safe conditions

- Preparation of plans and procedures to train personnel and respond to emergencies

- Management standards for containers, tanks, incinerators, and treatment units

- Design and performance standards for land disposal facilities

- Groundwater monitoring system design and performance.

Many of these requirements will depend on the particular remediation activity undertaken, and will have to be identified as remediation proceeds.

One key area of potential action-specific RCRA ARARs are the 40 CFR Part 268 LDRs. In addition to the contaminant-specific constituent concentration limits established in the LDRs (as previously discussed in Section 6.2.1), EPA has identified best demonstrated available treatment technologies (BDATs) for various waste streams. The EPA could require the use of BDATs prior to allowing land disposal of wastes generated during remediation of the 200 East Groundwater Aggregate Area. The EPA's imposition of the LDRs and BDAT requirements will depend on various factors.

Applicability to CERCLA actions is based on determinations of waste "placement/disposal" during a remediation action. According to OSWER Directive 9347.3-05FS, EPA concludes that Congress did not intend in situ consolidation, remediations, or improvement of structural stability to constitute placement or disposal. Placement or disposal would be considered to occur if the following:

- Wastes from different units are consolidated into one unit (other than a land disposal unit within an area of contamination)

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- Waste is removed and treated outside a unit and redeposited into the same or another unit (other than a land disposal unit within an area of contamination)

- Waste is picked up from a unit and treated within the area of contamination in an incinerator, surface impoundment, or tank and then redeposited into the unit (except for in situ treatment).

Consequently, the requirement to use BDAT would not apply under the land disposal restrictions standards unless placement or disposal had occurred. However, remediation actions involving excavation, groundwater extraction, and/or treatment could trigger the requirements to use BDAT for wastes subject to the LDR standards. In addition, the agencies could consider BDAT technologies to be relevant and appropriate when developing and evaluating potential remediation technologies.

Two additional components of the LDR program should be considered with regard to an excavate and treat remedial action. First, a national capacity variance was issued by EPA for contaminated soil and debris for a two-year period ending May 8, 1992 (54 FR 26640). The agency extended that variance for an additional year through May 8, 1993. The EPA recently issued proposed rules on January 9, 1992 (57 FR 958) for LDR on contaminated debris for review and comment. Second, a series of variances and exemptions may be applied under an excavate and treat scenario. These include the following:

- A no-migration petition
- A case-by-case extension to an effective date
- A treatability variance
- Mixed Waste Provisions of a federal Facilities Compliance Act
- TPA land disposal restrictions (LDR) provisions.

The applicability and relevance of each of these options will vary based on the specific details of 200 East Groundwater Aggregate Area remedial actions. An analysis of these variances can be developed once engineering data on remedial options becomes available.

The effect of the LDR program on mixed waste management is significant. Currently, limited technologies are available for effective treatment of these

waste streams and no commercially available treatment facilities exist except for liquid scintillation counting fluids used for laboratory analysis and testing. The EPA recognized that inadequate capacity exists and issued a national capacity variance until May 8, 1992, to allow for the development of such treatment capacity. The agency is considering extension of that variance for an additional year, and in the interim, will apply the mixed waste storage enforcement policy described below.

Lack of treatment and disposal capacity also presents implications for storage of these materials. Under 40 CFR 268.50, mixed wastes subject to LDRs may be stored for up to one year. Beyond one year, the owner/operator has the burden of proving such storage is for accumulating sufficient quantities for treatment. On August 29, 1991, EPA issued a mixed waste storage enforcement policy providing some relief from this provision for generators of small volumes of mixed wastes. However, the policy was limited to facilities generating less than 28 m^3 (1,000 ft^3) of land disposal-prohibited waste per year. Congress is considering amendments to RCRA postponing the storage prohibition for another five years; however, final action on these amendments has not occurred.

- **Clean Water Act (40 CFR 122).** Regulations adopted pursuant to the Clean Water Act (40 CFR 122) under the NPDES mandate use of best available treatment technologies (BAT) prior to discharging contaminants to surface waters. The NPDES requirements for use of BAT would not be ARARs for actions conducted only within the 200 East Groundwater Aggregate Area. However, these requirements could constitute potential ARARs for cleanup actions which would result in discharge of treated wastewaters to the Columbia River, and associated treatment systems could be required to utilize BAT.

- **Department of Transportation Standards (40 CFR 171 to 177).** The Department of Transportation standards contained in 40 CFR 171-177 specify the requirements for packaging, labeling, and placarding for offsite transport of hazardous materials. These standards ensure that hazardous substances and wastes are safely transported using adequate means of transport and with proper documentation.

- **Occupational Health and Safety Administration Standards (29 CFR 1910).** The Occupational Health and Safety Administration requirements contained in 29 CFR 1910 outline standards for provision of safe and healthful places of employment for workers. Section 1910.120 specifically addresses standards for workers engaged in hazardous waste operations and emergency response, and includes detailed standards on the procedures and equipment required.

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6.4.2 State of Washington Requirements

- **Hazardous Waste Management (WAC 173-303).** As discussed in Section 6.4.1, there are various requirements addressing the management of hazardous wastes that may be potential action-specific ARARs. Pertinent Washington regulations appear in Chapter 173-303 WAC (under the authority of RCW 70.105) and generally parallel federal management standards. Determination of potential ARARs will be on a case-by-case basis as cleanup actions proceed.

- **Solid Waste Management (WAC 173-304).** Washington State regulations describe management standards for solid waste in Chapter 173-304 WAC (under the authority of RCW 70.95). Some of these management standards may be potential ARARs for disposal of cleanup wastes within the 200 East Groundwater Aggregate Area. Solid waste standards include such requirements as the following:

  - Inspecting waste management areas to ensure proper performance and safe conditions

  - Management standards for incinerators and treatment units

  - Design and performance standards for landfills

  - Groundwater monitoring system design and performance.

  Many of these requirements will depend on the particular remediation activity undertaken, and will have to be identified as remediation proceeds.

- **Water Quality Management.** Chapter 90.48 RCW, the Washington State Water Pollution Control Act (WPCA), requires use of all known, available, and reasonable treatment technologies (AKART) for treating contaminants prior to discharge to waters of the state. Implementing regulations appear principally at Chapters 173-216, 173-220, and 173-240 WAC.

  The WPCA requirements for groundwater could be potential ARARs for actions conducted within the 200 East Groundwater Aggregate Area if such actions would result in discharge of liquid contaminants to the soil column, reinjection of withdrawn groundwater, or other actions that could introduce or return contaminants to the groundwater. In this event, Ecology would require use of AKART to treat the liquid discharges prior to soil disposal.

The WPCA requirements for surface water would not necessarily be potential ARARs for the 200 East Groundwater Aggregate Area. However, these requirements could constitute potential ARARs for cleanup actions which would result in discharge of treated wastewaters to the Columbia River and associated treatment systems could be required to demonstrate they meet AKART.

- **Air Quality Management (RCW 70.94).** Under the authority of the Washington Clean Air Act (RCW 70.94) the Toxic Air Pollutant regulations for new air emission sources, promulgated in Chapter 173-460 WAC, require use of best available control technology for air toxics (T-BACT). The Toxic Air Pollutant regulations may be potential ARARs for cleanup actions at the 200 East Groundwater Aggregate Area that could result in emissions of toxic contaminants to the air. Ecology may require the use of T-BACT to treat such air emissions.

- **Water Well Construction (RCW 18.104).** This regulation establishes authority for Ecology to require the licensing of water well contractors and operators and for the regulation of water well construction.

- **Nuclear Energy and Radiation (RCW 70.98).** Chapter 70.98 RCW establishes a program to establish procedures for assumption and performance of certain regulatory responsibilities with respect to byproduct, source, and special nuclear materials.

- **Pollution Disclosure Act (RCW 90.52).** Chapter 90.52 RCW describes the authority of the state to regulate reports for any commercial or industrial discharge, other than sanitary sewage, into waters of the state.

- **Water Resources Act (RCW 90.54).** Chapter 90.54 RCW gives the state authority to implement water related resources programs.

- **Minimum Standards for Construction and Maintenance of Wells (Chapter 173-160 WAC).** Well construction regulations establish minimum standards for water well construction and require the preparation of construction reports.

- **Rules and Regulations Governing the Licensing of Well Contractors and Operators (Chapter 173-162 WAC).** Chapter 173-162 WAC establishes requirements for licensing of well drillers.

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- **State Waste Discharge Permit Program (Chapter 173-216 WAC).** Chapters 173-216 WAC establishes a permit system for discharges of wastewater to groundwater and surface water via the municipal sewage system.

- **Underground Injection Control Program (Chapter 173-218 WAC).** Chapter 173-218 WAC pertains to the injection of wastes into aquifers that are used for drinking water.

- **Incinerators (Chapter 173-303-670 WAC).** If incinerators are used for a remedial technology this regulation would be applicable.

6.5 OTHER CRITERIA AND GUIDANCE TO BE CONSIDERED

In addition to the potential ARARs presented, other federal and state criteria, advisories, guidance, and similar materials are TBC in determining the appropriate degree of remediation for the 200 East Groundwater Aggregate Area. A myriad of resources may be potentially evaluated. The following represents an initial assessment of pertinent potential TBC provisions.

6.5.1 Health Advisories

The EPA Office of Drinking Water publishes advisories identifying contaminants for which health advisories have been issued.

6.5.2 International Commission of Radiation Protection/National Council on Radiation Protection

The International Commission of Radiation Protection and the National Council on Radiation Protection have a guidance standard of 100 mrem/yr whole body dose of gamma radiation. These organizations also issue recommendations on other areas of interest regarding radiation protection.

6.5.3 Environmental Protection Agency Proposed Corrective Actions for Solid Waste Management Units

In the July 27, 1990, Federal Register (55 FR 30798), EPA published proposed regulations for performing corrective actions (cleanup activities) at solid waste management units associated with RCRA facilities. The proposed 40 CFR Part 264 Subpart S includes

requirements that would be potential TBCs for determining an appropriate level of cleanup at the 200 East Groundwater Aggregate Area. In particular, EPA included an appendix, "Appendix A - Examples of Concentrations Meeting Criteria for Action Levels," which presented recommended contaminant concentrations warranting corrective action. These contaminant-specific TBCs for water are included in Table 6-1 for the preliminary contaminants of concern.

6.5.4 Department of Energy Standards for Radiation Protection

A number of DOE Orders exist which could be TBCs. The DOE Orders that establish potential contaminant-specific or action-specific standards for the remediation of radioactive wastes and materials are discussed below.

- **DOE Order 5400.5 - DOE Standards for Radiation Protection of the Public and Environment.** The DOE Order 5400.5 establishes the requirements for DOE facilities to protect the environment and human health from radiation including soil and air contamination. The purpose of the Order is to establish standards and requirements for operations of the DOE and DOE contractors with respect to protection of members of the public and the environment against undue risk from radiation.

  The Order mandates that the exposure to members of the public from a radiation source as a consequence of routine activities shall not exceed 100 mrem from all exposure sources due to routine DOE activities. In accordance with the Clean Air Act, exposures resulting from airborne emissions shall not exceed 10 mrem to the maximally exposed individual at the facility boundary. The DOE Order 5400.5 provides Derived Concentration Guide values for releases of radionuclides into the air or water. Derived Concentration Guide values are calculated so that, under conditions of continuous exposure, an individual would receive an effective dose equivalent of 100 mrem/yr. Because dispersion in air or water is not accounted for in the Derived Concentration Guide, actual exposures of maximally exposed individuals in unrestricted areas are considerably below the 100 mrem/yr level.

  The DOE Order 5400.5 also provides for establishment of soil cleanup levels through a site-specific pathway analysis such as the allowable residual contamination level method. The calculation of allowable residual contamination level values for radionuclides is dependent on the physical characteristics of the site, the radiation dose limit determined to be acceptable, and the scenarios of human exposure judged to be possible and to result in the upper-bound exposure.

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- **DOE Order 5820.2A - Radioactive Waste Management.** The DOE Order 5820.2A applies to all DOE contractors and subcontractors performing work that involves management of waste containing radioactivity. This Order requires that wastes be managed in a manner that assures protection of the health and safety of the public, operating personnel, and the environment. The DOE Order 5820.2A establishes requirements for management of high-level, transuranic (TRU), and low-level wastes as well as wastes containing naturally occurring or accelerator produced radioactive material, and for decommissioning of facilities. The requirements applicable to the 200 East Groundwater Aggregate Area remediation activities include those related to TRU waste and low-level radioactive waste. These are summarized below.

  - **Management of Transuranic Waste.** The TRU waste resulting from the 200 East Groundwater Aggregate Area remedial action must be managed to protect the public and worker health and safety, and the environment, and performed in compliance with applicable radiation protection standards and environmental regulations. Practical and cost-effective methods must be used to reduce the volume and toxicity of TRU waste.

    The TRU waste must be certified in compliance with the Waste Isolation Pilot Plant (WIPP) Acceptance Criteria, placed in interim storage, if required, and sent to the WIPP. Any TRU waste that the DOE has determined, with the concurrence of the EPA Administrator, does not need the degree of isolation provided by a geologic repository or TRU waste that cannot be certified or otherwise approved for acceptance at the WIPP must be disposed of by alternative methods. Alternative disposal methods must be approved by DOE Headquarters and comply with NEPA requirements and EPA/state regulations.

  - **Management of Low-Level Radioactive Waste.** The requirements for management of low-level radioactive waste presented in DOE Order 5820.2A are relevant to the remedial alternative of removal and disposal of 200 East Groundwater Aggregate Area wastes. Performance objectives for this option shall ensure that external exposure to the radioactive material released into surface water, groundwater, soil, plants, and animals does not result in an effective dose greater than 25 mrem/yr to the public. Releases to the environment shall be at levels as low as reasonably achievable. An inadvertent intruder after the institutional control period of 100 years is not to exceed 100 mrem/yr for continuous exposure or 500 mrem for a

single acute exposure. A performance assessment is to be prepared to demonstrate compliance with the above performance objectives.

Other requirements under DOE Order 5820.2A which may affect remediation of the 200 East Groundwater Aggregate Area include waste volume minimization, waste characterization, waste acceptance criteria, waste treatment, and shipment. The low-level radioactive waste may be stored by appropriate methods prior to disposal to achieve the performance objectives discussed above. Disposal site selection, closure/post-closure, and monitoring requirements are also discussed in this Order.

6.6 POINT OF APPLICABILITY

A significant factor in the evaluation of remedial alternatives for the 200 East Groundwater Aggregate Area will be the determination of the point at which compliance with identified ARARs must be achieved (i.e., the point of a specific ARAR's applicability). These points of applicability are the boundaries at which the effectiveness of a particular remedial alternative will be assessed.

For most individual radioactive species transported by either water or air, Ecology and Health standards generally require compliance at the boundaries of the Hanford Site (e.g., Clean Air Act, Section 6.2.1). 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. Although Health is responsible for monitoring and enforcing the air standards promulgated by Ecology, and generally recognizes the site boundary as the point of applicability, Ecology has recently indicated that compliance may be required at the point of emission.

The point at which compliance with identified ARARs must be achieved will be a significant factor in evaluating appropriate remedial alternatives in the 200 East Groundwater Aggregate Area. Applicability of ARARs at the point of discharge, at the boundary of the disposal unit, at the boundary of the AAMS, at the boundary of the Hanford Site, and/or at the point of maximum exposure will need to be determined.

6.7 POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS EVALUATION

Evaluation of ARARs is an iterative process that will be conducted at multiple points throughout the remedial process:

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- When the public health evaluation is conducted to assess risks at the 200 East Groundwater Aggregate Area, the potential contaminant-specific ARARs and the potential location-specific ARARs will be identified more comprehensively and used to help determine the cleanup goals

- During detailed analysis of alternatives, all the potential ARARs for each alternative will be examined to determine what is needed to comply with other laws and to be protective of public health and the environment.

Following completion of the investigation, the remedial alternative selected must be able to attain all ARARs unless one of the six statutory waivers provided in Section 121 (d)(4)(A) through (F) of CERCLA is invoked. Finally, during remedial design, the technical specifications of construction must ensure attainment of ARARs. The six reasons ARARs can be waived are as follows:

- The remedial action is an interim measure, where the final remedy will attain ARARs upon completion

- Compliance will result in greater risk to human health and the environment than will other options

- Compliance is technically impracticable

- An alternative remedial action will attain the equivalent performance of the ARAR

- For state ARARs, the state has not consistently applied (or demonstrated the intention to consistently apply) the requirements in similar circumstances

- For CERCLA-financed actions under Section 104, compliance with the ARAR will not provide a balance between the need for protecting public health, welfare, and the environment at the facility, and the need for fund money to respond to other sites (this waiver is not applicable at the Hanford Site).

Once investigations have been completed and final remedies have been selected, the ARARs that must be met will be formally identified in the Record of Decision (ROD). Compliance with those ARARs specified in the ROD will be achieved through the remedial action. The ARARs may need to be reevaluated if unanticipated circumstances are encountered during remediation which prevent the ability to satisfy the identified ARARs.

Table 6-1. Potential Contaminant-Specific ARARs and TBCs for Preliminary Inorganic Organic, and Radionuclides of Concern.

	SDWA		RCRA	RCRA	MTCA	RCRA	DOE Order 5400.5	DOE Order 5400.5
	Drinking Water Standards		TCLP Designation Limit	LDR Limits For Wastewaters	Groundwater Cleanup Levels	Proposed Corrective Action Levels	Ingested Water	4% Ingested Water[k]
	MCL in mg/L	SMCL in mg/L	in mg/L	CCW in mg/L	Method A µg/L	Water in mg/L	DCG pCi/L	DCG pCi/L
INORGANIC COMPOUNDS								
Aluminum	–	–	–	–	–	–	–	–
Antimony	0.006[a]	–	–	–	–	–	–	–
Arsenic	0.05	–	5	5	2	–	–	–
Barium	2[b]	–	100	100	–	1	–	–
Beryllium	0.004[a]	–	–	0.82	–	0.000008	–	–
Boron	–	–	–	–	–	–	–	–
Cadmium	0.005[a]	–	1	1	2	0.01	–	–
Calcium	–	–	–	–	–	–	–	–
Chromium	0.1	–	5	5	50	0.1[e]	–	–
Cobalt	–	–	–	–	–	–	–	–
Copper	TT[d]	1	–	1.3	1000	–	–	–
Cyanide	0.2[a]	0.3	–	1.9	–	0.7	–	–
Iron	–	–	–	–	–	–	–	–
Lead	0.05/TT[d]	–	5	5	5	0.05	–	–
Lithium	–	–	–	–	–	–	–	–
Magnesium	–	–	–	–	–	–	–	–
Manganese	–	0.05	–	–	–	–	–	–
Mercury	0.002	–	0.2	0.2	2	0.002	–	–
Nickel	0.1[a]	–	–	0.55	–	0.7	–	–
Potassium	–	–	–	–	–	–	–	–

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	Drinking Water Standards		TCLP Designation Limit	LDR Limits For Wastewaters	Groundwater Cleanup Levels	Proposed Corrective Action Levels	Ingested Water	4% Ingested Water[b]
	MCL in mg/L	SMCL in mg/L	in mg/L	CCW in mg/L	Method A µg/L	Water in mg/L	DCG pCi/L	DCG pCi/L
Selenium	0.05	–	1	1	–	–	–	–
Silicon	–	–	–	–	–	–	–	–
Silver	–	0.1	5	5	–	0.05	–	–
Sodium	–	–	–	–	–	–	–	–
Strontium	–	–	–	–	–	–	–	–
Thallium	0.002[a]	–	–	–	–	–	–	–
Titanium	–	–	–	–	–	–	–	–
Uranium	–	–	–	–	–	–	–	–
Vanadium	–	–	–	0.042	–	–	–	–
Zinc	–	5	–	1	5000	–	–	–
ORGANIC COMPOUNDS								
Chloroform	0.1 (THM)	–	6	0.046[a]	–	0.006	–	–
Carbon Tetrachloride	0.005	–	0.5	0.057[a]	–	0.0003	–	–
Methylene Chloride	0.005[a]	–	–	0.44	5	0.005	–	–
1,1-Dichloroethane	–	–	–	0.059[a]	–	–	–	–
1,2-Dichloroethane	0.005	–	0.5	0.21[a]	1	0.005	–	–
Cis-1,2-Dichloroethylene	0.07	–	–	–	–	–	–	–
Trans-1,2 Dichloroethylene	0.1	–	–	–	–	–	–	–
1,1,1-Trichloroethane	0.2	–	–	0.054[a]	200	3	–	–
1,1,2-Trichloroethane	0.005[a]	–	–	0.03	–	–	–	–

Table 6-1. Potential Contaminant-Specific ARARs and TBCs for Preliminary Inorganic Organic, and Radionuclides of Concern.

	SDWA		RCRA	RCRA	MTCA	RCRA	DOE Order 5400.5	DOE Order 5400.5
	Drinking Water Standards		TCLP Designation Limit	LDR Limits For Wastewaters	Groundwater Cleanup Levels	Proposed Corrective Action Levels	Ingested Water	4% Ingested Water[k]
	MCL in mg/L	SMCL in mg/L	in mg/L	CCW in mg/L	Method A µg/L	Water in mg/L	DCG pCi/L	DCG pCi/L
Trichloroethylene	0.005	–	0.5	0.54[e]	5	0.005	–	–
Tetrachloroethylene	0.005	–	0.4	0.56[e]	1	0.0007	–	–
Pyrene	–	–	–	–	–	–	–	–
Styrene	0.1	–	–	–	–	–	–	–
Toluene	1	–	–	0.08[e]	40	10	–	–
2,4-Dinitrotoluene	–	–	0.13	0.32[e]	–	–	–	–
Phenol	–	–	–	0.039	–	–	–	–
2,3,4,6-Tetrachlorophenol	–	–	–	–	–	–	–	–
2,4-Dichlorophenol	–	–	–	0.044[e]	–	0.1	–	–
2,4-Dimethylphenol	–	–	–	–	–	–	–	–
2,4-Dinitrophenol	–	–	–	0.12[e]	–	0.07	–	–
2-Chlorophenol	–	–	–	0.044[e]	–	0.2	–	–
o-Nitrophenol	–	–	–	–	–	–	–	–
Acetone	–	–	–	–	–	–	–	–
Methyl Ethyl Ketone	–	–	200	0.28	–	2	–	–
4-Methyl-2-Pentanone	–	–	–	–	–	–	–	–
Cyclohexanone	–	–	–	–	–	–	–	–
Aldrin	–	–	–	0.21[e]	–	–	–	–

Table 6-1. Potential Contaminant-Specific ARARs and TBCs for Preliminary Inorganic Organic, and Radionuclides of Concern.

	SDWA		RCRA	RCRA	MTCA	RCRA	DOE Order 5400.5	DOE Order 5400.5
	Drinking Water Standards		TCLP Designation Limit .	LDR Limits For Wastewaters	Groundwater Cleanup Levels	Proposed Corrective Action Levels	Ingested Water	4% Ingested Water[b]
	MCL in mg/L	SMCL in mg/L	in mg/L	CCW in mg/L	Method A µg/L	Water in mg/L	DCG pCi/L	DCG pCi/L
DDD	–	–	–	0.023	–	0.0001	–	–
DDT	–	–	–	0.0039[e]	0.12	0.0001	–	–
Dieldrin	–	–	–	0.017[e]	–	0.000002	–	–
Endrin	.0002/0.002[f]	–	0.02	0.0028[e]	–	0.0002	–	–
Endrin Aldehyde	–	–	–	–	–	–	–	–
Gamma-BHC	–	–	–	–	–	–	–	–
Heptachlor	0.0004	–	0.003	0.0012[e]	–	0.000008	–	–
Bis(2-ethylhexyl) phthalate	0.006	–	–	0.54[e]	–	–	–	–
Diethyl Ether	–	–	–	–	–	–	–	–
Dimethoate	–	–	–	–	–	0.7	–	–
Ethyl Cyanide	–	–	–	0.24[e]	–	–	–	–
Hydrazine	–	–	–	–	–	–	–	–
P-chloro-m-cresol	–	–	–	–	–	–	–	–
Phorate	–	–	–	–	–	–	–	–
Trichloromonofluoromethane	–	–	–	0.02[e]	–	–	–	–
Triethylene Glycol	–	–	–	–	–	–	–	–
CONVENTIONAL CONSTITUENTS								
Ammonium Ion	–	–	–	–	–	–	–	–
Bromide	–	–	–	–	–	–	–	–

Table 6-1. Potential Contaminant-Specific ARARs and TBCs for Preliminary Inorganic Organic, and Radionuclides of Concern.

	SDWA		RCRA	RCRA	MTCA	RCRA	DOE Order 5400.5	DOE Order 5400.5
	Drinking Water Standards		TCLP Designation Limit	LDR Limits For Wastewaters	Groundwater Cleanup Levels	Proposed Corrective Action Levels	Ingested Water	4% Ingested Water[k]
	MCL in mg/L	SMCL in mg/L	in mg/L	CCW in mg/L	Method A µg/L	Water in mg/L	DCG pCi/L	DCG pCi/L
Chloride	–	250	–	–	–	–	–	–
Fluoride	4	2	–	35	–	–	–	–
Nitrate (as N)	10	–	–	–	–	–	–	–
Nitrite (as N)	1[c]	–	–	–	–	–	–	–
Phosphate	–	–	–	–	–	–	–	–
Sulfate	–[h]	250	–	–	–	–	–	–
Total Dissolved Solids	–	500	–	–	–	–	–	–
Coliform Bacteria	–	–	–	–	–	–	–	–
RADIONUCLIDES								
Gross Alpha	15 pCi/L[j]	–	–	–	–		NS	NS
Gross Beta	4 mrem/yr[j]	–	–	–	–	–	NS	NS
Tritium	20,000 pCi/L[j]	–	–	–	–	–	2,000,000	80,000
Beryllium-7	–	–	–	–	–	–	1,000,000	40,000
Carbon-14	–	–	–	–	–	–	70,000	2,800
Potassium-40	–	–	–	–	–	–	7,000	280
Cobalt-60	–	–	–	–	–	–	5,000	200
Zinc-65	–	–	–	–	–	–	9,000	360
Strontium-90	8 pCi/L[j]	–	–	–	–	–	1,000	40
Zirconium/Niobium-95	–	–	–	–	–	–	40,000	1,600
Technetium-99	–	–	–	–	–	–	100,000	4,000

Table 6-1. Potential Contaminant-Specific ARARs and TBCs for Preliminary Inorganic Organic, and Radionuclides of Concern.

	SDWA		RCRA	RCRA	MTCA	RCRA	DOE Order 5400.5	DOE Order 5400.5
	Drinking Water Standards		TCLP Designation Limit	LDR Limits For Wastewaters	Groundwater Cleanup Levels	Proposed Corrective Action Levels	Ingested Water	4% Ingested Water[b]
	MCL in mg/L	SMCL in mg/L	in mg/L	CCW in mg/L	Method A µg/L	Water in mg/L	DCG pCi/L	DCG pCi/L
Ruthenium-106	–	–	–	–	–	–	6,000	240
Antimony-125	–	–	–	–	–	–	50,000	2,000
Iodine-129	–	–	–	–	–	–	500	20
Cesium-134	–	–	–	–	–	–	2,000	80
Cesium-137	–	–	–	–	–	–	3,000	120
Cerium/Praseodymium-144	–	–	–	–	–	–	7,000	280
Europium-154	–	–	–	–	–	–	20,000	800
Europium-155	–	–	–	–	–	–	100,000	4,000
Lead-212	–	–	–	–	–	–	3,000	120
Radium	5 pCi/L[a]	–	–	–	–	–	100	4
Uranium	–	–	–	–	–	–	NS	NS
Uranium-234	–	–	–	–	–	–	500	20
Uranium-235	–	–	–	–	–	–	600	24
Uranium-238	–	–	–	–	–	–	600	24

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	SDWA		RCRA	RCRA	MTCA	RCRA	DOE Order 5400.5	DOE Order 5400.5
	Drinking Water Standards		TCLP Designation Limit	LDR Limits For Wastewaters	Groundwater Cleanup Levels	Proposed Corrective Action Levels	Ingested Water	4% Ingested Water[k/]
	MCL in mg/L	SMCL in mg/L	in mg/L	CCW in mg/L	Method A µg/L	Water in mg/L	DCG pCi/L	DCG pCi/L
Plutonium-238	–	–	–	–	–	–	40	1.6
Plutonium-239/40	–	–	–	–	–	–	30	1.2
Americium-241	–	–	–	–	–	–	30	1.2

a/ = Effective Date January 17, 1994.
b/ = Effective Date - January 1, 1993, current MCL = 1.0 mg/L.
c/ = Effective Date - July 30, 1992.
d/ = Treatment technique requirement in effect. Effective Date - December 7, 1992.
e/ = Based on analysis of composite samples.
f/ = Revised MCL effective January 17, 1994.
g/ = Treatment standards based upon incineration in units operated in accordance with the technical requirements of 40 CFR Part 264 Subpart 0, or based upon combustion in fuel substitution units operating in accordance with applicable technical requirements.
h/ = Sulfate was proposed for an MCL of 400-500 mg/L, but this regulation has been deferred (57 FR 31776, July 17, 1992).
i/ = "Picocurie (pCi)" means the quantity of radioactive material producing 2.22 nuclear transformations per minute.
j/ = To use the DCGs for comparison with the DOE drinking water systems criterion of 4 mrem/yr, use the 4 percent DCG values for ingestion.
k/ = "Rem" means the unit of dose equivalent from ionizing radiation to the total body of any internal organ or organ system. A "millirem (mrem)" is 1/1000 of a rem.

Abbreviations:

CCW = Constituent Concentration in Waste
DCG = Derived Concentration Guide
DOE = Department of Energy
LDR = Land Disposal Restrictions
MCL = Maximum Contaminant Level
MTCA = Washington State Model Toxic Control Act
NS = Not Specified
RCRA = Federal Resource Conservation and Recovery Act
SDWA = Federal Safe Drinking Water Act
SMCL = Secondary Maximum Contaminant Level
TCLP = Toxicity Characteristics Leaching Procedure
THM = Trihalomethanes

Table 6-2. Potential Location-Specific ARARs.

Location	Requirement	Prerequisite	Citation	ARAR
GEOLOGICAL:				
Within 200 feet of a fault displaced in Holocene time.	New treatment, storage or disposal of hazardous waste prohibited.	Hazardous waste management near Holocene fault.	40 CFR 264.18; WAC 173-303-420	Not ARAR. No Holocene fault.
Holocene faults and subsidence areas.	New solid waste disposal facilities prohibited over faults with displacement in Holocene time, and in subsidence areas.	New solid waste management activities near Holocene fault.	WAC 173-304-130	Not ARAR. No Holocene fault.
Unstable slopes.	New solid waste disposal areas prohibited from hills with unstable slopes.	New solid waste disposal on an unstable slope.	WAC 173-304-130	Not ARAR. No unstable slope.
100-year floodplains.	Solid and hazardous waste disposal facilities must be designed, built, operated, and maintained to prevent washout.	Solid or hazardous waste disposal in a 100-year floodplain.	40 CFR 264.18; WAC 173-303-420; WAC 173-304-460	Potential ARAR.
	Avoid adverse effects, minimize potential harm, restore/preserve natural and beneficial values in floodplains.	Actions occurring in a floodplain.	40 CFR Part 6 Subpart A; 16 USC 661 et seq; 40 CFR 6.302	Potential ARAR.
Salt dome and salt bed formations, underground mines, and caves.	Placement of non-containerized or bulk liquid hazardous wastes is prohibited.	Hazardous waste placement in salt dome, salt bed, mine, or cave.	40 CFR 264.18	Not ARAR. None of these units.

Table 6-2. Potential Location-Specific ARARs.

Location	Requirement	Prerequisite	Citation	ARAR
SURFACE WATER:				
Wetlands.	New hazardous waste disposal facilities prohibited in wetlands (including within 200 feet of shoreline).	Hazardous waste disposal within 200 feet of surface water.	WAC 173-303-420	Potential ARAR.
	New solid waste disposal facilities prohibited within 200 feet of surface water (stream, lake, pond, river, salt water body).	Solid waste disposal within 200 feet of surface water.	WAC 173-304-130	Potential ARAR.
	New solid waste disposal facilities prohibited in wetlands (swamps, marshes, bogs, estuaries, and similar areas).	Solid waste disposal in a wetland (swamp, marsh, bog, estuary, etc.).	WAC 173-304-130	Not ARAR. No wetlands present.
	Discharge of dredged or fill materials into wetlands prohibited without a permit.	Discharges to wetlands and navigable waters.	40 CFR Part 230; 33 CFR Parts 303, and 320 to 330	Potential ARAR.
	Minimize potential harm, avoid adverse effects, preserve and enhance wetlands.	Construction or management of property in wetlands.	40 CFR Part 6 Appendix A	Not ARAR. No wetlands present.
Shorelines.	Actions prohibited within 200 feet of shorelines of statewide significance unless permitted.	Actions near shorelines.	Chapter 90.58 RCW; Chapter 173-14 WAC.	Potential ARAR.

Table 6-2. Potential Location-Specific ARARs.

Location	Requirement	Prerequisite	Citation	ARAR
Rivers and streams.	Avoid diversion, channeling or other actions that modify streams or rivers, or adversely affect fish or wildlife habitats and water resources.	Actions modifying a stream or river and affecting fish or wildlife.	40 CFR 6.302	Potential ARAR.
GROUNDWATER:				
Sole source aquifer.	New solid and hazardous waste land disposal facilities prohibited over a sole source aquifer.	Disposal over a sole source aquifer.	WAC 173-303-402; WAC 173-304-130	Not ARAR. No sole source aquifer.
Uppermost aquifer.	Bottom of lowest liner of new solid waste disposal facility must be at least 10 feet above seasonal high water in uppermost aquifer (5 feet if hydraulic gradient controls installed).	New solid waste disposal.	WAC 173-304-130	Not ARAR. Groundwater is deeper than 10 feet.
Aquifer Protection Areas.	Activities restricted within designated Aquifer Protection Areas.	Activities within an Aquifer Protection Area.	Chapter 36.36 RCW.	Not ARAR. Not an Aquifer Protection Area.
Groundwater Management Areas.	Activities restricted within Ground Water Management Areas.	Activities within a Groundwater Management Area.	Chapter 90.44 RCW; Chapter 173-100 WAC	Not ARAR. Not a Groundwater Management Area.

Table 6-2. Potential Location-Specific ARARs.

Location	Requirement	Prerequisite	Citation	ARAR
DRINKING WATER SUPPLY:				
Drinking water supply well.	New solid waste disposal areas prohibited within 1,000 feet upgradient, or 90 days travel time, of drinking water supply well.	New solid waste disposal within 1,000 feet of drinking water supply well.	WAC 173-304-130	Not ARAR. No drinking water supply wells.
Watershed.	New solid waste disposal areas prohibited within a watershed used by a public water supply system for municipal drinking water.	New solid waste disposal in a public watershed.	WAC 173-304-130	Not ARAR. Not a public watershed.
AIR:				
Non-attainment areas.	Restrictions on air emissions in areas designated as non-attainment areas under state and federal air quality programs.	Activities in a designated non-attainment area.	Chapter 70.94 RCW; Chapters 173-400 and 173-403 WAC.	Not ARAR. Not a non-attainment area.
SENSITIVE ENVIRONMENTS:				
Endangered/threatened species habitats.	New solid waste disposal prohibited from areas designated by US Fish and Wildlife Service as critical habitats for endangered/ threatened species.	New solid waste disposal in critical habitats.	WAC 173-304-130	Not ARAR. Not a critical habitat.
	Actions within critical habitats must conserve endangered/threatened species.	Activities where endangered or threatened species exist.	50 CFR Parts 200 and 402.	Potential ARAR.

Table 6-2. Potential Location-Specific ARARs.

Location	Requirement	Prerequisite	Citation	ARAR
Parks.	No new solid waste disposal areas within 1,000 feet of state or national park.	New solid waste disposal near state/national park.	WAC 173-304-130	Not ARAR. No state/national park.
	Restrictions on activities in areas that are designated state parks, or recreation/ conservation areas.	Activities in state parks or recreation/conservation areas.	Chapter 43.51 RCW; Chapter 352.32 WAC	Not ARAR. None of these state areas.
Wilderness areas.	Actions within designated wilderness areas must ensure area is preserved and not impaired.	Activities within designated wilderness areas.	16 USC 1131 et seq; 50 CFR 35.1 et seq	Not ARAR. Not a wilderness area.
Wildlife refuge.	Restrictions on actions in areas that are part of the National Wildlife Refuge System.	Activities within designated wildlife refuges.	16 USC 668dd et seq; 50 CFR Part 27	Not ARAR. Not a wildlife refuge.
Natural areas preserves.	Activities restricted in areas designated as having special habitat value (Natural Heritage Resources).	Activities within identified Natural Area Preserves.	Chapter 79.70 RCW; Chapter 332-650 WAC	Not ARAR. Not a Natural Area Preserve.
Wild, scenic, or recreational rivers.	Avoid actions that would have adverse effects on designated wild, scenic, or recreational rivers.	Activities near wild, scenic, and recreational rivers.	16 USC 1271 et seq; 40 CFR 6.302; Chapter 79.72 RCW	Potential ARAR.
Columbia River Gorge	Restrictions on activities that could affect resources in the Columbia River Gorge.	Activities within the Columbia River Gorge.	Chapter 43.97 RCW	Not ARAR. Not in Columbia River Gorge.

Table 6-2. Potential Location-Specific ARARs.

Location	Requirement	Prerequisite	Citation	ARAR
UNIQUE LANDS AND PROPERTIES:				
Natural resource conservation areas.	Restrictions on activities within designated Conservation Areas.	Activities within designated Conservation Areas.	Chapter 79.71 RCW	Not ARAR. Not a Conservation Area.
Forest lands.	Activities restricted within state forest lands to minimize fire hazards and other adverse impacts.	Activities within state forest lands.	Chapter 76.04 RCW; Chapter 332-24 WAC	Not ARAR. Not a forest land.
	Restrictions on activities in state and federal forest lands.	Activities within state and federal forest lands.	16 USC 1601; Chapter 76.09 RCW	Not ARAR. Not a forest land.
Public lands.	Activities on public lands are restricted, regulated, or proscribed.	Activities on state-owned lands	Chapter 79.01 RCW	Not ARAR. Not a state land.
Scenic vistas.	Restrictions on activities that can occur in designated scenic areas.	Activities in designated scenic vista areas.	Chapter 47.42 RCW	Not ARAR. Not a scenic area.
Historic areas.	Actions must be taken to preserve and recover significant artifacts, preserve historic and archaeologic properties and resources, and minimize harm to national landmarks.	Activities that could affect historic or archaeologic sites or artifacts.	16 UST 469, 470 et seq; 36 CFR Parts 65 and 800; Chapters 27.34, 27.53, and 27.58 RCW.	Not ARAR. No historic or archaeologic sites.

Table 6-2. Potential Location-Specific ARARs.

Location	Requirement	Prerequisite	Citation	ARAR
LAND USE:				
Neighboring properties.	No new solid waste disposal areas within 100 feet of the facility's property line.	New solid waste disposal within 100 feet of facility property line.	WAC 173-304-130	Not ARAR. Not near facility boundary.
	No new solid waste disposal areas within 250 feet of property line of residential zone properties.	New solid waste disposal within 250 feet of property line of residential property.	WAC 173-304-130	Not ARAR. No residential property near.
Proximity to airports.	Disposal of garbage that could attract birds prohibited within 10,000 feet (turbojet aircraft)/5,000 feet (piston-type aircraft) of airport runways.	Garbage disposal near airport.	WAC 173-304-130	Not ARAR. No airports near.

7.0 PRELIMINARY REMEDIAL ACTION TECHNOLOGIES

Previous sections identified contaminants of concern in the 200 East Groundwater Aggregate Area, potential routes of exposure, and potentially applicable or relevant and appropriate requirements (ARARs). Section 7.0 identifies preliminary remedial action objectives (RAOs) and develops preliminary remedial action alternatives consistent with reducing the potential hazards of this contamination and satisfying ARARs. The overall objective of this section is to identify viable and innovative remedial action alternatives for groundwater in the 200 East Groundwater Aggregate Area.

The process of identifying remedial action alternatives consists of several steps. In Section 7.1, RAOs are identified. Next, in Section 7.2, general response actions are identified along with general treatment, resource recovery, and containment technologies applicable to each general response action. Specific process options belonging to each technology are identified, and these process options are subsequently screened based on their effectiveness, implementability, and relative cost (Section 7.3). Process options are combined into alternatives in Section 7.4, which also includes descriptions and diagrams for the alternatives. Section 7.5 provides a brief discussion of the integration of innovative technologies into the process for selecting remedial action alternatives. Criteria are then identified in Section 7.6 for preliminary screening of alternatives that may be applicable to groundwater operable units identified in the 200 East Groundwater Aggregate Area. Figure 7-1 is a flowchart diagramming the development of the remedial action alternatives starting with media-specific RAOs.

