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Phase 1 Remedial Investigation Report for the Hanford Site 1100-EM-1 Operable Unit

Environmental Engineering Group

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Prepared for the U.S. Department of Energy
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United States
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Approved for Public Release

PREFACE

This Phase I Remedial Investigation Report for the Hanford Site 1100-EM-1 Operable Unit documents operable unit characterization findings as of the August, 1990, publication date. These findings, appropriately refined, will be used to develop and evaluate effective remedial alternatives for operable unit releases of hazardous substances.

This report was prepared with two rounds of air monitoring data, an extensive amount of soil data, and two rounds of ground-water monitoring data. As of the date of report publication, not all of the second round ground-water monitoring data were received, and critical portions of these data were received two weeks prior to publication. A draft report was produced using the first round results of air and ground-water monitoring. Evaluation of the second round of ground-water monitoring data altered the findings of the draft report; however, due to time constraints, some of the analyses from the draft report were retained for informational purposes.

A major objective of this report is to facilitate communication between participating Hanford Site and regulatory project personnel. As a secondary document submitted for regulatory review under the Hanford Federal Facility Agreement and Consent Order, this report will not be revised. Instead, comments will be used in the development of the 1100-EM-1 Operable Unit Phase II Remedial Investigation Work Plan, the Phase I/II Feasibility Study Report, and the Phase II Remedial Investigation Report.

Specificity in commenting at this point in the project will enhance the quality of subsequent plans, work efforts, and documents. Useful comments are those that are related to specific project objectives, and referenced to specific statutory, regulatory, scientific, or editorial concerns. All statutes and regulations consulted in the preparation of this report were those in effect, as amended, on the date of report publication. Changes in applicable statutes and regulations will be addressed, as necessary, in future project plans and reports.

This document has been prepared in accordance with: Publications Services Group, 1988, *Publications Style Guide*, WHC-IP-0003, Westinghouse Hanford Company, Richland, Washington.

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ACRONYMS

amsl	above mean sea level
ARARs	legally applicable, or relevant and appropriate, federal and state environmental standards, requirements, criteria, and limitations
BEHP	bis(2-ethylhexyl)phthalate
BWTF	Buried Waste Test Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CFWQC	chronic freshwater quality criterion
DNR	Washington State Department of Natural Resources
DOE	United States Department of Energy
DOE-RL	United States Department of Energy, Richland Operations Office
DOW	Washington State Department of Wildlife
Ecology	Washington State Department of Ecology
EIS	environmental impact statement
EM	equipment maintenance
EMI	electromagnetic inductance
EPA	United States Environmental Protection Agency
ERDA	United States Energy Research and Development Administration
FS	feasibility study
GAI	Golder Associates Inc.
GMU	game management unit
GPR	ground penetrating radar
HEHF	Hanford Environmental Health Foundation
HMS	Hanford Meteorological Station
HQ	hazard quotient
HRS	Hazard Ranking System
HSDB	Hazardous Substances Data Base
HSPA	Hanford Site Performance Assessment
HWQHC	human water quality health criterion
HWQWC	human water quality welfare criterion
ICR	incremental cancer risk
IRIS	Integrated Risk Information System
IU	isolated unit
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAA	National Oceanographic and Atmospheric Administration
NPL	National Priorities List
OSHA	United States Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
PEL	permissible exposure limit
PNL	Pacific National Laboratory
PSPL	Puget Sound Power and Light
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act

ACRONYMS
(Continued)

RfD	reference dose
RHO	Rockwell Hanford Operations
RI	remedial investigation
SC	specific conductance
SCS	United States Soil Conservation Service
SDG	sample delivery group
SF	slope factor
SQL	sample quantitation limit
SVOC	semivolatile organic compound
TAL	target analyte list
TCL	target compound list
TDS	total dissolved solids
TIC	tentatively-identified compounds
TDLo	lowest observed toxic dose
TOC	total organic carbon
TOX	total organic halogen
TPA	Tri-Party Agreement
TSD	treatment, storage, or disposal
UN	unplanned and unauthorized release
USC	United States Code
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UTL	upper tolerance limit
VOC	volatile organic compound
WAC	Washington Administrative Code
Westinghouse Hanford	Westinghouse Hanford Company
WHC	Westinghouse Hanford Company
WIDS	Waste Information Data System
WOE	weight-of-evidence
WPPSS	Washington Public Power Supply System
WSU	Washington State University

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1.0 INTRODUCTION

The 1100-EM-1 Operable Unit is one of four hazardous substance response project units associated with the 1100 Area of the United States Department of Energy's (DOE's) Hanford Site. In July 1989, the United States Environmental Protection Agency (EPA) placed the 1100 Area, and three other Hanford Site areas, on the National Priorities List (NPL) contained within Appendix B of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP, 40 CFR 300). (Note: All regulatory and statutory citations within this report refer to the version of the regulation or statute in effect, as amended, on the date of report publication.) The EPA took this action pursuant to their authority under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 42 USC 9601 et seq.).

In anticipation of this regulatory action, DOE Richland Operations Office (DOE-RL) divided the 1100 Area into four operable units and initiated CERCLA response planning for 1100-EM-1, the operable unit assigned the highest priority, within both the 1100 Area and the Hanford Site as a whole, by DOE-RL, EPA, and the Washington State Department of Ecology (Ecology).

The DOE-RL, EPA, and Ecology issued the Hanford Federal Facility Agreement and Consent Order—the Tri-Party Agreement, TPA (Ecology et al. 1989)—in May 1989. This agreement, among other things, governs all CERCLA efforts at the Hanford Site. In August 1989, a remedial investigation/feasibility study (RI/FS) work plan for the 1100-EM-1 Operable Unit (DOE-RL 1989a) was issued pursuant to the TPA. Upon publication of this work plan, DOE-RL initiated a full-scale effort on the first phase of the 1100-EM-1 RI.

In November 1989, Westinghouse Hanford Company (Westinghouse Hanford or WHC, DOE-RL's Hanford Site operations contractor) issued Task G-90-7, under Westinghouse Hanford Letter Order MDR-SVV-666693, to Golder Associates Inc. (GAI). This task authorized GAI to use RI data, obtained either by or under the direction of Westinghouse Hanford, to prepare the Phase I RI report contained herein.

1.1 PURPOSE OF REPORT

The purpose of the 1100-EM-1 RI is to gather and develop a sufficient amount of the necessary information required to support the development and analysis of operable unit remedial alternatives during the FS. The remedial alternatives analysis will, in turn, be used by TPA signatories to make a risk-management-based selection of remedies for releases of hazardous substances found to have occurred from the operable unit.

In accordance with the TPA, the 1100-EM-1 RI/FS is being conducted in a concurrent, interactively phased manner. The data collected and evaluated during the RI provides the information needed to develop and analyze remedial alternatives in the FS, while the preliminary FS analyses provide a focus for further RI activities. The goal of the first phase of the RI is to increase the initial understanding of 1100-EM-1 by characterizing the nature and extent of the threat to human health and the environment posed by releases of hazardous substances from the operable unit.

The purpose of this report, therefore, is to document the findings of the Phase I RI to allow DOE-RL, EPA, and Ecology to assess the focus of the project, determine the need for further RI activities, and initiate the FS. This report is consistent with the statutory requirements of CERCLA and the regulatory requirements of both the NCP and the TPA.

Under the TPA, a Phase I RI report is considered a secondary document; therefore, this report is an interim interpretation of 1100-EM-1 conditions. The primary purpose of this report is to facilitate open communication among project personnel from all participating Hanford Site and regulatory organizations. Comments that arise due to the review of this report will be considered in the development of a Phase II RI work plan and will be incorporated, along with Phase II RI findings, into a Phase II RI report.

1.2 REPORT ORGANIZATION

This Phase I RI report for the 1100-EM-1 Operable Unit is organized in a format similar to that recommended by EPA (1988a). This subsection assists the reader in understanding the presentation format and in locating information of specific interest. The Phase I RI report consists of seven sections, in addition to this introduction, and associated appendices.

The introduction, specifically Section 1.3, provides a general history and physical background of 1100-EM-1. More detailed physical background information, as noted below, can be found in Section 3.

An outlined description of the 1100-EM-1 Phase I RI data collection activities is presented in Section 2. This information is derived from the RI/FS work plan (DOE-RL 1989a) and is presented by environmental medium. The purpose of this presentation is not to reiterate the work plan, but to concisely summarize the initial data collection activities so that the actual work performed in the first phase of the RI is documented. Section 2 also contains specific references to the validated data—contained in appendices or published literature, as appropriate—that were used to develop the operable unit characterizations presented in subsequent sections.

Section 3 initiates the presentation of Phase I RI findings with a description of the relevant physical characteristics of the 1100-EM-1 Operable Unit. The setting of the operable unit and its vicinity is presented by environmental medium and is based on information gathered during project scoping and implementation of Phase I RI activities.

The nature and extent of contamination in each environmental medium is presented in Section 4. Natural and non-1100-EM-1-specific anthropogenic contributions to the chemical environment are documented so as to focus the findings on operable-unit-specific releases. Note that Section 4 focuses on the contaminant setting of the operable unit, as opposed to the physical setting focus of Section 3.

Evaluations of the findings presented in Sections 3 and 4 are conducted to develop interpretations of the environmental fate and transport of the operable unit contaminants of potential concern. These interpretations are presented in Section 5. Potential operable unit contaminant migration pathways are documented, contaminant characteristics relevant to migration are

assessed, and transport modeling is applied to estimate current and future contaminant concentrations in each environmental medium.

Estimates of the actual human health and environmental threats posed by hazardous substances released from 1100-EM-1 are presented in the baseline risk assessment in Section 6. Human exposures to operable unit contaminants of potential concern are estimated, toxicological characteristics of the 1100-EM-1 contaminants are assessed, and all potentially significant human health risks attributable to the operable unit are characterized. An evaluation of risks posed to non-human organisms is presented, and operable unit contaminants of concern are identified, in this section, as well.

Concise summaries of the Phase I RI findings related to the operable unit physical characteristics, the nature and extent of contamination, contaminant fate and transport, and human health and environmental risks are provided in Section 7. Recommendations for removal actions, additional RI activities, and initial FS activities are also included.

References cited within the body of the report are provided in Section 8.

Appendices are used to present letters and memoranda cited, concise summaries of validated data, and detailed technical analyses needed to confirm the findings contained within the text. Other relevant information is incorporated by reference, rather than appended, whenever it is published and readily available to Hanford Site and regulatory project personnel.

1.3 1100-EM-1 OPERABLE UNIT BACKGROUND

The Hanford Site is a 150,000 ha (560 mi^2) reservation operated by the federal government since 1943. The primary mission of the Hanford Site has been plutonium production for military use and nuclear energy research and development. The Hanford Site is located along the Columbia River in southeastern Washington and covers portions of Benton, Grant, Franklin, and Adams counties (Figure 1-1). The 1100 Area, which is adjacent to the City of Richland in Benton County, comprises the southeastern-most portion of the Hanford Site.

The designation of areas and operable units at the Hanford Site is complex; therefore, some clarification is offered prior to substantive background discussions. Designated areas of the Hanford Site (100, 200, 300, 400, 600, 700, 1100, and 3000) are shown in Figure 1-1.

The 1100 Area, as defined by EPA for the purposes of NPL site designation (the 1100 Area NPL Site), includes portions of the 600, 700, and 3000 Areas. The 600 Area includes all land within the Hanford Site not otherwise within the 100, 200, 300, 400, or 1100 Areas. The 600 Area, therefore, consists mostly of undeveloped land and some relatively remote facilities. The 700 Area is primarily comprised of administrative buildings and is located outside of the Hanford Site in downtown Richland; it is centered around the Federal Building. The 3000 Area is located outside of, but adjacent to, the Hanford Site; it is comprised mostly of administrative buildings and some research and development and warehouse storage facilities.

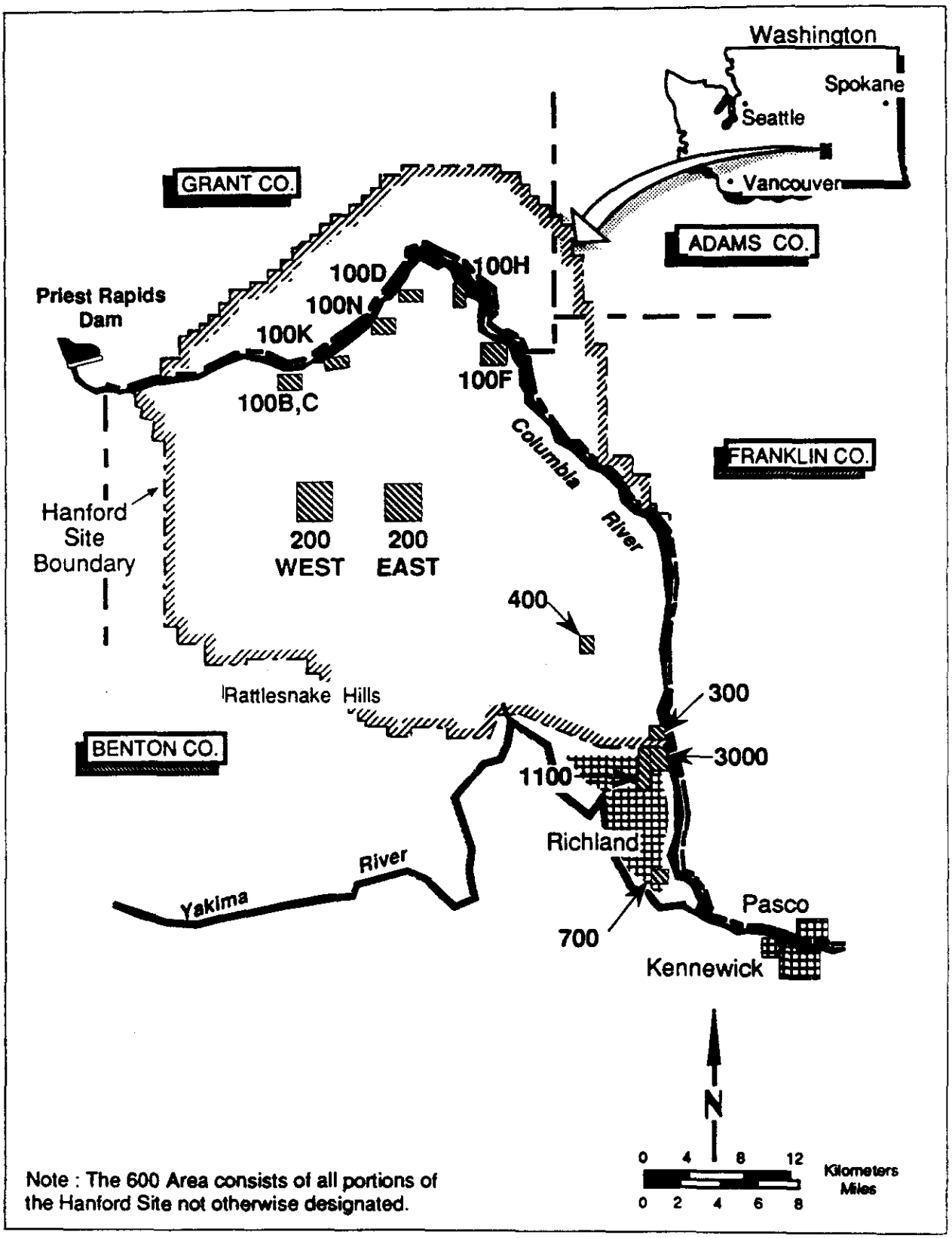

Figure 1-1. Hanford Site and Area Designations.

The 1100 Area NPL Site is currently divided into four operable units, as shown in Figure 1-2: 1100-EM-1, 1100-EM-2, 1100-EM-3, and 1100-IU-1. Each operable unit is designated with a three-part code. The first part indicates the NPL site affiliation, in this case the 1100 Area NPL Site. The second part provides a shorthand description of the operable unit type: EM indicates "equipment maintenance"; IU indicates "isolated unit." The final portion of the code simply provides a unique numeric designator for each operable unit.

The 1100-IU-1 Operable Unit is located in the 600 Area, in the Rattlesnake Hills (see Figure 1-1), and is about 24 km (15 mi) west of the actual 1100 Area. Given the distinct separation of 1100-IU-1 from the 1100-EM-1 Operable Unit, it is not considered further in this report. The 1100-EM-3 Operable Unit contains only 3000 Area waste management units and is physically separated from the actual 1100 Area by a major highway, Stevens Drive.

The 1100-EM-1 and 1100-EM-2 Operable Units, which are discussed further in Sections 3.1.3 and 4.1.2, consist of different sets of waste management units which are, for the most part, located within the actual 1100 Area. Two 600 Area waste management units, located near the 1100 Area, are assigned to 1100-EM-1; one waste management unit associated with the 700 Area is assigned to 1100-EM-2. As many of the waste management units within these two operable units are spatially interspersed, 1100-EM-1 and 1100-EM-2 are not locationally distinct. As a result, it is sometimes necessary to focus on the 1100 Area, in addition to the 1100-EM-1 Operable Unit, in the following background discussion.

1.3.1 1100 Area Operations

The 1100 Area is a central warehousing, vehicle maintenance, and transportation distribution center; it is the main portal to the Hanford Site. The specific missions of the 1100 Area are:

- Vehicle, heavy equipment, bus, and railroad maintenance
- Bulk storage of petroleum products
- Gasoline station
- Bus system operations—main dispatch, holding, and transit center
- Rail system operations—main delivery, dispatch, and export center
- Warehousing operations
- Excess construction, maintenance, and administrative materials storage
- Hazardous and flammable construction and maintenance materials storage
- Classified materials destruction
- Administrative control for the above operations.

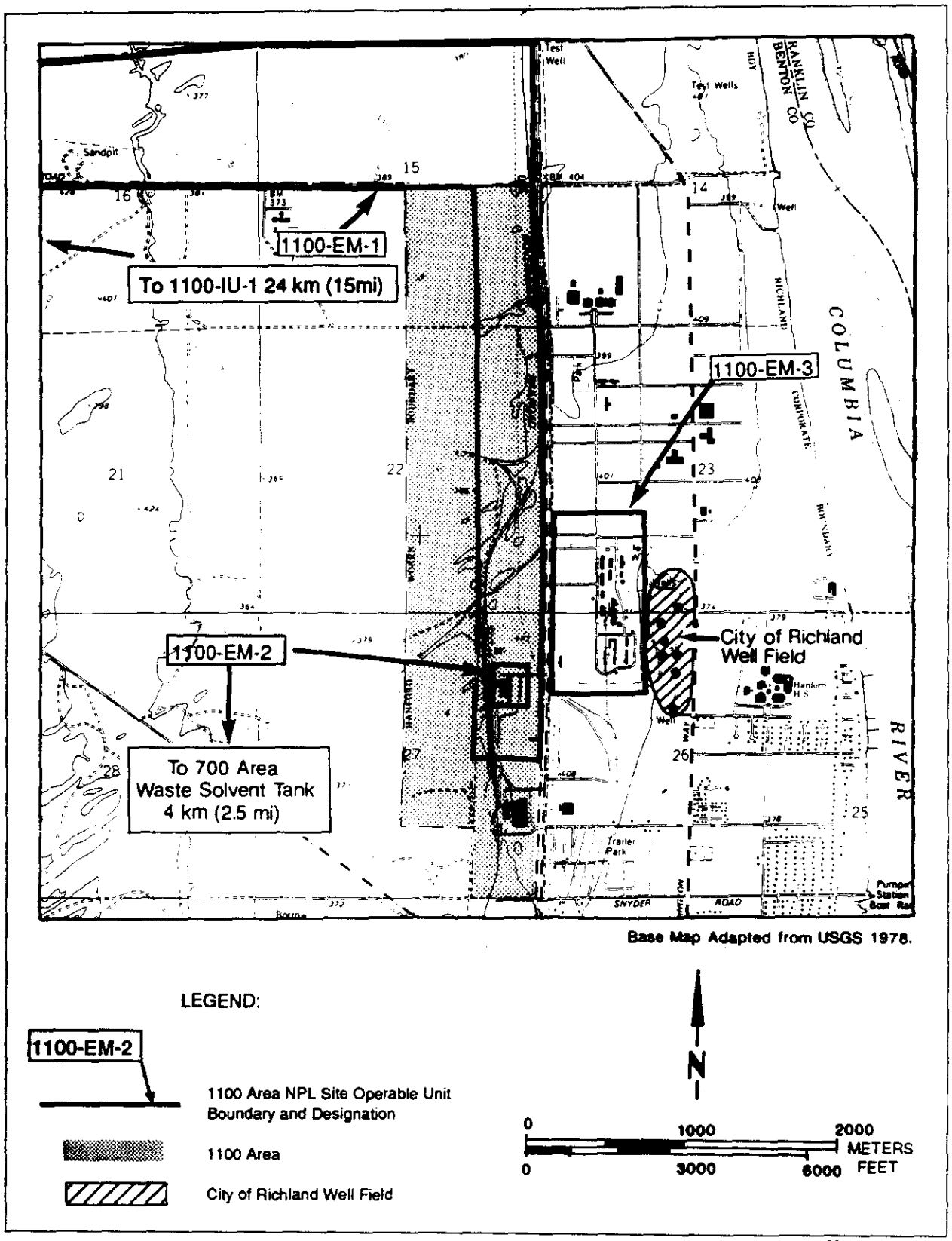

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Figure 1-2. Operable Units within the 1100 Area NPL Site.

1.3.2 1100-EM-1 Operable Unit Description

The 1100-EM-1 Operable Unit consists of eight waste management units (DOE-RL 1989a and 1989b; WHC 1989). Each of these waste management units is distinct in terms of location; they can therefore be regarded as operable subunits. The eight 1100-EM-1 operable subunits, shown in Figure 1-3, are:

- 1100-1 (the Battery Acid Pit)
- 1100-2 (the Paint and Solvent Pit)
- 1100-3 (the Antifreeze and Degreaser Pit)
- 1100-4 (the Antifreeze Tank Site)
- UN-1100-5 (the Radiation Contamination Incident)
- UN-1100-6 (the Discolored Soil Site)
- The Horn Rapids Landfill
- The Hanford Patrol Academy Demolition Site.

The numeric or alphanumeric identifiers for the first six waste management units are those assigned in the Hanford Site Waste Information Data System (WIDS) (DOE-RL 1989b). The UN prefix indicates that the waste management unit was created by an unplanned and unauthorized release. No WIDS identifiers have yet been assigned to the Horn Rapids Landfill or the Hanford Patrol Academy Demolition Site. The Horn Rapids Landfill is also referred to, in Hanford Site literature, as the Horn Rapids Disposal Site. The former term, however, is used throughout this report because of its more descriptive nature.

A brief history of the waste storage and disposal practices at 1100-EM-1 is presented below by operable subunit. Details of each of the six subunits evaluated further in this report are presented in Sections 3 (Physical Characteristics of the 1100-EM-1 Operable Unit) and 4 (Nature and Extent of 1100-EM-1 Operable Unit Contamination). The information below, unless otherwise noted, was obtained from DOE-RL (1989a), DOE-RL (1989b), or WHC (1989).

1.3.2.1 1100-1 (Battery Acid Pit). The Battery Acid Pit—an abandoned French drain constructed within native soil with a bottom lining of sand and gravel—is situated about 30 m (100 ft) from the southwest corner of the 1171 Building, just east of the 1100 Area railroad tracks, in the south-central portion of the 1100 Area (see Figure 1-3). From approximately 1954 to 1977, up to an estimated 57,000 L (15,000 gal) of battery acid wastes from vehicle maintenance activities were disposed in this pit. Suspicion about disposal of other substances (e.g., waste oil, antifreeze, solvents) has been voiced, but such activities are not documented. During the service life of the pit, acid-saturated sand was periodically removed for disposal at an unknown location. Fresh sand was then added to the pit. The pit was backfilled upon retirement. It appears to have been about 1.8 m (6 ft) deep, with a diameter of about 1.8 m (6 ft).

1.3.2.2 1100-2 (Paint and Solvent Pit). The Paint and Solvent Pit, located in the east-central portion of the 1100 Area, just west of Stevens Drive (see Figure 1-3), was originally a sand and gravel pit. The pit is currently an subcircular depression having a depth of 1.2 to 1.8 m (4 to 6 ft); approximate length and width are 110 m (360 ft) and 106 m (330 ft), respectively. The pit was used for the disposal of construction debris from 1954 through 1985. The debris is reported to have consisted of primarily concrete, asphalt, and

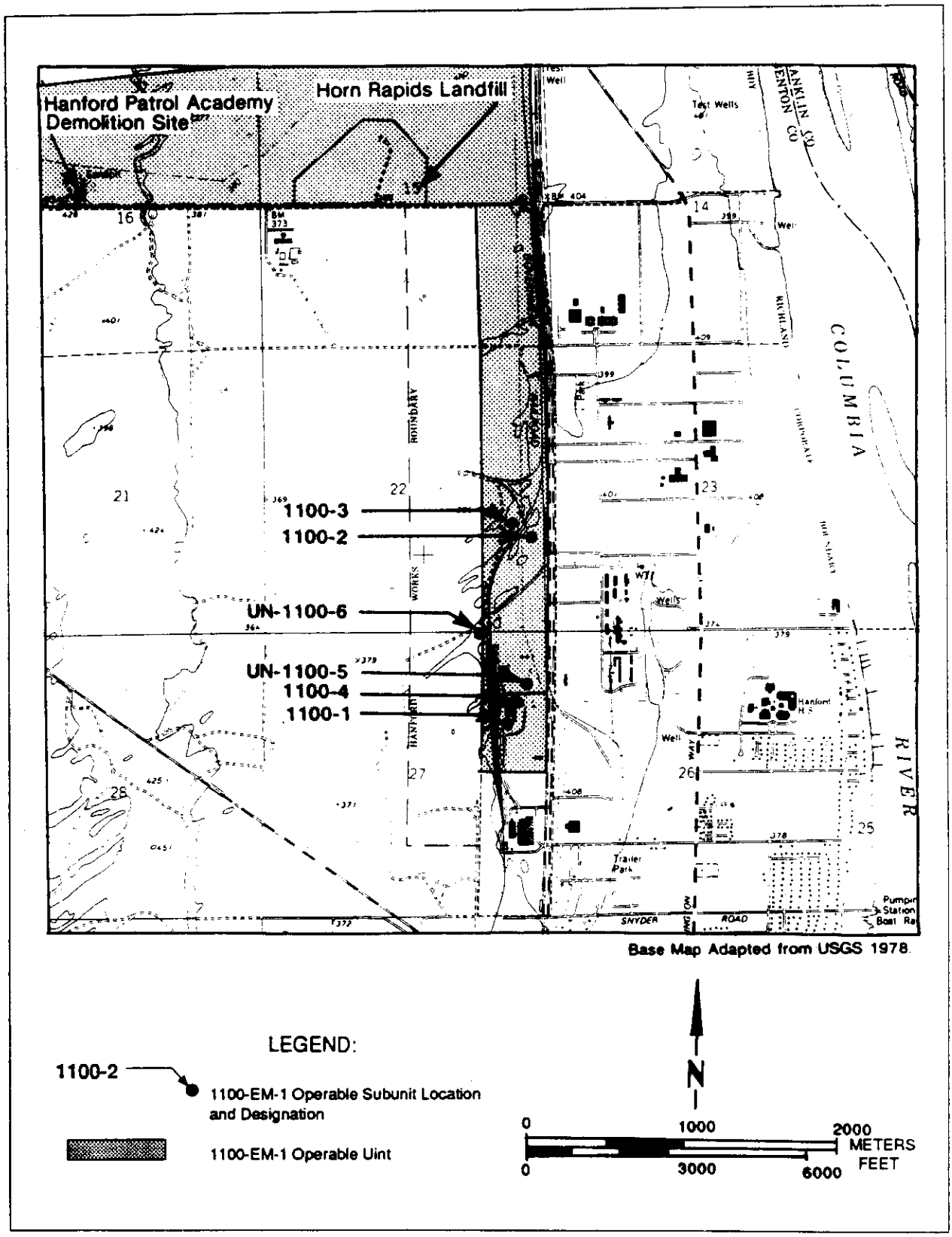

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Figure 1-3. Operable Units within the 1100-EM-1 Operable Unit.

lumber generated from the demolition activities on the Hanford Site. In addition, the past disposal of waste solvents, paints, and paint thinners in this pit, at rates of up to 380 L/yr (100 gal/yr), is suspected. Approximately 1.2 to 4.9 m (4 to 16 ft) of backfill material, mixed with a small quantity of waste asphalt from nearby highway construction activities, currently covers the pit.

1.3.2.3 1100-3 (Antifreeze and Degreaser Pit). The Antifreeze and Degreaser Pit is located to the west of 1100-2, on the west side of the railroad tracks (see Figure 1-3). 1100-3 is a shallow, roughly circular depression approximately 76 m (250 ft) in diameter and 1.8 to 2.4 m (6 to 8 ft) in depth. This pit, too, was originally a sand and gravel excavation. From 1979 to 1985, this pit was used for the disposal of construction debris that consisted primarily of used roofing gravel and concrete rubble. Occasional disposal of waste antifreeze and degreasing solutions from 1171 Building vehicle maintenance operations is also suspected, but not documented.

1.3.2.4 1100-4 (Antifreeze Tank Site). This operable subunit is the location of a former 19,000-L (5,000-gal) steel underground antifreeze disposal tank that was located beneath the concrete floor of the 1171 Building (see Figure 1-3). The tank, known only to have been installed sometime prior to 1978, was emptied, excavated, cleaned, and removed in 1986 due to suspected leakage.

1.3.2.5 UN-1100-5 (Radiation Contamination Incident). The Radiation Contamination Incident occurred in 1962 in the parking lot northwest of the 1171 Building (see Figure 1-3), although the precise location is not now known. A leaking cask of radioactive material was situated on a truck trailer parked in this lot. The radioactive material consisted of metal specimens irradiated at the Idaho National Engineering Laboratory that were transported on the trailer for analysis at the Hanford Site. The specimens were packed in water, and the water was found to be leaking from the cask when other material was off-loaded in the 1100 Area. A radiation survey found contamination on the bed of the trailer, but no contamination was reported on the parking lot surface. An analysis of the water showed the presence of iodine-131, barium-140, and lanthanum-140, each of which is a very short-lived radioisotope.

McCain (1990) demonstrates that if an amount of contamination present on the trailer bed were to have been spilled on the parking lot surface (an extremely conservative assumption, given that no ground surface contamination was reported), all of the radioisotopes present would have completely decayed long ago. Given this analysis, along with a recent surface radiation survey—conducted at the time of initial scoping for the 1100-EM-1 RI/FS—that failed to detect any radioactivity in the parking lot, UN-1100-5 is deemed to pose no threat whatsoever to human health or the environment. Therefore, this operable subunit is given no further consideration in this report, other than an acknowledgement of the surface radiation survey in Section 2 and a recommendation for no further action in the summary and conclusions section (Section 7).

1.3.2.6 UN-1100-6 (Discolored Soil Site). The Discolored Soil Site is an unplanned release, discovered during the 1100-EM-1 RI/FS scoping process, that is located west of the railroad tracks within the central portion of the 1100 Area. This subunit consists of a patch of oily, discolored soil in an elongated, natural depression and appears to be the location of at least one,

and possibly several, unrecorded disposal incidents. The area of affected soil suggests that one or only a few drums of liquid substance were poured on the ground. The date of this incident, or incidents, is unknown.

1.3.2.7 **Horn Rapids Landfill.** The Horn Rapids Landfill is located in the 600 Area immediately to the north of the 1100 Area (see Figure 1-3). This landfill, roughly 20 ha (50 ac) in size, was used from the early 1950s to 1970 for the disposal of primarily office and construction wastes and apparently consists of several distinct cells. One of the landfill cells is marked as an asbestos disposal site, one open trench contains old tires, another area appears to have been used to dispose of sludges of some kind. A burn cage that was used to destroy classified documents also exists on the landfill. Some long-time employees have alleged the disposal of drummed waste solvents at this facility.

1.3.2.8 **Hanford Patrol Academy Demolition Site.** The Hanford Patrol Academy Demolition Site, an ash pit used since 1984 for the disposal of unstable chemicals by detonation, is also located in the 600 Area, approximately 2 km (1 mi) to the west of the Horn Rapids Landfill (see Figure 1-2). While this demolition site is identified in WHC (1989) as a Resource Conservation and Recovery Act (RCRA, 42 USC 6901 et seq.) treatment, storage, or disposal (TSD) waste management unit, no mention of it is made in DOE-RL (1989a). This facility will be addressed separately, if necessary, under Ecology's RCRA authority. Therefore, this subunit is given no further consideration in this report. All further reference in this report to the 1100-EM-1 Operable Unit will exclude the Hanford Patrol Academy Demolition Site.

1.3.3 Previous 1100 Area Investigations

Findings of previous environmental investigations related specifically to concern over potential hazardous substance contamination from the 1100 Area are briefly summarized below. The purpose of this summary is to give the reader an appreciation of the chronology of events that led to NPL designation for the 1100 Area and of the need to assess the various operable subunits within 1100-EM-1. Details, where relevant, can be found in Sections 3 and 4; otherwise, the literature cited should be reviewed for further information. Some of the investigations listed below were implemented out of concern of potential impacts to the nearby City of Richland well field. This supplemental municipal drinking water supply is located about 0.8 km (0.5 mi) to the east of the 1100 Area (see Figure 1-2).

- In 1986, the Hanford Environmental Health Foundation (HEHF) conducted a limited ground-water sampling effort including 11 wells within and near the 1100 and 3000 Areas (Thurman, P., HEHF [Letter to C. Bishop, Pacific Northwest Laboratory (PNL)] August 20, 1986). The purpose of this effort was to determine whether or not ground water in the vicinity was contaminated from previous or ongoing operations. Some potential contaminants were found at generally low levels, but the effort was considered semi-quantitative, at best, and further investigation was recommended.

- The antifreeze disposal tank that was located at what is now the 1100-4 operable subunit was excavated in 1986. Analyses of the underlying soils showed no evidence of contamination (Nessel, J.,

Northwest Enviroservice Inc. [Memo to M. Romsos, Rockwell Hanford Operations (RHO)] November 5, 1986).

- In 1988, eight surface soil samples were obtained from four of the 1100-EM-1 operable subunits to help focus RI/FS planning efforts (DOE-RL 1989a). At 1100-1, evidence of elevated lead and sulfate concentrations, along with potentially increased amounts of arsenic, chromium, mercury, and polychlorinated biphenyls (PCBs), was found; samples from 1100-2 and 1100-3 contained no evidence of contamination; and UN-1100-6 showed evidence of elevated total organic carbon (TOC) and discernable amounts of phthalates and other semivolatile organic compounds (SVOCs).

- The results of a Hanford Site equivalent to a CERCLA preliminary assessment were published by Stenner et al. (1988). Upon evaluation against the criteria presented in EPA's Hazard Ranking System (HRS, Appendix A of the NCP), the 1100-1, 1100-4, and the Horn Rapids Landfill operable subunits received scores of 38.54, 34.58, and 0.00, respectively. The five other operable subunits were not evaluated in this assessment. The EPA's current threshold HRS score for NPL designation is 28.50. The 1100-EM-1 Operable Unit was assigned an aggregate score of 35.33 based on the potential for off-site impact to the City of Richland well field and due to the lack of an established ground-water monitoring system.

- Westinghouse Hanford installed five ground-water monitoring wells between the 1100 Area and the City of Richland well field in 1988 (Law 1989). All potential contaminants detected in samples obtained from these wells were well below established drinking water standards.

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2.0 1100-EM-1 OPERABLE UNIT PHASE I REMEDIAL INVESTIGATION DATA COLLECTION ACTIVITIES

An RI consists of numerous data collection and data evaluation activities. Necessary data can be collected by compiling existing relevant site information, interviewing persons possessing pertinent knowledge about a site, and performing various environmental measurements at a site.

The first phase of the 1100-EM-1 RI was conducted in substantive accordance with the operable unit RI/FS work plan (DOE-RL 1989a). As with any major environmental investigation effort, the evaluation of the early Phase I data indicated a need for minor deviations from the work plan. These deviations were necessary to adhere to the original overall intent and scope of the plan. The purpose of this section is to provide the reader with an understanding of the various data collection activities that were actually undertaken during the course of the initial phase of the 1100-EM-1 RI. Interpretations of these data are provided in subsequent sections of this report.

Phase I RI data collection activities are presented below by the following environmental-medium- or environmental-discipline-specific task categories:

- Contaminant sources—waste facilities (Section 2.1)
- Meteorology—air (Section 2.2)
- Surface hydrology—surface-water and aquatic sediments (Section 2.3)
- Geology—characteristics and structure of bedrock and unconsolidated sediments (Section 2.4)
- Pedology—soils (Section 2.5)
- Hydrogeology—ground water (Section 2.6)
- Ecology—potential receptor organisms (Section 2.7).

These categories, with one exception, represent environmental compartments within which operable unit contaminants can potentially reside or be transported. The exception, geology, is included to allow for an integrated assessment of unsaturated and saturated soil and bedrock information pertinent to the operable unit. There are no absolute boundaries between the geological, pedological, and hydrogeological media nor, for that matter, between any given environmental media discussed in this report; they are recommended by EPA (1988a) and are adopted in this report as a matter of general convenience. A similar environmental medium format is used in Sections 3 and 4 to present interpretations of the physical characteristics of the operable unit and the nature and extent of contamination, respectively.

Activities conducted during the Phase I RI are presented within each medium-specific investigation category. A brief summary is presented under each activity that describes what the data collection activity consisted of,

why it was conducted, where it was conducted, when the activity was conducted, how it was conducted, and where detailed results can be found.

All environmental measurement activities, with the exception of compilation of existing data and the collection of immediately upgradient ground-water samples at the Horn Rapids Landfill, were conducted under a quality assurance project plan (QAPP) approved by DOE-RL, EPA, and Ecology. Westinghouse Hanford validated all such environmental measurements. Additional details on the environmental measurement methods used during the Phase I RI are found in the QAPP contained within the 1100-EM-1 RI/FS work plan (DOE-RL 1989a). The QAPP cites the specific procedures used. In situations where two or more options were specified in a particular procedure, the options actually implemented are indicated in the methods summaries within this section.

For detailed environmental measurement results, the reader will be referred, as appropriate, to either an appendix to this report or a published document that is readily available to all participating Hanford Site and regulatory project personnel.

2.1 CONTAMINANT SOURCE INVESTIGATION

The contaminant source investigation for the 1100-EM-1 Phase I RI consisted of the following data collection activities:

- Existing source information compilation
- Geodetic surveys and subsequent mapping of the operable subunits
- Geophysical surveys at four of the operable subunits
- Soil gas surveys at four of the operable subunits
- Surface radiation surveys at five of the operable subunits.

Each of these activities is summarized below. The results of the evaluations of the collected contaminant source data are presented in Sections 3.1 (Source Facility Characteristics) and 4.1 (Contaminant Sources).

2.1.1 Source Data Compilation

Existing source information was compiled during the development of, and presented in, the 1100-EM-1 RI/FS work plan (DOE-RL 1989a). This information was obtained to provide a description of relevant operable unit waste-related facility and waste characteristics. Therefore, the source data compilation task for the first phase of the operable unit RI consisted of a review of the pertinent source information contained within the work plan. Four key documents used in the preparation of the work plan—the Hanford Site hazard ranking evaluation report (Stenner et al. 1988), the waste management units report for the Hanford Site (DOE-RL 1989b), a preliminary baseline risk assessment for 1100-EM-1 (Clark 1990a), and the operable units designation report for the Hanford Site (WHC 1989)—and two sets of historical aerial photographs (EPA 1989b and 1990b), were also reviewed for this report. Results of this activity are incorporated into the discussions in Sections 3.1.2 and 4.1.1.

2.1.2 Geodetic Survey

Each of the operable subunits—1100-1, 1100-2, 1100-3, 1100-4, UN-1100-6, and the Horn Rapids Landfill—was geodetically surveyed and mapped. In addition, a map of the 1100 Area, including the Horn Rapids Landfill, was developed. Project base maps were developed in May 1989 and have been periodically updated to provide current and precise sampling location information.

Base maps were developed by aerial photography and on-the-ground surveying by a licensed surveyor. The coordinate system employed is the Lambert NAD 83 projection, converted from meters to feet; the base maps are plotted with a 1-ft elevational contour interval. Grids for subsequent sampling were surveyed in at four of the operable subunits. At 1100-2 and 1100-3, a grid on 12-m (40-ft) centers was established; 3-m (10-ft) centers were used at UN-1100-6; and 30-m (100-ft) centers were established at the Horn Rapids Landfill.

The base maps developed during this activity, and modifications, are used throughout this report to convey appropriate locational information.

2.1.3 Geophysical Survey

Geophysical surveys were conducted at 1100-1, 1100-2, 1100-3, and the Horn Rapids Landfill to determine subsurface facility characteristics, the location of buried wastes, and the location of any underground utilities. The information generated from this activity was used to define the location and extent of potential contaminant sources for the purpose of refining subsequent intrusive sampling activities. Initial project scoping, conducted during the development of the 1100-EM-1 RI/FS work plan (DOE-RL 1989a), gave no indication of physical subsurface disturbance at UN-1100-6, and previous excavation of the antifreeze disposal tank at 1100-4 precluded the need for geophysical surveys at this operable subunit.

Geophysical survey transects and points were defined by grids established at each operable subunit. The grid dimensions and areal coverage for each subunit were:

- 1100-1: 0.76 by 1.5 m (2.5 by 5 ft) over 0.039 ha (0.096 ac)
- 1100-2: 3.0 by 12 m (10 by 40 ft) over 1.1 ha (2.7 ac)
- 1100-3: 3.0 by 12 m (10 by 40 ft) over 1.5 ha (3.7 ac)
- Horn Rapids Landfill: 30 by 30 m (100 by 100 ft) over 25 ha (61 ac).

These grids are shown in Figures 2-1 through 2-4, for 1100-1, 1100-2 and 1100-3, and the Horn Rapids Landfill, respectively. A suite of geophysical techniques was used at each operable subunit—ground penetrating radar (GPR), electromagnetic inductance (EMI), magnetometry, and metal detection.

All four techniques were conducted along transects defined by the survey grids. The GPR signal source was towed along these transects at normal

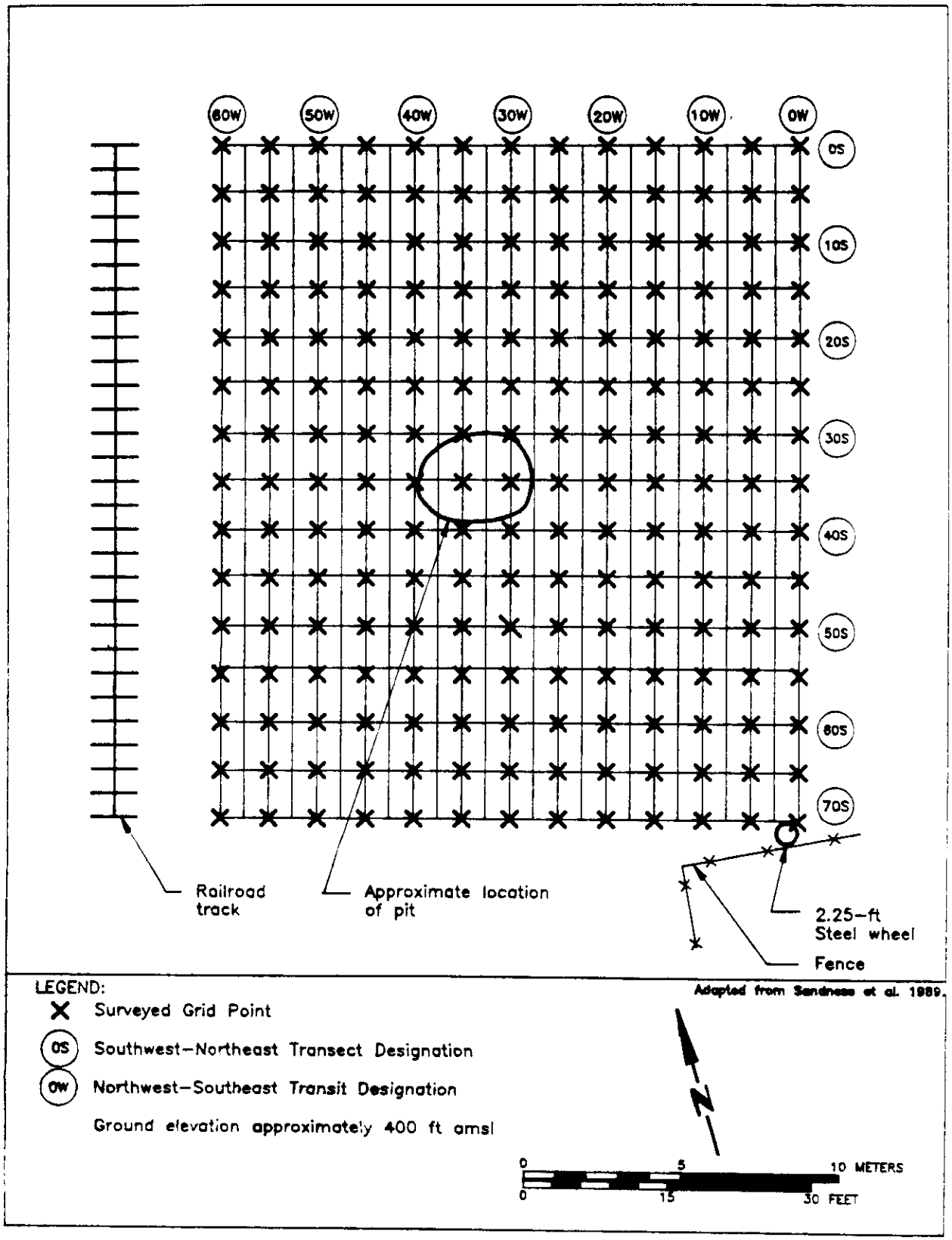

Figure 2-1. 1100-1 Operable Subunit Geophysical Survey Transects.

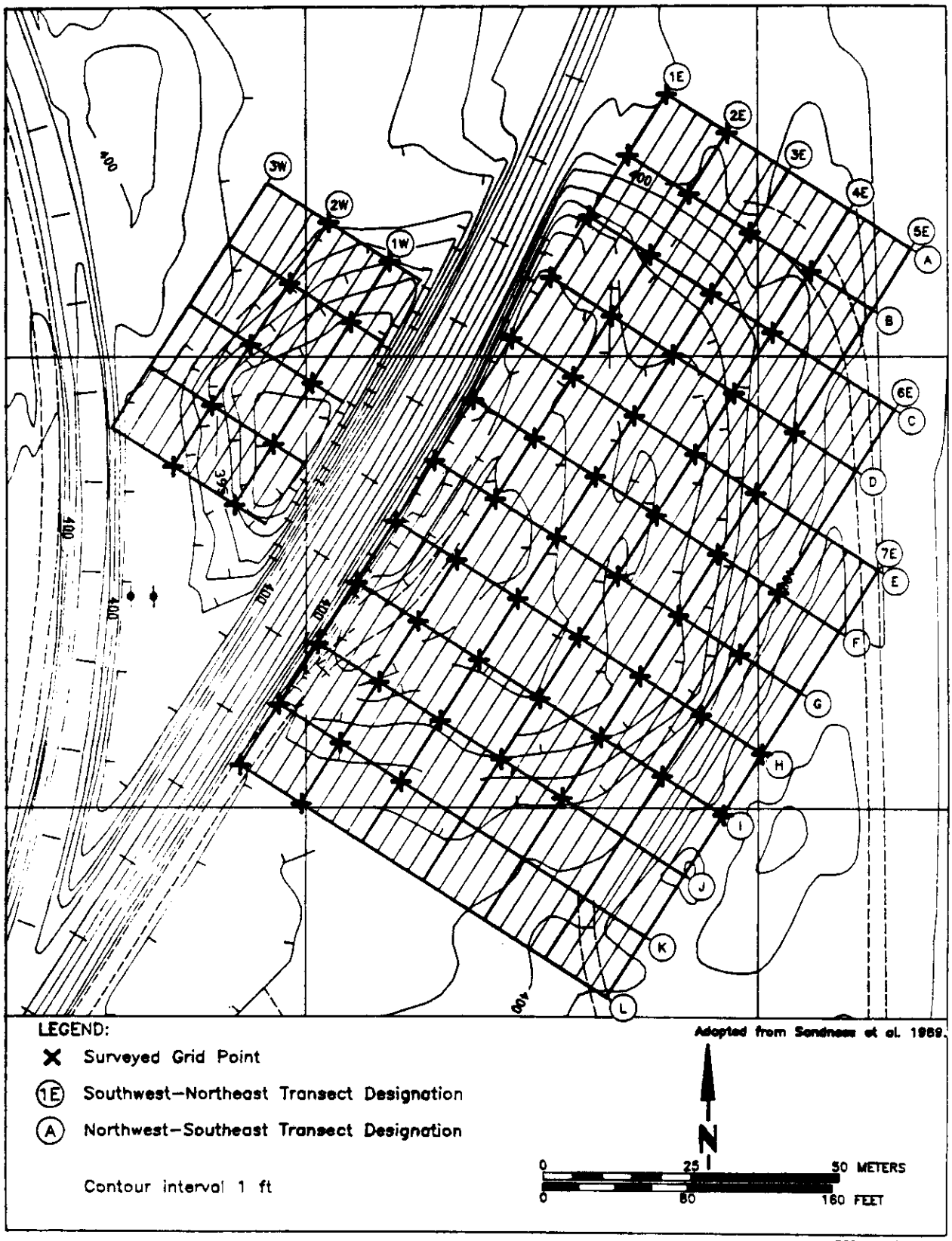

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Figure 2-2. 1100-2 Operable Subunit Geophysical Survey Transects.

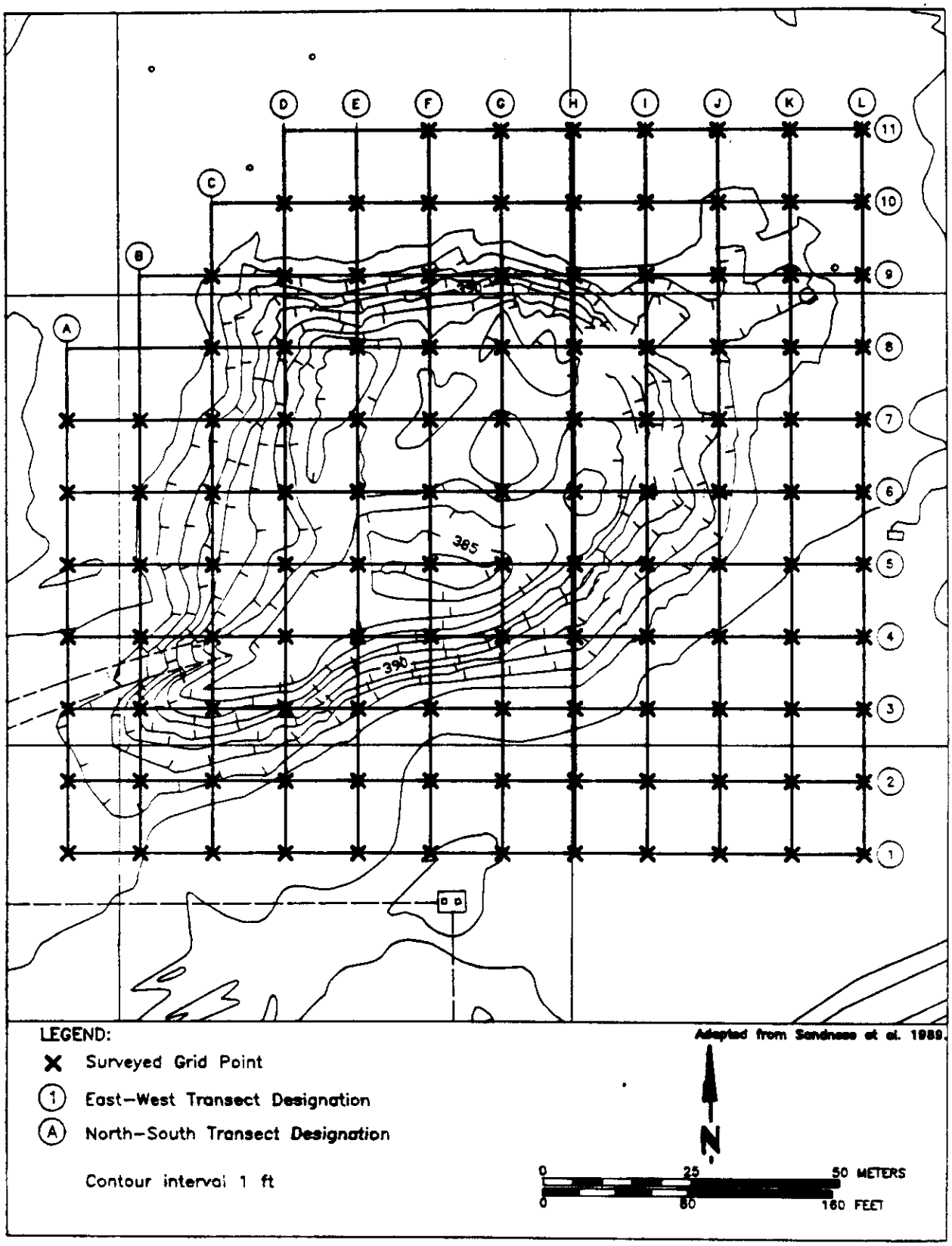

Figure 2-3. 1100-3 Operable Subunit Geophysical Survey Transects.

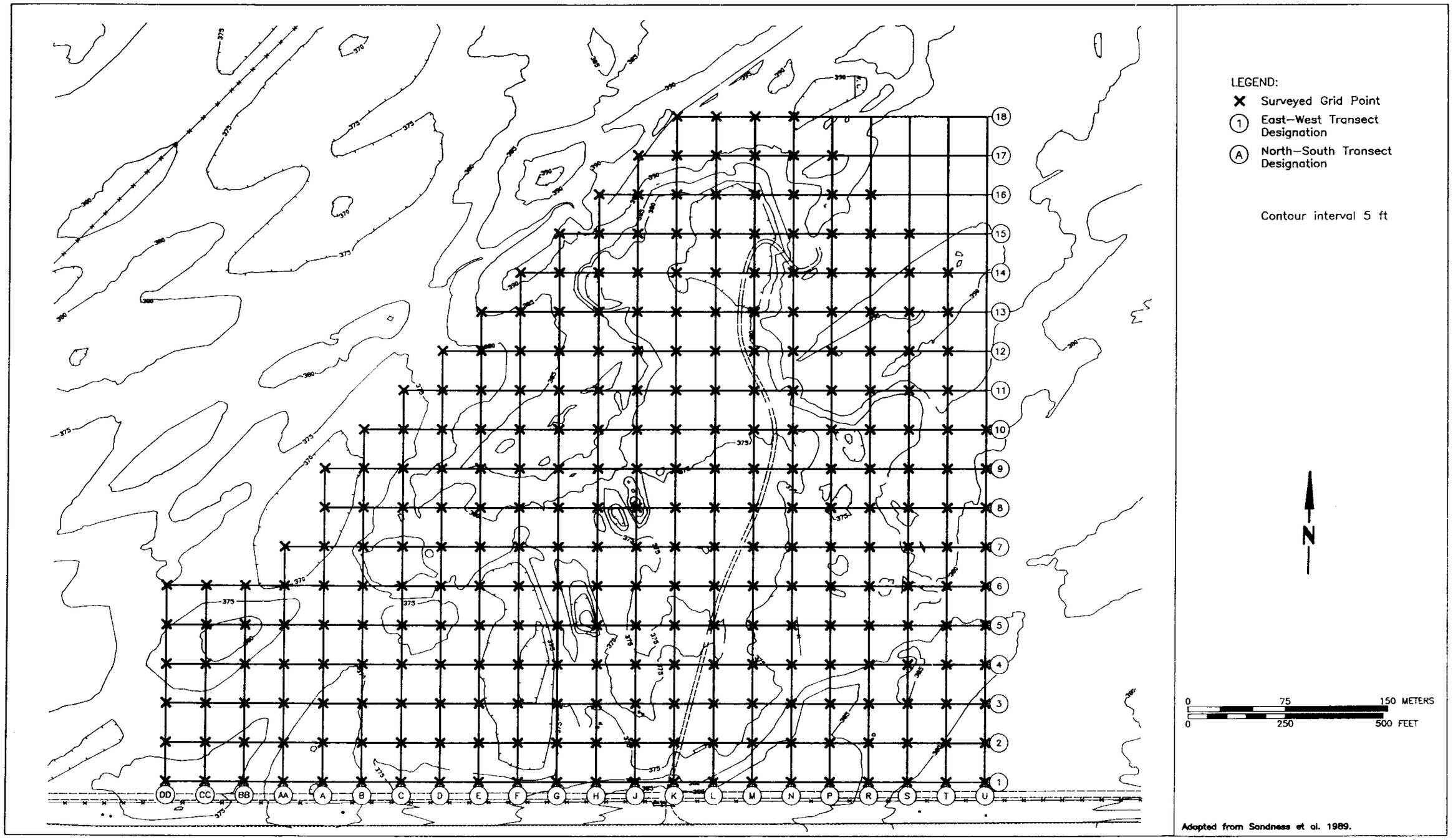

Figure 2-4. Horn Rapids Landfill Operable Subunit Geophysical Transects.

walking speed and data were digitally acquired at a rate that provided a data spacing of approximately 10 cm (4 in). The EMI and magnetometry data were also obtained at a normal walking speed. The digital data acquisition rates used with these techniques resulted in a data spacing of approximately 30 cm (12 in). Metal detection was conducted continuously along each transect until a response was obtained. At that point, the boundaries of the buried object were delineated before resuming the survey.

Detailed results of the 1100-EM-1 geophysical surveys, along with further details on methodology, are presented in Sandness et al. (1989); a summary of the results, by operable subunit, is presented in Appendix B; results are discussed in Section 3.1.2.

2.1.4 Soil Gas Survey

Soil gas surveys were conducted at 1100-1, 1100-2, 1100-3, and the Horn Rapids Landfill to determine the nature and areal extent of any volatile organic compound (VOC) contamination at these operable subunits. Soil gas contamination can be derived from either leaking buried waste containers, contamination of soils from prior direct disposal to this medium, or volatilization from an underlying plume of contaminated ground-water. Initial project scoping, performed during RI/FS work plan development, gave no indication of VOC contamination at either 1100-4 or UN-1100-6; therefore, soil gas surveys were not conducted at these two subunits.

The survey at each operable subunit, except 1100-1, was conducted once, during the period from March through June 1989. Two surveys within this time period were conducted at 1100-1 because blockage of the soil gas probes during the initial survey was suspected. The number of sampling points established at each subunit was:

- 1100-1 5
- 1100-2 62
- 1100-3 42
- Horn Rapids Landfill 209.

The locations of these respective sampling points are shown in Figures 2-5 through 2-8.

Soil gas probes, with terminal sampling ports, were installed to a depth of 1.2 m (4 ft) and left in the ground to equilibrate for at least 12 h, with the exception of those at 1100-2, prior to sampling. Most probes installed at 1100-2 were allowed to equilibrate for only a short time.

Detailed results of the 1100-EM-1 soil gas surveys, and detailed descriptions of the sampling and analytical methods used, can be found in Evans (1989). A Westinghouse Hanford project memorandum (Clark, S., WHC [Memo to B. Wright, GAI] February 22, 1990) provides a description of various areas within the Horn Rapids Landfill based on soil gas and geophysical survey results and discernable surface features. A summary of the results of the 1100-EM-1 soil gas survey is presented in Appendix C; these results are discussed in Section 4.1.1.

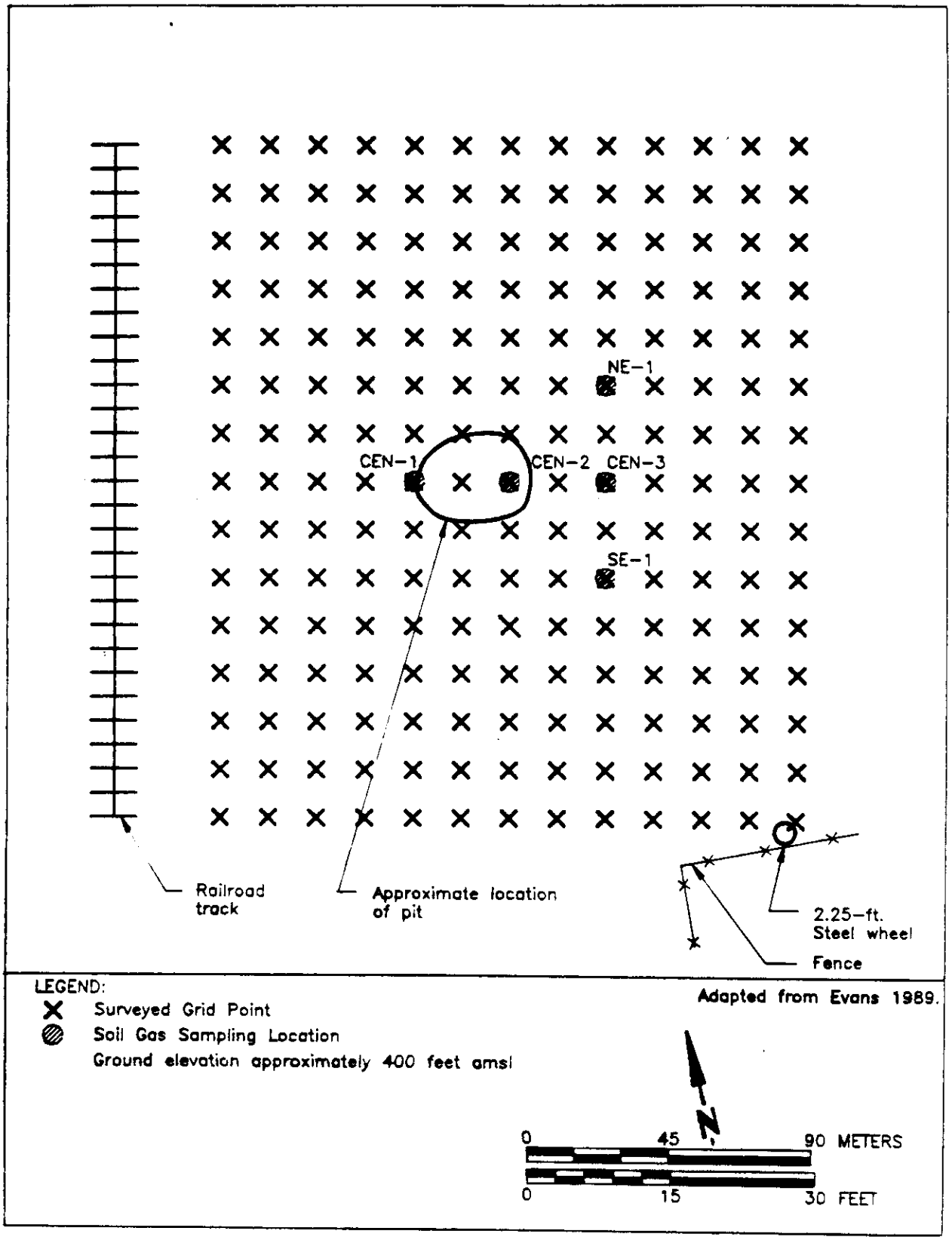

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Figure 2-5. 1100-1 Operable Subunit Soil Gas Survey Locations.

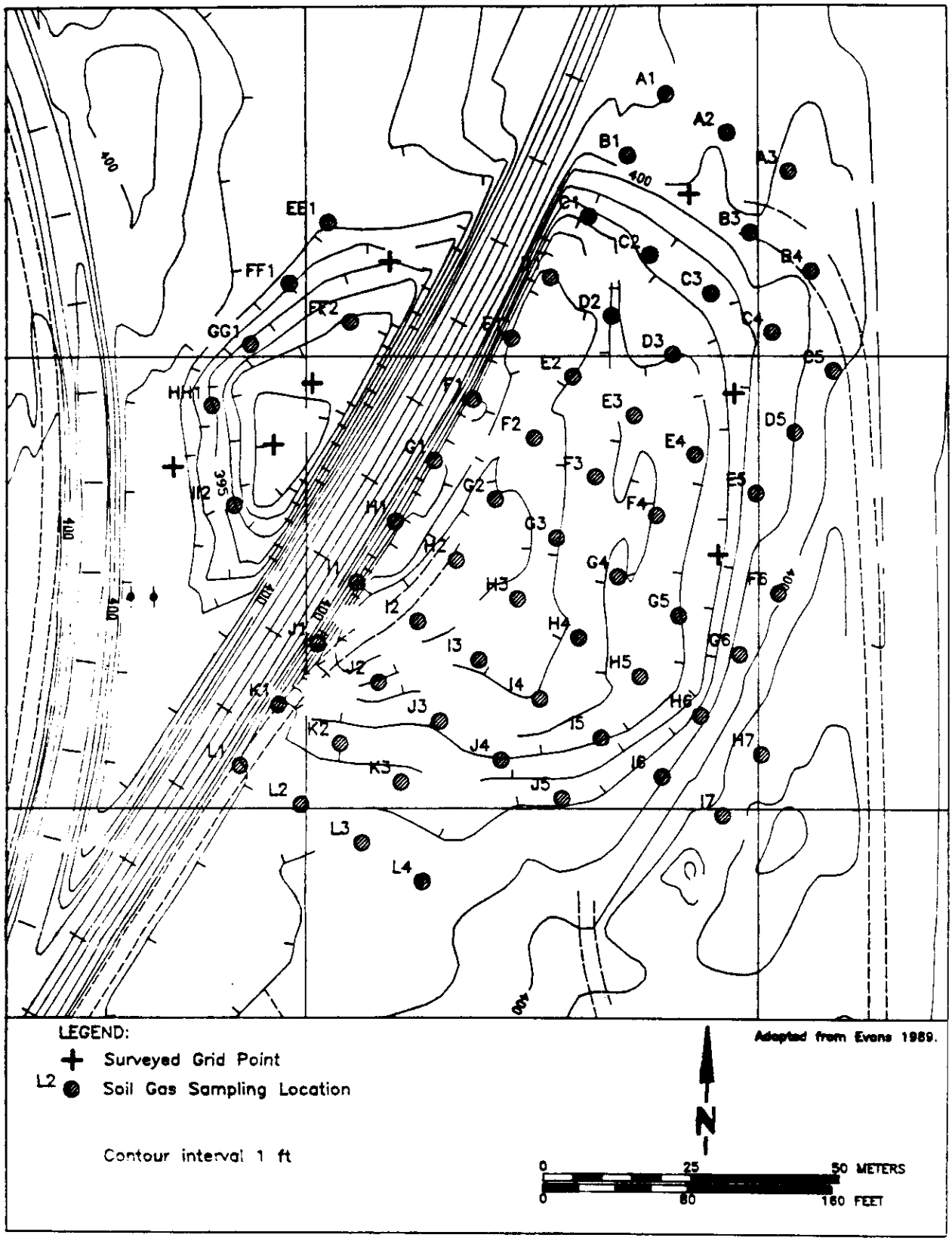

Figure 2-6. 1100-2 Operable Subunit Soil Gas Survey Locations.

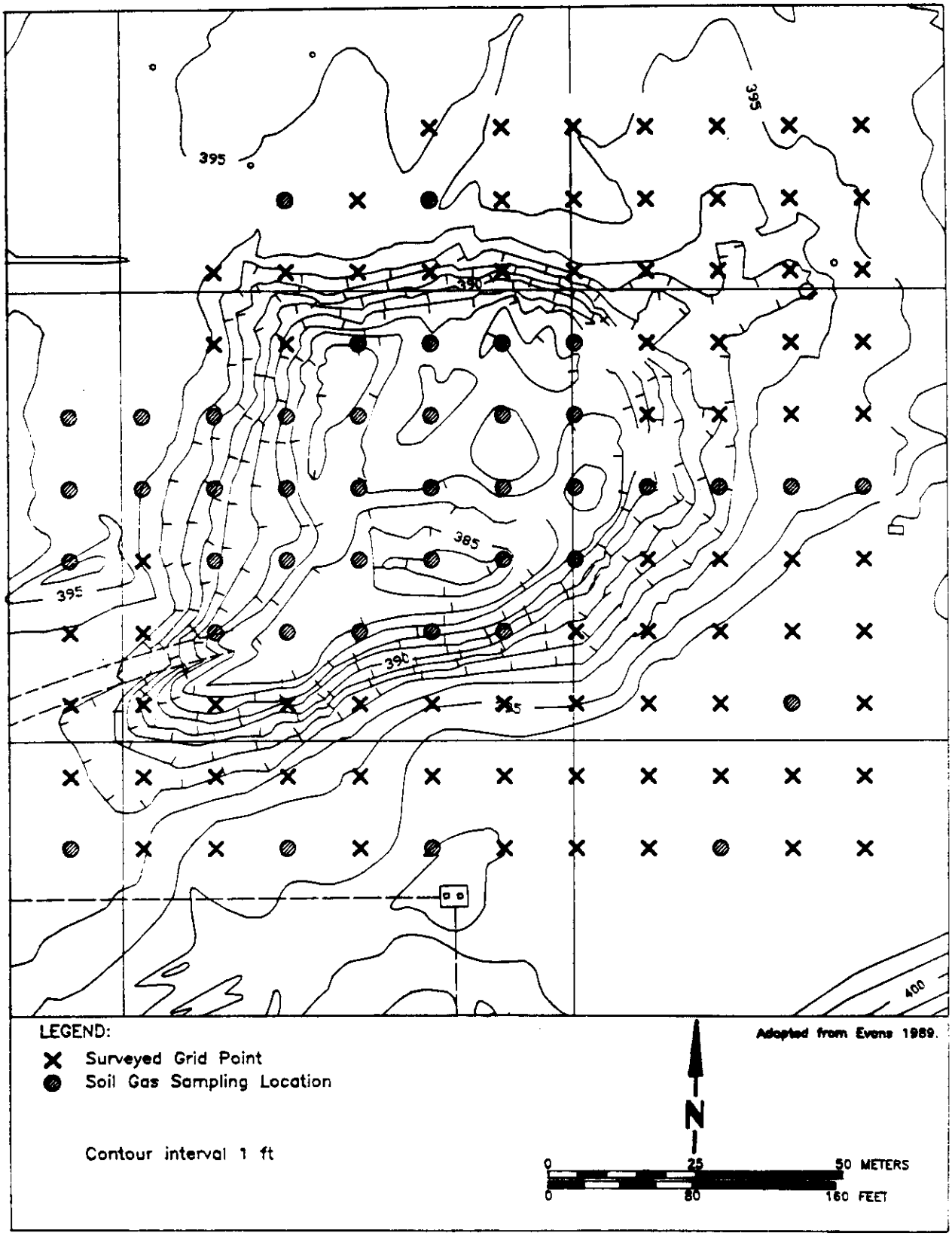

Figure 2-7. 1100-3 Operable Subunit Soil Gas Survey Locations.

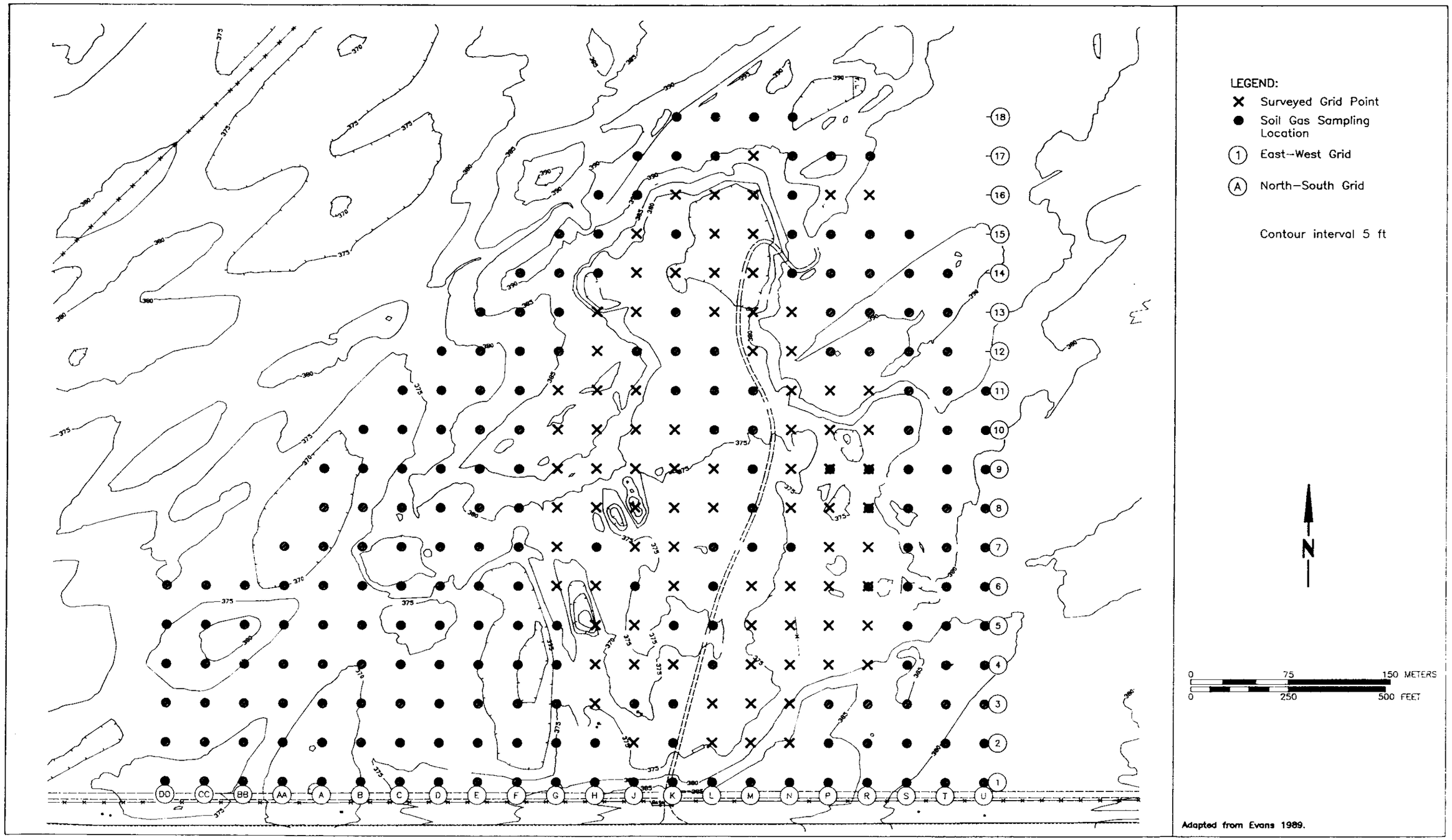

Figure 2-8. Horn Rapids Landfill Operable Subunit Soil Gas Survey Locations.

2.1.5 Surface Radiation Survey

Prior to commencement of intrusive 1100-EM-1 field activities, in November and December 1989, one-time radiation surveys were conducted over the surfaces of 1100-1, 1100-2, 1100-3, 1100-4, and the Horn Rapids Landfill. A surface radiation survey was also performed in the parking lot north of the 1171 Building in which UN-1100-5 is presumed to be located (see Section 1.3.2.5). These surveys were conducted to confirm the suspected absence of radioactive contamination at each of these operable subunits.

The surveys employed a combination of hand-held and vehicle-mounted gross-beta/gamma radiation detectors. The detailed results of these surveys, and the procedures used, are contained within Clark (1990b); result summaries are incorporated into Section 4.1.1.

2.2 METEOROLOGICAL INVESTIGATION

The meteorological investigation for the 1100-EM-1 Phase I RI consisted of two activities:

- Existing meteorological data compilation
- Air quality monitoring.

Each activity is described below. Findings based on the evaluation of the data gathered under these activities are presented in Sections 3.2 (Meteorological Characteristics) and 4.2 (Air Contamination).

2.2.1 Meteorological Data Compilation

Meteorological data for the 1100-EM-1 Phase I RI were compiled at both the regional and local scales to characterize the climatology of the 1100 Area. Original data were collected at various stations; the locations of these stations are shown in Figure 2-9, and are described below.

Regional climatology was characterized with the data available from the Hanford Meteorological Station (HMS), which is located between the 200 West and 200 East Areas. This station provides long-term meteorological data. From 1100-EM-1, HMS is located approximately 32 km (20 mi) to the northwest.

A summary of the HMS data for the period from 1946 through 1979 was obtained from Stone et al. (1983). Regional evapotranspiration data were obtained from United States Weather Bureau and SCS (1962).

Regional meteorological data were supplemented with local wind velocity data obtained from two stations situated within 1.6 km (1 mi) of 1100-EM-1. Both the 300 Area wind tower, to the north, and the Richland Airport weather station, to the south, are used by PNL to record wind observations. Wind velocity summaries for both stations, for the years 1982 through 1989, are provided in Appendix D.

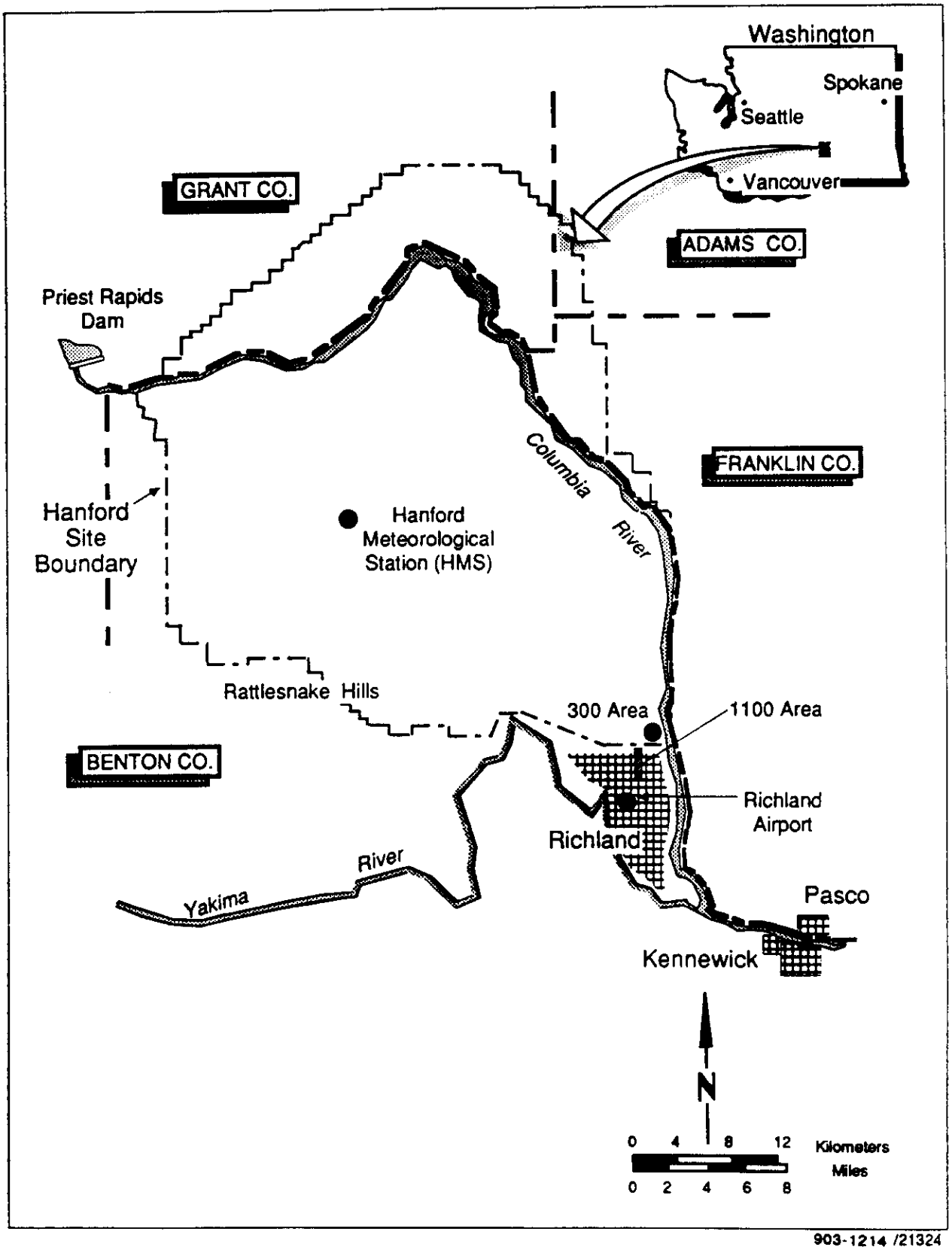

Figure 2-9. Meteorological Monitoring Stations

2.2.2 Air Quality Monitoring

Air quality monitoring at four of the operable subunits within 1100-EM-1—1100-1, 1100-2 and 1100-3, and the Horn Rapids Landfill—was conducted during the Phase I RI. This monitoring was conducted to identify any potential airborne contaminants emitted from the operable subunits. No air monitoring was conducted at 1100-4 due to its subsurface location beneath the 1171 Building and the relative non-volatility of antifreeze constituents; air monitoring at UN-1100-6 was deemed unnecessary because initial project Figure 2-9 scoping activities indicated an absence of VOC contamination at this subunit (DOE-RL 1989a).

For air monitoring purposes, 1100-2 and 1100-3 were treated as a single subunit. One upwind and two downwind sampling stations were established at each subunit except for 1100-1, where, due to space limitations imposed by the proximity of the 1171 Building, only one downwind station was used. The location of these stations are shown in Figure 2-10.

Two rounds of sampling were conducted at the operable unit. During the first round, each subunit was monitored one time in April and May of 1989, prior to soil and ground-water drilling activities. During the second round, the Horn Rapids Landfill was monitored at the time that such activities were in progress in January 1990.

During the first round of air monitoring, samples were obtained for the analysis of a wide range of parameters, including various particulate elements, VOCs, and SVOCs; asbestos sampling was also conducted. Specific analytical parameters and sampling and analytical methodologies are described in detail in Glantz and Laws (1990a). Specific first round analytical parameters, along with documentation of sampling conditions, are presented in Appendix E; the first round monitoring results is also presented in Appendix E.

A second round of air monitoring was conducted primarily to assess the potential for occupational safety and health impacts during RI drilling activities. Samples obtained were analyzed for VOCs and SVOCs. Specific second round analytical parameters, sampling and analytical methods, and results are contained in Glantz and Laws (1990b).

2.3 SURFACE HYDROLOGICAL INVESTIGATION

Existing literature was compiled to develop regional and local surface hydrological characterizations. The following references were reviewed: the 7.5′ United States Geological Survey (USGS) topographic map (USGS 1978), a local wetlands inventory map (United States Fish and Wildlife Service, USFWS 1976), an early discussion of waste management operations at the Hanford Site (United States Energy Research and Development Administration, ERDA 1975), a flood analysis of a major ephemeral drainage on the Hanford Site (Skaggs and Walters 1981), a doctoral dissertation on aquifer intercommunication at the Hanford Site (Graham 1983), a regulatory variance request for Hanford Site non-radioactive dangerous waste landfill (Fuchs et al. 1985), a recent environmental impact statement (EIS) prepared for the disposal of Hanford Site defense wastes (DOE-RL 1987), an evaluation of the City of Richland well field

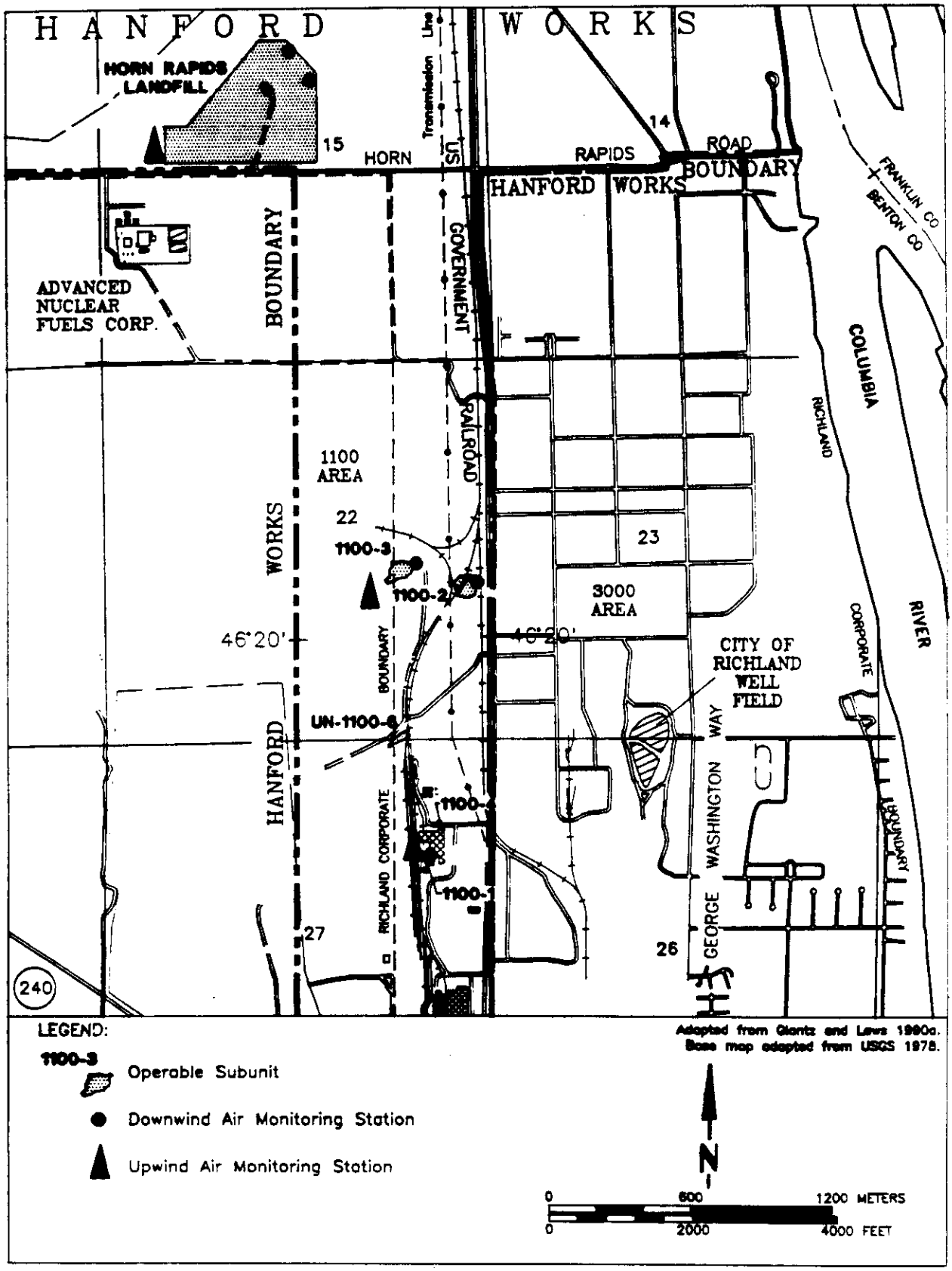

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Figure 2-10. Air Monitoring Station Locations for 1100-EM-1 Operable Unit.

(CWC-HDR, Inc. 1988), and a recent USGS compilation of water resource data for the State of Washington (McGavock et al. 1989).

Interpretations of the compiled information are presented in Sections 3.3 (Surface Hydrological Characteristics) and 4.3 (Surface-Water and Aquatic-Sediment Contamination).

2.4 GEOLOGICAL INVESTIGATION

The geological investigation for the first phase of the 1100-EM-1 Operable Unit RI consisted of the compilation of existing literature describing the regional and local geology, and the compilation of pertinent data obtained under the pedological and hydrogeological investigations. The purpose of this task was to provide an integrated evaluation, interpretation, and presentation of operable-unit-specific geology, including the thickness and areal extent of stratigraphic units, lithology, mineralogy, and particle-size distribution for sediments overlying bedrock. The activities conducted under the initial 1100-EM-1 pedological and hydrogeological investigations are described in Sections 2.5 and 2.6, respectively. The existing geologic literature used for this report is discussed below.

Existing regional and local geological information was obtained for review. A study of the geology and hydrogeology of the Hanford Site is provided in a USGS professional paper (Newcomb et al. 1972). This study evaluated the conditions that govern disposal of radioactive waste to the geologic environment, the general geologic conditions at the site, and the availability of ground water for various industrial and domestic water supplies. More recent studies were carried out at the Hanford Site in the early 1980's in support of nuclear plant licensing efforts, including those for the Washington Public Power Supply System (WPPSS 1981) and the Puget Sound Power and Light's (PSPL's) Skagit/Hanford Nuclear Project (PSPL 1982). Lindberg and Bond (1979) provide a geohydrological characterization of the nearby 300 Area, as do Schalla et al. (1988), and CWC-HDR, Inc. (1988) provides a geologic description of the City of Richland well field.

The regional geology has been studied in detail during the effort to site a proposed deep-geologic, high-level, commercial nuclear waste repository. Myers and Price (1979) presents a status report of regional geologic studies that were performed from 1977 to 1979 in support of this DOE program. Reidel et al. (1983) summarizes regional geologic structure. Much of the information known about the Hanford Site geology—particularly near the 200 West Area where the repository was to be located—is summarized within DOE (1988), the draft site characterization plan for the candidate geologic repository.

Borehole logs for various holes at the Hanford Site were obtained from Summers and Schwab (1977) and Fecht and Lillie (1982). Geologic logs of boreholes, from both the RI and relevant previous activities that were conducted within the operable unit vicinity, are presented in Appendix F. Pertinent physical analytical results from soil testing conducted at the operable unit are presented in Appendix H.

An interpretation of the regional and local geology for 1100-EM-1 is presented in Section 3.4 (Geological Characteristics).

2.5 PEDOLOGICAL INVESTIGATION

For the purposes of this report, the term "pedology" is applied in a manner consistent with the meaning of the word among the international community of soil scientists: the study of the nature, properties, formation, distribution, classification, function, and uses of soils. Furthermore, the term "soil" is used broadly, as a synonym to "regolith," to refer to all unconsolidated materials overlying the bedrock at the Hanford Site.

The pedological investigation for the Phase I 1100-EM-1 RI consisted of two data collection activities:

- Existing soil data compilation
- Sampling and analysis of surface and subsurface soils.

Both of these activities are described below. Interpretations of the collected soil data can be found in Sections 3.5 (Pedological Characteristics) and 4.4 (Soil Contamination).

2.5.1 Soil Data Compilation

Available existing soil information was reviewed to supplement the survey and environmental measurement information gathered during implementation of the first phase of the 1100-EM-1 RI. Published information compiled under this activity consists of a generalized soil survey of the western United States (Western States Land-Grant Universities and Colleges and United States Soil Conservation Service (SCS) 1964), a soil survey of Benton County (Kocher et al. 1921), and two soil survey reports for areas adjacent to, but excluding, the 1100 Area (Hajek 1966; Rasmussen 1971). Results of previously conducted contaminant analyses of operable unit soils were also gathered. These data are found in the 1100-EM-1 RI/FS work plan (DOE-RL 1989a). A file memorandum also documents previous contaminant analysis results at 1100-4 (Cramer, K., PNL [Memo to Files] February 24, 1988) (see Appendix A).

2.5.2 Soil Sampling and Analysis

Both surface and subsurface soils were sampled for subsequent physical and chemical characterization during the initial phase of the 1100-EM-1 RI. This activity was conducted to define the nature and extent of contamination at the surface and within the soil column, as appropriate, at each operable subunit, and to determine the geological characteristics of the operable unit.

Locations of surface sampling points and subsurface boreholes are shown in Figure 2-11 (1100-1 and 1100-4), Figure 2-12 (1100-2), Figure 2-13 (1100-3), Figure 2-14 (UN-1100-6), and Figure 2-15 (Horn Rapids Landfill). Surface soils were characterized at two miscellaneous locations within the operable unit, at an operational gravel pit (Pit 1) and at the location of an ephemeral pool that is infrequently formed from parking lot runoff during high intensity precipitation events. These two locations are shown in Figure 2-16. Background soil sampling stations, two located west of the railroad tracks in the 1100 Area and one located west of the Horn Rapids Landfill, are depicted

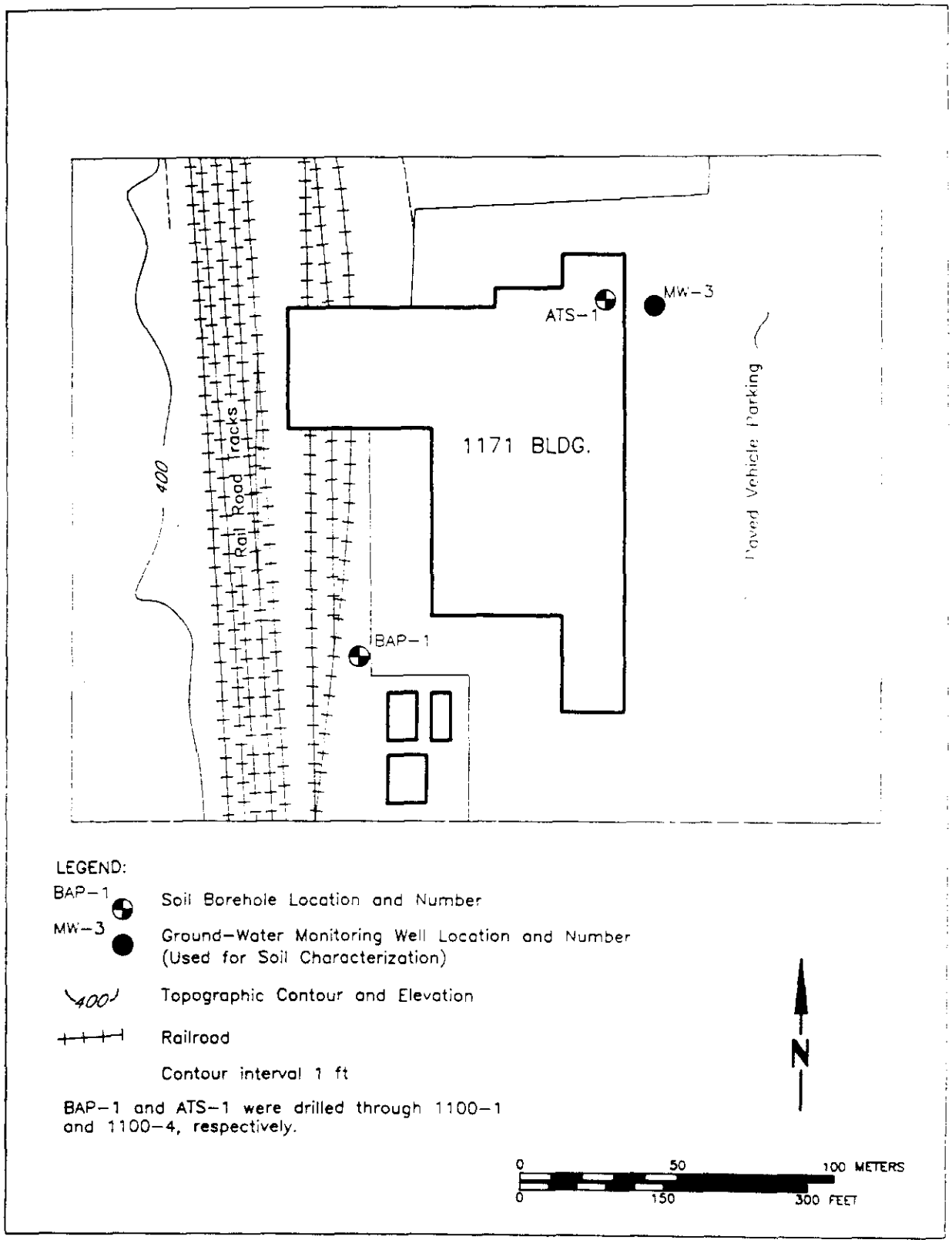

Figure 2-11. 1100-1 and 1100-4 Operable Subunit Soil Sampling Locations.

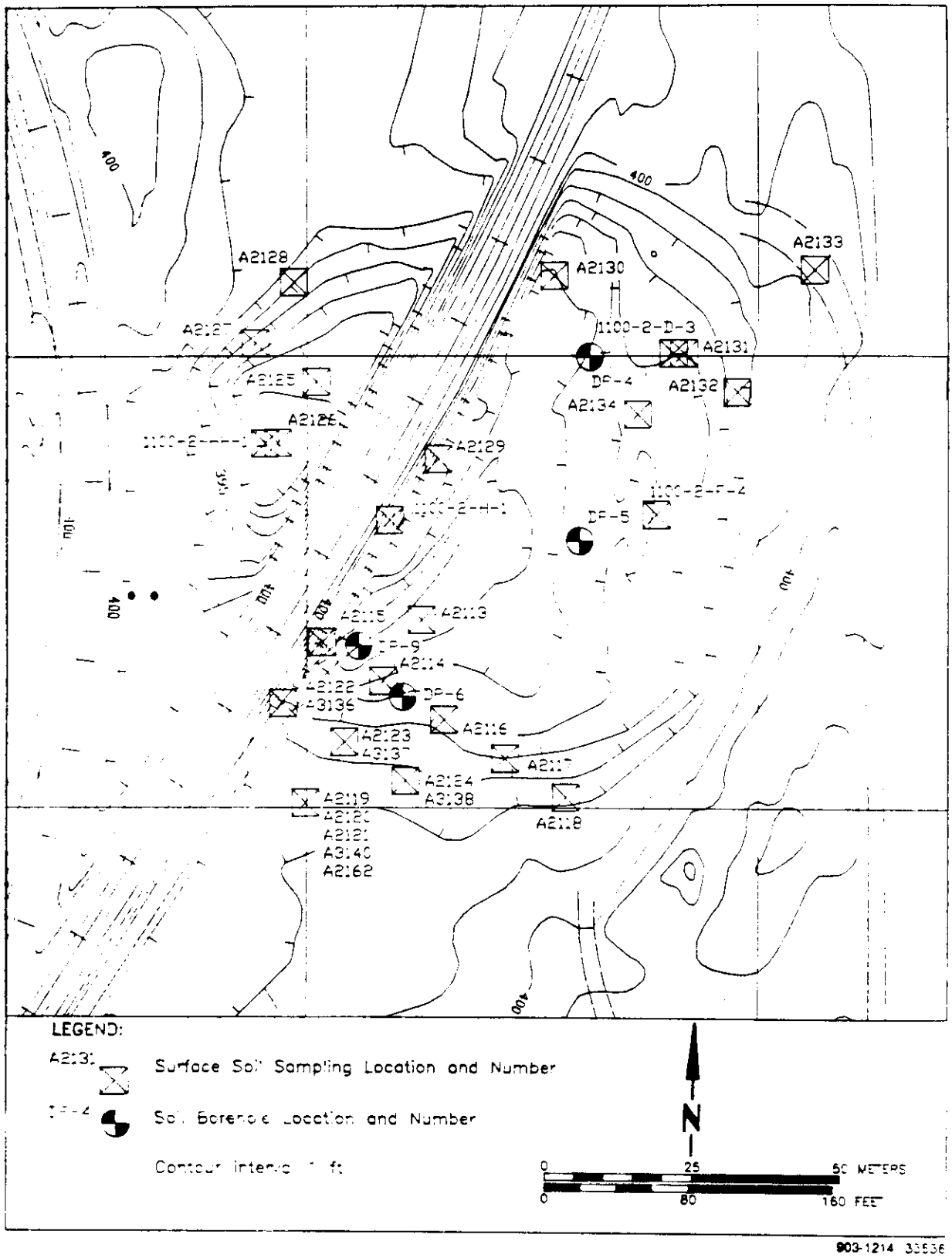

Figure 2-12. 1100-2 Operable Subunit Soil Sampling Locations.

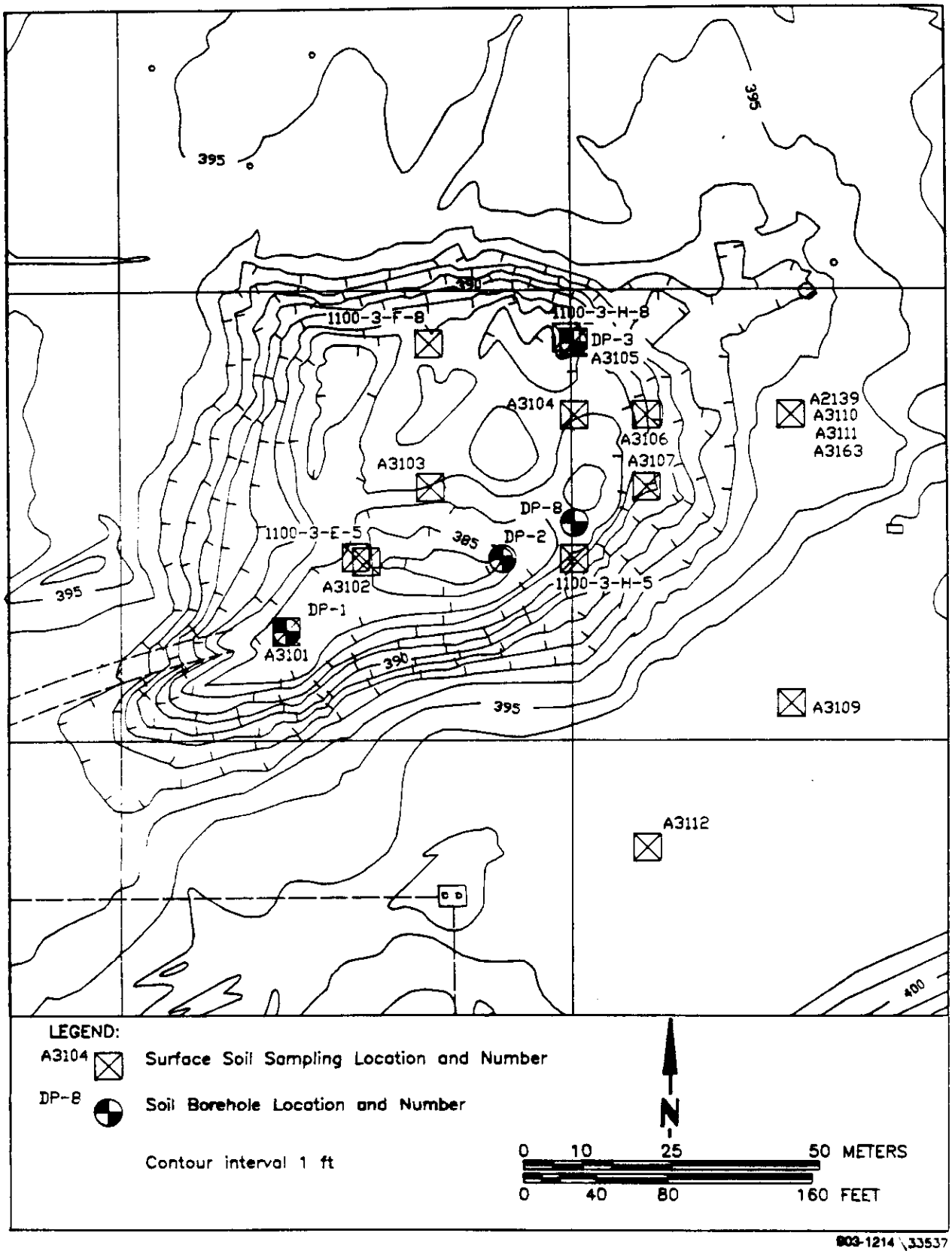

Figure 2-13. 1100-3 Operable Subunit Soil Sampling Locations.