Because of uncertainty regarding the nature and extent of contamination at the 200 East Groundwater Aggregate Area, recommendations for remedial alternatives are general and cover a broad range of actions. Remedial action alternatives will be considered and more fully developed in future focused feasibility studies. The *Hanford Site Past-Practice Strategy* (DOE/RL 1992a) is used to focus the range of remedial action alternatives that will be evaluated in future studies. The *Hanford Site Past-Practice Strategy* implements the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Remedial Investigations (RIs)/Feasibility Studies (FSs) and RCRA Facility Investigation (RFI)/Corrective Measures Studies (CMS) are components of this strategy and are implemented through a combination of interim remedial measures (IRMs), limited field investigations (LFIs) for final remedy selection where interim actions are not clearly justified, and focused or aggregate area feasibility/treatability studies for further evaluation of treatment alternatives. After completion of an IRM, data will be evaluated including concurrent characterization and data

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monitoring to determine if a final remedy can be selected directly, without additional characterization.

With respect to evaluating remedial alternatives for the 200 East Groundwater Aggregate Area, it should be noted that several of the groundwater contamination problems are similar to engineering problems that have been encountered in previous Hanford Site facility effluent wastewater treatment and disposal studies. In particular, treatment of extracted groundwater may be similar in concept to Hanford Site wastewater treatment projects (C-018H Facility, N-Reactor Effluent, Project L-045H 300 Area Treated Effluent Disposal Facility) conducted under the guidance for *Best Available Technology (BAT) Guidance Document for the Hanford Site* (WHC 1988b). The general response action of containment of contaminated groundwater was evaluated in *Engineering Evaluation of Containment Alternatives for N-Springs Releases* (WHC 1991b). In another example, the *Expedited Response Action Proposal for 200 West Area Carbon Tetrachloride Plume* (DOE/RL 1991a) describes a feasible approach for disposal of secondary wastes generated during the potential air stripping of groundwater. These documents are recognized as important tools to guide both this initial screening and future selection of remedial alternatives.

A secondary purpose of the evaluation of preliminary remedial action alternatives is to identify additional information needed to complete the evaluation. This information may include field data needs, review of literature, validation of existing data, focused feasibility studies, or treatability tests of selected technologies. Alternatives involving proven technologies, identified in Sections 7.3 and 7.4, typically require detailed data delineating site conditions, as well as bench-scale and pilot-scale treatability studies. Innovative technologies, discussed in Section 7.5, are expected to require additional literature searches, research and development, and other studies. Thus, another purpose of this evaluation is to identify the treatability studies required to fully evaluate proven technologies and to scope the research necessary to evaluate promising technologies. Additional data will be developed for most sites or waste groups during future data gathering activities (e.g., LFIs, ERAs, or treatability studies). Data needs are summarized in Section 8.0. New data will be used to refine and supplement the RAOs and the proposed alternatives identified in this initial study. Conclusions regarding the feasibility of some individual technologies may change after new data become available.

The bias-for-action philosophy of addressing contamination at the Hanford Site requires an expedited process for implementing remedial actions. Implementation of general response actions may be accomplished using an observational approach in which the implementation is redirected as information is obtained. This observational approach is an iterative process of data acquisition and refinement of the conceptual model. Data needs are determined by the model, and data collected to fulfill these needs are used as additional input to the model. Use of the observational approach while conducting response actions in the source aggregate

areas within the 200 East Area will allow integration of these actions with longer-range objectives of final remediation of similar areas and the entire 200 East Groundwater Aggregate Area. Site characterization and remediation data will be collected concurrently with the use of LFIs, ERAs, and treatability testing. The knowledge gained through these different activities will be applied to similar areas. The overall goal of this approach is convergence on an appropriate response action as early as possible while continuing to obtain valuable characterization information during remediation phases.

7.1 PRELIMINARY REMEDIAL ACTION OBJECTIVES

The RAOs are remediation goals for protection of human health and the environment that specify the contaminants and media of concern, exposure pathways, and allowable contaminant levels. The RAOs discussed in this section are considered to be preliminary and may change or be refined as new data are acquired and evaluated.

The fundamental objective of the corrective action process at the 200 East Groundwater Aggregate Area is to protect environmental resources and human receptors from the potential threats that may exist because of known or suspected contamination in the groundwater. Specific interim and final RAOs will depend in part on current and reasonable potential future groundwater use in the 200 East Groundwater Aggregate Area. The RAOs also take into account the preference under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for isolation and permanent or significant reduction of volume, toxicity or mobility of hazardous substances.

To focus the corrective actions with a bias for action through implementing IRMs and ERAs, preliminary RAOs based on current use are identified for the 200 East Groundwater Aggregate Area. The potential final RAO and interim action objective is as follows:

> Reduce the risk of harmful effects to the environment and human users of the area by isolating and permanently reducing the toxicity, mobility, or volume of contaminants from the source areas to meet ARARs or risk-based levels that will allow industrial use of the area. (This is a potential final RAO, and an intermaction objective based on current use of the 200 Area.

The RAOs are further developed in Table 7-1 for groundwater and applicable exposure pathways (see Sections 4.1 and 4.2) for the 200 East Groundwater Aggregate Area. The potential exposure pathways include the following:

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- Contaminated water supplies, the use of which could result in inhalation, ingestion, direct contact, and/or direct radiation exposure to humans

- Contaminated groundwater that could migrate to surface waters (i.e., the Columbia River, Yakima River, or West Lake) resulting in inhalation, ingestion, direct contact, and/or direct radiation exposure to humans

- Biota uptake of contaminated groundwater

- Release of groundwater contaminants to soil and vadose zone via vadose zone vapors and offgassing into the air pathway.

The two pathways of biota uptake and soils/vadose zone vapors as an exposure medium are not addressed in this 200 East Groundwater Aggregate Area Management Study Report (AAMSR), but are addressed in each of the four source 200 East Area AAMSRs.

Preliminary contaminant concentration standards that are to be applied to media-specific RAOs are developed from the preliminary identification of potential ARARs in Section 6.0 or by numerical assessment of the expected exposures and associated risks for each contaminant.

RAOs are likely to differ based upon the proposed remedial action. Short-term actions (defined as ERAs and IRMs in Section 9.0) may have different goals than actions which focus on long-term solutions (defined as the final remedy in Section 9.0). Short-term RAOs will likely focus primarily on risk reduction to meet a stopping point based on either a concentration threshold (which is a multiple higher than a final threshold) or on reaching an asymptote on the remediation production curve (the point of diminishing returns).

7.2 PRELIMINARY GENERAL RESPONSE ACTIONS

General response actions represent broad classes of remedial measures that may be appropriate to achieve both interim and final RAOs at the 200 East Groundwater Aggregate Area, and are presented in Table 7-2. The following are the general response actions for the 200 East Groundwater Aggregate Area followed by general discussions of applicability:

- No action

- Institutional controls

- Groundwater removal, treatment, and disposal

- Groundwater containment
- In situ groundwater treatment
- Point-of-use treatment
- Point-of-discharge treatment
- Combinations of the above actions.

7.2.1 No Action and Institutional Control

No action is included for evaluations as required by the National Environmental Policy Act (NEPA) and National Contingency Plan (NCP) [40 CFR 300.68 (f)(l)(v)] to provide a baseline for comparison with other response actions. The no action alternative may be appropriate for some facilities and sources of contamination if risk assessments determine that acceptable natural resource or human health risks are posed by those sources or facilities and that no exceedences of contaminant-specific ARARs occur.

The general response actions focus on permanently reducing the volume, mobility, and toxicity of the contaminants. Active remedial measures to achieve these goals will be supplemented by institutional controls in many cases. Institutional controls involve the use of above-ground physical barriers, plume monitoring, well closures, and a variety of groundwater use restrictions to reduce or eliminate public exposure to contaminated groundwater. Considering the nature of the 200 Areas as a whole, institutional controls will likely be an integral component of all interim remedial alternatives and will be combined with active groundwater treatment steps. Many groundwater use restrictions are currently in place at the Hanford Site and will remain in place during implementation of interim remedial measures. Long-term groundwater use at the 200 Areas will be restricted due to the institutional control measures necessary to support on-going waste disposal activities in the 200 Areas.

Application of institutional control and no action alternatives to 200 East Groundwater Aggregate Area cleanup will be affected by many other factors as well. For example, the substantial quantity of groundwater potentially requiring treatment and/or containment may make timely treatment actions prohibitively costly. Risk and groundwater migration studies may conclude that natural attenuation, accompanied by appropriate institutional controls combined with, for example, point-of-use treatment is preferred over the adverse consequences of large-scale source treatment alternatives. Such adverse consequences include increased risks to human health and the environment due to construction activities, disposal of secondary wastes, increased disruption of existing groundwater use, and potential generation of large quantities of radiation-contaminated

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remediation equipment requiring offsite burial. Evaluation of potential adverse effects will play a vital role in establishing the appropriateness of institutional control and no action alternatives.

7.2.2 Extraction and Treatment (Pump and Treat) Technologies

Groundwater removal and treatment or disposal, commonly known as "pump and treat," involves the extraction of contaminated groundwater and above-ground treatment. Once extracted and treated, it is anticipated that the groundwater would be reinjected into the ground or disposed of to land or surface waters. An example is the planned discharge to soil of 200 East Area liquid process wastes via the Liquid Effluent Retention Basin and proposed Treated Effluent Disposal Facility (Figure 2-2), as described in Section 2.7. Extraction, treatment, and reinjection options can be varied to achieve a variety of RAOs. For example, the large-scale extraction of groundwater, followed by treatment of contaminants and disposal of the groundwater to nonhydrogeologically related surface waters, treats the groundwater and hydraulically contains contaminated groundwater remaining in the aquifer. A second possible approach is small-scale extraction of isolated contamination plumes followed by removal of high risk contaminants and reinjection near the area of extraction, achieving a net reduction of risk without requiring offsite disposal of groundwater. Pump and treat actions can be used to achieve a wide variety of goals, but may not be needed, or may only be required on a small scale, to protect human health and the environment for the industrial uses of the 200 East Area.

Pump and treat technologies begin with groundwater extraction using techniques including extraction wells, drains, and trenches. Subsurface sediments at the 200 East Area consisting of mostly sand and gravel are well suited to efficient groundwater extraction using extraction wells. Before initiating pumping (especially large-scale pumping), a detailed understanding of the site's groundwater system including the presence of confined and unconfined aquifers, radius-of-influence, permeability, recharge rates, and preferential flow paths, is used to predict how pumping will alter system hydraulics to move and potentially mix contaminant plumes. Based on these site-specific conditions, a network of extraction wells is installed to effect the desired removal of groundwater.

Following extraction, treatment of extracted groundwater will vary in scope and complexity according to the variety of chemical constituents present in the groundwater and level of removal required by applicable ARARs and RAOs. Because 200 East Area groundwater contains a variety of chemical constituents, treatment of extracted groundwater may involve the use of a combination of biological, physical, or chemical technologies to achieve treatment goals. Typical options for treatment of extracted contaminants likely to be

present in 200 Areas groundwater include vapor extraction, UV oxidation, reverse osmosis, chemical precipitation, and ion exchange. For the unique radiochemical tritium, treatment options are limited because of tritiated water's near chemical identity to water.

It is expected that a treatment system for extracted groundwater will be designed in accordance with Hanford BAT guidance (WHC 1988b) to facilitate the beneficial transfer of prior experience with potentially applicable technologies acquired on other similar projects (such as C-018H Facility, N-Reactor Effluent, and 300 Area TEDF). Interaction with innovative technology development programs at the Hanford Site (see Section 7.5) may also play a viable role in design of the treatment process. Because of the wide variety of chemicals present (both introduced and natural) in 200 Areas groundwater, bench and possibly pilot treatability tests are likely to be required to obtain critical design and proof-of-principal information for applicable technologies. These tests will be critical to fully evaluate feasible approaches for groundwater treatment in the 200 East Area.

Once treated, the groundwater must be disposed of in accordance with applicable regulations. Disposal may include discharge to uncontaminated soils and water. Disposal may alternatively include reinjection of the treated groundwater into the contaminated source from which it came. In all cases, determination of applicable regulations and standards will be necessary.

A limitation of the groundwater pump-and-treat alternative is that its success may require years to decades of operation and treatment of voluminous quantities of water. Key factors in evaluating the time to completion are the site-specific mobility of chemicals detected in groundwater, soil characteristics, and hydrogeologic conditions. Chemicals such as some metals and radionuclides, which adsorb strongly to soil, are more difficult to extract by pumping groundwater. Site-specific mobility is a result of partitioning between dissolved and adsorbed phases of chemicals. The DNAPLs can adsorb to soils or be held in residual saturation forming long-term sources that may dissolve into groundwater for a long time. Silts and fine sands may adsorb many chemicals more readily and also have a low permeability, thereby increasing the time and effort required to remove contaminants. Hydrogeologic characteristics like fissures, lenses, confining layers, and preferential flow paths can divert groundwater and inhibit the uniform extraction of constituents from target zones.

In many cases, groundwater pump and treat programs have reported a significant decrease in contaminant concentrations after only a short operating period, particularly when the initial contaminant concentrations are relatively high. However, the reduction of chemical concentrations with time tends to follow an asymptotic function, with low concentrations of contaminants persisting over a very long time. Further operations result in the extraction of large volumes of water which must be treated to remove increasingly

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smaller amounts of contaminants. Thus, the efficiency of the pump and treat operation continues to decrease. Because the 200 East Groundwater Aggregate Area is characterized as containing large volumes of water with relatively low levels of many chemical and radionuclide contaminants, operations are not expected to achieve dramatic reductions initially, and the achievement of specified cleanup levels will likely require a lengthy operation during which the rate of contaminant reductions are expected to be low.

During the extended operating period, using the pump and treat system for plumes in the 200 East Area (estimated 300,000 to 20,000,000 m^3 for contaminant plumes identified in Section 4.1.1) would result in treating millions of gallons of water. If long-term success of the groundwater treatment is potentially questionable, secondary effects such as by-product wastes and economic considerations may overshadow the benefits of installing a pump and treat system.

Even with the limitations discussed, pump-and-treat technologies are considered the primary, proven technology available to remove and treat contaminants in groundwater. Detailed knowledge of the extractability of target chemicals, groundwater treatability RAOs applicable to discharges, and potentially adverse secondary effects are keys to understanding the applicability of pump-and-treat systems in 200 East Groundwater Aggregate Area remedial actions.

7.2.3 Containment Technologies

Groundwater containment includes the use of technologies to minimize, divert, or prevent the movement of contaminated groundwater. Containment technologies can be used to reach RAOs for groundwater remediation in a variety of ways. Containment can be implemented to stop groundwater flow and hence isolate contaminants. Alternatively, containment can be used to divert groundwater, increasing migration time before it reaches a receptor, and hence allow for increased natural attenuation. Typically, containment is achieved by installing either impermeable barriers (either vertical or horizontal) or by using dynamic hydraulic pumping and/or injection systems. Impermeable barriers (cutoff walls) can be constructed with metal, grouts, or soil freezing. Dynamic systems are based on the removal or injection of sufficient quantities of water to affect groundwater flow.

The 200 East Groundwater Aggregate Area consists of large volumes of groundwater located about 37 to 104 m (121 to 341 ft) below ground surface. In addition, potentially contaminated confined groundwater extends to depths of 170 m (558 ft). These depths will pose new challenges for the implementation of containment technologies. For example, cutoff walls are typically a moderate cost option. However, when installed at the depth required to contain the unconfined aquifer and especially the deeper confined aquifer, relative

costs may rise disproportionately compared to other alternatives. Monitoring the effectiveness of cutoff walls at these depths requires innovative solutions.

Similarly, dynamic hydraulic systems can often be straightforward and efficient to implement, but the operation of a containment system may be complicated in the 200 East Groundwater Aggregate Area because of the large volumes of water involved. Management options for the large volumes of extracted water will present technical treatment challenges and regulatory complications. Furthermore, pumping and/or injection may change overall groundwater flow directions and gradients, which requires that the changes be considered and monitored.

Containment technologies have proven effective in groundwater remediation. Because they are based on physical installation, they achieve the desired goal relatively quickly. They can be used to achieve isolation of groundwater, or partial hydrogeologic flow modification, and with proper evaluation, could be a valuable tool in designing remedial alternatives for the 200 East Groundwater Aggregate Area.

7.2.4 In Situ Groundwater Technologies

In situ groundwater technologies include chemical, physical, and biological treatments to remove, immobilize, or destroy groundwater contaminants in the subsurface. Examples of process options include chemical additions to pump and treat systems to assist flushing or precipitation of contaminants, oxygenating groundwater to enhance natural biological degradation, or sparging to strip chemical contaminants from groundwater.

In situ technologies may be low cost or may have minimal adverse effects, but their dependencies on geological conditions, site-specific chemical/biological background conditions, and time are not well known. Successful in situ treatment has been simulated in the laboratory and tested in the field for a few chemicals in a limited range of site-specific conditions. These studies have demonstrated the potential benefits of in situ treatment. However, they have also revealed that improved understanding of subsurface mixing, effects of existing background conditions, hazards associated with by-product production, and other failure/success modes is needed before in situ technologies can be recommended and implemented successfully.

The relatively high permeability of much of the saturated subsurface soil column in the 200 East Area fulfills a key prerequisite for successful in situ remediation. High permeability soils help overcome the poor mixing and reagent delivery which typically hamper in situ treatments. The effectiveness and implementability of in situ technologies to the range of chemicals and site conditions at the Hanford Site is currently the subject of

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research and development through innovative technology development programs. The role of in situ treatment technology in the 200 East Groundwater Aggregate Area will depend on the outcome of these programs.

7.2.5 Treatment at Point-of-Use and Point-of-Discharge Locations

Groundwater treatment at point-of-use and point-of-discharge locations is a variation of pump-and-treat technologies that attempt to mitigate groundwater problems by treating only the portion of groundwater directly associated with an exposure pathway. These technologies address the limitations of general pump and treat and containment technologies by treating only the groundwater extracted to which humans or environmental receptors may be exposed, rather than all contaminated groundwater regardless of its potential use or discharge. Point-of-use and point-of-discharge response actions are applicable to sites where use and discharge points of the groundwater are limited and can be effectively controlled. In the case of the 200 East Groundwater Aggregate Area, future use and discharge points will likely continue to consist of a few wells and discharge points along the Columbia River.

Several advantages are gained by this approach. First, only contaminants present in the groundwater at the point of use or discharge must be treated. By limiting treatment to those contaminants associated with actual exposure pathways, less treatment is necessary. Allowing groundwater to remain in the ground during its migration from the source to the receptor allows time for natural decay of radionuclides, natural precipitation and adsorption of inorganic metals, and natural biodegradation of organic chemicals before its discharge or use. The natural loss mechanisms potentially simplify treatment and minimize adverse impacts. A second advantage is that if natural attenuation is effective, the volume of water requiring treatment is significantly reduced, which improves the economics and efficiency of treatment. The third advantage is that remedial action alternatives can be customized for the known human or environmental exposure at each point of use or point of discharge. This allows flexibility in the goals of the treatment train design based on actual exposure.

Remedial actions that rely on treatment at the point of use or point of discharge have several potential limitations. These actions only address exposure pathways concerning human use, and may have to be combined with other remedial technologies to be acceptable. If natural attenuation is ineffective, allowing the groundwater to migrate to the point of discharge may result in an increase in the volume of groundwater which requires treatment. It may also be impractical to build the required treatment facilities at the point of discharge or point of use due to physical, legal, or political restrictions. For example, if the point of use is a relatively small private well, and the groundwater contains a recalcitrant chemical, it may be physically difficult to build a suitably small treatment unit. In another example, if

the point of discharge occurs in near a community, the regional politics may prevent the construction of a large-scale treatment plant to treat groundwater.

Like the other alternatives, remedial actions that rely on treatment at the point of use or point of discharge have specific advantages and limitations. Because of the size and complexity of the 200 East Groundwater Aggregate Area, point-of-use and point-of-discharge alternatives that take advantage of natural attenuation processes to reduce contaminant concentrations in situ may play a role in the final remedy.

7.2.6 Combinations of General Response Actions

The above broad classes of response actions may be combined into additional remedial alternatives. As discussed in the above sections, each general response action has particular advantages and disadvantages when applied to the site-specific conditions located at a 200 East Area location. No single action may be able to achieve all RAOs, but a combination of actions may be successful.

For example, containment actions which mitigate hazards resulting from groundwater movement, but are limited in implementability due to the large size of the 200 East Groundwater Aggregate Area and the great depth to groundwater, could be used in combination with pump-and-treat actions to effectively control a highly contaminated source area. In situ treatment may be combined with pump-and-treat actions to decrease the time required to achieve cleanup goals. Containment could be combined with in situ treatment to contain and reduce contamination. In all cases, institutional controls (i.e., fences and deed restrictions) may be a required component to prevent disruption of the containment system and reduce the risk to human health and the environment until other classes of response actions are effective.

In the next section, specific process options within each general response action are evaluated.

7.3 TECHNOLOGY SCREENING

In this section, potentially applicable technology types and process options for each general response action are identified. These process options are then screened using effectiveness, implementability, and relative cost as criteria to eliminate those process options that would not be feasible at the site. Consideration of innovative technologies is maintained throughout the screening process. When applicable, technologies that have high potential benefits, but failed screening due to lack of development, are retained as innovative

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technologies. The selected process options are then grouped into viable remedial alternatives in Section 7.4. A limited discussion of innovative technologies is presented in Section 7.5.

7.3.1 Screening Criteria

The effectiveness criterion focuses on: (1) the potential effectiveness of process options in handling the estimated areas or volume of groundwater and meeting the RAOs; (2) the potential impacts to human health and the environment during the construction and implementation phase; and (3) how proven and reliable the process is with respect to the contaminants and conditions at the site. This criterion also concentrates on the ability of a process option to treat a contaminant type (organic, inorganic, metals, radionuclides, etc.) rather than a specific contaminant (nitrate, cyanide, chromium, plutonium, etc.).

The implementability criterion places greater emphasis on the institutional aspects of implementability, such as the ability to obtain necessary permits for offsite actions; the availability of treatment, storage, and disposal services; and the availability of necessary equipment and skilled workers to implement the technology. This criterion also focuses on the process option's developmental status, whether it is an experimental or established technology.

The relative cost criterion is an estimate of the overall cost of a process, including capital and operating costs. At this stage in the process, the cost analysis is made on the basis of engineering judgment, and each process is evaluated as to whether costs are high, medium, or low relative to other process options.

A process option is rated effective if it can handle the amount of area or media required, if it does not adversely impact human health or the environment during the construction and implementation phases, and if it is a proven or reliable process with respect to the contaminants and conditions at the site. Also, a process option is considered more effective if it treats a wide range of contaminants rather than a specific contaminant.

An easily implemented process option is an established technology; uses readily available equipment and skilled workers; uses treatment, storage, and disposal services that are readily available; and has few regulatory constraints. Preference is given to technologies that are easily implemented. Preference is also given to lower cost options, but a process option is not eliminated based on cost alone.

7.3.2 Screening of Technologies

Technologies are identified, organized by general response actions, and presented in Table 7-2. Results of the screening process for each identified technology are then shown in Table 7-3. To help clarify the numerous variety of pump-and-treat groundwater technologies identified, a summary of retained groundwater technologies is presented in Table 7-4.

Results of the screening process are shown in Table 7-3. Brief descriptions of the process options are given, followed by comments regarding the three evaluation criteria defined in Section 7.3.1. The effectiveness and implementability criteria comments formed the primary basis for evaluating each option. Cost criteria comments are very general and did not play a primary role in evaluating options. The last column of the table indicates whether the process option is rejected, retained but recognized as an innovative technology, or carried forward for possible alternative formation. Each of the technologies presented in the table addresses RAOs for both surface water and groundwater exposure routes discussed previously in this groundwater.

The "conclusions" column of Table 7-3 indicates that in addition to no action and monitoring, 30 process options were retained as potentially applicable. Of these, nine classified as innovative (for separate discussion); the remaining 21 options were retained for further development of alternatives. These options are carried forward into the development of preliminary alternatives.

Table 7-4 summarizes the 22 technologies retained from the screening process for use as a quick reference. Footnotes are provided on the table to highlight specific aspects of each technology.

7.4 PRELIMINARY REMEDIAL ACTION ALTERNATIVES

This section develops and describes several remedial alternatives applicable to 200 East Groundwater Aggregate Area radionuclides and hazardous organic and inorganic contaminants of concern (Sections 4.0 and 5.0). These alternatives are not intended as recommended actions for any particular contaminant, but are intended only to provide potential options. Selection of the actual remedial alternatives would be partly based on future expedited or interim actions and limited field investigations, as recommended in Section 9.0 of this report. Selection of final alternatives would be conducted within the framework of the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a), and the strategy outlined in Section 9.4.

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The remedial alternatives are developed in Section 7.4.1. In Sections 7.4.2 through 7.4.7, the remedial action alternatives are described. Detailed evaluations and costs are not provided because site-specific conditions must be further investigated before meaningful technical and cost evaluations can be conducted.

7.4.1 Development of Remedial Alternatives

Potentially feasible remedial technologies were described and screened in Section 7.3. Some of those technologies were found to be proven, effective, and constructible, while other technologies are in the development or "innovative" stages. EPA guidance on feasibility studies (EPA 1989a) for uncontrolled waste management units recommends that a limited number of candidate technologies be grouped into "Remedial Alternatives." For this study, technologies were combined to develop remedial alternatives and provide at least one alternative for each of the general response actions previously discussed:

- No action
- Institutional controls
- Groundwater removal, above-ground treatment, and disposal (i.e., pump and treat)
- Containment of groundwater
- In situ treatment of groundwater
- Point-of-use treatment
- Point-of-discharge treatment
- Combination of the above actions.

The alternatives are intended to treat all or the highest risk portion of contaminants of the 200 East Groundwater Aggregate Area groundwater plumes. Consistent with the development of RAOs and technologies, alternatives were initially developed based on treating classes of compounds (radionuclides, heavy metals, inorganic, and organic) rather than specific contaminants. At a minimum, the alternative must be a complete package. For example, extraction of groundwater followed by treatment must be combined with either reinjection or disposal of the groundwater and treatment of secondary wastes.

Both no action and institutional control alternatives are evaluated as required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) RI/FS guidance. The purpose of including these alternatives is to provide decision-makers with information on the entire range of available remedial actions. For the containment alternative, engineered frozen barriers and slurry walls are presented. Two alternatives are presented for pump and treat strategies. One alternative proposes large-scale extraction of groundwater followed by comprehensive treatment and disposal. The second alternative addresses limited-scale groundwater extraction followed by treatment for high-priority compounds. Finally, one example of point-of-use and one example of point-of-discharge options are presented. In situ technologies are addressed in the innovative technologies sections.

This evaluation does not include an exhaustive list of all possible combination of process options. However, the alternatives presented provide a reasonable range of remedial actions that are likely to be evaluated in future feasibility studies. The remedial alternatives presented in this report are summarized as follows:

- No action
- Institutional controls
- Containment barriers engineered from freeze or grout technologies
- Extraction of groundwater, comprehensive treatment, and disposal
- Limited extraction of groundwater, treatment of high priority compounds, and reinjection in zone of extraction
- Treatment at point of use
- Treatment at point of discharge, followed by reinjection.

These alternatives, with the exception of no action and institutional controls, were created to satisfy a number of RAOs simultaneously and use technologies that are appropriate for a wide range of contaminant types. For example, installation of a comprehensive pump-and-treat system can effectively treat radionuclides, heavy metals, inorganic compounds, and organic compounds and provide a measure of hydraulic containment simultaneously. It satisfies the RAO of protecting human health and the environment from exposures to contaminated groundwater as well as reducing migration of contaminated groundwater to the Columbia River.

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It is likely that groundwater will require a combination of treatment technologies to completely address all contaminants. Air stripping is highly effective for removing volatile organics present in groundwater, but has little effect on metals. Ion exchange is highly effective on most metals but is typically ineffective in treating volatile organics. Tritium, because of its near chemical identity to water, can currently only be treated by natural attenuation. Because groundwater is likely to contain multiple classes of chemicals, and because it is likely that extraction well drawdown will enhance the mixing of contaminants from operable units, final alternatives will probably require a combination of treatment technologies.

The use of contaminant-specific remedial technologies was avoided because there appear to be few, if any, groundwater plumes where a single contaminant appears alone. It is possible to construct alternatives that include several contaminant-specific technologies, but the number of combinations of technologies required to address the contaminant mixtures would result in an unmanageable number of alternatives. Moreover, the possible presence of unidentified contaminants may render specific alternatives unusable. Alternatives can be refined as more contamination data are acquired. For now, the alternatives will be directed at remediating the major classes of compounds (radionuclides, heavy metals, inorganics, and organics).

In all action alternatives it is assumed that monitoring and institutional controls are required, although they may be temporary. These features are not explicitly mentioned, and details on monitoring programs and institutional controls are purposely omitted until a more detailed evaluation is performed in subsequent studies.

In the next sections, the preliminary remedial action alternatives (exclusive of the no action and institutional controls alternatives) are described in more detail.

7.4.2 Alternative 1--Engineered Vertical Barriers

Alternative 1 consists of containment of contaminated groundwater. Screening of potential containment technologies indicated that containment of groundwater at the depth occurring at 200 East Groundwater Aggregate Area can be achieved by two methods--subsurface freezing and grouting. Figure 7-2 shows schematic examples of these technologies. Both barriers achieve the same goal, but have unique cost and implementability factors. Installation of either type of barrier to the depth of groundwater present at the site (over 200 ft) will challenge existing applications of these techniques. The feasibility of these two technologies for unconfined aquifers at depth was previously evaluated in the *Engineering Evaluation of Containment Alternatives for N-Springs Releases* (WHC 1991b). Although not directly analogous to the 200 East Groundwater Aggregate Area, the analyses presented in the report suggest that physical barriers may be successfully

installed at great depths. However, the use of this technology may be especially challenging for confined aquifers.

Subsurface freezing and grouting could be designed to achieve a variety of goals within the 200 East Area such as:

- Mitigate/delay flow of contaminated groundwater to the Columbia River
- Segregate operable units for treatment
- Block natural recharge pathways which accentuate mobility of contaminated groundwater.

Because of the large size of the 200 East Groundwater Aggregate Area, and the fact that no contaminant destruction occurs, engineered vertical barriers are not likely to be used as a single permanent solution, but will likely be included as a key component in a combined technology solution. Detailed evaluation of site hydrogeology, costs, feasibility, and adverse consequences is required to determine the best use of containment alternatives in remediation of 200 East Groundwater Aggregate Area groundwater.

7.4.3 Alternative 2--Groundwater Extraction, Comprehensive Treatment, and Disposal

Alternative 2, a pump-and-treat option, consists of extraction of groundwater, comprehensive treatment, and disposal. In this alternative, groundwater contaminated with one or more chemicals is treated using multiple treatment technologies to meet long-term RAOs established for the site. The treated groundwater is discharged to surface water, groundwater, or soil column. Additionally, extraction of groundwater followed by offsite discharge is assumed to result in a reversal of the groundwater flow gradient, resulting in hydraulic containment of the contaminant plume.

Figure 7-3 shows a schematic diagram of this alternative. Extraction wells would be installed and operated near the center of contamination within identified contaminant plumes. Pump tests on existing wells, aquifer characterization, analysis of sorption, and exchange properties of contaminants detected in groundwater and adsorbed in soils would be used to predict the spacing for new extraction wells, pumping rates, and operating time necessary to effect the desired hydraulic containment and treatment.

A multi-technology wastewater treatment train would be employed to treat the groundwater to meet discharge limits. Depending on the contaminants located in the target plume, the treatment train would consist of one or more of treatment technologies such as

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chemical precipitation, filtration, coagulation, reverse osmosis, vapor extraction, ultraviolet (UV) oxidation, and/or ion exchange. Table 7-4 provides a preliminary screening of treatment technologies applicable to the chemicals detected in the 200 East Area groundwater. Technologies would be selected and combined in accordance with Hanford BAT guidance to create a reliable, effective, comprehensive treatment train. All secondary waste generated by the comprehensive treatment train would have to be disposed of or treated accordingly. Detailed understanding of the variability in groundwater to be extracted, potential new chemicals introduced during future plume mixing caused by groundwater extraction, as well as effects of site-specific background chemicals (such as iron) would be required to design an effective treatment system. Some chemicals, such as tritium, have no known treatment, and therefore could not be addressed by this alternative. For other chemicals, the known removal technology might not be able to achieve cleanup standards determined by potential ARARs and RAOs without additional research and development.

An appropriately permitted discharge site likely to be similar to the SALDS proposed for the C-018H and -049H effluents would be required to dispose of the groundwater. This site would be evaluated to ensure that hydrogeologic effects of the discharge on existing groundwater would be negligible. Discharge water could be potentially beneficial by providing an introduced gradient that enhances the containment of existing contaminated groundwater.

Alternative 2 would provide a combination of complete treatment of all contaminants and mitigation of groundwater movement, thus successfully addressing the most stringent RAOs. However, the alternative is limited by the inability of pump-and-treat systems to quickly achieve cleanup goals and potentially require treatment of excessive quantities of water. A detailed feasibility study is needed to evaluate the performance, costs, and potential adverse effects associated with this alternative. Other recognized limitations of the pump-and-treat system should be evaluated in the feasibility study, such as remediation of plumes where chemicals have adsorbed to soils, or where DNAPLs or zones of low hydraulic conductivity are present.

7.4.4 Alternative 3--Limited Extraction of Groundwater, Treatment of High Priority Compounds, and Reinjection in Zone of Extraction

Under Alternative 3, groundwater would be extracted from a contaminant plume, and partially treated to remove the compounds which represent the highest risk to human health. After treatment, the groundwater would be reinjected to the same groundwater regime for management by other technologies (such as containment or institutional controls). The treatment technology selected would depend on the contaminants identified as posing the highest risk in the operable unit. The reinjected groundwater could be used to hydraulically

contain and enhance the removal of the target high-risk contaminants. Discharge of the treated groundwater to surface water, as in Alternative 2, would not be possible due to the presence of trace nontarget chemicals.

The partial treatment of groundwater described in this alternative (rather than the comprehensive treatment described in Alternative 2) may be appropriate because plume definition and technology screening indicate that groundwater contains a sufficient variety of chemicals to potentially mandate the use of multiple, linked, treatment technologies (see Table 7-4). This multiplicity could lead to the delay, or possible prevention, of the implementation of both short-term and long-term remedies. For example, the treatability programs required to effectively link several technologies may be long when compared to the treatability program required for the single technology that addresses the highest risk chemical. It also may be found that the groundwater contains isolated chemical(s) for which treatment is not available in the near future (such as tritium). To allow the timely implementation of existing, effective technologies, partial treatment of extracted groundwater may be recognized as a viable option.

A key issue raised by Alternative 3 is the feasibility and/or regulatory acceptability of reinjecting groundwater that still contains untreated or partially treated chemical groups. Although the groundwater is being reinjected into the area from which it originated, thereby reducing the risk and improving local groundwater quality, long-term ARARs or RAOs for groundwater quality may not be met. As a result, Alternative 3 may require that location-specific reinjection standards be developed recognizing that the reinjected contaminants will be managed by alternative methods.

For example, Figure 7-4 shows a schematic of this alternative applied to removing volatile organics from groundwater that also contains chemicals such as tritium for which treatment is not effective. Technology screening indicates that air stripping is an effective technology for removing volatile organics identified in the 200 East Groundwater Aggregate Area, including the chlorinated solvent chemicals (trichloroethylene, trichlorethane, tetrachloroethylene, etc.) found near the central landfill. Extraction wells and reinjection wells are placed to effect the desired groundwater removal and containment. An appropriately sized air stripping unit, with off-gas treatment potentially based on experience being gained in the *Expedited Response Action Proposal for the 200 West Area Carbon Tetrachloride Plume* (DOE/RL 1991a), would be installed. Its design would consider potential side effects associated with the contaminant plume. Quantities of tritium and ^{129}I, both of which have significant vapor pressures, would be evaluated to determine if they would co-strip with the volatile organics. Iron and other metals, occurring naturally, would be evaluated to determine pretreatment required to avoid fouling the stripping unit. Other recognized limitations of the pump and treat systems, such as adsorption of chemicals to soils

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or the presence of DNAPLs, should be evaluated to determine the ability of Alternative 3 to effectively remove the target volatile organic chemicals.

In another example, Figure 7-5 shows a schematic of this alternative as applied to groundwater which has a variety of inorganic metals, as well as trace organic chemicals for which natural biodegradation has been determined to be effective. Technology screening indicates that chemical precipitation is an effective technology to remove many inorganic metals identified in the 200 East Groundwater Aggregate Area *(Project L-045H 300 Area TEDF,* WHC 1991c). As in the previous example, extraction and reinjection wells are designed and installed to effect the desired extraction, hydraulically contain the contaminant plume, and potentially assist in the removal of metal ions remaining in the groundwater. The side effects of all trace, nontarget chemicals on chemical precipitation would be evaluated before implementing the system. All secondary waste would be evaluated and disposed of properly. Once treated the groundwater would be returned to the plume where the trace organics would biodegrade at their natural rate.

Similar systems could be devised for other technologies such as ion exchange, reverse osmosis, UV oxidation, and other process options identified in Table 7-4. Several technologies could be combined if required. It is important to recognize that the selectivity of available technologies is likely to be limited to chemical groups rather than specific chemicals; however, some chemical-specific technologies may be identified in future work. As with the previous two examples, bench-scale testing should be performed to ensure compatibility with other trace, nontarget chemicals contained in groundwater plumes being treated. For each class of chemical contaminant, treatability studies with extracted groundwater should be conducted to evaluate potential interference reactions and pretreatment requirements. Secondary wastes must also be evaluated and secondary treatment tested. The recognized limitations of pump and treat systems, such as the potentially long time to completion and the cost and secondary waste production associated with long-term operation of treatment facilities may limit the net effectiveness of Alternative 3.

Identification of target high priority classes of chemicals that would warrant use of this alternative should be based on evaluation of plume maps, risk analysis, the selectivity of available treatment technologies, and application of ARARs and RAOs.

7.4.5 Alternative 4--Treatment of Groundwater at the Point of Use

This alternative proposes remediation of only the portion of groundwater that actually will be used. Because of the depth of the groundwater on the site and the lack of natural surface connections such as springs or seeps, present or future points of use would likely be defined by the presence of a water supply well.

Figure 7-6 shows a schematic of this alternative. Depending on the location of the point of use, a different range of contaminants would be present. Low mobility contaminants would not migrate far from their source, whereas high mobility contaminants could affect wells located downgradient. As the groundwater travels from sources to the point of use, natural attenuation through decay of radionuclides, precipitation and adsorption of metals, and possible biodegradation of organic compounds can reduce contaminant levels. Point-of-use treatment has the significant advantage of focusing on only those contaminants that pose risks to receptors.

During installation of a water supply well at the point of use, a treatment train would be installed. The treatment train would be designed in accordance with Hanford BAT to meet the required water quality standards for consumer use. Because natural attenuation can reduce the number and concentration of contaminants at the point of use, the treatment train design may be a simplified version of those proposed in source-related alternatives (Alternatives 2 and 3). The treatment train would be properly maintained to ensure sufficient quality and quantity of water for the duration of end-user needs.

The point-of-use remedial alternative has two important disadvantages. First, point-of-use treatment will only address the potential routes of groundwater exposure to humans. Alone, it is not likely to achieve RAOs. Many regulatory programs reflected in the RAOs require protection of the environment and other factors in addition to protection of human consumption. Point of use may not effectively address these other regulatory concerns. Second, point-of-use treatment requires that a water treatment system be constructed relatively near the point of use. Depending on the chemical composition of groundwater at the point of use, the water quality required, and the volume of water being treated, construction of a treatment system adjacent to the point of use may not be practical. Point-of-use treatment may be a viable alternative for certain limited operable units, but prior to its use, chemical characteristics and potential volumes need to be thoroughly evaluated.

7.4.6 Alternative 5—Treatment of Groundwater at Point of Discharge

Alternative 5 proposes treatment of only the portion of groundwater that is discharged. Because of the hydrogeology at the 200 East Groundwater Aggregate Area, points of discharge are expected to include the Columbia River, West Lake, or the Yakima River. As with the point-of-use alternative, the chemical composition of groundwater at the point of discharge will be substantially different than the chemical composition of groundwater near the source. Various mechanisms associated with natural decay of radionuclides, precipitation and adsorption of metals, and biological decay of organics will alter the composition of groundwater as it travels from the source to the point of discharge. Point-of-discharge treatment has the significant advantage of focusing on only those contaminants that pose a

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significant risk to receptors. In addition, because point of discharge exploits natural attenuation, it may be the only viable alternative for tritium.