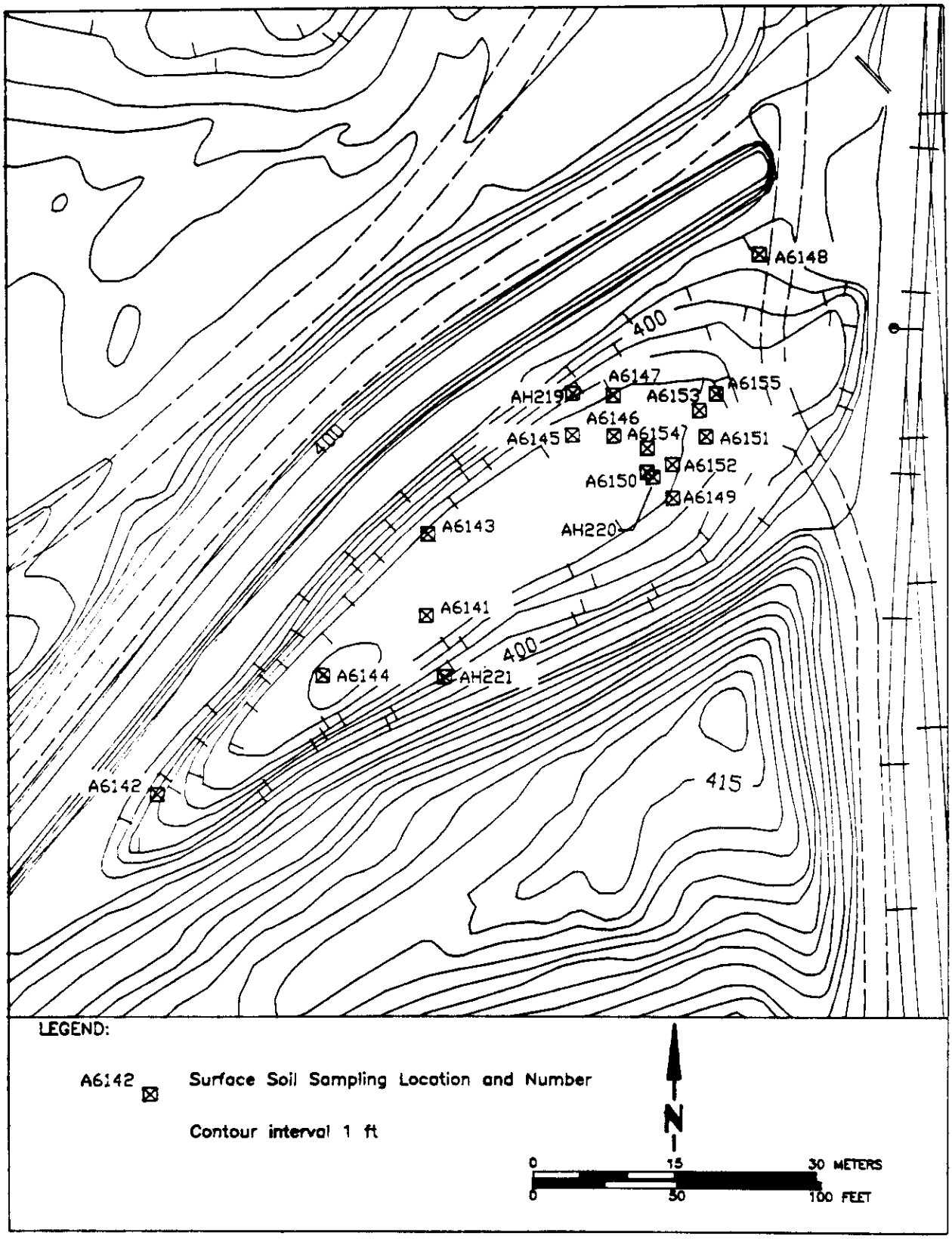

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Figure 2-14. UN-1100-6 Operable Subunit Soil Sampling Locations.

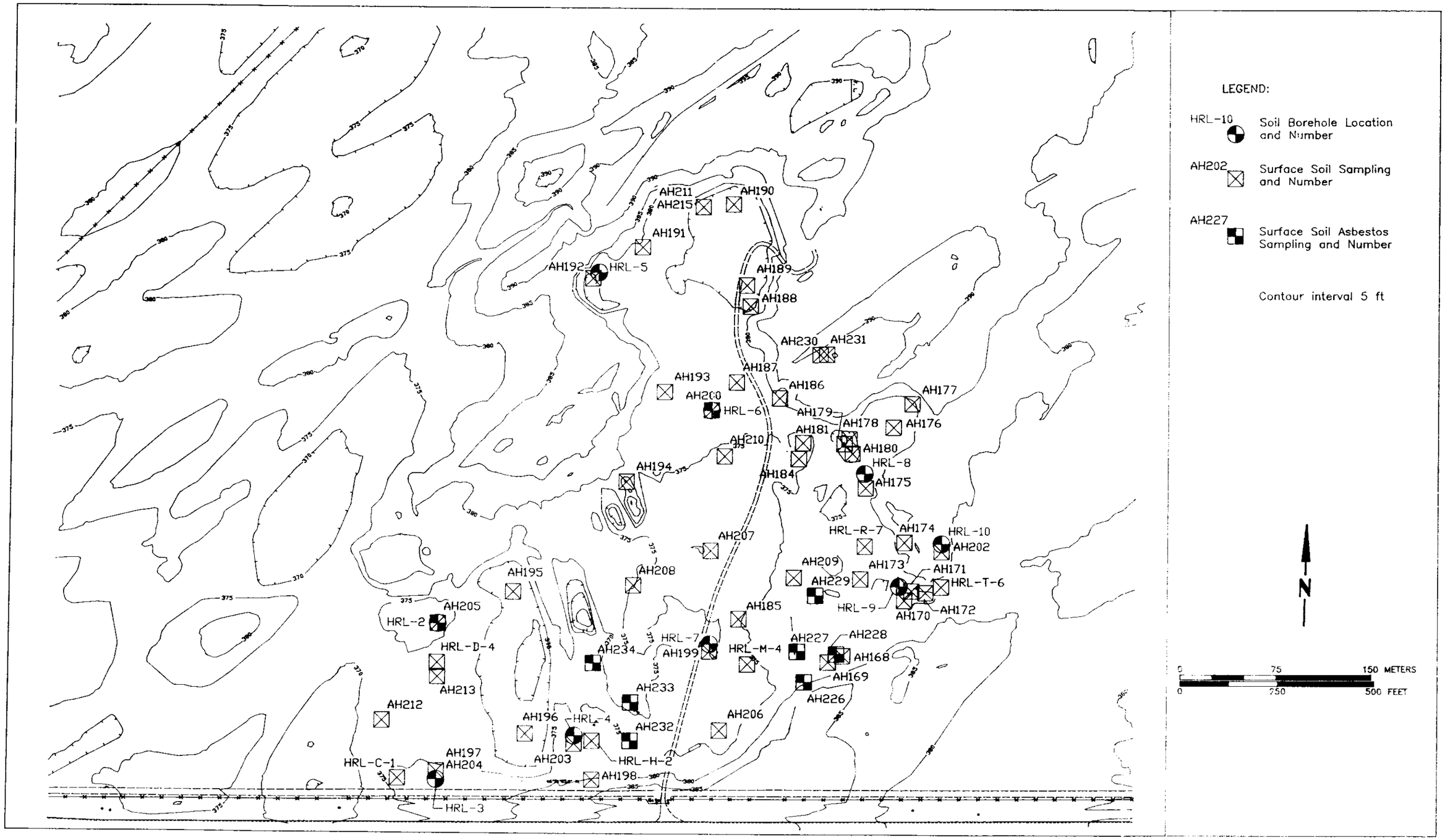

Figure 2-15. Horn Rapids Landfill Operable Subunit Soil Sampling Locations.

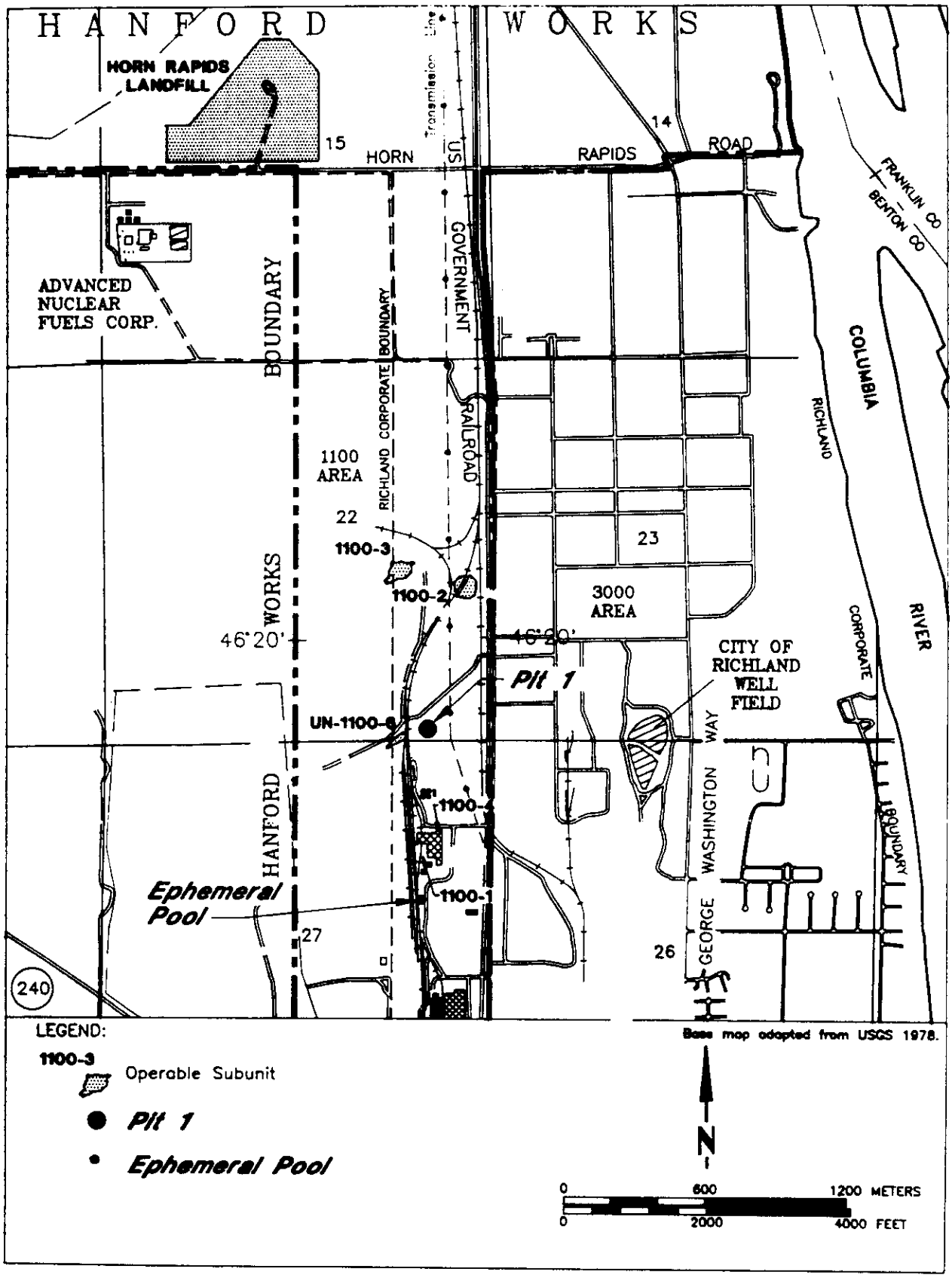

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Figure 2-16. Locations of Pit 1 and Ephemeral Pool.

in Figure 2-17. The 1100-EM-1 soil samples were collected during the period from August 1989 to February 1990.

The surface and subsurface soil characterization activities are summarized separately below. Additional soil characterization, performed during the installation of ground-water monitoring wells, is discussed in Section 2.6 (Hydrogeological Investigation).

2.5.2.1 Surface Soil Sampling and Analysis. Surface soils were obtained at each operable subunit (with the exception of 1100-1 and 1100-4) and the two miscellaneous locations. Surface contamination at the 1100-1 and 1100-4 operable subunits was considered unlikely due to the fact that both were backfilled—1100-1 at the time of facility retirement, and 1100-4 at the time of tank excavation. Surface samples were also obtained at nearby, undisturbed locations to characterize project-specific background conditions.

Surface soil samples were collected by means of a stainless steel auger, trowel, or shovel, depending on the amounts and sizes of the gravel and cobble fractions at each particular sampling point. Soils were excavated to a depth of no greater than 0.15 m (0.5 ft) at each station (Environmental Engineering Group, WHC [Technical Memo 81220-90-120 to S. Clark, WHC] April 12, 1990).

Surface soil samples analyzed for chemical constituents were screened to remove gravel and larger fractions, as necessary, before being placed in sample containers. The chemical analytical parameters consisted of EPA target analyte list (TAL) and target compound list (TCL) parameters (EPA 1988b and 1988c, respectively), and, for some samples obtained at the Horn Rapids Landfill, asbestos. Three surface soil samples at UN-1100-6, four each at 1100-2 and 1100-3, and six at the Horn Rapids Landfill were obtained for grain-size distribution analysis (see Figures 2-14, 2-12, 2-13, and 2-15, respectively).

Surface soil physical analytical results are provided in Appendix H, chemical results are in Appendix I, and asbestos analytical results are contained in a HEHF letter report contained in Appendix A (Hamilton, M. and G. Thomas, HEHF [Letter to P. Bartley, WHC] April 13, 1990).

2.5.2.2 Subsurface Soil Sampling and Analysis. Subsurface soil samples were obtained at 1100-1, 1100-2, 1100-3, 1100-4, the Horn Rapids Landfill and at three background locations for subsequent chemical and physical characterization. Subsurface sampling at UN-1100-6 was considered unnecessary because the subunit is assumed to be an area of surficial contamination, resulting from the disposal of a relatively small quantity of waste, where significant infiltration is unlikely (DOE-RL 1989a).

All subsurface soil borings were drilled with a cable-tool drilling rig, with the exception of two, in the Horn Rapids Landfill (HRL-6 and HRL-10), which were drilled with a hollow stem auger rig. All borings were logged by a geologist to record stratigraphy, drilling method and characteristics, types and locations of downhole samples, and visual soil characteristics. Downhole samples for both chemical and physical analyses were generally obtained at 1.5-m (5-ft) intervals and at changes in lithology. A detailed summary of the 1100-EM-1 subsurface soil sampling and analysis scheme is provided in Appendix G.

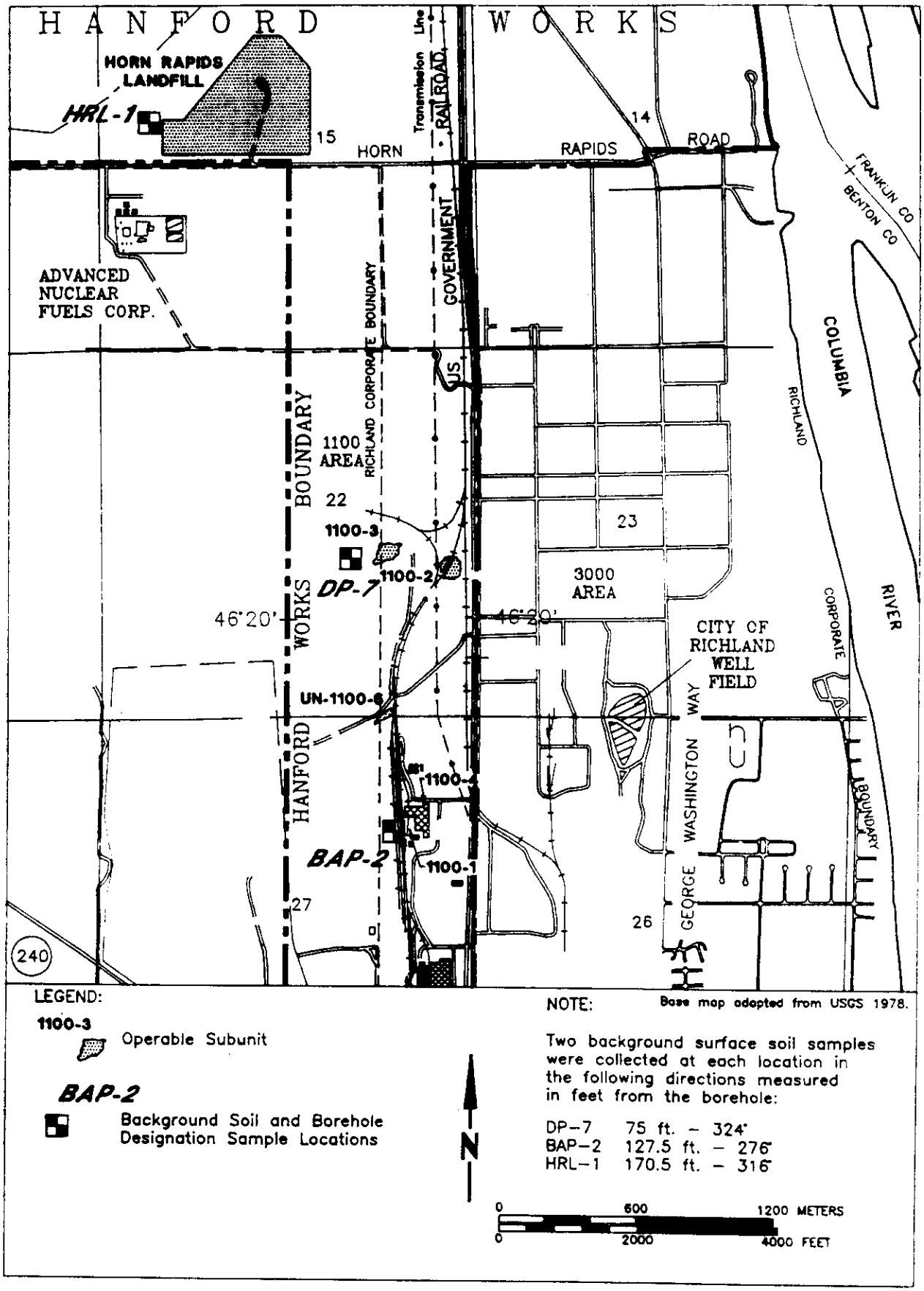

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Figure 2-17. Background Soil Sampling Locations.

The borehole log for the Antifreeze Tank Site (ATS-1, see Figure 2-11) is actually a composite of three separate but adjacent boreholes sampled at varying depths. Backfill material emplaced after the removal of the tank (see Section 1.3.2.4) caused drilling difficulties, thus repeated efforts were necessary at this location.

Downhole samples for chemical analysis were obtained with a split spoon sampler; downhole samples for physical analysis were obtained with either a core barrel or split spoon sampler. Details on sampling procedures used are provided in a Westinghouse Hanford technical memorandum (Geosciences Group, WHC [Technical Memo 81232-90-017 to S. Clark, WHC] March 20, 1990). Chemical analyses were conducted for TAL and TCL parameters; samples from 1100-4 were also analyzed for ethylene glycol. Physical analyses were conducted for grain-size distribution and moisture content.

All soil borehole logs developed during the Phase I RI for the 1100-EM-1 Operable Unit are contained within Appendix F. Physical analytical results for all soils are provided in Appendix H; chemical analytical results are found in Appendix I.

2.6 HYDROGEOLOGICAL INVESTIGATION

The hydrogeological investigation for the 1100-EM-1 Phase I RI consisted of the following data collection activities:

- Existing ground-water information compilation
- Well installation and soil sampling and analysis
- Aquifer testing
- Ground-water sampling and analysis.

Each of these activities is summarized below. Interpretations of the ground-water data are presented in Sections 3.6 (Hydrogeological Characteristics) and 4.5 (Ground-Water Contamination).

2.6.1 Ground-Water Data Compilation

Existing regional and local ground-water information, including information pertaining to the hydrogeological characteristics of the vadose zone, was compiled to supplement data gathered during implementation of the first phase of the 1100-EM-1 hydrogeological investigation. This included the compilation of the published documents discussed below.

Regionally, Bierschenk (1957), Kipp and Mudd (1973), Deju and Fecht (1979), Gephart et al. (1979), DOE (1988), and Freshley and Graham (1988) provide information on the hydraulic characteristics of aquifers at the Hanford Site. Myers and Price (1979) present a status report of regional geologic studies. A discussion of aquifer intercommunication at the Hanford Site is presented by Graham (1983). Zimmerman et al. (1986) evaluate historical changes in the Hanford Site water table. Recharge at the Hanford Site, and the rate of water transport through the vadose zone, is addressed by Gee (1987) and Rockhold et al. (1990).

Locally, CWC-HDR, Inc. (1988) discusses the hydrogeology associated with the City of Richland well field and Freshley et al. (1989) present the results of some preliminary ground-water modeling in the vicinity of the 1100 Area. Law (1989) provides some preliminary ground-water quality data for the 1100 Area. Lindberg and Bond (1979) present a detailed study of the hydrogeology of the nearby 300 Area. A Hanford Site ground-water data base is maintained by PNL (1990); this data base was consulted to obtain existing water quality information from relevant wells in the operable unit vicinity.

A well inventory for the 1100-EM-1 vicinity was obtained from Ecology in January and February of 1990. The Ecology well inventory information is contained within Appendix J. An inventory for vicinity wells located within the Hanford Site was obtained from McGhan (1989); this information is also contained within Appendix J. Both sets of well information were verified by Westinghouse Hanford (Geology Section, WHC [Technical Memo 81232-90-055 to S. Clark, WHC, 3 attachments] June 26, 1990). In February 1990, the City of Richland provided recent water usage rates for their nearby well field. These water use rates are presented in Appendix K.

2.6.2 Well Installation and Soil Sampling and Analysis

During the first phase of the 1100-EM-1 RI, 16 ground-water monitoring wells were installed. These wells were installed to provide additional ground-water sampling stations, to define geological and hydrogeological characteristics, and, in one instance (MW-3), to further define the nature and extent of contamination in the soil column.

The locations of these new wells are shown in Figure 2-18. Well installation occurred from November 1989 through February 1990. The cable-tool method was used to drill the wells, and wells were constructed with stainless steel screen and casing assemblies. All construction was performed in accordance with state standards for resource protection wells (WAC 173-160-500). Further procedural details are provided in a Westinghouse Hanford technical memorandum (Geosciences Group, WHC [Technical Memo 81232-90-038 to S. Clark, WHC] May 1, 1990).

Soil analyses were conducted for the following physical parameters: grain-size distribution, moisture content, and permeability. Soil samples for chemical analysis were obtained only at MW-3. These samples were analyzed for TAL and TCL parameters.

All well borings were logged by a geologist who noted details on stratigraphy, drilling method and characteristics, types and locations of downhole samples, visual soil characteristics, and well construction. Samples for physical analysis, and chemical analysis in MW-3, were obtained at approximately 1.5-m (5-ft) intervals and at changes in lithology. A detailed summary of the distribution of downhole soil samples is provided in Appendix G. Table 2-1 contains a summary of well completion information.

Summary borehole logs for each monitoring well installation are presented in Appendix F; results of physical analyses of soil samples are presented in Appendix H; and soil chemical analytical results are included in Appendix I.

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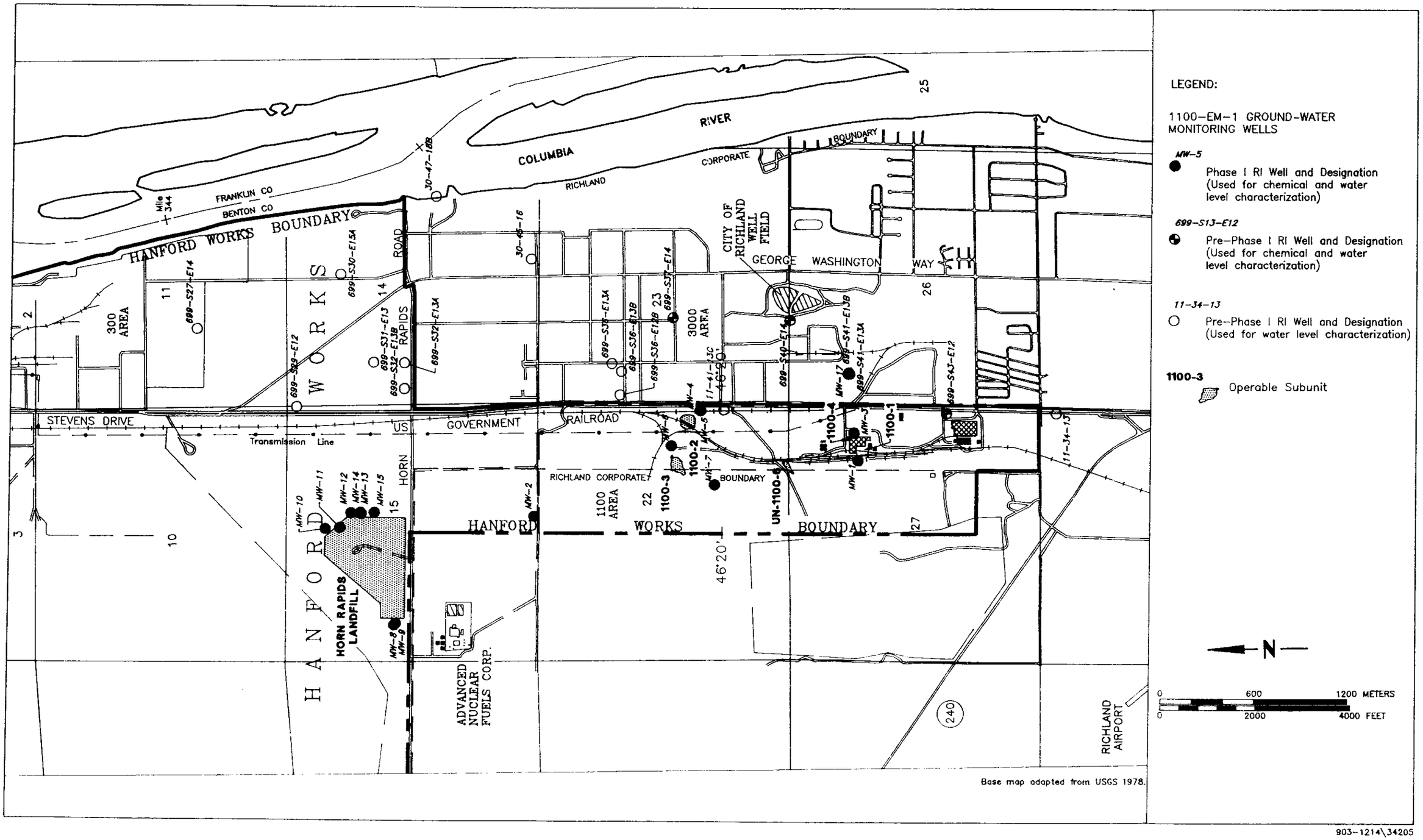

Figure 2-18. Wells Sampled During First Round of Ground-Water Monitoring.

Table 2-1. Completion Summary for Ground-Water Monitoring Wells Sampled During the Phase I Remedial Investigation[a]. (Sheet 1 of 2)

Well ID	Installation Date (mo/yr)	Top-of-Casing Elevation (ft amsl)[b]	Top-of-Screen Elevation (ft amsl)[b]	Screen Length (ft)[b]	Sand Pack Interval (ft amsl)[b]	Screen Type[c]	Aquifer
MW-1	01/90	401.37	365.0	20	367.8 - 341.3	CP	unconfined
MW-2	02/90	382.38	361.0	20	364.1 - 336.9	10-S	unconfined
MW-3	02/90	402.00	360.0	20	362.6 - 333.5	10-S	unconfined
MW-4	02/90	404.96	361.0	20	364.9 - 340.0	CP	unconfined
MW-5	12/89	405.01	333.0	15	336.6 - 316.4	CP	unconfined
MW-6	01/90	399.31	363.0	20	366.1 - 339.5	CP	unconfined
MW-7	12/89	398.61	363.0	20	365.8 - 339.6	CP	unconfined
MW-8	12/89	374.77	362.0	20	364.6 - 340.6	20-S	unconfined
MW-9	02/90	375.79	307.0	10	309.1 - 295.1	CP	confined
MW-10	11/89	392.30	358.0	20	361.5 - 335.5	10-S	unconfined
MW-11	12/89	392.08	358.0	20	360.1 - 334.2	CP	unconfined
MW-12	01/90	384.58	358.0	20	362.1 - 336.6	CP	unconfined
MW-13	01/90	383.73	358.0	15	360.9 - 339.7	10-S	unconfined
MW-14	01/90	382.92	339.0	10	344.7 - 329.0	CP	unconfined
MW-15	12/89	380.59	361.0	20	364.6 - 337.3	10-S	unconfined
MW-17	01/90	410.69	300.0	10	304.9 - 303.0	CP	confined
699-S27-E14	04/48	399.76	339.0	45	--	PC	unconfined
699-S29-E12	11/71	387.96	329.0	20	--	M	unconfined
699-S30-E15A	10/71	400.14	342.2	20	--	M	unconfined
699-S31-E13	10/79	394.06	344.1	18	--	M	unconfined
699-S32-E13A	09/79	390.46	340.4	20	--	M	unconfined
699-S32-E13B	10/79	394.72	344.7	20	--	M	unconfined
699-S36-E13A	09/79	399.31	347.3	20	--	M	unconfined
699-S36-E12B	10/79	399.04	299.0	--	--	--	unconfined
699-S36-E13B	10/79	399.63	349.6	20	--	M	unconfined
699-S37-E14	10/88	408.28	361.3	16	--	20-S	unconfined
699-S40-E14	10/88	402.85	368.9	26	372.7 - 340.4	10-S	unconfined

Table 2-1. Completion Summary for Ground-Water Monitoring Wells Sampled During the Phase I Remedial Investigation[a]. (Sheet 2 of 2)

Well ID	Installation Date (mo/yr)	Top-of-Casing Elevation (ft amsl)[b]	Top-of-Screen Elevation (ft amsl)[b]	Screen Length (ft)[b]	Sand Pack Interval (ft amsl)[b]	Screen Type[c]	Aquifer
699-S41-E13A	10/88	410.56	363.6	15	367.1 - 343.6	20-S	unconfined
699-S41-E13B	10/88	410.10	333.1	10	338.1 - 315.1	20-S	unconfined
699-S43-E12	10/88	405.60	363.6	16	368.3 - 343.9	20-S	unconfined
11-34-13	10/47	394.78	332.8	--	--	--	unconfined
11-41-13C	03/44	405.98	311.0	--	--	--	unconfined
30-45-16	--	408.77	--	3	--	--	unconfined
30-47-18B	12/48	373.97	350.0	47	--	PC	unconfined
ANF-14	--	--	--	--	--	--	unconfined
ANF-15	--	--	--	--	--	--	unconfined
ANF-16	--	--	--	--	--	--	unconfined

[a]See Figures 2-18 and 2-19 for well locations and uses.
[b]1 m = 0.3048 ft.
[c]CP = 10-slot channel pack; 10-S = 10-slot wire wrapped; 20-S = 20-slot wire wrapped; PC = perforated casing; M = manufactured well screen of unknown type.
-- Not available.

Wells were developed after installation in accordance with procedures documented in a Westinghouse Hanford technical memorandum (Geosciences Group, WHC [Technical Memo 81232-90-019 to S. Clark, WHC] March 20, 1990).

2.6.3 Aquifer Testing

Following construction, each of the 1100-EM-1 ground-water monitoring wells was tested to estimate flow properties of the aquifer within which it was completed. To prevent the generation of large quantities of potentially contaminated water, slug tests, rather than pump tests, were used. Each well constructed during the first phase of the RI (see Figure 2-18) was tested once during the period from January through February of 1990.

The results of the aquifer tests are provided in Appendix L, and further details on methodology can be found in a Westinghouse Hanford technical memorandum (Geosciences Group, WHC [Technical Memo 81232-90-020 to S. Clark, WHC] March 20, 1990).

2.6.4 Ground-Water Sampling and Analysis

Two rounds of ground-water sampling and analysis were conducted for the Phase I RI; two additional rounds of sampling are currently planned (DOE-RL 1989a). The sampling was conducted to determine the nature and extent of operable unit contamination within the unconfined aquifer, and to make an initial determination as to the vertical extent of contamination within the ground-water system. The locations of all wells sampled during the first round of ground-water monitoring are shown in Figure 2-18, Figure 2-19 shows the locations of the wells sampled during the second round, and Table 2-1 presents a summary of well completion information for all wells sampled.

The 16 monitoring wells installed during the Phase I RI and five previously existing wells installed in 1988 (Law 1989) were sampled once in January and February of 1990 during a period that spanned approximately one month. Two samples of water obtained from distribution lines at the City of Richland well field were also obtained during this time period. The second round on ground-water sampling was conducted in May 1990. Eight additional existing wells were included in the second round—three immediately upgradient of the Horn Rapids Landfill, and five in a general downgradient direction from the landfill.

All ground-water sampling, with the exception of the three immediately upgradient wells at the Horn Rapids Landfill, was conducted by Westinghouse Hanford; Advanced Nuclear Fuels Corp. performed the sampling at the other three wells. As a result, the data from the three other wells were not collected under procedures outlined in the 1100-EM-1 RI/FS QAPP.

Ground-water samples that were obtained by Westinghouse Hanford were analyzed on-site for temperature, specific conductance, pH, and turbidity in accordance with project procedures (Geosciences Group, WHC [Technical Memo 81232-90-021 to S. Clark, WHC] March 21, 1990). These samples were then subjected to laboratory analyses for Ecology landfill leachate indicator parameters (WAC 173-304-490(2)(d)(i)), EPA primary and secondary drinking water parameters (40 CFR 141 and 40 CFR 143, respectively), and TAL and TCL

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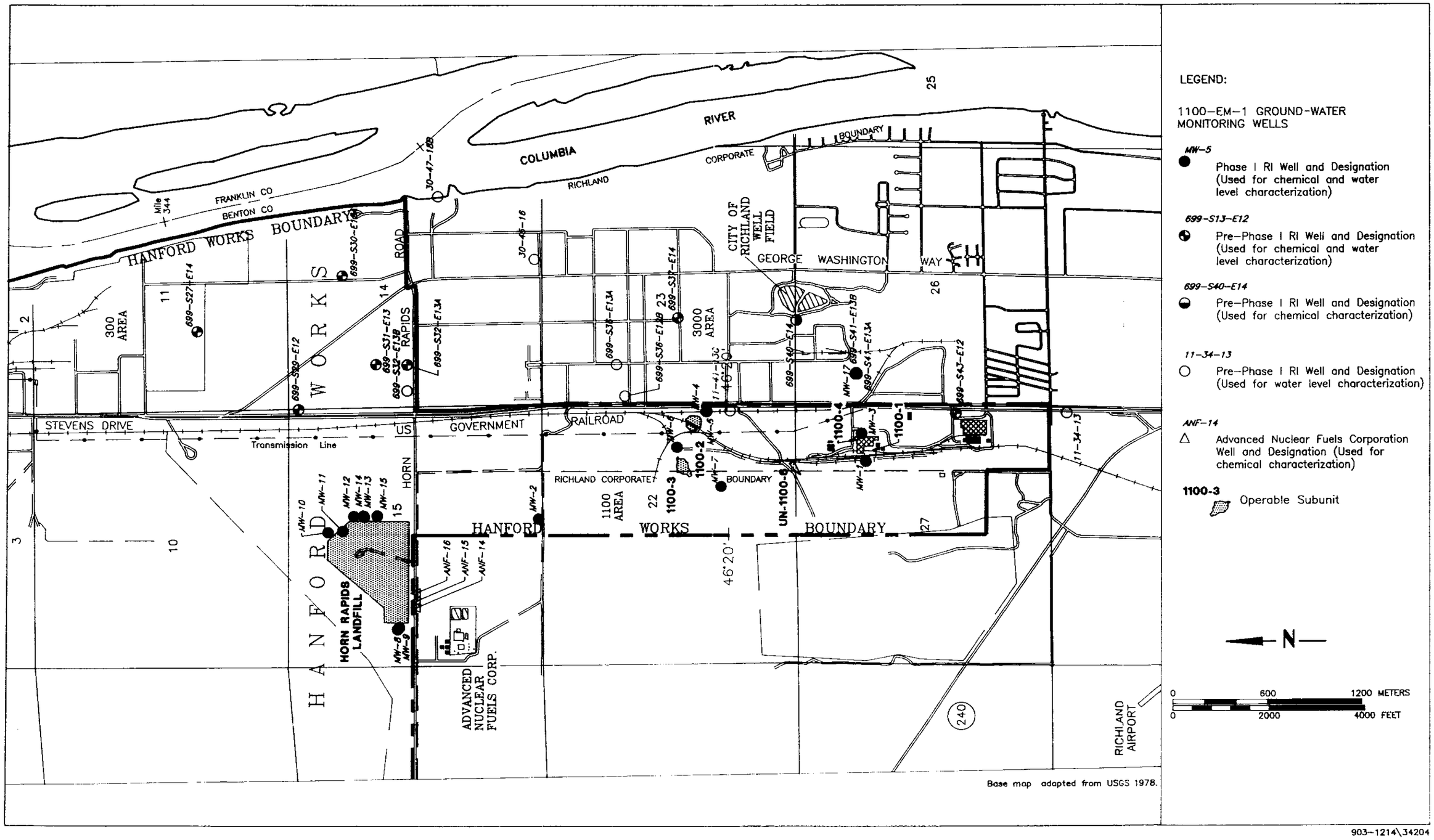

Figure 2-19. Wells Sampled During Second Round of Ground-Water Monitoring.

parameters. Ground-water samples obtained by Advanced Nuclear Fuels Corp. were analyzed for TAL and TCL parameters, and for most of the same leachate and drinking water parameters.

Ground-water elevation measurements are provided in Appendix M. These data were obtained in accordance with established procedures (Geosciences Group, WHC [Technical Memo 81232-90-018 to S. Clark, WHC] March 20, 1990). The results of the on-site and laboratory analyses of the 1100-EM-1 ground-water samples are provided in Appendix N.

2.7 ECOLOGICAL INVESTIGATION

The ecological investigation for the first phase of the 1100-EM-1 RI consisted of data collection activities related to the characterization of potential receptor organism populations—both human and wildlife—in the vicinity of the operable unit. Human and wildlife investigational activities are described in further detail below. An interpretation of the ecology of the operable unit, from both a human and wildlife perspective, can be found in Section 3.7 (Ecological Characteristics).

2.7.1 Human Ecological Investigation

All data collection activities related to characterization of the human populations within the operable unit vicinity were conducted by compiling existing information—published documents were reviewed and appropriate state, regional, county, city, and Hanford Site officials were interviewed. Operable unit visits conducted by project personnel supplemented the information obtained under this process.

The human ecological investigation for 1100-EM-1 consisted of the compilation of:

- Land use information
- Water use information
- Cultural (i.e., archeological and historical) information.

Each of these data collection activities is described below.

2.7.1.1 Land Use Data Compilation. County and city zoning ordinances (Benton County Code Title 11, Ordinance No. 62; City of Richland Ordinances—Title 23) were obtained to determine restrictions on land use in the vicinity of 1100-EM-1. County and city comprehensive land use plans (Benton County Board of Commissioners 1985; City of Richland 1988) were also obtained to determine long-range, local government planning goals for the area near the operable unit.

During the course of the initial phase of the RI, officials from the following organizations were interviewed to gather information pertaining to current and anticipated future land use and demography in the vicinity of the 1100 Area:

- Benton County Planning and Building Department
- Benton County Road Department, Engineering Division

- City of Richland Community Development Department
- City of Richland Department of Water, Sewage, and Refuse
- City of Richland Economic Development Department
- Port of Benton
- Westinghouse Hanford Site Development Planning.

Aerial photographs used to develop operable unit maps (see Section 2.1.2) were also reviewed to obtain relevant local land use information. Operable unit visits also provided local land use information. The information obtained during this process is presented in Section 3.7.

Regional and local demographic information was obtained from 1980 census data (United States Bureau of the Census 1982) and a marketing atlas (Rand McNally 1990).

2.7.1.2 **Water Use Data Compilation.** Water use can be divided into ground-water and surface-water uses. Hanford Site and Ecology well records were obtained to determine ground-water withdrawal points within the vicinity of 1100-EM-1. The Hanford Site records are found in McGhan (1989); Ecology records for the operable unit vicinity were obtained and are provided in Appendix J, along with pertinent information from McGhan (1989).

Surface-water use in the area of the operable unit was determined by a review of Jacquish and Mitchell (1988). This existing information was supplemented by topographic map reviews and operable unit visits that were conducted to document the location of water intakes, boat ramps, docks, swimming areas, and other relevant facilities. The results of the map reviews and operable unit visits are included in Section 3.7.

In November 1989, officials of the Benton Franklin District Health Department were interviewed to obtain any pertinent information regarding ground-water and surface-water use and related health monitoring. The City of Richland Department of Water, Sewage, and Refuse was also contacted about this subject. The results of these interviews are incorporated in Section 3.7.

2.7.1.3 **Cultural Data Compilation.** Known archeological and historical sites on the Hanford Site are catalogued by PNL. This organization was contacted (Chatters, J., PNL [Personal communication] January 31, 1990) to determine the existence of any known, significant archeological or historical sites within the 1100-EM-1 Operable Unit. This information is needed to prevent potential disturbances of valued cultural resources during any subsequent remediation efforts. Findings on this issue are presented in Section 3.7.

2.7.2 Wildlife Ecological Investigation

Data gathered under the wildlife ecological investigation for the Phase I 1100-EM-1 RI included the compilation of existing biological information and a reconnaissance survey of the operable unit. These two activities are summarized below.

2.7.2.1 **Biological Data Compilation.** Existing biological information was compiled to develop a general understanding of the wildlife ecology of the operable unit and vicinity. A description of the general wildlife ecology of the Hanford Site was obtained from the Hanford Site defense waste disposal EIS

(DOE-RL 1987), a recent annual environmental monitoring report for the Hanford Site (Jacquish and Mitchell 1988), a recent resource assessment of the Hanford Reach of the Columbia River (Hanford Reach Study Task Force 1990). A preliminary natural resource assessment conducted by the United States National Oceanographic and Atmospheric Administration (NOAA) was obtained (NOAA 1988), and operable-unit-specific information pertaining to the occurrence of certain bird species was found in a PNL memorandum (Rickard, B., PNL [Memo to R. Gephart, PNL] December 8, 1988).

An endangered and threatened species survey for the 1100-EM-1 Operable Unit was conducted. The purpose of this survey was to determine the potential for adverse impacts to protected species, or habitats critical to their existence, from either operable unit contaminant releases or subsequent remediation efforts. This survey consisted of a review of literature published by the Washington State Department of Wildlife (DOW 1987) and the Washington State Department of Natural Resources (DNR 1987). The DOW and DNR were also requested to review their records for sightings of endangered or threatened animal or plant species, respectively, in the vicinity of the operable unit. The results of these records reviews are contained within letters received from DOW and DNR (Cyra, T., DOW [Letter to L. Johnson, GAI] February 12, 1990; Sprague, N., DNR [Letter to L. Johnson, GAI] February 6, 1990) (see Appendix A).

2.7.2.2 **Biological Survey.** Westinghouse Hanford conducted a reconnaissance biotic survey of the 1100-EM-1 Operable Unit in March and April of 1989. The survey was conducted to locate and evaluate any evidence of, or potential for, uptake of toxic substances by plants or animals. Hanford Site biologists documented evidence of impacted plants by location and species. Observations were also made of evidence of small mammal and bird occurrences and animal-burrowing activities. The results of this survey are provided in a project memorandum (Landeen, D., WHC [Memo to M. Adams, WHC] May 4, 1989) (see Appendix A).

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3.0 PHYSICAL CHARACTERISTICS OF THE 1100-EM-1 OPERABLE UNIT

This section provides a description of the relevant physical characteristics of the 1100-EM-1 Operable Unit. The physical setting of the operable unit and its vicinity is presented by the seven environmental media introduced in Section 2: Section 3.1 describes the facility characteristics associated with each of the six operable subunits within 1100-EM-1; Section 3.2 provides an atmospheric characterization; Section 3.3 focuses on surface waters near the operable unit; the geological setting is described in Section 3.4; Section 3.5 contains a discussion of soil characteristics; ground water is described in Section 3.6; and Section 3.7 provides a description of potential receptor organisms within and near the operable unit.

Each environmental-medium-specific discussion, with the exception of Section 3.1 (Source Facility Characteristics), is initiated with a characterization of the regional setting, which in turn is followed by a description of the local characteristics. The regional setting for the 1100-EM-1 Operable Unit varies in scale, depending upon the environmental medium under discussion; however, it can generally be visualized as consisting of the Pasco Basin (the topographic basin, described further in Section 3.4, in which the Hanford Site is located), the Hanford Site, or the Tri-Cities Region (i.e., the cities of Richland, Kennewick, and Pasco, or, from a metropolitan perspective, the counties of Benton and Franklin). The local setting is generally considered to be that area within an approximate 1.6-km (1-mi) radius of the operable unit.

The focus of Section 3 is limited to a description of the physical characteristics of the operable unit. The chemical or contaminant characteristics of 1100-EM-1 are described in Section 4.

3.1 SOURCE FACILITY CHARACTERISTICS

The purpose of this subsection is to provide a description of the waste facility characteristics of the 1100-EM-1 Operable Unit. Waste facility characteristics consist of such factors as waste source location, types of engineered structures, facility security, and nearby surface features. This information is provided below by operable subunit; a summary of other potentially significant waste facilities in the vicinity of the operable unit follows the subunit characterizations. Known characteristics of the wastes themselves, for both the subunits and the other nearby waste facilities, are presented in Section 4.1 (Contaminant Sources).

Before describing the source characteristics of each operable subunit and the other nearby waste facilities, a description of the general facility characteristics of the 1100-EM-1 Operable Unit vicinity is warranted. This vicinity, for the purposes of this subsection, is that area generally situated within an approximate 2-km (1.2-mi) radius of the operable unit.

3.1.1 1100-EM-1 Operable Unit Vicinity

The 1100-EM-1 Operable Unit is located in an area between the Columbia and Yakima Rivers, and is oriented in a generally north-south direction.

Figure 3-1 is a topographic map of the 1100-EM-1 Operable Unit and surrounding vicinity, which is located entirely within Township 10 North, Range 28 East. The 1100-EM-1 Operable Unit lies within the following sections of Township 10 North, Range 28 East: the north-half of Section 15, the east-half of the southeast-quarter of Section 15, the east-half of the east-half of Section 22, and the east-half of the northeast-quarter of Section 27. So defined, the operable unit encompasses an area of approximately 260 ha (1 mi^2); however, Figure 3-1 shows that the actual area occupied by the six discrete operable subunits of concern is much smaller.

The elevation of the land surface ranges from approximately 116 m (380 ft) above mean sea level (amsl) at the Horn Rapids Landfill to approximately 122 m (400 ft) amsl at the 1100-1 Battery Acid Pit. Northeast-trending sand dunes, with amplitudes up to 6 m (20 ft), mantle some parts of the operable unit. An elongated, north-south plateau lies within the southern portion and to the east of the 1100-EM-1 Operable Unit. This north-south plateau is generally flat—at approximately 122 m (400 ft) amsl—to a point eastward where the land surface slopes toward the Columbia River, which is located approximately 1.5 to 1.8 km (0.9 to 1.1 mi) to the east of the operable unit. The elevation of the Columbia River is approximately 104 m (340 ft) amsl (USGS 1978).

To the west of the operable unit, the slope gently decreases to a minimum elevation of approximately 113 m (370 ft) amsl, then generally increases to a maximum of about 146 m (480 ft) amsl before the land surface slopes west-southwestward toward the Yakima River, at a point about 3.6 km (2.2 mi) from 1100-EM-1. The elevation of the Yakima River is approximately 113 m (370 ft) amsl (USGS 1978).

The 1100-EM-1 Operable Unit is the location of central warehousing, vehicle maintenance, and transportation operations facilities that support Hanford Site activities. Engineered facilities within the operable unit that support the specific mission functions of the 1100 Area (see Section 1.3.1) include buildings, paved and unpaved areas, railroad tracks, dirt roads, various utilities, and disposal pits. Before describing the facility characteristics associated with each of the six operable subunits within 1100-EM-1, an overview of the engineered features of the operable unit vicinity is provided.

There are five major transportation corridors within the approximate 2-km (1.2-mi) radius of the operable unit (see Figure 3-1). Stevens Drive is the divided highway running north-south that forms the eastern boundary of 1100-EM-1; it is the primary access route to the Hanford Site. Horn Rapids Road runs east-west through the operable unit, forming the northern boundary of the 1100 Area and the southern boundary of the Horn Rapids Landfill. Highway 240, located west of the operable unit, exits the City of Richland to the northwest. The area that is approximately delineated by Stevens Drive, Horn Rapids Road, and Highway 240 is commonly referred to as the Horn Rapids Triangle. George Washington Way is another major north-south road that provides access to the Hanford Site; it is located 0.8 km (0.5 mi) east of Stevens Drive. The fifth major transportation corridor is the federal government railroad that transits the operable unit from north to south and serves all designated areas of the Hanford Site.