The treatment of groundwater recovered at the point of discharge would be designed in accordance with Hanford BAT to meet the standards required to protect the discharge receptor. As discussed in Section 7.4.5, the treatment train at the point of discharge may be a modified version of the treatment train proposed in the other source-related treatment alternatives (Alternatives 2 and 3). Figure 7-7 depicts an example of this alternative.

The point-of-discharge remedial alternative has a number of disadvantages. First, point-of-discharge treatment focuses on protecting the discharge receptors' water quality standards (such as the Columbia River surface water quality) and therefore is not likely to be acceptable alone in achieving site-wide RAOs. Many regulatory programs reflected in the RAOs require protection of the environment and other factors in addition to protection of discharge receptors. Point of discharge may not effectively address these other regulatory concerns. Second, if natural attenuation is insufficient in reducing contaminant levels, contamination may be diluted and spread over a considerable length of the Columbia River, factors that may make extraction and treatment more difficult and costly.

If available treatment technologies are unable to treat groundwater at the point of discharge to meet standards for the discharge receptor, it may be possible to discharge treated groundwater to an alternative location. Once reinjected, the groundwater would begin a second migration towards the point of discharge. This second migration would increase the time allowed for natural attenuation. For chemicals such as tritium, whose only known treatment is natural attenuation, this second migration may enable groundwater to meet treatment standards established at the point of discharge.

7.5 INNOVATIVE TECHNOLOGIES

All remedial alternatives presented in the previous section were composed of proven process options that passed the required screening criteria for effectiveness, implementability, and cost. Some technologies that did not meet these criteria were retained and identified as innovative technologies. Innovative technologies recognized to potentially play a key role in 200 East Groundwater Aggregate Area remediation are discussed in this section. Technology screening in Section 7.4 identified three types of innovative technologies applicable to groundwater.

First, in situ treatments may be especially suited for treatment of groundwater contamination in the 200 Areas. In situ treatments use the soil/groundwater matrix as a treatment bed and are facilitated by the potential for good mixing offered by the high

permeability of the 200 Areas soils. Because in situ treatment conducts the treatment in soil/groundwater matrix, secondary waste generation can be minimized, adverse affects are diminished, and treatment costs are potentially reduced. In addition, for groundwater which cannot be successfully remediated by conventional technologies, in situ treatment may be the only viable solution. For example, low mobility compounds such as plutonium are not amenable to remediation through pump and treat technologies, since extraction of groundwater cannot completely remove the plutonium. In situ precipitation of the plutonium could render the plutonium essentially immobile. Alternatively, in situ solubilization could increase plutonium's mobility to allow pump and treat to effectively remove the plutonium in an acceptable time frame. Of course, increasing the mobility of toxic chemicals in groundwater would be performed only after evaluating the potential benefits and adverse effects.

In another example of in situ technologies, air sparging may effectively remove volatile organics from groundwater. Sparging air is pumped into an injection well and released into groundwater. As the air expands and rises through the groundwater, small bubbles extract and transport volatile chemicals upward to the soil in the vadose zone. Once the bubbles reach the vadose zone, vacuum extraction wells would remove the air. The air would then be treated and either discharged or recycled for additional reinjection/extraction cycles. Air sparging can also be used to enhance natural degradation by adding oxygen, or if steam is used for sparging, by adding heat and increasing the speed of naturally occurring biodegradation.

A second area of innovative technologies to be explored is in wastewater treatment. Currently, each chemical class in the wide range of chemicals found in Hanford Site groundwater (organics, radionuclides, and metals) requires unique treatment technologies. These technologies must be linked to provide a successful comprehensive treatment. Additionally, although many of these technologies are effective in producing an effluent that meets cleanup standards, many produce large volumes of secondary waste. Innovative technologies such as supercritical extraction, oxidation, freeze crystallization, and membrane separation may be able to treat broader classes of compounds while providing low cost, effective secondary waste treatment. An example of this is that membrane fouling problems have traditionally prevented reverse osmosis' use for wastewater treatment including organic and inorganic classes of chemical compounds. However, if new anti-fouling, multi-chemical class membranes can be identified, membrane separation has the potential to treat the full range of chemicals in 200 Areas groundwater, simplifying the current multi-technology treatment trains that are required.

In another example of innovative wastewater treatments, freeze technologies may provide an energy efficient way to concentrate secondary waste generated from membrane technologies or ion exchange. These secondary wastes comprise up to 10% of influents

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entering these processes and can be a major impediment to their implementation. Freeze technologies can potentially concentrate the volumes of these secondary wastes, replacing the traditional method of evaporation, at a potential cost savings with fewer adverse effects.

The third area of innovative technologies which would warrant development is the installation of horizontal barriers at the depths of groundwater encountered in the 200 Areas. Because vertical flows of contaminants may further degrade groundwater quality, barriers that prevent vertical flows may be desired. However, large-scale installation of deep horizontal barriers is a developmental procedure, so technologies in grouting and freezing need to be evaluated to determine if blockage of vertical flows is possible. Application of these technologies would likely include right angle drilling and/or sophisticated grouting techniques which have not been proven for remediation applications.

A final area of innovative technology concerns the treatment of tritium. Because the structures of are tritated water and nontritated water nearly identical, no removal treatments that achieve levels lower than those present in groundwater are known. Soil columns and retention systems that retain tritium for sufficient periods to allow natural decay may be effective implementable options which need only to be proven through testing.

To encourage research and development of innovative technologies, the AAMS program personnel interface regularly with the DOE Office of Technology Development.

7.6 PRELIMINARY REMEDIAL ACTION ALTERNATIVES APPLICABLE TO GROUNDWATER OPERABLE UNITS

The purpose of this section is to discuss how preliminary remedial action alternatives could be used to remediate specific situations identified in 200 East Groundwater Aggregate Area operable units. The decision criteria are as follows:

- **Alternative 1--Physical Containment.** Alternative 1 could be used on any chemical contaminant plume where restriction of groundwater flow is required to stop migration or to support the effectiveness of another alternative.

- **Alternative 2--Groundwater Extraction, Treatment with a Comprehensive System, and Disposal.** Alternative 2 could be used on any plume where all the contaminants identified could be extracted and treated with known technologies. The plume would have to be sufficiently large to justify the substantial cost associated with comprehensive treatment.

- **Alternative 3--Groundwater Extraction with Treatment to Remove a Single Chemical Class, and Reinjection.** Alternative 3 could be used on any operable unit for which a single class of contaminants poses significantly more risk than other classes and is amendable to pump and treat technologies. It can also be used on a plume that contains isolated chemical(s) for which pump and treat is not effective, but is required for treating the remaining chemicals. The more disproportionate the risk or treatment practicality between chemical groups in a contaminant plume, the more advantageous is Alternative 3. However, the technology required to remove the target chemical group must be carefully evaluated for nontarget chemicals which could interfere with treatment or trigger regulatory reinjection hurdles. Additionally, this evaluation should determine if it is economically efficient to remove the target group selectively, rather than with the comprehensive treatment proposed in Alternative 2.

- **Alternative 4--Treatment at Point of Use.** Alternative 4 could be used for a contaminant plume where the RAOs can be focused on the groundwater ingestion exposure pathways alone. Because one of the primary benefits of point-of-use treatment is the natural attenuation time, contaminant plumes that benefit from natural attenuation are more appropriate candidates for Alternative 4.

- **Alternative 5--Treatment at Point of Discharge.** Alternative 5 could be used for contaminant plumes where the RAOs can be focused on exposure pathways associated with surface water alone. Since one of the primary benefits of point-of-discharge treatment is the large natural attenuation time allowed, contaminant plumes with chemicals such as tritium that will benefit from natural attenuation are candidates for Alternative 5.

Using these criteria, Table 7-5 was created showing possible preliminary action alternatives that could be used to remediate each of the contaminant plumes identified in Section 4.1. These criteria are not meant to be exclusive. The criteria and preliminary remedial alternatives are presented as an initial screening only. Operable units which may contain one or more contaminant plumes, may use one or several of these alternatives to achieve applicable RAOs. Also, more specific waste treatment alternatives could be identified and evaluated as more information concerning innovative technologies is acquired. Since the primary mechanism for groundwater treatment involves various forms of pump and treat, many alternatives overlap.

As mentioned previously, the selection of the treatment technologies for Alternatives 2 through 5, which involve treatment of extracted groundwater, is not straightforward. After using Table 7-5 to identify the appropriate remedial alternative, Table 7-4 should be used to identify the required treatment technologies, potential interferences, and limitations.

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However, Table 7-4 is not a complete reference nor is it completely accurate in cases where multiple contaminants are present. Interferences between chemical classes is common and often unpredictable. Treatments that are effective for one chemical may not work when a second chemical is present. Final treatment technologies for use in alternatives that depend on extraction and treatment of groundwater should be selected according to the Hanford BAT document (which seeks to facilitate technology transfer) to ensure reliable success in designs for water treatment.

Before selecting a remedial alternative for an operable unit, detailed feasibility studies, bench-scale, and pilot-scale treatment tests must be performed. These studies and tests should develop a better understanding of groundwater hydrogeology and chemical mobilities to successfully implement extraction alternatives. A more complete identification of RAOs is required to determine the applicability of point-of-use and point-of-discharge alternatives. Completion of these studies and the acquisition of additional site characterization data will focus the remedial action model and begin to narrow the range of potentially applicable technologies and alternatives. Finally, continuing efforts by the DOE Office of Technology Development, Westinghouse Integrated Programs and Demonstrations programs, and Battelle Pacific Northwest Laboratory to evaluate in situ treatments, advanced wastewater treatment, and the treatment of tritium will be important in arriving at remedial alternatives for the 200 East Groundwater Aggregate Area.

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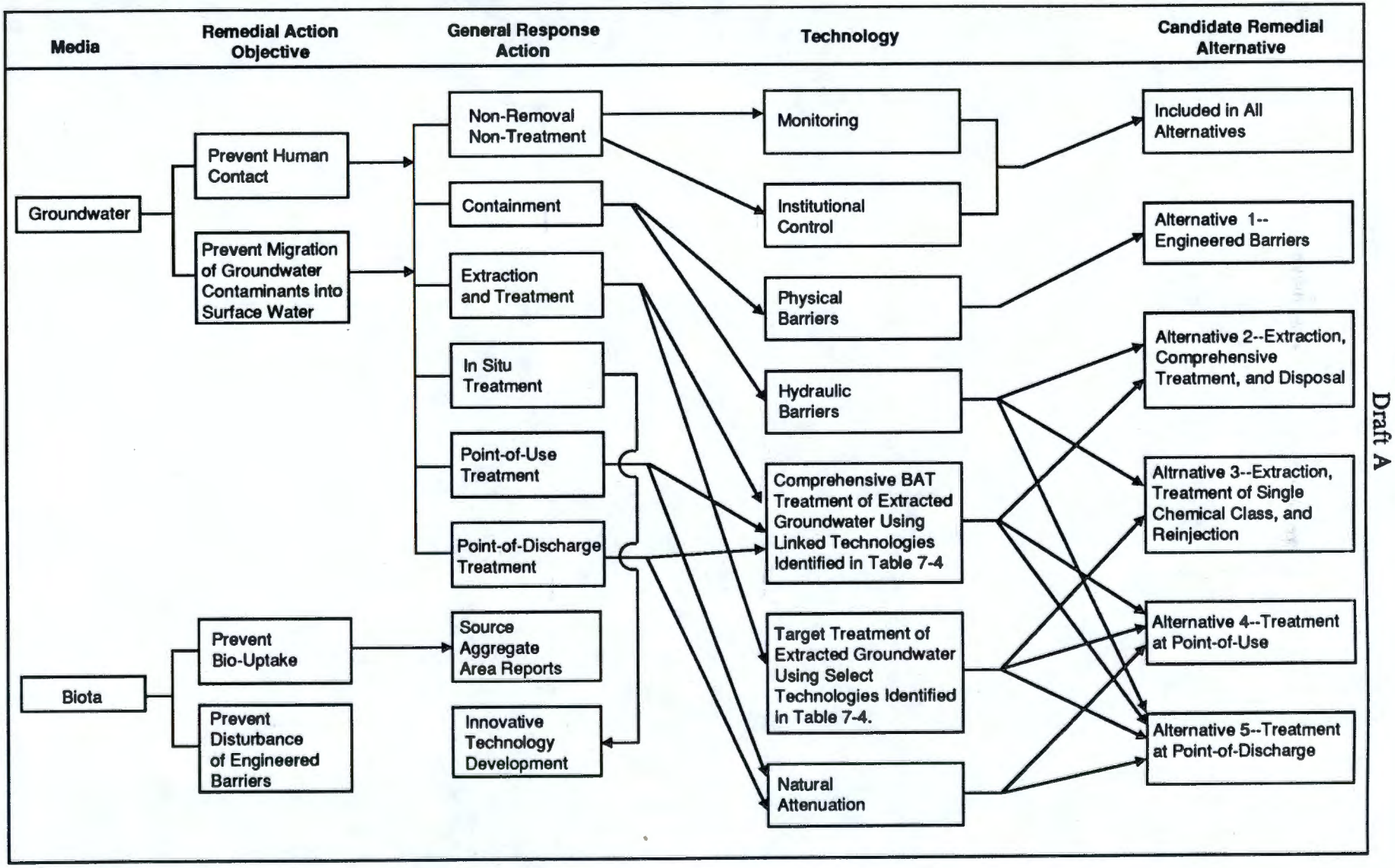

Figure 7-1. Development of Candidate Remedial Alternatives for 200 East Groundwater Aggregate Area.

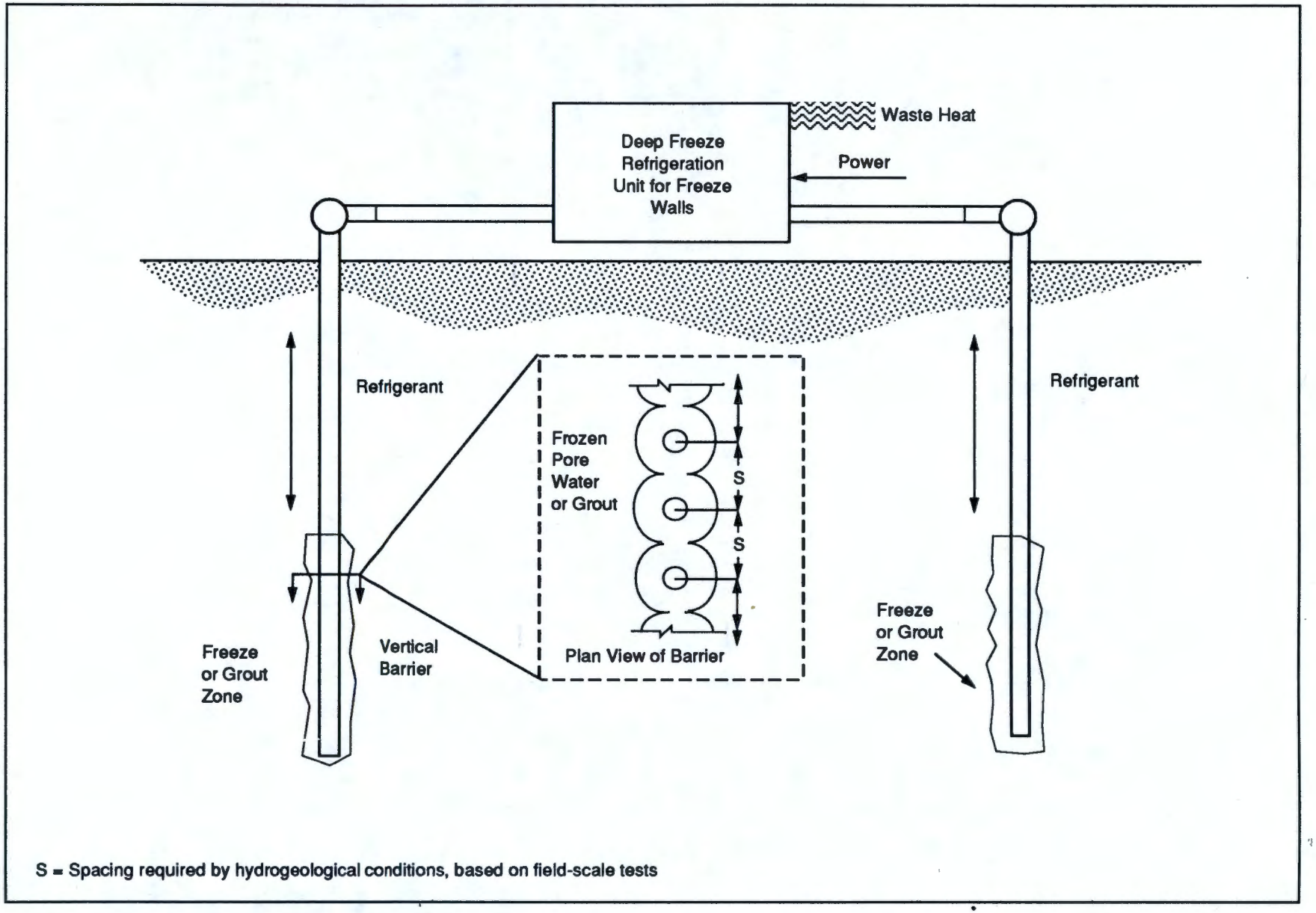

Figure 7-2. Alternative 1—Engineered Vertical and/or Horizontal Barriers.

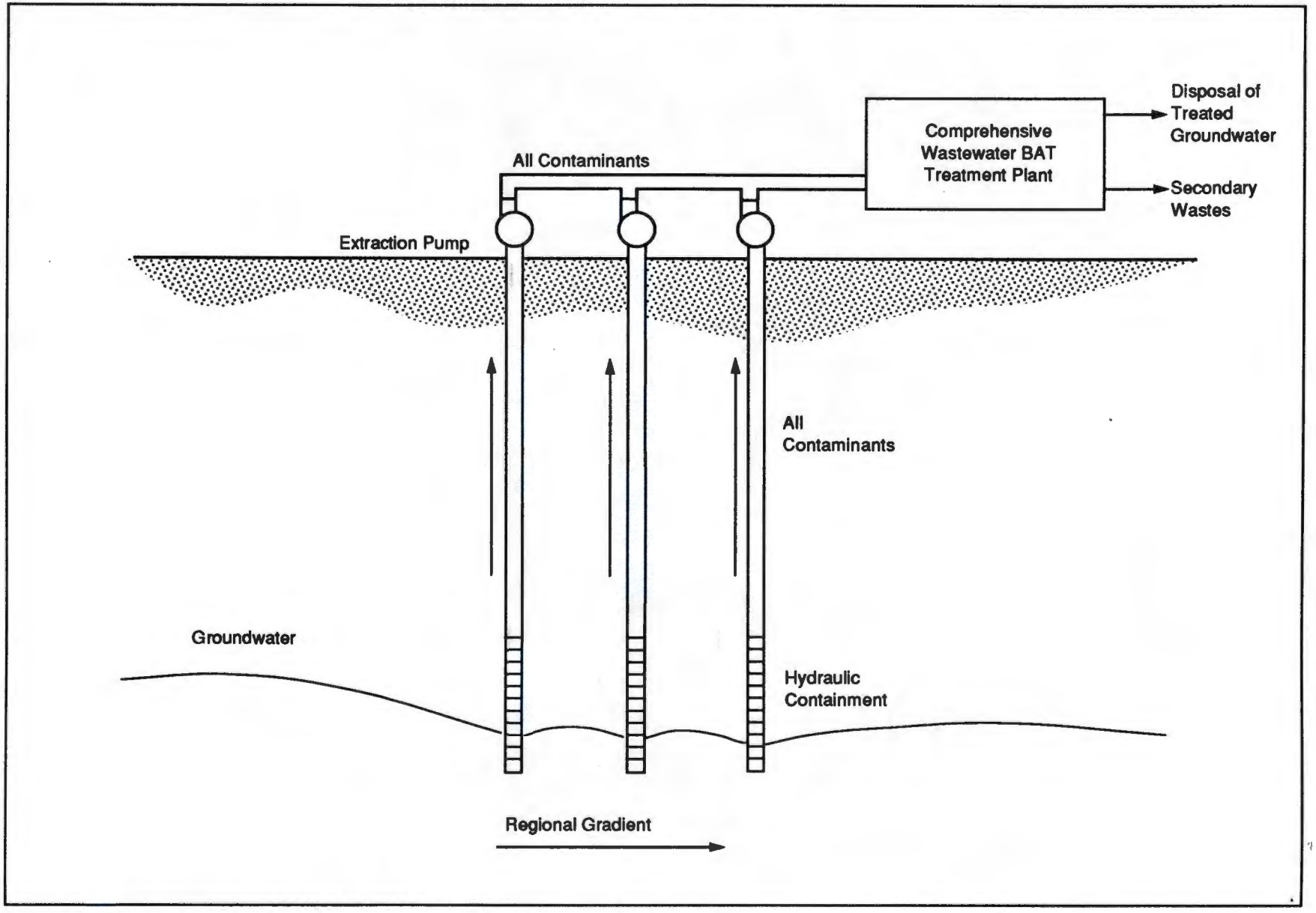

Figure 7-3. Alternative 2—Groundwater Extraction, Comprehensive Treatment, and Disposal.

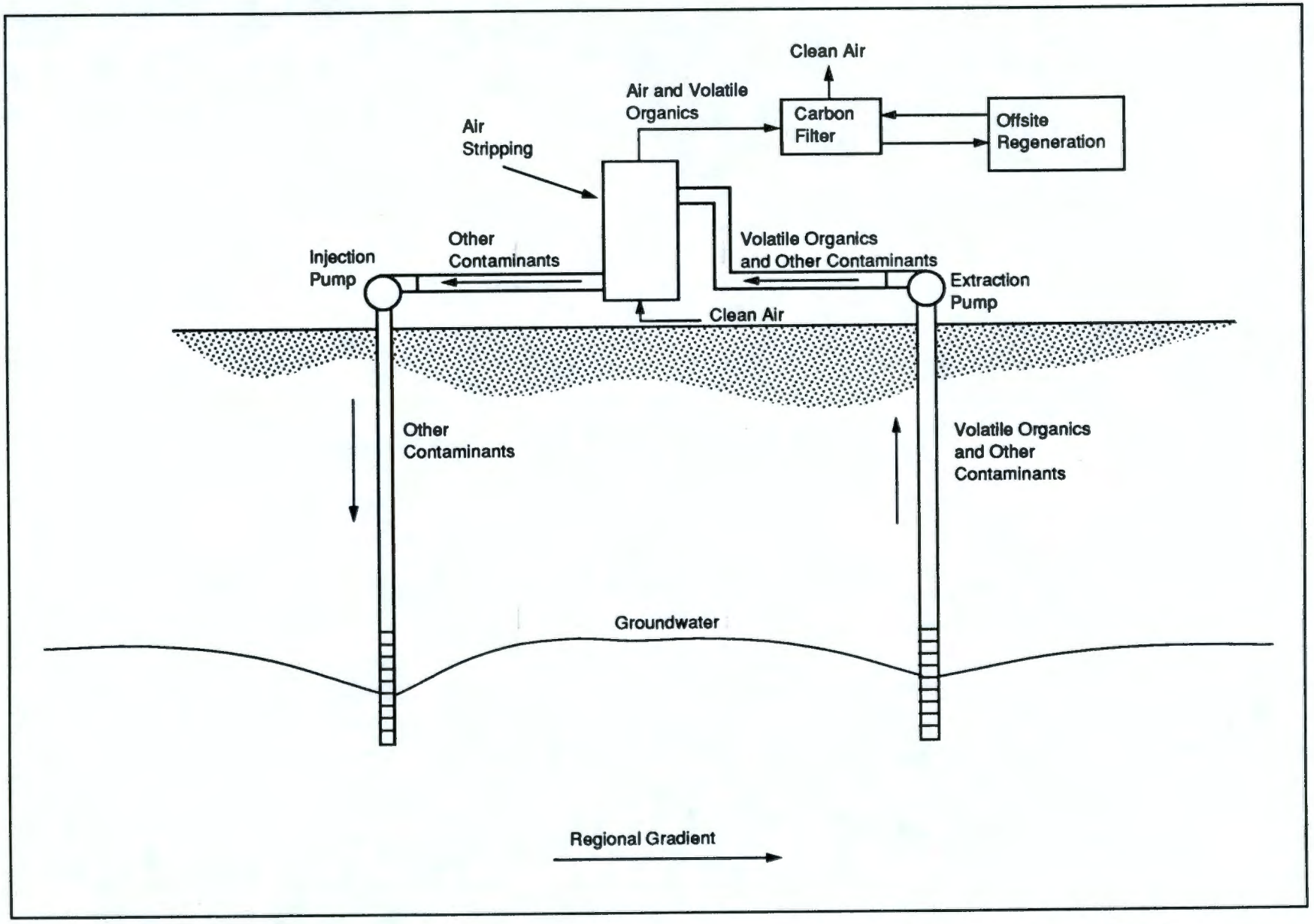

Figure 7-4. Alternative 3—Extraction of Groundwater, Treatment of Single Class of Compounds (Volatile Organics), and Reinjection in Zone of Extraction.

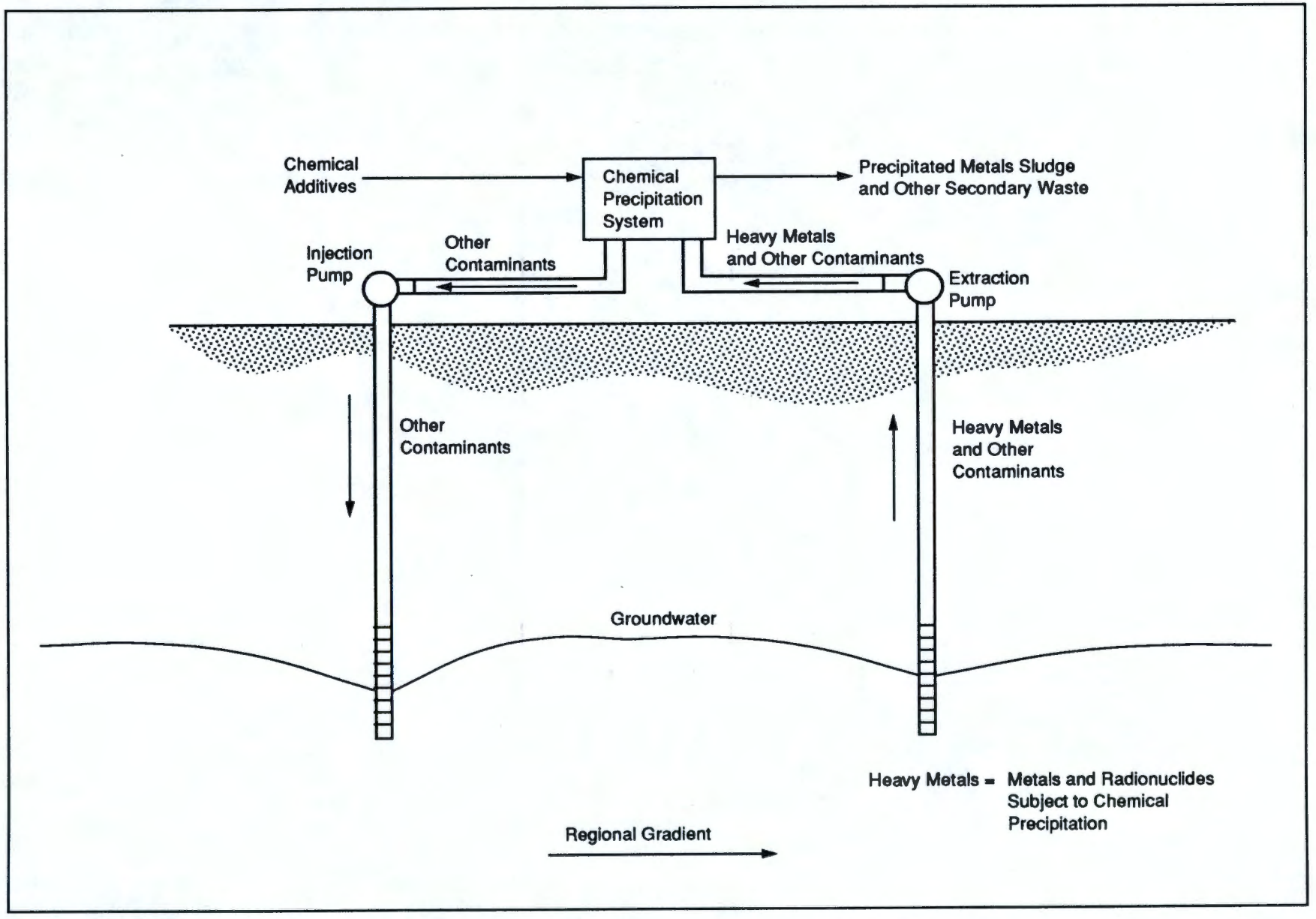

Figure 7-5. Alternative 3—Extraction of Groundwater, Treatment of Single Class of Compounds (Inorganic Heavy Metals), and Reinjection in Zone of Extraction.

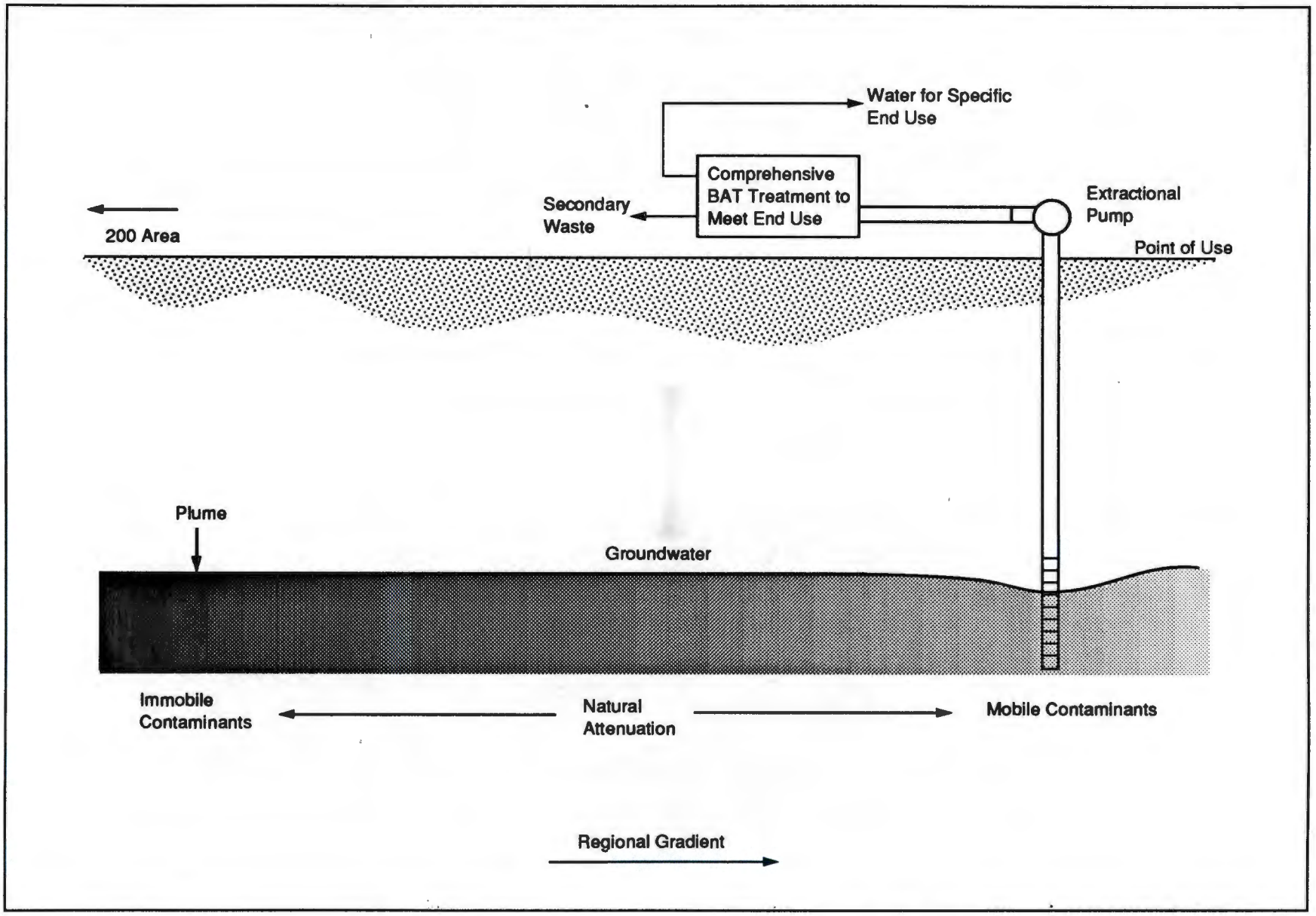

Figure 7-6. Alternative 4—Treatment of Groundwater at Point of Use.

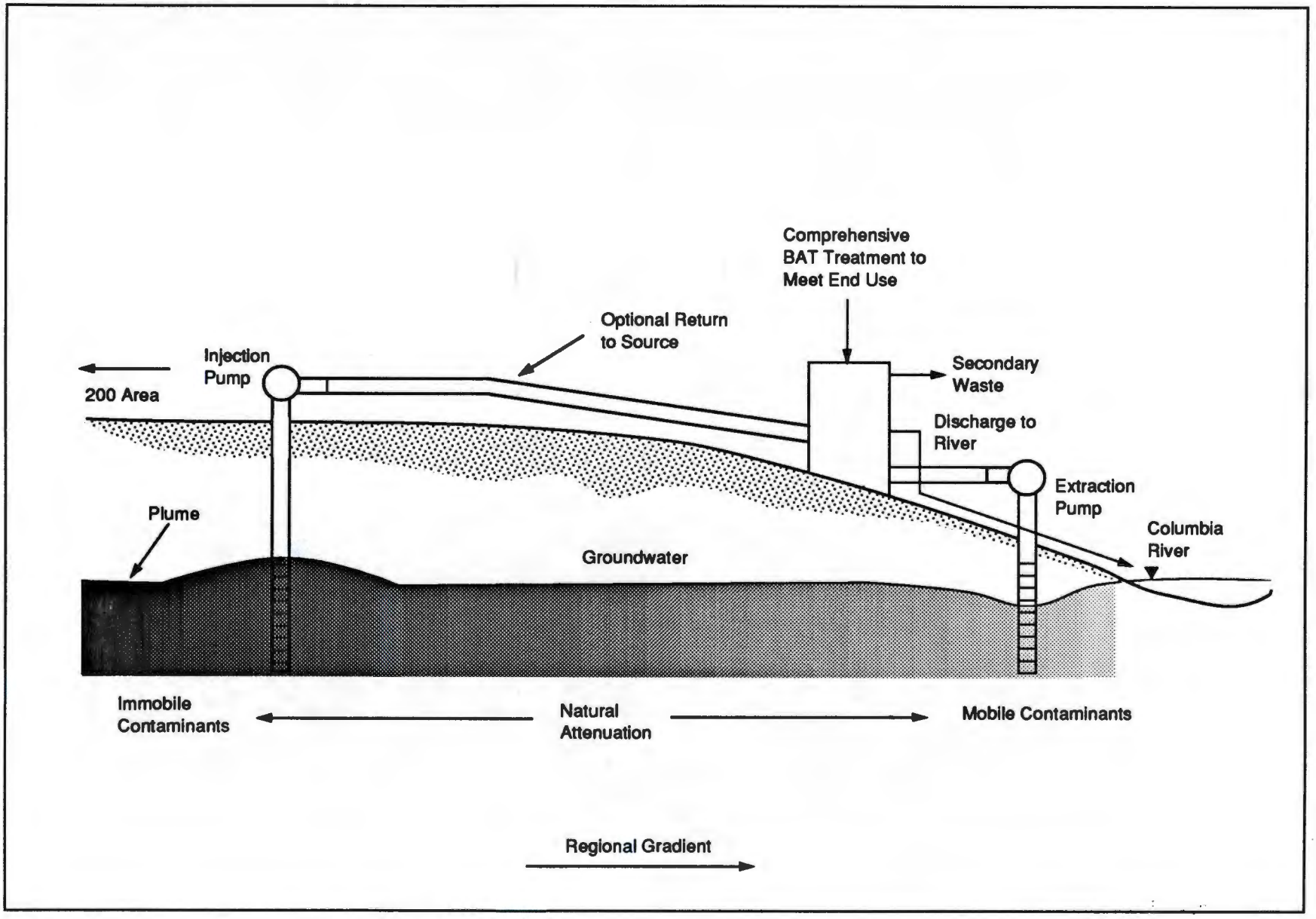

Figure 7-7. Alternative 5—Treatment of Groundwater at Point of Discharge.

Table 7-1. Preliminary Remedial Action Objectives and General Response Actions.

Remedial Action Objectives			
Environmental Media	Human Health	Environmental Protection	General Response Actions
Groundwater	• Prevent ingestion, inhalation, or direct contact with groundwater containing radioactive and/or hazardous constituents present at concentrations above MTCA and DOE standards for industrial sites (or subsequent risk-based standards). • Prevent discharge of groundwater to surface water or transmission of contaminants from groundwater to surface water that would cause surface water to exceed MTCA and DOE standards at the compliance point location	• Prevent migration of radionuclides and hazardous constituents that would result in surface water, air, or biota contamination with constituents at concentrations exceeding ARARs.	• No Action • Institutional Controls/Monitoring • Containment • Groundwater Removal and Treatment • In Situ Groundwater Treatment • Point-of-Use Treatment • Point-of-Discharge Treatment

Table 7-2. Preliminary Remedial Action Technologies for Groundwater.

General Response Action	Technology Type	Process Option	Contaminants Treated*
No Action	No Action	No Action	None
Institutional Controls	Groundwater Use Restrictions	Deed Restrictions	None
	Access Controls	Well Prohibitions Closures and Controls	None
		General Area Access Control	None
	Monitoring	Monitoring	None
Containment	Vertical Physical Barriers	Freeze Walls	I,M,R,O,V,S,T
		Slurry Walls	I,M,R,O,V,S,T
		Grout Curtains	I,M,R,O,V,S,T
		Sheet Piles	I,M,R,O,V,S,T
		Membrane installation	I,M,R,O,V,S,T
	Horizontal Physical Barriers	Block Displacement	I,M,R,O,V,S,T
		Capping	I,M,R,O,V,S,T
		Grouting	I,M,R,O,V,S,T

Table 7-2. Preliminary Remedial Action Technologies for Groundwater.

General Response Action	Technology Type	Process Option	Contaminants Treated*
		Horizontal/Right Angle drilling with Freeze technologies	I,M,R,O,V,S,T
		Horizontal/Right Angle Drilling with Grout Curtains	I,M,R,O,V,S,T
	Hydraulic Containment	Trenching	I,M,R,O,V,S,T
		Injection Wells	I,M,R,O,V,S,T
		Extraction Wells	I,M,R,O,V,S,T
		Drains	I,M,R,O,V,S,T
Extract and Treat	Chemical Treatment	Reduction	M
		Chemical Oxidation	O,V
		Supercritical Oxidation	O,V
		UV Oxidation	O,V
		Hydrolysis	I
		Precipitation	I,M,R
		Dechlorination	O,V (chlorinated only)
		Neutralization	I,M,R

Table 7-2. Preliminary Remedial Action Technologies for Groundwater.

General Response Action	Technology Type	Process Option	Contaminants Treated*
Extract and Treat	Physical Treatment	Air Stripping	V
		Steam Stripping	V,O
		Filtration	R,S,M
		Ion Exchange	I,M,R,O,V,S
		Reverse Osmosis	I,M,R,O,V,S
		Solvent Extraction	I,M,R,O,V
		Supercritical Fluid Extraction	I,M,R,O,V
		Gravity Separation	R,S,O
		Alumina Adsorption	R,S,M
		Carbon Adsorption	O,V,M
		Flocculation	R,S,M
		Filtration	R,S,M
Extract and Treat	Biological Treatment	Aerobic	O,V
		Anaerobic	O,V
Extract and Treat	Thermal Treatments	Solar Evaporation	I,M,R,O,S
		Distillation	I,M,R,O,S
		Destructive Incineration	I,M,R,O,V,S
		Wet Air Oxidation	O,V

Table 7-2. Preliminary Remedial Action Technologies for Groundwater.

General Response Action	Technology Type	Process Option	Contaminants Treated*
In Situ Treatment	Physical	Sparging	V
		Vapor Extraction	V
In Situ Treatment	Chemical	Precipitation	I,M,R
		Solubilization	I,M,R,O,V
		Degradation	O,V
In Situ Treatment	Biological	Aerobic	O,V
		Anaerobic	O,V

Target Chemical Code
I = Other Inorganics contaminants applicability
M = Heavy Metals contaminants applicability
R = Radionuclide contaminants applicability
O = Organic contaminants applicability
V = Volatile Organic contaminants applicability
S = Suspended Solid
T = Tritium
NA = Not Applicable
* Tritium is classified as a single chemical due to its unique chemical treatability characteristics

Table 7-3. Technology Screenings.