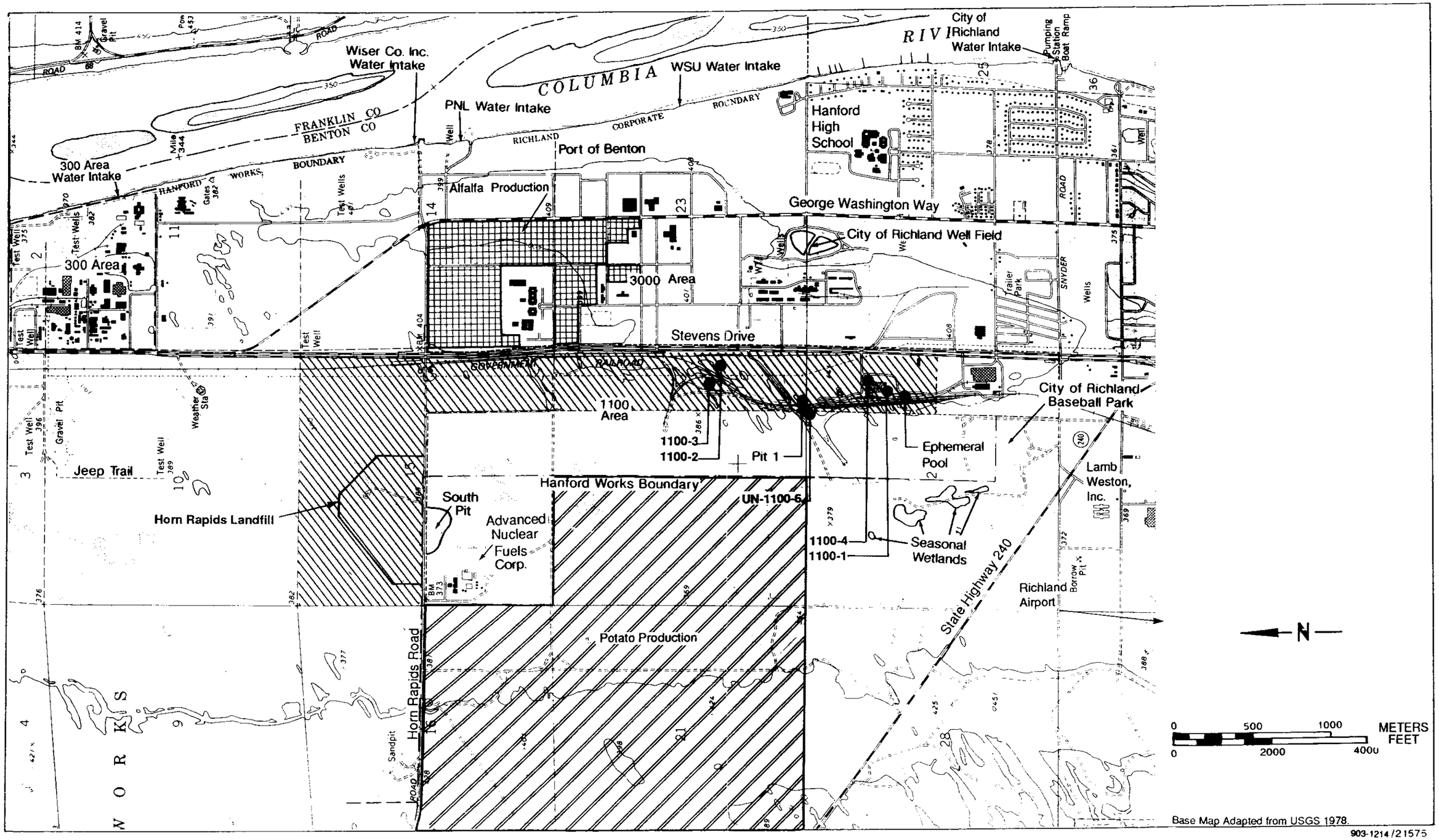

Figure 3-1. 1100-EM-1 Operable Unit Vicinity.

The 3000 Area, located east of the 1100 Area, is considered a part of the Hanford Site, although it is not actually situated within the site boundaries. The 3000 Area functions primarily as an administration center, but the area contains some research and development and warehouse storage facilities, as well. Port of Benton facilities, many of which are leased to Hanford Site employers, occupy the easternmost portion of the 3000 Area. Some portions of the 3000 Area are leased for agricultural use and are irrigated for forage crop production. The PNL water intake in the Columbia River provides the irrigation water for these crops. The 3000 Area can be approximately described as occupying the south-half of Section 14, the north-half and southwest-quarter of Section 23, and the northwest-quarter and the north-half of the southwest-quarter of Section 26.

Two large ponds lie within the area just described, straddling Sections 23 and 26 (see Figure 3-1). These ponds, and the surrounding wells, comprise the City of Richland well field and are not part of the actual 3000 Area. The ponds are used to infiltrate water obtained from the Columbia River. Once the river water is filtered in this manner, the city extracts it with the surrounding wells to satisfy seasonal and peak water demands. The city's Columbia River water intake and water-treatment plant are located adjacent to the river in the southwest-quarter of Section 25. This water-treatment plant is the primary supply of city water.

The Hanford High School, and Junior High School, are located east of 1100-EM-1 in the northwest-quarter of Section 25; an elementary school is located near the center of Section 35. Washington State University (WSU) irrigates some cropland north of the high school with water provided by a nearby river intake.

Residential areas—homes and trailer parks—are situated to the southeast and south of the operable unit. A potato processing plant, operated by Lamb-Weston, Inc., lies within the northwest-quarter of Section 34, just north of the Richland Airport. A City of Richland ball park is located in the southwest-quarter of the southeast-quarter of Section 27, adjacent to the southern portion of the 1100 Area.

To the west of the operable unit are four small and discrete seasonal wetlands in the northwest-quarter of Section 27. Northwest of these wetlands, irrigated land (in Section 21, the western-half of Section 22, and the southern-half of Section 16) is used for potato production; the Wiser Co. Inc. intake on the Columbia River provides the irrigation water.

In the southwest-quarter of Section 15, just south of Horn Rapids Road, Advanced Nuclear Fuels Corp. operates a nuclear fuel fabrication facility. Advanced Nuclear Fuels supplies uranium fuel rods for commercial power reactors. East of the Advanced Nuclear Fuels complex, just south of Horn Rapids Road, is the South Pit, an apparent former gravel or waste disposal pit (EPA 1990b).

In the north-half of Section 11, within the Hanford Site and adjacent to the Columbia River, is the 300 Area. The 300 Area is the nuclear fuel fabrication complex for the federal plutonium production reactors on the Hanford Site; numerous research and development facilities are also located in the 300 Area. The 300 Area has its own water intake on the river.

3.1.2 Operable Subunits

The source facility characteristics of each operable subunit within 1100-EM-1 are described more fully below. Following the subunit discussions, brief descriptions of other nearby waste facilities are provided.

3.1.2.1 1100-1 (Battery Acid Pit). The Battery Acid Pit is located approximately 30 m (100 ft) southwest of the southwestern corner of the 1171 Building—the vehicle service, maintenance, and repair facility for the Hanford Site—and approximately 18 m (60 ft) northwest of two warehouse buildings. Stevens Drive is approximately 270 m (900 ft) to the east of the pit, and the federal railroad tracks are about 11 m (35 ft) to the west. The 1100-1 operable subunit lies within the southeast-quarter of the northeast-quarter of Section 27 (see Figure 3-1).

Figure 3-2 is a topographic map of the 1171 Building vicinity which shows the location of 1100-1. The ground surface elevation is approximately 122 m (400 ft) amsl. The area slopes very gently toward the west and south. Large asphalt-paved areas that provide vehicle parking and storage space are found south and east of the 1171 Building and north of the above-mentioned warehouse buildings. Unpaved parking lots and storage areas are found north and east of the 1171 Building. Dirt roads are present along the west side and adjacent to the 1171 Building which lead northward to UN-1100-6, 1100-2, and 1100-3.

The Battery Acid Pit was an unlined dry sump, or French drain, used for the disposal of waste vehicle battery acid; it was operated from the mid-1950's and backfilled in 1977. The occasional disposal of waste oils, antifreeze, and solvents is also suspected (DOE-RL 1989a). Results of the 1100-1 geophysical survey (see Appendix B) seem to indicate a pit diameter of approximately 1.8 m (6 ft); the borehole log for soil boring BAP-1 (see Appendix F) indicates that this pit was approximately 1.8 m (6 ft) deep, based on the presence of asphalt debris in the soil samples. Soil discoloration is common in this boring to a depth of 4.9 m (16 ft). During the service life of the pit, acid-saturated sand fill was periodically scraped off and disposed at an unknown location; fresh sand was then added to the pit. Upon retirement, the pit was backfilled with sand and gravel locally mixed with asphalt debris, thereby eliminating direct access to any contamination.

The geophysical survey results indicate that much of the ground near 1100-1 has been disturbed by past excavation and fill activities (see Appendix B). The results point to several buried trenches, pipelines, cables, and isolated metallic objects nearby. One pipeline, buried to a depth of approximately 1.2 m (4 ft), was identified as a water pipe supplying an emergency shower adjacent to the Battery Acid Pit location.

3.1.2.2 1100-2 (Paint and Solvent Pit). The center of the 1100-2 Paint and Solvent Pit is approximately 91 m (300 ft) west of Stevens Drive, about 1.6 km (1 mi) north of the 1171 Building, in the northeast-quarter of the southeast-quarter of Section 22 (see Figure 3-1). The operable subunit is fairly well isolated. The nearest building, a construction services facility, is located about 490 m (1,600 ft) to the southeast, on the other side of Stevens Drive. An electrical substation is located about 150 m (500 ft) south of the pit. A topographic map of the 1100-2 vicinity is provided in Figure 3-3.

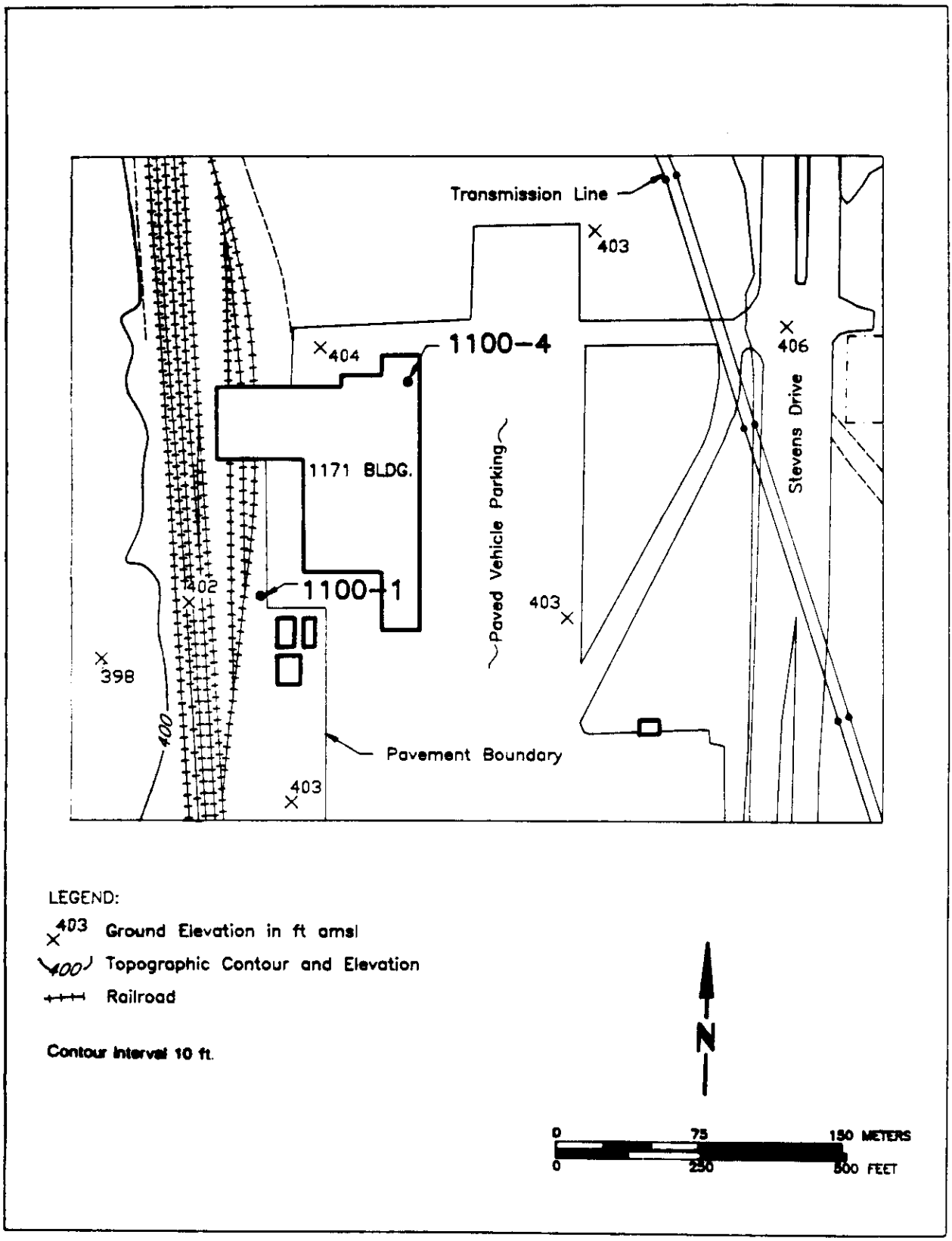

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Figure 3-2. Topographic Map for the 1100-1 and 1100-4 Operable Subunits.

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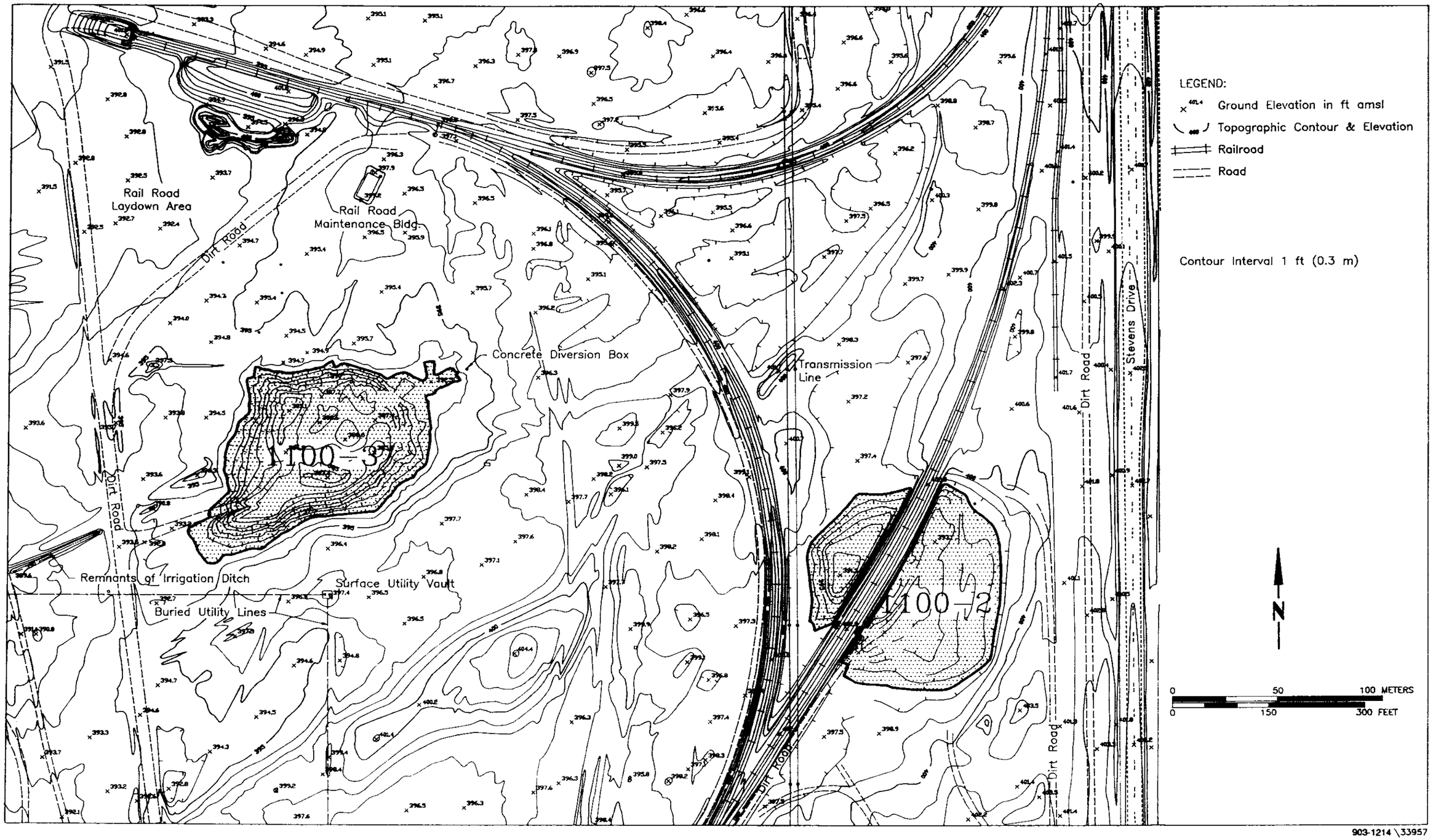

Figure 3-3. Topographic Map for the 1100-2 and 1100-3 Operable Subunits.

An existing railroad track divides the pit, with about one-third of the pit to the west of the track and two-thirds to the east. The two sections of the pit do not share a connection but are separated by the track bed that is raised 4 m (11 ft) above the lowest point in the pit. Another railroad track is located approximately 15 m (50 ft) west of the western margin of 1100-2.

A dirt road, which originates at the vehicle maintenance buildings, runs along the base of the existing railroad ballast and enters the southern portion the pit from the southwest. It then crosses to the north, where it emerges from the pit and joins a dirt road that generally follows an old rail alignment parallel to and west of Stevens Drive. Another dirt road enters to the southeast of the pit. A north-south, above-ground utility line runs approximately 9 m (30 ft) west of the western edge of the pit.

The ground surface elevation of 1100-2 is approximately 121 to 122 m (397 to 399 ft) amsl at the margins of the pit and 119 m (392 ft) amsl in the pit centers on both sides of the railroad tracks. The tracks are at an elevation of approximately 123 m (403 ft) amsl. The surrounding terrain generally slopes toward the waste pit.

The 1100-2 pit is a roughly circular depression approximately 110 m (360 ft) long, 106 m (330 ft) wide, and 1.2 to 1.8 m (4 to 6 ft) deep; it covers a total area of approximately 0.4 ha (1 ac). The subunit was originally a sand and gravel pit that was subsequently used for the disposal of construction debris from 1954 through 1985. It is also reported to have received irregular disposal of paints, thinners, and solvents (DOE-RL 1989a). Backfill material, of a depth ranging from 0 to 4.9 m (0 to 16 ft) currently covers the eastern portion of the pit. The borehole log for boring DP-4 (see Appendix F) indicates that chunks of asphalt are present to a depth of 2 m (7 ft), and the log for boring DP-9 shows asphalt debris to a depth of 1.2 m (4 ft). Asphalt and tar-like material were present in boring DP-5 to a depth of 4.9 m (16 ft). Warning signs ("Authorized Personnel Only" and "Caution, Suspected Hazardous Waste Site, Keep Out") are posted at this operable subunit.

Geophysical survey results indicate an original pit depth of approximately 3 m (10 ft) (see Appendix B). Most of the waste deposits within 1100-2 appear to be concentrated in an irregularly-shaped mass which fills a major portion of that part of the pit located east of the railroad tracks. There is no geophysical evidence of any waste deposits in that portion of the pit on the west side of the tracks. Much of the waste material in the eastern pit appears to be concrete and asphalt rubble, based on what material is visible at the surface and the relatively low amplitude of the magnetic anomalies detected which are consistent with reinforced concrete rubble.

During the geophysical survey, Sandness et al. (1989) located a buried, east-trending irrigation pipeline to the north of 1100-2. Another underground pipeline was located beneath the powerline at the west edge of the pit.

3.1.2.3 1100-3 (Antifreeze and Degreaser Pit). The center of the 1100-3 Antifreeze and Degreaser Pit is approximately 396 m (1300 ft) west of Stevens Drive, and about 289 m (950 ft) northwest of the center of 1100-2. Along with 1100-2, 1100-3 is also located within the northeast-quarter of the southeast-quarter of Section 22 (see Figure 3-1). The topography of the 1100-3 vicinity is also shown in Figure 3-3.

At their closest point, curving railroad tracks are located approximately 168 m (550 ft) northeast of the center of 1100-3. A railroad laydown area, which includes a maintenance building and a materials storage yard, is approximately 122 m (400 ft) north-northeast of the center of the pit. A north-northwest-trending dirt service road, which runs from the 1171 Building to the rail yard, is approximately 100 m (330 ft) west of the pit center, and an east-trending side road from this service road provides access directly to the pit from the southwest. A surface utilities vault is located 30 m (100 ft) south of the waste pit and is the junction for eastward- and southward-directed buried utilities lines.

The ground surface elevation at 1100-3 is approximately 120 m (394 ft) amsl at the margin of the pit and 117 m (385 ft) amsl in the center. Several shallow mounds occupy the center of the pit. The slope of the ground surface decreases very gently to the west and increases to the east and southeast.

The pit is currently a shallow, slightly-elongated depression, approximately 98 m (320 ft) in width, 131 m (430 ft) in length, and 3 m (9 ft) in depth. The area of 1100-3 is approximately 0.8 ha (2 ac). This subunit was originally a sand and gravel pit that was subsequently used for the disposal of roofing gravel and concrete rubble from 1979 through 1985. It is also reported to have been used for the disposal of waste antifreeze and degreasers. Approximately 1.5 m (5 ft) of backfill material locally covers 1100-3. Warning signs ("Caution, Suspected Hazardous Waste Site, Keep Out") are currently posted at 1100-3.

Waste materials within 1100-3 appear to be concentrated in one large and two small deposits; however, small pieces of buried debris are scattered throughout the pit (Sandness et al. 1989). Geophysical readings eliminate the possibility of a large deposit of 55-gal drums at this subunit. Most of the relatively weak magnetic anomalies are assumed to be attributable to the presence of reinforced concrete rubble which is occasionally visible at the surface. The borehole log for boring DP-2 identified landfill debris near the southeastern margin of the pit to a depth of 1.6 m (5.3 ft). Evidence exists to indicate the presence of an irrigation ditch, and an associated set of underground tile pipes connected to a concrete diversion box, at the 1100-3 location (Sandness et al. 1989). These facilities were disturbed during excavation of the original gravel pit. Remains of the ditch are visible to the north of the access road, and remnants of the pipes are visible near the diversion box which is located in the northeast corner of the pit.

3.1.2.4 1100-4 (Antifreeze Tank Site). An antifreeze disposal tank was located inside the northeastern corner of the 1171 Building, the vehicle service, maintenance, and repair facility for the Hanford Site. The northeastern portion of the 1171 Building is surrounded by asphalt-paved driveway and parking areas. The 19,000-L (5,000-gal) steel holding tank was located beneath the concrete floor of the building, between two actively-used vehicle service bays. The topographic map of the 1171 Building vicinity (see Figure 3-2) shows the location of 1100-4. The ground surface elevation of the 1171 Building is approximately 122 m (400 ft) amsl. The Antifreeze Tank Site is situated within the northeast-quarter of the northeast-quarter of Section 27 (see Figure 3-1).

The tank was used for the disposal of waste antifreeze from prior to 1978 until 1986, when it was emptied, excavated, cleaned, and removed. The

borehole log for ATS-1 (see Appendix F) indicates prior excavation to a depth of approximately 3.7 m (12 ft); concrete debris was encountered in this boring to a depth of approximately 3.4 m (10 ft), which was underlain by approximately 0.6 m (2 ft) of bedding sand. This depth represents the maximum depth at which the bottom of the antifreeze tank would have been located. Workers in the 1100 Area have unrestricted access to the 1171 Building, but a concrete floor, with a steel plate covering the RI borehole location, currently impedes access to the ground surface above 1100-4. Once investigation and any remediation activities are completed, and the concrete floor restored, no direct access to 1100-4 will exist.

3.1.2.5 UN-1100-6 (Discolored Soil Site). The Discolored Soil Site appears to be the location of at least one, and possibly several, incidents where containers of liquid organic material were emptied on the ground. Figure 3-4 is a topographic map of UN-1100-6. The Discolored Soil Site is located approximately 381 m (1250 ft) north of the 1171 Building and 381 m (1250 ft) west of Stevens Drive. The operable subunit is located in the southeast-quarter of the southeast-quarter of Section 22 and the northeast-quarter of the northeast-quarter of Section 27 (see Figure 3-1).

The operable subunit is bounded on the east by north-south-oriented railroad tracks, and on the northwest by an abandoned, concrete-lined irrigation canal. A dirt road, parallel to and west of the tracks, runs through the easternmost portion of UN-1100-6 and continues north, as a supply road, to the railroad maintenance yard adjacent to 1100-3. Another dirt road is located along the western side of the irrigation canal and intersects the same road passing through the easternmost portion of the disposal unit. Several lightly-used roads lie to the west-northwest. No permanent buildings are within the area bounded by Stevens Drive to the east, but a fenced area contains a temporary waste and materials storage area 90 m (300 ft) to the southeast of the subunit. An overhead power line is located approximately 244 m (800 ft) east of the track and west of Stevens Drive. A group of office buildings is located east of UN-1100-6 on the opposite side of Stevens Drive.

The ground surface elevation is approximately 121 m (396 ft) amsl at the center of the subunit, with a northeast trending dune—at 127 m (416 ft) amsl—located directly to the south. The depth of the depression is approximately 2 m (6 ft). Except for the dune to the south, the UN-1100-6 vicinity is generally flat.

The Discolored Soil Site is oriented in a southwest-northeast direction and is situated within a natural depression. The operable subunit, as defined by the sampling grid established for the RI, is 104 m (340 ft) long and 30 m (100 ft) wide at its widest point. The grid covers an area of approximately 0.2 ha (0.4 ac), but far exceeds the boundaries of the stained soil. Access to this subunit is not restricted at this time.

3.1.2.6 Horn Rapids Landfill. The Horn Rapids Landfill is located approximately 3 km (2 mi) north of the 1171 Building; entrance to the landfill is gained from a gravel road off Horn Rapids Road, 1 km (0.6 mi) west of Stevens Drive. The landfill lies within the north-half of Section 15 (see Figure 3-1). A topographic map of the landfill is provided in Figure 3-5.

The gravel road providing access to the landfill runs generally north-northeast through the center of the operable subunit. A firebreak dirt road

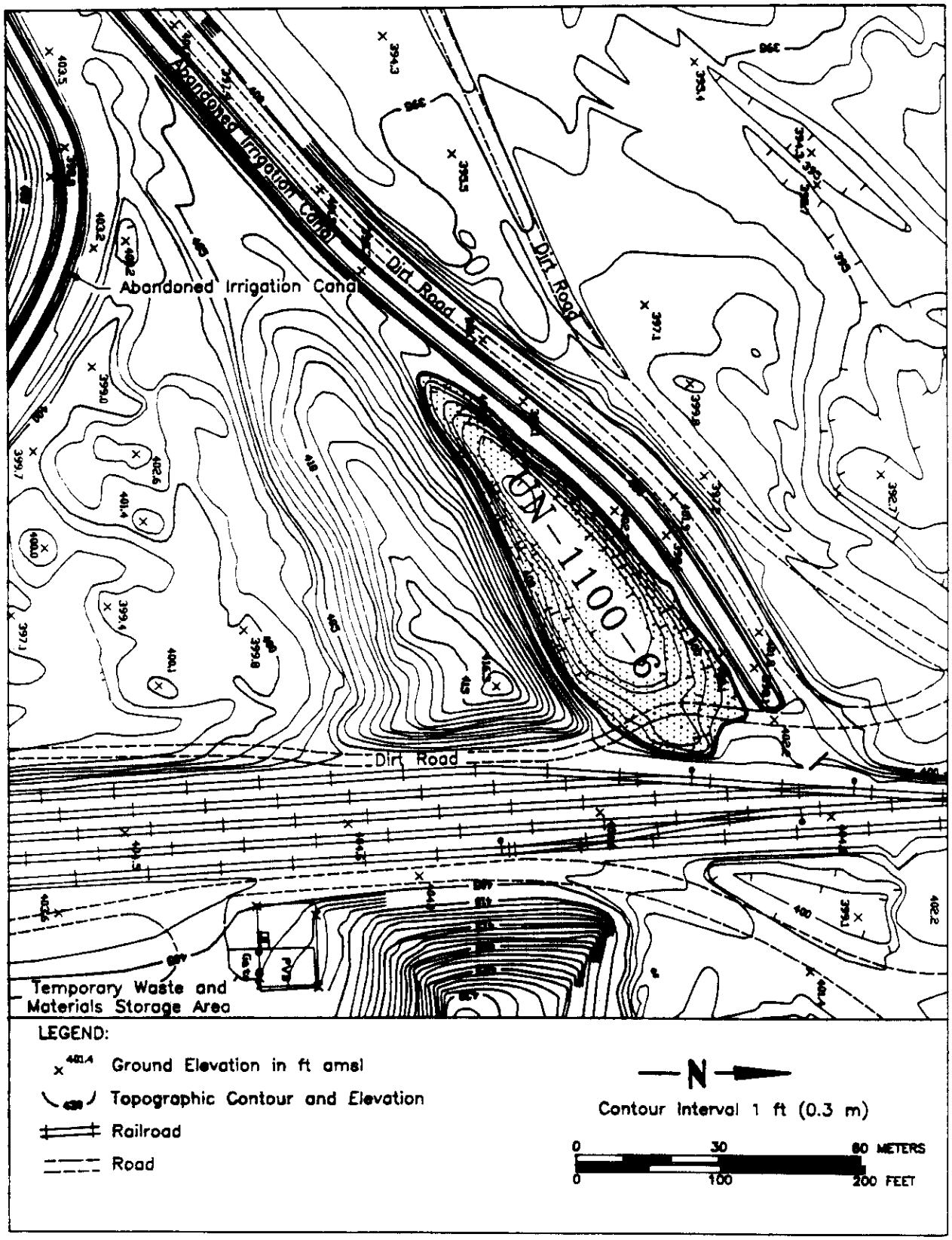

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Figure 3-4. Topographic Map for the UN-1100-6 Operable Subunit.

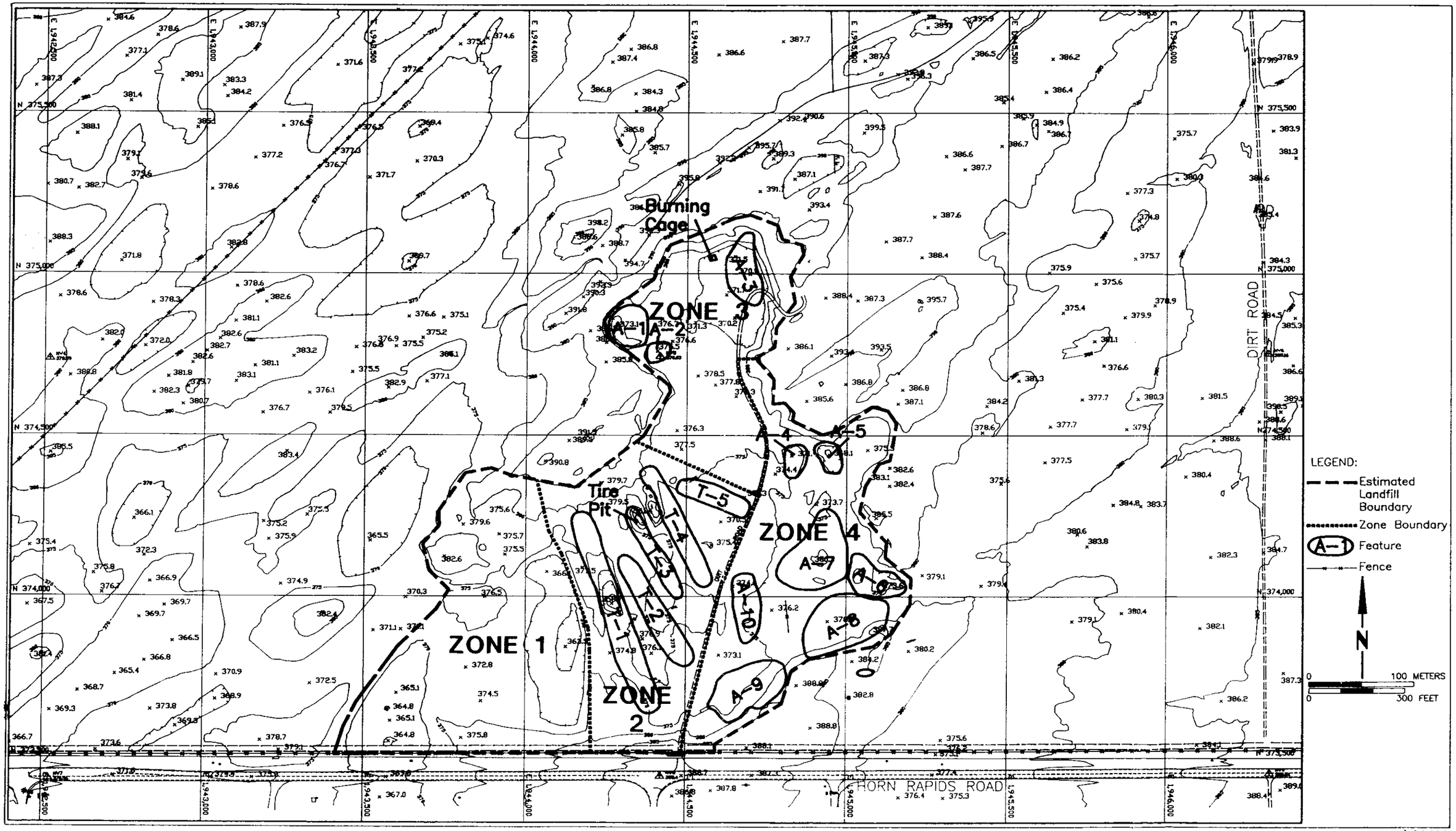

Figure 3-5. Topographic Map for the Horn Rapids Landfill Operable Subunit.

is located along the southern margin of the landfill, parallel to and north of Horn Rapids Road. The nearest facilities are the Advanced Nuclear Fuels complex, approximately 305 m (1,000 ft) to the southwest, and the southern boundary of the 300 Area, 3.7 km (2.3 mi) to the northeast.

The topography of the surrounding ground surface is irregular. The landfill is in a depression, with slopes that increase gently to the east and west. The landfill boundary is relatively distinct due to topographic alterations from past excavation and fill activities.

The landfill is of irregular shape—518 m (1,700 ft) long and 640 m (2,100 ft) wide—and covers an area of approximately 20 ha (50 ac). The lowest point of the landfill is at 109 m (359 ft) amsl. The surrounding vicinity contains north-northeast-trending sand dunes that attain an average height of 116 m (380 ft) to 119 m (390 ft) amsl. The landfill was primarily used for office and construction waste disposal from the early 1950's to 1970. Other wastes suspected of being present include asbestos, sewage sludge, and fly ash, as well as various unidentified liquids possibly contained in 55-gal drums. During landfill operations, standing water was periodically observed in the burial trenches, indicating that at least some portion of the fill material was deposited at or beneath the water table.

Surface features, noted in Figure 3-5, are divided into 4 zones. Several major areas can be designated within the boundaries of the Horn Rapids Landfill on the basis of discernable surface features and subsurface features delineated during the geophysical and soil gas surveys (Clark, S., WHC [Memo to B. Wright, GAI] February 22, 1990; see Appendix A). The major areas include a broad irregular area in Zone 1, five elongated trenches in Zone 2, two circular pits and an oval area in Zone 3, and two small irregular depressions and a large irregular area, consisting of an irregular depression and four oval-shaped waste deposits, in Zone 4.

Geophysical survey results indicate that much of the buried waste deposits at this operable subunit are concentrated in locations associated with the five trenches in Zone 2 and the large, irregular area in Zone 4 (Sandness et al. 1989). Various types of debris, such as paint cans, steel cables, sheet metal, concrete rubble, and miscellaneous materials, lie scattered over much of the landfill.

The broad irregular area in Zone 1, the southwesternmost corner of the landfill, is 191 m (625 ft) long and 167 m (550 ft) wide. Shallow, 1.2- to 2.4-m (4- to 8-ft) depressions occupy the western and eastern borders of this area, which may have been excavated at one time, then backfilled. A firebreak road constitutes its southern boundary.

Five north-northwest-trending trenches, some of which were not backfilled to grade, occupy an area of 260 m (850 ft) in length and 170 m (550 ft) in width. The trenches themselves range in length from 76 m (250 ft) to 213 m (700 ft) and are located in Zone 2 to the east of the large irregular area in Zone 1. The trenches are all to the west of the gravel road that divides the landfill north-to-south.

Trench number 1 is the largest waste burial cell at the Horn Rapids Landfill. The base of the exposed face, at an elevation of 109 m (359 ft) amsl, is in the northern extent of the trench. Geophysical data suggest that

this trench extends further to the north; however, it appears that no waste deposits exist in the northwest end (Sandness et al. 1989; see Appendix B). Based on the geophysical results, the trench appears to be anywhere from 107 to 213 m (350 to 700 ft) long and 24 to 37 m (80 to 120 ft) wide. The southern extent of this cell is posted with signs indicating the presence of buried asbestos.

Trench number 2 is located to the northeast of trench number 1. The trench is approximately 116 m (380 ft) long and 21 to 30 m (70 to 100 ft) wide. Its presence is discerned from geophysical data, as it appears to be completely backfilled and is no longer evident from existing topographic features.

Trench number 3 is located between two spoil piles. The trench has not been entirely backfilled, and the open portion contains numerous discarded tires. This burial cell, including the open tire pit, is approximately 97 m (320 ft) long and 21 m (70 ft) wide.

Trench numbers 4 and 5 may also be waste burial cells that have been completely backfilled. Trench number 4 is about 140 m (460 ft) long and 18 m (60 ft) wide, and trench number 5 is about 76 m (250 ft) long and 18 m (60 ft) wide. Mounds are located in the northwestern portions of both trenches, and an additional mound occupies the southeastern portion of the fourth trench. A rectangular area approximately 18 m (60 ft) by 9 m (30 ft) intersects trench number 4. Trench number 5 is discernable only on the surface by an irregular area of contrasting vegetation; the geophysical survey results provide no evidence of subsurface disturbance (see Appendix B). Sandness et al. (1989) estimate the bottom of the fill in trenches numbered 2, 3 and 4 to be at 5.5 m (18 ft) or more below the ground surface.

Two circular pits are located in Zone 3, near the landfill boundary. The northwesternmost of the two pits, noted as A-1 in Figure 3-5, is 30 m (100 ft) in diameter; the second pit, noted as A-2 in Figure 3-5, is 15 m (50 ft) in diameter. Both appear to be former gravel pits.

An oval area, approximately 100 m (330 ft) in length and 46 m (150 ft) in width, occupies the northernmost portion of the landfill in Zone 3. This area, noted as A-3 in Figure 3-5, is located southeast and adjacent to the site of a burning cage situated in the northernmost section of the landfill. This burning cage was used to destroy classified Hanford Site documents. The oval area exhibits a noticeable soil discoloration. A shallow waste deposit appears to exist in that section of the oval area lying approximately 30 m (100 ft) east of the burning cage (Sandness et al. 1989).

Two irregular depressions are found along the east-central boundary of the landfill in Zone 4. The first and westernmost of these depressions, noted as A-4 in Figure 3-5, has a relatively flat surface and appears to have been part of a diked impoundment. It has length and width dimensions of approximately 30 m (100 ft) and 18 m (60 ft), respectively. The second depression, noted as A-5 in Figure 3-5, is similar in size, but has a more irregular surface. It contains visual evidence of various waste disposal episodes, including broken laboratory glassware. The borehole log for boring HRL-8 (see Appendix F), located just to the south of this depression, indicates traces of red brick fragments within the depth range of 6.3 to 6.9 m (20.7 to 22.8 ft), indicating possible fill material to this depth.

The large irregular area located in Zone 4 is adjacent to the eastern boundary and bordered by the firebreak road on the south. The area is 244 m (800 ft) long and 152 m (500 ft). This area is generally flat in the center, but a slight mound occupies the eastern portion. There is also a small irregular depression, noted as A-6 in Figure 3-5, about 46 m (150 ft) to the northeast of the mound. It appears that four oval-shaped waste deposits, noted as A-7, A-8, A-9, and A-10 in Figure 3-5, are located in this section of the landfill (Sandness et al. 1989). These deposits seem to be close to the surface and only a few meters (feet) thick. To the east of the apparent boundary of the landfill, in the vicinity of a soil gas anomaly, the borehole log for boring HRL-10 indicated soil discoloration at an approximate depth of 5.8 m (19 ft).

The southern boundary of the Horn Rapids Landfill, along Horn Rapids Road, is fenced to deter unauthorized access to the subunit. Several signs ("DOE Property, No Trespassing"; "Controlled Area, Authorized Entrance Only"; "Disposal Area, For Project Use Only"; and "Curlew Nesting Area") are also posted to inhibit unauthorized entry.

3.1.3 Other Waste Facilities in the 1100-EM-1 Operable Unit Vicinity

There are several other significant facilities in and around the 1100-EM-1 Operable Unit, where waste is generated and disposed of, that have the potential to impact the immediate environment. These facilities, not all of which are related to the Hanford Site, include: the nearby waste management units assigned to the 1100-EM-2 and 1100-EM-3 Operable Units; the Lamb-Weston, Inc. potato processing plant; the Advanced Nuclear Fuels Corp. nuclear fuel fabrication complex; the 300 Area of the Hanford Site; and the City of Richland's municipal landfill.

In addition to the other specific waste facilities described below, nearby transportation corridors, service stations, and agricultural plots serve as potential sources of impact to the 1100-EM-1 environment.

3.1.3.1 1100-EM-2 Operable Unit. All of the waste management units assigned to the 1100-EM-2 Operable Unit, with the exception of one remote facility, are located in or adjacent to the 1171 Building (see Figure 1-2). This puts the seven units of concern within the actual boundary of the 1100-EM-1 Operable Unit, as defined in the initial paragraph of this subsection. These seven waste management units include (DOE-RL 1989b):

- The 1100 Area Hazardous Waste Staging Area, an area of temporary storage of acid and paint wastes
- The 1100 Area Bus Shop Underground Hoist Rams, hydraulic hoist systems
- Two underground steam pad tanks that received oily waste water from bus and heavy equipment cleaning activities
- Three used-oil tanks that stored waste oils for eventual recycling.

Although not specifically assigned to 1100-EM-2, a major service station is located in the vicinity of the 1171 Building.

3.1.3.2 1100-EM-3 Operable Unit. Seven waste management units are assigned to the 1100-EM-3 Operable Unit. All seven of these facilities are located in the southern portion of the 3000 Area that lies between the 1100-EM-1 Operable Unit and the City of Richland well field (see Figure 1-2). The seven waste management units within 1100-EM-3 include (DOE-RL 1989b):

- Four hazardous waste staging areas, areas of temporary storage of waste paints, solvents, oils, antifreeze, and degreasers
- One staging area where hazardous, radioactive, and nonhazardous wastes are temporarily stored
- An underground used-oil tank, used for storage of waste oil for eventual recycling
- An unplanned release of radioactive waste into the City of Richland sewer system.

The site of a former service station is located in the northern portion of the operable unit.

3.1.3.3 Lamb-Weston, Inc. Lamb-Weston operates a potato processing plant, located to the south-southwest of the 1100-EM-1 Operable Unit, that produces frozen french fries. Waste water produced during washing and cooking operations is land-applied to adjacent fields.

3.1.3.4 Advanced Nuclear Fuels Corp. Advanced Nuclear Fuels Corp.'s nuclear fuel fabrication facility is located to the southwest of, and across Horn Rapids Road from, the Horn Rapids Landfill. Process waste water generated from their uranium fuel manufacturing process is discharged to a lined lagoon system for pretreatment prior to discharge to the City of Richland sewer system. The fuel manufacturing process also results in gaseous emissions to the atmosphere.

3.1.3.5 300 Area. The nuclear fuel fabrication and research and development complex for the Hanford Site, the 300 Area, is located along the Columbia River to the northeast of the Horn Rapids Landfill. Process and laboratory waste streams are currently discharged to unlined trenches for disposal by means of infiltration and evaporation. Numerous other waste streams exist for this complex, including sanitary, solid, industrial, gaseous, hazardous, radioactive, and mixed-hazardous-radioactive streams. Numerous unplanned releases have also been documented (DOE-RL 1989b).

3.1.3.6 Richland Municipal Landfill. The City of Richland operates a municipal solid waste landfill located approximately 3.2 km (2 mi) west of the Horn Rapids Landfill, just south of Horn Rapids Road. The municipal landfill is also known as the Horn Rapids Landfill; to avoid confusion with the 1100-EM-1 subunit of the same name, the city's landfill will be referred to as the Richland Municipal Landfill in this report.

3.2 METEOROLOGICAL CHARACTERISTICS

This subsection presents an interpretation of meteorological data collected in the Pasco Basin at the Hanford Meteorological Station (HMS), the

300 Area, and the Richland Airport. Two discussions are provided. The first, Regional Meteorology (Section 3.2.1), is based primarily on data collected at HMS, which provides a thorough long-term base of information. The HMS is located between the 200 East and 200 West Areas of the Hanford Site, approximately 32 km (20 mi) to the northwest of 1100-EM-1. A second discussion, Local Meteorology (Section 3.2.2), evaluates wind data collected at the nearby 300 Area and the Richland Airport. These latter two stations are located north and south of the 1100-EM-1 Operable Unit, respectively, at distances of less than 1.6 km (1 mi).

3.2.1 Regional Meteorology

A large compilation and summary of HMS data, for the period from 1946 to 1980, was conducted by Stone et al. (1983). The following discussion, unless otherwise noted, is based on this reference. The regional meteorology is presented below by general climate, temperature, precipitation, and wind.

The HMS is a large meteorology facility located on a plateau in the center of the Hanford Site at an elevation of 223 m (733 ft) amsl which is approximately 101 m (333 ft) higher than 1100-EM-1 (see Figure 2-9). The HMS is located about 16 km (10 mi) to the west of the Columbia River, whereas the operable unit is situated within 4.8 km (3 mi) of both the Columbia and Yakima River valleys. South, west and north of HMS, within 24 to 48 km (15 to 30 mi), mountain ridges reach elevations of 610 to 910 m (2,000 to 3,000 ft) amsl.

3.2.1.1 Precipitation. The Cascade Range is located approximately 130 km (80 mi) west of the Hanford Site and has an average crest elevation of about 1,800 m (6,000 ft) amsl. This mountain range creates a rain shadow that limits total annual precipitation to about 18 cm (7 in) at HMS. Rain is the usual form of precipitation at HMS, but snowfall regularly occurs during winter, and hail storms, although unusual, may occur during the summer thunderstorm season.

The largest volume of precipitation occurs in winter, between October and February; July is the driest month with an average of only 0.5 cm (0.2 in). Figure 3-6 shows the monthly average precipitation for HMS, and also includes monitoring data collected in Richland by an independent meteorologist, as reported in Stone et al. (1983). On average, Richland receives slightly more precipitation than HMS, notably more in the winter and spring. Precipitation intensity, shown on Figure 3-7, is greatest in the summer months, June through August. This seasonal intensity peak correlates with the thunderstorm season. A comparison of Figures 3-6 and 3-7 indicates that a storm of 1 to 1.5 h duration, with an intensity equivalent to the average maximum intensity of 0.48 cm/h (0.2 in/h) for June, could account for that month's average total precipitation allotment. However, such intensities most likely occur for very short times during thunderstorm activity.

Snowfall accumulations in winter are generally limited to depths of less than 15 cm (6 in). Complete snowmelt generally occurs within a month of a snowstorm. A thunderstorm season lasts from April to November, and cold and warm fronts of larger scale may cross the area during any month.

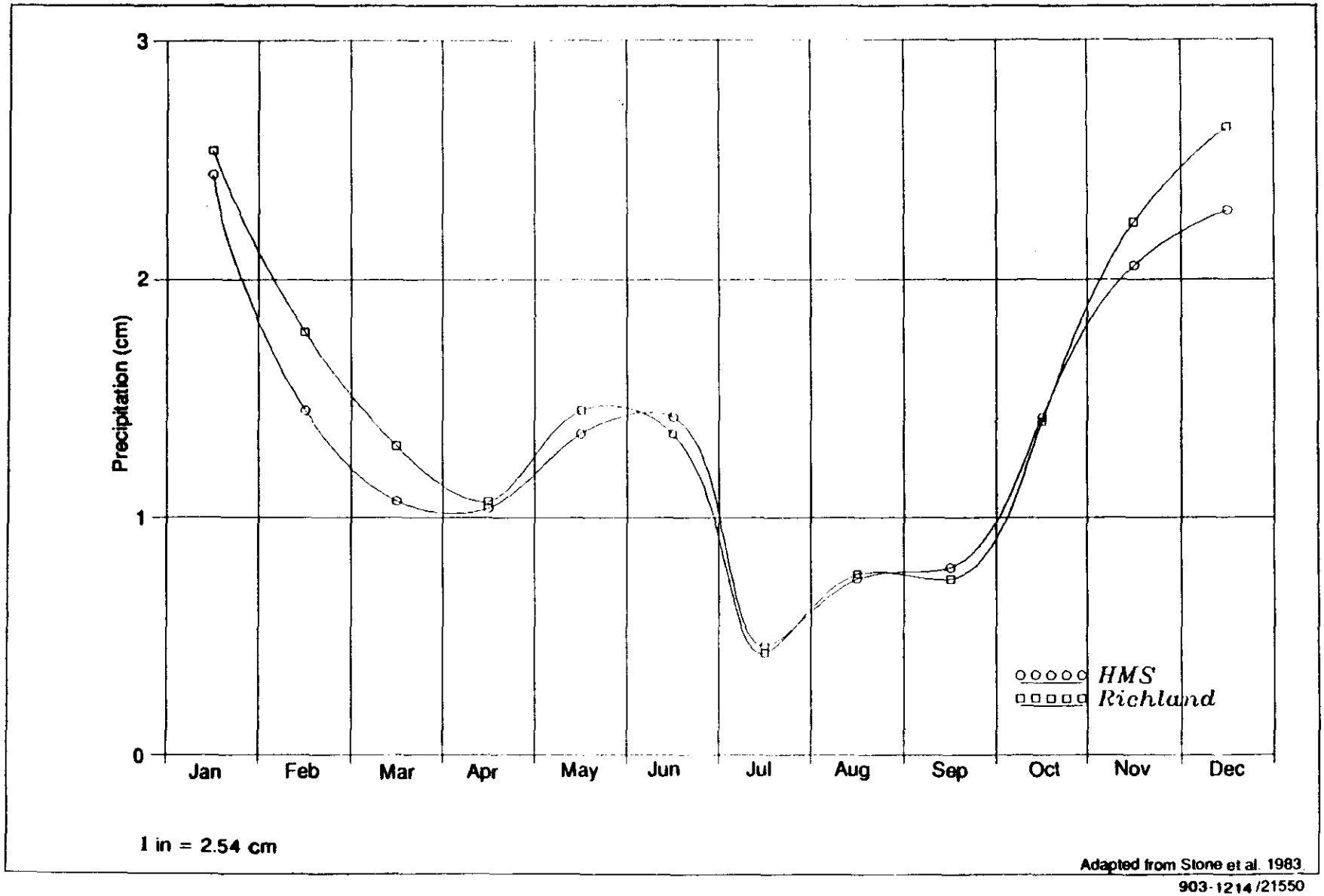

Figure 3-6. HMS and City of Richland Monthly Average Precipitation, 1946-1980.