Technology			Evaluation Criteria			
Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Conclusions
No Action	None	Does nothing to cleanup contamination or reduce the exposure pathways	Not effective in reducing the contamination or exposure pathways	Easily implemented, but might not be acceptable to regulatory agencies, local governments, and the public	Low	Retained as a "baseline case"
Groundwater Use Restrictions	Deed Restrictions	Identify contaminated areas and prohibit groundwater usage though restriction of deed	Depends on continued implementation. Does not reduce contamination	Administrative decision is easily implemented	Low	Retained to be used in conjunction with other process options
Access Controls	Well Prohibitions Closures and Controls	Close all wells in area and prohibit installation by general ordinance	Effective if closure controls are maintained	Easily implemented. Restrictions of well installation and use	Low	Retained to be used in conjunction with other process options
	General Area Access Control	Restrict access to all land which may allow access to groundwater	Very effective in keeping people out of the contaminated areas	Equipment and personnel easily implemented and readily available	Low	Retained to be used in conjunction with other process options
Monitoring	Monitoring	Analyze groundwater to monitor movement of contamination	Does not reduce the contamination, but is very effective in tracking the contaminant levels	Easily implemented, standard technology	Low	Retained to be used in conjunction with other process options
Vertical Physical Barriers	Freeze Walls	Circulate refrigerant in pipes surrounding groundwater to create a frozen curtain of pore water	Effective in blocking lateral movement of all types of groundwater contamination. May be difficult to monitor effectiveness for deep contamination	Specialized engineering design required. Requires ongoing freezing	Medium	Retained because of effectiveness and implementability
	Slurry Walls	Trench around areas of groundwater and fill with soil/cement/bentonite slurry which solidifies to form impermeable barriers	Effective in blocking lateral movement of all types of groundwater contamination. May be difficult to monitor effectiveness for deep contamination	Commonly used practice but difficult to install at depth	Medium	Rejected due to implementability problems at depth
	Grout Curtains	Pressure inject grout in regular pattern of drilled holes	Effective in blocking lateral movement of all types of groundwater contamination. May be difficult to monitor effectiveness for deep contamination	Commonly used practice and easily implemented but depends on soil type. May be difficult to ensure continuous wall	Medium	Retained because of effectiveness and implementability
	Sheet Piles	Physically drive sheets of steel to form impermeable barriers	Effective in blocking lateral movement of all types of groundwater contamination	Commonly used practice but difficult to install at depth	Low	Rejected due to implementability problems at depth
	Impermeable Membrane installation	Trench around areas of groundwater contamination and install impermeable membranes prior to backfilling.	Effective in blocking lateral movement of all types of groundwater contamination	Difficult to install at depth	Medium	Rejected due to implementability problems at depth

Table 7-3. Technology Screenings.

Technology			Evaluation Criteria			
Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Conclusions
Horizontal Physical Barriers	Capping	Construct impermeable cover over surfaces known to provide recharge to groundwater	Combined with proper runoff control, effective in preventing rainwater recharge to groundwater	Easily implemented. Restriction of future land use will be necessary	Low	Rejected because of limited applicability and/or implementability problems
	Block Displacement	Inject in multiple subsurface mono-planer locations, high pressure grout. Hydraulic pressure will lift soil, and form horizontal barrier of grout	Effective in restricting vertical movement of groundwater contamination. May not be effective for deep groundwater	Difficult to install at depth	Medium	Rejected because of limited applicability and/or implementability problems
	Grouting	Pressure inject grout at screened depths in regular pattern of drilled holes	Effective in restricting vertical movement of groundwater contamination. May not be effective for deep groundwater	Difficult to install at depth	Medium	Rejected because of limited applicability and/or implementability problems
	Horizontal/Right Angle Drilling with Freeze Technologies	Circulated refrigerant in pipes installed both horizontally and vertically	Effective in restricting vertical movement of groundwater contamination	Specialized right angle drilling and freeze engineering required	High	Retained as innovative technology
	Horizontal/Right Angle Drilling with Grout Curtains	Pressure inject grout in regular pattern of drilled holes installed both horizontally and vertically	Effective in restricting vertical movement of groundwater contamination	Specialized right angle drilling required	Medium	Retained as innovative technology
Hydraulic Containment	Trenching	Dig subsurface trenches to capture and divert groundwater flow	Effective in diverting near-surface groundwater flow. May not be effective for deep groundwater	Easily implemented for shallow groundwater. Difficult to implement for deep groundwater	Medium	Rejected due to implementability problems at depth
	Injection Wells	Inject water to alter gradient of groundwater	Effective if hydrogeology is known. Requires source of water to inject	Easy to implement providing adequate source of water is available	Medium	Retained because of effectiveness and implementability
	Extraction Wells	Extract water from deep wells to alter gradient of groundwater	Effective if hydrogeology is known	Easy to implement providing disposal options for extracted water are available	Medium	Retained because of effectiveness and implementability

Table 7-3. Technology Screenings.

Technology			Evaluation Criteria			
Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Conclusions
Extraction & Chemical Treatment	Reduction	Use Redox reactions to alter chemical form of contaminants	May be effective in treating some heavy metal groundwater contamination. Radioactivity will not be reduced	Implementable. Treatability tests are necessary. Well developed technology and commercially available	Medium	Rejected because of limited applicability and/or implementability problems
	Chemical Oxidation	Use oxygenating chemicals such as peroxide to destroy chemicals through oxidation	May be effective in treating organic groundwater contaminants. Can be highly chemical matrix specific	Implementable. Treatability tests are necessary. Well developed technology and commercially available	Medium	Rejected because similar technologies have broader effectiveness
	Supercritical Oxidation	Use of supercritical fluids to destroy chemicals through oxidation	May be effective in treating organic groundwater contaminants. May be applicable to broad range of chemicals	May be implementable. Treatability tests are necessary. Relatively new technology, but commercially available	High	Rejected because similar technologies have broader effectiveness
	UV Oxidation	Use of ultraviolet light and appropriate catalysts to destroy chemicals through oxidation	May be effective in treating organic groundwater contaminants. May be applicable to broad range of chemicals	Implementable. Treatability tests are necessary. Well developed technology and commercially available	Medium	Retained because of effectiveness and implementability
	Hydrolysis	Use of water to destroy water reactive chemicals	Not effective on groundwater contaminants because of aqueous state	Not implementable on aqueous solution	Low	Rejected because of limited applicability and/or implementability problems
	Precipitation	Use of chemical additives to alter the solubility of chemicals, and cause their precipitation from solution	May be effective in treating inorganic groundwater contaminants. Applicable to a broad range of metals and radionuclides	Implementable. Treatability tests are necessary. Common technology, commercially available	Medium	Retained because of effectiveness and implementability
	Dechlorination	Use of strong reducing agents to remove chlorine from chemical and hence reduce their toxicity	May be effective on chlorinated organic contaminants in groundwater	May be difficult to implement. Most often used on organic matrixes. Treatability tests for aqueous matrixes required	Medium	Rejected because similar technologies have broader effectiveness
	Neutralization	Use of acids or bases to remove corrosivity from groundwater	Not applicable to chemicals identified in groundwater. May be effective as pretreatment for other options	Implementable. Common industrial practice. Commercially available	Low	Retained to be used in conjunction with other process options

Table 7-3. Technology Screenings.

Technology			Evaluation Criteria			
Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Conclusions
Extraction & Physical Treatment	Air Stripping	Use of air to remove chemicals from groundwater. Chemical must be volatile. Subsequent air containing chemicals must be treated.	Effective in removing many volatile organic groundwater contaminants. Ineffective for inorganics and radionuclides	Implementable. Requires emission treatment for organics and capture system for radionuclide and volatilized metals	Low	Retained because of effectiveness and implementability
	Steam Stripping	Use of steam to remove chemicals from groundwater. Chemical must be semivolatile or volatile. Subsequent steam containing chemicals must be treated.	Effective in removing many volatile, and some semivolatile organic groundwater contaminants. Ineffective for inorganics and radionuclides	Implementable. Requires emission treatment for organics and capture system for radionuclide and volatilized metals	Medium	Retained because of effectiveness and implementability
	Filtration	Use of sand or filters to separate chemical by particle size.	May be effective in removing groundwater contaminants absorbed to suspended solids. Not effective on dissolved chemicals	Implementable. Requires treatability study to determine specific filtration equipment. Commercially available	Low	Retained to be used in conjunction with other process options
	Ion Exchange	Use of special resin to exchange ionic chemical between groundwater and resin. Regeneration solution containing exchanged chemical must be treated.	Effective in removing ionic inorganic groundwater contaminants. Requires treatment of regeneration solutions	Implementable. Treatability studies required to determine specific resin required. Fouling by organic contaminants likely	Medium	Retained because of effectiveness and implementability
	Reverse Osmosis	Use of molecular size membranes and osmotic pressure to separate chemical from groundwater. Concentrated solution with chemical must be treated.	Effective in removing suspended soils, metals, and radionuclides from groundwater. Requires treatment of concentrated reject streams	Implementable. Treatability studies required to determine membranes required. Fouling by organic contaminants likely	High	Retained because of effectiveness and implementability
	Solvent Extraction	Use of special solvents to extract chemical from groundwater. Contaminated solvents must be treated.	May be effective in removing specific groundwater chemicals (such as plutonium or organics). Requires treatment of solvents	May be implementable. Treatability studies to determine suitable solvent. Target chemicals must be identified. Secondary solvents must be treated	Medium	Rejected because of limited applicability and/or implementability problems
	Gravity Separation	Use of differences in chemical density to separate chemical from groundwater. Includes settling, DAF, and centrifuging.	May be effective in removing groundwater contaminants absorbed to suspended solids. Not effective on dissolved chemicals	Implementable. Requires treatability study to determine which specific separation equipment will be most effective. Commercially available	Low	Retained to be used in conjunction with other process options
	Activated Alumina	Use of activated alumina to absorb chemical from groundwater. Contaminated alumina must be disposed of.	May be effective for removing some radionuclides and suspended solids. Requires regeneration of alumina	Implementable. Commercially available data for effectiveness for many chemicals. Treatability tests will be required for other chemicals	Low	Rejected because similar technologies have broader effectiveness

Table 7-3. Technology Screenings.

Technology			Evaluation Criteria			
Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Conclusions
	Coagulation/ Flocculation	Use of colloidal interactions to remove suspended solids and some dissolved phase chemicals.	May be effective for removing chemicals associated with suspended solids	Implementable. Commercial systems readily avaialable	Low	Retained for use with other options
	Carbon Absorption	Use of activated carbon to absorb chemicals from groundwater. Contaminated carbon must be disposed of.	Effective in removing organic and some inorganic groundwater contaminants. Treatment of spent carbon required	Implementable. Well documented effectiveness for many chemicals. Evaluation of treatment of spent carbon required	Medium	Retained because of effectiveness and implementability
	Freeze Separation	Use of liquid/solid	May be effective to remove most groundwater contaminants	May be implementable at this time. Occasionally used in other industries. Media-specific treatability tests required	Medium	Retained as innovative technology because of potential high benefits
Extraction & Biological Treatment	Aerobic	Use of oxygen breathing biological organisms to destroy chemicals	Effectiveness is very contaminant and concentration specific. Treatment has been identified for a variety of organic compounds. Not effective on inorganics or radionuclides	Potentially implementable. Various options are commercially available to produce contaminant degradation. Treatability tests required to determine site-specific conditions	Low	Rejected because of limited applicability and/or implementability problems
	Anaerobic	Use of nonoxygen breathing biological organisms to destroy chemicals	Effectiveness is very contaminant- and concentration-specific. Treatment has been identified for a variety of organic compounds. Not effective on inorganics or radionuclides	Potentially implementable. Various options are commercially available to produce contaminant degradation. Treatability tests required to determine site-specific conditions	n/a	Rejected because of limited applicability and/or implementability problems
Extraction & Thermal Treatments	Solar Evaporation	Use of solar energy to evaporate groundwater to air, leaving non-volatile chemical behind	Effective in concentrating non-volatile groundwater contaminants. Requires large spaces. May be difficult to control radionuclide trace emissions	Difficult to implement. Requires large spaces. Air emission controls difficult to implement over the large space. Air pollution permitting required	Low	Rejected because of limited applicability and/or implementability problems
	Distillation	Use of thermal energy to separate groundwater from chemical by differing vapor pressures	Effective for non-volatile groundwater contaminants. Energy intensive. Concentrated distillation bottoms require treatment	Implementable. Technology is well developed. Energy requirements and disposal of distillation bottoms should be addressed	High	Retained to be used in conjunction with other process options
	Destructive Incineration	Use of thermal energy and oxidation to distil groundwater from nonvolatile chemical and oxidize at high temperature all remaining chemicals.	Effective in destroying organic groundwater contaminants, and concentration non-volatile groundwater contaminants. Air emissions and ash likely to require further treatment	Implementable. Technology is well developed. Mobile units are available for small volumes. Energy requirements and disposal of distillation bottoms should be addressed	High	Rejected because of limited applicability and/or implementability problems
	Wet Air Oxidation	Use of thermal energy and oxidation to force destruction of organic chemical while in aqueous phase.	Effective for organic groundwater contaminants. Applicable to broad range of organic chemicals	Implementable. Specialized industrial process. Commercially available. Treatability test required to determine media-specific effectiveness	High	Rejected because similar technologies have broader effectiveness

Table 7-3. Technology Screenings.

Technology			Evaluation Criteria			
Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Conclusions
In Situ Physical Treatment	Sparging	Injection of air into groundwater zone to distribute chemicals or effect a stripping operation	May be effective in removing volatile organic chemicals or dispersing other in situ treatment chemicals	May be implementable. Detailed permeability of soil must be known. Treatability studies must be performed to evaluate site-specific effects	Low	Retained as innovative technology because of potential high benefits
In Situ Chemical Treatment	Precipitation	Injection of chemical designed to reduce mobility of contaminants in groundwater	May be effective in reducing mobility of metals and radionuclides	May be implementable. Techniques to enhance mixing of chemical additives and groundwater must be developed	Low	Retained as innovative technology because of potential high benefits
	Solubilization	Injection of chemical designed to increase mobility of contaminants in groundwater	May be effective in increasing mobility of metals and radionuclides. The increased mobility would enhance performance of pump and treat technologies	May be implementable. Techniques to enhance mixing of chemical additives and groundwater must be developed	Low	Retained as innovative technology because of potential high benefits
	Destruction	Injection of chemical designed to destroy contaminants in groundwater	May be effective in destroying organic chemical. Secondary by-products may be generated	Difficult to implement. Chemical with destructive potential, such as oxidizers, are affected by sand media. Techniques to enhance mixing required	Low	Retained as innovative technology because of potential high benefits
In Situ Biological Treatment	Aerobic	Use of oxygen breathing biological organisms to destroy chemicals	Effective for organic compounds under proper chemical conditions. Ineffective for inorganics and radionuclides	Difficult to implement. Treatability studies and thorough subsurface characterization required	Low	Retained as innovative technology because of potential high benefits
	Anaerobic	Use of non-oxygen breathing biological organisms to destroy chemicals	Effective for some volatile and complex organics. Not effective for inorganics and radionuclides	Difficult to implement. Anoxic groundwater conditions required. Treatability studies and thorough subsurface characterization required	Low	Retained as innovative technology because of potential high benefits

Table 7-4. Summary of Retained Groundwater Technologies.

Chemical Class	Proven Technologies											Innovative Technologies				
	Containment		Groundwater Treatments									Groundwater Treatments		In Situ		Containment
	Grout wall	Freeze wall	UV Oxidation	Precipitation	Air Stripping	Steam Stripping	Coagulation and Filtration	Reverse Osmosis	Carbon Absorbtion	Evaporation	Ion Exchange	Freezing	Supercritical extraction	Air Sparging and/or biodegradation	Flushing and/or precipitation	Horizontal Grout and/or Freeze walls
Organics	A	A	A	D	D	C	C	X,I	B	E	X	I,C	I	E,I	I	I
Volatile Organics	A	A	A	D	B	B	D	X,I	B	C,X	X	I,B	I	I	I	I
Inorganics	A	A	D,X	C	D,X	D,X	D	B,I	C	B,X	B	I,B	I	E,I	I	I
Metals	A	A	D,X	A	D,X	D,X	C	A	C	A	A	I,A	I	E,I	I	I
Radionuclides	A	A	D	A	D,X	D,X	C	A	C,X	A	A	I,A	I	E,I	I	I
Suspended Solids	A	A	X	E	X	X	A	A	X	A	X	I,A	I	E,I	I	I
Tritium*	A	A	E	E	E	E	E	E	E	E	E	E	I	E,I	E,I	I

A= Applicable to most chemicals in class.
B= Applicable to many chemicals in class.
C= Applicable to some chemicals in class.
D= Applicable to few chemicals in class.
E= Not specifically applicable to chemicals in class.
X= Known to be susceptible to interference due to fouling, media contamination, or other uncontrollable effects.
I= Potential innovative application.
* Tritium is classified as a single chemical group due to its unique chemical characteristics

Table 7-5. Preliminary Remedial Action Alternative Applicable to Chemical Classes of Groundwater Operable Units.

Chemical Plume	Alternative 1 Containment	Alternative 2 Groundwater Extractions and Comprehensive Treatment	Alternative 3 Groundwater Extraction, Treatment of a Single Class, and Reinjection	Alternative 4 Treatment at Point-of-Use	Alternative 5 Treatment at Point-of-Discharge
Arsenic	A	B	B	E	E
Chromium	A	B	B	E	E
Cyanide	A	B	B	E	E
Fluoride	A	B	B	E	E
Nitrate	A	B	B	E	E
Co-60	A	B	B	E	E
Sr-90	A	B	B	E	E
Cs-137	A	B	B	E	E
Gross Alpha	A	F	F	FD	FD
Gross Beta	A	F	F	FD	FD
Tritium	A	X	X	D	D
Technetium-99	A	B	B	E	E
Plutonium	A	B	B	E	E
Iodine-129	A	B	B	E	E
Organics	A	BC	BC	E	E

A = Applicability.
B = Possible applicability but treatment interferences may be encountered if plumes overlap and long-term performance may be hampered by absorbed chemicals.
C = Long-term performance may be additionally hampered by presence of DNAPLS.
D = Possible applicability if natural attenuation time is sufficiently long.
E = Possible applicability.
F = Applicability depends on which chemicals are emitting alpha or beta.
X = Not likely to be effective.

8.0 DATA QUALITY OBJECTIVES

As described in Section 1.2.2, this aggregate area management study (AAMS) process, as part of the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a), is designed to focus the remedial investigation (RI)/feasibility study (FS) process toward comprehensive cleanup or closure of all contaminated areas at the earliest possible date and in the most effective manner. The fundamental principle of the *Hanford Site Past-Practice Strategy* is a "bias for action" which emphasizes the maximum use of existing data to expedite the RI/FS process as well as allow decisions about work that can be done at the site early in the process, such as expedited response actions (ERAs), interim remedial measures (IRMs), limited field investigations (LFIs), and focused feasibility studies (FFSs). The data have already been described in previous sections (2.0, 3.0, and 4.0). Remediation alternatives are described in Section 7.0. However, data, whether existing or newly acquired, can only be used for these purposes if it meets the requirements of data quality as defined by the data quality objective (DQO) process developed by the U.S. Environmental Protection Agency (EPA) for use at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites (EPA 1987). This section implements the DQO process for this, the scoping phase in the 200 East Groundwater Aggregate Area.

In the guidance document for DQO development (EPA 1987), the process is described as involving three stages which have been used in the organization of the following sections:

- Stage 1--Identify decision types (Section 8.1)
- Stage 2--Identify data uses and needs (Section 8.2)
- Stage 3--Design a data collection program (Section 8.3).

8.1 DECISION TYPES (STAGE 1 OF THE DQO PROCESS)

Stage 1 of the DQO process is undertaken to identify:

- The decision makers (thus the most important data users) relying on the data to be developed (Section 8.1.1)
- The data available to make these decisions (Section 8.1.2)
- The quality of these available data (Section 8.1.3)

9 2 1 2 7 5 1 6 5 6

- The conceptual model into which these data must be incorporated (Section 8.1.4)

- The objectives and decisions that must evolve from the data (Section 8.1.5).

These issues serve to define, from various sides, the types of decisions that will be made on the basis of the 200 East Groundwater AAMS.

8.1.1 Data Users

The data users for the 200 East Groundwater AAMS and subsequent investigations such as LFIs, RI/FSs, and Resource Conservation and Recovery Act (RCRA) Facility Investigations (RFIs)/Corrective Measures Studies (CMSs) are the following:

- The decision makers for policies and strategies on remedial action at the Hanford Site. These are the signatories of the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1990) including the U.S. Department of Energy (DOE), EPA, and the Washington State Department of Ecology (Ecology).

Nominally these responsibilities are assigned to the heads of these agencies (the Secretary of Energy for DOE, the Administrator of EPA, and the Director of Ecology). However, the political process requires that more local policy-makers (e.g., the Regional Administrator of EPA and the head of the U.S. Department of Energy, Richland Operations Office [DOE/RL]) or technical and policy-assessment staff of these agencies to be involved in the decision-making process.

- Unit managers of Westinghouse Hanford and potentially other Hanford Site contractors who will implement remedial activities for the 200 East Groundwater Aggregate Area. Staff of these contractors will have to make the lower level (tactical) decisions about appropriate scheduling of activities and allocation of funding, personnel, and equipment to accomplish the recommendations of the AAMS.

- Concerned members of the wide community involved with the Hanford Site. These may include:

  - Other state (Washington, Oregon, and other states) and federal agencies
  - Affected Indian tribes

- Special interest groups
- The general public.

These groups will be involved in the decision process through the implementation of the Community Relations Plan (CRP) (Ecology et al. 1989), and will apply their concerns through the "primary" data users, the signatories of the Tri-Party Agreement.

The needs of these users will have a pivotal role in issues of data quality. Some of this influence is already imposed by the guidance of the Tri-Party Agreement.

8.1.2 Available Information

The *Hanford Site Past-Practice Strategy* specifies a "bias for action" which intends to maximize use of existing data for initial decisions about remediation. This emphasis can only be implemented if the existing data are adequate for the purpose.

Available data for the 200 East Groundwater Aggregate Area are presented in Sections 2.0, 3.0, and 4.0 and in topical reports prepared for this study. The available data for this 200 East Groundwater Aggregate Area Management Study Report (AAMSR) are slightly different from those presented in the B Plant, PUREX, Semi-Works, and 200 North Area AAMSRs for waste management units in the 200 East and 200 North Areas. For many aspects of the site data, the source AAMSRs are given primacy and the 200 East Groundwater AAMSR simply summarizes the data developed in those studies. Only in regard to data about groundwater, the deeper geologic layers in which it is found, and the monitoring of this medium, does the 200 East Groundwater AAMSR present separately developed data. As described in Section 1.2.2, these data should address several issues:

- Issue 1: Facility and process descriptions and operational histories for waste sources (mainly in source AAMSRs, but summarized here in Sections 2.2, 2.3, and 2.4)

- Issue 2: Waste disposal records defining dates of disposal, waste types and waste quantities (also mainly in source AAMSRs, but again summarized here in Section 2.4)

- Issue 3: Sampling events of waste effluents and affected media (left strictly to the source AAMSRs)

- Issue 4: Site conditions including the site physiography, topography, geology, hydrology, meteorology, ecology, demography, and archaeology (Section 3.0)

9 2 1 2 7 5 1 6 5 8

- Issue 5: Environmental monitoring data for affected media--for this groundwater AAMSR, this is specifically groundwater (Section 4.1).

For the purposes of the 200 East Groundwater AAMSR, the most relevant data pertain to issues 4 and 5 and will be discussed further in the following paragraphs. Results of groundwater sampling and analysis (issue 5) reveal the nature and extent of groundwater contamination. Site characterization data (issue 4) on the other hand indicate the dynamics of the situation: where the contamination is likely to migrate, how it might be transformed in the process, and where potential receptors may be located.

Nature and Extent of Contamination. The data available about nature and extent (detections and concentrations) of contaminants in groundwater (Section 4.1.1) are relatively extensive and comprehensive, especially when compared to the data available for the waste management units in the individual source AAMSRs. There are gaps (particularly in the front end of plumes which have migrated into the 600 Areas where there are fewer wells but also in parts the southern portion of the 200 East Area) but the lateral extent of the plumes (and their constituents) appear to be well defined although there is a deficiency of data on the vertical extent of contamination. This AAMSR emphasizes the most recent data (1988 to 1991) because they are more complete than any earlier data set: more wells were sampled (including newer wells) at greater frequency and consistency, more constituents analyzed, and better methodology was used for both field procedures and laboratory methods (e.g., detection limits). While these data are not perfect, they provide a fairly consistent basis to compare concentrations across the site, and thereby delineate plumes. While the data base is adequate for this purpose, earlier data across the Hanford Site (including in the 200 East Area) have been deficient in analyzing groundwater samples for a wide enough range of constituents and at detection levels sensitive enough to delineate plumes in areas where they must have been present.

To a limited extent, these data are supported by the data regarding the sources of these plumes: contaminant releases from waste management units (Sections 2.3 and 4.1.2). These data include inventory (liquid waste volumes and contaminant quantities), and results of borehole logging for gross gamma radiation. The extent and limitations of this information are discussed more fully in the individual AAMSRs and are only summarized in this report. However, some inconsistencies between the reported releases and known groundwater contaminant plumes indicate that the inventories may be incomplete.

The inventory data are supplemented by the results of geophysical gross gamma logging in boreholes near the waste management units that indicate the depth to which gamma-emitting radionuclides have penetrated the subsurface. These data are limited in two ways: the boreholes are generally some distance away from the unit and thus may not

observe contamination directly beneath the unit; and the method does not differentiate what radionuclide species are actually present. These limitations may be removed with further field investigations in the source areas and the use of the Radionuclide Logging System (RLS), which can differentiate different radionuclides. Additional information on previous geophysical logging is given in the topical reports for the source aggregate areas (B Plant, PUREX, Semi-Works, and 200 North) (Chamness et al. 1992a; 1992b; 1992c; Teel et al. 1992). Further information on the RLS program will be presented in a 200 East Area borehole geophysics field characterization topical report.

Contaminant Transport Potential. Besides knowing the type and location of the contamination, it is also necessary to know its direction. In this respect the data for the 200 East Groundwater Aggregate Area are again fairly comprehensive.

Site characterization data relating to contaminant transport potential vary more than those on nature and extent. The stratigraphic constraints on groundwater flow (Section 3.5.2.1) are well known on a broad scale, and are limited mainly by the spacing of wells that have been drilled and the quality of the geologic logging; most of the earlier logs were compiled by the driller rather than a geologist, and generally display a limited understanding of important depositional and textural features. Stratigraphic data from the wells can be interpolated relatively inexpensively across the large spaces without wells by using seismic reflection or refraction geophysical surveys. However, the applications have been limited in the past. The main use of surface geophysics on the Hanford Site was for the Basalt Waste Isolation Project (BWIP), where features in the basalt were more important than those in the "suprabasalt" sediments. The results of the investigation reflect this need (DOE 1988).

Other data for understanding the potential for contaminant migration in groundwater include those describing the geohydrology of the aquifer(s) of concern. These data include information on recharge and discharge from the aquifer (Section 3.5.2.2); mappings of the potentiometric surface across the Hanford Site to determine groundwater flow directions and gradients (Section 3.5.2.3); and aquifer and vadose zone properties such as hydraulic conductivity (saturated and unsaturated), transmissivity, matric potential (capillary pressure/moisture relation), porosity, and storativity/specific yield (Sections 3.5.1 and 3.5.2). In addition to the data summarized in these sections, the topical reports *Unconfined Aquifer Hydrologic Test Data Package for the 200 East Area* and *Confined Aquifer Hydrologic Test Data Package for the 200 Areas Groundwater Aggregate Areas Management Studies* (Newcomer et al. 1992a and 1992c) contains more information. In spite of the complexity of the flow system and the uncertainties of future recharge to the aquifer, all these parameters are known to a reasonable degree of accuracy, which allows groundwater models to estimate the likely flow patterns and the advective component of contaminant transport which they determine.

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Even to the extent that groundwater flow is known, however, contaminant-specific factors can cause the different constituents to move at different rates in relation to the groundwater and to change in concentration, phenomena known as retardation and attenuation. Because of the complexity of some of the potential chemical interactions, retardation is not as well understood as the groundwater flow system. Some aspects of attenuation such as radionuclide half-life are well understood while others, such as dispersion, are not. However, here again reasonable approximations to the parameters are possible (Section 4.2). In addition, the modeling process of calibration, i.e., fitting the model results to the known history of a physical process, can allow these parameters to be corrected to the conditions actually found in the aquifer. The main limitation to accomplishing such a calibration process is the long time frame during which these changes occur, usually requiring a longer record of data than is generally available. The errors in estimating retardation are multiplicative to those for groundwater advection, and the problem of other errors adds to the noise in the observed data being fitted.

Receptors. In assessing the significance of the groundwater contaminant concentrations and their likely transport, the final stage in the development of data is at the point of impact: are there receptors who may be affected by this contamination? This question is generally not a data issue, but rather a regulatory one. Because no one can predict future land use at the Hanford Site, a conservative approach may be required that specifies the point of compliance for applicable or relevant and appropriate requirements (ARARs) and the exposure point for risk assessment to be established on the site. Nevertheless, the data for present day land/water use, ecology, and demography are available (Sections 3.6, 3.7, and 3.8) and are reasonably complete.

Therefore, the data described above appears to be sufficient to carry out risk assessment and ARARs assessment for the 200 East Groundwater Aggregate Area.

8.1.3 Evaluation of Available Data

EPA (1987) has specified indicators of data quality, the five "PARCC" parameters (precision, accuracy, representativeness, completeness, and comparability), which can be used to evaluate the existing data and to specify requirements for future data collection.

- Precision--the reproducibility of the data

- Accuracy--the lack of a bias in the data.

  Much of the existing data appears to be acceptably accurate and precise. The contamination concentration data were checked by comparing the range of the

detected concentrations (c_{max} : c_{min}) of a given constituent in a well. The range is a similar measure to other statistical estimates of accuracy, such as relative percent difference or relative standard deviation, which are used for comparison of laboratory duplicate samples. Because the samples in this test are not exact duplicates but simply other samples from the same well taken at another time, this measurement would be expected to be much higher than would be allowed in assessing quality assurance (QA) for an analytical lab. For example, the steep front-end part of the contaminant plume may have passed through the well location during the period of record, at which time the concentration would have gone up by a large factor, possibly by several orders of magnitude. Nevertheless, for most of the analyses checked, the range was less than an order of magnitude for more than 90% of the wells (with two or more detections). This indicates that these concentration values can be considered to be accurate to about half an order of magnitude (i.e., plus or minus half the range). Some cases with ranges larger than this level appeared to be caused by isolated "outlier" data, caused perhaps by errors in transcription (some appeared to be off by three orders of magnitude, as if the results were thought to be in mg/L rather than μg/L). These data have generally not been checked thoroughly against lab documentation to assure that such errors have not occurred, but this is apparently only an occasional problem.

Accuracy is normally assured through the use of field and trip blanks and (in the laboratory) through matrix spikes which give estimates of percent recovery. These methods are becoming common for analyses of samples from the site.

Earlier groundwater contaminant data may be more suspect (the earlier they are the more suspect), because of the subsequent improvement in analytical methodologies and QA procedures since the time these samples were collected.

Other data for groundwater which mainly involve site characterization issues (e.g., aquifer properties and other parameters to predict transport of water and contaminants) also have some questions about precision and accuracy. Slug tests may not be accurate for highly transmissive aquifers such as the uppermost aquifer at the Hanford Site and may depend on factors of well construction such as filter pack grain size and screen slot size. This is also in part an issue of representativeness, see below. Even pump tests have been criticized because the well construction as partially penetrating the aquifer does not satisfy the assumptions of the most common analysis methods.

There is also an issue of accuracy in regard to aspects which are derived from boreholes (such as stratigraphic logging, grain size distribution, carbonate

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content, porosity, and other material properties). These data are interpolated among a limited and widely spaced set of sampling locations.

The *Hanford Site Past-Practice Strategy* (DOE/RL 1992a) recommends that existing data be used to the maximum extent possible, at two levels: first to formulate the conceptual model, conduct a qualitative risk assessment, and prepare work plans, but also as an initial data set that can be the basis for a fully-qualified data set through a process of review, evaluation, and confirmation. The recently collected data, although not fully-qualified, appear to be acceptable to be such an initial data set.

- Representativeness--the degree to which the appropriate environmental parameters or media have been sampled.

In most cases the data regarding groundwater meet the criterion of representativeness because the groundwater has been sampled directly. It is this groundwater that is transporting contamination toward potential offsite receptors. Well tests stress the aquifer zones where much of the contamination has been detected and where pump-and-treat remediation can be applied.

Limitations of the data in regard to representativeness are generally minor. For example, slug tests sample the hydraulic conductivity in only a narrow zone around the well being tested, perhaps only the gravel pack. For this reason, the slug test data were excluded from recent hydraulic conductivity assessment for the uppermost aquifer (Connelly et al. 1992a), as discussed in Section 3.5. Also, wells are not always located exactly where they can give the most representative information--this is particularly true of the lack of wells at the down-gradient portions of the plumes and in some portions (particularly the southern part) of the 200 East Area. Even in regard to groundwater elevations, the location of wells near waste disposal facilities may result in unrepresentative sampling. Finally, soil moisture retention data for modeling moisture transport through the vadose zone may be a very important feature of the contaminant transport regime to be assessed, but these data have been obtained only from very few samples from boreholes in the 200-BP-1 Operable Unit of the B Plant Aggregate Area, B Pond area, and the area east of B Pond (Connelly et al. 1992a). For vadose zone transport modeling, the sampling methods used for the soil samples could be critical to maintaining the structure of the soil to assure that the sample is really representative of the soils in situ.

In many cases it is necessary to use nonsite-specific data (i.e., from the vicinity of the 200 Areas or even elsewhere on the Hanford Site) rather than data specific

to the 200 East Area. For most purposes of characterization for transport mechanisms, this procedure is acceptable given the screening level of the present study.

- Completeness--the fraction of samples whose measurements are considered "valid."

  Only a small fraction of the previously gathered data on groundwater concentrations in the 200 East Groundwater Aggregate Area has been "validated" in the EPA Contract Laboratory Program (CLP) sense, although varying levels of quality control have been applied to the sampling and analysis procedures. The data are generally adequate for characterization purposes, but may not be suitable for use in a formal risk assessment. The best indication of the validity of the data is the reproducibility of the results, and this indicates that validity (completeness) is one of the less significant problems with the data.

- Comparability--the confidence that can be placed in the comparison to two data sets (e.g., separate samplings).

  Although varying levels of quality control and varying procedures for sample acquisition and analysis may have limited the comparability of early groundwater data, this problem has generally been eliminated for most recent data.

While these limitations cannot in most cases be quantified (and some such as representativeness are specifically only qualitative), most of the data gathered in the 200 East Groundwater Aggregate Area can be seen to satisfy the PARCC parameters to a reasonable degree. These data can be used for preliminary risk assessments (human health and ecological), planning of additional characterization studies, and FFSs for groundwater remediation.

In addition to these site-specific data, there are also a limited number of nonsite-specific sampling programs that are being developed to determine background levels of naturally occurring constituents (see Section 4.1.1.2). These data can be used to differentiate the effect of the environmental releases from naturally occurring background levels.

8.1.4 Conceptual Models

The initial conceptual model of the sites in the 200 East Groundwater Aggregate Area is presented and described in Section 4.2 (Figure 4-19). The model is based on best estimates of where contaminants were discharged and their potential for migration from

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release points. The conceptual model is designed to be conservatively inclusive in the face of a lack of data. This migration pathway was included if there is any possibility of contamination travelling on it, historically or at present. In most cases there may not be a significant flux of such contamination for many of the pathways shown on the figure.

The one pathway on Figure 4-19 that has undoubtedly transported the largest amount of water through vadose zone soils to the uppermost aquifer is associated with releases from surface water bodies at the various ponds, ditches, and trenches in the 200 East Area. Contamination can be demonstrated to have been present at some of these waste management units based on results of sediment and surface water sampling. If significant levels of dissolved constituents were present in the surface water bodies, the large quantities of water would have contributed to their mobilization and transport through the vadose zone. However, there is little information confirming that large amounts of contamination actually have been transported along this pathway. The pathway from cribs, trenches, and reverse wells and especially from the 216-B-5 Reverse Well (west side of the B Plant Aggregate Area) to groundwater is possibly more significant since many of the waste streams discharged to cribs, trenches, and reverse wells are known to be contaminated. Most of the plumes that have been delineated in the unconfined aquifer can be traced back to releases from cribs and the reverse well (Section 4.1). These and other pathways can be traced on the conceptual model. All are possible; only a few are likely because of the conservatism inherent in including all conceivable pathways. More importantly, even if a pathway carries significant levels of a contaminant, it still may not have carried contamination to the ultimate receptors, human or ecological. This can only be assessed by sampling at the exposure point on this pathway, or sampling at some other point and extrapolation to the exposure point, to indicate the dosage to the receptors. To a great extent this can be demonstrated for groundwater contamination in the 200 East Area, as only tritium and nitrate plumes are known to have reached the Columbia River, and no plumes are known to have migrated to any water supply wells. For this area the conceptual model can best be used to estimate likely <u>future</u> impacts.

8.1.5 Aggregate Area Management Study Objectives and Decisions

The specific objectives of the 200 East Groundwater AAMS are listed in Section 1.3. They include the following:

- Assemble site data (as described in Section 8.1.2)
- Describe site conditions (see Section 3.0)
- Conduct limited new site characterization work (see separate topical reports)

- Develop a preliminary site conceptual model (see Section 8.1.4)

- Identify contaminants of concern and their distribution (Section 4.0)

- Identify potential ARARs (Section 6.0)

- Define preliminary remedial action objectives and screen potential remedial technologies to prepare preliminary remedial action alternatives (Section 7.0) and provide recommendations for focused FS (Section 9.4.1) and treatability studies (Section 9.5)

- Define data needs, establish general DQOs, and set priorities

- Recommend ERA, IRM, LFI, or other actions (Section 9.0)

- Redefine and prioritize, as data allow, operable units, their boundaries, and work plan activities with emphasis on supporting early cleanup actions and a Record of Decision (ROD)

- Integrate RCRA treatment, storage, or disposal (TSD) closure activities with past practices activities.

The decisions that will have to be made on the basis of this AAMS can best be described according to the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a) flow chart (Figure 1-2 in Section 1.0) that must be conducted on a site-by-site basis. Decisions are shown on the flow chart as diamond-shaped boxes, and include the following:

- Is an ERA justified?

- Is less than six months' response needed (is the ERA time critical)?

- Are data sufficient to formulate the conceptual model and perform a qualitative risk assessment?

- Is an IRM justified?

- Can the remedy be selected?

- Can additional required data be obtained by LFI?

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- Are data (from field investigations) sufficient to perform risk assessment?

- Can an operable unit/aggregate area ROD be issued?

The last two questions will only be asked after additional data are obtained through field investigations, and so are DQO issues only in assessing scoping for those investigations.

Most of these decisions are actually a complicated mix of many smaller questions, and will be addressed in Section 9.0 in a more detailed flowchart for assessing the need for remediation or investigation.

Similarly, the tasks to be performed after the AAMS that will drive the data needs for the study are found in the rectangular boxes on the flow chart. These include the following:

- ERA (if justified)

- Definition of threshold contamination levels, and formulation of a conceptual model, performance of qualitative risk assessment and FS screening (IRM preliminaries)

- FFS for IRM selection

- Determination of minimum data requirements for IRM path

- Negotiation of Scope of Work, relative priority, and incorporation into integrated schedule, performance of LFI

- Determination of minimum data needs for risk assessment and final remedy selection (preparation of RI/FS pathway).

These stages of the investigation must be considered in assessing data needs (Section 8.2.1).

8.2 DATA USES AND NEEDS (STAGE 2 OF THE DQO PROCESS)

Stage 2 of the DQO development process (EPA 1987) defines data uses and specifies the types of data needed to meet the project objectives. These data uses and needs are based on the Stage 1 results, but must be more specific. The elements of this stage of the DQO process include:

- Identifying data uses (Section 8.2.1)
- Identifying data types (Section 8.2.2.1)
- Identifying data quality needs (Section 8.2.2.2)
- Identifying data quantity needs (Section 8.2.2.3)
- Evaluating sampling/analysis options (Section 8.2.2.4)
- Reviewing data quality parameters (Section 8.2.2.5)
- Summarizing data gaps (Section 8.2.3).

Stage 2 is developed on the basis of the conceptual model and the project objectives. The following sections discuss these issues in greater detail.

8.2.1 Data Uses

For the purposes of the remediation of 200 East Area groundwater, most data uses fall into one or more of four general categories:

- Site characterization
- Public health evaluation and human health and ecological risk assessments
- Evaluation of remedial action alternatives
- Worker health and safety.