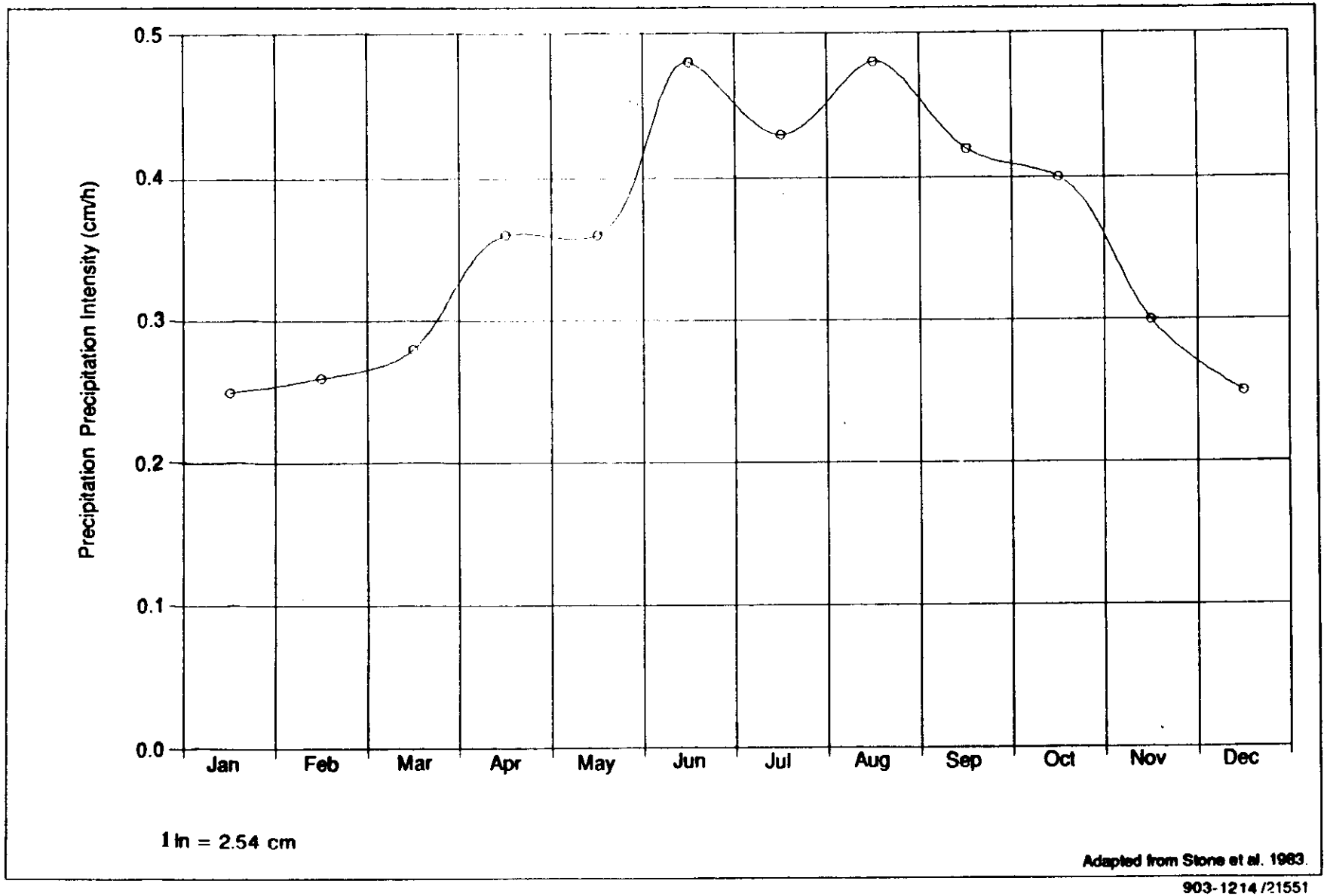

Figure 3-7. HMS Monthly Average Precipitation Intensity, 1946-1971, 1974-1980.

3.2.1.2 Temperature. The summer months at the Hanford Site are typically hot and dry, and winters are moderately cold. Air temperatures for HMS on average reach highs of 37°C (100°F) in the summer and lows of -5°C (23°F) in winter (Figure 3-8); historical extreme temperature readings of 46°C (115°F) and -29°C (-20°F) have been recorded. Annual high temperatures are normally recorded in July, while the coldest temperatures occur in January. The diurnal temperature range is substantial, due to low humidity. During summer months, when the average relative humidity is 30 to 40%, the diurnal temperature range is greatest, on the order of 15°C (27°F). In winter, with relative humidity ranging from 60 to 80%, the diurnal temperature range is reduced to about 8°C (14°F).

Temperatures in the upper 2 cm (0.8 in) of soil fluctuate daily and seasonally with air temperature, potentially exceeding 37°C (100°F) during summer and falling below 0°C (32°F) during the winter. At depth, 0.4 m (1.3 ft) below the ground surface, obvious diurnal fluctuations are not observed, although a seasonal trend, correlated to air temperature, has been observed to a depth of at least 0.9 m (3 ft). At the 0.9-m (3-ft) depth, monthly average soil temperatures range from 4 to 26°C (40 to 80°F).

3.2.1.3 Wind. Wind directions from west-northwest to northwest predominate at HMS, averaging 10 to 12 km/h (6 to 7 mi/h) in winter and 13 to 17 km/h (8 to 10 mi/h) in summer. Elsewhere on the Hanford Site, the predominant wind direction may differ from those at HMS, as shown on Figure 3-9. Mountain ridges and river valleys locally influence wind direction, particularly along the Columbia River where predominant wind directions parallel the river. There is also a strong diurnal effect observed from March through August, when wind speed tends to increase 7 to 10 km/h (4 to 6 mi/h) during the afternoon and evening hours.

The strongest winds observed, with speeds up to 130 km/h (80 mi/h), generally do not occur from the northwest, but are southwesterly. Most hourly wind speeds greater than 52 km/h (31 mi/h) are from the south-southwest to west-southwest and occur at the highest frequency from March through May. Greater than 90% of the southwesterly winds exceed 30 km/h (18 mi/h).

Wind-blown dust accompanies strong winds on the Hanford Site. Blowing dust originating from the site itself has been observed at wind speeds greater than 32 km/h (19 mi/h). Dust entrained elsewhere and transported to the Hanford Site has been observed for lower wind speeds of 7 km/h (4 mi/h).

3.2.1.4 Evapotranspiration. Mean annual potential evapotranspiration for the Tri-Cities Region has been estimated to be approximately 74 cm (29 in). The estimated annual rate of actual evapotranspiration is approximately 18 cm (7 in) (United States Weather Bureau and SCS 1962). Thus, the rate of actual evapotranspiration is expected to approximate the rate of annual precipitation (see Section 3.2.1.1).

3.2.2 Local Meteorology

Local meteorology data for the 1100-EM-1 Operable Unit were obtained from monitoring stations at the 300 Area, about 1.6 km (1 mi) north of the operable unit, and the Richland Airport, about 1.6 km (1 mi) south of 1100-EM-1 (see Figure 2-9). The data collected at these two stations consist only of wind

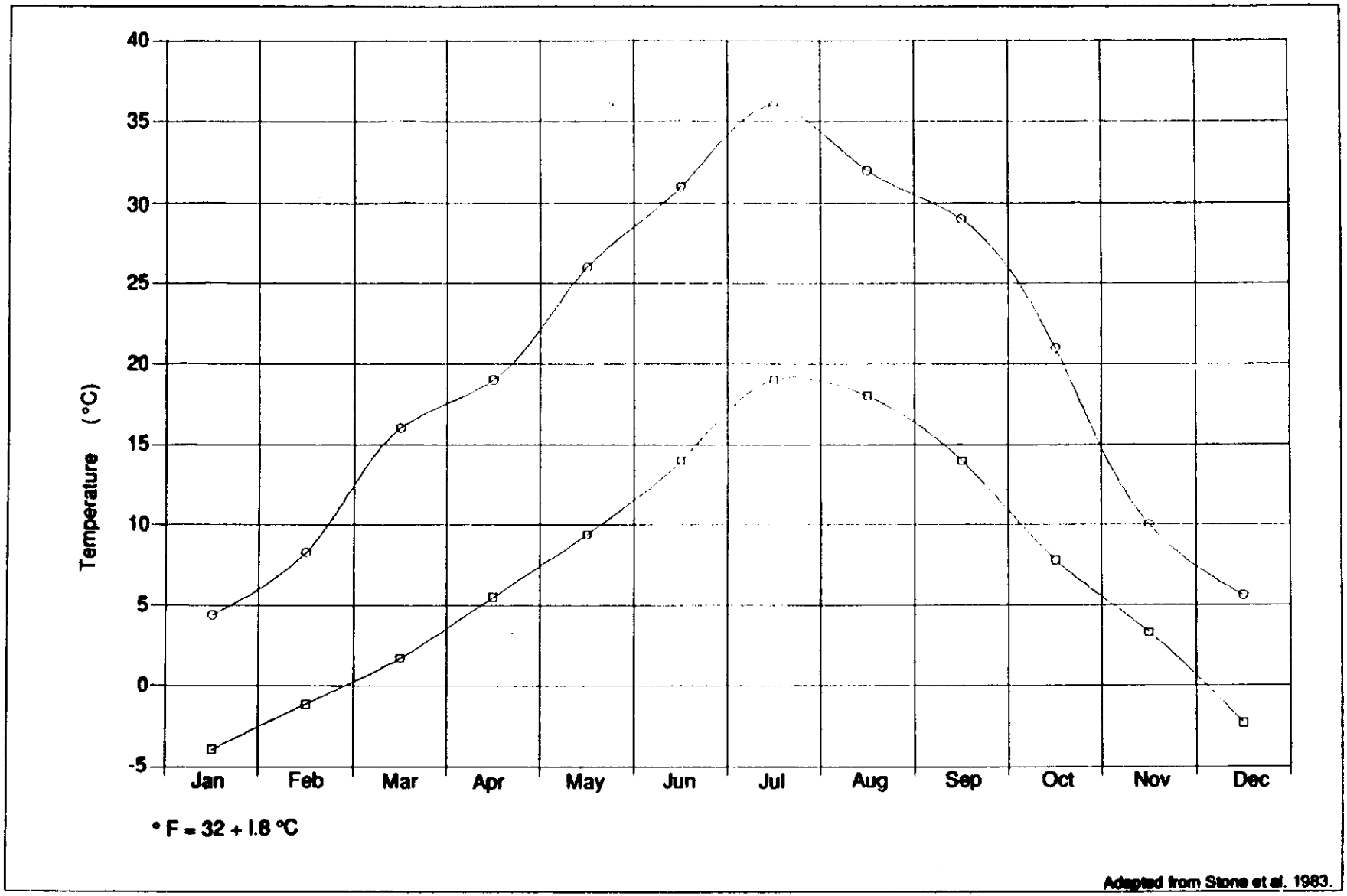

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Figure 3-8. HMS Monthly Average High and Low Air Temperatures, 1951-1980.

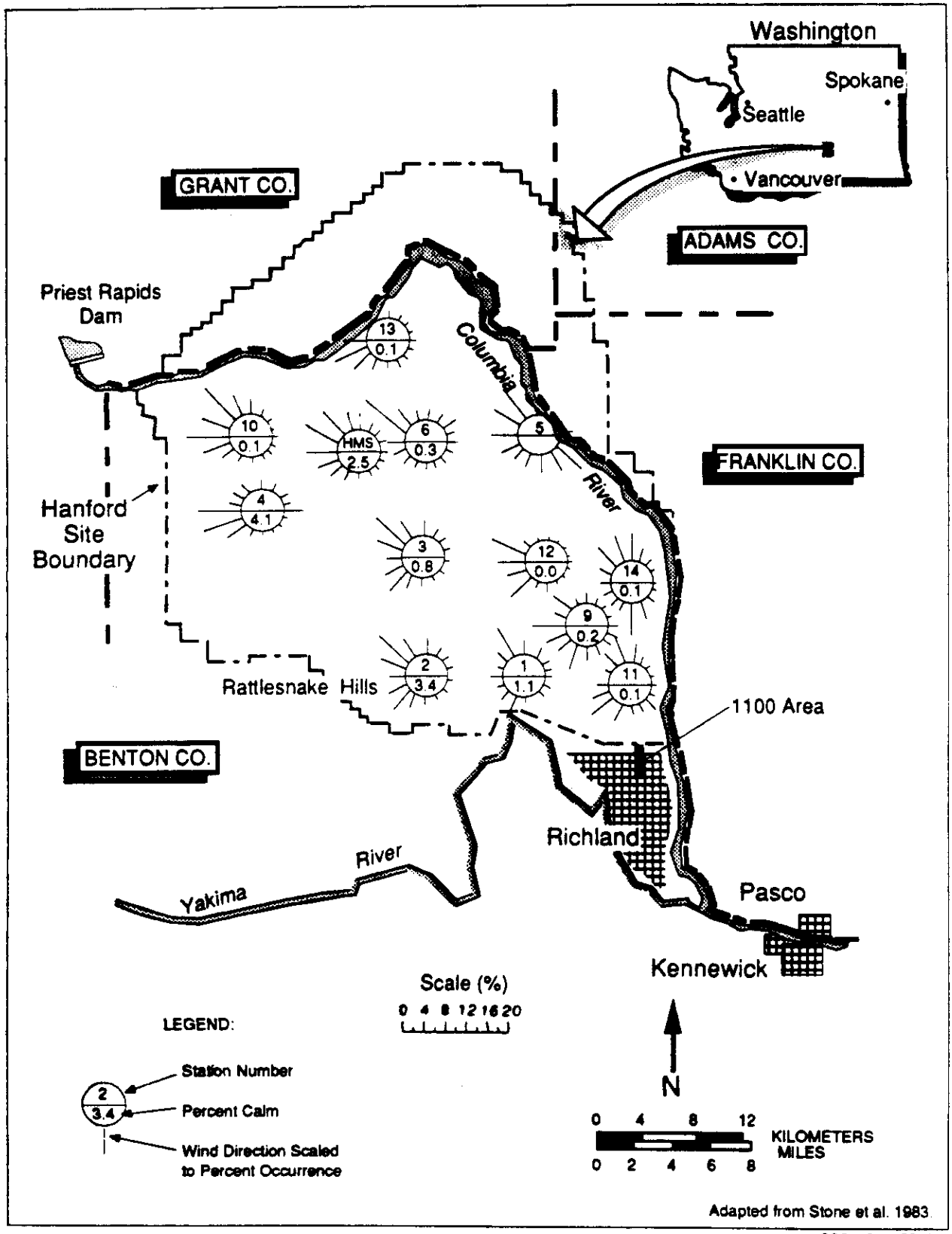

Figure 3-9. Wind Roses for the Hanford Site.

velocities (i.e., wind speed and direction). Local precipitation conditions are likely similar to HMS, based on the observed similarity between HMS and Richland (see Section 3.2.1.3 and Figure 3-6). Both stations are operated by PNL and are equipped with automated data logging systems, which record average wind velocities on an hourly basis each day of the year.

Data for the period from 1982 through 1989, which include approximately 70,000 observations at each station, were made available for this project. The original observations were reduced to provide daily average values (approximately 2,500 observations); this data summary is presented in Appendix D.

3.2.2.1 **Wind Direction**. Wind direction at the 300 Area varies over 360°, with a mean direction falling in the 180°-to-240° azimuth interval. The wind direction at the Richland Airport is more westerly, with a mean direction falling in the 210°-to-270° interval. Therefore, winds at the 1100-EM-1 Operable Unit originate predominantly from the southwest. At both stations, wind direction shifts southerly from the fall to winter and northerly from the spring to summer.

Wind direction frequencies for the 300 Area and the Richland Airport are shown on Figure 3-10. The most frequent wind directions at both stations occur in the interval 215° to 240° (225° midpoint). The Richland Airport data show less dispersion in the possible wind direction than the 300 Area data.

Differences in wind directions between the 300 Area and the Richland Airport are shown on Figure 3-11. The differences are presented in a histogram of the absolute difference between the daily average wind direction measured at the two stations on the same day. The histogram intervals are each 20°. Usually, about 45% of the time, wind directions at the two stations differ by less than 20°; 80% of the time, wind directions differ by less than 60°. These differences are minor, especially considering the differences in proximity to the Columbia River. The 300 Area station is much closer to the river, which could be expected to influence local wind directions. The Richland Airport is situated farther inland, but may be influenced by the Yakima River to the west.

3.2.2.2 **Wind Speed**. Daily average wind speed at the 300 Area ranges from 8 km/h (5 mi/h) to 16 km/h (10 mi/h); daily average wind speed at the Richland Airport ranges from about 6 km/h (4 mi/h) to 13 km/h (8 mi/h). The range of daily average wind speeds for both stations is the same—calm to 40 km/h (25 mi/h). Wind speed cumulative frequencies are shown for both stations on Figure 3-12. The data appear to follow very similar distributions, with wind speed at the Richland Airport being notably less than at the 300 Area. Median daily average wind speed at the 300 Area is about 11 km/h (7 mi/h), as compared to about 10 km/h (6 mi/h) at the Richland Airport. The 0.95 percentiles of the daily average are 23 km/h (14 mi/h) for the 300 Area and 21 km/h (13 mi/h) for the Richland Airport.

A comparison of daily average wind speeds at the two stations is shown on Figure 3-13. Wind speeds are similar at both stations, with the difference being less than 3 km/h (2 mi/h) nearly 80% of the time. Essentially, all daily average wind speeds are within 10 km/h (6 mi/h) of each other.

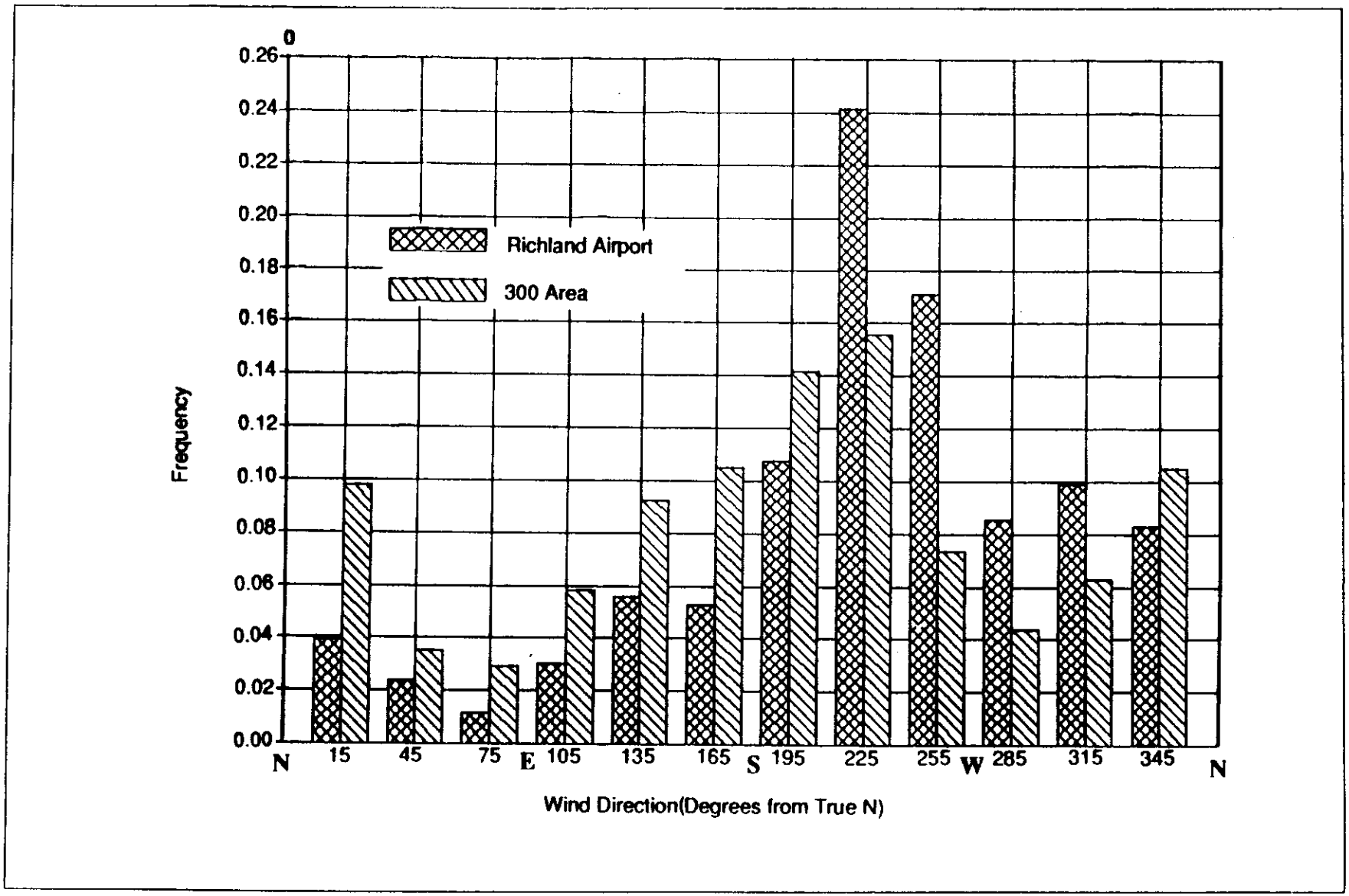

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Figure 3-10. Histogram of Daily Average Wind Direction, Richland Airport and 300 Area, 1982-1989.

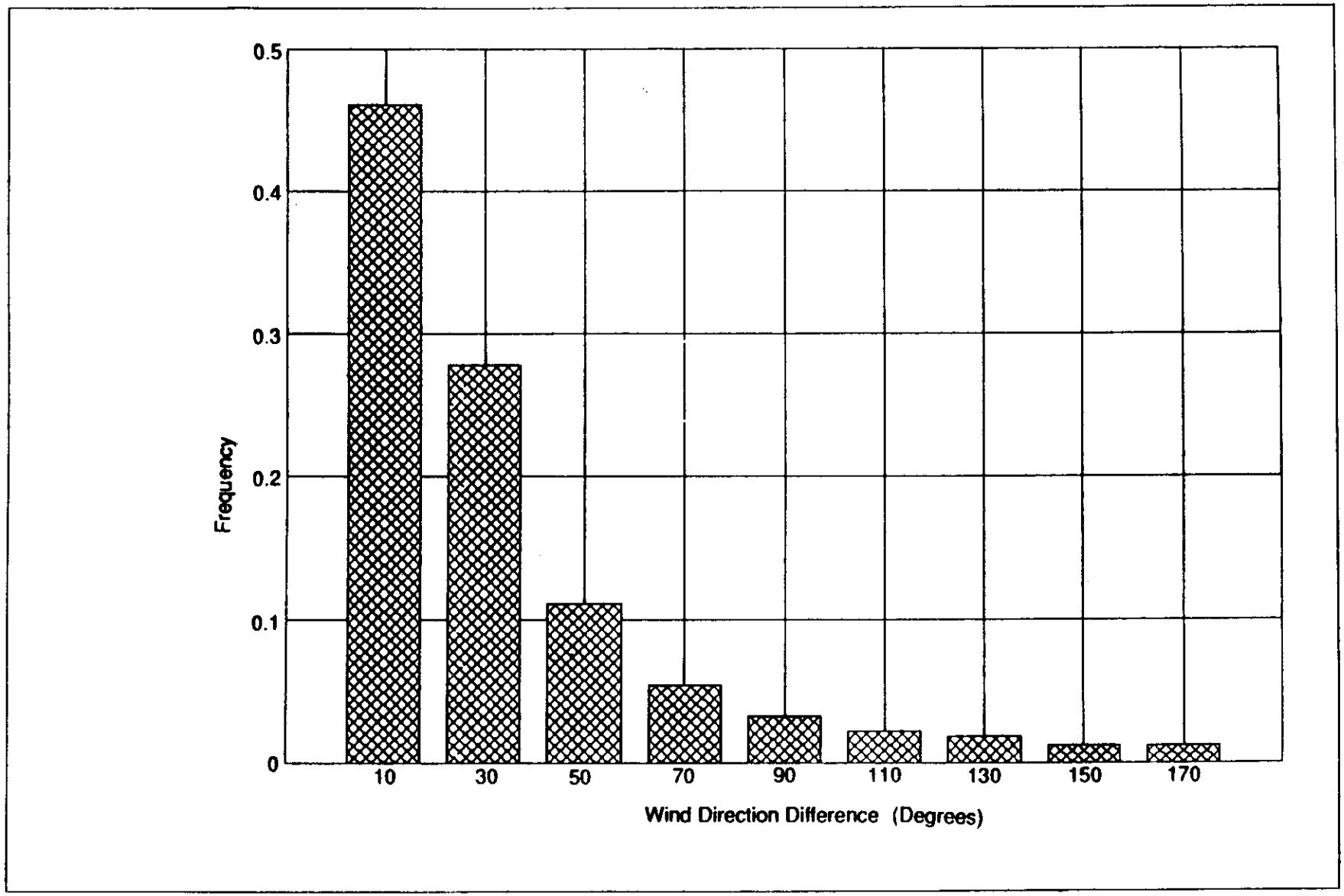

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Figure 3-11. Histogram of Daily Average Wind Direction, Richland Airport and 300 Area, 1982-1989.

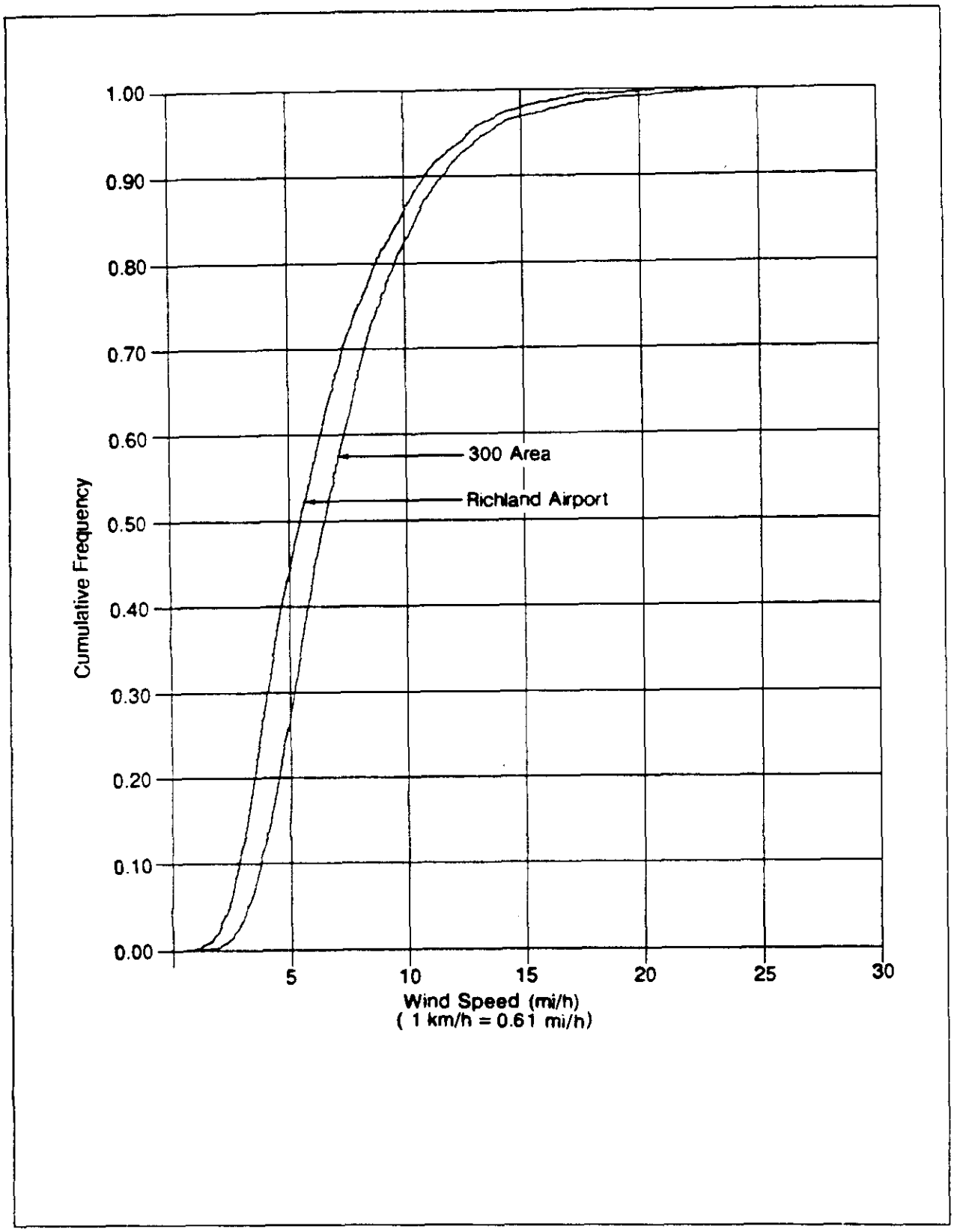

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Figure 3-12. Cumulative Frequency of Wind Speed, Richland Airport and 300 Area,1982-1989.

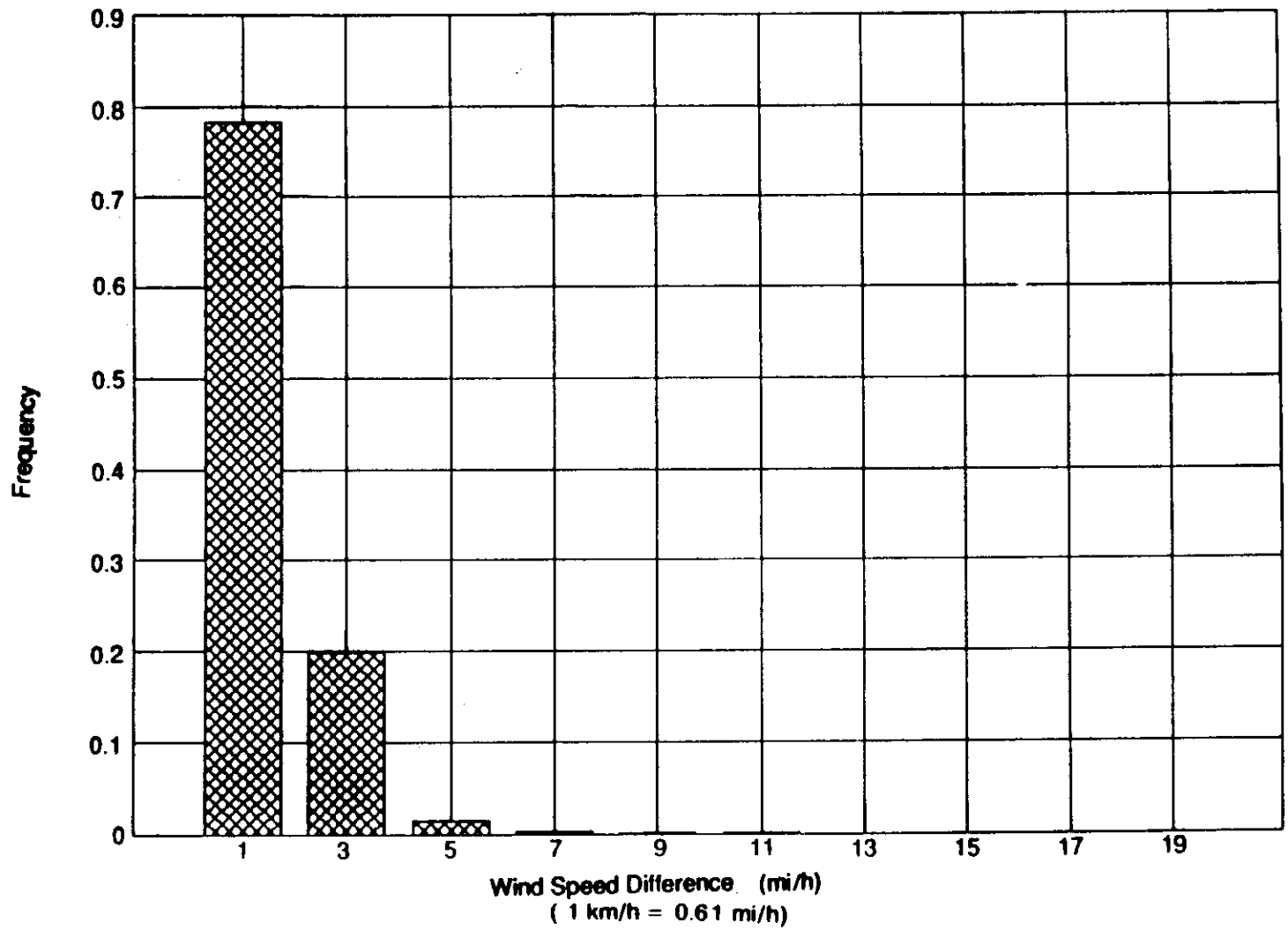

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Figure 3-13. Histogram of Daily Average Wind Speed Difference, Richland Airport and 300 Area,1982-1989.

The two monitoring stations are generally similar with respect to both wind speed and direction, although slight differences are well defined based on the daily averages. The use of daily averages likely enhances the station similarities. Analysis of the individual hourly averages would likely reveal greater differences between the stations; however, the general data trends and prevailing conditions discussed would likely be unaltered.

3.3 SURFACE HYDROLOGICAL CHARACTERISTICS

This subsection provides a characterization of surface-water hydrology, regionally within the Pasco Basin and locally in the vicinity of the 1100-EM-1 Operable Unit. Water quality characteristics and the known nature and extent of surface-water contamination associated with the operable unit are presented in Section 4.3 (Surface-Water and Aquatic-Sediment Contamination).

3.3.1 Regional Surface Hydrology

Within the near vicinity of the Hanford Site, surface water occurs in two major rivers, ephemeral streams, a natural pond, and man-made ditches and ponds. The major water bodies are shown in Figure 3-14. Physical aspects of these surface-water bodies are discussed below.

3.3.1.1 Major Rivers. The major surface-water body in the Pasco Basin is the Columbia River, which flows from the Canadian Rocky Mountains through Washington State, and along the Oregon border, to the Pacific Ocean. Enroute to the Pacific, the Columbia River crosses the northern portion of the Hanford Site, then turns southward to form the site's eastern boundary (see Figure 3-14).

The Yakima River, a major tributary of the Columbia, is the third largest river in the Pasco Basin; the Snake River, the second largest river in the basin, enters the Columbia River well downstream of the Hanford Site (see Figure 3-14). Flowing southeasterly in the southern portion of the Pasco Basin, the Yakima River merges with the Columbia River south of Richland. Both the Yakima and the Columbia are important sources of water for domestic, agricultural, industrial, and recreational users in the Pasco Basin (DOE-RL 1987; Jacquish and Mitchell 1988).

The Hanford Reach of the Columbia River extends from Priest Rapids Dam, the first dam upriver from the Hanford Site (approximately 8.5 km or 5.3 mi above the Site boundary), to the head of Lake Wallula (approximately at the southeastern Site boundary), which is created by McNary Dam, the nearest dam downstream. The Hanford Reach, which is approximately 100 km (60 mi) in length, is the only substantial remaining stretch of the Columbia River within the United States that is not impounded by a dam (Jacquish and Mitchell 1988).

Along the Hanford Reach, the channel is 370 to 550 m (1,200 to 1,800 ft) wide and 3 to 12 m (10 to 40 ft) deep (ERDA 1975). The channel does not meander strongly, but contains longitudinal bars of large size, a few of which support tree growth. Channel sediments predominantly consist of sand and gravel with cobbles of up to 20 cm (8 in) in diameter; silt and clay occur in areas of low-energy flow, such as pools and channel margins.

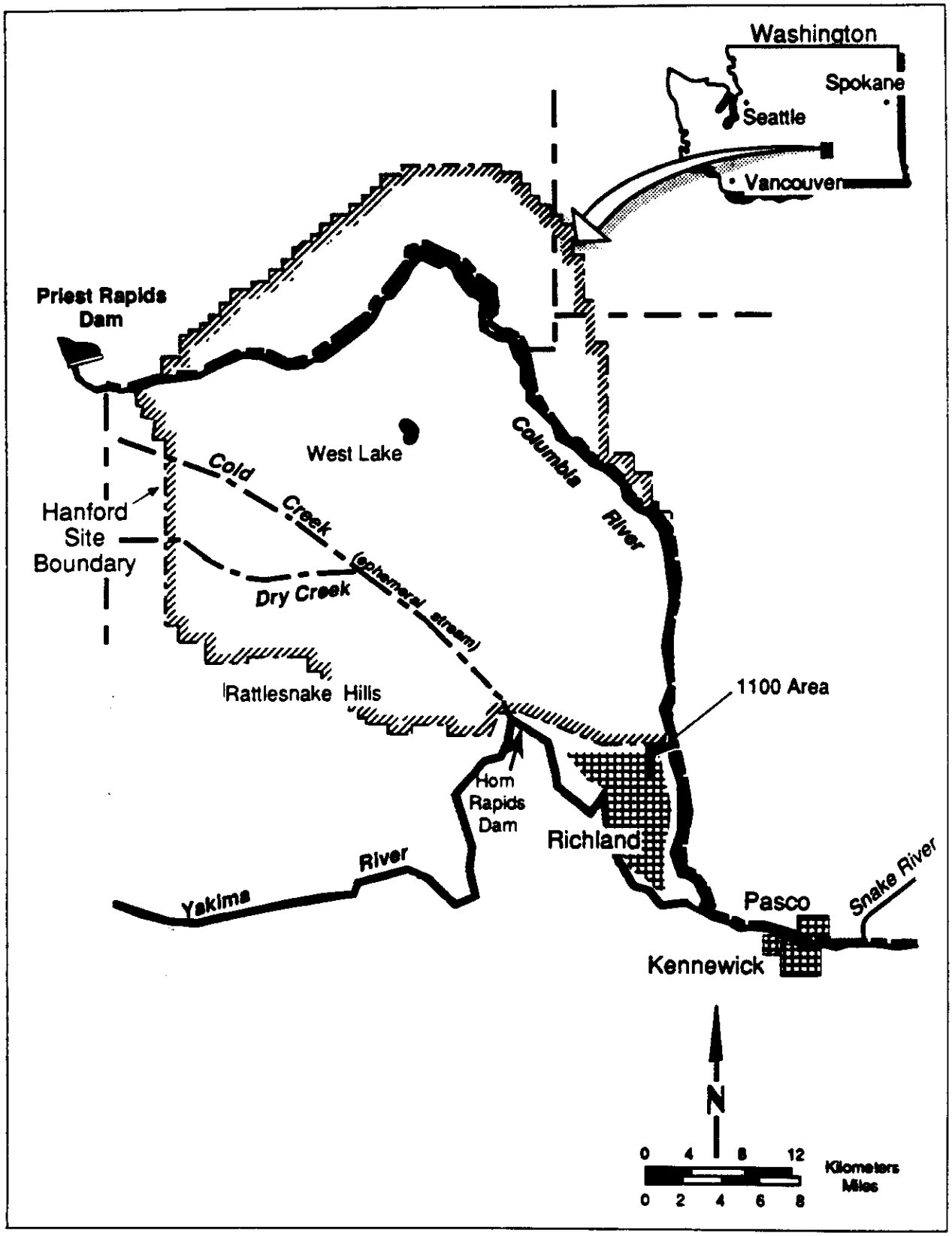

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Figure 3-14. Major Surface Water Features of the Hanford Site.

Volumetric flow rates in the Columbia River along the Hanford Reach vary widely and erratically due to operations of the Priest Rapids Dam, which is operated by Public Utility District No. 2 of Grant County. Daily flow rates may range from 1,000 to 4,500 m^3/s (36,000 to 160,000 ft^3/s) and are accompanied by fluctuations in river stage of about 1.5 m (5 ft) (ERDA 1975). The lower end of the instantaneous flow range quoted is the minimum required discharge from Priest Rapids Dam under Federal Energy Regulatory Commission license no. 2114 (Johnson, M., Public Utility District No. 2 of Grant County [Personal communication] May 14, 1990). The flow velocity, which also varies along the reach, may range from 1 to 3 m/s (3 to 11 ft/s).

The Yakima River, originating in the Cascade Range to the west, is one-fifth to one-third the size of the Columbia in width. East of the Cascade Range, the river channel meanders within a flood plain valley. The valley is about 1 to 2 km (0.5 to 1 mi) wide, with narrow gorge sections; the average river channel width is about 60 m (200 ft). Volumetric flow rates in the Yakima River range from 37 to 600 m^3/s (1,300 to 20,000 ft^3/s) (ERDA 1975). The Yakima River dam situated nearest to the Hanford Site is the Horn Rapids Dam. Located about 17 km (10 mi) northwest of Richland, the Horn Rapids Dam provides irrigation water and is operated by the Columbia Irrigation District.

Regional flooding within the Columbia and Yakima Rivers is controlled by hydroelectric power dams and irrigation structures (Skaggs and Walters 1981). Except for extreme flooding scenarios, flooding in either river is not anticipated to inundate the 1100-EM-1 Operable Unit. One such scenario includes a 50% breach of Grand Coulee Dam, located on the Columbia River approximately 300 km (180 mi) upstream from Priest Rapids Dam. Under this flooding scenario, a flow of about 230,000 m^3/s (8,000,000 ft^3/s) would occur at Richland, and the river would inundate the 300 Area, 3000 Area, 1100 Area, Richland, and the Yakima River channel upstream to Horn Rapids Dam (Skaggs and Walters 1981).

3.3.1.2 Other Naturally-Occurring Surface Waters. The arid-to-semiarid climate of the Pasco Basin does not support any perennial streams; however, a few ephemeral streams do exist. Cold Creek—and its main tributary, Dry Creek—are two major ephemeral streams located along the southwestern boundary of the Hanford Site (see Figure 3-14). The Cold Creek drainage ultimately connects to the Yakima River about 2 km (1 mi) upstream from Horn Rapids Dam. Actual flow in these creeks, which results from precipitation onto Rattlesnake Hills, Umtanum Ridge, and Yakima Ridge, is not well documented; however, flood magnitudes in Cold Creek, having recurrence intervals of 5 and 10 yr, were estimated to be 60 and 120 m^3/s (2,100 and 4,400 ft^3/s), respectively, in the creek's lower reaches (Skaggs and Walters 1981).

West Lake, located about 3.2 km (2 mi) north of the 200 East Area, is the only naturally-occurring pond on the Hanford Site. The pond is shallow, with an average depth of about 1 m (3 ft), and has a surface area of about 4 ha (10 ac) (Fuchs et al. 1985). The source of recharge to the pond is ground water, which is locally mounded due to infiltration resulting from 200 Areas operations (Graham 1983); the pond's size fluctuates with the height of the ground-water mound.

3.3.1.3 Man-Made Ditches and Ponds. On the Hanford Site, waste-water discharge into ponds and ditches occurs in the 200 and 300 Areas. At these

locations, several ponds and ditches exist to hold waste waters, which eventually evaporate or infiltrate.

3.3.2 Local Surface Hydrology

Topography within the 1100-EM-1 Operable Unit is generally flat, with no obvious drainage channels or ponds. The ground surface has been reworked by winds, which have created a southwest-to-northeast-trending pattern in the soil surface (see Figure 3-1). The flat topography, with a lack of well-defined drainages, and the arid-to-semiarid climate suggest that little if any surface water accumulates within the operable unit. The vast majority of precipitation that falls directly on the Hanford Site is lost through evapotranspiration, leaving little or minor amounts of water to generate surface runoff (ERDA 1975).

A small ephemeral pool is infrequently formed during high-intensity precipitation events due to runoff from the impermeable surface of the 1100 Area parking lot. The water in this pool is quickly lost to infiltration and evaporation.

Near to the 1100-EM-1 Operable Unit, man-made ponds exist at the Advanced Nuclear Fuels Corp. facility and at the City of Richland well field (USGS 1978; CWC-HDR, Inc. 1988). The lined Advanced Nuclear Fuels ponds are used for pretreatment of waste water, whereas those in the city well field are specifically intended to recharge the ground water with water obtained from the Columbia River. Water filtered in this manner is then extracted to satisfy seasonal and peak municipal demands.

Four small and discrete wetlands exist in a band located approximately 0.8 km (0.5 mi) to the west-through-southwest of the 1100-1 Battery Acid Pit (see Figure 3-1). These wetlands, which together cover approximately 3 ha (7 ac), are located in topographic depressions with no drainage outlets and are vegetated with trees or shrubs and emergent plants (USFWS 1976).

3.4 GEOLOGICAL CHARACTERISTICS

This subsection provides a description, regionally and locally, of the geological characteristics of the 1100-EM-1 Operable Unit. Pertinent geologic information includes geomorphology, location and thickness of stratigraphic units, lithology, particle size and sorting, and geologic structure of bedrock strata. This information is provided below. Additional details on the physical characteristics of operable unit soils and ground water can be found in Sections 3.5 (Pedological Characteristics) and 3.6 (Hydrogeological Characteristics), respectively.

3.4.1 Geomorphology

The 1100-EM-1 Operable Unit is located within the Central Plains geomorphic section of the Columbia Basin subprovince, which is in turn located within the Columbia Intermontane physiographic province (Thornbury 1965). The Central Plains geomorphic section, shown on Figure 3-15, comprises low-relief areas adjacent to and between folded basalt bedrock ridges. The Pasco and

Figure 3-15. Geomorphic Units within the Central Highlands and Columbia Basin Subprovinces of the Columbia Intermontane Province.

Quincy Basins are two major topographic and structural basins within the Central Plains section. These basins served as major centers for deposition of catastrophic flood sediments, associated with failures of ice dams during the Pleistocene epoch, and contain both aggradational and degradational landforms attributable to the action of Pleistocene flood waters. The 1100-EM-1 Operable Unit is within the Pasco Basin, the southernmost of the two basins.

The arid-to-semiarid climate of the Central Plains section is a controlling factor of present-day geomorphic processes. Major drainages within the Pasco Basin include the Columbia, Snake, and Yakima Rivers, and fluvial aggradational and degradational processes are most active within the channels and flood plains of these rivers. Eolian processes are also currently active within the Central Plains section, and are responsible for the maintenance of large dune fields and for loess deposits that mantle portions of the terrain.

The location of the 1100-EM-1 Operable Unit within the Pasco Basin is shown on Figure 3-16. The 1100-EM-1 Operable Unit is situated on a sand and gravel plain within the southwestern portion of the Central Plains section, between the Columbia and Yakima Rivers.

Northeast-trending longitudinal sand dunes mantle much of the Hanford Site and extend up to and across the operable unit. The northeast orientation of the dunes reflects the effect of topographic features located to the southwest, upgradient of the prevailing wind direction. The amplitude of most of the dunes is on the order of 3 m (10 ft). The dunes are locally active, but, for the most part, have been stabilized by vegetation or have been reworked by grading and excavation during the construction and operation of the various facilities within and near the operable unit. Where not covered by sand dunes, the ground surface is mantled by catastrophic, Pleistocene-age flood deposits or thin eolian deposits.

3.4.2 Regional Geology

A summary of the regional geological characteristics of the Pasco Basin and the Hanford Site is presented below in terms of stratigraphy (Section 3.4.2.1) and structure (Section 3.4.2.2). Local geology and structure of the 1100-EM-1 Operable Unit are discussed in Section 3.4.3.

3.4.2.1 Regional Stratigraphy. The Hanford Site is within the Pasco Basin, a regional structural and topographic, sediment-filled basin within the Columbia Plateau (see Figure 3-16). The sediments within the Pasco Basin are underlain by the Miocene-age Columbia River Basalt Group, a thick sequence of flood basalts that covers a large area in eastern Washington, western Idaho, and northeastern Oregon. The sediments overlying the basalts, from oldest to youngest, include: the Miocene-Pliocene Ringold Formation, local alluvial deposits of possible latest Pliocene or probable early Pleistocene age, local early "Palouse" soil of mostly eolian origin derived from either the reworked Plio-Pleistocene unit or upper Ringold material, glaciofluvial deposits of the Pleistocene Hanford formation, and surficial Holocene eolian and fluvial sediments. Because the relatively deep basalt bedrock is not expected to influence the transport of contaminants at the 1100-EM-1 Operable Unit, this report focuses on the suprabasalt sediments.

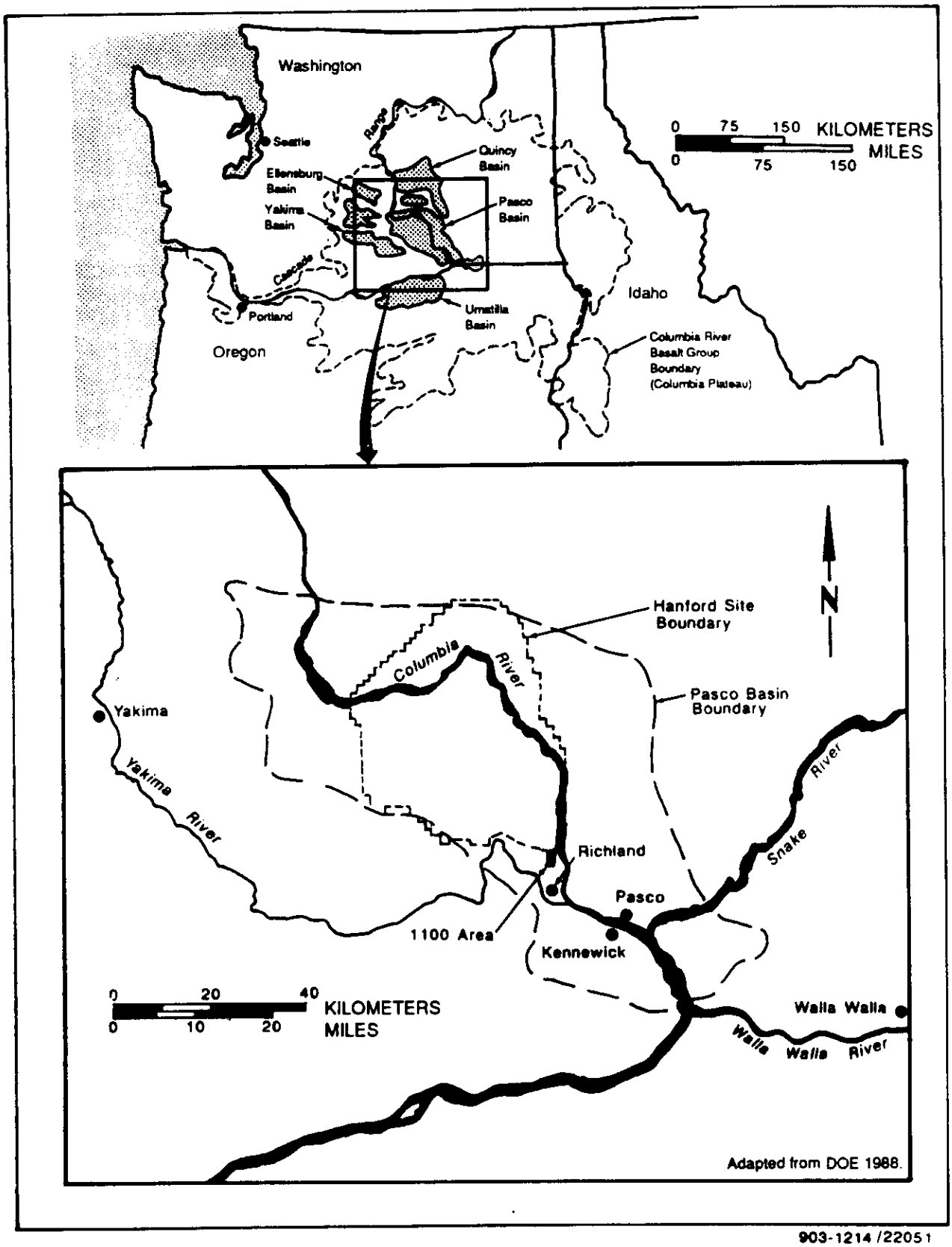

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Figure 3-16. Location of the 1100 Area within the Pasco Basin.