Site characterization refers to a process that includes determination and evaluation of the physical and chemical properties of any wastes and contaminated media present at a site, and an evaluation of the nature and extent of contamination. This process normally involves the collection of basic geologic, hydrologic, and meteorologic data and data on specific contaminants and sources that can be incorporated into the conceptual model to indicate the relative significance of the various pathways. Site characterization is not an end in itself, as stressed in the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a), but rather the data must ultimately assess the need for remediation (according to risk assessment methods, either qualitative or quantitative, or compliance with ARARs) and provide appropriate means of remediation (through an FFS, FS, or CMS). A primary set of tools for assessing these

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issues is the group of groundwater models selected for use at the Hanford Site: UNSAT-H, PORFLO-3, VAM3D, and CFEST. These models in turn impose additional data requirements. The understanding of the site characterization, based on existing data, is presented in Sections 2.0, 3.0, and 4.0, and summarized in the conceptual model (Section 4.2).

Data required to conduct a public health evaluation, and human health and ecological risk assessments for groundwater in the 200 East Groundwater Aggregate Area include the following: input parameters for various performance assessment models (e.g., the Multimedia Environmental Pollutant Assessment System); site characteristics; and contaminant data required to evaluate the threat to public and environmental health and welfare through exposure to the various media. These needs usually overlap with site characterization needs. An extensive discussion of risk assessment data uses and needs is presented in the *Risk Assessment Guidance for Superfund*, Vol. 1 (EPA 1989b) and *EPA Region 10 Supplemental Risk Assessment Guidance for Superfund dated August 16, 1991* (EPA 1991). The risk assessments will follow the guidance outlined in the M-29-03 milestone document, *Hanford Site Baseline Risk Assessment Methodology* (DOE/RL 1991d). The present understanding of site risks is presented in the selection of constituents of concern (Section 5.0). The data needs for quantitative risk assessments will be considered in developing sampling and analysis plans according to the *Hanford Site Past-Practice Strategy*.

Data collected to evaluate remedial action alternatives for ERAs, IRMs, FFSs, or the full RI/FS, include site screening of alternatives, feasibility-level design, and preliminary cost estimates. Once an alternative is selected, much of the data collected from field site investigations (LFI or RI) can also be used for the final engineering design. Generally, collection of data during the investigations specifically for use in the final design is not cost effective because many issues must be decided about appropriate technologies before effective data gathering can be undertaken. It is preferable to gather such specific information during a separate predesign investigation or at the time of remediation [i.e., the "observational approach" of the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a)]. Based on the existing data, broad remedial action technologies and objectives have been identified in Section 7.0.

The worker health and safety category includes data collected to establish the required level of protection for workers during various investigation activities. These data are used to determine if there is concern for the personnel working in the vicinity of the aggregate area. The results of these assessments are also used in the development of the various safety documents required for field work (see Health and Safety Plan, Appendix B).

It should be noted that each of these data use categories (site characterization, risk assessment needs, remedial actions, and health and safety) will be required at each decision

point on the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a) flow chart, as discussed at the end of Section 8.1.5. Areas are prioritized and not all areas of possible contamination will be investigated to the same degree. In general, the existing data for groundwater are adequate to initiate efforts to all these uses.

8.2.2 Data Needs

The data needs for the 200 East Groundwater Aggregate Area are discussed in the following sections according to the categories of data type (Section 8.2.2.1), data quality needs (8.2.2.2), data quantity needs (8.2.2.3), sampling and analysis options (8.2.2.4), and data quality parameters (8.2.2.5).

8.2.2.1 Data Types. Data use categories described in Section 8.2.1 define the general purpose of collecting additional data. Based on the intended uses, a concise statement regarding the data types needed can be developed. Types of data needed for characterization purposes in regard to the 200 East Groundwater Aggregate Area are quite varied. A major consideration is that the most important tools for characterization are models to address groundwater and vadose zone flow and contaminant transport. The data requirements for such models have been described (DOE/RL 1991e) to include climatic data, plant and vegetation data, precipitation recharge, flow domain characteristics, soil characteristics (the critical hydrologic parameters), contaminant distribution/transport parameters, and contaminant source characteristics (Table 8-1).

Risk assessment is supported by these same models, and so has the same needs, but adds other types of data required to determine exposure and impact (e.g., toxicity). Much of the latter data is imposed by regulatory agencies rather than being acquired by site investigation. Toxicity data are generally supplied from standardized databases such as the *Integrated Risk Information System* (IRIS) and the *Health Effects Assessment Summary Tables* (HEAST).

The data type requirements for the preliminary remedial action alternatives developed in Section 7.4 are summarized in Table 8-2. In addition, the same groundwater models discussed in regard to characterization and risk assessment uses will also be vital to the assessment of remedial alternatives. Capabilities of features such as barriers, pumping, and recharge, possible technologies used in remediation of the groundwater, should be built-in to the model in its development so that the success or failure of these remedial actions can be readily predicted.

Types of data required for human health and safety involve contaminant concentrations and radioactivities in site media (groundwater and soils) that could cause exposures to

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personnel conducting intrusive investigation work, and parameters to predict transport, exposure, and toxicity. These data include volatilization partial pressures, vapor density, explosivity, corrosivity, and acceptable levels of chemicals in breathing zones. These parameters are spelled out in health and safety guidance documents.

8.2.2.2 Data Quality Needs. The various tasks and phases of a CERCLA investigation may require different levels of data quality. Important factors in defining data quality include selecting appropriate analytical levels and validating and identifying contaminant levels of concern as described below. The Westinghouse Hanford document, *A Proposed Data Quality Strategy for Hanford Site Characterization,* will be used to help define these levels (McCain and Johnson 1990). The Data Quality Objectives (DQOs) will also be developed and defined on an operable unit basis in the work plans and specifically in the Quality Assurance Project Plans (QAPjPs) which will guide investigation activities.

Chemical and radionuclide laboratory analysis will be one of the most important data types for many groundwater samples with various levels of contamination. In general, increased accuracy, precision, and lower detection limits are obtained with increased cost and time. Therefore, the analytical level used to obtain data should be commensurate with the intended use. Table 8-3 defines five analytical levels associated with different types of characterization efforts. While the bulk of the analysis during LFIs/RIs will be at the screening level (DQO Level I or II), these data will require confirmatory sampling and analysis to allow final remedial decisions through quantitative risk assessment methods. Individual DQO analytical PARCC parameters for Level III or IV analytical data associated with each contaminant anticipated in the 200 East Groundwater Aggregate Area (as developed in Section 5.0) are given in Table 8-4. These parameters will be used to develop site-specific sampling and analysis plans and quality assurance plans for investigations and remediations in the aggregate area.

Before laboratory or even field data can be used in the selection of the final remedial action, they must first be validated. Validation involves determining the usability and quality of the data. Exceptions are made for initial evaluations of the sites using existing data, which may not be appropriate for validation but will be used on a screening basis based on the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a). Other screening data (e.g., estimates of contaminant concentration inferred from field analyses) may also be excepted.

Once data are validated, they can be used to successfully complete the remedial action selection process. Activities involved in the data validation process include the following:

- Verification of chain-of-custody and sample holding times

- Confirmation that laboratory data meet Quality Assurance/Quality Control (QA/QC) criteria

- Confirmation of the usability and quality of field data, which includes geological logs, hydrologic data, and geophysical surveys

- Proper documentation and management of data so that they are usable.

Validation may be performed by qualified Westinghouse Hanford personnel from the Office of Sample Management (OSM), other Westinghouse Hanford organizations, or a qualified independent participant subcontractor. Data validation of laboratory analyses will be performed in accordance with *A Proposed Data Quality Strategy for Hanford Site Characterization* (McCain and Johnson 1990) and standards set forth by Westinghouse Hanford.

To accomplish the second point, all laboratory data must meet the requirements of the specific QA/QC parameters as set up in the QAPjP for the project before it can be considered usable. The QA/QC parameters address laboratory precision and accuracy, method blanks, instrument calibration, and holding times.

The usability of field data must be assessed by a trained and qualified person. The project hydrogeologist/geophysicists will review the geologic logs, hydrologic data, geophysical surveys, and results of physical testing, and senior technical reviews will be conducted periodically throughout the project.

Data management procedures are also necessary for validation. Data management includes proper documentation of field activities, sample management and tracking, and document and inventory control. Specific consistent procedures are discussed in the Information Management Overview (Appendix D).

8.2.2.3 Data Quantity Needs. The number of samples that need to be collected during an investigation can be determined by using several approaches. In instances where data are lacking or are limited, a phased sampling approach may be appropriate. However, this approach is difficult for groundwater because of the expense in installing the sampling access (wells). In the absence of any available data, an approach or rationale must be developed to justify the sampling locations (wells), the number of them to be installed and sampled, and at what frequency. This will be accomplished and documented by Westinghouse Hanford in the production of work plans and field sampling plans, under the guidance and review of the Tri-Party Agreement participants. Specific locations for wells and numbers (frequency) of sampling will be determined based on data collected up to the time for the well placement.

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In situations where and when available data are more complete, geostatistical techniques may be useful in determining the additional data required.

Some locations are obvious as sites for proposed installation and sampling of new wells as indicated by the plume maps (Figures 4-1 to 4-15). For example, sampling data for ^{129}I and tritium are very sparse southeast of the 200 East Area, and the extent of these plumes and interconnection of plume lobes for each of these constituents is very uncertain because of the limited number of wells in this area. Other examples are easy to find, since many plumes are heading out of the 200 East Area into the 600 Area where well coverage is less complete. There are statistical packages available that not only interpolate the plume concentration in such areas, but also estimate the errors associated with this interpolation. One such package is Geostatistical Environmental Assessment Software (GEO-EAS) (Englund and Sparks 1988). The relative risk interpretation methods discussed in Section 5.0 can be used in this method so that the placement of new wells can at the highest priority resolve the most significant issues regarding the risks associated with groundwater contamination.

8.2.2.4 Sampling and Analysis Options. Data collection activities are structured to obtain the needed data in a cost-effective manner. Developing a sampling and analysis approach that ensures that appropriate data quality and quantity are obtained with the resources available may be accomplished by using field screening techniques and focusing the higher DQO level analyses on a limited set of samples at each site. The groundwater investigations should take advantage of this approach for a comprehensive characterization of the site in a cost-effective manner.

A combination of lower level (Levels I and II) and higher level analytical data (Levels III and IV) should be collected. For instance, at least one of the samples collected from each well should be analyzed at DQO Level IV and validated to provide high quality data to confirm the less expensive but more extensive lower level analyses. This approach would provide the certainty necessary to determine contaminants present in plumes. Samples collected will be analyzed by *Test Methods for Evaluating Solid Wastes* ("SW-846," EPA 1986b), CLP (EPA 1988a, EPA 1989b), *Methods for Chemical Analysis of Water and Wastes* (EPA 1983), or *Prescribed Procedures for Measurement of Radioactivity in Drinking Water* (EPA 1980) or other standard methods.

8.2.2.5 Data Quality Parameters. The PARCC parameters indicate data quality. Ideally, the end use of the data collected should define the necessary PARCC parameters. Once the PARCC requirements have been identified, then appropriate analytical methods can be chosen to meet established goals and requirements. Definitions of the PARCC parameters are presented in Section 8.1.2.

In general the precision and accuracy objectives are governed by the capabilities of the available methodologies and in most cases these are more than adequate for the needs of the investigations. Chemical analyses can usually attain parts per billion detection range in soils and water, and this level is adequate to the needs of the risk assessment for most analytes. Radiological analyses can similarly reach levels of pCi/L. Table 8-4 shows detection levels, generally obtained from the method description or from experience with laboratory analysis. Some constituents (e.g., arsenic) would require analysis to much lower levels, but this is generally impossible because of the limitations of analytical methods and the effects of natural background levels of the analyte. In some cases, special analytical methods can be developed to obtain lower detection limits. In addition, risk assessment is conventionally computed only to a single digit of precision and uses conservative assumptions, which reduce the impact of measurements with lower accuracy.

For other measurements, such as physical parameters, the precision and accuracy capabilities of existing measurement technologies are sufficient for the evaluation methods used to produce characterization data, so the objectives are usually based on the limitations of the analysis methodologies.

Representativeness is maintained by fitting the sampling program to the governing aspects of the sources and transport processes of the site, as demonstrated in the site conceptual model (Section 4.2). Sampling for groundwater should concentrate on representative locations of all anticipated transport mechanisms. Moisture and contaminant transport through the vadose zone are especially poorly understood and are as such good candidates for sampling (this is more appropriately done during source investigations). If necessary, the following activities can focus on aspects or locations that were not anticipated but were demonstrated by the more general results.

Completeness is generally attained by specifying redundancy on critical samples and maintaining quality control on their acquisition and analysis. As with representativeness, the initial sampling program may lead to modifications of which samples should be considered critical during subsequent sampling activities.

Comparability will be met through the use of Westinghouse Hanford standard procedures generally incorporated into the *Environmental Investigation and Site Characterization Manual* (WHC 1988c).

8.2.3 Data Gaps

Considering the data needs developed in Section 8.2.2, and the data available to meet these needs as presented in Section 8.1.2, it is apparent that a number of data gaps can be

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identified. These should be the focus of LFIs conducted for groundwater. The data gaps have been gathered from the assessment of the data and a review of previous assessments of groundwater data needs (DOE/RL 1991e). These data gaps include the following:

- **Gaps in Plume Extents**--the extent of some plumes, especially those which have exited the 200 East Area, is not well defined. New wells will have to be placed in these areas which will better delineate the actual extents of contamination. Some wells (e.g. southeast of the 200 East Area) will be required to fill in gaps in the network. Of particular concern is the need to define the vertical extent of the plumes. Appropriate methodology for addressing this data gap is the installation of either clusters of wells drilled to different depths, or the drilling and casing of a well that can be sealed off and sampled at different depths, while maintaining an adequate seal between aquifer layers or portions of the aquifer.

- **Confined Aquifers**--the lower portion of the unconfined aquifer (Ringold gravel unit A) becomes locally confined by the Ringold lower mud sequence in the southern part of the 200 East Area and near the B Pond complex (See Section 3.5.2 and Figures 3-30 and 3-31). To date a limited number of wells have been screened in this confined zone, and therefore groundwater flow directions (Section 3.5.2), and the extent of contamination (Section 4.1.1) have been only partially evaluated. It will be necessary to construct new wells in this zone that are sufficient in number to determine gradients and possibly complicated groundwater flow patterns, and to allow for sampling and analysis.

  Although the confined aquifers located in interbeds of the basalt are possible receptors of contaminant migration from the unconfined aquifer, they have generally been underrepresented in sampling and water level measurements in the 200 East Area. Existing wells should be checked for suitability, and additional wells should be installed to provide additional coverage of the Rattlesnake Ridge aquifer, and at least screening coverage of the Selah aquifer. Also, analytical results for some constituents were reported for wells installed in deeper, confined aquifers, but not for adjacent wells in the unconfined system. Future sampling should include both shallow and deep wells in a given area to allow a more-complete delineation of vertical contamination extent.

- **Analytical Data Limitations**--historic groundwater concentrations data vary in quality from very questionable to adequate. Different analytical methods and detection limits plus poor quality control compromise the results. Sampling methods, such as the use of a bailer instead of a pump, can affect the quality of the samples obtained.

  Some data in the present data set appear erroneous such as reports of concentrations three orders of magnitude different from other values in the same well; this may

indicate a confusion between μg/L (ppb) and mg/L (ppm) units. Situations like these should be identified and wells resampled if necessary.

The historical data should be reviewed in light of these issues, and compared to each other to limit the likelihood of erroneous results.

- **Background Concentrations of Inorganic Constituents**--while this data gap is already being addressed (Hoover and LeGore 1991, DOE/RL 1992d, see Section 4.1.1.2), it still impedes proper interpretation of the concentrations of inorganics being observed in sampling.

- **Detection Limits**--some contaminants which may be present at low concentrations have toxicities high enough to render these concentrations important to health and environment concerns. These include hydrazine, bis(2-ethylhexyl)phthalate, 2,4-dinitrotoluene, beryllium, pentachlorophenol, thallium, antimony, styrene, and selenium. Methods may have to be developed to obtain lower detection limits to adequately delineate these possibly important constituents.

- **Single Detections of Chemicals**--some of the chemicals included in the list of detections (Table 4-1) were detected only once in a well and only in one well. These chemicals include pentachlorophenol, 1,2-dichloroethane, 1,1,2-trichloroethane, several other organic compounds, silver (filtered), and thallium (both filtered and unfiltered). These detections should be reviewed and validated, and the well resampled and reanalyzed to confirm or refute these potentially spurious results. Particularly when only one member of a chemical family requires analysis, the cost of the analysis goes up significantly. To continue analyzing throughout the site for chemicals that were misreported in the first place is a misallocation of scarce resources.

- **Plumes at Only One Well**--for the chemicals listed above that were detected only once, or have been detected only in a single well, it is difficult to assess the significance of the resulting "plume" found only at that location. For these cases, the presence of the plume should be confirmed by repeated sampling. It is possible that this contamination is due to some local conditions, such as transport along the well casing, and that the contamination is not as high elsewhere, but if the level is high enough to be of regulatory concern, the potential for a plume should be checked with other wells located immediately downgradient.

- **Well Construction Data**--some wells may be appropriate or inappropriate for particular uses (sampling, aquifer tests, geophysical logging) but this cannot be determined because of inconsistencies in the recorded information on their construction (especially screened depths) as well as their current condition (e.g., screen clogging).

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The depth of the wells could be especially significant in cases where the declining water table could leave a well dry; this could result in a loss of data until a new well can be installed.

Based on review of existing well construction data and comparison to hydrostratigraphy, many of the wells have been screened across different hydrostratigraphic units. Some of these wells are identified on Table 4-2, and have groundwater elevations (and analytical results) which may therefore be unrepresentative of either screened unit. As discussed in Section 3.5.2, groundwater level elevations from the deeper aquifers or from wells representative of more than one hydrostratigraphic unit may have been included with unconfined aquifer elevations on existing water table maps.

Well construction issues could easily be resolved to a considerable degree by television logging and other simple methods. All wells with screened intervals which are known or suspected to include multiple hydrostratigraphic units should be identified, and water levels from these wells should be reviewed for consistency and representativeness.

- **Well Locations and Elevations**--a more precise accounting of well locations and elevations is becoming increasingly important to the investigation. The locations of wells are important to allow development of detailed geologic models (cross sections) for field sampling plans, and the elevations are needed to provide the basis for calculating groundwater gradients. The gradients are so low in an area in the western portion of the 200 East Area that errors of less than 15 cm (6 in.) are significant, and distances between wells in this area are far enough that ordinary (third order) surveying techniques may not be sufficient. As recommended by Jensen (1987) some of the 600 Area wells need to be resurveyed due to suspiciously low unconfined aquifer groundwater elevations (pre-1987) and changes in top-of-casing elevations due to casing movement. Based on date-of-survey information provided by Westinghouse Hanford, the wells have not been resurveyed to date.

- **Aquifer Properties**--aquifer properties such as hydraulic conductivity, transmissivity, storage coefficient, and porosity are not well determined. To date, aquifer testing has consisted of slug testing and some poorly designed pump tests. Pump testing has been difficult to carry out due to problems disposing of fluids, and slug testing may not provide representative aquifer properties. Pump testing issues could be negotiated and solved, and properly designed tests carried out.

- **Potential for Continuing Releases from the Vadose Zone**--many source waste management units have been inactive for years and so have not added moisture to the soil column during this time. It is unknown how long after shutdown the soil under

such a unit will continue to drain, and to transport contamination down to the groundwater. Since such a process, if it is occurring, would constitute a continuing source of groundwater contamination, it is important to predict when it will occur. This also applies to dry sites that have never received free liquids but through which wastes could be leached by precipitation recharge or by continuing discharges of clean water to soils (via septic drain fields). Modeling efforts for transport through the vadose zone are ongoing, using models such as UNSAT-H, PORFLO-3, and VAM3D-CG, and so specific data requirements of these models will be included in the field investigation programs. A generic list of these data needs is presented in Table 8-2. It is also vital to obtain better data on the levels and depths of chemical and radiologic constituents in the soil column which are available for transport. This last issue is the responsibility of source investigations.

Another alternative in this regard is to monitor the transport of contaminants through the soil using borehole geophysical logging like the RLS program. This has the advantages of monitoring actual rather than theoretical migration rates of the contaminants of concern directly and cuts through the multitude of assumptions and approximations inherent in such modeling. It has the major disadvantage of requiring a much longer program to come up with results and the interpretation of the results may not allow extrapolation to other sites. In addition, many radionuclides do not have sufficient gamma emissions to allow detection of their migration.

There is also a potential problem with the well installation methods presently employed. The use of annular seals (clay-based grout) compromises the detection capability of the logging by attenuating radiation from beyond the borehole and introducing other radionuclides in the grout.

- **Estimation of Recharge Rates**--available data from previous studies (such as lysimeter studies, see Section 3.5.1.5.1) indicate a wide range of estimates of recharge through natural or disturbed Hanford Site soils. Since this could affect both the transport from dry or inactive sites as well as changes in concentration in the saturated zone during transport, it is potentially very important. Freshley and Graham (1988) indicate that the range of possible recharge rates lead to predictions of very different flow patterns in the unconfined aquifer, including opposite directions of flow through Gable Gap.

- **Hydraulic Interconnections with Confined Aquifers**--the effect of connections with confined aquifers, particularly the Ringold unit A gravels in the southern part of the 200 East Area, and the confined portions of the Rattlesnake Ridge interbed, can be of significant concern, mainly for the potential for allowing further spread of contamination but also due to its potential effects on flow in the unconfined aquifer. This is especially a potential in areas where the interbed sediments are exposed to

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overlying sediments through eroded areas of the basalt, such as between the 200 East Area and Gable Gap. This area is downgradient of many of the contaminant plumes in the 200 East Area, and so is of especial concern.

- **Groundwater Inflows from Off-Hanford Site**--the quantity of flow entering the Hanford Site from upgradient (from the west), particularly from the Cold Creek and Dry Creek basins, is not well understood, and will affect the modeling by imposing important boundary conditions on the model. The sources could be natural infiltration of runoff or recharge from irrigation.

- **Contaminant Travel Time to the Columbia River**--this issue addresses the degree to which degradation can be anticipated to affect contaminant concentrations. If the travel time is known, then the decay of radioactive constituents can be accurately determined. This travel time can be obtained from groundwater modeling, and so interacts with a great many other factors with their own data needs, particularly hydraulic conductivity, porosity, gradients, and retardation parameters. It is significant to note that for the purposes of modeling these data are required for the entire area of potential migration across the Hanford Site to the Columbia River.

- **Dense Nonaqueous Phase Liquids (DNAPLs)**--some liquid chemicals that are denser than water, low in viscosity, and relatively insoluble in water can form deposits of relatively pure chemicals in zones at the bottom of an aquifer, if disposed originally in sufficient quantity. This could be the situation with many of the chlorinated organic constituents listed on Table 4-1, particularly where these compounds are not associated with a petroleum hydrocarbon matrix. This possibility appears to be less likely in the 200 East Area than in the 200 West Area, where high concentrations of carbon tetrachloride have been observed, but could be occurring near the central landfill. If these deposits are present, they could act as "secondary sources" and continue to feed groundwater contamination even after the vadose zone is remediated (e.g., via vapor extraction). The presence of DNAPLs would also have an influence on the nature of the plume, making it more concentrated near the bottom of the aquifer than at the top (the case with vadose-zone sources). Density plumes could also occur from high-salt wastes and could have a similar effect. One location where such a density plume is thought possibly to originate from is the BY Cribs near the 216-B-5 Reverse Well (impacting Well 299-E33-12, for example, see Sections 4.1.1.7.9 and 4.1.1.7.12). However, these waste materials may be less likely to lodge for extended periods of time in the aquifer and travel by their density gradient because of their solubility and high viscosity.

- **Enhancement of Contaminant Transport by Complexing**--some chemicals can help transport other possibly more toxic chemicals by forming complexes with them. At

many sites a great variety of chemicals were potentially disposed, including some that were selected for the processes in which they were used to form such complexes.

- **Dispersivity**--this parameter is difficult to estimate in situ or from physical properties of the soils and is impossible to duplicate at laboratory scale. The best methods are by calibration to the behavior of plumes that have been tracked over time (mainly tritium and nitrate). The value of these parameters will significantly affect the changes in concentration as the plumes transit the site.

- **Vertical Extent of Plumes**--there are very few well groups that adequately assess the thickness of the contaminant plumes within the unconfined aquifer. Many of the newer wells are screened only in the shallow part of the unconfined aquifer, across the water table at the top of the saturated zone; some of the old wells have very long screened sections across multiple hydrostratigraphic units. Neither of these will give information about the depth to which contamination can be found in the plume in the unconfined aquifer or deeper aquifers. The existing well network should be supplemented with deeper wells to assess the vertical distribution of contamination. The data would assist evaluation of dispersivity and would assist in the screening of remedial technologies. These data are especially important for chemical constituents which can form DNAPLs such as chlorinated hydrocarbons listed on Table 4-1.

- **Vertical Gradients**--existing data on vertical gradients (Section 3.5) is largely based on previous work including DOE (1988), Jensen (1987), Graham et al. (1984) for the unconfined aquifer and the Rattlesnake Ridge interbed. More detailed assessment of vertical gradients between the shallow and deep portions of the unconfined aquifer, and between the unconfined aquifer and confined Ringold unit A gravels is necessary. Additional well installations in the deep unconfined and confined aquifers of the Ringold unit A gravels would provide supplemental information on vertical gradients, as well as contaminant distribution data. Vertical components can result in thicker plumes (based solely on advection, not dispersion) and thus will have to be taken into account.

- **Effects of Old Monitoring Well Construction**--wells constructed before the late 1980's were generally constructed of mild carbon steel rather than stainless steel. This construction is thought to affect the measured concentrations of both radioactive and hazardous constituents by adsorbing them. This can also have an effect on the use of the wells for gamma ray logging. It will be very expensive to replace these wells, and so some level of study should be put into determining if this is really a problem.

- **Focussed Feasibility Studies of Remedial Technologies**--some of the technologies suggested for use on groundwater should be assessed at various scales for their

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applicability in the 200 East Area groundwater environment. In part this investigation should include a comprehensive best available technology (BAT) assessment of applicable technologies, and should consider costs (per unit volume), secondary wastes, and adverse effects. Various properties for contaminant treatability should also be obtained through treatability testing; these include strippability, adsorbability, biodegradability (natural biodegradation), heavy metal properties, and natural degradability for radionuclides.

- **Innovative Technologies**--these state-of-the-art technologies for cleaning up groundwater should be assessed in a separate program which is linked to the AAMS studies by providing data requirements to field programs, and treatability studies (at various scales) to develop needed parameters and to preliminarily assess their applicability to site conditions.

8.3 DATA COLLECTION PROGRAM (STAGE 3 OF THE DQO PROCESS)

The data collection program is Stage 3 of the process to develop DQOs. Conducting an investigation by a sequentially-adapted process that uses the data as it comes in is a common method for optimizing the quantity and quality of the data collected. It would be very inefficient and overly expensive to specify beforehand all the well location depths sampling schedules, and analyses that will yield the most complete and accurate understanding of the contamination and physical behavior of the site. Data adequate to achieve the goals and objectives for remedial action decisions are obtained at a lower cost by using the information obtained in the field to focus the ongoing investigation and remediation process.

Initial sampling should collect new data believed most necessary to confirm and refine the conceptual model particularly along transport pathways with priority constituents or quantities of flow. Sampling may then be extended to further reduce uncertainty, to fill in remaining data gaps, to collect more detailed information for certain points where such information is required, or to conduct any needed treatability studies or otherwise support the data needs of the remedial action selection process. The need for subsequent investigation phases will be assessed throughout the investigation and remediation activities as data become available. Assessing completeness of the investigation data through a formal statistical procedure is not possible, given the complexity and uncertainty of the parameters required to describe the site and the time to make decisions. Rather, the use of engineering judgment is considered sufficient to the decision process.

8.3.1 General Rationale

The general rationale for the investigation of groundwater contamination in the 200 East Groundwater Aggregate Area is to collect needed data that are not available. Because of the size of the aggregate area, the complexity of past operations, and the number of potential sources and plumes, a large amount of new information will be required such as the specific radionuclides and chemicals present, their spatial distribution and form, and the presence of special migration pathways such as potential (localized) perched groundwater systems.

The following work plan approach will be used for LFIs and RI/FS in the 200 East Groundwater Aggregate Area. The results are described in Sections 8.3.2 and 8.3.3 in a general form.

- Existing data as described in Sections 2.0, 3.0, and 4.0 should be used to the maximum extent possible. Although existing data are not validated fully, the data are still useful in developing a preliminary conceptual model (Section 4.2) and in helping to focus and guide the planning of investigations, expedited actions, and interim measures. The data as is are sufficient for preliminary risk assessment purposes.

- Additional data at validated and screening levels should be collected to obtain the maximum amount of useful information for the amount of time and resources invested in the investigation.

- Data should be collected to support the intended data uses identified in Section 8.2.1.

- Data collected from initial investigation activities should be used to confirm and refine the conceptual model (Section 4.2), refine the analyte constituents of concern, adjust the locations for subsequently installed monitoring wells, and provide information to conduct interim response actions or risk assessment activities.

- Additional investigation activities are proposed to support quantitative baseline risk assessments for final cleanup actions and further refine the conceptual model.

- Field investigation techniques should be used to minimize the amount of hazardous or mixed waste generated. Any waste generated will be in accordance with EII 4.2, "Interim Control of Unknown Suspected Hazardous and Mixed Waste " (WHC 1988c).

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8.3.2 General Strategy

The overall objective of any field investigation (LFI, IRM, or RI) of the groundwater in the 200 East Groundwater Aggregate Area will be to gather additional information to support risk assessment and remedial action selection according to the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a) flow chart discussed in Section 8.1.5. The general approach or strategy for obtaining this additional information is presented below.

- The investigations should interface closely with the source operable unit field investigations to achieve data goals of both projects with a minimal field program. For example, if geologic assessment is required in a particular source area, the data should be shared with the groundwater operable units, to allow refinement of the hydrogeological model. When samples are to be taken in saturated zones (for other reasons) they should also allow testing of parameters required for groundwater models.

- New wells should be situated according to the most recent data about plume extents and locations, to reduce uncertainty most efficiently. Thus, as data become available regarding groundwater concentrations, they should be incorporated in the model of plume distributions and the locations of subsequent wells to be reviewed according to this most recent information. Existing wells should be evaluated, and those which may be providing pathways for contaminant transport to deeper strata should be abandoned or remediated (this is a continuation of an already on-going program).

- Specification of analytical parameters should start with the long list of potential contaminants of concern and be narrowed to a shorter list as quickly as possible, perhaps with different lists in different areas limited to those of concern at the specific area. Increased use of field screening methods at the well head may also reduce the cost of analysis and increase the amount of meaningful data obtained for the cost expended by allowing submittal of only those samples most likely to be contaminated. Occasional samples should continue to be analyzed for the long list, but the best allocation of resources is to analyze for those constituents which will give the most information. Nondetects, if highly predictable, do not convey much additional information.

8.3.3 Investigation Methodology

Initial field investigations (mainly LFIs, but also associated with IRMs for appropriate plumes and possibly some RIs) may include some or all of the following integrated methodologies:

- Plume Nature and Extent Investigation (Section 8.3.3.1)
- Groundwater Transport Investigation (Section 8.3.3.2)
- Source Release Investigation (Section 8.3.3.3)
- Geologic Investigation (Section 8.3.3.4)
- Geodetic Survey (Section 8.3.3.5)

Each investigation methodology is briefly outlined in the following sections. Specific field methods such as well construction methods have not been recommended to allow flexibility in the development of field sampling plans which can be sensitive to very local conditions. Some of the data needs are very local especially for specific limited plumes, others must be addressed on an area-wide basis (e.g., stratigraphy interpretation). More detailed descriptions and specific methods and instrumentation will be included in site-specific work plans, sampling and analysis plans, and field sampling plans for LFIs/IRMs for plumes that require these investigations.

These investigations are presented in the approximate priority of their need, with the plume, nature and extent investigation first because of its importance to the decisions about remedial action on a site-by-site basis. The other investigations are of lower priority, and will be conducted according to the availability of resources.

8.3.3.1 Plume Nature and Extent Investigation. The purpose of the plume investigation is to confirm the characteristics and locations of the plumes in the 200 East Groundwater Aggregate Area. "Nature" encompasses the contaminants present in the plume as well as their concentrations and interrelations. "Extent" involves the areal bounds of the plumes but also their thicknesses (vertical extent). This investigation will address data gaps (Section 8.2.3) relating to the limitations in well coverage of plumes including single-well plumes, missing or unusual chemical constituents, confirmation or refutation of single detection chemicals, and the issue of vertical extent. Activities for this investigation methodology may include the following:

- **Installation of New Monitoring Wells**--this will allow gaps in the coverage of known plumes to be filled in. In particular, new wells should be situated just downgradient from single-well plumes (those with repeated confirmations of the presence of a chemical but only in one well), in areas with the greatest uncertainty about the location of existing plumes (e.g., in parts of the 200 East Area and 600 Area where wells are sparse and the plumes have moved beyond monitoring control in the 200 East Area), at

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lower portions of the unconfined aquifer, in the zone where the Ringold A becomes a confined aquifer, and in the uppermost confined basalt aquifers. Locations of these wells will be derived for priority plumes of concern in separate field sampling plans to be developed by Westinghouse Hanford. Some wells may be required on an aggregate area basis rather than at an operable unit scale.

- **Sampling and Analysis**--sampling of some existing wells that have not been adequately covered in the past and new wells should include analyses of constituents that have been reported or can reasonably be expected to be released in some of the waste streams going to cribs or other liquid waste disposal facilities. Appendix A includes Tables A-1 and A-2 that list the chemicals and radionuclides detected in samplings of wells and their maximum detections. Table A-3 lists constituents that have not been detected in any of these wells, including the number of times the constituent was analyzed for and the analysis detection limit. Table A-4 lists all wells where chemical constituents have been detected. These tables, in conjunction with the table of contaminants of concern (Table 4-5) can allow for selection of target analyte lists in the vicinity of specific plumes. To some extent, the ongoing groundwater sampling in support of the 200 Areas AAMS will address these issues.

  For the case of single-detection plumes where the compound in question is of concern at low concentrations, analysis at the well with the detection, as well as other nearby wells which may also be affected, should employ special analytical methods with lower detection limits. This will help delineate the actual extent of a plume with lower concentrations, and get a better estimate of the concentration even in the well with the detection. Wells with elevated gross alpha and/or gross beta should include tests for specific radionuclides which may be causing the indicator parameter.

  Some potentially highly toxic constituents may require method development to give suitably low detection limits.

  Determination of background levels (Hoover and LeGore 1991, DOE/RL 1992c, see Section 4.1.1.2) will also be supported by analysis of these groundwater samples.

  The proposed investigation will also include reviewing and television logging of wells to determine their suitability for sampling.

8.3.3.2 Groundwater Transport Investigation. The purpose of the groundwater transport investigation is to gather additional information about groundwater transport to determine future plume directions, changes in concentration, and potential impacts. To a great extent, this investigation will be interdependent on the development of groundwater models for the

Hanford Site which are already under way under a separate Tri-Party Agreement milestone (M29-00), which is developing more detailed data requirements for the models.

Data gaps that this investigation will address include recharge rates both at former disposal sites as well as generally across the site, the potential for interconnections with other aquifers (also addressed by new wells listed in the plume investigation, Section 8.3.3.1), groundwater inflows from Cold Creek and Dry Creek valleys, dispersivity, vertical gradients (also to be addressed with additional wells), and travel time issues. Data needs for contaminant mobilization and transport will also be developed, such as K_d, Eh, and/or pH measurements for speciation, solubility and mobility of inorganics, and organic carbon contents for transport of organics.

8.3.3.3 Source Release Investigation. A very significant data gap is whether former liquid disposal sites continue to release contamination to groundwater after disposal is terminated. This issue can be addressed in two ways, each of which may be confirmatory of the other. First, models should be calibrated using available data that will predict the flows in these unsaturated systems. This also may involve obtaining additional data to supply parameters for these models through field investigation, as determined by the model developers. Second, an investigation should be carried out to track levels of contamination beneath these facilities to see if there is a net movement of the contamination. This latter investigation will probably use radioactive contaminants such as tracers for contamination, and detect their levels and depths through spectral gamma logging, such as the RLS surveys being conducted in support of the AAMS study. Both studies should coordinate with field investigations being conducted for the source operable units to assure proper parameters are collected for the vadose zone transport models and that permanent logging wells are to be installed through representative facilities. Another aspect of the confirmatory field studies is to track groundwater concentrations at the tail end of plumes to determine from the groundwater side the possibility of continuing releases.

8.3.3.4 Geologic Investigation. The purpose of the geologic investigation is to clarify the stratigraphic constraints on groundwater flow. This may utilize geophysical methods in conjunction with geologic and geophysical logging in boreholes. It is essential that this investigation be coordinated with the field investigations at the various source operable units. This would minimize the drilling cost by drilling characterization wells once rather than twice (once for vadose zone properties then a separate boring for the saturated zone).

8.3.3.5 Geodetic Survey. Geodetic surveys will be conducted after the installation and completion of each investigation activity. Horizontal and vertical locations of all wells will be surveyed. The survey should also include existing wells with known or suspected erroneous reference elevations. The geodetic survey should be conducted by a professional surveyor licensed in the state of Washington and should be referenced to both historic (e.g.,

Hanford coordinates) and current coordinate datums (e.g., North American Datum of 1983 - NAD-83), both vertical and horizontal.

8.3.4 Data Evaluation and Decision Making

Data will be evaluated as soon as results (e.g., soil gas, radiation screening, drilling results) become available for use in restructuring and focusing the investigation activities. Data reports will be developed that summarize and interpret new data. This includes the ongoing groundwater sampling and RLS borehole logging as part of the AAMS and the results of the source investigations under the various source AAMS. Data will be used to refine the conceptual model, further assess potential contaminant-specific ARARs, develop the quantitative risk assessment, and assess remedial action alternatives.

The objectives of data evaluation are:

- To reduce and integrate data to ensure that data gaps are identified and that the goals and objectives of the 200 East Groundwater AAMS are met
- To confirm that data are representative of the media sampled and that other QA/QC criteria have been met.

Table 8-1. Data Requirements for Modeling Flow and Transport in the Vadose Zone. Page 1 of 2

C.1 CLIMATIC DATA

- 1.1 Precipitation Data (from Meteorological Measurements)
  - 1.1.1 Rainfall
  - 1.1.2 Snowmelt
  - 1.1.3 Runoff from Precipitation Events (Field-Measured)
- 1.2 Potential Evapotranspiration Data (From Meteorological Measurements)
  - 1.2.1 Air Temperature
  - 1.2.2 Relative Humidity (Wet and Dry Bulk)
  - 1.2.3 Wind Speed
  - 1.2.4 Solar Radiation

C.2 PLANT AND VEGETATION DATA

- 2.1 Transpiration Function (Field-Measured)
  - 2.1.1 Plant Type and Depth of Root System
  - 2.1.2 Plant Density
- 2.2 Plant Cover
  - 2.2.1 Leaf Area Index (Field-Measured)

C.3 FLOW DOMAIN CHARACTERISTICS

- 3.1 Size of Flow Domain (Based on Field Data)
  - 3.1.1 Spatial Discretization (Numerical Input)
  - 3.1.2 Temporal Discretization (Numerical Input)
- 3.2 Boundary Conditions
  - 3.2.1 Flow (Field-Measured Moisture Contents of Fluxes)
  - 3.2.2 Contaminant Transport (Field-Measured Concentration or Mass Fluxes for Various Species)
- 3.3 Initial Conditions
  - 3.3.1 Flow (Field-Measured Moisture Contents or Pressure Potentials)
  - 3.3.2 Contaminant Transport (Field-Measured Concentrations for Various Contaminant Species)
- 3.4 Depth to Water Table (Field-Measured)
- 3.5 Thickness and Hydraulic Properties of the Unconfined Aquifer (Field-Measured)
- 3.6 Location and Rates of Pumping/Injection Wells (Field Data)

C.4 SOIL CHARACTERISTICS (These are considered to be the critical hydrologic parameters)

- 4.1 Heterogeneity and Anisotropy (Field-Measured)
  - 4.1.1 Layering (Thickness and Continuity of Various Layers)
  - 4.1.2 Anisotropic Characteristics of Various Layers

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Table 8-1. Data Requirements for Modeling Flow and Transport in the Vadose Zone.