Figure 3-17 illustrates the suprabasalt stratigraphy in the Pasco Basin. This figure does not show the early "Palouse" soil, which has a poorly-defined upper contact and may grade upward or lie intercalated with the Hanford formation. The stratigraphic units within the Pasco Basin are discussed further below from oldest to youngest, in the order of their deposition.

Columbia River Basalt Group

The Columbia River Basalt Group, which is composed of numerous basalt flows and interbedded sediments, is the bedrock unit in the Pasco Basin. The Columbia River Basalts erupted from vent systems in north-central and northeastern Oregon, eastern Washington, and western Idaho. Basaltic accumulations within the downwarped Pasco Basin are to depths in excess of 3,000 m (10,000 ft) (DOE 1988).

The Saddle Mountains Basalt Formation is the youngest formation of the Columbia River Basalt Group. Sedimentary units, or interbeds, of the Ellensburg Formation occur within the Saddle Mountains Basalt Formation. Underlying the Saddle Mountains Basalt are the Grande Ronde and Wanapum Basalt Formations. The most recent basalt flow comprising the Saddle Mountains Basalt Formation in the eastern Pasco Basin is the Ice Harbor Member; in the western Pasco Basin, the most recent flow is the Elephant Mountain Member. These flows have been dated at 8.5 and 10.5 million yr before present, respectively (DOE 1988).

Ringold Formation

The late Miocene to Pliocene Ringold Formation overlies the Columbia River Basalt Group in the Pasco Basin, and consists of interstratified deposits of sand, silt, clay, and gravel. The Ringold Formation exhibits three lateral facies changes interpreted by DOE (1988) to represent variations in the paleogeography during Ringold time. These facies are:

- Fluvial main channel—gravel and associated sand and silt representing deposits formed by a major migrating channel
- Fluvial overbank—primarily sand, silt, and clay deposited away from the influence of the main channel
- Fanglomerate—primarily angular basaltic debris of sidestream alluvium derived from bedrock ridges.

Figure 3-18 shows the general distribution of the Ringold facies types in the Pasco Basin.

Four units of the Ringold Formation were identified by Myers and Price (1979) in the Pasco Basin, and were refined by DOE (1988) in the west-central portion of the Hanford Site. In this location, the Ringold is interpreted to consist of fluvial facies. The four units are, from youngest to oldest:

- Upper Ringold unit—fine sands and muds
- Middle Ringold unit—a thick sequence of semiconsolidated sand and gravel of mixed lithologies, with lenses of sand and mud

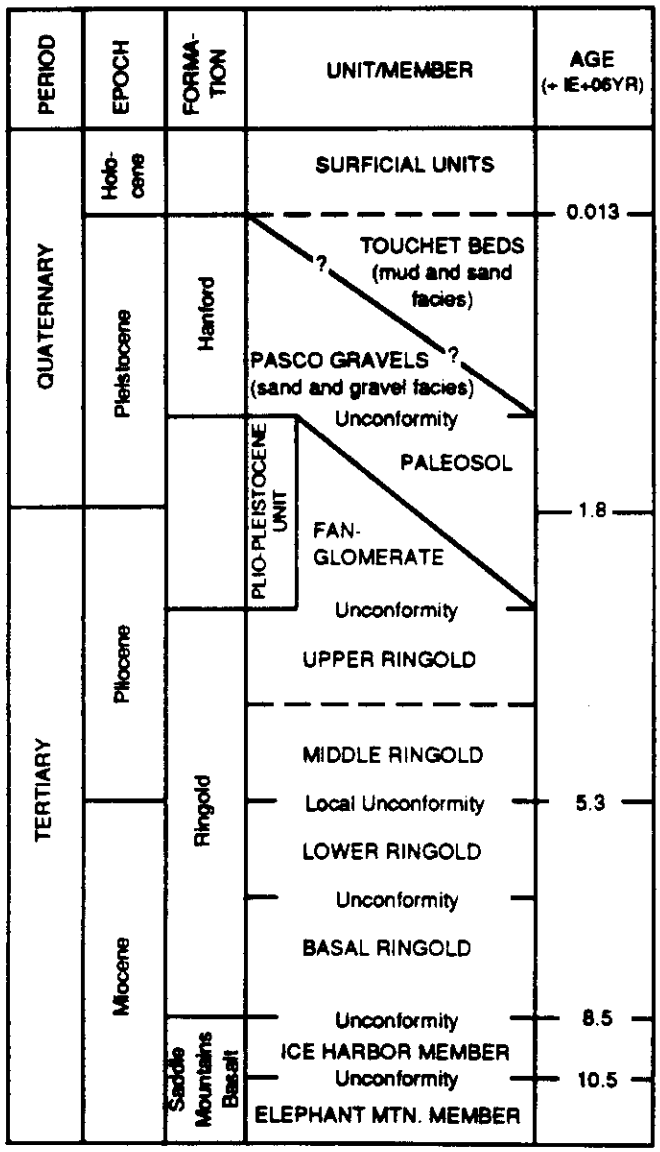

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Figure 3-17. Suprabasalt Stratigraphy of the Pasco Basin .

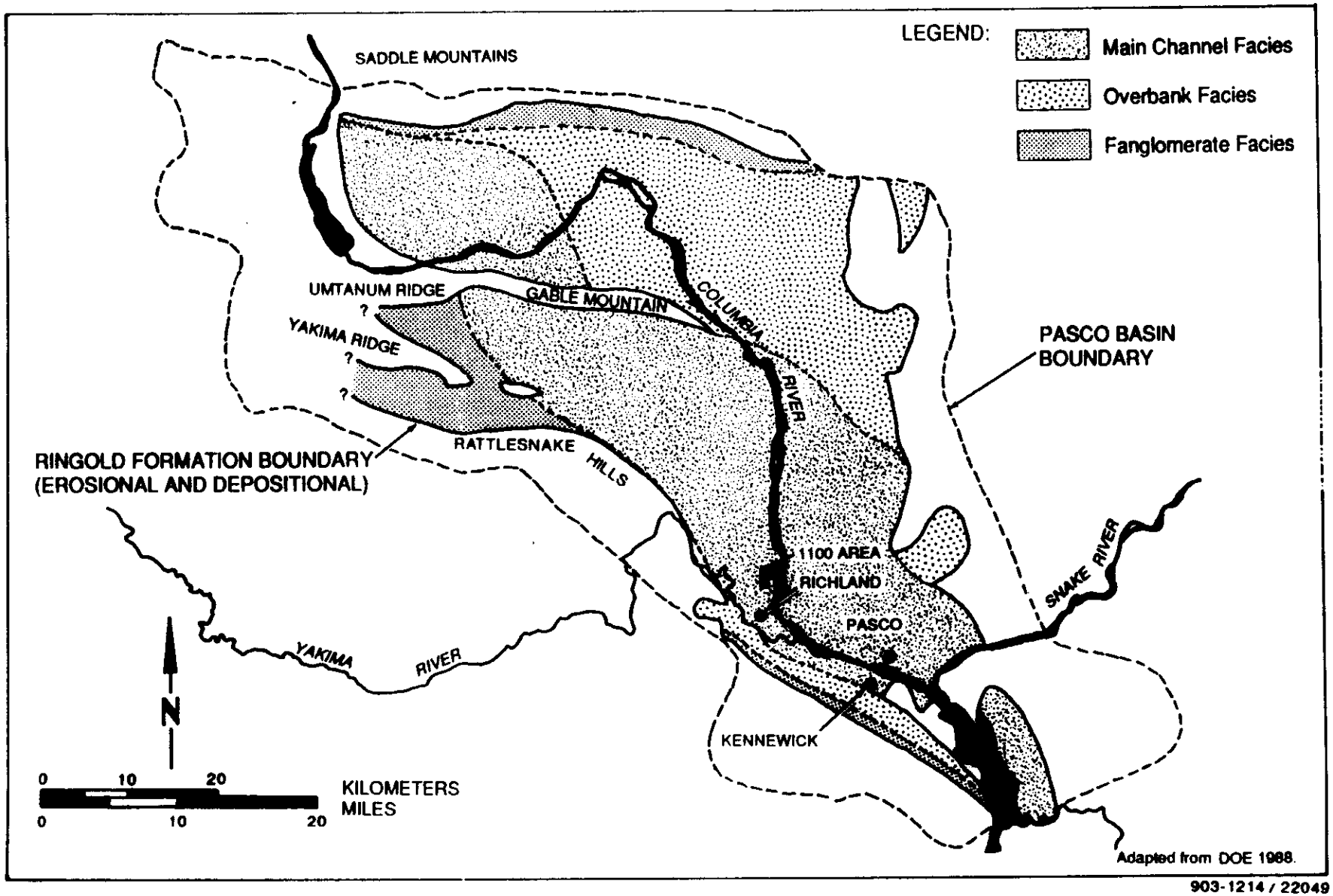


Figure 3-18. Distribution of Ringold Formation Facies in the Pasco Basin.

- Lower Ringold unit—gray-to-yellow clay, silt, and fine sand, with local lenses of gravel

- Basal Ringold unit—a sequence of predominantly gravelly sand, fining upward to sand or olive-colored clay that is capped by a palesol sequence.

In the east-central portion of the Hanford Site, south of Gable Mountain, PSPL identified four fining-upward sedimentary units within the Ringold Formation—Units I, II, III, and IV, from oldest to youngest, respectively (PSPL 1982). Each of these units is composed of basal gravels overlain by fine-grained sediments. The gravels of Unit I are basalt-rich and have a bluish color, whereas the gravels in Units II, III, and IV contain lithologies derived primarily from outside of the Pasco Basin, and have yellow, sandy cement rinds. The fine-grained sediments of Unit I are olive-gray and contain a paleosol at the top; the fine-grained sediments of Units II, III, and IV are yellowish-gray in color. In this location, the Ringold depositional environment is interpreted to be primarily fluvial, with some contribution from floodplain and lacustrine environments. The four Ringold Formation units in the east-central portion of the Hanford Site appear to be correlative with the basal, lower, middle, and upper Ringold units identified to the west (PSPL 1982).

The type section of the Ringold Formation is located along the southern end of the White Bluffs, east of the Hanford Site along the Columbia River. At this locality, Newcomb (1958) divided the Ringold Formation into three textural facies consisting of a coarse-grained middle member bounded above and below by fine-grained members, as follows: a lower "blue clay" member, a middle conglomerate member, and an upper member of silt and fine sand. Only the middle and upper members are exposed at the type section; these members correlate with the middle and upper Ringold units of DOE (1988). The lower "blue clay" member, a term used locally by drillers, is actually composed of blue- and green-colored silts and clayey silts containing interbeds of sand and gravel (Newcomb 1958). Puget Sound Power and Light correlated their Ringold fine-grained Unit I sediments with the "blue clay" member (PSPL 1982). The "blue clay" member is not exposed at the White Bluffs, but is commonly reported in borehole logs in the Richland area and southeastward to Kennewick and Pasco (Newcomb et al. 1972).

Plio-Pleistocene Unit

The Plio-Pleistocene unit unconformably overlies the Ringold Formation in the western Pasco Basin. The DOE (1988) separates this unit into two facies. One is a sidestream fanglomerate that is generally composed of basaltic gravel derived from adjacent ridges; the other is a caliche-rich paleosol that developed subaerially atop the eroded Ringold surface.

Early "Palouse" Soil

The early "Palouse" soil has been mapped by DOE (1988) in the western Pasco Basin. This unit, a fine-grained eolian sand to silt, locally overlies the Plio-Pleistocene unit. It is thickest in the southeastern portion of the 200 West Area of the Hanford Site and pinches out toward the margins of the Pasco Basin (DOE 1988). The upper contact with the overlying Hanford formation is ill defined.

Hanford Formation

The upper stratigraphic unit in the Pasco Basin, other than the surficial, eolian silty sands, consists of moderately-to-poorly-sorted, unconsolidated, glaciofluvial sediments. These sediments are informally referred to as the Hanford formation; they were deposited during several episodes of catastrophic flooding associated with failures of ice dams in western Montana and northern Idaho during the late Pleistocene epoch (Baker 1981). At least three major flood episodes are recognized in the Pasco Basin, and many more minor flood events probably occurred during each of these major episodes (DOE 1988). The last major flood sequence has been dated at about 13,000 years before present (Mullineaux et al. 1977).

Within the Pasco Basin, the coarse-grained, main-channel facies of these flood deposits are informally referred to as the Pasco gravels member of the Hanford formation (Myers and Price 1979). The Pasco gravels are composed predominantly of basaltic gravels with a sand or silty-sand matrix and local sand lenses. The Pasco gravels were deposited on an irregular erosional surface along main channelways of the catastrophic floods. The 1100-EM-1 Operable Unit lies along one of these main flood channelways (Figure 3-19). A finer-grained, slack-water facies of the Hanford formation, known as the Touchet beds member, was deposited adjacent to flood waters and in back-water areas, and is generally synchronous with the Pasco gravels.

Within the Pasco gravels of the east-central portion of the Hanford Site, two stratigraphic units are recognized (PSPL 1982). The older unit, termed Pre-Missoula flood gravels, unconformably overlies the Ringold Formation and contains primarily non-basaltic gravel clasts in a sand matrix. These gravels are interpreted to represent late-Pliocene or early-Pleistocene glaciofluvial floods restricted to the Spokane and Columbia River drainages (PSPL 1982). The younger unit, the Missoula flood gravels, overlies the Pre-Missoula gravels and is primarily basaltic in composition. Pre-Missoula and Missoula gravels are considered equivalent to the basal and upper parts of the Pasco gravels, respectively (PSPL 1982). The existence of Pre-Missoula gravels is not documented in the western portion of the Hanford Site (DOE 1988).

Surficial Deposits

Surficial Holocene deposits of dune and sheet sand, alluvium, loess, and colluvium locally overlie the Hanford formation on the Hanford Site (DOE 1988). Cumulative thicknesses of these deposits rarely exceed 3 m (10 ft).

3.4.2.2 Regional Geologic Structure. The Columbia River Basalt Group within the west-central portion of the Columbia Basin has been deformed, primarily by north-south compression (DOE 1988). This deformation has created broad structural and topographic basins separated by asymmetric, generally east-west-trending, anticlinal ridges, known as the Yakima folds, which developed during Miocene and Pliocene time. The tightly-folded anticlines, which commonly form exposed ridges, are separated by broad synclines that contain thick accumulations of sediments. The Hanford Site is located within the Pasco Basin, which is bounded on the north, west, and south by the Yakima folds, and on the east by a broad zone of gradually-increasing elevation of the basalt surface (Figure 3-20).

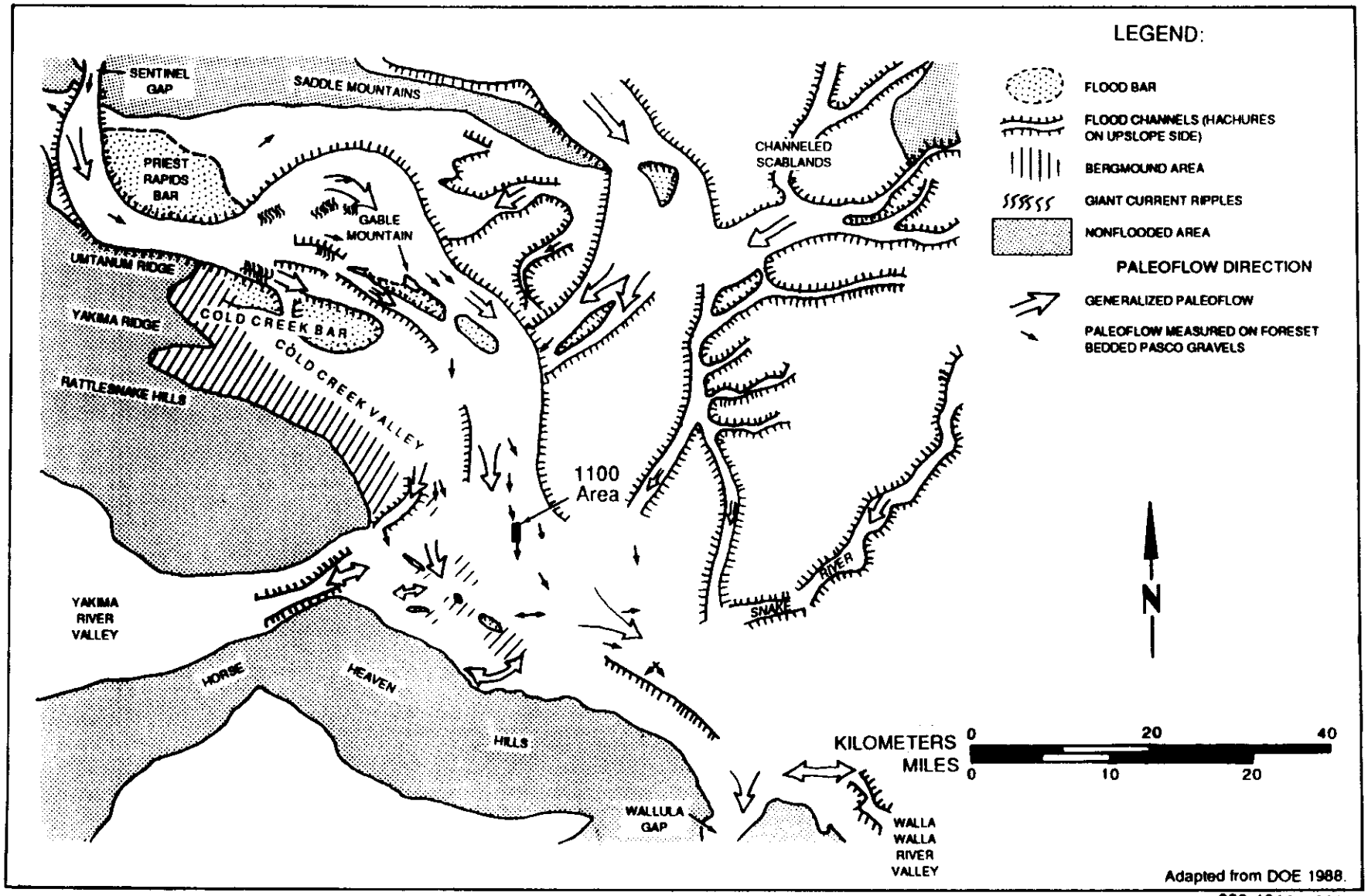
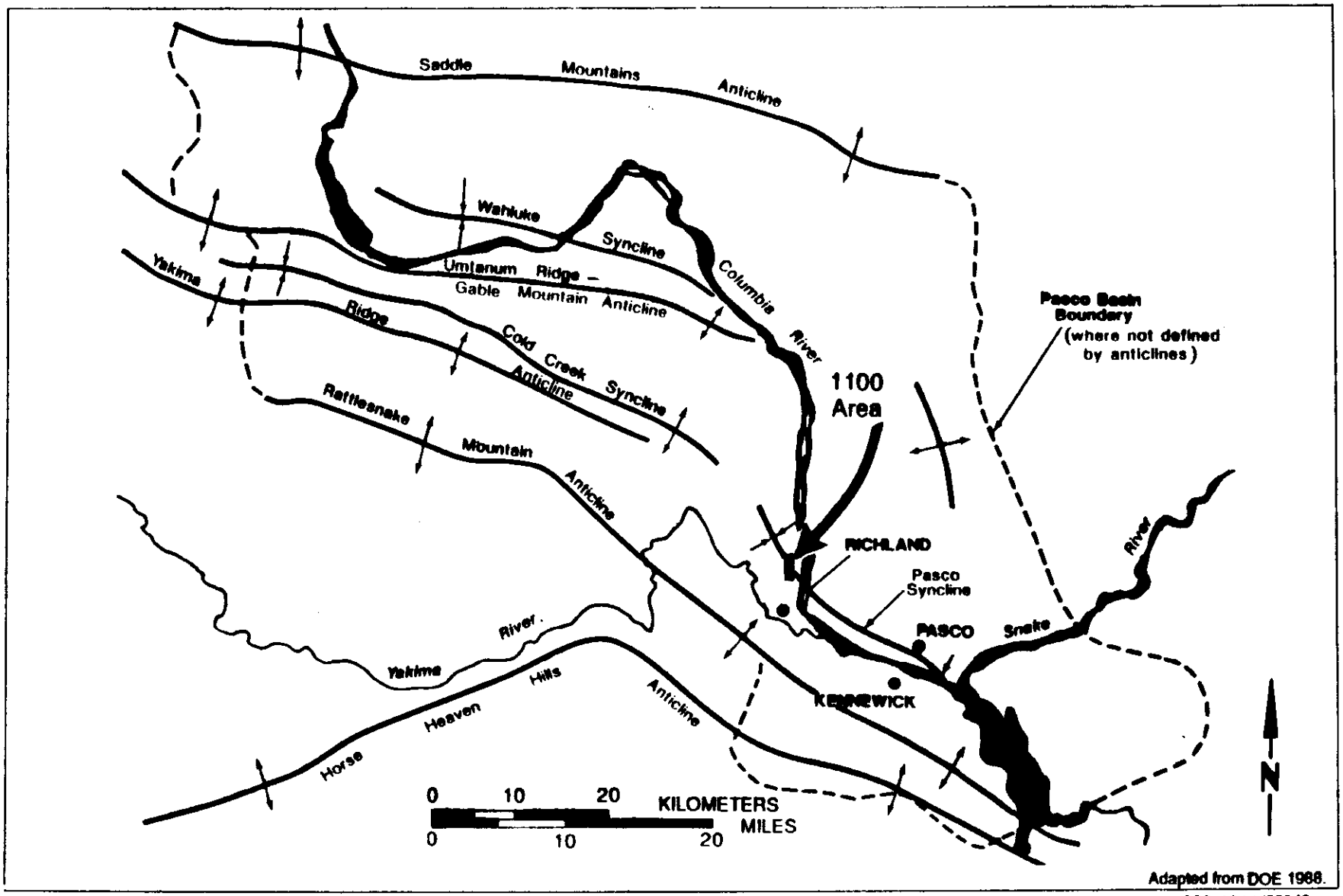


Figure 3-19. Pleistocene Flood Channels.



Adapted from DOE 1988.

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Figure 3-20. Major Regional Geologic Structures.

Because deformation continued during Ringold deposition, the lower units of the Ringold Formation within the Pasco Basin generally have dips similar to the underlying basalt flows. The dips decrease with decreasing age in the Ringold section (PSPL 1982; DOE 1988). The history of deformation since the end of Ringold time is less clear because the upper surface of the Ringold Formation has been eroded by Pleistocene flood waters, and is therefore less the result of structures than the result of erosion. Reidel et al. (1983) summarize evidence for the continuation of deformation, from the Miocene to the present, within the Pasco Basin. The evidence is: 1) thinning or nondeposition on ridges and continued deposition and accumulation of sediments in synclines; 2) cumulative deformation in the suprabasalt sedimentary deposits; and 3) average rates of uplift and subsidence, extrapolated from the Miocene to the present, that can account for the present structural relief. The reader is referred to Riedel et al. (1983) and DOE (1988) for further discussion of structural features in the Pasco Basin.

3.4.3 Local Geology

No detailed geologic information has been published specifically on the 1100-EM-1 Operable Unit. Geohydrologic and ground-water quality studies of the 300 Area (Lindberg and Bond 1979; Schalla et al. 1988) describe the suprabasalt stratigraphic units approximately 1.6 km (1 mi) northeast of the Horn Rapids Landfill. The following description of the geology of the 1100-EM-1 Operable Unit is based on geologic logs prepared during the first phase of the RI (see Sections 2.4, 2.5.3, and 2.6.2, and Appendix F), on geologic logs for five ground-water monitoring wells constructed in the 1100 Area in October 1988 (Bryce and Goodwin 1989), and on geologic logs for selected, previously-existing wells located in and near the operable unit (Newcomb et al. 1972; Summers and Schwab 1977; Fecht and Lillie 1982; CWC-HDR, Inc. 1988; Geology Section, WHC [Technical Memo 81232-90-042 to S. Clark, WHC] May 11, 1990). Copies of published logs from the pertinent, previously-existing wells are also included in Appendix F.

3.4.3.1 Local Stratigraphy. The generalized suprabasalt stratigraphic column for the 1100-EM-1 Operable Unit is shown in Figure 3-21. The Plio-Pleistocene unit, the early "Palouse" soil, and the Touchet beds member of the Hanford formation, which are discussed in Section 3.4.2.1, are not present in the vicinity of the 1100-EM-1 Operable Unit. The stratigraphic column for the upper portion of the Ringold Formation and the Hanford formation in the figure is based on information obtained from the drilling of 22 soil borings and 16 ground-water monitoring wells during the initial phase of the operable unit RI, and five ground-water monitoring wells installed between the 1100 Area and the City of Richland well field in 1988 (Bryce and Goodwin 1989).

The limited depth of these borings and wells limits the direct evidence as to the depth, thickness, and characteristics of the basalts and the lower portion of the Ringold Formation beneath the 1100-EM-1 Operable Unit. The interpretation of the lower stratigraphic units on Figure 3-21 is based on a log for a nearby, previously-existing well that extends to basalt—10/28-10G1. This log is published in Newcomb et al. (1972), and the location of the well is shown in Figure 3-22. The log for this well is also included in Appendix F.

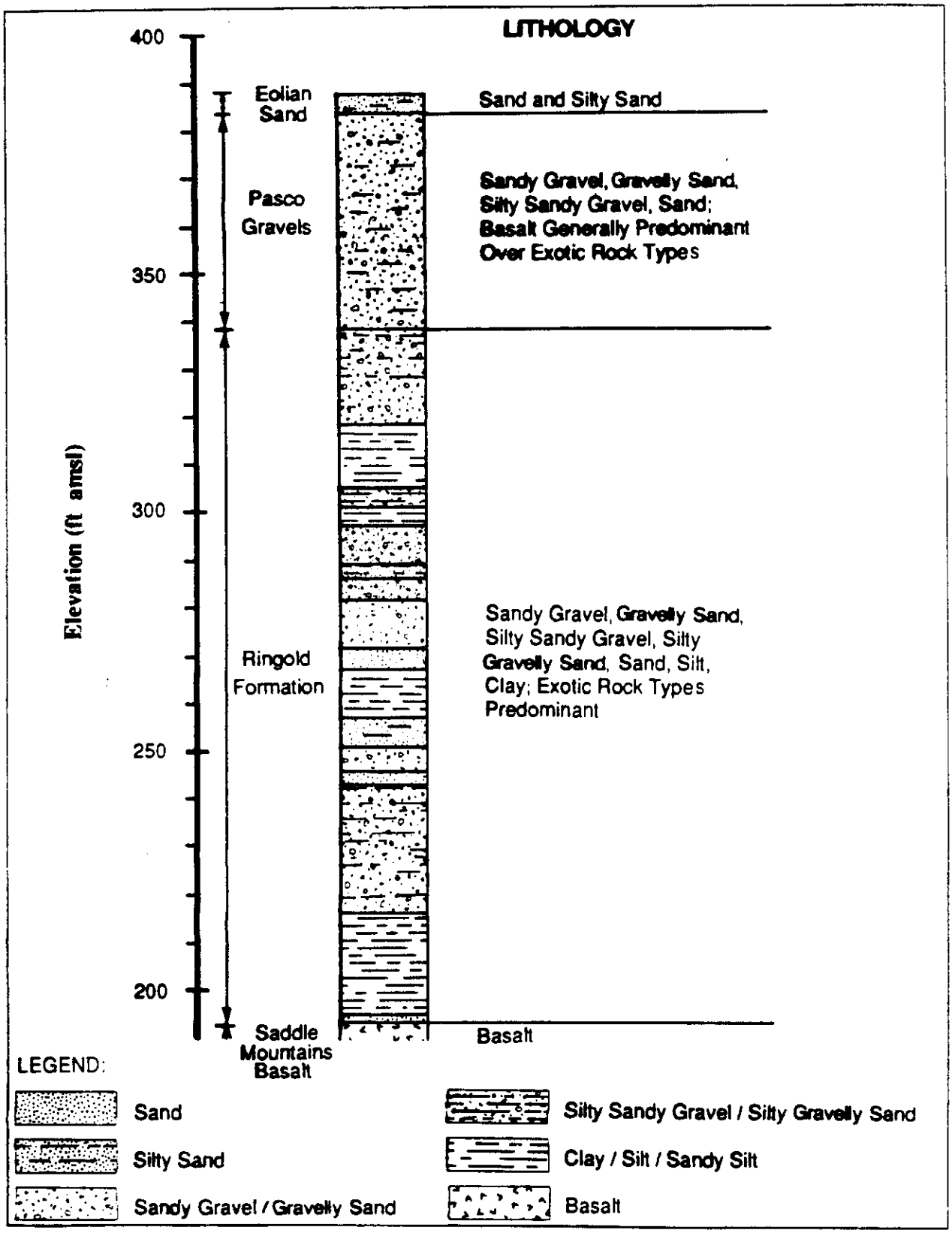

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Figure 3-21. Generalized Suprabasalt Stratigraphic Column for the 1100-EM-1 Operable Unit.

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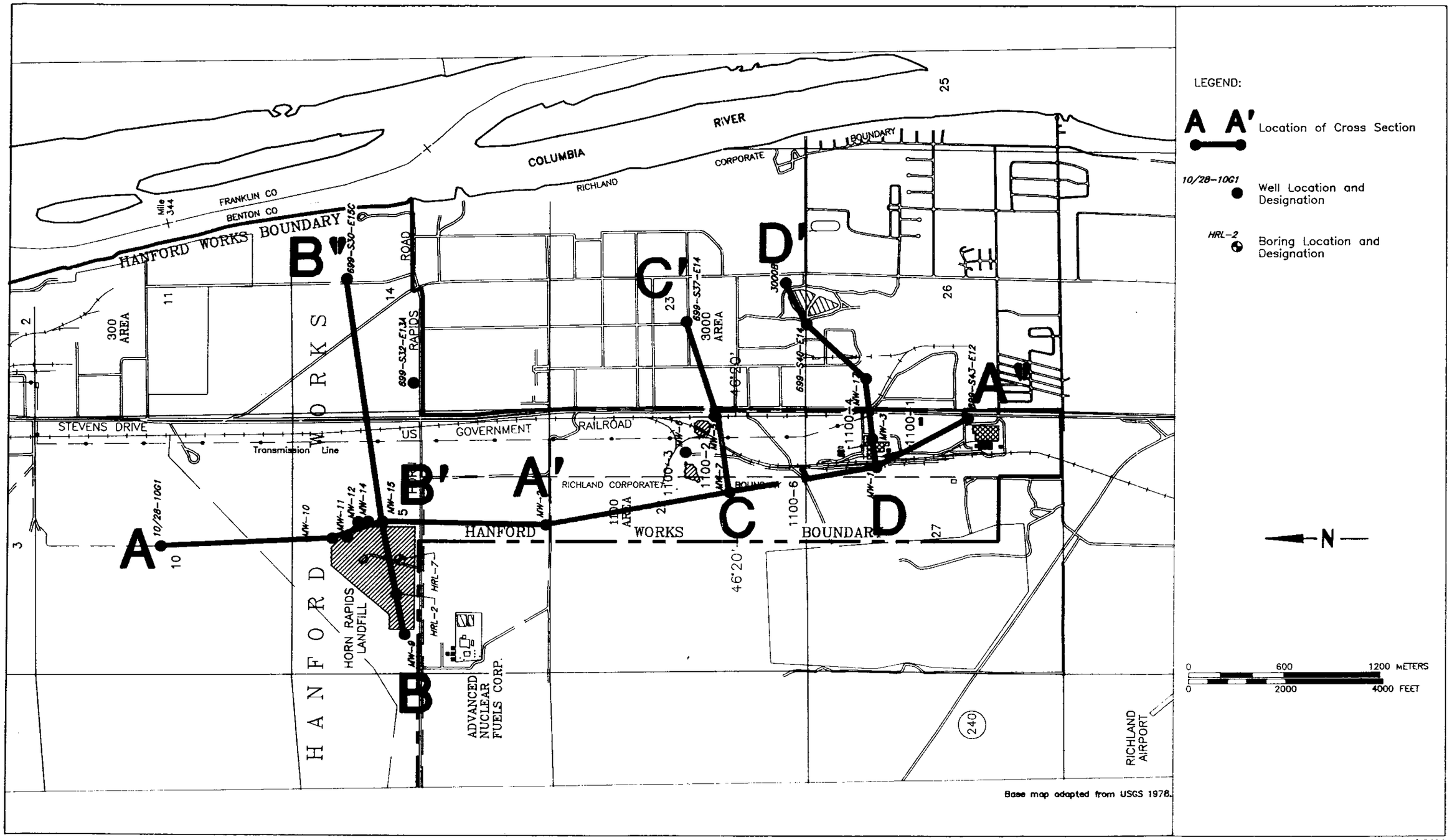

Figure 3-22. Cross Section Location Map.

A cross section identification map is provided in Figure 3-22. Cross section A-A''(which runs north-south from the Horn Rapids Landfill to south of the 1171 Building) is shown in Figure 3-23. Three east-west cross sections are also provided: B-B''(through the Horn Rapids Landfill) in Figure 3-24, and C-C' (near the 1100-2 and 1100-3 operable subunits) and D-D' (near the 1100-1 and 1100-4 operable subunits) in Figure 3-25.

It should be noted that the lithologies shown in the borehole logs in Appendix F for the monitoring wells and soil borings constructed during the first phase of the RI are based on visual field estimates of grain-size distribution using the Wentworth grain-size scale, as modified by Folk (1974). As discussed in Section 3.5.2.2, Soil Physical Properties, selected soil samples were analyzed in the laboratory to determine grain size, using the Unified Soil Classification System to define the lithology. The results of the more precise laboratory sieve analyses were used to define the lithologies shown on the cross sections if there was a significant discrepancy between the sieve analysis and the lithologic type identified on the borehole log. However, where there were only minor variations in the amount of interstitial silt or sand recorded on the borehole log versus the sieve analysis, the lithology on the borehole log was retained on the cross sections.

Each of the stratigraphic units at the operable unit is described further below in order of deposition. Appendix F includes a table showing the depths and elevations of the stratigraphic units identified in the borings and wells constructed during the first phase of the 1100-EM-1 RI.

Columbia River Basalt Group

The Ice Harbor Member of the Saddle Mountains Basalt Formation is reported by DOE (1988) to be the uppermost basalt flow in the vicinity of the 1100-EM-1 Operable Unit. This flow erupted approximately 8.5 million years before present (McKee et al. 1977). Logs from two nearby wells, located approximately 1,220 m (4,000 ft) to the north and 1,520 m (5,000 ft) to the east of the Horn Rapids Landfill—10/28-10G1 and 699-S30-E15C, respectively—indicate that the depth to basalt is approximately 59 to 65 m (195 to 213 ft) below the ground surface. A well approximately 1.6 km (1 mi) south of the 1100 Area is reported to have intersected basalt at a depth of approximately 66 m (216 ft) (Myers and Price 1979). However, no well number or log could be found to verify this reported depth.

Ringold Formation

Data available for the characterization of the Ringold Formation in the vicinity of the 1100-EM-1 Operable Unit are somewhat limited in number. Of the monitoring wells installed and soil borings sampled during the initial phase of the RI, 20 penetrated the upper portion of the Ringold Formation to depths ranging from 7.7 to 38 m (25.3 to 125 ft) below the ground surface. The data show the upper portion of the Ringold Formation to consist primarily of interfingering sandy gravels, gravelly sands, silty sandy gravels, and silty gravelly sands, with discontinuous sand lenses. Data from the deeper monitoring wells show that these coarse-grained sediments are underlain by finer-grained facies comprised of silt, clay, sandy silt, and sand.

Gravels and sands in the upper portion of the Ringold Formation are poorly to moderately consolidated, and are calcareous in some wells. Sorting

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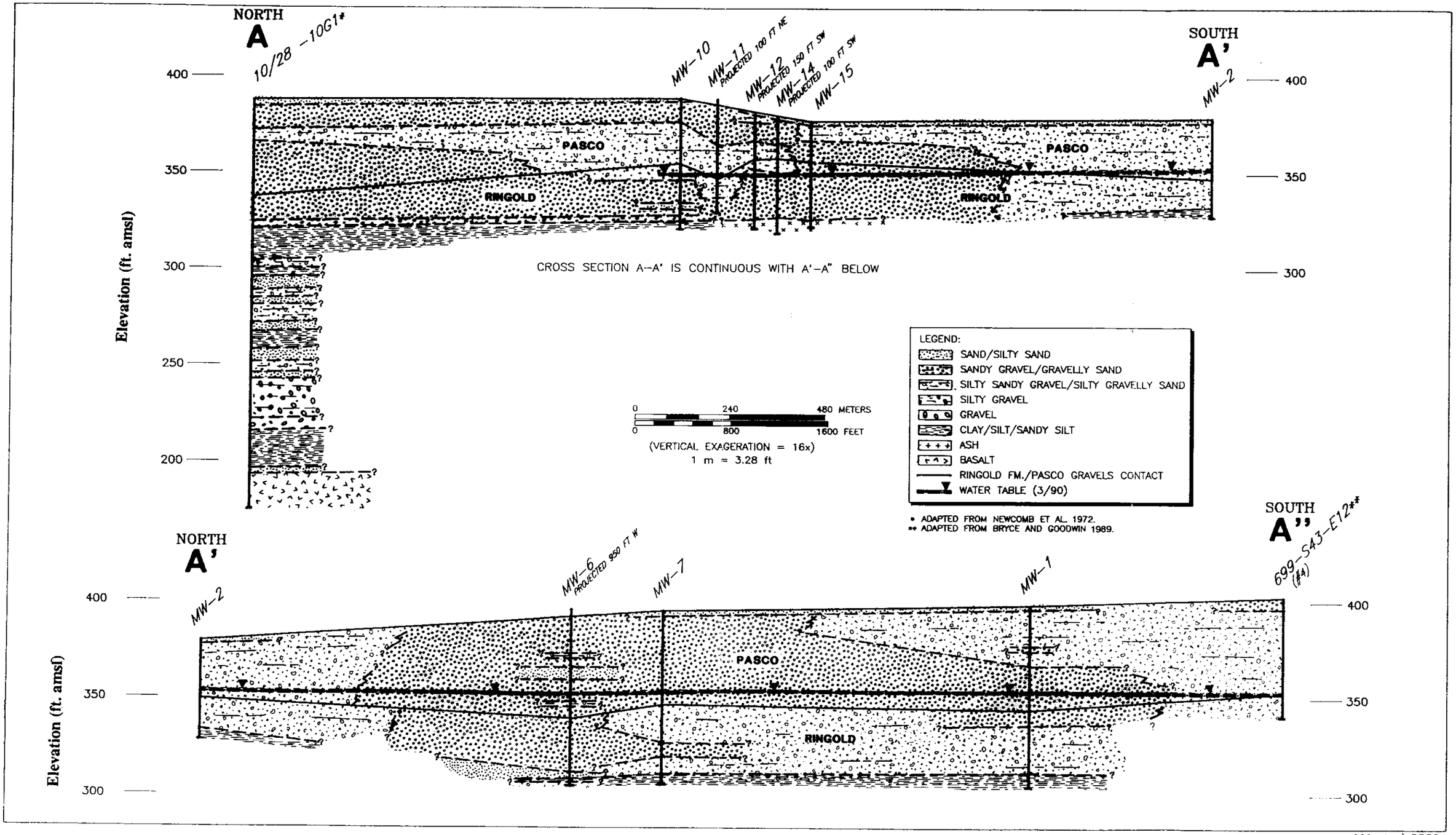

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Figure 3-23. Cross Section A-A" (See Figure 3-22).

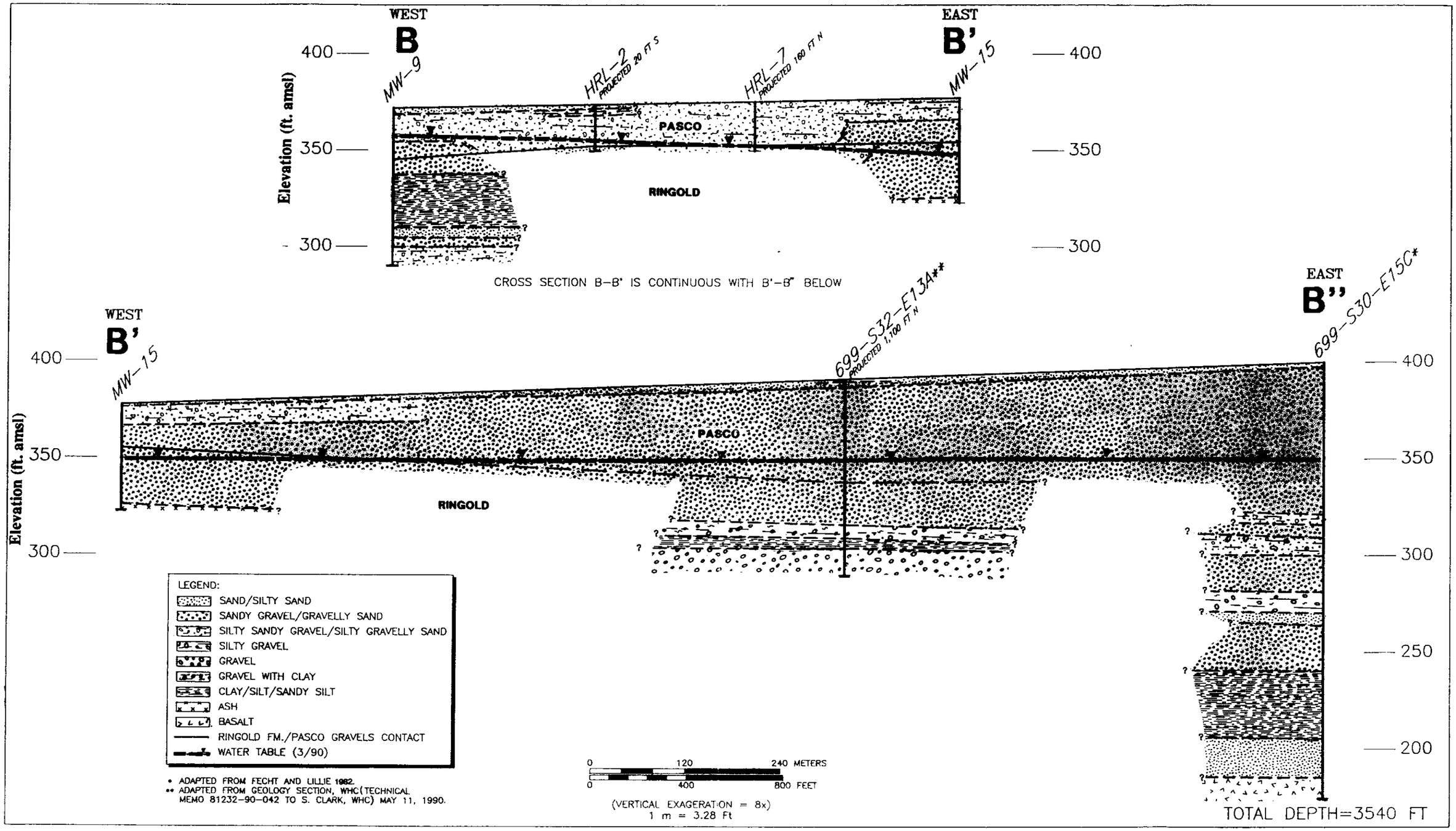

Figure 3-24. Cross Section B-B" (See Figure 3-22).

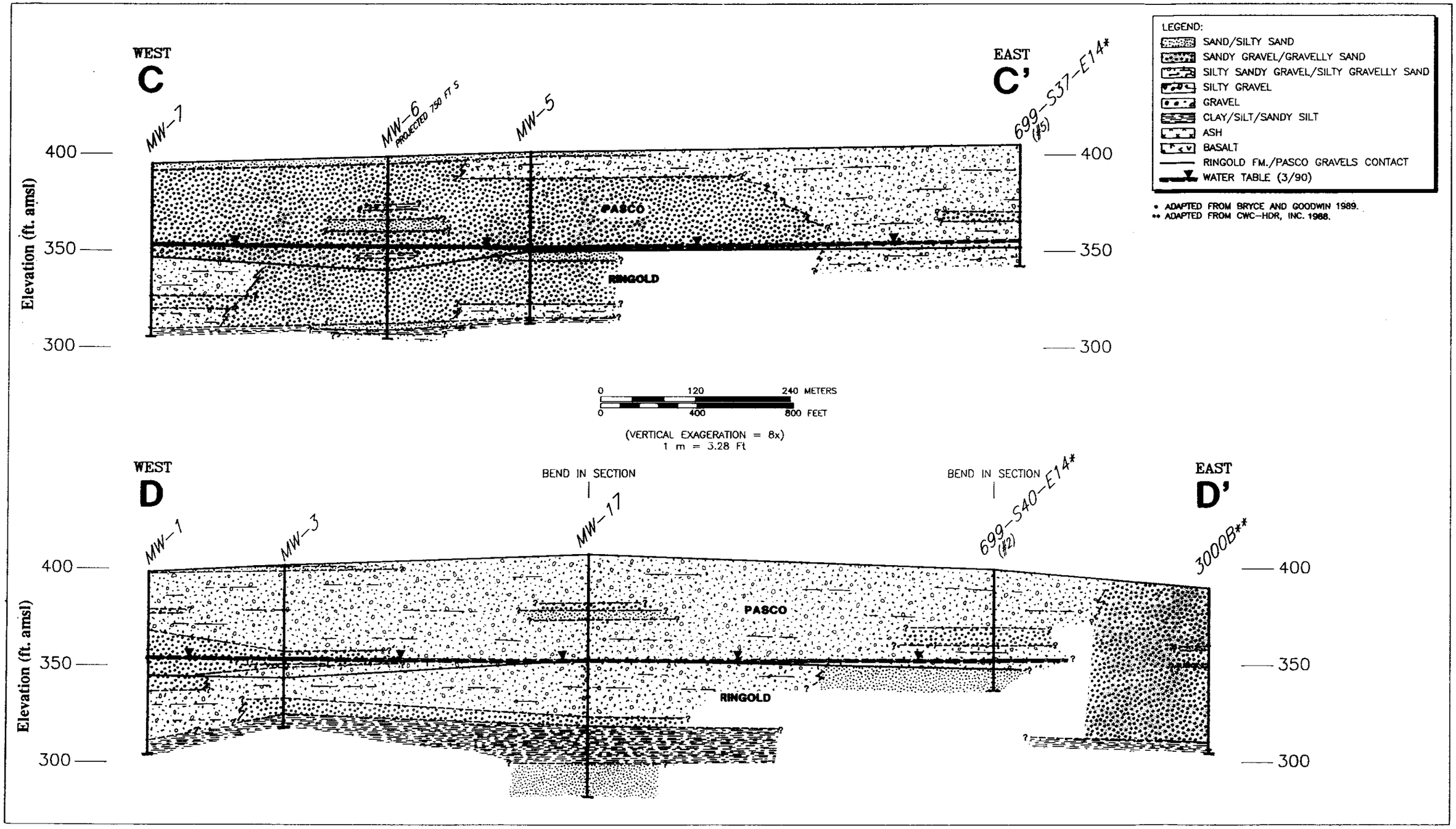

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Figure 3-25. Cross Section C-C "and D-D" (See Figure 3-22).

of the gravelly horizons is generally poor, whereas the sand units are primarily well-sorted. Sands are commonly angular to subangular, micaceous, and quartzitic. The gravels and sands are generally brown-gray to gray-brown, with olive grays and olive browns occurring locally. The lithologies of the gravel clasts indicate that they were derived principally from granitic and metamorphic rocks from outside the Pasco Basin. Within the gravel horizons, however, basaltic gravels and sands locally predominate, reflecting upstream erosion in basaltic portions of the Columbia River course.

The fine-grained sediments underlying the coarse-grained facies are commonly moderately consolidated, and the clayey horizons are generally plastic. The uppermost fine-grained unit consists of a brown to yellow-brown to olive silt-to-clay horizon that was encountered at all the deeper monitoring wells throughout the operable unit vicinity. In the few wells where the entire silty unit was penetrated, the thickness varies. In MW-9, at the Horn Rapids Landfill, and in MW-17, east of the 1171 Building, the silty unit is approximately 10 and 5.5 m (33 and 18 ft) thick, respectively. Between the Horn Rapids Landfill and the 1171 Building, however, MW-6 appears to penetrate only a 1.2-m (4-ft) thick silty sand and silt horizon underlain by silty gravelly sand.

The elevation of the top of the uppermost fine-grained Ringold Formation facies varies across the operable unit. As shown in north-south cross section A-A′ (see Figure 3-23), the fine-grained facies decreases in elevation southward, from approximately 99 to 103 m (324 to 337 ft) at the Horn Rapids Landfill to approximately 94 m (310 ft) in the vicinity of monitoring well MW-1, west of the 1171 Building. There is a 7-m (23-ft) decrease in elevation of the top of the silt between MW-2, where the elevation is 101 m (333 ft), and MW-6 and MW-7 to the south, where the elevations are approximately 94 m (310 ft). As shown in east-west cross section D-D′ (see Figure 3-25), there is a 4-m (13-ft) increase in elevation of the top of the silt between MW-1, west of the 1171 Building, and MW-3, located approximately 168 m (550 ft) to the east.

Similar fine-grained facies are reported in the upper portion of the Ringold Formation in many borehole logs for existing wells in and near the operable unit. In well 10/28-10G1, north of the Horn Rapids Landfill, an uppermost clay horizon is approximately 5 m (17 ft) thick (Newcomb et al. 1972) (see Figure 3-23). However, the quality of many of the existing borehole logs is such that the fine-grained sediments noted can not be definitively correlated with those present in the monitoring wells constructed for the first phase of the RI.

The available data therefore preclude determining whether the fine-grained Ringold sediments are laterally continuous over a broad area. Because of it's considerable thickness in MW-9, MW-17, and 10/28-10G1, the fine-grained facies may be laterally continuous within and near the operable unit. However, the fine-grained facies may have been eroded locally prior to deposition of the overlying Ringold Formation gravels, creating an irregular erosional surface at the top, and these sediments may have been completely eroded in some areas.

The probable depositional environment of the upper portion of the Ringold Formation beneath the operable unit is fluvial, in which the coarse-grained facies are interpreted to be high-energy, migratory river channel deposits,

and the fine-grained facies are interpreted to be overbank and lacustrine floodplain deposits.

In MW-12, MW-14, and MW-15, east of the Horn Rapids Landfill, a distinctive ash layer was encountered at an approximate elevation of 99 m (325 ft) (see Figures 3-23 and 3-24). The ash was examined by microscopy and shown to consist of white, angular-to-subangular, glassy, silt-sized grains showing no evidence of alteration other than mechanical breakage. Dark accessory mineral grains, probably heavy minerals and other mafic grains, constitute less than 1% of the ash. Some of the ash grains appear to be fragments of bubble-walls (glass containing gas bubbles entrapped during solidification). With the exception of a few very-thin layers of fine sand or of staining along depositional surfaces, bedding is mostly absent in core barrel and split spoon samples.

A thickness of 2.1 m (6.9 ft) of ash was penetrated in MW-14; because the three wells were ended prior to reaching the base of the ash unit, the total thickness is unknown. No ash of a comparable thickness or in a similar stratigraphic position has been reported from the Ringold Formation beneath the Hanford Site. The lateral extent of the ash appears to be very limited, in that the three closest wells to the south, west, and north (MW-2, MW-9, and MW-10, respectively) contained massive, brown-to-tan silt and clay (see Figures 3-23 and 3-24) at the same elevation as the ash. Ash is not reported to occur in the same stratigraphic position to the northeast in the 300 Area (Lindberg and Bond 1979; Schalla et al. 1988), and available existing borehole logs to the east and southeast do not report an ash unit in this stratigraphic position.

The depositional environment of the ash interval is unclear. The subangularity of the ash grains, the lack of abundant bubble-wall shards, and the presence of minor sand stringers or staining along depositional surfaces suggests that some reworking by fluvial processes has occurred subsequent to deposition, presumably by airfall. However, the generally massive bedding and the lack of non-volcanic material, as well as the absence of chemically weathered grains, suggests that reworking was not extensive.

The ash appears to be laterally continuous with the uppermost Ringold Formation clayey silt in nearby wells at the Horn Rapids Landfill. The clayey silt in this vicinity has been tentatively identified as a paleosol, based on the absence of bedding fabric, the massive appearance, a pattern of disaggregation typical of paleosols in the Ringold Formation throughout the Hanford Site, and the mixing of silt- and clay-sized grains, which suggests bioturbation. Based on current knowledge of the Ringold depositional system, this paleosol is inferred to have formed in an overbank setting where muds deposited by floods were subjected to pedogenic alteration.

The most-favored hypothesis to interpret the relationships between the environment of deposition of the ash and the apparently laterally continuous clayey silt paleosol is that they are separated by an erosional surface (disconformity). The clayey silt is tentatively interpreted to be a paleosol formed in an overbank setting where muds deposited by floods subsequently underwent pedogenic alteration. The absence of chemical weathering in the ash precludes it from being correlative with the paleosol. The ash unit is tentatively interpreted to be an airfall ash deposit of limited extent that was subsequently reworked by a fluvial system on a local erosional surface

capping the clayey silt paleosol. The ash may have been transported to its present location by a nearby drainage, possibly the ancestral Yakima River, which drained the volcanic Cascade terrain. A relatively close source could account for the purity of the ash and the lack of major mechanical erosion resulting in only minor reworking of the ash.

This proposed hypothesis is supported by the abrupt lateral change from ash to clayey silt, the evidence of a paleosol in the clayey silt, the subangularity of some ash grains, and the thin layers of sand and stringers of staining along horizontal depositional planes in the ash unit. However, insufficient data are available to allow a complete understanding of the geometry and depositional environment of the ash interval.

The shallow depth of the monitoring wells constructed during the first phase of the RI precludes determining the nature and thickness of the lower portion of Ringold Formation beneath the operable unit. The overall thickness of the Ringold Formation has therefore been estimated, based on the assumption that the approximate elevation of the top of basalt is 59 m (195 ft) (Myers and Price 1979), and that elevation of the top of the Ringold Formation ranges from 103 to 111 m (337 to 364 ft). Using these assumptions, the thickness of the Ringold Formation beneath the operable unit is estimated to range from approximately 43 to 52 m (142 to 169 ft). This thickness is consistent with the thickness of the Ringold Formation in the north Richland well field area, which is reported by CWC-HDR, Inc. (1988) to range from 30 to 46 m (100 to 150 ft). Total thickness of the Ringold Formation in test well 10/28-10G1, located approximately 1.3 km (0.7 mi) north of the Horn Rapids Landfill, is reported by Newcomb et al. (1972) to be approximately 44 m (144 ft). In the 300 Area, approximately 1.9 km (1 mi) northeast of the Horn Rapids Landfill, the Ringold Formation is approximately 46 m (150 ft) thick (Lindberg and Bond 1979).

The lithologic units in the upper portion of the Ringold Formation beneath the 1100-EM-1 Operable Unit, as recorded in the borehole logs for the ground-water monitoring wells constructed for the first phase of the RI, are tentatively interpreted to be equivalent to the middle Ringold textural facies of Newcomb (1958) and Myers and Price (1979). It is also proposed that, based on the elevation of the middle and upper Ringold units exposed east of the operable unit along the White Bluffs, the upper portion of the middle Ringold unit and the upper Ringold unit of Newcomb (1958) and Myers and Price (1979) are not present beneath the operable unit, and have most likely been removed by erosion.

The composition of the lower portion of Ringold Formation beneath the operable unit shown in the stratigraphic column in Figure 3-21 is based on the borehole log for test well 10/28-10G1. The lowermost 7 m (23 ft) of this test well are reported by Newcomb et al. (1972) to consist of gray-tan and blue-gray silts and clays overlying a thin basal basaltic sand. This fine-grained facies is tentatively interpreted in this investigation to be equivalent to the lower Ringold lithofacies of Newcomb (1958) and Myers and Price (1979). The overlying Ringold sediments in well 10/28-10G1 consist primarily of gravel, gravelly sand, sand, and silty sand, with interbeds of clay and siltstone. These sediments are assumed in this study to be equivalent to the middle Ringold lithofacies of Newcomb (1958) and Myers and Price (1979).

The upper surface of the Ringold Formation beneath the operable unit is gently undulating, and is the result of glaciofluvial erosion by the overlying Pasco gravels of the Hanford formation.

Hanford Formation

The Pasco gravels are the dominant facies of the Hanford formation in the vicinity of the 1100-EM-1 Operable Unit. The distinction between the Pasco gravels and the Ringold Formation is generally made on the basis of mineralogy, grain size, weathering of basalt clasts, and cementation. Pasco gravels have a higher percentage of basaltic materials, and are generally coarser-grained and uncemented. Pasco gravel basalt clasts are commonly less weathered than basalt clasts in the Ringold Formation.

The Pasco gravels unconformably overlie the Ringold Formation at the 1100-EM-1 Operable Unit and consist of a variable mixture of boulders, cobbles, pebbles, sands, and silts. Most of the Pasco gravels can be classified as moderately-to-poorly-sorted, unconsolidated sandy gravels to gravelly sands and silty sandy gravels. Sand lenses up to 2 m (7 ft) thick are present locally. The gravels are composed primarily of subrounded-to-rounded, unweathered basalt clasts with lesser amounts of mixed granitic and metamorphic lithologies. Calcium carbonate rinds occur on some gravel clasts and reworked caliche clasts are present locally. The sand fraction is angular-to-rounded and medium-to-coarse grained, and contains from 20 to 90% basalt. The color ranges primarily from dark grays to dark browns, with lighter-brown materials locally present near the ground surface.

Within the 1100-EM-1 Operable Unit, the Pasco gravels range in thickness from approximately 7.6 m (25 ft) at the Horn Rapids Landfill to 17 m (56 ft) in the vicinity of the 1171 Building. Within the five ground-water monitoring wells constructed east of the 1100 Area, the thickness of the Pasco gravels was identified as approximately 15 m (50 ft) (Bryce and Goodwin 1989).

The Pasco gravels were deposited during multiple Pleistocene glaciofluvial flood events on an irregular erosional surface of the Ringold Formation. The predominantly coarse-grained facies present beneath the 1100-EM-1 Operable Unit indicate that the area was within a main channelway of these floods.

Lindberg and Bond (1979) have identified two cycles of graded bedding within the Pasco gravels at the 300 Area. They interpret each fining-upward sequence to represent deposition of coarse sediments during initial surges of flood waters; the finer sediments were deposited later as each flood surge decreased. The finer portion of the second, or upper, cycle is not present in the 300 Area, and Lindberg and Bond (1979) suggest that it may have been removed by erosion. These fining-upward sequences in the Pasco gravels were not recognized in the vicinity of the 1100-EM-1 Operable Unit.

Surficial Deposits

Holocene eolian deposits locally form a thin veneer that generally overlies the Hanford formation at the operable unit. This veneer ranges from less than 0.3 m (1 ft) to more than 1.8 m (6 ft) in thickness. The eolian deposits are wind-transported sand that was derived primarily from reworked Hanford formation sediments. In some portions of the 1100-EM-1 Operable Unit,

these sands form dunes with amplitudes of more than 3 m (10 ft); the dune south of UN-1100-6 has an amplitude of approximately 6 m (20 ft).

These sands are generally composed of brown, very-fine-to-medium-grained sand or silty sand. They are moderately-to-well sorted, contain from 10 to 80% mafic constituents, and commonly contain root hairs and plant material. Surficial materials at some 1100-EM-1 operable subunits also include backfill, which is commonly indistinguishable from the in-situ Pasco gravels.

3.4.3.2 Local Geologic Structure. The Columbia River Basalts within the area of 1100-EM-1 are interpreted by Myers and Price (1979) to be folded into a broad, gentle, northwest-trending syncline, identified as the Pasco syncline (Figure 3-26). The 1100-EM-1 operable subunits are located near the axis of this syncline, on its gently-sloping western flank. The Pasco syncline slopes gently northwestward toward a flat structural low referred to as the Wye Barricade depression (DOE 1988), where it loses definition. Geologic structures in the upper portion of the Ringold Formation and the Pasco gravels have not been identified in the area of the 1100-EM-1 Operable Unit.

3.5 PEDOLOGICAL CHARACTERISTICS

As mentioned earlier, the term "pedology" is used in this report to refer broadly to the study of the nature, properties, formation, distribution, classification, function, and uses of soils. The term "soil" is also used broadly as a synonym for regolith, and thus refers to all unconsolidated materials overlying the basalt bedrock.

Pertinent pedological characteristics discussed below, on both the regional and local scales, include surface, unsaturated, and saturated soil types and variabilities and general engineering and biological properties. Section 3.4 (Geological Characteristics) provides an overview of the entire relevant geologic system; Section 3.6 (Hydrogeological Characteristics) contains a discussion of physical characteristics of the ground-water system, including a description of the hydrologic properties of the vadose and saturated zones. The known nature and extent of contamination in the 1100-EM-1 soil system is presented in Section 4.4 (Soil Contamination).

3.5.1 Regional Pedology

The earliest soil survey of Benton County, which includes most of the Hanford Site, was performed in 1916 by Kocher et al. (1921). Maps generated from this survey indicate that the soils in the Hanford Site area belong to four major groups that can be classified according to their origin: "soils derived from loessial or wind-borne material; soils derived from eolian or wind-blown material; soils derived from old valley-filling material, mainly lake-laid; and soil derived from stream-laid material." Kocher et al. (1921) mapped 26 classes of soils within these four groups, and three classes of miscellaneous nonagricultural material, including scabland, river wash, and dune sand.

The major soil types mapped in the southeastern portion of the Hanford Site included Winchester sand, Winchester fine sand, Ephrata sand, and Ephrata fine sandy loam. The soils of the Winchester series are basaltic, loose and

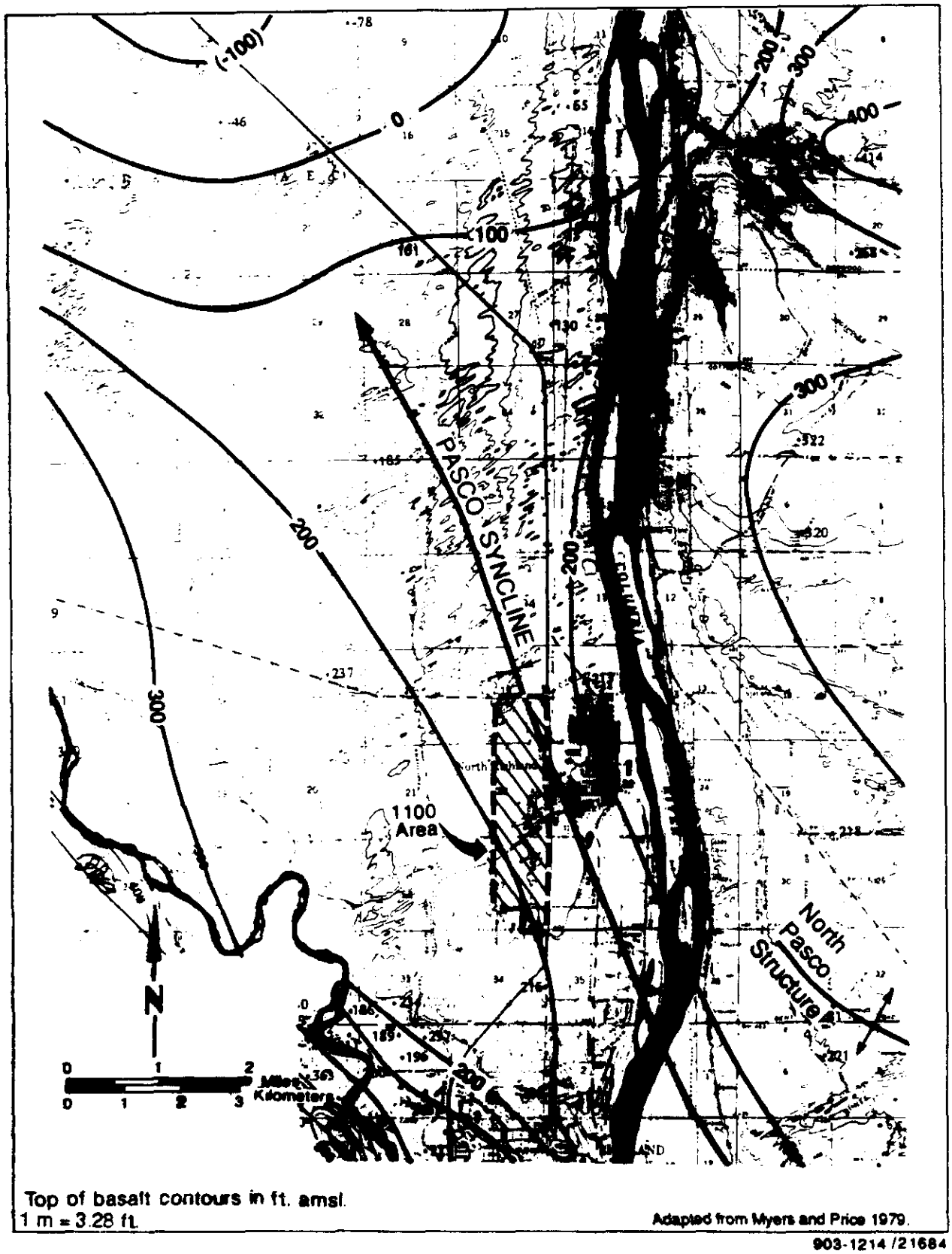

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Figure 3-26. Top of Basalt Contour Map Showing Local Geologic Structure.

open, and of low moisture-retaining capacity. The Ephrata series overly a substratum of gravels and sand and are somewhat calcareous. The gravelly phase and the heavy phase of the Ephrata fine sandy loam are reported by Kocher et al. (1921) to be the soils of greatest agricultural significance in Benton County.

A generalized soil survey of the western United States (Western States Land-Grant Universities and Colleges and SCS 1964) describes the Hanford Site area of the Pasco Basin, south and west of the Columbia River, as containing predominantly immature soils on unconsolidated upland materials and eolian sands. These soils are classified primarily as regosols, based on the soil classification system of Baldwin et al. (1938) as revised by Thorp and Smith (1949).

Regosols are largely dominated by the characteristics of the parent materials, and soil development is limited to weak accumulations of organic matter. Few or no clearly defined soil horizons are present in regosols. The regosols of the Hanford Site area occur on glaciofluvial deposits that have been continually shifted and sorted by wind erosion and deposition. These soils support a shrub-steppe vegetation community, and are used principally for grazing and limited irrigated crop production. Regosols are classified as entisols under a more recent classification system (SCS 1960).

A detailed soil survey of Benton County was performed by Rasmussen (1971). This survey excludes the Hanford Site and the Horn Rapids Triangle. West of the Horn Rapids Triangle, Rasmussen (1971) indicates that the dominant soil association is the Hezel-Quincy-Burbank association, consisting of fine-to-coarse-textured soils that have a loamy sand surface layer formed in wind-blown sand, lacustrine material, or alluvium. Soils of the Hezel-Quincy-Burbank association are classified as regosols. Rasmussen (1971) indicates that these soils, if managed properly, are suitable to support irrigated croplands. The engineering properties are variable because of the range of textures represented by this soil association.

Hajek (1966) presents a soil map and descriptive report of soils in the Benton County portion of the Hanford Site, exclusive of the 1100 Area. He identifies thirteen major soil types on the Hanford Site, on the basis of morphologic and genetic characteristics. He also provides an approximate land use capability classification for these soils, on the basis of soil limitations for, and damage risks associated with, agricultural use. Approximate engineering classifications for these soils, using the Unified Soil Classification System, are also provided in Hajek's report.

North of Horn Rapids Road on the Hanford Site, Hajek (1966) identifies three major soil types: Rupert sand, Burbank loamy sand, and Ephrata sandy loam. The predominant soil type in this area, Rupert sand, represents one of the most extensive soils on the Hanford Site. This soil type is classified as a regosol that developed under a growth of grass, sagebrush, and hopsage in coarse, sandy glaciofluvial deposits that are mantled by wind-blown sand. Relief characteristically consists of hummocky terraces and dune-like ridges.

Hajek (1966) indicates that Rupert sands can be used for limited grazing and extremely limited irrigated cropland use. He assigned the surface Rupert sands to engineering soil Group SM, which consists of silty sands containing

more than 12% fines that have little or no plasticity. Kocher et al. (1921) identified the Rupert sand as Winchester sand and Winchester fine sand.

Hajek (1966) also identifies small areas of Burbank loamy sand and Ephrata sandy loam north of the Horn Rapids Road. These two soil types are underlain by sandy gravel and gravelly sands and are generally associated with one another. Hajek (1966) classified the Burbank loamy sand as a regosol and the Ephrata sandy loam as a seirozem-intergrade-to-regosol. Seirozem soils have a thin surface horizon underlain by a lighter-colored subsoil and a layer of carbonate accumulation. In the Benton County area, seirozem soils developed in loess, alluvium, and lacustrine deposits (Rasmussen 1971). Using the more recent SCS classification system (SCS 1960), Hajek (1966) classified the Burbank loamy sand as a typic torripsamment and the Ephrata sandy loam as an andic mollic camborthid, a great soil group of the order aridisol.

Both the Burbank and Ephrata soil types can be used for grazing, and the Ephrata sandy loam has some irrigated cropland potential. Hajek (1966) assigns the surface Burbank soil, along with the Rupert sand, to engineering soil Group SM. He assigns the surface Ephrata soils to Groups SM to ML (silty sands to silts having relatively low plasticity). Kocher et al. (1921) identified Burbank loamy sand as Ephrata sand, and Ephrata sandy loam as Ephrata fine sandy loam.

3.5.2 Local Pedology

The only soil survey available for the 1100-EM-1 Operable Unit is one that was conducted in 1916 by Kocher et al. (1921). Five soil types were identified within and near what is now the operable unit. These soils, with Hajek's (1966) nomenclature for soil types in parentheses, were: Winchester sand (Rupert sand), Winchester fine sand (Rupert sand), Ephrata fine sandy loam (Ephrata sandy loam), Ephrata sand (Burbank loamy sand), and Beverly very-fine sand (Burbank loamy sand). Each of these soils is discussed below in Section 3.5.2.1. Measured physical properties of the operable unit soils are discussed in Section 3.5.2.2.

3.5.2.1 Soil Types. The areal distribution of the five soil types identified in the operable unit vicinity is shown in Figure 3-27. The most prevalent of the five soil types is Winchester sand (Rupert sand). In addition to the five types, a localized deposit of dune sand exists to the south of UN-1100-6 and to the north-northeast of 1100-1 and 1100-4 (i.e., the 1171 Building). The dune sand is not discussed below because it was not regarded as a soil of agricultural significance by Kocher et al. (1921).

Winchester Sand (Rupert Sand)

The most extensive soil is the Winchester sand (see Figure 3-27), a dark-gray-to-almost-black, loose, medium-to-coarse sand with an average depth of 30 cm (12 in) (Kocher et al. 1921). The subsoil is a dark-brownish-gray-to-nearly-black sand that overlies loose, black, coarse-grained sand at 0.9 to 1.5 m (3 to 5 ft). The Winchester sand surface is generally covered with a thin mantle of dark-colored coarse sand, composed largely of small, rounded and subangular particles of basalt. The finer material, containing basalt and quartz grains, has a characteristic "pepper and salt" appearance. The soil is low in organic matter, well drained, and easily drifted by wind. In some

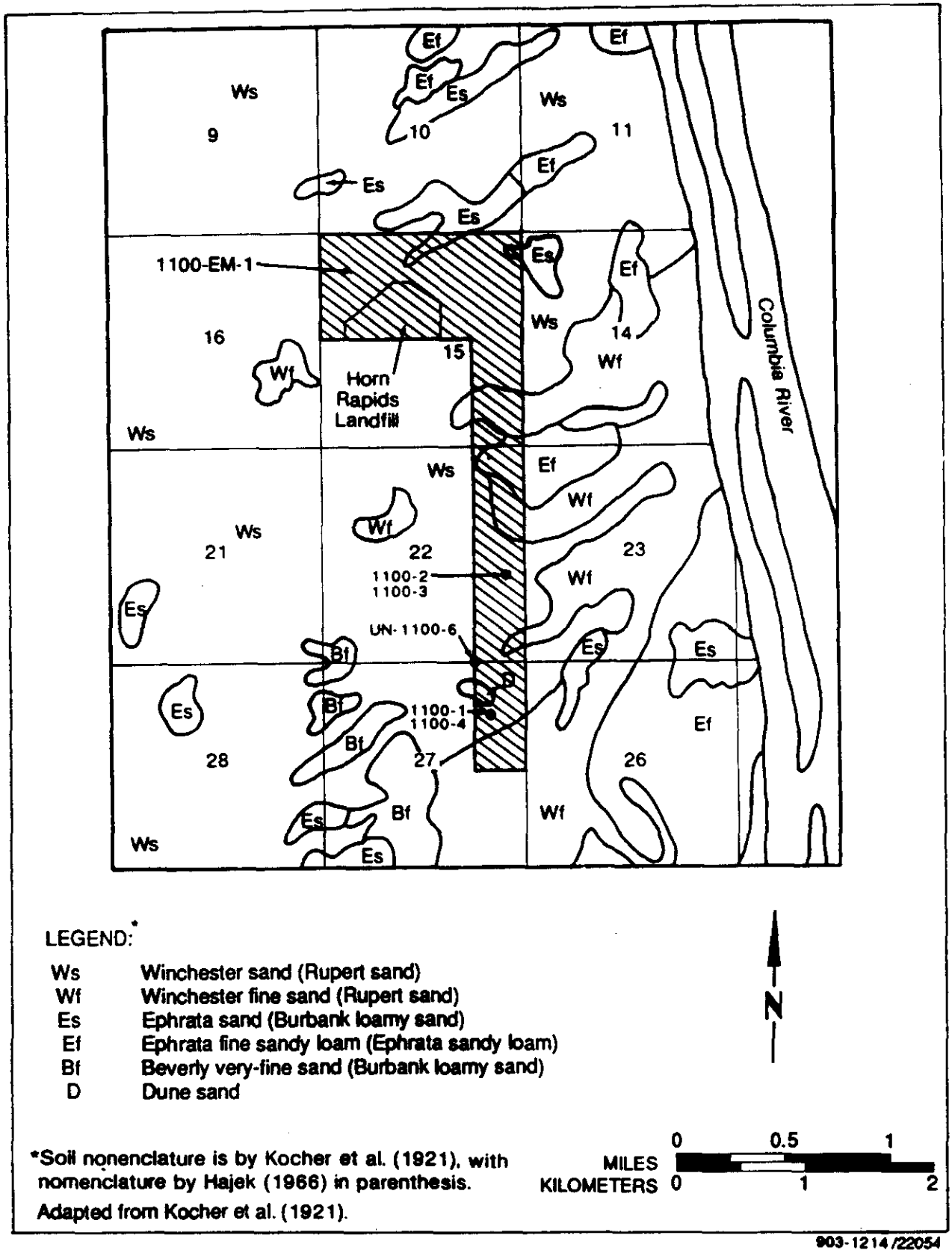

Figure 3-27. Soil Types in the 1100-EM-1 Operable Unit.

areas, basalt gravel occurs on the surface and within the first few upper centimeters (inches) of the soil.

Kocher et al.'s (1921) Winchester sand, north of Horn Rapids Road, was identified as Rupert sand by Hajek (1966). The Rupert sand is a regosol, according to the classification system devised by Baldwin et al. (1938), and a typic torripsamment, a great soil group of the entisol order, according to the SCS classification system (SCS 1960). The Unified Soil Classification System engineering classification of the surface Rupert soil is Group SM (a silty sand with little or no plasticity); the subsoil classification is SP to SM (poorly graded sand with silt) (Hajeck 1966).

In 1916, the Winchester sand in the vicinity of the operable unit supported a growth of only sagebrush and other desert shrubs (Kocher et al. 1921). However, elsewhere in the region, where irrigation was used, good yields of fruit were reported at the time. Hajek (1966) states that Rupert sands can be used for limited grazing and extremely limited irrigated crop production. A small irrigated plot of this soil, west of the 1100-EM-1 Operable Unit, is currently used for commercial potato production, and some portions of this soil are irrigated for the production of forage crops in the 3000 Area (see Section 3.1.1 and Figure 3-1).

Winchester Fine Sand (Rupert Sand)

This soil type is the second most common identified by Kocher et al. (1921) within what is now the 1100-EM-1 Operable Unit. This soil occurs near the 1100-2 and 1100-3 operable subunits and in the vicinity of the 1100-1 and 1100-4 subunits; the soil becomes more extensive east and southeast of the operable unit (see Figure 3-27). The Winchester fine sand is fine-grained, dark-gray-to-brownish-gray, loose sand that occurs to a depth of approximately 30 cm (12 in). The subsoil is a dark-brownish-gray-to-grayish-brown loose fine sand overlying sandy gravel at a depth of 0.9 m (3 ft) or more. Both the surface soil and the subsoil are low in organic matter, porous, and unconsolidated. The soil contains mica and basalt and has a characteristic "pepper and salt" appearance. Kocher et al. (1921) report that gravel may occur on the surface and throughout the soil section.

Soils identified as Winchester fine sand in 1916, along with the Winchester sand, were classified as Rupert sands by Hajek (1966). Kocher et al. (1921) indicates that Winchester fine sand was of little agricultural importance at the time, with only a few such areas of this soil type under cultivation in Benton County. The native vegetation on this soil in 1916 consisted primarily of sagebrush and greasewood, with very sparse bunchgrass. Currently, some portions of this soil within the nearby 3000 Area are irrigated for the production of forage crops (see Section 3.1.1 and Figure 3-1).

Ephrata Fine Sandy Loam (Ephrata Sandy Loam)

Kocher et al. (1921) identified a body of Ephrata fine sandy loam to the northeast of the 1100-2 and 1100-3 subunits; this soil becomes more extensive east of the southern half of the 1100-EM-1 Operable Unit (see Figure 3-27). Occurring to an average depth of 30 cm (12 in), the Ephrata fine sandy loam is a light-brown fine sandy loam that commonly contains a high percentage of very-fine sand. The subsoil is a light grayish-brown fine sandy loam or very-

fine sandy loam that occurs to an average depth of 1.5 m (5 ft) and overlies dark-colored sandy gravel. Both the surface soil and subsoil are compact. In some areas, gravel is abundant throughout the soil section.

Hajek (1966) classified the Ephrata fine sandy loam as Ephrata sandy loam, which is a seirozem-intergrade-to-regosol, in accordance to Baldwin et al. (1938), and an andic mollic camborthid, in accordance to SCS (1960). This soil type belongs within engineering classification Group SM to ML (silty sand to silt), with the subsoil being more narrowly confined within Group SM characteristics. Ephrata fine sandy loam (Ephrata sandy loam) is regarded as good soil for irrigated crop production, and portions of it are used for the production of forage crops in the 3000 Area; it is more commonly used for grazing.

Ephrata Sand (Burbank Loamy Sand)

Kocher et al. (1921) identified small bodies of Ephrata sand north of the Horn Rapids Landfill and south, west, and east of the operable unit (see Figure 3-27). The Ephrata sand is well-drained, light-brown-to-grayish-brown sand of medium-to-fine texture that extends to a depth of approximately 30 cm (12 in). The subsoil is generally similar to the surface soil, though it is lighter colored locally. The soil is underlain at depths of 76 cm (30 in) to 1.5 m (5 ft) with gravel embedded in coarse, black basaltic sand. Gravel is on the surface locally and, in places, through the entire soil column.

The Ephrata sand was identified by Hajek (1966) as Burbank loamy sand. The Burbank loamy sand is classified as a regosol based on the Baldwin et al. (1938) classification system, and a typic torripsamment in accordance with the SCS (1960) classification system. The Unified Soil Classification System engineering classification of the surficial Burbank soil is Group SM; the subsoil is classified as GM to GP (poorly-graded gravel with silt and sand) (Hajek 1966). The Ephrata sand (Burbank loamy sand) can be used for grazing (Kocher et al. 1921; Hajek 1966).

Beverly Very-Fine Sand (Burbank Loamy Sand)

To the west and southwest of the southern portion of the 1100-EM-1 Operable Unit, Kocher et al. (1921) identified bodies of Beverly very-fine sand (see Figure 3-27). In 1916, much of this soil type, within the vicinity of the current operable unit, was found in an elongated, northwest-trending wetland area situated within portions of Sections 27 and 35. Small remnants of this wetland exist today (see Figure 3-1). The Beverly very-fine sand was identified by Hajek (1966) as Burbank loamy sand, which is discussed above.

The soil of the Beverly very-fine sand is light brown with low organic content to an average depth of 03 cm (12 in). The subsoil, to 91 cm (36 in) or more in depth, is a compact, light-grayish-brown very-fine sandy loam. Both the surface soil and subsoil contain varying quantities of gravel, and the substratum below approximately 91 cm (36 in) is commonly gravelly. Gravel is also common on the surface in some areas of this soil type. In 1916, a small extent of this soil was under irrigation in the Richland area, and Kocher et al. (1921) stated that irrigation was necessary for the successful farming of the soil.

3.5.2.2 Soil Physical Properties. Surface soil and subsurface soil samples were collected for physical analysis—grain-size distribution and moisture content—during the first phase of the 1100-EM-1 RI. The results of the grain-size analyses are described below by operable subunit, for surface soils, and geologic stratum, for subsurface soils. Moisture content results are addressed separately on an operable unit basis. Soil permeability measurements, conducted during the first phase of the RI in association with the installation of ground-water monitoring wells, are presented and discussed in Section 3.6 (Hydrogeological Characteristics).

Grain-Size Distribution in Surface Soils

Grain-size distribution analyses were completed on approximately 250 soil samples collected from soil boreholes, monitoring well boreholes, and surface samples. The greatest sampling depth was 38 m (125 ft) below ground surface. Sample collection was done using either drive barrel or split spoon samplers during drilling or by scooping soils from the ground surface. Classification of the samples followed the Unified Soil Classification System. Appendix H contains a Unified Soil Classification for each sample analyzed. For surface soils, the average soil fraction exceeding 0.84 mm is provided to allow for subsequent wind erosion estimates in Section 5 (Contaminant Fate and Transport Analysis) in accordance with Skidmore and Woodruff (1968). The lower one-tailed 95% confidence limit of the mean fraction for the surface soils of each operable subunit, calculated by t-test, is presented as a conservatively biased estimate of the mean soil fraction exceeding 0.84 mm.

Seventeen surface soil samples were collected for grain-size analysis. Four samples were collected from the 1100-2 operable subunit (see Figure 2-12), four from 1100-3 (see Figure 2-13), three from UN-1100-6 (see Figure 2-14), and six samples from the Horn Rapids Landfill (see Figure 2-15). The gravel fraction of the samples includes particles failing to pass a no. 4 sieve (> 4.75 mm). Sand particles occur in the range from the no. 4 sieve to the no. 200 sieve (4.75 mm to 0.075 mm). Silt particles include the remaining fraction which passed the no. 200 sieve (< 0.075 mm). The surface soil textures are further described below according to operable subunit.

Areas sampled within the 1100-2 operable subunit have been disturbed by earth-moving equipment and are covered by sparse vegetation. The textures of the surface materials vary across the subunit, but are generally coarse-grained. Soil textures include gravel with silt and sand, sand with silt and gravel, and silty sand with gravel. The mean proportion of the 1100-2 surface soil exceeding 0.84 mm is 54%; the lower, one-tailed confidence limit of this estimate is 35% ($n = 4$; $\alpha = 0.05$).

The sampled areas within the 1100-3 operable subunit have also been disturbed and are covered by moderate-to-no vegetation. Soil textures are variable and include silty sand with gravel, gravel with silt and sand, and sand with silt and gravel. The mean fraction of surface soil that exceed 0.84 mm is 57%; the lower, one-tailed confidence limit is 37% ($n = 4$; $\alpha = 0.05$).

The soil textures from the three samples at the UN-1100-6 operable subunit are finer-grained and range from silty sand to poorly-graded sand. Vegetative cover at these sample locations is virtually nonexistent. Surface soil at UN-1100-6 is much more subject to wind erosion than at the other operable subunits due to predominance of the smaller grain sizes. The mean

fraction exceeding 0.84 mm is only 14%, with a lower, one-tailed confidence limit of 5% ($n = 3$; $\alpha = 0.05$).

Areas sampled within the Horn Rapids Landfill have been disturbed by earth-moving equipment and are covered by sparse-to-moderate vegetation. The textures of the surface materials vary considerably across the landfill, but are generally coarse-grained according to the Unified Soil Classification System. Soil textures include sand to silty sand with gravel and gravel with sand. One fine-grained sample (HRL-T-6-AH-172) contained sandy silt. There is no vegetative cover at this sample location. The average proportion of soil exceeding 0.84 mm is 51%; the lower, one-tailed confidence limit for this value at the landfill is 29% ($n = 6$; $\alpha = 0.05$).

Grain-Size Distribution in Subsurface Soils

The grain-size distribution summary for subsurface soils is based on samples collected from monitoring well boreholes that are widely distributed over the operable unit. These samples provide a general description of the soil textures at depth for both the Hanford formation and Ringold Formation, which are described below. Gravel, sand, and silt textures were defined based on sieve sizes described above for the surface samples.

Histograms of gravel, sand, and silt percentages occurring in samples from the Hanford formation are shown in Figure 3-28. The histograms indicate that most samples contain largely sand and gravel (35 to 65%) with little silt (0 to 10%). In terms of averages, the Hanford formation contains 43% gravel, 50% sand, and 7% silt. The coarse fraction of the grain-size analyses is predominantly classified as gravel, although cobbles are also observed in the samples. Note that the very coarse textures occurring in the Hanford formation, which potentially include boulders, are not well represented by either drive barrel or split spoon samples due to the relatively small size of the samplers.

Histograms of gravel, sand, and silt percentages observed in the Ringold Formation are shown in Figure 3-29. The histograms indicate that the texture distributions are complex, having multiple modes. There are notably greater percentages of silt in the Ringold Formation in comparison with the Hanford formation. This is likely attributable to the occurrence of silt-dominated strata within the Ringold Formation, whereas such strata are not observed in the Hanford formation. Excluding samples classified as silt, the average texture distribution for the Ringold Formation consists of 48% gravel, 44% sand, and 8% silt. In general, these coarse soils are very similar to those of the Hanford formation.

Soil Moisture Content

Soil moisture content was evaluated using samples collected above the water table in monitoring well boreholes. The moisture contents of these samples are generally representative of the in-situ moisture, as drainage from the soils during retrieval is unlikely and evaporation can only occur for a short period of less than about 10 min before the sample is contained. The group of samples evaluated were primarily from the Hanford formation, as the Ringold Formation occurs predominantly below the water table at the 1100-EM-1 Operable Unit.

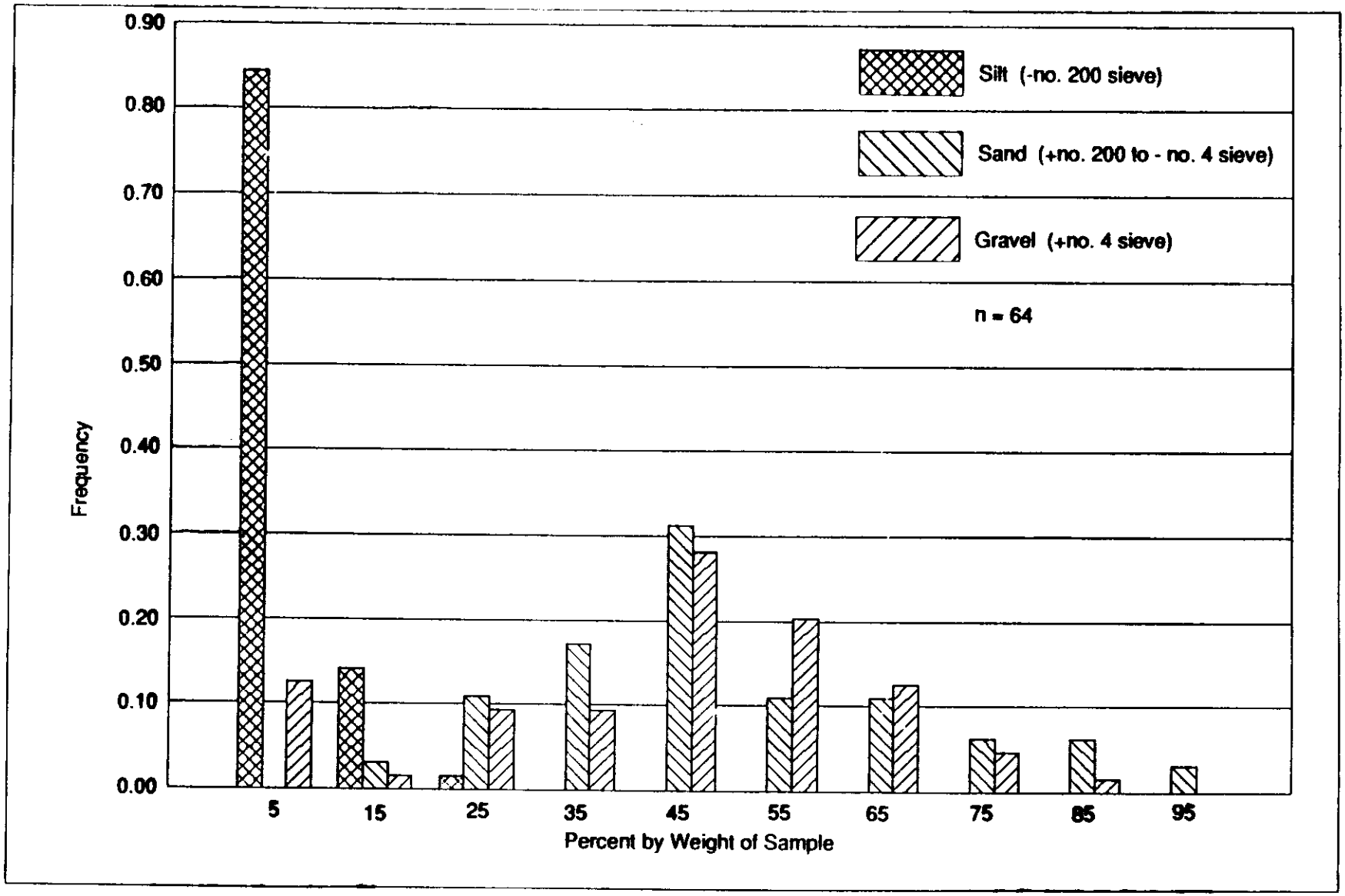

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Figure 3-28. Grain-Size Distribution Histograms for the Hanford Formation (Pasco Gravel Unit).

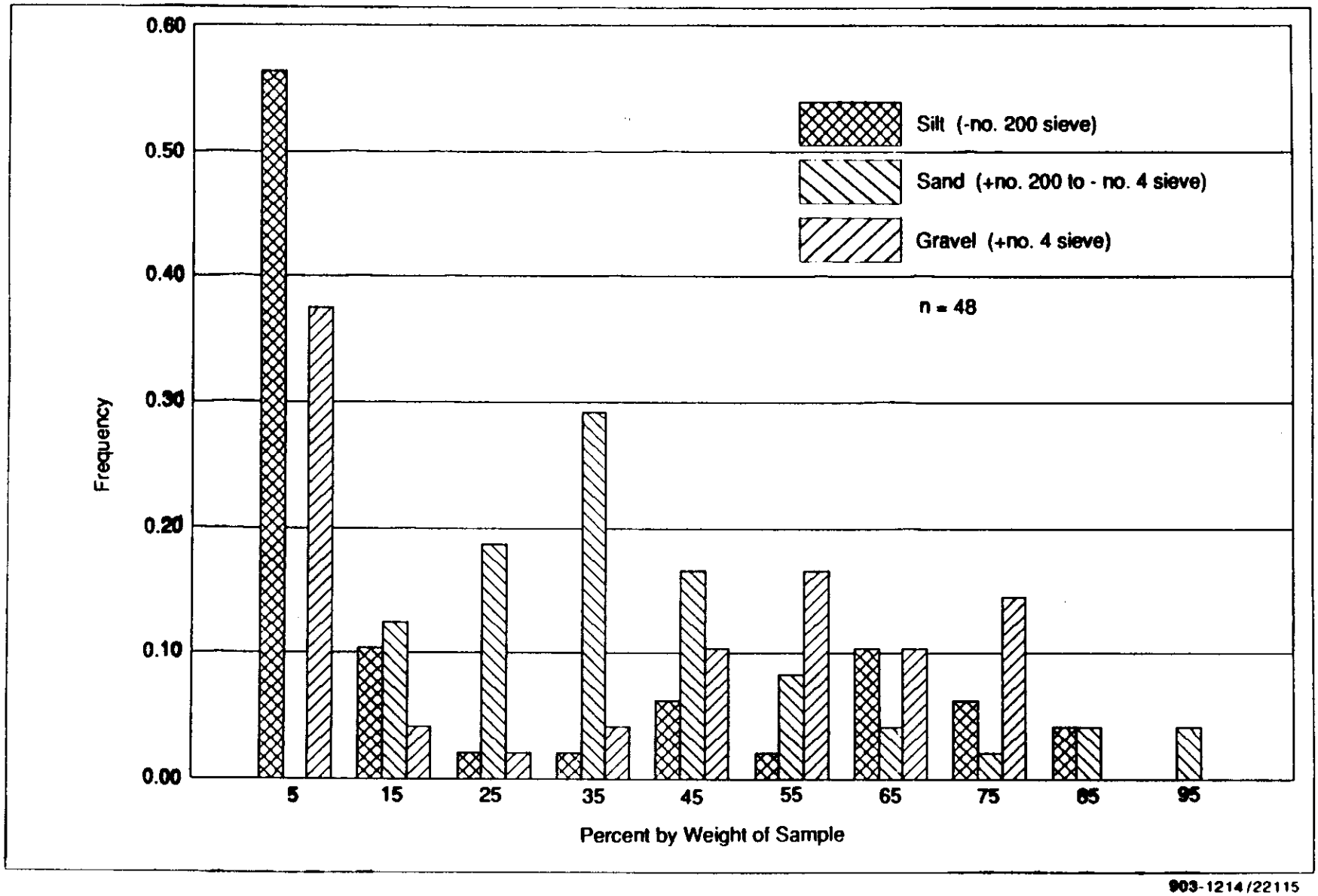

Figure 3-29. Grain-Size Distribution Histograms for the Ringold Formation.

Moisture content in the soils ranged from 1.09 to 7.28%. These values indicate the water content of the soils to be near or at residual levels.

3.6 HYDROGEOLOGICAL CHARACTERISTICS

This subsection presents the regional and local hydrogeology for the 1100-EM-1 Operable Unit. The discussion on regional hydrogeology summarizes ground-water conditions in the Pasco Basin, detailing the primary aquifers and providing the regional context necessary to understand the local hydrogeology. The local hydrogeology discussion, relying primarily on data collected during the initial phase of the RI, addresses each of the individual operable subunits within the 1100-EM-1 Operable Unit.

3.6.1 Regional Hydrogeology

Geologic structures and stratigraphy have a major influence on hydrogeology in the Pasco Basin and have been reviewed in detail in Section 3.4. In summary, the Pasco Basin is underlain by a thick sequence of basaltic rock (the Columbia River Basalt Group), which is overlain by unconsolidated fluvial (the Ringold Formation) and glaciofluvial (the Hanford formation) soils, respectively. The basalt and lower portion of the Ringold Formation were folded predominantly by north-south compression during Miocene-Pliocene time, creating a series of easterly-trending asymmetric synclines and anticlines (Figure 3-30). The synclinal portions of folds are generally broad areas of thick sediment accumulation, while their counterpart anticlines are more tightly folded, forming exposed ridges.

Aquifers within the Pasco Basin occur in both the basalt and the overlying sediments. The major aquifers include a near-surface unconfined aquifer in the sediments and confined aquifers in the lower portion of the Ringold Formation and in the interbeds, flow tops, and flow bottoms of the basalt. The unconfined aquifer is part of a flow system that is local to the Pasco Basin, as are the uppermost basalt interbed aquifers (Gephart et al. 1979, DOE 1988). Deeper in the basalt, interbed aquifer systems are part of the regional flow system, which extends outside the margins of the Pasco Basin (DOE 1988). Confined-to-semi-confined aquifers of more limited extent also occur in the soils of the Pasco Basin. These confined zones are generally located within the local flow system, between the unconfined aquifer and the underlying basalt surface. Figure 3-31 is a general hydrogeologic cross section showing this aquifer system (see Figure 3-30 for cross section orientation). Further discussion of the aquifer system is provided below.

3.6.1.1 Unconfined Aquifer. The uppermost aquifer in the Pasco Basin is a highly transmissive unconfined aquifer hosted by the middle unit of the Ringold Formation (as defined by Myers and Price 1979), and locally by the Pasco gravels member of the Hanford formation (Newcomb et al. 1972; Gephart et al. 1979; Deju and Fecht 1979; Graham 1983; Freshley and Graham 1988; DOE 1988). The aquifer is laterally extensive, occurring below most of the Hanford Site with thicknesses ranging from 15 to 60 m (50 to 200 ft).

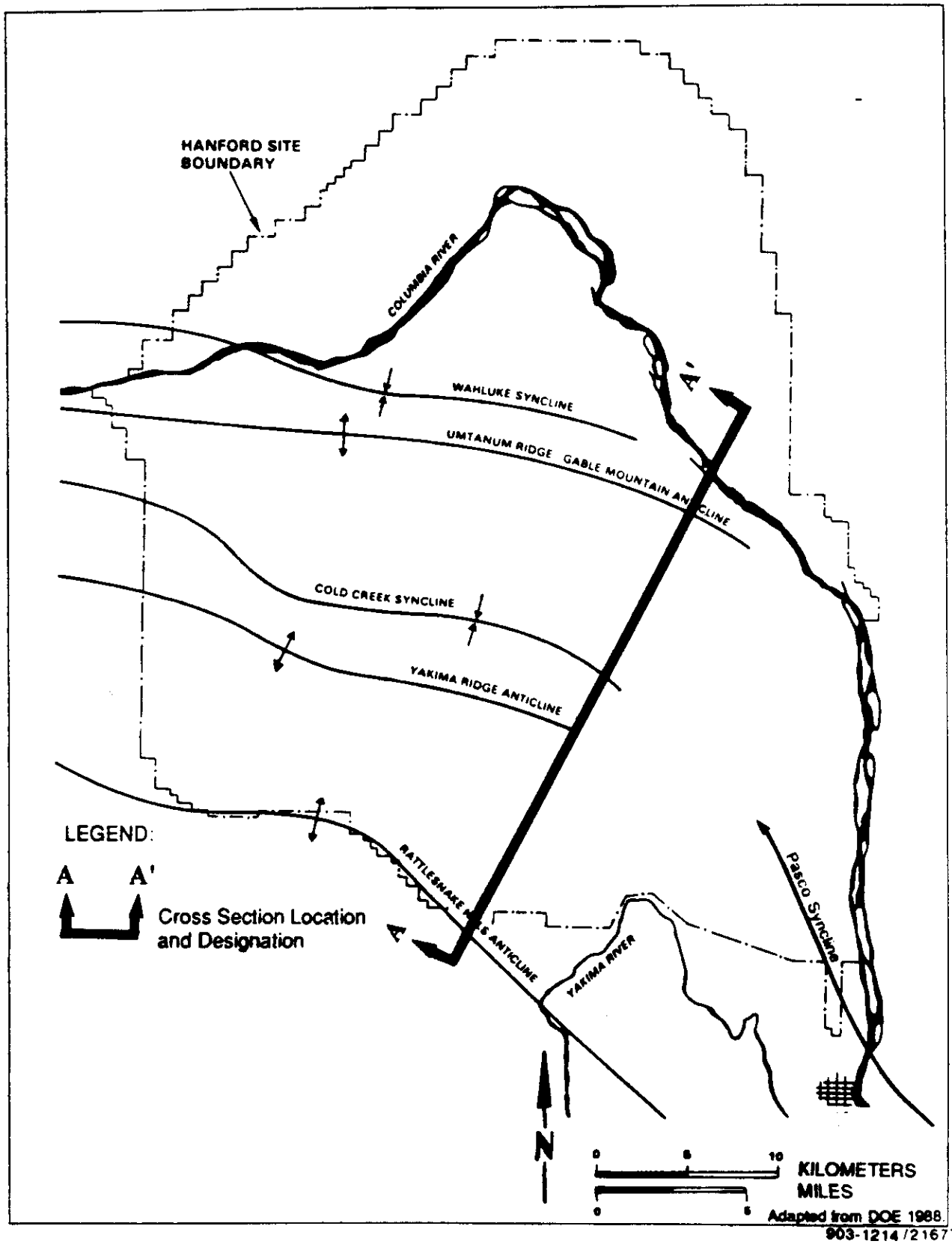

Figure 3-30. Major Geologic Structures of the Hanford Site.