	4.2	Moisture Characteristic Curves for Each Layer	
		4.2.1	Moisture Content Versus Pressure Potential Curves (Field or Laboratory Measured)
		4.2.2	Hydraulic Conductivity Versus Moisture Content Curves (Field- or Laboratory-Measured or Derived From Moisture Content Versus Pressure Potential Curves)
		4.2.3	Hysteresis Data for Wetting and Drying Cycles (Field- or Laboratory-Measured)
	4.3	Soil Bulk Density and Porosity for Each layer (Field- or Laboratory-Measured)	
C.5	CONTAMINANT TRANSPORT PARAMETERS		
	5.1	Diffusion Coefficients (Laboratory-Measured or Obtained From Literature)	
	5.2	Hydrodynamic Dispersion Coefficients (Laboratory-Measured or Obtained from Literature)	
	5.3	Retardation Coefficients (Laboratory-Measured or Obtained From Literature)	
	5.4	Radioactive Decay Constants (Laboratory-Measured or Obtained From Literature)	
C.6	CONTAMINANT SOURCE CHARACTERISTICS		
	6.1	Major Radionuclides and Their Concentrations	
	6.2	Mass Source Loading Rate for Radionuclide	

Source: DOE/RL1991e

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Table 8-2. Data Needs for Preliminary Remedial Action Technologies for 200 East Groundwater Aggregate Area Operable Units. Page 1 of 2

Technology Group	Physical Attribute	Chemical Attribute
Physical Containment Examples: • Freeze wells • Grout curtains	• Areal extent • Depth • Hydrogeologic conditions • Geologic conditions • Potential siting for operational refrigeration units • Surface access along corridor of installation	• Radioactivity
Hydraulic Containment Examples: • Injection wells • Extraction wells	• Areal extent • Depth • Hydrogeologic conditions • Potential water disposal sites • Sources of water for injection	• Chemical contaminants which affect disposal of extracted water
Pump and Treat Examples: • Comprehensive BAT treatment • Target treatment of single chemical class Treatment options • Ion exchange • Chemical precipitation • Air stripping • Carbon absorption • Reverse osmosis • Evaporation • UV oxidation • Filtration	• Areal extent • Vertical extent • Hydrogeologic conditions • Geologic conditions • Potential water disposal/ reinjection sites • Siting for potential treatment facilities	• Applicable treatment options depend on complex, interrelated contaminant matrix • Contaminant variability • Geochemistry of saturated soils
Natural Attenuation Examples: • Point of use • Point of discharge	• Areal extent • Migration pathways • Geologic conditions between source and point of use • Hydrogeologic conditions between source and point of use • Siting conditions for treatment facility at point of use	• Chemical matrix at point of use • Applicable treatment options depend on complex, interrelated contaminant matrix • Geochemistry between source and point of use • Natural attenuation potential of contaminant

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Table 8-2. Data Needs for Preliminary Remedial Action Technologies for 200 East Groundwater Aggregate Area Operable Units. Page 2 of 2

Technology Group	Physical Attribute	Chemical Attribute
In Situ Treatment Examples: • Air sparging • In situ precipitation • In situ destruction • In situ mobilization • In situ natural attenuation	• Areal extent • Vertical extent • Hydrogeologic conditions • Geologic conditions	• Specific treatment is contaminant dependent • Geochemistry of saturated soils • Contaminant heterogeneity

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Table 8-3. Analytical Levels for the 200 East Groundwater Aggregate Area.

Level	Description
LEVEL I	Field screening. This level is characterized by the use of portable instruments which can provide real-time data to assist in the optimization of sampling point locations and for health and safety support. Data can be generated regarding the presence or absence of certain contaminants (especially volatiles) at sampling locations.
LEVEL II	Field analysis. This level is characterized by the use of portable analytical instruments which can be used onsite, or in mobile laboratories stationed near a site (close-support laboratories). Depending on the types of contaminants, sample matrix, and personnel skill, qualitative and quantitative data can be obtained.
LEVEL III	Laboratory analysis using methods other than the Contract Laboratory Program (CLP) Routine Analytical Services (RAS). This level is used primarily in support of engineering studies using standard EPA-approved procedures. Some procedures may be equivalent to CLP RAS without the CLP requirements for documentation.
LEVEL IV	Contract Laboratory Program (CLP) Routine Analytical Services (RAS). This level is characterized by rigorous QA/QC protocols and documentation and provides qualitative and quantitative analytical data. Some regions have obtained similar support via their own regional laboratories, university laboratories, or other commercial laboratories.
LEVEL V	Nonstandard methods. Analyses which may require method modification and/or development are considered Level V by CLP Special Analytical Services (SAS).

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Table 8-4. Data Quality Objective Parameters for Chemical/Radiochemical Analyses.

	Soil/Sediment				Water			
	Analysis Method	Practical Quantitation Limit (pCi/g)	Precision (RPD)	Accuracy (%)	Analysis Method	Practical Quantitation Limit (pCi/L)	Precision (RPD)	Accuracy (%)
RADIONUCLIDES								
Gross Alpha	900.0 M	TBD	±30	±25	900.0	10	±25	±25
Gross Beta	900.0 M	TBD	±30	±25	900.0	5	±25	±25
Gamma Scan	D3699 M	TBD	±30	±25	D3649 M	TBD	±25	±25
Actinium-225	907.0 M	TBD	±30	±25	907.0	TBD	±25	±25
Actinium-227	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Americium-241	Am-01	TBD	±30	±25	Am-03	TBD	±25	±25
Americium-242	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Americium-242m	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Americium-243	Am-01	TBD	±30	±25	Am-03	TBD	±25	±25
Antinomy-126	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Antimony-126m	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Barium-137m	D3649 M	TBD	±30	±25	D3649 M	TBD	±25	±25
Bismuth-210	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Bismuth-211	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Bismuth-213	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Bismuth-214	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Carbon-14	C-01 M	TBD	±30	±25	TBD	TBD	±25	±25
Cesium-134	D3649 M	TBD	±30	±25	D3649 M	TBD	±25	±25
Cesium-135	901.0 M	TBD	±30	±25	901.0	TBD	±25	±25
Cesium-137	D3649 M	TBD	±30	±25	D3649 M	TBD	±25	±25
Cobalt-60	D3649 M	TBD	±30	±25	D3649 M	TBD	±25	±25
Curium-242	907.0 M	TBD	±30	±25	907.0	TBD	±25	±25
Curium-244	907.0 M	TBD	±30	±25	907.0	TBD	±25	±25
Curium-245	907.0 M	TBD	±30	±25	907.0	TBD	±25	±25
Europium-152	D3649 M	TBD	±30	±25	D3649 M	TBD	±25	±25
Europium-154	D3649 M	TBD	±30	±25	D3649 M	TBD	±25	±25

Table 8-4. Data Quality Objective Parameters for Chemical/Radiochemical Analyses.

	Soil/Sediment				Water			
	Analysis Method	Practical Quantitation Limit (pCi/g)	Precision (RPD)	Accuracy (%)	Analysis Method	Practical Quantitation Limit (pCi/L)	Precision (RPD)	Accuracy (%)
RADIONUCLIDES (cont.)								
Europium-155	D3649 M	TBD	±30	±25	D3649 M	TBD	±25	±25
Francium-221	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Iodine-129	902.0 M	TBD	±30	±25	902.0	TBD	±25	±25
Lead-209	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Lead-210	Pb-01 M	TBD	±30	±25	Pb-01	TBD	±25	±25
Lead-211	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Lead-212	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Lead-214	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Neptunium-237	907.0 M	TBD	±30	±25	907.0	TBD	±25	±25
Neptunium-239	D35649 M	TBD	±30	±25	D3649 M	TBD	±25	±25
Nickel-59	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Nickel-63	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Niobium-93m	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Plutonium	Pu-02	TBD	±30	±25	Pu-10	TBD	±25	±25
Plutonium-238	Pu-02	TBD	±30	±25	Pu-10	TBD	±25	±25
Plutonium-239/240	Pu-02	TBD	±30	±25	Pu-10	TBD	±25	±25
Plutonium-241	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Polonium-214	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Polonium-215	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Polonium-218	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Potassium-40	D3649 M	TBD	±30	±25	D3649 M	TBD	±25	±25
Protactinium-231	TBD	TBD	±30	±25	TBD	TBD	±25	±25

Table 8-4. Data Quality Objective Parameters for Chemical/Radiochemical Analyses.

	Soil/Sediment				Water			
	Analysis Method	Practical Quantitation Limit (pCi/g)	Precision (RPD)	Accuracy (%)	Analysis Method	Practical Quantitation Limit (pCi/L)	Precision (RPD)	Accuracy (%)
RADIONUCLIDES (cont.)								
Protactinium-234m	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Radium	Ra-04	TBD	±30	±25	Ra-05	TBD	±25	±25
Radium-225	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Radium-226	Ra-04	TBD	±30	±25	Ra-05	TBD	±25	±25
Ruthenium-106	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Samarium-151	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Selenium-79	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Sodium-22	D3649 M	TBD	±30	±25	D3649 M	TBD	±25	±25
Strontium-90	Sr-02	TBD	±30	±25	Sr-02	TBD	±25	±25
Technetium-99	Tc-01 M	TBD	±30	±25	Tc-01	TBD	±25	±25
Thallium-207	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Thorium-227	00-06	TBD	±30	±25	00-07	TBD	±25	±25
Thorium-229	00-06	TBD	±30	±25	00-07	TBD	±25	±25
Thorium-230	00-06	TBD	±30	±25	00-07	TBD	±25	±25
Thorium-231	TBD	TBD	±30	±25	TBD	TBD	±25	±25
Tritium	906.0 M	TBD	±30	±25	906.0	300	±25	±25
Uranium	U-04	TBD	±30	±25	U-04	TBD	±25	±25
Uranium-233	U	TBD	±30	±25	908.0	TBD	±25	±25
Uranium-234	U	TBD	±30	±25	908.0	TBD	±25	±25
Uranium-235	U	TBD	±30	±25	908.0	TBD	±25	±25
Uranium-238	U	TBD	±30	±25	908.0	TBD	±25	±25
Yttrium-90	Sr-02	TBD	±30	±25	Sr-02	TBD	±25	±25
Zirconium-93	TBD	TBD	±30	±25	TBD	TBD	±25	±25

Table 8-4. Data Quality Objective Parameters for Chemical/Radiochemical Analyses.

	Soil/Sediment				Water			
	Analysis Method	Practical Quantitation Limit (mg/kg)	Precision (RPD)	Accuracy (%)	Analysis Method	Practical Quantitation Limit (μg/L)	Precision (RPD)	Accuracy (%)
INORGANICS								
Arsenic	7061	0.02	±25	±30	7061	10	±20	±25
Barium	6010	0.02	±25	±30	6010	20	±20	±25
Boron	6010	TBD	±25	±30	6010	TBD	±20	±25
Cadmium	6010	0.09	±25	±30	6010	1	±20	±25
Chromium	6010	0.07	±25	±30	6010	10	±20	±25
Copper	6010	0.06	±25	±30	220.2	10	±20	±25
Cyanide	9010	TBD	±25	±30	335.3	50	±20	±25
Fluoride	300 M	TBD	±25	±30	300	50	±20	±25
Iron	6010	20	±25	±30	6010	70	±20	±25
Lead	6010	0.45	±25	±30	6010	450	±20	±25
Manganese	6010	0.02	±25	±30	6010	20	±20	±25
Mercury	7471	0.02	±25	±30	245.2	2	±20	±25
Nickel	6010	1.5	±25	±30	6010	50	±20	±25
Nitrate	300 M	TBD	±25	±30	300	130	±20	±25
Nitrite	300 M	TBD	±25	±30	300	40	±20	±25
Selenium	6010	0.75	±25	±30	270.2	20	±20	±25
Silver	6010	2	±25	±30	272.2	10	±20	±25
Titanium	6010	TBD	±25	±30	6010	TBD	±20	±25
Vanadium	6010	0.08	±25	±30	286.2	40	±20	±25
Zinc	6010	0.02	±25	±30	6010	20	±20	±25

Table 8-4. Data Quality Objective Parameters for Chemical/Radiochemical Analyses.

	Soil/Sediment				Water			
	Analysis Method	Practical Quantitation Limit (mg/kg)	Precision (RPD)	Accuracy (%)	Analysis Method	Practical Quantitation Limit (μg/L)	Precision (RPD)	Accuracy (%)
ORGANICS								
Acetone	8240	0.1	±25	±30	8240	100	±20	±25
Carbon tetrachloride	8240	0.005	±25	±30	8240	1	±20	±25
Chloroform	8240	0.005	±25	±30	8240	5	±20	±25
Kerosene	8015M	20	±35	±30	8015M	500	±35	±25
Methylene chloride	8240	0.005	±25	±30	8240	5	±20	±25
MIBK	8240	0.5	±25	±30	8240	5	±20	±25
1,1,1-Trichloroethane	8240	0.005	±25	±30	8240	5	±20	±25
Toluene	8240	0.005	±25	±30	8240	5	±20	±25
Tributyl phosphate	TBD	TBD	±25	±30	TBD	TBD	±30	±25

TBD = To Be Determined
M = method modified to include extraction from the solid medium, extraction method is matrix and laboratory-specific
RPD = Relative Percent Difference
Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA 1980)
Test Methods for Evaluating Solid Wastes (EPA 1986b)
Methods for Chemical Analysis of Water and Wastes (EPA 1983)
Eastern Environmental Radiation Facility Radiochemistry Procedures Manual (EPA 1984)
Precision and accuracy are goals. Since these parameters are highly matrix dependent they could vary greatly from the goals listed.

9.0 RECOMMENDATIONS

The purpose of the aggregate area management study (AAMS) is to compile and evaluate the existing body of knowledge to support the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a) decision making process. A primary task in achieving this purpose is to assess each contaminant within the groundwater aggregate area to determine the most effective path for remediation within the statutory requirements of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) and Resource Conservation and Recovery Act (RCRA). The existing body of pertinent knowledge regarding the 200 East Groundwater Aggregate Area was summarized and evaluated in the previous sections of this study. A data evaluation process has been established that uses the existing data to develop preliminary recommendations on the appropriate remediation path for each contaminant detected in groundwater monitoring wells. This data evaluation process is a refinement of the *Hanford Site Past-Practice Strategy* (Figure 1-2) and establishes criteria for selecting appropriate *Hanford Site Past-Practice Strategy* paths (expedited response action [ERA], interim remedial measure [IRM], limited field investigation [LFI], and final remedy selection) for contaminant releases within the 200 East Groundwater Aggregate Area. The process is an extension of, and is consistent with, the process used in source AAMS to plan remediation for waste management units and unplanned releases. A discussion of the criteria for path selection and the results of the data evaluation process are provided in Sections 9.1 and 9.2, respectively. Figure 9-1 provides a flowchart of the data evaluation process that will be discussed. Table 9-1 provides a summary of the results of the data evaluation assessment of each constituent. Table 9-2 provides the decisional matrix patterns followed for each constituent.

This section presents recommended assessment paths for the contaminants detected in the 200 East Groundwater Aggregate Area. These recommendations are only proposed at this time and are subject to adjustment and change. Factors that may affect development of final recommendations include, but are not limited to, comments and advice from the U.S. Environmental Protection Agency (EPA), Washington State Department of Ecology (Ecology), or U.S. Department of Energy (DOE); identification and development of new information; and modification of the criteria used in the assessment path decision-making process. The data evaluation process depicted on Figure 9-1 and discussed in Section 9.1 was developed to facilitate only the technical data evaluation step shown on the *Hanford Site Past-Practice Strategy* (Figure 1-2). Procedural and administrative requirements to implement the recommendations provided in this AAMS will be performed in accordance with the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1990) and the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a). Changes in recommendations will be addressed, and more detail on recommended assessment

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paths for groundwater contamination will be included in work plans for the actual investigation and remediation activities as they are developed.

Many of the distinct contaminant plumes in the 200 East Groundwater Aggregate Area with the highest rankings have enough information on the nature and extent of contamination for at least preliminary risk assessments based on their present day concentrations and distribution of contaminants. Some constituents with lower concentrations or poorly defined plumes will require an LFI or remedial investigation (RI) to verify that contamination is present, or to assess the extent of contamination to support IRM path decisions.

ERAs. The data evaluation process recommends that an ERA be initiated for the highest concentration portion (greater than 800 pCi/L, 100 times the 4% Derived Concentration Guide (DCG) standard of 8 pCi/L) of the Strontium-90 (^{90}Sr) plume in the immediate vicinity of the 216-B-5 Reverse Well. This ERA would have to deal with what is potentially a very recalcitrant problem, as indicated by the fact that the well was last used for disposal in 1947, and these highest levels have only shown up in two of the closest monitoring wells, 299-E28-23 and 299-E28-25. The ERA will probably have to attempt a variety of remedial technologies, including innovative processes such as in-situ soil washing or solubilization or in-situ precipitation, or a combination of extraction, treatment (by ion exchange, precipitation, co-precipitation/adsorption, or reverse osmosis), and disposal of the effluent, possibly by reinjection into the aquifer for containment and flushing. The actual remediation will be chosen through the Engineering Evaluation/Cost Analysis (EE/CA) process required for ERAs.

The ^{90}Sr plume recommended for an ERA overlaps at the two nearby wells with the highest concentrations of the plumes of Cesium-137 (^{137}Cs) and Plutonium-239,240 ($^{239,240}Pu$), both of which are proposed for other remediation paths. While the ERA will focus on removing the ^{90}Sr, the other radioactive contaminants of concern will behave similarly to the ^{90}Sr and so will also likely be removed during the ERA.

The ^{90}Sr plume represents the highest contribution to the maximum carcinogenic relative risk at present according to the Multimedia Environmental Pollutant Assessment System (MEPAS) model (Section 5.0), with only the unconfirmed detections of hydrazine and bis(2-ethylhexyl)phthalate that would if confirmed show higher carcinogenic relative risk. This radionuclide is not a major contributor to future carcinogenic risk, probably because of its retardation, and thus limited tendency to migrate.

IRMs. The next highest contributor to present carcinogenic relative risk, and the highest contributor to future carcinogenic relative risk, is Technetium-99 (^{99}Tc), which is a proposed IRM. The ^{99}Tc plume effectively coincides with areas where nitrate, cyanide, and Cobalt-60 (^{60}Co) are above drinking water standards maximum contaminant levels (MCLs) or

4% of DCGs; therefore, all these plumes should be addressed collectively under a single multicontaminant IRM centered at Well 699-50-53A. Nitrate and cyanide are respectively the seventh and third highest present noncarcinogenic relative risk, and respectively second and third ranked for future noncarcinogenic relative risk. There are also high levels of several dissolved metals, including selenium, strontium, magnesium, and potassium, which contribute to the noncarcinogenic relative risk. Dealing with the nitrate and the cyanide at this location also mitigates the second and third highest future noncarcinogenic relative risk.

Also proposed for IRMs are ^{137}Cs and $^{239\text{-}240}Pu$, which are above their 4% DCGs near the 216-B-5 Reverse Well. This IRM is included here for completeness; the contamination will largely be remediated as part of the ^{90}Sr ERA.

The fourth IRM involves possible remediation of uranium (U), including its three isotopes most common at Hanford (^{234}U, ^{235}U, and ^{238}U), at the one well (299-E28-21) where ^{234}U and ^{238}U exceed standards.

LFIs/RI. Other inorganic constituents that may present significant relative risks, including aluminum, antimony, arsenic, beryllium, cadmium, chromium, selenium, and thallium, will require at least an LFI assessment of background levels to confirm potential risks or exceedances before IRMs are initiated. Similar studies (under the RI rather than an LFI) will be necessary before a risk assessment can be completed for barium, boron, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, nickel, potassium, silver, sodium, strontium, vanadium, and zinc. Two radiochemicals, Potassium-40 (^{40}K) and uranium, will require determination of their naturally-occurring levels as well. Some studies may also be necessary to better determine the extent of any or all of these constituents. Of these inorganics, beryllium, thallium, selenium, aluminum, and antimony are major contributors to noncarcinogenic relative risk.

Lead lacks an EPA-approved toxicity value; therefore, risk-related action for this constituent may not be possible to determine. One inorganic which is not naturally occurring, hydrazine, will require an LFI to determine the nature and extent of its plume, and even to confirm that it is present (the two wells in which it was detected have apparently not been resampled and analyzed). Hydrazine, if present at the concentration detected, would be ranked far and away the highest carcinogenic relative risk of all constituents in the 200 East Groundwater Aggregate Area. The presence of hydrazine is uncertain because the two wells in which it was detected are distant from each other, but since it was used in the separations processing it is possible that releases have occurred.

Another area for a combined organics LFI involves several pesticides which have a strikingly consistent pattern of detections among a limited set of wells. The pesticides include:

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Aldrin
DDD
DDT
Dieldrin
Endrin
Endrin Aldehyde
Gamma BHC
Heptachlor

These pesticides were detected in five wells near the grout vault area: 299-E25-29P, -31, -33, -32P, and 299-E34-8. It must yet be confirmed that these are actual detections, by validation of the results and confirmation sampling, and if so the LFI should be extended to determine their nature and extent. These pesticides include some (endrin, dieldrin, and heptachlor) which are major contributors to carcinogenic relative risk, and two (endrin and heptachlor) which are above their MCLs.

Recommended LFI activities in support of other possible IRMs for organics include verification and/or plume delineation of bis(2-ethylhexyl)phthalate, 2,4-dinitrotoluene, 2,4-dinitrophenol, and pentachlorophenol. These constituents are potentially contributors of some of the highest levels of relative risk. Because of its high detection limit (10 ppb), bis(2-ethylhexyl)phthalate is above its MCL (6 ppb) in all thirteen wells where it was detected. Other detected organics do not appear to be of sufficient concern to merit special investigation before the RI is initiated in the 200 East Aggregate Area.

Among other radionuclides, tritium (^{3}H) is proposed for inclusion in the final remedy risk assessment; gross alpha and beta are proposed for LFIs to determine the specific radionuclides which contribute to these indicator parameters, and ^{40}K, Ruthenium-106 (^{106}Ru), and Iodine-129 (^{129}I) are proposed for LFIs to support decisions on whether an IRM is justified. The LFIs should mainly be scoped to better delineate the nature and extent of these plumes. Finally, other detected radionuclides are proposed for the RI to support final remedy risk assessment.

In some cases various separate geographic portions of the plumes, as shown in the plume maps (Figures 4-1 through 4-15), are recommended for LFI or RI investigations while the higher priority portion is recommended for IRM activities.

A discussion of the four decision-making paths shown on Figure 9-1 (ERA, IRM, LFI, and final remedy selection) is provided in Section 9.1. Section 9.2 provides a discussion of the contaminants categorized under each of these paths. A discussion of regrouping and prioritization of the contaminants is provided in Section 9.3. Recommendations for defining and prioritizing groundwater operable units within the 200 East Groundwater Aggregate Area

are provided in Section 9.3. All recommendations for future characterization needs (see Section 8.0) will be more fully developed and implemented through work plans. Plan development and submittal will be accomplished in accordance with requirements of the *Hanford Site Past-Practice Strategy* and the Tri-Party Agreement (Ecology et al. 1990) and could include RI/FS or LFI work plans. Sections 9.4 and 9.5 provide recommendations for focused feasibility and treatability studies, respectively. Section 9.6 discusses recommendations for site characterization on an aggregate area scale.

9.1 DECISION MAKING CRITERIA

The criteria used to assess the most appropriate and expeditious remediation process path are based primarily on urgency for action and whether data are adequate to proceed along a given path (Figure 9-1). Chemical-specific contaminant plumes [i.e., contaminants detected, as developed by Connelly et al. (1992a) and checked by a direct access of the Westinghouse Hanford groundwater contamination data base] in 200 East Area groundwater are considered evidence of a release and are thus initially evaluated in the data evaluation process as candidates for an ERA. However, gross alpha and beta are considered indicator parameters and are not developed as distinct constituents. Conditions that might trigger an ERA are the determination of an unacceptable health or environmental risk or that minimal time is available to mitigate the problem (DOE/RL 1992a). As a result, candidate ERA constituents were evaluated against a set of criteria to determine whether potential for exposure to unacceptable health or environmental risks currently exists. Despite the fact that there presently are no receptors (e.g., no drinking water wells in the vicinity, no seeps, etc.), and thus no present risk from the groundwater, the presence of high levels of contaminants in groundwater could be considered an unacceptable release. Contaminants recommended for ERAs will undergo a formal evaluation following the selection process outlined in WHC (1991b).

Constituents that are not recommended for an ERA continue through the data evaluation process. Contaminants continuing through the process that potentially pose a high relative risk (refer to Section 5.0) become candidates for an IRM. The criteria used to determine a high risk potential, thereby indicating a high priority, include relative risk and/or exceedance of standards. The candidate IRM contaminants are identified in Table 9-2 with "Y" in the IRM section. Candidate IRMs were then further evaluated to determine if an IRM is appropriate. Candidate IRM contaminants that did not meet the IRM criteria were placed into the final remedy selection path.

Specific criteria used to develop initial recommendations for ERAs, LFIs, and IRMs for constituents detected within the 200 East Groundwater Aggregate Area are provided in

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Sections 9.1.1 and 9.1.2. Constituents not initially addressed under an ERA, LFI or IRM will be evaluated under the final remedy selection path discussed in Section 9.1.3.

9.1.1 Expedited Response Action Path

All detected constituents are assessed against the ERA criteria to determine if they pose an unacceptable health or environmental risk. Again, in the absence of receptors, this must be considered a theoretical health or environmental risk. The *Hanford Site Past-Practice Strategy* describes conditions that might trigger abatement under an ERA. Generally, these conditions would rely on a determination of, or suspicion of, existing or future unacceptable health or environmental risks, and a short time-frame available to mitigate the problem. Conditions include, but are not limited to:

- Actual or potential exposure to nearby human populations, biota, or the food chain from hazardous substances and radioactive or mixed waste contaminants
- Actual or potential contamination of drinking water supplies or sensitive ecosystems
- Threats of release of hazardous substances and radioactive or mixed waste contaminants
- High levels of hazardous substances and radioactive or mixed waste contaminants in soils that pose or may pose a threat to human health or the environment, or have the potential for migration
- Weather conditions that may increase the potential for release or migration of hazardous substances and radioactive or mixed waste contaminants
- The availability of other appropriate federal or state response mechanisms to respond to the release
- Time required to develop and implement a final remedy
- Further degradation of the medium which may occur if a response action is not expeditiously initiated
- Risks of fire or explosion or potential for exposure as a result of an accident or failure of a container or handling system

- Other situations or factors that may pose threats to human health, welfare, or the environment.

These conditions were used as the initial screening criteria to identify candidate contaminants for ERAs. Candidate contaminants that did not meet these conditions were not assessed through the ERA evaluation path. Contaminants were eliminated if the constituents were not hazardous, i.e., if they did not have EPA risk parameters. Additional criteria for further, detailed screening of ERA candidates were developed based on the conditions outlined in the *Hanford Site Past-Practice Strategy*. These additional screening criteria are shown in Figure 9-1 and are described below.

Constituents were first assessed to determine if they pose unacceptable (theoretical) health or environmental risks. The criteria used to determine "unacceptable" are based on the maximum concentration detected (averaged for all samples collected in a well during 1989 through 1992). For hazardous or radioactive constituents at concentrations that are 100 times the applicable standard (">100*Std?" on Table 9-2), the contaminant continues to be considered for an ERA. Application of the criterion of 100 times applicable standards is for quantification of the strategy criteria which addresses "high levels of hazardous substances and radioactive or mixed waste contaminants ...." The factor of 100 is based on engineering judgment of what constitutes a high level of contamination warranting expedited action. Standards applied include MCLs under the Safe Drinking Water Act and 4% of DOE DCGs as prescribed by DOE Order 5400.5, Section II.1.d(2) for radionuclides which do not have promulgated MCLs. The application of these standards does not imply they are recognized as applicable or relevant and appropriate requirements (ARARs). Final promulgation of the most recent MCLs was considered an adequate basis for their use in this screening; their effective dates were not considered.

The ERA screening criteria, in addition to those presented in the *Hanford Site Past-Practice Strategy*, were applied to provide a consistent quantitative basis for making recommendations in this AAMS. Final decisions to implement the recommendations developed in this AAMS will be made collectively between DOE, EPA, and Ecology.

If a groundwater contaminant concentration is unacceptable with respect to health or environmental risk according to these criteria, it may still be necessary to verify if the contamination level is real. It is possible that some detections are spurious, due to either laboratory error or a transcription error in conveying the laboratory results to the data base used in this analysis. Thus, an ERA should not be initiated on the basis of single isolated analytical results. Only if the concentration is confirmed (abbreviated "Conf?" on Table 9-2), and is based on more than one analytical result will the constituent continue to be considered for an ERA. The other constituents will drop down for consideration on the IRM path. Even in a worst-case scenario (e.g., a newly detected true high-concentration plume is

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dropped from the ERA path), LFI confirmation studies will be initiated to support an IRM and the situation would be controlled.

At the next decision step, even if a contaminant concentration is a true high priority, a technology must be readily available to control the contaminant plume for it to be considered for an ERA. An example that would require substantial technology development before implementation of cleanup is the tritium plume since no established treatment technology is available to separate low concentrations of tritium from water. This is referred to on Figure 9-1 and Table 9-2 as best demonstrated available technology (BDAT). The availability of funds to develop technology for these contaminants is beyond the scope of this AAMS.

The next step in the ERA evaluation path involves determining whether implementation of the available technology would have adverse consequences that would offset the benefits of an ERA. Examples of adverse consequences (abbreviated "adv cnsq" on Table 9-2) include: (1) use of technologies that result in risks to cleanup personnel or the public that are much greater than the risks of the contaminant; (2) the ERA would preclude future remedial actions; and (3) the ERA would prevent or greatly hinder future data collection activities. If adverse consequences are not expected, the constituent remains in consideration for an ERA. At this point, because all criteria are satisfied, the recommendation for an ERA is made.

The final decision regarding whether ERAs are pursued in groundwater aggregate areas will be made among DOE, EPA, and Ecology based, at least in part, on the recommendations provided in this section, results of the final selection process outlined in WHC (1991b), and availability of resources.

9.1.2 Limited Field Investigation and Interim Remedial Measure Paths

An IRM is desired for high priority contaminants/plumes where extensive characterization is not necessary to reach defensible cleanup decisions. The first step, therefore, in the IRM evaluation path is a screening based on (1) exceedance of MCLs provided in applicable standards, e.g., drinking water standards (40 CFR 141) or 4% of the DCGs (DOE Order 5400.5), and (2) semiquantitative relative risk indices (RRIs) developed in Section 5.0. Both of these numerical criteria are presented in Table 9-2.

Comparison of the maximum contaminant concentrations in groundwater to the MCLs and DCGs identified those contaminants that would be considered for an IRM. The RRI values provided a supplementary basis for prioritizing potential IRMs for contaminants that do not have an MCL. These high priority contaminants were considered in the IRM path.

High priority contaminants were then evaluated to determine if sufficient need and information exists such that an IRM could be pursued. Implementation of an IRM for a contaminant with minimal characterization may rely on observational data acquired during remedial activities, including full-scale treatability studies, pump tests to determine aquifer properties, and confirmatory sampling using existing wells. Successful execution of this strategy is expected to reduce both time and cost for cleanup of the site groundwater without impacting the effectiveness of the implemented action.

The next step in the IRM evaluation path is to assess data adequacy. The existing data are evaluated to determine if: (1) existing data are sufficient to develop a conceptual model and perform a qualitative risk assessment; (2) the IRM will work for this path; (3) implementing the IRM will have adverse impacts on the environment, future remediation activities or data collection efforts; (4) the benefits of implementing the IRM are greater than the costs. If data are not adequate, an assessment will be made to determine if an LFI might provide enough data to perform an IRM. If an LFI is not expected to collect sufficient data to perform an IRM, the contaminant will be addressed in the final remedy selection path.

The final step in the IRM evaluation process is to assess if the IRM will work without significant adverse consequences. This includes: will the IRM be successful? will it create significant adverse environmental impacts (e.g., environmental releases)? will the costs outweigh the benefits? will it preclude future cleanup or data collection efforts? and will the risks of the cleanup be greater than the risks of no action? Units are recommended for IRMs where remediation is considered to be possible without adverse consequences outweighing benefits of the remediation.

Final decisions will be made between DOE, EPA, and Ecology on whether particular IRMs are pursued based, at least in part, on the recommendation provided in this AAMSR, results of any supporting LFI, and the availability of resources.

9.1.3 Final Remedy Selection Path

Contaminants recommended for initial consideration in the final remedy selection path are low priority contaminants not previously recommended for IRMs, LFIs, or ERAs. It is recognized that all contaminants of concern within the aggregate area will eventually be addressed collectively under the final remedy path to support a final Record of Decision (ROD).

The initial step in the final remedy selection process path is to assess whether the combined data from the AAMS, and any completed ERAs, IRMs, and LFIs, are adequate for performing a risk assessment and selecting a final remedy. Whereas the scope of an ERA or

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IRM is limited to an individual contaminant or a single multicontaminant plume, the final remedy selection path will likely address all contaminants and plumes within the operable unit or aggregate area.

If the data are collectively sufficient, an operable unit or aggregate area risk assessment will be performed. If sufficient data are not available, additional needs will be identified and collected.

9.2 PATH RECOMMENDATIONS

Initial recommendations for ERA, IRM, and LFI are discussed in Section 9.2.1 through 9.2.3, respectively. Contaminants proposed for initial consideration under the final remedy selection path are discussed in Section 9.2.4. Table 9-1 provides a summary of the data evaluation process path assessment. A summary of the responses to the decision points on the flowchart that led to the recommendations is provided in Table 9-2. Following approval by DOE, EPA, and Ecology, these recommendations will be further developed and implemented in work plans.

9.2.1 Proposed Contaminants for Expedited Response Actions

The ^{90}Sr plume at the 216-B-5 Reverse Well is proposed for an ERA. The following section describes the selection of this plume and the likely ERA activity. Implementing an ERA now may reduce further spread of contaminant plumes in advance of a potentially lengthy RI/FS process, will extract high levels of contamination, and is expected to provide significant progress toward remediation. Remedial technologies are suggested in the following descriptions, although final selection of the appropriate means will require completion of an EE/CA.

Remedial actions under ERAs should be scoped as a containment/control program or a limited cleanup with a stopping point based on either a concentration threshold (such as the 100 times standards used in the selection criteria) or on reaching an asymptote on the remediation production curve (the point of diminishing returns). The objective is to provide substantial risk reduction within a short time frame, not to complete cleanup of groundwater contamination over the entire extent of the plume geometry. As there are no present day receptors for this groundwater contamination, there are also presently no immediate health and safety concerns.

9.2.1.1 Strontium-90 ERA Selection. The DCG for ^{90}Sr is 200 pCi/L (DOE Order 5400.5), so the drinking water standard (4% DCG) is 8 pCi/L. The highest concentrations

found in the groundwater, nearly 5,150 pCi/L, are almost 650 times higher than the standard. The ^{90}Sr at this well is ranked highest in carcinogenic relative risk index (RRI), except only for hydrazine and bis(2-ethylhexyl)phthalate which are unconfirmed. The area in which ^{90}Sr exceeds the 800 pCi/L (100 times standard) is apparently very small—it is only in two wells, 299-E28-23 and 299-E28-25, which are located only 7.4 m (24 ft) apart. The source of the contamination appears to be the 216-B-5 Reverse Well, which from April 1945 to October 1947, received 31 million liters (8 million gallons) of liquid wastes containing some 4 kg (9 lb) of plutonium and 3,800 Ci of beta-gamma activity (see Section 2.0 for more details, including inventory). The B Plant source AAMSR recommended an ERA for this waste management unit based on its release history; the two proposed ERAs will however be integrated into a single ERA.

The location of the ^{90}Sr ERA plume also contains concentrations greater than standards of other contaminants, notably $^{239,240}Pu$ and ^{137}Cs. Also ^{238}Pu is found here at its highest concentration in the 200 East Area, although not above the 4% DCG level. The gross beta measurement is found here at its highest level (10,250 pCi/L), so there may be other fission products present. While it is likely that the most feasible remediation technology will treat all of these constituents, it is possible that one or more of the constituents may not be adequately treated. The residual contaminants co-existing with the ^{90}Sr plume would continue as candidates for future IRMs.

This ERA addresses what is clearly the most serious groundwater contamination issue in the 200 East Groundwater Aggregate Area, based on the combined carcinogenic risk associated with the contaminants in the groundwater at this location. It is apparently true that the contamination at this location has not migrated any substantial distance in the 45 years since waste was disposed here. Nevertheless, the contaminants are mobile (as demonstrated by the fact that they are in the sampled groundwater) and therefore constitute a groundwater contaminant plume of some extent.

9.2.1.2 ERA Remediation Alternatives. Remedial alternatives which may be suitable for the proposed ERA on the ^{90}Sr plume include:

- Pump and treat--extraction of the contaminated groundwater and treatment by any of several systems which would remove the ^{90}Sr. Suitable candidate technologies include precipitation, ion exchange, coprecipitation/adsorption, and reverse osmosis. Other treatment technologies can be added to a pump and treat system to treat other contaminants.

- In situ immobilization--immobilization of ^{90}Sr by introducing reagents that precipitate or grout the compounds of concern in the subsurface. There will likely be gratuitous treatment of $^{239,240}Pu$ and ^{137}Cs, but the ERA will be driven

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by the strontium concentration. Bench and pilot scale treatability studies would be needed before implementing a full scale in situ immobilization system. Because of the time needed to develop this technology and the need for rapid response under an ERA, in situ immobilization may be used to supplement the pump and treat option rather than be used as a stand-alone system.

- In situ solubilization--heavy metal solubilization, in which reagents such as mild acids are added to dissolve the strontium, plutonium, and cesium. In situ solubilization would be coupled with an aggressive program of groundwater extraction and monitoring to minimize fugitive releases of the contaminants of concern. Bench and pilot scale treatability studies would be needed prior to implementing a full scale in situ solubilization system. Because of this constraint and the need for rapid response under an ERA, in situ solubilization may be used to supplement the pump and treat option rather than be used as a stand-alone system.

9.2.2 Proposed Contaminants for Interim Remedial Measures

Seven constituents are proposed for direct application of IRMs: nitrate, ^{60}Co, ^{99}Tc, ^{137}Cs, uranium (^{234}U and ^{238}U), $^{239/240}Pu$, and cyanide. These are organized into three operational IRM groups:

- ^{137}Cs and $^{239/240}Pu$
- ^{99}Tc, ^{60}Co, Cyanide, and Nitrate
- Uranium (^{234}U and ^{238}U)

These are discussed in the following sections.

Like ERAs, IRMs should not be designed just to specifically meet ARARs (e.g., MCLs), but should also be based on risk reduction. Groundwater remediation should proceed until the response objective (e.g., reduction in RRI or containment) is met or until contaminant concentrations reach an asymptote, beyond which the returns on a treatment effort diminish or natural attenuation exceeds active treatment. After the response objective is met or the concentration asymptote is reached, the IRM should be discontinued and any residual plume be addressed in the final remedy selection path.

9.2.2.1 ^{137}Cs and $^{239/240}Pu$ IRMs. The highest concentrations of these two radiochemicals are found in the same wells (299-E28-23, -24, -25) near the 216-B-5 Reverse Well which is

the subject of the ^{90}Sr ERA. This is also the only location where these constituents are above their drinking water standards (4% of DCGs). The ^{137}Cs at this well is ranked fifth highest in present carcinogenic RRI, and the $^{239,240}Pu$ is ranked third. In addition to these contaminants, ^{238}Pu and fluoride are found in these wells at their highest concentrations in the 200 East Area, as well as high levels of tritium and uranium. The same treatment which would be used for the ^{90}Sr will probably also treat the other major heavy metal constituents (the cesium, plutonium, and uranium) at this location. Because of the limited extent of the detections, these radionuclides may be fully addressed as part of the ^{90}Sr ERA.

9.2.2.2 ^{99}Tc, ^{60}Co, Cyanide, and Nitrate IRMs. These IRMs are located north of the 200 East Area, primarily around Well 699-50-53A. This single well had the highest levels of these four constituents, as well as a number of inorganics (selenium, strontium, magnesium, potassium, and sulfate). The concentration of ^{99}Tc yields a present carcinogenic RRI ranked second, just behind the ^{90}Sr which is recommended for an ERA; ^{60}Co is ranked tenth. Well 699-49-55A also has high levels of ^{99}Tc and nitrate, and should also be included. The IRMs address the only plume area of cyanide (Figure 4-3), plume B of nitrate (Figure 4-4), plume C of gross beta (Figure 4-7), the only plume area of ^{60}Co (Figure 4-10), and plume B of ^{99}Tc (Figure 4-12). With such a variety of constituents it may be necessary to use pump and treat with a multi-component treatment train, although ion exchange may be sufficient for most of the constituents. It may also be necessary to do some additional field investigation (LFI) to better determine the extent of this plume and its nature.

9.2.2.3 Uranium (^{234}U and ^{238}U) IRM. This IRM is proposed to deal with a localized area of high uranium concentrations near Well 299-E28-21. This well is the only one with uranium isotopic concentrations above the required 4% DCG drinking water standard, although the extent of uranium contamination can be shown to extend some distance beyond this well. The uranium isotopes are respectively ranked eleventh and twelfth in present carcinogenic RRI. The well does not have levels above drinking water standards of other constituents except tritium, although the levels may be high enough to affect remedial technologies.

9.2.3 Proposed Contaminants for Limited Field Investigation

Nineteen contaminants appear to be eligible for IRMs but data were insufficient to determine whether an IRM is justified. It is recommended that these constituents first undergo LFI to supply additional data required to support the conceptual model and a qualitative risk assessment. Another purpose of the data acquisition would be to delineate the vertical and horizontal extent of their plumes. These constituents include the following:

- Bis(2-ethylhexyl)phthalate

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- Methylene chloride
- 2,4-dinitrotoluene
- 2,4-dinitrophenol
- Pentachlorophenol
- Pesticides (aldrin, dieldrin, and endrin)
- Potassium-40
- Ruthenium-106
- Iodine-129
- Antimony
- Arsenic
- Beryllium
- Cadmium
- Chromium
- Hydrazine
- Selenium
- Thallium.

The two radioactivity parameters (gross alpha and gross beta) should also be investigated in the course of the LFI activities to determine the radionuclides which constitute the highest levels of these plumes.

In addition to these contaminants, some contaminant plumes for which an IRM is recommended also have portions where an LFI is recommended. These secondary plumes (e.g., nitrate plumes A, C, D, and E on Figure 4-4) are classified differently to avoid confusion in identifying contaminant plumes. These secondary plumes typically require better delineation of vertical and horizontal extent before an IRM can be initiated.

The rationale and scope for the IRMs and LFIs will be more completely developed in work plans; however, the following address possible considerations during work plan development:

- Confirm contamination to be present in well(s) and determine average levels of that contamination. Some contaminants designated for LFIs had only a single detection or only one at a level of concern. "Plumes" with less than three wells delineating the extent of concentrations over MCL or risk levels are not adequately defined for risk assessment or remediation decision making. Lower detection limit analyses may be required for some contaminants with very low action levels.

- Background concentrations of inorganics must be determined to gauge the significance of the detected levels. A program is presently underway to determine site background levels (Hoover and LeGore 1991, DOE/RL 1992c, see Section 4.1.1.2) which may be sufficient to answer this data gap.

- The nature of the radionuclides making up the beta radiation must be determined. Much may be ^{60}Co, ^{90}Sr, ^{99}Tc, or ^{137}Cs, which are known to exist in the vicinity of high beta levels, but other fission products may be contributing. The same study requirement exists for high gross alpha levels.

- Toxicity data may be required for some constituents, although these data must be sanctioned by EPA before final risk assessment is possible. This includes lead and uranium (for its chemical toxicity) as well as some of the lesser-known organics which were detected.

- Remediation methods will require data gathering, and may lead into treatability testing.

- Cesium-137 and $^{239,240}Pu$, proposed for IRMs are located within the boundaries of the ^{90}Sr ERA. The ERA will likely remediate these IRM constituents of concern. Nevertheless, there may still be an LFI required to evaluate the effectiveness of the ERA as a final remediation of the IRM constituents. At a minimum, it will be necessary for the ERA to consider the presence of these contaminants, as well as others such as tritium which are present, in regard to remediation and disposal options.

- Well-designed pump tests should be conducted to determine geohydrological properties such as hydraulic conductivity, transmissivity, and storage coefficients and thus help estimate flow rates in areas considered for groundwater extraction.

9.2.4 Proposed Contaminants for Final Remedy Selection

Several of the low priority contaminants have been proposed for the final remedy selection path. Section 9.2.4.2 discusses those proposed for direct inclusion in the final remedy selection risk assessment. An RI is recommended for the remainder of the contaminants due to the lack of information to support a final risk assessment and select a final remedy(ies). These are discussed in Section 9.2.4.1.

9.2.4.1 Proposed Contaminants for Remedial Investigation. An RI should be conducted for several contaminants of apparent low priority, poor definition, and uncertain verification. These include:

- Organics: Chloroform, carbon tetrachloride, pyrene, styrene, toluene, phenol, o-nitrophenol, 2-chlorophenol, 2,4-dichlorophenol, 2,3,4,6-tetrachlorophenol, 2,4-dimethylphenol, acetone, methyl ethyl ketone, 4-methyl-2-pentanone, cyclohexanone, DDD, DDT, endrin aldehyde, gamma-BHC, heptachlor, diethyl ether, dimethoate, ethyl cyanide, p-chloro-m-cresol, phorate, trichloromonofluoromethane, and triethylene glycol. These also require confirmation and development of lower detection limits.

- Radionuclides: ^{7}Be, ^{14}C, ^{65}Zn, $^{95}Zr/Nb$, ^{125}Sb, ^{134}Cs, $^{144}Ce/Pr$, ^{154}Eu, ^{155}Eu, ^{212}Pb, radium, ^{235}U, ^{238}Pu, and ^{241}Am. These share the need for verification and even any indication that there is contamination in cases where the detection is unconfirmed. Background levels of uranium and ^{40}K will also be required.

- Inorganics: aluminum, ammonium, barium, boron, bromide, calcium, chloride, cobalt, copper, fluoride, iron, lead, lithium, magnesium, manganese, mercury, nickel, phosphate, potassium, silicon, silver, sodium, strontium, titanium, uranium (from a chemical point of view), vanadium, and zinc. These constituents generally require confirmation, better delineation (if actually at levels of concern), and sampling and analysis of background levels.

- Miscellaneous Parameters/Constituents: Other parameters will also be considered during the RI although they do not constitute constituent/contaminant plumes of concern, such as total carbon and total organic carbon, total dissolved solids, total organic halogens, chemical oxygen demand, alkalinity, pH, conductivity, turbidity, and coliform bacteria.

In addition, some geographic portions (sub-plumes) of IRM contaminants of concern will require consideration under the RI phase, even though other parts of these contaminant

plumes are addressed by IRM or LFI activities. Residual contamination after ERA/IRM completion for all constituents, will also be included in the RI scope if necessary.

9.2.4.2 Proposed Contaminants for Risk Assessment. The tritium plume presents a high risk level and exceeds standards: 4,270,000 pCi/L at Well 299-E24-11 is more than 200 times the standard (MCL) of 20,000 pCi/L. It also has the fourth highest carcinogenic RRI, in both present and in future scenarios. Nevertheless, because of its chemical similarity with water, there is presently no commercially viable treatment systems to remove tritiated water from the groundwater. No ERA could therefore be proposed. One possible strategy would be to extract tritium-contaminated groundwater and reinject it upgradient to increase the groundwater travel time, thereby increasing the time for natural decay before a receptor is reached.

The tritium plume is well enough defined to proceed directly into risk assessment without attempting any further investigation. If the risk assessment confirms the need for remediation, then the RI/FS process will investigate further remedial alternatives.

9.3 GROUNDWATER OPERABLE UNIT DEFINITION AND PRIORITIZATION

The investigation process can be made more efficient if plumes with multiple contaminants in the same general vicinity can be studied together. The data needs and remedial actions required for many of the contaminants are frequently the same. It is much easier to ensure a consistent level of effort, investigation methodology, prioritization, funding, and regulatory oversight if associated constituents are grouped together. Economies of scale also make the investigation process more cost effective if larger areas are studied together.

9.3.1 Groundwater Operable Unit Definition

An objective of the 200 East Groundwater AAMS is to define appropriate groundwater-specific operable units. A groundwater operable unit is a portion or aspect of a remedial action site which can best be planned and remediated as a single entity. At the Hanford Site, a source area operable unit is usually a group of waste management units which are spatially close to each other and generally shared a similar disposal history. Prior to the AAMS process, 12 of the 21 operable units in the 200 East and 200 North Areas were designated as combination source and groundwater contamination. These include the following:

- 200-PO-1

- 200-PO-2
- 200-PO-4
- 200-PO-5
- 200-BP-1
- 200-BP-2
- 200-BP-3
- 200-BP-4
- 200-BP-11
- 200-IU-6
- 200-SO-1
- 200-NO-1.

To maximize the efficiency of the investigation of groundwater flow and contamination, it is recommended that separate groundwater operable units be defined for the 200 East Area and vicinity on the basis of flow patterns and plume distributions, both of which are hydrologic in nature and do not respect the geographic boundaries established for the source operable units. In addition, the groundwater plumes as discussed in previous sections frequently overlap or coincide, and so the groundwater at a point may have several contaminants at significant concentrations from different sources and source operable units. For these reasons, each of the 200 East source AAMS reports recommends that groundwater be deleted from the source operable units and be placed in a groundwater-specific operable unit.

Because of the interrelations of the contaminant plumes in the 200 East Area, it is considered best to have a relatively small number of groundwater-specific operable units. It is also important, however, to keep the size and complexity of groundwater operable units small enough so that each can efficiently handle all groundwater issues in that portion of the 200 East Area.

With these considerations, two operable units are recommended for the 200 East Groundwater Aggregate Area. These would be divided on the basis of the hydrologic flow

system which is present under the aggregate area. Two hydrologic regimes can be defined, originating at the groundwater divide in the center of the 200 East Area and moving from this east-west line in opposite directions (Figures 3-44 and 3-61). Groundwater flow on the north side of the divide generally flows north towards Gable Gap. Groundwater south of the divide generally flows south and then east towards the Columbia River. The distributions of the contaminant plumes in the 200 East Groundwater Aggregate Area reflect these flow conditions. Contaminant plumes in one regime or the other generally do not mix. These two groundwater flow regimes can therefore be the basis of the two groundwater operable units. The line of their division runs approximately along the northern edge of the 200-SS-1 Operable Unit (see Figure 9-2), the southern edge of 200-SO-1, and the northern edges of 200-PO-3 and 200-PO-5 until it reaches the 216-B-3 Pond System. (The divide is so gradual that the exact location is not well determined and does not need to be.) While this divide will change according to recharge conditions, which will vary, it should be consistent enough over the period of time during which studies will be done that further modifications will not be necessary.

The south groundwater operable unit, tentatively called GW-OU-3 because GW-OU-1 and -2 have previously been identified as 200 West groundwater operable units, could be identified with PUREX and the plumes originating in that area. The northerly groundwater operable unit, tentatively GW-OU-4, includes those plumes in the B Plant Aggregate Area (including Gable Mountain Pond). This includes the ^{90}Sr ERA plume, and the ^{137}Cs and $^{239/240}$Pu IRMs; the ^{99}Tc, ^{60}Co, cyanide, and nitrate, IRMs; and the uranium (^{234}U and ^{238}U) IRM.

To keep the number of operable units constant over the 200 Areas, including both source and groundwater, it is advisable to combine source operable units, so that new groundwater-specific operable units can be created. Candidates may be obtained from the source AAMSRs. The B Plant AAMSR has already indicated the availability of 200-BP-8 as a name for GW-OU-4. There does not appear to be a similarly available operable unit name in the PUREX Plant Aggregate Area to be used for GW-OU-3; it may be necessary to create a new operable unit name (e.g., 200-PO-7). Efficiencies should be obtained by developing groundwater specific operable units.

9.3.2 Investigation Prioritization

Although contaminants have been individually recommended for an ERA or IRM, the scope of a remediation activity will likely address multiple contaminants because many of the priority groundwater contaminants in the 200 East Area are collocated. Implementing ERAs and IRMs may also result in addressing contaminants of lower priority. As a result,

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recommendations for functionally grouping contaminants and their relative priority were provided in the functional groups recommended for IRMs (Section 9.2.2).

The ^{90}Sr ERA plume coincides with the ^{137}Cs and $^{239,240}Pu$ IRM plumes. Because of similarities in chemical and physical properties between these constituents, it is reasonable to expect that they can be coremediated. As a result, it is recommended that the ERA activity at least address ^{137}Cs and $^{239,240}Pu$ in addition to ^{90}Sr. Although ^{137}Cs and $^{239,240}Pu$ and other constituents may be treated as part of the ERA, ^{90}Sr concentrations should specifically determine the starting and stopping points for the ERA. That is, when the ^{90}Sr concentration decreases to levels that satisfy the ERA objective, the ERA should be discontinued. This ERA addresses what is clearly the most critical groundwater contamination issue in the 200 East Groundwater Aggregate Area and should receive the highest priority.

Overlapping plumes should be coremediated under single multicontaminant IRMs as described in Section 9.2.2 to the extent the technology is available. These IRMs should receive priority according to the carcinogenic and noncarcinogenic relative risks associated with each multicontaminant plume. These IRMs would be prioritized in the following order: ^{137}Cs and $^{239/240}Pu$ IRMs (under the ^{90}Sr ERA); ^{99}Tc, ^{60}Co, cyanide, and nitrate IRMs; and the uranium (^{234}U and ^{238}U) IRM.

To summarize, remedial actions or investigations in cases of overlapping plumes should normally be driven by the highest priority activity. For example, if an ERA plume overlaps an IRM plume, the overlapping areas should be first addressed by the ERA activities which are higher in priority. The ERA will dictate the extent of treatment, such that when the ERA goals are satisfied, the ERA activities will be discontinued in the region of overlap. The overlapping area, if necessary, can then be addressed more completely under an IRM. In the case of overlapping plumes that require IRMs, LFIs, and RIs, the work plans and other planning and implementation activities should address the overlapping plumes on a case-by-case basis.

Although ERAs and IRMs will likely be implemented based on multicontaminant plumes, LFIs should be implemented based on the operable unit work plan framework. As a result, arsenic (plumes C and D in Figure 4-1), hydrazine, 2,4-dinitrophenol, pesticides (aldrin, dielrin, and endrin), ^{106}Ru, and ^{129}I (Figure 4-13) should be addressed under an LFI work plan for GW-OU-3; and chromium (plumes A, B, and C in Figure 4-2), thallium, 2,4-dinitrotoluene, and pentachlorophenol should be addressed under an LFI work plan for GW-OU-4. Studies of gross alpha (Figure 4-6) and gross beta (plumes A, B, and C in Figure 4-7) are also included in GW-OU-4. Priority should be given to GW-OU-4.

Individually (i.e., outside the operable unit work plan framework), LFIs would be prioritized in the following order: bis(2-ethylhexyl)phthalate, beryllium, selenium, antimony, arsenic (general aspects), methylene chloride, ^{40}K, cadmium, and chromium.

Tritium is the only plume for direct risk assessment, and does not require prioritization.

The RI activities should be performed simultaneously on the following constituents: aluminum, ammonium, barium, boron, bromide, calcium, chloride, cobalt, copper, fluoride, iron, lead, lithium, magnesium, manganese, mercury, nickel, phosphate, potassium, silicon, silver, sodium, strontium, sulfate, titanium, uranium (from a chemical point of view), vanadium, and zinc; coliform bacteria; chloroform, carbon tetrachloride, 1,2-dichloroethane, cis- and trans-1,2-dichloroethylene, 1,1,2-trichloroethane, pyrene, styrene, toluene, phenol, o-nitrophenol, 2-chlorophenol, 2,4-dichlorophenol, 2,3,4,6-tetrachlorophenol, 2,4-dimethylphenol, acetone, methyl ethyl ketone, 4-methyl-2-pentanone, cyclohexanone, DDD, DDT, endrin aldehyde, gamma-BHC, heptachlor, diethyl ether, dimethoate, ethyl cyanide, p-chloro-m-cresol, phorate, trichloromonofluoromethane, and triethylene glycol; ^{7}Be, ^{14}C, ^{65}Zn, $^{95}Zr/Nb$, ^{125}Sb, ^{134}Cs, $^{144}Ce/Pr$, ^{154}Eu, ^{155}Eu, ^{212}Pb, radium, ^{235}U, ^{238}Pu, and ^{241}Am.

9.3.3 RCRA Facility Interface

As discussed in Section 2.8, groundwater monitoring programs are underway at several RCRA facilities in the 200 East Groundwater Aggregate Area. If these monitoring programs indicate that groundwater contamination is originating from a RCRA treatment, storage or disposal (TSD) unit, it is likely that groundwater remediation will need to be integrated with the overall CERCLA remediation program for the 200 Areas. It is recommended that groundwater remediation activities associated with RCRA TSD units be fully integrated with the past practice program. Even though efforts have been made by the regulators to integrate the RCRA and CERCLA programs, further site specific integration decisions will be required at the NPL site- or waste management unit-level.

Section 2.6 described the RCRA TSD groundwater monitoring programs in the 200 East Area. RCRA units with groundwater monitoring programs in the 200 East Area are listed below along with the planned actions (e.g., closure under interim status, final facility operating permit):

TSD Unit	Planned Action
200 East Area Liquid Effluent Retention Facility (LERF)	Storage Facility Permit

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216-A-10 Crib	Closure
216-A-36B Crib	Closure
216-A-29 Ditch	Closure
216-B-3 Pond System (Includes 216-B-3, -3A, -3B, -3C Ponds and 216-B-3-3 Ditch)	Closure
216-B-63 Trench	Closure
218-E-10 Burial Ground (LLWMA-1)	Landfill Operating Permit
218-E-12B Burial Ground (LLWMA-2)	Landfill Operating Permit
Single-Shell Tanks (Includes 241-A, -AX, -B, -BX, -BY and -C Farms)	Closure
2101-M Pond	Closure
Grout Treatment Facility	Treatment/Landfill Permit

Closure of the single-shell tanks will be addressed under RCRA by the Single-Shell Tank Program (see Section 2.7.1), which presently incorporates groundwater. After closure of the surface facilities, however, it is likely that any groundwater contamination will be remediated under the CERCLA program. Sections 9.3.3.1 through 9.3.3.3 discuss CERCLA/RCRA integration considerations for the remaining RCRA TSD units within the 200 East Groundwater Aggregate Area in terms of:

- Common, baseline activities which must be integrated
- The approach used to recommend whether groundwater monitoring and remediation activities should be addressed under CERCLA or RCRA for RCRA TSD units within the groundwater aggregate area
- Considerations which must be addressed to ensure RCRA conformance under CERCLA activities.

Section 2.7 discussed interactions with other site programs. Coordination with the Expedited Response Action Program will be required for the proposed ERAs and for any IRMs which interact with these ERAs.

The Effluent Treatment Program is developing treatment and disposal facilities for remaining site effluent streams. Such a facility (such as the SALDS, see Section 2.7.3) could potentially be used for treatment and disposal of extracted groundwater under either an ERA or IRM.

Finally, the Remedial Technology Development Program could have a significant role in the development of appropriate remedial alternatives for the mixtures of contaminants which may be found in groundwater at the site of an ERA or IRM.

9.3.3.1 Common RCRA/CERCLA Integration Considerations. Regardless of the program chosen for groundwater characterization and remediation activities at individual units, the needs and requirements of both programs must be considered during the planning and execution of the various project phases. Integration of the requirements of both RCRA and CERCLA into these activities will accomplish several goals, including:

- Coordinate document preparation, investigation and remediation efforts
- Maximize use of existing and collected data
- Minimize amount of additional/duplicative data collection
- More efficient use of resources
- Ensure compatibility of selected remedial measures
- Provide consistency of cleanup action levels

The needs of both the CERCLA and RCRA programs in the groundwater aggregate area should be considered when planning monitoring well installations. The numbers and locations of the wells, the type and depth of well screening, and the type of well installation (e.g., single, nested) should be determined in such a manner as to ensure that both CERCLA and RCRA program needs are served to the maximum extent possible.

Sampling frequencies, and the monitoring parameters and constituents that the samples will be analyzed for, in all monitoring wells in the groundwater aggregate area should be selected to ensure that data necessary to support both the RCRA and CERCLA programs are collected while minimizing sampling efforts.

Analytical methods and QA/QC protocols should be chosen carefully during the preparation of workplans or groundwater monitoring plans to ensure that sample analytical requirements for both the CERCLA and RCRA programs will be met to the maximum extent possible. For example, groundwater activities under RCRA generally rely upon the use of methods from *Test Methods for Evaluating Solid Wastes* (EPA 1986b), while definitive CERCLA activities are generally performed using Contract Laboratory Program (CLP) analytical methods and quality assurance protocols. Specific quantitation limit requirements, such as those established in 40 CFR Part 264 Appendix IX, may also need to be met. The

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methods used for interpretation and statistical analysis of the data collected must also be chosen to ensure both RCRA and CERCLA program requirements will be met.

A single, consistent approach should be used to establish Health Based Levels (HBLs) for RCRA groundwater monitoring programs and cleanup limits for CERCLA groundwater remediation efforts within the groundwater aggregate area. This approach should ensure that common risk levels, compound toxicity factors, and uptake/transport assumptions are used for both programs to the maximum extent possible.

Preparation of the documents necessary to plan and execute characterization and remediation activities (e.g., work plans, closure plans) should be coordinated to ensure that all documentation is available in the time frames necessary to support integrated actions. Time constraints, including Tri-Party Agreement commitments, may dictate whether actions at individual RCRA TSD units are taken under the RCRA or CERCLA programs.

Furthermore, remedial actions should be designed to be mutually beneficial whenever appropriate. Potential adverse effects from remedial actions, such as those that may be associated with modifying groundwater flow patterns or chemistry, should be minimized.

9.3.3.2 RCRA Facility Interface Strategy. Groundwater programs exist for a number of RCRA TSD units. Although the source AAMS reports have provided recommendations for integrating past practice and TSD waste management unit activities with respect to vadose zone contamination, some of the TSD units may have contributed, or are recognized as potential contributors, to groundwater contamination. Thus, it is necessary to have a strategy for deciding if groundwater contamination associated with a TSD unit (or group of TSD units) would best be addressed under the RCRA or CERCLA program. Such a strategy has been developed to facilitate CERCLA/RCRA groundwater integration decisions, and is outlined in this section.

The acceptability of a strategy which allows the use of past practice programs to remediate groundwater contamination at TSD units scheduled for either permitting or closure is discussed in the Tri-Party Agreement. Part One, Article III of the Tri-Party Agreement notes that one purpose of the agreement is to:

> *"... promote an orderly, effective investigation and cleanup of contamination at the Hanford Site* [Section 13B] ... *and coordinate* [RCRA TSD unit] *closure with any inter-connected remedial action at the Hanford Site* ... [Section 14A]"

To ensure that this objective is achieved, integration of CERCLA and RCRA groundwater remediation activities is specifically addressed in Part One, Article IV of the Tri-Party Agreement, which states in part that:

"... *The Parties agree that past practice authority may provide the most efficient means for addressing groundwater contamination plumes originating from both TSD and past practice units ... remedial actions that address TSD groundwater contamination, excluding situations where there is an imminent threat to the public health or environment, will meet or exceed the substantive requirements of RCRA* [Section 17] ... *the Parties recognize and agree that remediation of groundwater contamination from TSD units at the Hanford Site may be managed either under Part Three of this Agreement* [Remedial and Corrective Actions], *or under Part Two of this Agreement* [Permitting/Closure of TSD Facilities] ... [Section 18]"

In keeping with the principles outlined above, groundwater contamination associated with a RCRA TSD unit should be investigated/remediated under CERCLA if any one of the following criteria are met:

- There is minimal contribution from the TSD unit to a major, overall CERCLA groundwater unit. For example, if the TSD unit represents a small "island" contributing minimally to the larger past-practice derived contamination which will be dealt with under the CERCLA program.

- If the TSD unit has been closed and the interim status or final permit has been terminated or nearly terminated (e.g., public notice has been issued).

- If a planned CERCLA ERA or IRM would result in completely or substantially remediating any groundwater releases from the TSD unit.

- If the source TSD unit is addressed under CERCLA as part of an analogous group as a part of a source aggregate area.

For TSD units meeting the following criteria, groundwater activities should remain under the RCRA Program:

- There is no evidence of groundwater contamination at an active or closed TSD unit. Where applicable, active TSD units or TSD units closed as landfills would maintain established detection monitoring programs.

- Groundwater contamination is clearly dominated by contributions from a RCRA TSD unit and any CERCLA contaminants present would be adequately addressed under a RCRA corrective action.

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- Groundwater associated with the TSD unit is hydrologically isolated and has little or no interaction with established groundwater operable units addressed under CERCLA.

Using this strategy, the unit-specific integration recommendations outlined in Sections 9.3.3.2.1 through 9.3.3.2.9 have been developed for the RCRA TSD units currently involved in a groundwater monitoring program.

9.3.3.2.1 200 East Area Liquid Effluent Retention Facility. At the close of 1991, LERF completed a background monitoring program and is currently in a detection monitoring program for indicator parameters. The RCRA final facility status permit application for LERF was submitted in 1991, and is currently under agency review. LERF is currently operating, and it has been recommended in the B Plant source AAMSR that final closure of the source unit occur under the RCRA program.

Groundwater beneath LERF is not hydrologically isolated, and interacts with groundwater from other locations in the 200 East Area. There is currently no evidence that groundwater has been contaminated by releases associated with the LERF. It is recommended that groundwater monitoring activities continue under the RCRA program, integrating CERCLA program needs as described in Section 9.3.3.1. If future detection monitoring indicates that groundwater has been contaminated, it may be necessary to reevaluate the status of groundwater activities at LERF for possible inclusion in the CERCLA program.

9.3.3.2.2 216-A-10 and 216-A-36B Cribs. The 216-A-10 and 216-A-36B Cribs are currently in detection monitoring program for indicator parameters. The 216-A-10 and 216-A-36B Cribs are inactive and are slated for closure in 1996. It is anticipated that the 216-A-10 and 216-A-36B Crib source units will be clean closed under RCRA.

Groundwater beneath the 216-A-10 and 216-A-36B Cribs is not hydrologically isolated, and interacts with groundwater from other locations in the 200 East Area. There is no direct evidence that groundwater beneath these cribs has been contaminated by releases associated with the 216-A-10 or 216-A-36B Cribs. The 216-A-10 Crib is spatially related to the Iodine-129 contamination beneath the 216-A-29 Ditch and a possible contributor to this contamination, as discussed below; however, sample data are currently insufficient to define the source or character of the observed contamination. It is recommended that groundwater monitoring activities at these cribs continue under the RCRA program, integrating CERCLA program needs as described in Section 9.3.3.1. If future detection monitoring indicates that groundwater beneath these cribs has been contaminated as a result of releases from the cribs, it may be necessary to reevaluate the status of groundwater activities at 216-A-10 and 216-A-36B Cribs for possible inclusion in the CERCLA program.

9.3.3.2.3 216-A-29 Ditch. The 216-A-29 Ditch is currently undergoing a groundwater quality assessment due to elevated specific conductance in one downgradient well. The 216-A-29 Ditch is inactive and has undergone interim stabilization. The 216-A-29 Ditch currently is scheduled for clean closure under RCRA; the closure plan is scheduled for submittal in 1996. It has been recommended in the B Plant AAMSR that the 216-A-29 Ditch source unit be transferred to Operable Unit 200-BP-11 and be addressed as part of the 216-B-3 Pond system.

Groundwater beneath the 216-A-29 Ditch is not hydrologically isolated and interacts with groundwater from other locations in the 200 East Area. A portion of the known Iodine-129 plume, believed to be the result of releases from the 216-A-10 and 216-A-45 Cribs, is located beneath the 216-A-29 Ditch (See Figure 4-13). Although there is evidence of possible additional groundwater contamination resulting from releases at the 216-A-29 Ditch, sample data are currently insufficient to define the source or character of the observed contamination. It is recommended that groundwater monitoring continue at the 216-A-29 Ditch under the RCRA program, integrating CERCLA program needs as described in Section 9.3.3.1. Once the nature and apparent source of the groundwater contamination beneath the 216-A-29 Ditch are confirmed, the status of groundwater activities at 216-A-29 Ditch should be reevaluated for possible inclusion in the CERCLA program.

9.3.3.2.4 216-B-63 Ditch System. Currently the 216-B-63 Ditch has completed background monitoring and is in detection monitoring for indicator parameters. The RCRA closure plan is scheduled to be submitted in 1996. The 216-B-63 Ditch is scheduled for closure under the RCRA program. It has been recommended in the B Plant AAMSR that the 216-B-63 Ditch be transferred to Operable Unit 200-BP-11 and be addressed as part of the 216-B-3 Pond system.

Groundwater beneath the 216-B-63 Ditch is not hydrologically isolated, and interacts with groundwater from other locations in the 200 East Area. Currently there is no direct evidence that groundwater has been contaminated as a result of releases from the 216-B-63 Ditch. It is recommended that groundwater monitoring continue under RCRA.

9.3.3.2.5 216-B-3 Pond System. The 216-B-3 Pond System is currently undergoing a groundwater quality assessment due to elevated total organic halogen and total organic carbon concentrations in samples collected in 1990. Assessment monitoring parameters include herbicides, pesticides, PCBs, volatile organics, semi-volatile organics, hydrazine, ammonium, and tritium. All groundwater quality parameter concentrations were below applicable primary or secondary drinking water standards in samples collected in 1991; tritium levels exceeded 180,000 pCi/L (DOE/RL 1992b).

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Groundwater beneath the 216-B-3 Pond System is not hydrologically isolated, and interacts with groundwater from other locations in the 200 East Area. Arsenic and tritium plumes are known to exist beneath the 216-B-3 Pond System (see Figures 4-1 and 4-8). Tritium plumes A and B and arsenic plume A are probably the result of past discharges to the 216-B-3 Pond System; the 216-B-3 Pond System may also have been a contributor to arsenic plume B (See Section 4.1.2.2). A LFI has been recommended to further characterize the 200 East Area arsenic plumes prior to considering an IRM, while a detailed risk assessment and possible RI/FS have been recommended for the 200 East Area tritium plumes (see Sections 9.2.3. and 9.2.4). A LFI/IRM coordinated with RCRA closure activities has been recommended to address soil contamination in the source units in the B-Plant AAMSR. Clean closure is anticipated at the 216-B-3A, 216-B-3B, and 216-B-3C Ponds; the 216-B-3 Pond and 216-B-3-3 Ditch will likely be closed as landfills. Closure plans for the 216-B-3 Pond System were submitted for agency review in 1990.

The 216-B-3 Pond System is spatially related to arsenic plumes A and B, and is a potential contributor to these plumes. The extent of the arsenic plumes currently appears to be limited to the vicinity of the 216-B-3 Pond System, and the plumes do not currently overlap other inorganic contaminant plumes which will be addressed under CERCLA, with the exception of the tritium plume. Therefore, further investigation of the groundwater contamination associated with the 216-B-3 Pond System should occur under the RCRA program, integrating CERCLA program needs for the proposed northern groundwater operable unit (GW-OU-4) as discussed in Section 9.3.3.1. One goal of this investigation should be to better delineate and describe the potential extent of groundwater contamination from the 216-B-3 Pond System, including identifying other potential contaminants which should be addressed.

Assuming that the 216-B-3 Pond System was the source of arsenic contamination, and no other past-practice groundwater contaminants are discovered which do not appear to originate from the 216-B-3 Pond System, remediation of arsenic plumes A and B, if required, should occur under the RCRA program. Any remediation efforts taken under RCRA should be coordinated with similar CERCLA activities in the 200 East Area to ensure consistency of assumptions and approach.

Investigation of tritium plumes A and B should be integrated into the RCRA activities at the 216-B-3 Pond System, ensuring that CERCLA program needs are met as discussed in Section 9.3.3.1. Currently, a risk assessment under the CERCLA program has been recommended for the 200 East Area tritium plumes (see Section 9.2.4.2). Remediation of tritium plumes A and B, if required, would occur under the CERCLA program.

It is recommended that risk assessments under the CERCLA program and closure determinations under the RCRA program be performed in a consistent manner for all

groundwater contamination associated with units in the 216-B-3 Pond System. To accomplish this, groundwater contamination would be evaluated in accordance with the risk assessment methodology being developed and agreed to between DOE, EPA and Ecology under Tri-Party Agreement Milestone M-29-03. The latest presentation of the risk assessment protocols appears in *The Hanford Site Baseline Risk Assessment Methodology* (DOE/RL 1991d). It is expected that these risk assessment protocols will be at least as conservative as the guidelines established under EPA's proposed 40 CFR Part 264 Subpart S regulations published in the July 27, 1990 Federal Register. The Subpart S guidelines will provide the bases for closing RCRA units in a manner that will prevent future threats to human health and the environment. Use of the Milestone M-29-03 methodology would both satisfy the CERCLA past practices risk assessment procedures and allow evaluation of whether or not adequate closure of RCRA TSD units has been accomplished.

9.3.3.2.6 218-E-10 Burial Grounds. The 218-E-10 Burial Grounds make up the Low Level Waste Management Area Number 1 (LLWMA-1) RCRA groundwater monitoring unit. The LLWMA-1 unit is currently undergoing a groundwater quality assessment due to elevated specific conductivity noted in samples collected in 1989. Elevated concentrations of tritium, gross alpha, and gross beta have also been noted (DOE/RL 1992b). Chromium plume A is currently beneath the 218-E-10 Burial Ground (See Figure 4-2). The RCRA final facility permit application was submitted for the 218-E-10 Burial Ground in 1989, and is currently under agency review.

Groundwater beneath the LLWMA-1 unit is not hydrologically isolated, and interacts with groundwater from other locations in the 200 East Area. It is likely that the groundwater contaminants noted above originated from past practice units to the south and east of the 218-E-10 Burial Grounds (See Section 4.1.2.2 and DOE/RL 1992b), and is a part of the larger, overall past-practice contamination which will be dealt with by the CERCLA program in the 200 East Area. Therefore, it is recommended that groundwater contamination beneath the 218-E-10 Burial Ground be investigated and, if necessary, remediated under the CERCLA program (e.g., as a part of proposed groundwater operable unit GW-OU-4 as defined in Section 9.3.1), integrating RCRA program needs as described in Sections 9.3.3.1 and 9.3.3.3.

9.3.3.2.7 218-E-12B Burial Grounds. The 218-E-12B Burial Grounds make up the Low Level Waste Management Area Number 2 (LLWMA-2) RCRA groundwater monitoring unit. The LLWMA-2 is in a detection monitoring program for indicator parameters. The RCRA final facility permit application was submitted for the 218-E-12B Burial Ground in 1989, and is under agency review. The 218-E-12B Burial Ground source unit is recommended for LFI activities under CERCLA. Investigations of the active portion of the 218-E-12B Burial Ground will be included in the past practices investigation if the unit is deactivated prior to the investigation (DOE/RL 1992b).

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Groundwater beneath the 218-E-12B Burial Ground is not hydrologically isolated or unique. Groundwater associated with the Burial Ground interacts with groundwater from other locations in the 200 East Area. There is no evidence that groundwater has been contaminated by releases associated with the 218-E-12B Burial Ground. It is recommended that groundwater monitoring activities continue under the RCRA program, integrating CERCLA program needs as described in Section 9.3.3.1. If future detection monitoring indicates that groundwater has been contaminated, it may be necessary to reevaluate the status of groundwater activities at 218-E-12B Burial Ground for possible inclusion in the CERCLA program.

9.3.3.2.8 2101-M Pond. The 2101-M Pond, located southwest of the 2101-M Building, is currently in a detection monitoring program for indicator parameters. The 2101-M Pond is active, receiving small volumes of waste water from the 2101-M Building heating and air conditioning system. The RCRA closure plan was submitted in 1991 and is currently undergoing agency review. The 2101-M pond is currently scheduled for clean closure under the RCRA program.

Groundwater beneath the 2101-M Pond is not hydrologically isolated and interacts with groundwater from other locations in the 200 East Area. Arsenic plume D is located beneath the 2101-M Pond; this spatial relationship implies that the 2101-M Pond may be the source of arsenic plume D (See Figure 4-1). However, there is no historical record of arsenic compounds being discharged to the 2101-M Pond, and the apparent elevated arsenic concentrations have previously been attributed to local variations in background concentrations (DOE/RL 1991f). The extent of arsenic plume D appears to be limited to the vicinity of the 2101-M Pond, and this plume does not currently overlap other inorganic contaminant plumes which will be addressed under CERCLA. Therefore, further investigation of the groundwater contamination beneath the 2101-M Pond should occur under the RCRA program, integrating CERCLA program needs for GW-OU-3 as discussed in Section 9.3.3.1.

If future groundwater investigations indicate that groundwater has been contaminated by releases from the 2101-M Pond, it may be necessary to reevaluate the status of groundwater activities at the 2101-M Pond for possible inclusion in the CERCLA program.

9.3.3.2.9 Grout Treatment Facility. Currently, the Grout Treatment Facility is in a detection monitoring program for indicator parameters. The facility is currently active, stabilizing wastes with cementatious grout prior to disposal into onsite disposal vaults. The Part B RCRA TSD facility permit application for the Grout Treatment Facility was submitted in 1988 and is currently under agency review.

Groundwater beneath the Grout Treatment Facility is not hydrologically isolated and interacts with groundwater from other locations in the 200 East Area. Currently there is no evidence that groundwater has been contaminated as a result of releases from the Grout Treatment Facility. Groundwater beneath the Grout Treatment Facility contains elevated concentrations of several indicator parameters and contaminants (e.g., TOX, TOC, conductivity, tritium) believed to be the result of releases from other, past-practice units in the 200 East Area. It is recommended that groundwater monitoring activities continue under the RCRA program, integrating CERCLA program needs as described in Section 9.3.3.1. If future detection monitoring indicates that groundwater has been contaminated as a result of releases from the Grout Treatment Facility, it may be necessary to reevaluate the status of groundwater activities at the Grout Treatment Facility for possible inclusion in the CERCLA program.

9.3.3.3 Ensuring RCRA Conformance Under CERCLA Activities. In order to close or permit a RCRA TSD unit, it will be necessary to gather certain information and make certain demonstrations. In the event that groundwater associated with a TSD unit is investigated or remediated under CERCLA, the CERCLA activities should be performed in a manner that will support final RCRA actions. The goals of integrating RCRA requirements into CERCLA actions are:

- To ensure that cleanup and closure are performed <u>once</u>, in a single action;
- To demonstrate that the substantive requirements of RCRA have been satisfied;
- To support final permitting or closure of the TSD unit; and
- To minimize the need for post-closure care.

CERCLA activities will affect site conditions at neighboring and included RCRA TSD units. The potential impact that these affects may have on the data collected or the demonstrations being performed to achieve conformance with RCRA standards must be accounted for when planning CERCLA groundwater activities. An example where careful planning and integration would be necessary would be the case where groundwater extraction and treatment are being performed at a CERCLA operable unit, altering groundwater flow patterns and contaminant transport characteristics within groundwater monitoring networks which have been established to conform to RCRA requirements.

Investigation and remediation activities performed under CERCLA at RCRA TSD units must supply the data necessary to support RCRA TSD unit permit or demonstration needs. Examples would be ensuring that groundwater characterization data necessary to

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support a petition for exemption from dangerous waste tank release standards, or to demonstrate clean closure of a RCRA TSD unit, are collected.

CERCLA groundwater activities must ensure that RCRA groundwater closure requirements are met. For example, groundwater monitoring at RCRA TSD units closed through a CERCLA remedial action may be required to continue for as long as 30 years after completion of the remedial action. When possible, CERCLA groundwater remediation activities should be performed in such a manner as to ensure that only detection monitoring will be required for active or closed RCRA TSD units within the 200 East Groundwater Aggregate Area. When practical, CERCLA activities should be performed in such a manner as to demonstrate clean closure of the RCRA TSD unit. An example of such a case would be a RCRA TSD unit within a CERCLA operable unit where cleanup of the groundwater to RCRA cleanup criteria for the constituents of concern at the RCRA TSD unit is achievable.

9.3.4 Integration of Ongoing CERCLA Activities

CERCLA activities are currently underway at operable unit 200-BP-1 in the 200 East Area. This operable unit is addressing groundwater contamination originating from WMUs within the operable unit. Phase II RI activities are planned for 1993 at this operable unit, including the following investigations:

- Delineation of the erosional windows interconnecting the uppermost (unconfined) aquifer and the Rattlesnake Ridge confined aquifer
- Widened groundwater monitoring
- Aquifer testing
- Treatability studies

These activities address data needs which are not specific to 200-BP-1 but are also applicable to the broader groundwater operable unit as discussed in Section 9.3.2. The lack of groundwater monitoring data, plume definition, geologic characterization of the erosional windows, adequate aquifer testing, and treatability data were identified as a data gaps in Sections 8.3.2 and 9.2.3. In addition, 200-BP-1 contaminants of concern including ^{99}Tc ^{60}Co, cyanide, and nitrate have moved to the north beyond the source operable unit boundaries and have been recommended for an IRM in Section 9.2.2. As a result, it is recommended that the scope of work associated with 200-BP-1 Phase II activities be expanded to include the LFIs recommended for the northern ground water operable unit designated GW-04-4. This can be accomplished by preparing a joint or common work plan

(e.g., Groundwater Operable Unit 200-BP-8 Work Plan) that is appropriately prioritized to ensure that the original 200-BP-1 RI/FS schedule is maintained. This would be an initial step in integrating the 200-BP-1 program into the overall AAMS and Hanford Past-Practice Strategy (HPPS) process for the 200 Areas and consistent with the general recommendation to remove the groundwater from source operable units.

The scale of the proposed GW-OU-4 is somewhat larger than that of 200-BP-1, but the information derived from the needs of 200-BP-1 is directly applicable to the AAMS process. Groundwater and contaminant concentration data will be useful to both studies in defining the extent of contamination. Treatability study information from 200-BP-1 will be helpful in determining IRM treatment technologies for the $^{99}Tc/^{60}Co$/cyanide/nitrate plume. The remediation schedule for the plume should be enhanced if it is addressed as a priority IRM rather that go through the multiphase RI/FS process. As an added benefit, there would be savings associated with installing wells, collecting plume data, and performing other investigations that satisfy the needs of the broader study than if several studies were conducted independently of each other.

9.3.5 Contaminants Addressed by Other Programs

The 200 East Groundwater AAMS was instituted to address contamination emanating from sources within the 200 East source aggregate areas. Some contamination has been detected in monitoring wells which originate from outside the 200 East source aggregate areas. The constituents in this category are mainly chlorinated aliphatic hydrocarbons which have historically been used in solvents and as degreasing agents. They have been found near the Solid Waste Landfill (located in Operable Unit 200-IU-3) about 6 km (4 mi) southeast of the 200 East Area and are probably associated with it.

These constituents include tetrachlorethylene (PCE), trichloroethylene (TCE), 1,1,1-trichloroethane (TCA), 1,1,2-TCA (not confirmed), 1,1-dichloroethane (DCA), 1,2-DCA (not confirmed), cis- and trans- isomers of 1,2-dichloroethylene (DCE, neither confirmed), carbon tetrachloride (not confirmed), chloroform, and methylene chloride (not confirmed). These could be either residuals of solvent materials which may have been disposed of in the landfill, or breakdown products of such materials. Trichloroethylene and PCE exceeded their drinking water standards (MCLs) and are considered carcinogenic. The 1,1,1-TCA, although not above its MCL, is potentially a major contributor to noncarcinogenic risk (ranked second highest maximum present noncarcinogenic relative risk). 1,1-DCA contributes to carcinogenic risk.

These constituents are addressed by the Hanford Site Solid Waste Landfill Application (DOE/RL-90-38) and groundwater monitoring program per WAC 173-304.

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9.4 FEASIBILITY STUDY

Two types of FS will be conducted to support remediation in the 200 Areas including focused and the final FS. Focused feasibility studies (FFSs) are studies in which a limited number of contaminants or remedial alternatives are considered. A final FS will be prepared to provide the data necessary to support the preparation of final ROD. Data are insufficient to prepare either a focused or final FS for any contaminants in the 200 East Groundwater Aggregate Area. Sufficient data are considered available to prepare a FFS on selected remedial alternatives.

9.4.1 Focused Feasibility Study

IRMs are planned for the 200 East Groundwater Aggregate Area for various contaminants or groups of contaminants and will need to be supported by FFSs. The FFS applied in this manner is intended to examine a limited number of alternatives for a specific contaminant or groups of contaminants. The FFS supporting IRMs will be based on the technology screening process applied in Section 7.0, engineering judgment, and/or new characterization data such as that generated by an LFI.

In most cases, LFIs will be conducted at plumes initially identified for IRMs. The information gathered is considered necessary prior to making a final determination whether an IRM is actually necessary or whether a remedy can be selected.

Rather than being driven by an IRM, the FFS will also be prepared to evaluate select remedial alternatives. In this case the FFS focuses on technologies or alternatives that are considered to be viable based on their implementability, cost, and effectiveness and broad application to a variety of sites. The following recommendations are made for FS that focus on a particular technology or alternative:

- Pump and treat
- Barriers
- Gradient modification.

These recommendations reflect select technologies developed in Section 7.0 of this AAMSR.

The FFS is intended to provide a detailed analysis of select remedial alternatives. The results of the detailed analysis provide the basis for identifying preferred alternatives. The detailed analysis for alternatives consists of the following components:

- Further definition of each alternative, if appropriate, with respect to the volumes or areas of contaminated environmental media to be addressed, the technologies to be used, and any performance requirements associated with those technologies. Remedial investigations and treatability studies, if conducted, will also be used to further define applicable alternatives.

- An assessment and summary of each alternative against evaluation criteria specified in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988b).

- A comparative analysis of the alternatives that will facilitate the selection of a remedial action.

9.4.2 Final Feasibility Study

To complete the remediation process for an aggregate area, a final or summary FS will be prepared. This study will address those contaminants not previously evaluated and will summarize the results of preceding evaluations. The overall study and evaluation process for an aggregate area will consist of a number of FFSs, field investigations, and interim RODs. All of this study information will be summarized in one final FS to provide the data necessary for the final ROD. The summary FS will likely be conducted on an aggregate area basis.

9.5 TREATABILITY STUDIES

In accordance with EPA RI/FS guidance (EPA 1988b), treatability studies will be conducted when existing data are insufficient to provide required design values, practical cost ranges, or proof-of-principle for technologies identified in the feasibility study process. Treatability studies involve bench-scale testing, analysis of existing information and, in a few situations, pilot-scale proof-of-principle studies. It is important to conduct both treatability tests and pilot-scale tests at the earliest stages of the remediation process to allow overall schedules to be maintained.

The preliminary screening of technologies conducted in Section 7.0 identified several technologies that could play a key role in 200 East Area groundwater feasibility studies, but

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currently have insufficient data to establish engineering design values, functional cost estimates, or proof-of-principle. Therefore the following treatability studies are recommended.

9.5.1 Treatment of Extracted Groundwater

Treatment of extracted groundwater is likely to play an important role in 200 East Area groundwater remediation. The performance of even proven treatment technologies cannot sufficiently be predicted because of the numerous contaminants present in groundwater, the high level of performance required by potential RAOs, and the presence of interfering background chemicals common to groundwater (such as reduced iron). To establish the viability and practically of these proven technologies, treatability tests are required.

Key technologies identified in Section 7.0 include reverse osmosis, coagulation/filtration, chemical precipitation, ion exchange, and UV/oxidation. Treatability testing should include, at a minimum, an evaluation of fouling problems associated with background groundwater contaminants (such as reduced iron); technologies that have the widest range of applicability to contaminants identified in 200 East Area groundwater; interferences of these contaminants; secondary waste quantities (see Section 9.5.2); and other potential adverse effects. Most of these technologies are currently under evaluation for the C-018H and -049H Projects. These programs should be used as models for a groundwater treatability program. A key consideration will be establishing which technologies are capable of meeting the potentially stringent standards anticipated in final RAOs.

9.5.2 Treatment of Secondary Waste

Ion exchange, chemical precipitation, and reverse osmosis are candidate technologies for removing inorganics and radionuclides from groundwater; however the production of secondary waste in these technologies is an adverse effect. For ion exchange and reverse osmosis, the volume of secondary waste can exceed 10% of the influent mass. Typically at the Hanford Site, secondary waste is solidified and landfilled, or placed in double-shell tanks for later volume reduction by evaporation. Because these practices are increasingly undesirable, alternative secondary waste concentration technologies should be evaluated on a bench scale. Innovative technologies that might be evaluated include freeze crystallization and supercritical extraction.

9.5.3 Pilot Testing of Containment Technologies

Section 7.0 identified engineered barriers (i.e., containment) technologies including grout injection and freeze technologies as important in the final remedy for 200 East Area groundwater. Containment technologies are not believed to be a sole solution, but their unique qualities make them mandatory components of a final solution. Preliminary screening indicated that due to the depth of groundwater in the 200 Areas, implementation costs and effectiveness need to be established prior to their consideration.

Small-scale pilot tests (or other means) should be conducted to assess this uncertainty. Pilot-scale testing should be conducted to determine required grout injection point or freezing equipment spacing to identify special installation techniques needed, and to better understand potential cost ranges.

9.6 AGGREGATE AREA-SCALE CHARACTERIZATION RECOMMENDATIONS

The analysis of data needs (Section 8.2.3) and resulting investigation strategy (Section 8.3.3) pointed out a number of issues which should be addressed in investigations subsequent to the AAMS process. Some of these issues will be addressed as part of the LFIs and the RI, but some are not plume specific and would be better investigated on an aggregate area basis. These issues include:

- **Installation of additional monitoring wells**, mainly in areas where historically few wells have been located. These include the portion of the B Plant Aggregate Area north of the 200 East Area fenceline where the ^{99}Tc IRM is located; areas near the 216-B-5 Reverse Well; and other areas where plumes are not well delineated. In addition, many of the plumes have migrated into the 600 Area (i.e., outside the 200 East Area fenceline) and the number of wells is few here as well. While some of the wells required in this area will be installed in the course of the investigation of these plumes, it may be necessary to install others in the 600 Areas to provide sufficient coverage. An approximate number of about ten wells should be sufficient as an initial investigation. This process will also provide data to bridge gaps in the geologic understanding of this area.

- **Continued groundwater monitoring** is necessary to continue to augment the analytical data base. To some extent this will be supplied by other programs (especially the programs by the Westinghouse Hanford Operational Groundwater Monitoring Network and the Pacific Northwest Laboratory), but the coverage obtained by the AAMS sampling should also be continued and

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expanded. As the data base is checked, specific questions can be addressed in this program which can be configured to be flexible in such matters as which analytes and wells are to be included.

- **Computer modeling capabilities** should be enhanced and developed. This is necessary at three levels: at the source unit level, where vadose zone models must be calibrated and applied to determine the potential for continuing releases; at the aggregate area level to show the details of the groundwater flow system and the effects of various remedial alternatives; and at the Hanford Site level, which will estimate the long term effects of groundwater flow systems and contaminant plumes on receptors beyond the extent of the 200 East Groundwater Aggregate Area. The models for these purposes have been chosen, only their development on a site-specific basis and calibration remain.

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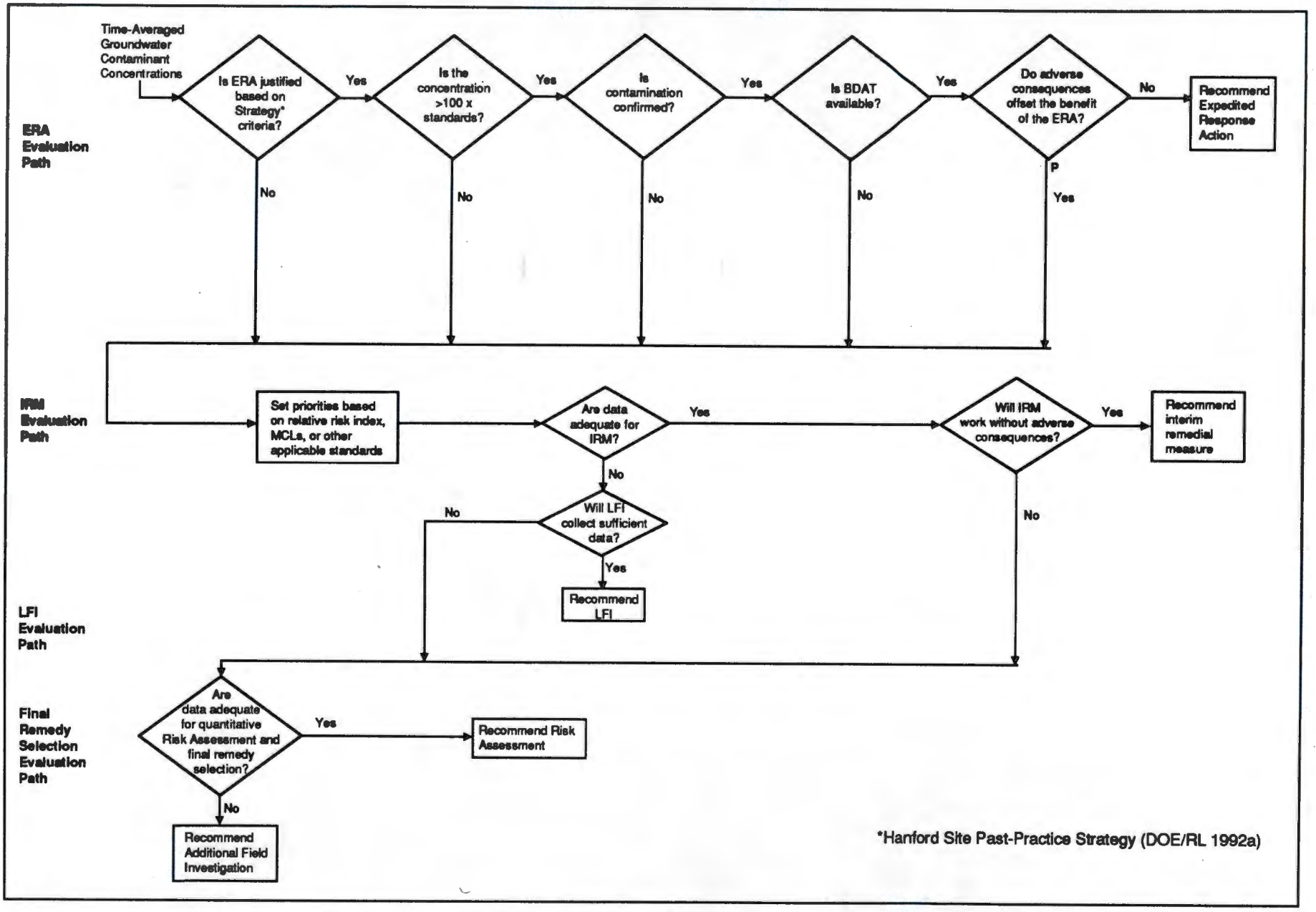

Figure 9-1. Groundwater Aggregate Area Management Study Data Evaluation Process.

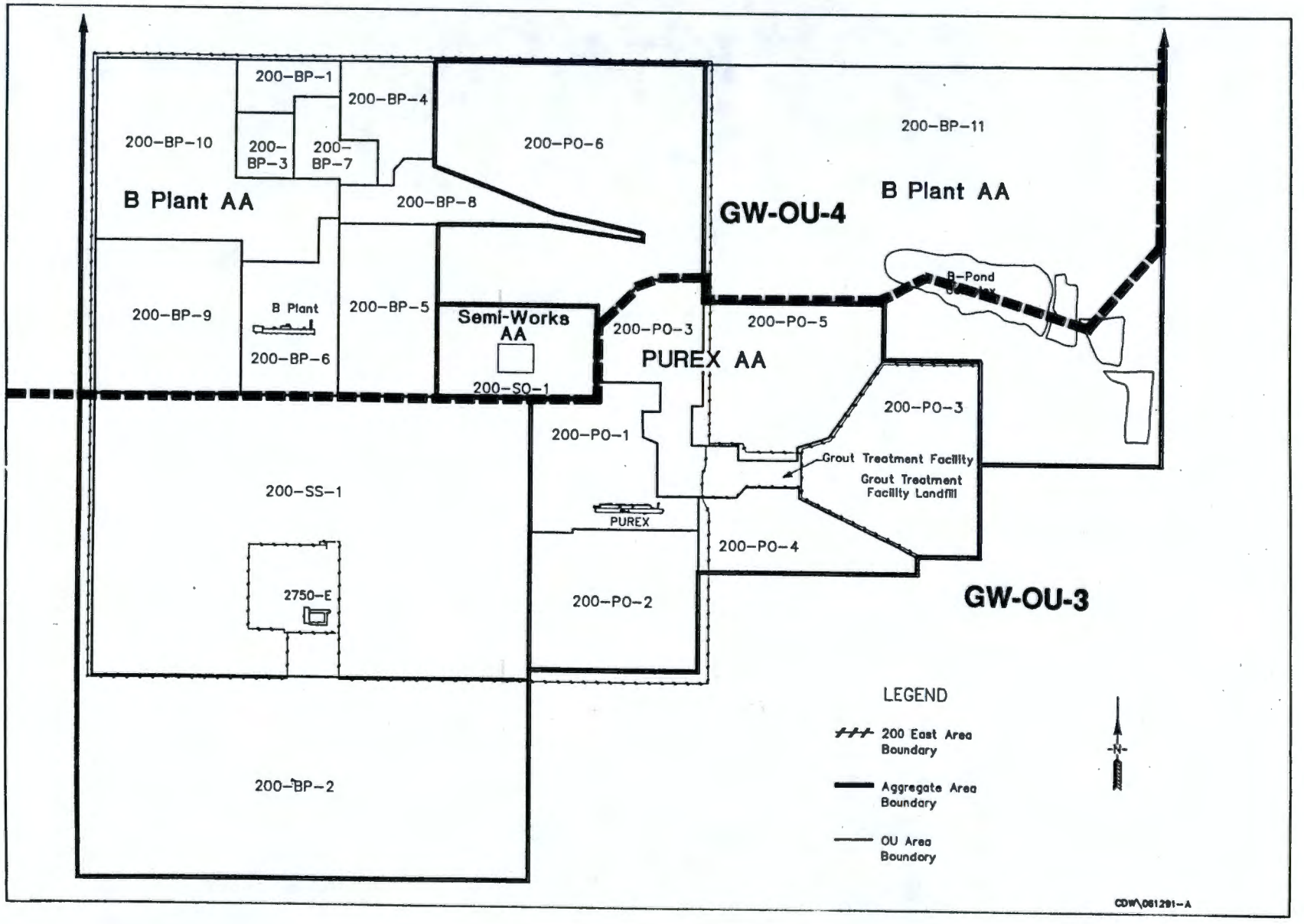

Figure 9-2. 200 East Aggregate Areas.

Table 9-1. Summary of the Results of the Data Evaluation Process Path Assessment.

Detected Constituent	ERA	IRM	LFI	RA	RI	Remarks
ORGANIC COMPOUNDS (μg/L)						
Chlorinated Aliphatics						
Chloroform (CHCl3)	--	--	--	--	X	
Carbon Tetrachloride (CCl4)	--	--	--	--	X	Not confirmed in any well detected (of 7)
Methylene Chloride	--	--	X	--	--	Possible laboratory contaminant
1,1-Dichloroethane (DCA)	--	--	--	--	--*	
1,2-Dichloroethane (DCA)	--	--	--	--	--*	Single detection, not confirmed
Cis-1,2-Dichloroethylene (DCE)	--	--	--	--	--*	Not confirmed in either well detected
Trans-1,2-Dichloroethylene (DCE)	--	--	--	--	--*	Not confirmed in either well detected
1,1,1-Trichloroethane (TCA)	--	--	--	--	--*	Below MCL but RRI rank = 2 (current, NC)
1,1,2-Trichloroethane (TCA)	--	--	--	--	--*	Single detection, not confirmed
Trichloroethylene (TCE)	--	--	--	--	--*	Above MCL in 2 wells
Tetrachloroethylene (PCE)	--	--	--	--	--*	Above MCL in 4 wells
Aromatics						
Pyrene	--	--	--	--	X	Single detection, not confirmed
Styrene	--	--	--	--	X	
Toluene	--	--	--	--	X	
2,4-Dinitrotoluene	--	--	X	--	--	Single detection, not confirmed
Phenols						
Phenol	--	--	--	--	X	Not confirmed in any well detected (of 5)
o-Nitrophenol	--	--	--	--	X	Neither detetion (of 2) confirmed
2,4-Dinitrophenol	--	--	X	--	--	Neither detection (of 2) confirmed
2-Chlorophenol	--	--	--	--	X	
2,4-Dichlorophenol	--	--	--	--	X	Single detection, not confirmed
2,3,4,6-Tetrachlorophenol	--	--	--	--	X	Single detection, not confirmed
Pentachlorophenol	--	--	X	--	--	Single detection, not confirmed
2,4-Dimethylphenol	--	--	--	--	X	Neither detection (of 2) confirmed
Ketones						
Acetone	--	--	--	--	X	Possible laboratory contaminant, no detection confirmed (of 25 wells)
Methyl ethyl ketone (MEK)	--	--	--	--	X	No detection confirmed (of 4 wells)
4-Methyl-2-Pentanone	--	--	--	--	X	Neither detection (of 2) confirmed
Cyclohexanone	--	--	--	--	X	Single detection, not confirmed
Pesticides						All pesticide detections colocated.
Aldrin	--	--	X	--	--	
DDD	--	--	--	--	X	

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Table 9-1. Summary of the Results of the Data Evaluation Process Path Assessment.

Detected Constituent	ERA	IRM	LFI	RA	RI	Remarks
DDT	--	--	--	--	X	
Dieldrin	--	--	X	--	--	
Endrin	--	--	X	--	--	
Endrin Aldehyde	--	--	--	--	X	
Gamma-BHC	--	--	--	--	X	
Heptachlor	--	--	--	--	X	
Miscellaneous Organics						
Bis(2-ethylhexyl) phthalate	--	--	X	--	--	Possible laboratory or sampling artifact
Diethyl ether	--	--	--	--	X	No detection confirmed (of 3 wells)
Dimethoate	--	--	--	--	X	
Ethyl cyanide	--	--	--	--	X	Single detection, not confirmed
P-chloro-m-cresol	--	--	--	--	X	
Phorate	--	--	--	--	X	Neither detection (of 2) confirmed
Trichloromonofluoromethane	--	--	--	--	X	Neither detection (of 2) confirmed
Triethylene glycol	--	--	--	--	X	Single detection, not confirmed
RADIONUCLIDES (pCi/L)						
Gross alpha	--	--	X	--	--	Indicator parameter
Gross beta	--	--	X	--	--	Indicator parameter
Tritium (H-3)	--	--	--	X	--	
Beryllium(Be)-7	--	--	--	--	X	No detection (of 5) confirmed
Carbon(C)-14	--	--	--	--	X	
Potassium(K)-40	--	--	X	--	--	Naturally occurring
Cobalt(Co)-60	--	X	--	--	--	Colocated with Tc-99, cyanide, and nitrate
Zinc(Zn)-65	--	--	--	--	X	No detection (of 4) confirmed
Strontium(Sr)-90	X	--	--	--	--	
Zirconium/Niobium(Zr/Nb)-95	--	--	--	--	X	Neither detection (of 2) confirmed
Technetium(Tc)-99	--	X	--	--	--	Overlaps with Co-60, nitrate, and cyanide
Ruthenium(Ru)-106	--	--	X	--	--	
Antimony(Sb)-125	--	--	--	--	X	
Iodine(I)-129	--	--	X	--	--	Single detection above 4% DCG
Cesium(Cs)-134	--	--	--	--	X	
Cesium(Cs)-137	--	X	--	--	--	Colocated with Sr-90
Cerium/Praseodymium(Ce/Pr)-144	--	--	--	--	X	Neither detection (of 2) confirmed
Europium(Eu)-154	--	--	--	--	X	No detection (of 11) confirmed
Europium (Eu)-155	--	--	--	--	X	No detection (of 4) confirmed
Lead(Pb)-212	--	--	--	--	X	No detection (of 4) confirmed
Radium (Ra)	--	--	--	--	X	

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Table 9-1. Summary of the Results of the Data Evaluation Process Path Assessment.

Detected Constituent	ERA	IRM	LFI	RA	RI	Remarks
Uranium (U)	--	--	--	--	X	
Uranium(U)-234	--	X	--	--	--	One well above 4% DCG
Uranium(U)-235	--	--	--	--	X	
Uranium(U)-238	--	X	--	--	--	One well above 4% DCG
Plutonium(Pu)-238	--	--	--	--	X	Colocated with Pu-239/240
Plutonium(Pu)-239/40	--	X	--	--	--	Colocated with Sr-90
Americium(Am)-241	--	--	--	--	X	
INORGANIC COMPOUNDS (μg/L)						Most inorganics require determination of background determination
Aluminum (Al)	--	--	--	--	X	
Ammonium ion (NH4)	--	--	--	--	X	
Antimony (Sb)	--	--	X	--	--	
Arsenic (As)	--	--	X	--	--	
Barium (Ba)	--	--	--	--	X	
Beryllium (Be)	--	--	X	--	--	No detection (of 8) confirmed
Boron (B)	--	--	--	--	X	
Bromide (Br)	--	--	--	--	X	No detection (of 4) confirmed
Cadmium (Cd)	--	--	X	--	--	
Calcium (Ca)	--	--	--	--	X	
Chloride (Cl)	--	--	--	--	X	
Chromium (Cr)	--	--	X	--	--	Long term relative risk
Cobalt (Co)	--	--	--	--	X	No detection (of 4) confirmed
Copper (Cu)	--	--	--	--	X	
Cyanide (CN)	--	X	--	--	--	Colocated with Co-60, Tc-99, and nitrate
Fluoride (F)	--	--	--	--	X	
Hydrazine	--	--	X	--	--	Neither detection confirmed
Iron (Fe)	--	--	--	--	X	
Lead (Pb)	--	--	--	--	X	
Lithium (Li)	--	--	--	--	X	
Magnesium (Mg)	--	--	--	--	X	
Manganese (Mn)	--	--	--	--	X	
Mercury (Hg)	--	--	--	--	X	No detection (of 3) confirmed
Nickel (Ni)	--	--	--	--	X	
Nitrate (NO3)	--	X	--	--	--	Highest levels colocated with Tc-99, Co-60, and cyanide
Nitrite (NO2)	--	--	--	--	X	
Phosphate (PO4)	--	--	--	--	X	
Potassium (K)	--	--	--	--	X	

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Table 9-1. Summary of the Results of the Data Evaluation Process Path Assessment.

Detected Constituent	ERA	IRM	LFI	RA	RI	Remarks
Selenium (Se)	--	--	X	--	--	
Silicon (Si)	--	--	--	--	X	
Silver (Ag)	--	--	--	--	X	Single detection, not confirmed
Sodium (Na)	--	--	--	--	X	
Strontium (Sr)	--	--	--	--	X	
Sulfate (SO4)	--	--	--	--	X	
Thallium (Tl)	--	--	X	--	--	Single detection, not confirmed
Titanium (Ti)	--	--	--	--	X	
Uranium (U), chemical	--	--	--	--	X	
Vanadium (V)	--	--	--	--	X	
Zinc (Zn)	--	--	--	--	X	

* Addressed separately from Aggregate Area Management Study

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Table 9-2. 200 East Groundwater Aggregate Area Data Evaluation Decision Matrix.

	ERA Evaluation Path								RRI Rank				IRM Path				Final Remedy Path		
									Current		Future								
Detected Constituent	Max Conc	HSPPS justfd?	GW Std	>100 *Std?	conf?	BDAT avail?	Adv Cnsq?	ERA?	C	NC	C	NC	Data Adeq?	LFI?	Adv Cnsq?	IRM?	Data Adeq?	RA?	RI?
ORGANIC COMPOUNDS (μg/L)																			
Chlorinated Aliphatics																			
Chloroform (CHCl3)	8.3	Y	100	N	–	–	–	N	18	–	–	–	N	N	–	–	N	–	Y
Carbon Tetra-chloride (CCl4)	4.5	Y	5	N	–	–	–	N	NR	–	–	–	N	N	–	–	N	–	Y
Methylene Chloride	1,286	Y	5	Y	N	–	–	N	NR	–	–	–	N	Y	–	–	–	–	–
1,1-Dichloro-ethane (DCA)	5.3	Y	NA	N	–	–	–	N	7	24	–	–	N	N	–	–	N	–	N*
1,2-Dichloro-ethane (DCA)	4.0	Y	5	N	–	–	–	N	NR	–	–	–	N	N	–	–	N	–	N*
Cis-1,2-Dichloro-ethylene (DCE)	1.2	Y	70	N	–	–	–	N	NR	–	–	–	N	N	–	–	N	–	N*
Trans-1,2 Dichloro-ethylene (DCE)	4.7	Y	100	N	–	–	–	N	NR	–	–	–	N	N	–	–	N	–	N*
1,1,1-Trichloro-ethane (TCA)	39.5	Y	200	N	–	–	–	N	–	2	–	–	N	N	–	–	N	–	N*
1,1,2-Trichloro-ethane (TCA)	2.1	Y	5	N	–	–	–	N	NR	–	–	–	N	N	–	–	N	–	N*
Trichloro ethylene (TCE)	12	Y	5	N	–	–	–	N	18	–	–	–	N	N	–	–	N	–	N*
Tetrachloro-ethylene (PCE)	8.2	Y	5	N	–	–	–	N	22	–	–	–	N	N	–	–	N	–	N*
Aromatics																			
Pyrene	8.5	Y	NA	N	–	–	–	N	–	NR	–	–	N	N	–	–	N	–	Y
Styrene	9.5	Y	100	N	–	–	–	N	–	5	–	–	N	N	–	–	N	–	Y
Toluene	30	Y	1,000	N	–	–	–	N	–	21	–	–	N	N	–	–	N	–	Y
2,4-dinitro-toulene	8.7	Y	NA	N	–	–	–	N	NR	–	–	–	N	Y	–	–	–	–	–

Table 9-2. 200 East Groundwater Aggregate Area Data Evaluation Decision Matrix.

	ERA Evaluation Path								RRI Rank				IRM Path				Final Remedy Path		
									Current		Future								
Detected Constituent	Max Conc	HSPPS justfd?	GW Std	>100 *Std?	conf?	BDAT avail?	Adv Cnsq?	ERA?	C	NC	C	NC	Data Adeq?	LFI?	Adv Cnsq?	IRM?	Data Adeq?	RA?	RI?
Phenols																			
Phenol	12.3	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
o-Nitrophenol	28	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
2,4-Dinitrophenol	120	Y	NA	N	--	--	--	N	--	NR	--	--	N	Y	--	--	--	--	--
2-Chlorophenol	15.3	Y	NA	N	--	--	--	N	--	12	--	--	N	N	--	--	N	--	Y
2,4-Dichloro-phenol	18	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
2,3,4,5-Tetra-chlorophenol	10	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
Pentachloro-phenol	67	Y	1	N	--	--	--	N	--	NR	--	--	N	Y	--	--	--	--	--
2,4-Dimethyl-phenol	20	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
Ketones																			
Acetone	140	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
Methyl ethyl ketone (MEK)	37	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
4-Methyl-2-Pentanone	11	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
Cyclohexanone	4	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
Pesticides																			
Aldrin	0.7	Y	NA	N	--	--	--	N	NR	--	--	--	N	Y	--	--	--	--	--
DDD	0.2	Y	NA	N	--	--	--	N	NR	--	--	--	N	N	--	--	N	--	Y
DDT	2.5	Y	NA	N	--	--	--	N	NR	--	--	--	N	N	--	--	N	--	Y
Dieldrin	1.6	Y	NA	N	--	--	--	N	NR	--	--	--	N	Y	--	--	--	--	--
Endrin	2.3	Y	2	N	--	--	--	N	--	NR	--	--	N	Y	--	--	--	--	--
Endrin Aldehyde	0.3	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y

Table 9-2. 200 East Groundwater Aggregate Area Data Evaluation Decision Matrix.

	ERA Evaluation Path								RRI Rank				IRM Path				Final Remedy Path		
									Current		Future								
Detected Constituent	Max Conc	HSPPS justfd?	GW Std	>100 *Std?	conf?	BDAT avail?	Adv Cnsq?	ERA?	C	NC	C	NC	Data Adeq?	LFI?	Adv Cnsq?	IRM?	Data Adeq?	RA?	RI?
Gamma-BHC	0.7	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
Heptachlor	0.6	Y	0.4	N	--	--	--	N	NR	--	--	--	N	N	--	--	N	--	Y
Miscellaneous Organics																			
Bis(2-ethy lhexyl) phthalate	56	Y	6	N	--	--	--	N	NR	--	--	--	N	Y	--	--	--	--	--
Diethyl ether	10	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
Dimethoate	5,243	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
Ethyl cyanide	5,003	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
P-chloro-m-cresol	15	Y	NA	N	--	--	--	N	--	20	--	--	N	N	--	--	N	--	Y
Phorate	11	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
Trichloromono-fluoromethane	11	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
Triethylene glycol	10	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
RADIONUCLIDES (pCi/l)																			
Gross alpha	167	Y	15	N	--	--	--	N	--	--	--	--	N	Y	--	--	--	--	--
Gross beta	10,254	Y	50	Y	Y	N	--	N	--	--	--	--	N	Y	--	--	--	--	--
Tritium (H-3)	4,270,000	Y	20,000	Y	Y	N	--	N	4	--	4	--	Y	N	Y	--	Y	Y	--
Beryllium(Be)-7	222	Y	40,000	N	--	--	--	N	NR	--	--	--	N	N	--	--	N	--	Y
Carbon(C)-14	38	Y	2,800	N	--	--	--	N	16	--	--	--	N	N	--	--	N	--	Y
Potassium(K)-40	240	Y	280	N	--	--	--	N	7	--	--	--	N	Y	--	--	--	--	--
Cobalt(Co)-60	474	Y	200	N	--	--	--	N	10	--	L	--	N	N	N	Y	--	--	--
Zinc(Zn)-65	7.5	Y	360	N	--	--	--	N	NR	--	--	--	N	N	--	--	N	--	Y
Strontium(Sr)-90	5,150	Y	8	Y	Y	Y	N	Y	1	--	L	--	--	--	--	--	--	--	--
Zirconium/ Niobium (Zr/Nb)-95	81	Y	1,600	N	--	--	--	N	NR	--	--	--	N	N	--	--	N	--	Y

Table 9-2. 200 East Groundwater Aggregate Area Data Evaluation Decision Matrix.

	ERA Evaluation Path								RRI Rank				IRM Path				Final Remedy Path		
									Current		Future								
Detected Constituent	Max Conc	HSPPS justfd?	GW Std	>100 *Std?	conf?	BDAT avail?	Adv Cnsq?	ERA?	C	NC	C	NC	Data Adeq?	LFI?	Adv Cnsq?	IRM?	Data Adeq?	RA?	RI?
Technetium (Tc)-99	21,700	Y	4,000	N	--	--	--	N	2	--	1	--	Y	N	N	Y	--	--	--
Ruthenium (Ru)-106	301	Y	240	N	--	--	--	N	12	--	--	--	N	Y	--	--	--	--	--
Antimony (Sb)-125	7.9	Y	2,000	N	--	--	--	N	23	--	--	--	N	N	--	--	N	--	Y
Iodine(I)-129	30	Y	20	N	--	--	--	N	7	--	3	--	N	Y	--	--	--	--	--
Cesium(Cs)-134	3.6	Y	80	N	--	--	--	N	17	--	--	--	N	N	--	--	N	--	Y
Cesium(Cs)-137	1,330	Y	120	N	--	--	--	N	5	--	L	--	Y	N	N	Y	--	--	--
Cerium/Prase-odymium(Ce/Pr)-144	29	Y	280	N	--	--	--	N	NR	--	--	--	N	N	--	--	N	--	Y
Europium (Eu)-154	12	Y	800	N	--	--	--	N	NR	--	--	--	N	N	--	--	N	--	Y
Europium(Eu)-155	9.4	Y	4,000	N	--	--	--	N	NR	--	--	--	N	N	--	--	N	--	Y
Lead(Pb)-212	13	Y	120	N	--	--	--	N	NR	--	--	--	N	N	--	--	N	--	Y
Radium (Ra)	1.6	Y	5	N	--	--	--	N	14	--	--	--	N	N	--	--	N	--	Y
Uranium (U)	21	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
Uranium(U)-234	33	Y	20	N	--	--	--	N	11	--	--	--	Y	N	N	Y	--	--	--
Uranium(U)-235	1.6	Y	24	N	--	--	--	N	18	--	--	--	N	N	--	--	N	--	Y
Uranium(U)-238	31	Y	24	N	--	--	--	N	12	--	--	--	Y	N	N	Y	--	--	--
Plutonium (Pu)-238	0.36	Y	1.6	N	--	--	--	N	15	--	--	--	N	N	--	--	N	--	Y
Plutonium (Pu)-239/40	74	Y	1.2	N	--	--	--	N	3	--	L	--	Y	N	N	Y	--	--	--
Americium (Am)-241	0.04	Y	1.2	N	--	--	--	N	21	--	--	--	N	N	--	--	N	--	Y
INORGANIC COMPOUNDS (µg/L)																			
Aluminum (Al), filtered	485	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
Ammonium ion (NH4)	1,109	N	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 9-2. 200 East Groundwater Aggregate Area Data Evaluation Decision Matrix.

	ERA Evaluation Path								RRI Rank				IRM Path				Final Remedy Path		
									Current		Future								
Detected Constituent	Max Conc	HSPPS justfd?	GW Std	>100 *Std?	conf?	BDAT avail?	Adv Cnsq?	ERA?	C	NC	C	NC	Data Adeq?	LFI?	Adv Cnsq?	IRM?	Data Adeq?	RA?	RI?
Antimony (Sb)	115	Y	6	N	--	--	--	N	--	5	--	--	N	Y	--	--	--	--	--
Arsenic (As), filtered	24	Y	50	N	--	--	--	N	6	--	2	--	N	Y	--	--	--	--	--
Barium (Ba), filtered	113	Y	2,000	N	--	--	--	N	--	16	--	--	N	N	--	--	N	--	Y
Beryllium (Be), filtered	5.3	Y	4	N	--	--	--	N	L	NR	--	--	N	Y	--	--	--	--	--
Boron (B), filtered	168	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
Bromide (Br)	862	N	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cadmium (Cd), filtered	4.2	Y	5	N	--	--	--	N	L	8	--	--	N	Y	--	--	--	--	--
Calcium (Ca), filtered	241,000	N	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chloride (Cl)	193,000	N	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Chromium (Cr), filtered	65	Y	100	N	--	--	--	N	L	10	L	1	N	Y	--	--	--	--	--
Cobalt (Co), filtered	30	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
Copper (Cu), filtered	26	Y	NA	N	--	--	--	N	--	17	--	--	N	N	--	--	N	--	Y
Cyanide (CN)	869	Y	200	N	--	--	--	N	--	1	--	3	Y	N	N	Y	--	--	--
Fluoride (F)	2,200	Y	4,000	N	--	--	--	N	--	7	--	--	N	N	--	--	N	--	Y
Hydrazine	38	Y	NA	N	--	--	--	N	NR	--	--	--	N	Y	--	--	--	--	--
Iron (Fe), filtered	592,000	Y	NA	N	--	--	--	N	--	15	--	--	N	N	--	--	N	--	Y
Lead (Pb), filtered	6.6	Y	50	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
Lithium (Li), filtered	16	Y	NA	N	--	--	--	N	--	23	--	--	N	N	--	--	N	--	Y
Magnesium (Mg), filtered	67,400	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
Manganese (Mn), filtered	295	Y	NA	N	--	--	--	N	--	18	--	--	N	N	--	--	N	--	Y

Table 9-2. 200 East Groundwater Aggregate Area Data Evaluation Decision Matrix.

	ERA Evaluation Path								RRI Rank				IRM Path				Final Remedy Path		
									Current		Future								
Detected Constituent	Max Conc	HSPPS justfd?	GW Std	>100 *Std?	conf?	BDAT avail?	Adv Cnsq?	ERA?	C	NC	C	NC	Data Adeq?	LFI?	Adv Cnsq?	IRM?	Data Adeq?	RA?	RI?
Mercury (Hg)	0.21	Y	2	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
Nickel (Ni), filtered	60	Y	100	N	--	--	--	N	L	14	--	--	N	N	--	--	N	--	Y
Nitrate (NO3)	503,000	Y	45,000	N	--	--	--	N	--	4	--	2	Y	N	N	Y	--	--	--
Nitrite (NO2)	1,080	Y	3,300	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
Phosphate (PO4)	9,470	N	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Potassium (K), filtered	14,500	Y	NA	N	--	--	--	N	--	22	--	--	N	N	--	--	N	--	Y
Selenium (Se), filtered	24	Y	50	N	--	--	--	N	--	3	--	--	N	Y	--	--	--	--	--
Silicon (Si), filtered	31,600	N	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Silver (Ag), filtered	12	Y	NA	N	--	--	--	N	--	NR	--	--	N	N	--	--	N	--	Y
Sodium (Na), filtered	74,900	Y	NA	N	--	--	--	N	--	18	--	--	N	N	--	--	N	--	Y
Strontium (Sr), filtered	1,009	Y	NA	N	--	--	--	N	--	10	--	--	N	N	--	--	N	--	Y
Sulfate (SO4)	405,500	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y
Thallium (Tl)	50	Y	2	N	--	--	--	N	--	NR	--	--	N	Y	--	--	--	--	--
Titanium (Ti)	1,120	N	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uranium (U), chemical	38	Y	NA	N	--	--	--	N	--	12	--	--	N	N	--	--	N	--	Y
Vanadium (V)	135	Y	NA	N	--	--	--	N	--	9	--	--	N	N	--	--	N	--	Y
Zinc (Zn)	358	Y	NA	N	--	--	--	N	--	--	--	--	N	N	--	--	N	--	Y

Y = Yes (decision)
N = No (decision)
NA = not available
NR = not ranked
L = low ranked (below MEPAS computation capability)
* = to be addressed separately from Aggregate Area Management Study process (see Section 9.3.1)

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