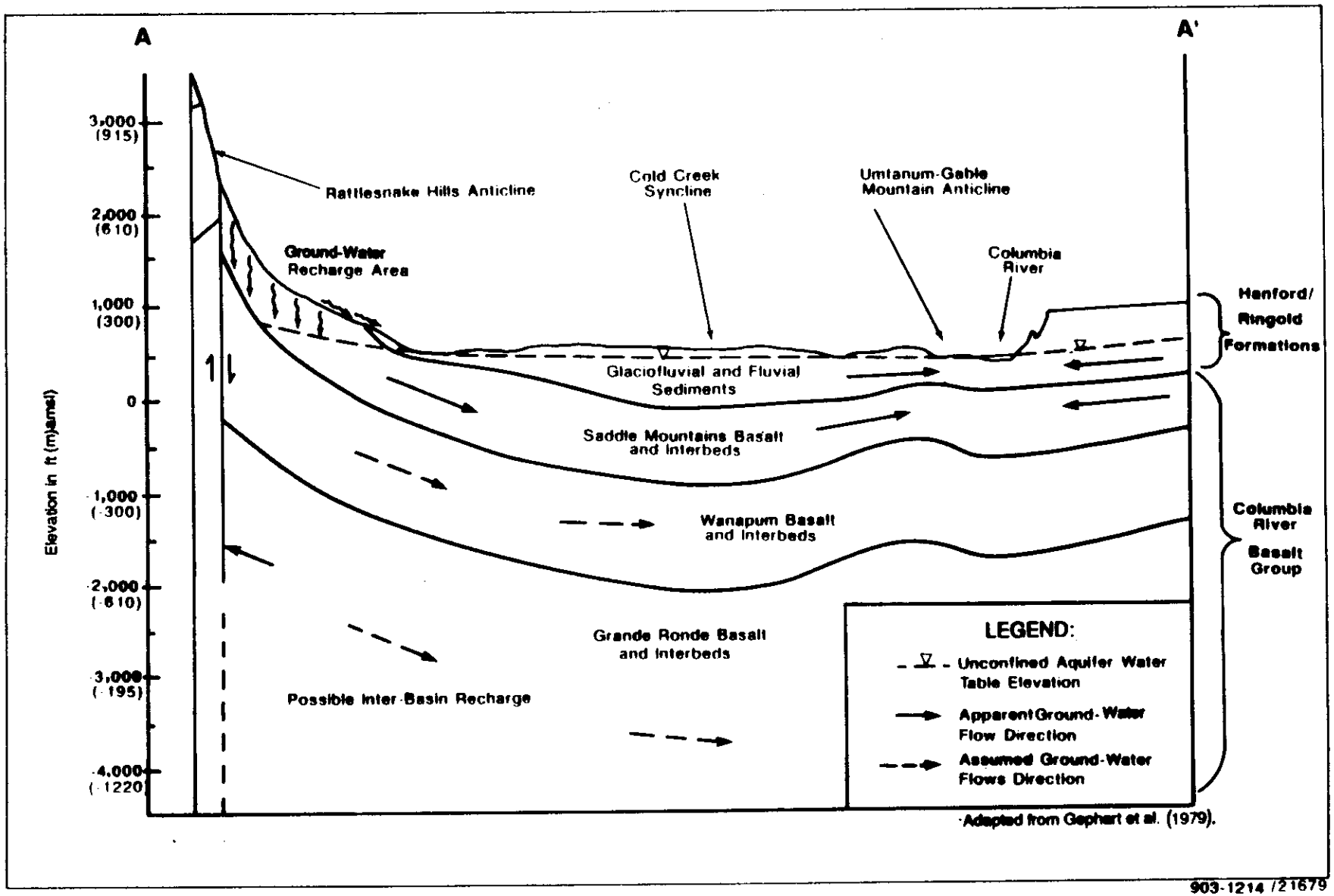

Figure 3-31. General Hydrogeologic Cross Section A-A' (See Figure 3-30).

Recharge

Natural recharge to the unconfined aquifer occurs primarily from run-off of precipitation onto Saddle Mountains, Umtanum and Yakima Ridges, and Rattlesnake Hills (Deju and Fecht 1979, Gephart et al. 1979; DOE 1988). The Yakima and Columbia Rivers also contribute to the total natural recharge, as may the deeper basalt aquifers (DOE 1988). In the vicinity of the 1100-EM-1 Operable Unit, the unconfined aquifer recharge is likely made up of discharge waters from the Yakima River (Freshley et al. 1989) and vertically discharging ground water from deeper basalt interbed aquifers (DOE 1988). Percolation of rain water directly to the unconfined aquifer appears to contribute little recharge. Ongoing lysimeter studies have shown direct precipitation recharge to range from 0 to 10 cm/yr (0 to 4 in/yr) (Gee 1987). During 1989, 4.3 cm (1.7 in) of water drained through gravel covered lysimeters in the 200 Area plateau (Rockhold et al. 1990).

Artificial recharge to the unconfined aquifer from industrial, agricultural, and municipal sources occurs at several locations in the Pasco Basin. Recharge through ponds and cribs at the 200 Areas is the largest single artificial recharge source, beginning in the late 1940's and continuing to present (Zimmerman et al. 1986; Graham 1983). Other artificial recharge sources include irrigation loss west of the 200 Areas (Graham 1983), infiltration ponds at Advanced Nuclear Fuels Corp. (USGS 1978), and infiltration ponds at the City of Richland well field (CWC-HDR, Inc. 1988).

Ground-Water Flow

Ground-water flow in the unconfined aquifer is predominantly horizontal from west to east (Zimmerman et al. 1986). Figure 3-32 shows a ground-water potential (elevation) map for the unconfined aquifer in December 1986 (DOE 1988). Horizontal ground-water flow occurs from areas of high potential to those of lower potential. Below the 200 East Area, where substantial artificial recharge has caused ground-water mounding, more variable flow directions have resulted. Under the influence of the mounding, flow in the unconfined aquifer is northward, passing between Gable Mountain and Gable Butte. Studies have shown that this flow may reverse if the artificial recharge were decommissioned, allowing the ground-water mound to dissipate (Engineering Science, Inc. and GAI 1989).

Discharge

Ground water discharges from the unconfined aquifer to the Columbia River along the eastern and northeastern margins of the Pasco Basin (Deju and Fecht 1979; Gephart et al. 1979; Freshley and Graham 1988; DOE 1988; Freshley et al. 1989). Away from the Columbia River toward the basin interior, ground-water discharge occurs into underlying Columbia River Basalt (Graham 1983, DOE 1988). Smaller ground-water volumes are discharged to water-supply wells used for domestic, municipal, and industrial purposes. Municipal wells at the City of Richland well field, located to the east of the 1100 Area, draw water from the unconfined aquifer for municipal supply with a total output capacity of 15,000 to 23,000 m^3/d (4,000,000 to 6,100,000 gal/d) (CWC-HDR, Inc. 1988). The well field is currently used as to supplement the city water supply during times of peak seasonal demand.

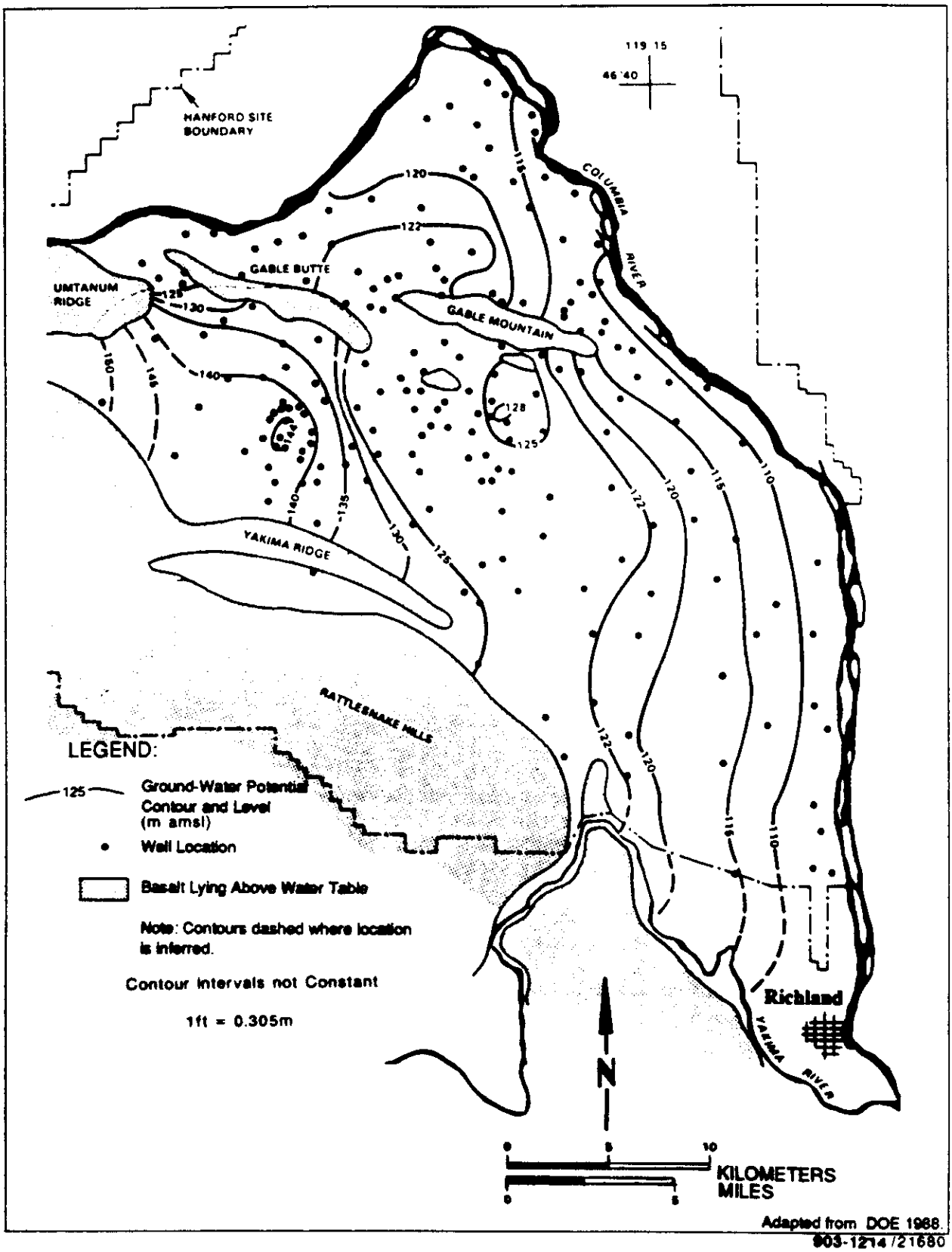

Figure 3-32. Ground-Water Potential Map for the Unconfined Aquifer, December 1986.

Hydraulic Properties

Equivalent hydraulic conductivity estimates for the unconfined aquifer have been mapped over the Hanford Site, as shown on Figure 3-33 (DOE 1988). The equivalent conductivities were obtained from pumping tests (Biershenk 1957; Kipp and Mudd 1973) and are not layer specific, but apply to the combined conductivity of all layers stressed during the test. The hydraulic conductivity range is from E-03 to E+00 cm/s (E+00 to E+03 ft/d), reflecting heterogeneity of the soils. Generally, saturated hydraulic conductivity is greater in the Hanford formation than in the Ringold Formation. Table 3-1 summarizes the anticipated ranges of saturated hydraulic conductivities for each stratigraphic interval in which the unconfined aquifer exists.

Fewer data are available on aquifer storativity for the unconfined aquifer. Storage coefficients determined in multiple well pumping tests for the unconfined aquifer ranged from 0.0002 to 0.07 (DOE 1988).

3.6.1.2 Confined Aquifers. Confined aquifers occur within the lower portion of the Ringold Formation, but are generally more limited in areal extent than the unconfined aquifer. In the western portion of the Pasco Basin, a confined-to-semi-confined aquifer is hosted by the basal unit of the Ringold Formation (as defined by DOE 1988; see Section 3.4.2.1). A thick silt deposit (the lower unit of the Ringold Formation as defined by DOE 1988) forms the intervening aquitard between the unconfined and confined zones. Other confined-to-semi-confined zones occur locally within the middle and lower units of the Ringold Formation as a result of interfingering silt aquitards and more permeable lenses of sand and gravel (see Section 3.6.2 below). These zones appear to be laterally discontinuous and likely merge with the unconfined system.

A multiple confined aquifer system occurs within the Columbia River Basalt Group underlying the Pasco Basin (Deju and Fecht 1979; Gephart et al. 1979; DOE 1988). The confined aquifers are primarily hosted by interbeds within the basalt (DOE 1988). The interbeds occur at lava flow contacts and consist of the flow top of the lower flow, intervening sedimentary deposits, and the flow bottom of the upper flow (Graham 1983). Flow interiors, comprised primarily of dense basalt, separate the interbeds forming confining aquitards. Sedimentary aquitards may also occur within the interbed layers. Communication among the interbed aquifers may be enhanced by fractures and faults present in the formation materials (DOE 1988).

The uppermost interbed aquifers are found in the Saddle Mountains Basalt. Interbed aquifers of the Saddle Mountains Basalt range in thickness from 6 to 35 m (20 to 110 ft) and are likely localized to the Pasco Basin by geologic structures along the basin margin (Gephart et al. 1979; DOE 1988). Deeper interbeds, which occur in the underlying Wanapum and Grande Ronde Basalt Formations, appear to be hydraulically connected with the regional flow system outside the Pasco Basin as well as upper interbed aquifers within the Pasco Basin (DOE 1988).

Recharge

Recharge to interbeds of the Saddle Mountains Basalt is obtained directly from precipitation onto the exposed basalt ridges surrounding and within the Pasco Basin (Deju and Fecht 1979; Gephart et al. 1979; DOE 1988). Leakage

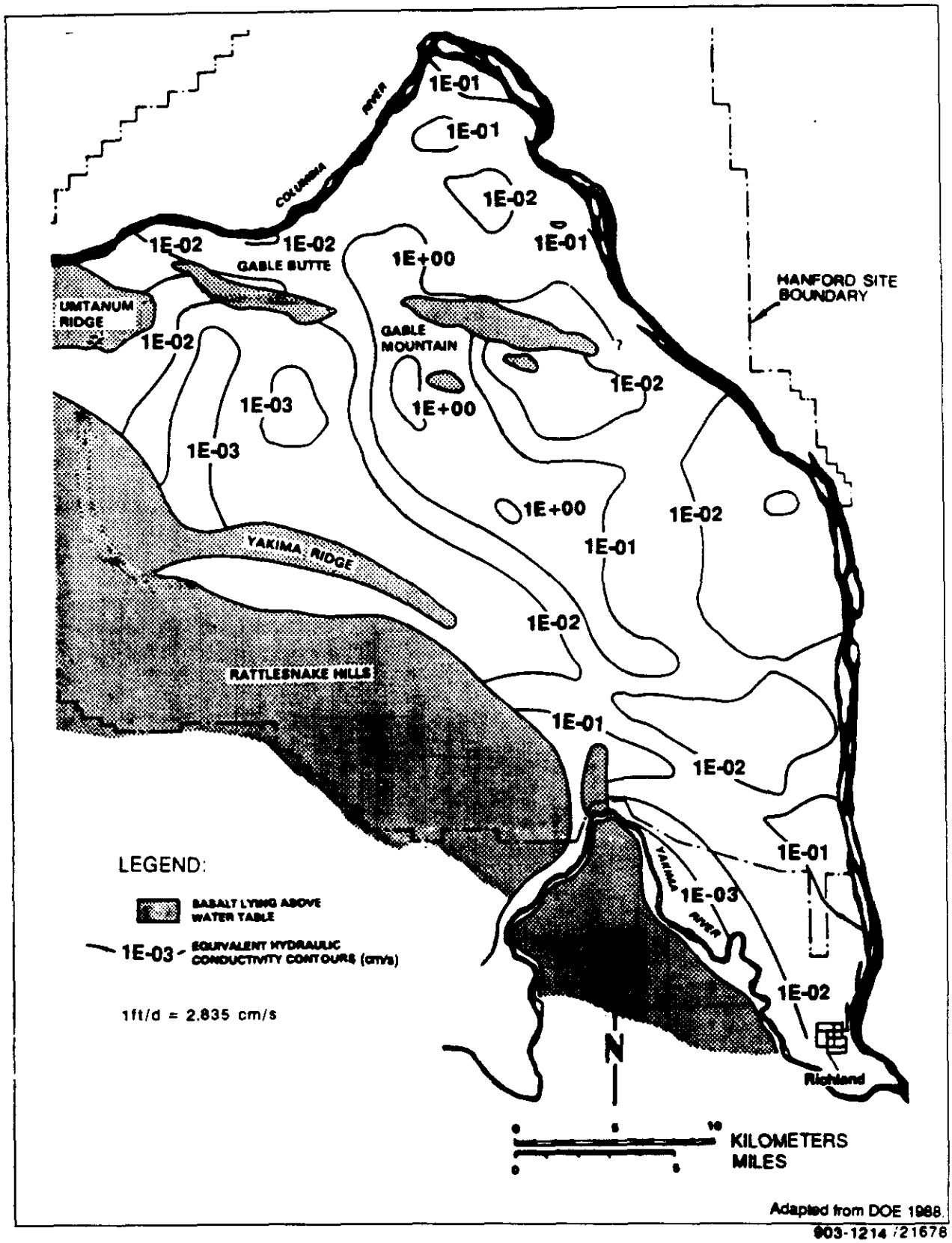

Figure 3-33. Areal Distribution of Hydraulic Conductivity for the Unconfined Aquifer.

Table 3-1. Representative Hydraulic Properties of the Hanford Site Unconfined Aquifer.

Stratigraphic Interval	Hydraulic Conductivity (cm/s)	Hydraulic Conductivity (ft/d)
Hanford formation	E-01 - E+01	E+03 - E+04
undifferentiated Hanford and middle Ringold unit	E-02 - E+00	E+02 - E+04
middle Ringold unit	E-03 - E-01	E+01 - E+03
lower Ringold unit	E-05 - E-03	E-01 - E+01

Adapted from Graham 1981; Ringold units are as defined by Myers and Price (1979) (see Section 3.4.2.1).

from the unconfined aquifer also recharges at least the uppermost interbed aquifer (the Rattlesnake Ridge interbed, which underlies the Elephant Mountain Basalt Member) below the 200 Areas plateau, especially where artificial recharge has caused mounding in the unconfined aquifer (Graham 1983; DOE 1988). In this area, erosion of the upper basalt flow (the Elephant Mountain member) has apparently enhanced the degree of hydraulic connection between the Rattlesnake Ridge interbed and the unconfined aquifer (Graham 1983). The deeper basalt interbed aquifers, such as in the Wanapum and Grande Ronde Basalts, obtain recharge waters in the Pasco Basin from vertical leakage of overlying interbed aquifers within the Saddle Mountains Basalt and horizontal inflow from the regional flow system to the east and west (DOE 1988).

Ground-Water Flow

Within the Pasco Basin, ground-water potentials of the Saddle Mountains Basalt indicate that flow is generally toward the Columbia River from both the east and west, similar to flow in the unconfined aquifer (DOE 1988). The deeper interbeds, within the Wanapum and Grande Ronde Basalts, also have ground-water potentials indicating that flow is toward the Columbia River. The majority of flow, however, is directed southeasterly, with a small area of northeasterly directed flow near Rattlesnake Hills (DOE 1988).

Discharge

Basalt interbed aquifers appear to discharge upward into overlying aquifers and eventually to the major surface-water bodies of the Columbia Plateau (DOE 1988). Within the Pasco Basin, the uppermost basalt interbeds apparently discharge upward into the overlying unconfined aquifer. The Rattlesnake Ridge interbed has been observed to have greater ground-water potential than the unconfined aquifer in the eastern portion of the Hanford Site, indicating that discharge to the unconfined aquifer may occur in this area (Figure 3-34) (DOE 1988).

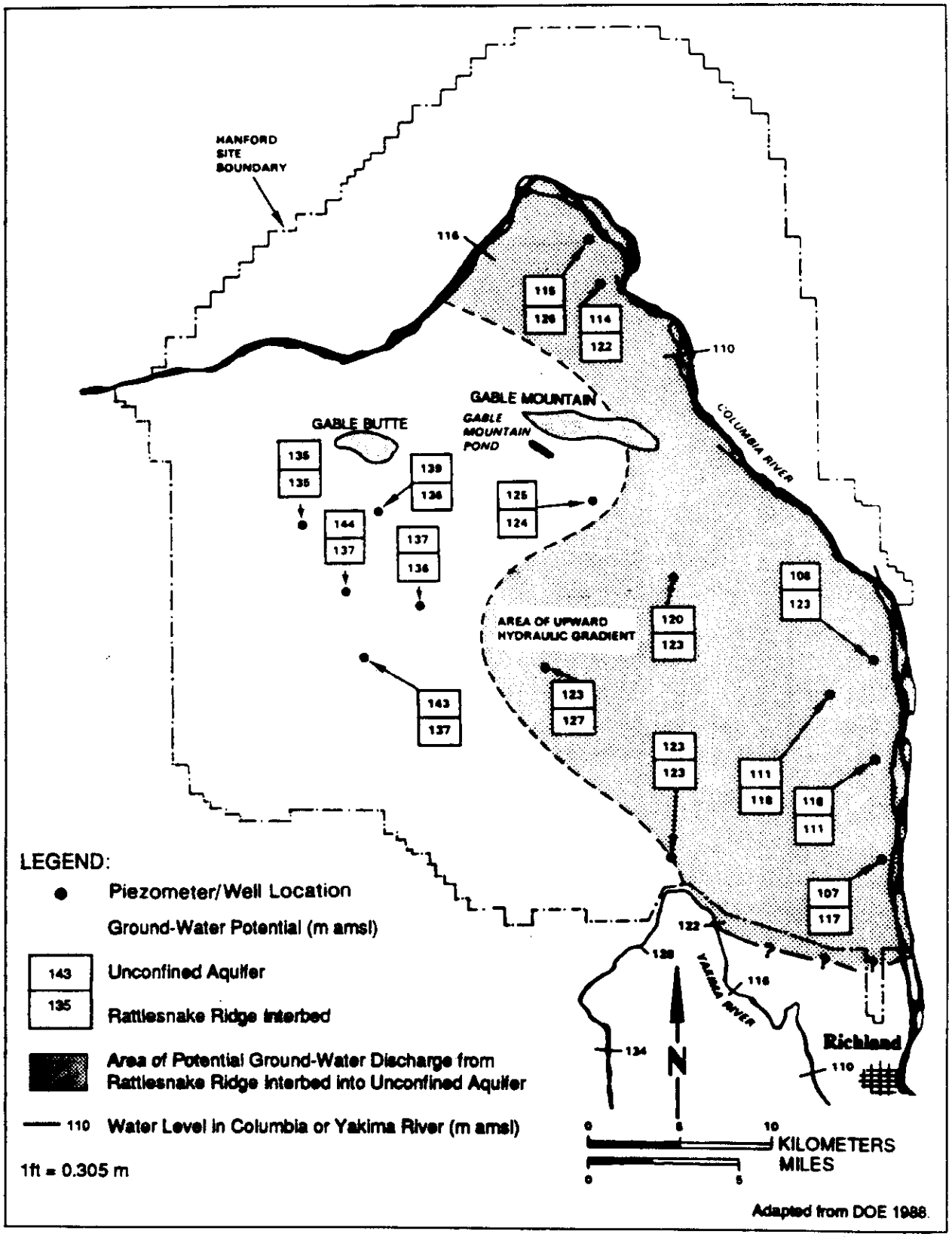

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Figure 3-34. Comparison of Observed Ground-Water Potentials in the Rattlesnake Ridge Interbed and Overlying Unconfined Aquifer.

Hydraulic Properties

Hydraulic conductivities within the basalt interbeds are generally orders of magnitude lower than those observed in the unconfined aquifer. Aquifer testing in interbeds of the Saddle Mountains Basalt yielded hydraulic conductivities ranging from E-04 to E-03 cm/s (E+00 to E+01 ft/d) (DOE 1988). The flow interiors of the basalt formations have hydraulic conductivities orders of magnitude lower than the interbeds, ranging from E-10 to E-04 cm/s (E-06 to E+00 ft/d) (DOE 1988). Storativity estimates for the basalts have not been made, but likely range from E-05 to E-03 (DOE 1988), with greater storage occurring in the interbeds.

3.6.2 Local Hydrogeology

The hydrogeologic system underlying the 1100-EM-1 Operable Unit is generally congruent with the regional hydrogeologic model of the Hanford Site. The vadose zone consists predominantly of sandy gravel, gravelly sand, and silty sandy gravel of the Hanford formation. The unconfined aquifer occurs within both the Hanford and Ringold formations and is continuous with the regionally extensive unconfined aquifer observed below most of the Hanford Site. It occurs below the entire operable unit, extending downward in the sediments to a silt aquitard. The silt aquitard, formed by strata within the Ringold Formation, is observed throughout the operable unit. The aquitard separates the unconfined aquifer from confined-to-semi-confined aquifers below. One or more of these confined-to-semi-confined aquifers likely occur below the aquitard within the Ringold Formation.

In deep well 10/28-10G1, approximately 1.3 km (0.7 mi) north of the operable unit, Newcomb et al. (1972) reported the Columbia River Basalt at an elevation of about 60 m (200 ft) amsl. As discussed in Section 3.4.3 (Local Geology), the Ice Harbor flow is likely the uppermost basalt encountered below the operable unit (DOE 1988). Figure 3-35 shows a generalized hydrogeologic stratigraphic column for the 1100-EM-1 Operable Unit.

3.6.2.1 Inventory of Local Ground-Water Wells. This section provides reference information concerning monitoring wells in and near to the 1100-EM-1 Operable Unit. Included are discussions of a well inventory, and the specific details of the monitoring wells used for the local hydrogeology assessment.

In the vicinity of the 1100-EM-1 Operable Unit, a preliminary inventory was performed to identify ground-water wells which may be impacted by contamination originating within the operable unit. Such wells may potentially be used for future ground-water monitoring. The area of interest for the survey was intended to include the locations of all wells which may tap ground water passing below the operable unit. From the operable unit boundaries, this area was conservatively defined to include all land directly east to the Columbia River and approximately 1.6 km (1 mi) to the north and south. The hydraulically upgradient land area extending 0.8 km (0.5 mi) west of the operable unit was also included.

The inventory was completed by reviewing a recent well inventory of the Hanford Site (McGhan 1989) and well logs on file at Ecology. Field verification of the wells was not conducted as part of the survey, leaving the current status of many wells unknown. The potential also exists for overlap

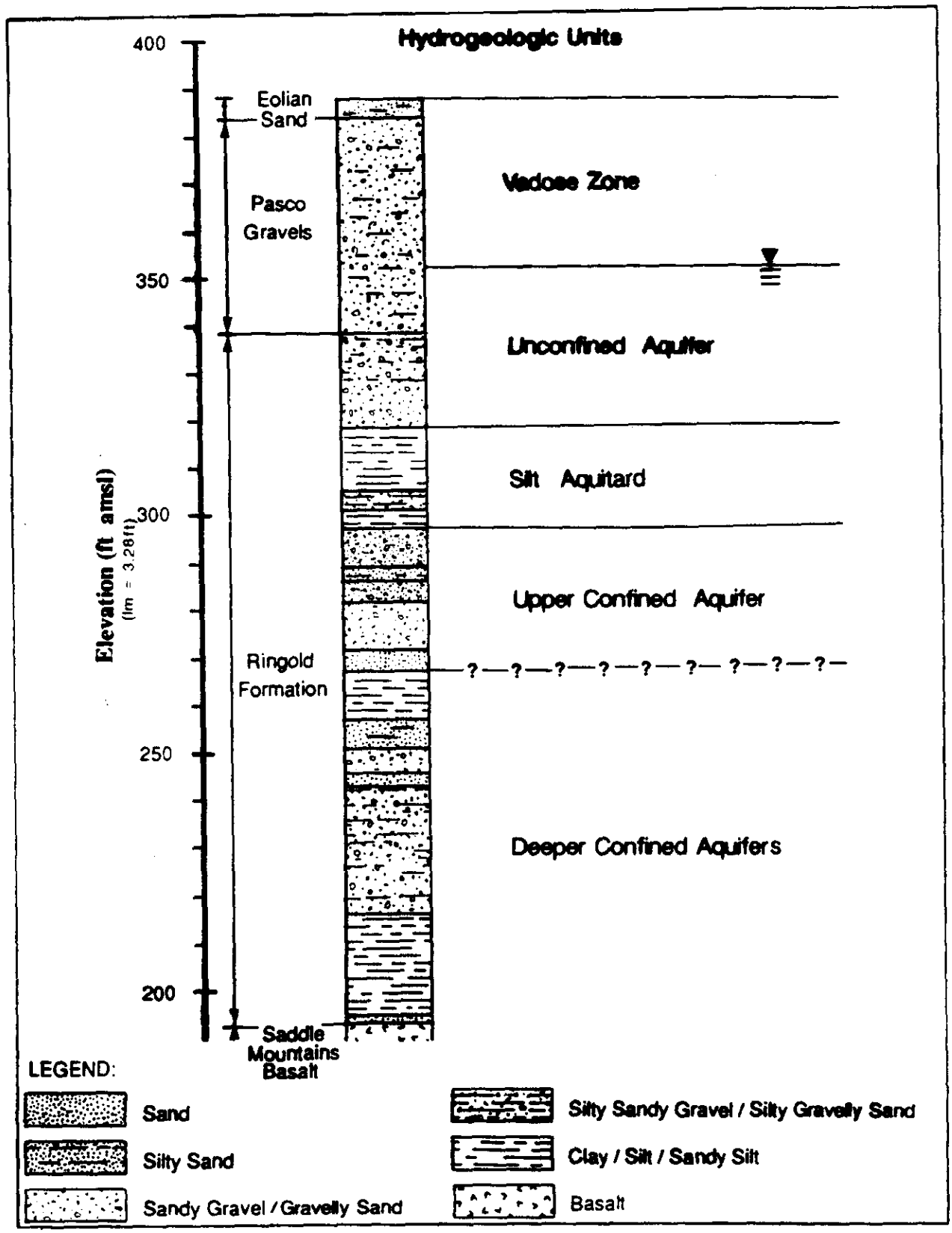

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Figure 3-35. Generalized Hydostatigraphic Column for the 1100-EM-1 Operable Unit.

of wells from the two information sources. Figure 3-36 presents the identified well locations, including those wells installed or sampled during the 1100-EM-1 Phase I RI. The certainty of well locations varies among the wells, as noted in the figure legend. Appendix J provides formal well identifications along with information concerning well construction and use.

A total of 37 wells was used to assess the local hydrogeology of the 1100-EM-1 Operable Unit (see Figure 2-18 and Table 2-1). Sixteen of these wells were new installations for the Phase I RI (MW-1 through MW-15, and MW-17). Five others were installed during 1988 to monitor ground water between the operable unit and the City of Richland well field (Bryce and Goodwin 1989), and three wells on Advanced Nuclear Fuels Corp. property were installed some time previous to the RI. The remaining 13 wells, which were used only for ground-water potential measurements, were installed earlier for other monitoring purposes.

3.6.2.2 Vadose Zone. The vadose zone consists predominantly of unsaturated interlayered sandy gravel, gravelly sand, and silty sandy gravel of the Hanford formation. It occurs between ground surface and the water table, as shown on the geologic cross-sections (see Figures 3-23 through 3-27). It is the zone through which natural and anthropogenic recharge waters may flow to ground water.

Below the 1100-EM-1 Operable Unit, the thinnest portion of the vadose zone occurs on the west side of the Horn Rapids Landfill, where it is only 6 m (20 ft) to the water table. East and south of the landfill, the vadose zone thickness gradually increases by 6 to 8 m (20 to 25 ft). Below the 1100-2 and 1100-3 operable subunits, it is about 15 m (50 ft) to ground water, and it is about 14 to 15 m (45 to 50 ft) to ground water below subunits 1100-1, 1100-4, and 1100-6.

Hydraulic testing and surface mapping to evaluate vadose zone recharge to ground water was not conducted during the initial phase of the 1100-EM-1 RI. The Hanford Site Performance Assessment (HSPA) project, however, has collected data at several locations on drainage and moisture in the vadose zone (Rockhold et al. 1990). Two of these locations are within 16 km (10 mi) of the 1100-EM-1 Operable Unit. The information from these locations can be generally applied to the vadose zone underlying the operable unit.

The two HSPA sites located nearest to the 1100-EM-1 Operable Unit are the Buried Waste Test Facility (BWTF) Site and the Grass Site (Rockhold et al. 1990). They are located about 16 km (10 mi) and 8 km (5 mi) north of the operable unit, respectively. The sites are instrumented to monitor in-situ water content of the sediments and cumulative drainage volumes. At the BWTF Site, lysimeters and caissons were installed using local repacked sieved sediments passing a 1.27 cm (0.5 in) mesh with about 3% silt and clay. At the Grass Site, neutron probe access tubes were installed in undisturbed sediments consisting of 74% sand, 21% silt, and about 5% clay. These sediments are similar to those occurring in the vadose zone of the operable unit, but are lacking in the very coarse fraction which includes large gravel, cobbles, and small boulders (see Section 3.5.2.2).

Water-balance calculations, completed for the period from 1985 to 1989, have provided cumulative drainage volumes for the BWTF Site. The calculations were performed on data collected from two weighing lysimeters (north and

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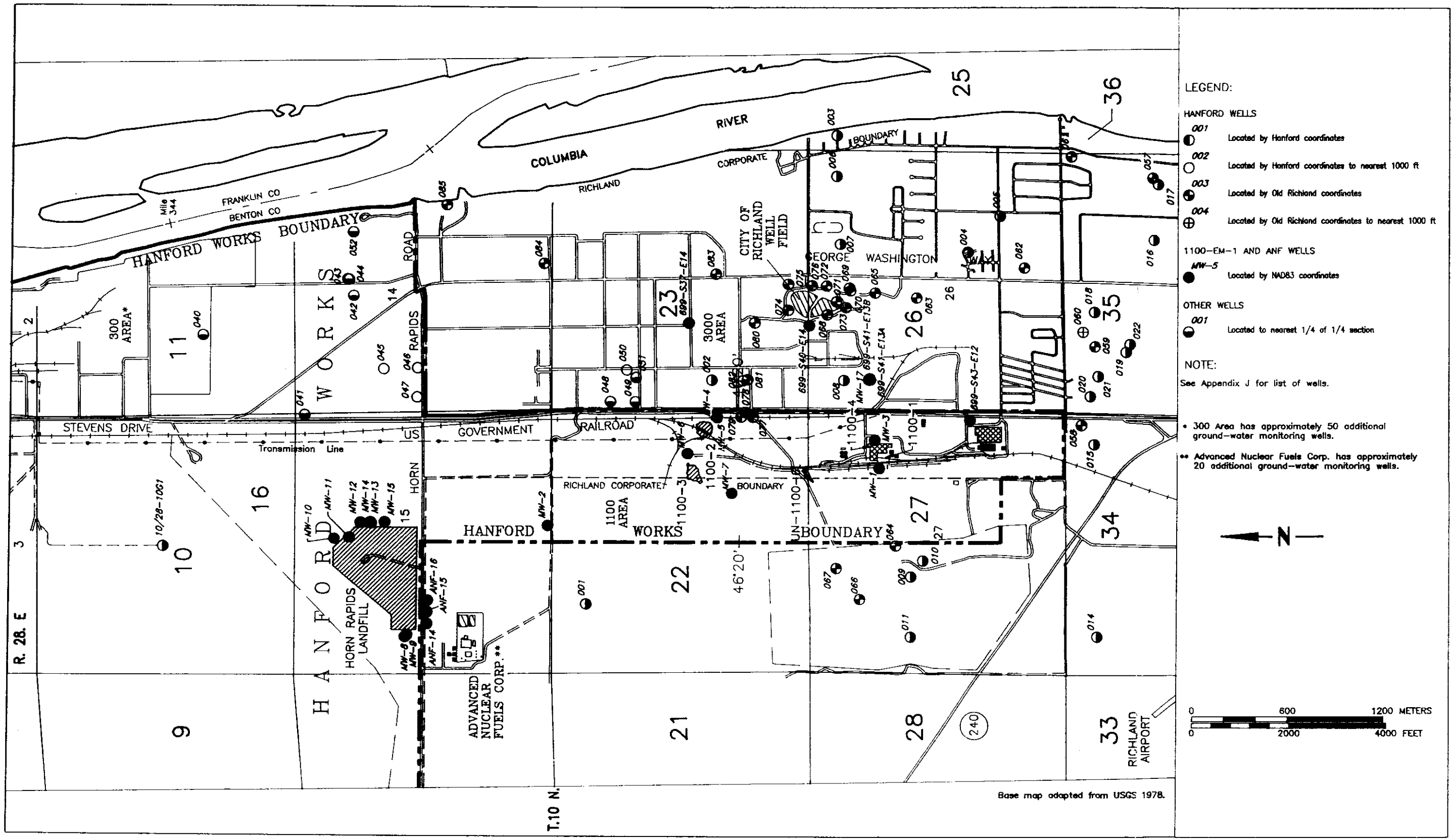

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Figure 3-36. Ground-Water Well Locations in the 1100-EM-1 Operable Unit Vicinity.

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south) and a caisson. Cumulative drainage volumes over the 4-yr study ranged from 0.0 to 10.6 cm (0.0 to 4.5 in) for the vegetated south weighing lysimeter, 3.1 to 10.0 cm (1.3 to 4.0 in) at the bare north weighing lysimeter, and 4.0 to 11.1 cm (1.7 to 4.5 in) at the south caisson, which is also bare and has greater depth than either the north or south weighing lysimeters (Rockhold et al. 1990).

In general, the vegetated south weighing lysimeter had 3 to 6 cm (1.3 to 2.5 in) less drainage than the north weighing lysimeter and the south caisson from 1986 to 1989. The drainage rate in the south caisson was also reported to be more regular due to its greater depth, as compared to both the north and south weighing lysimeters which were observed to show seasonal fluctuations (Rockhold et al. 1990). The south caisson extends to a depth of 7.6 m (25 ft), whereas the north and south weighing lysimeters extend to only 1.5 m (4 ft) below ground surface.

Fewer data are available to evaluate drainage from the Grass Site. A computed recharge rate for the Grass Site, based on the unit gradient principal and the average field-measured saturated hydraulic conductivity, was estimated at 0.44 cm/yr (0.17 in/yr) (Rockhold et al. 1990). The unit gradient was generally observed in the field moisture content data. The smaller recharge rate at the Grass Site was attributed to the finer-grained vegetated sediments.

Based on the HSPA project results to date, recharge through the vadose zone at the 1100-EM-1 Operable Unit is anticipated to vary within the ranges given above for the BWTF and Grass Sites, 0 to 11 cm/yr (0 to 4.5 in/yr). The upper end of this range is anticipated within the disturbed portions of the subunits due to a lack of vegetation and the occurrence of generally coarse-grained sediments. Away from the disturbed areas, where the ground surface is generally vegetated with grasses and shrubs and the sediments are finer-grained, the lower end of the range is more probable.

3.6.2.3 Unconfined Aquifer. The unconfined aquifer below the 1100-EM-1 Operable Unit occurs between the water table and the underlying silt aquitard, approximately 95 to 107 m (310 to 350 ft) amsl (see Figures 3-23 through 3-27). The aquifer occurs within the Hanford formation and the middle Ringold lithofacies, which are discussed in detail in Section 3.4.3.1 (Local Stratigraphy). The continuity of this aquifer with the unconfined aquifer occurring elsewhere below the Hanford Site and east of the operable unit is shown by the general similarity of geologic strata and ground-water potential between the operable unit and these locations.

Aquifer Thickness

The spatial distribution of aquifer thickness is shown on Figure 3-37. Below the 1100-EM-1 Operable Unit, the thickness gradually increases south from Horn Rapids Landfill to a trough which occurs in the vicinity of the 1100-2 and 1100-3 operable subunits. Directly south from these two subunits, toward the 1100-1 subunit, the thickness does not appear to change. Southeast from the 1100-2 and 1100-3 subunits and east from the 1100-1 subunit, the thickness decreases slightly. The maximum thickness observed is 13 m (44 ft), in the vicinity of the 1100-1, 1100-2, 1100-3, and UN-1100-6 subunits. The minimum observed thickness is 5 m (16 ft) and occurred on the west side of Horn Rapids Landfill.

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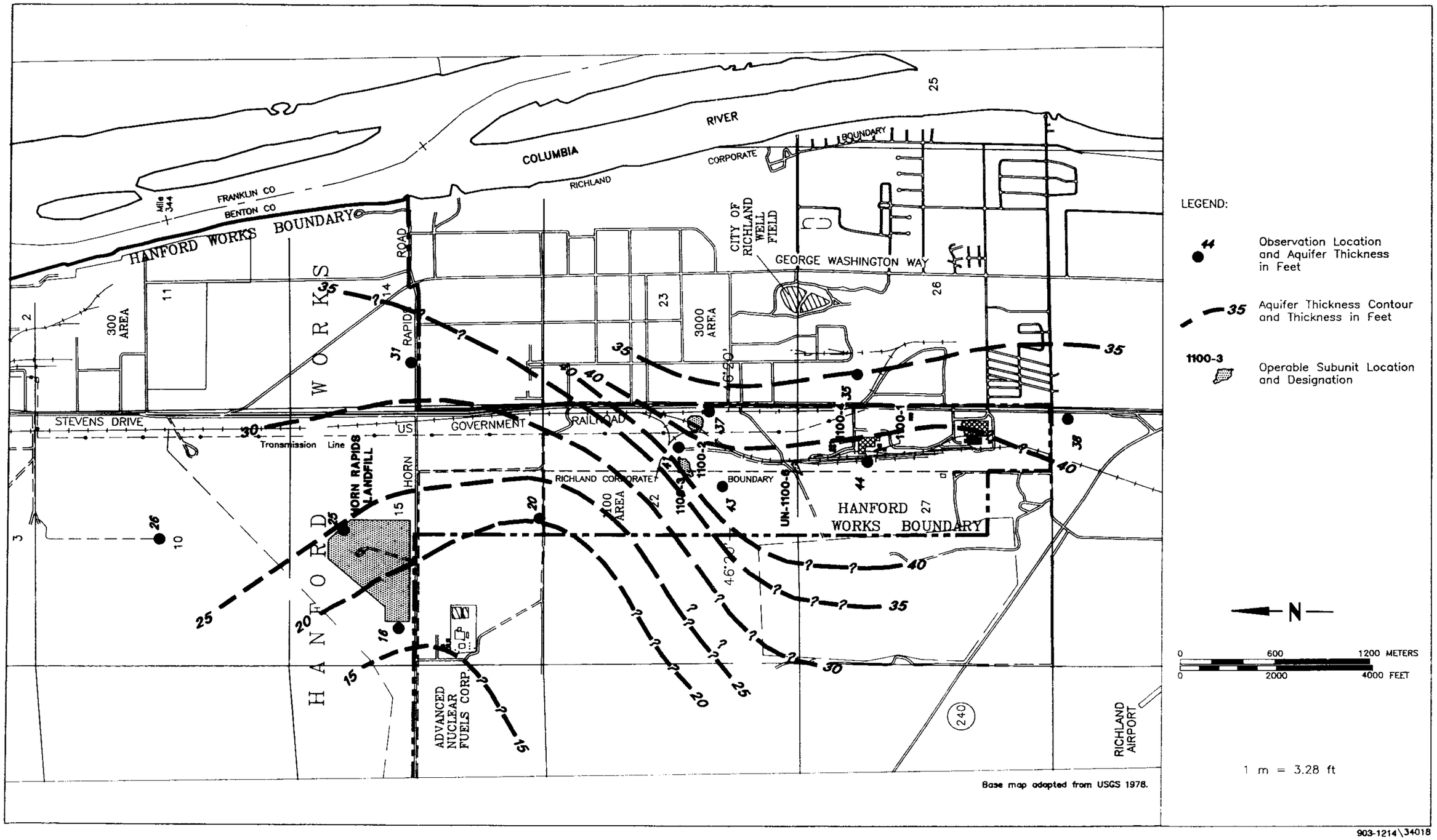

Figure 3-37. Saturated Thickness of the Unconfined Aquifer.

Outside of the operable unit, fewer data are available to map the aquifer thickness. In general, the thickness appears to increase toward the Columbia River.

Recharge

Ground-water recharge to the unconfined aquifer below the 1100-EM-1 Operable Unit results primarily from westward ground-water inflow. The source of this inflow is likely the Yakima River, which appears to discharge directly to the unconfined aquifer along the Horn Rapids Reach below Horn Rapids Dam (Freshley et al. 1989). Irrigation losses in the land area west of the operable unit likely contribute to the westward ground-water inflow volume.

Within the boundaries of the 1100-EM-1 Operable Unit, ground-water recharge also may occur as a result of natural precipitation. This recharge, which passes through the vadose zone, has been discussed above (see Section 3.6.1.1). In general, this volume of recharge is anticipated to be small relative to the westward ground-water inflow volume.

To the east of the 1100-EM-1 Operable Unit, the City of Richland well field artificially recharges the unconfined aquifer to provide treatment of turbid Columbia River water and enhance the well field capacity. This is a major source of recharge to the aquifer and causes ground-water mounding which extends west to the vicinity of the 1100-1, 1100-4, and UN-1100-6 subunits. However, because the well field is recharged intermittently, the mound may dissipate between periods of recharge. Monthly totals for recharge at the well field during 1988 and 1989 ranged from about 75,000,000 L (20,000,000 gal) to 1,500,000,000 L (400,000,000 gal) (see Appendix K).

Ground-Water Flow

Ground-water flow direction was determined from ground-water potential measurements in monitoring wells within and adjacent to the 1100-EM-1 Operable Unit. The well identifications are shown on Figure 3-36, and the ground-water potential measurements are provided in Appendix M.

Ground-water potential maps, showing horizontal flow directions, were constructed from the ground-water potential measurements taken on March 2, March 5, and May 23, 1990. These maps appear on Figures 3-38 through 3-40, respectively. Each figure shows northeasterly ground-water flow in the vicinity of Horn Rapids Landfill, easterly flow at the City of Richland well field, and easterly-to-southeasterly flow south of the well field.

The City of Richland well field was active during the period of these ground-water potential measurements. On March 2, 1990, 530,000 L (140,000 gal) of water were pumped from the aquifer and 20,300,000 L (5,370,000 gal) were recharged. On March 3, 1990, an additional 3,260,000 L (860,000 gal) were pumped from the aquifer while 44,700,000 L (11,800,000 gal) were recharged. One week earlier, on February 25, 1990, 9,620,000 L (2,540,000 gal) were pumped from the aquifer while 46,200,000 L (12,200,000 gal) were recharged. During May, 1990, the well field was much more active than in March. From May 16 to May 29, 1990, average rates for pumping and recharging were 85,700,000 L/d (3,030,000 gal/d) and 156,000,000 L/d (5,520,000 gal/d), respectively. Although the recharge-to-withdrawal ratio varied from less than

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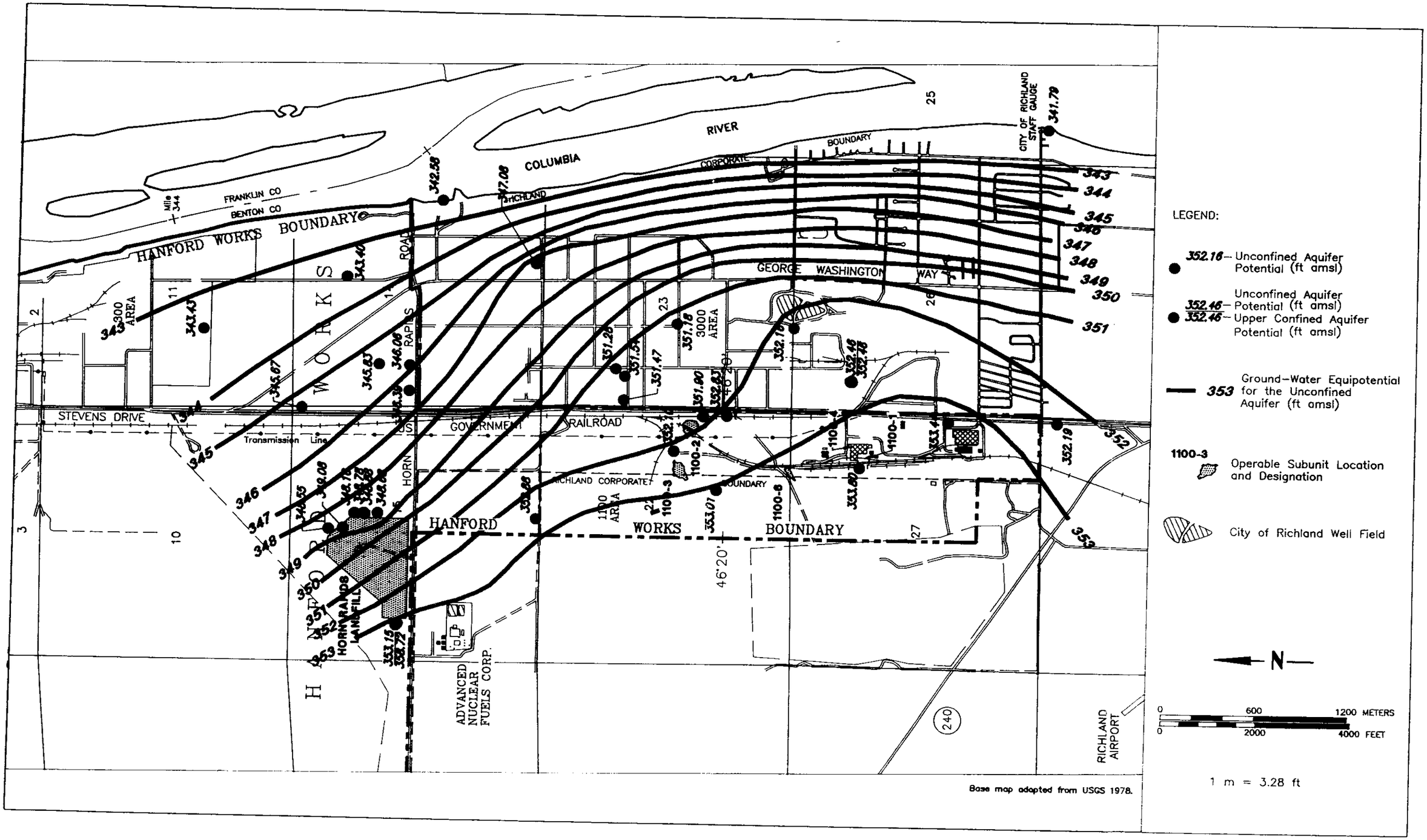

Figure 3-38. Ground-Water Potentiometric Surface for the Unconfined Aquifer on March 2, 1990.

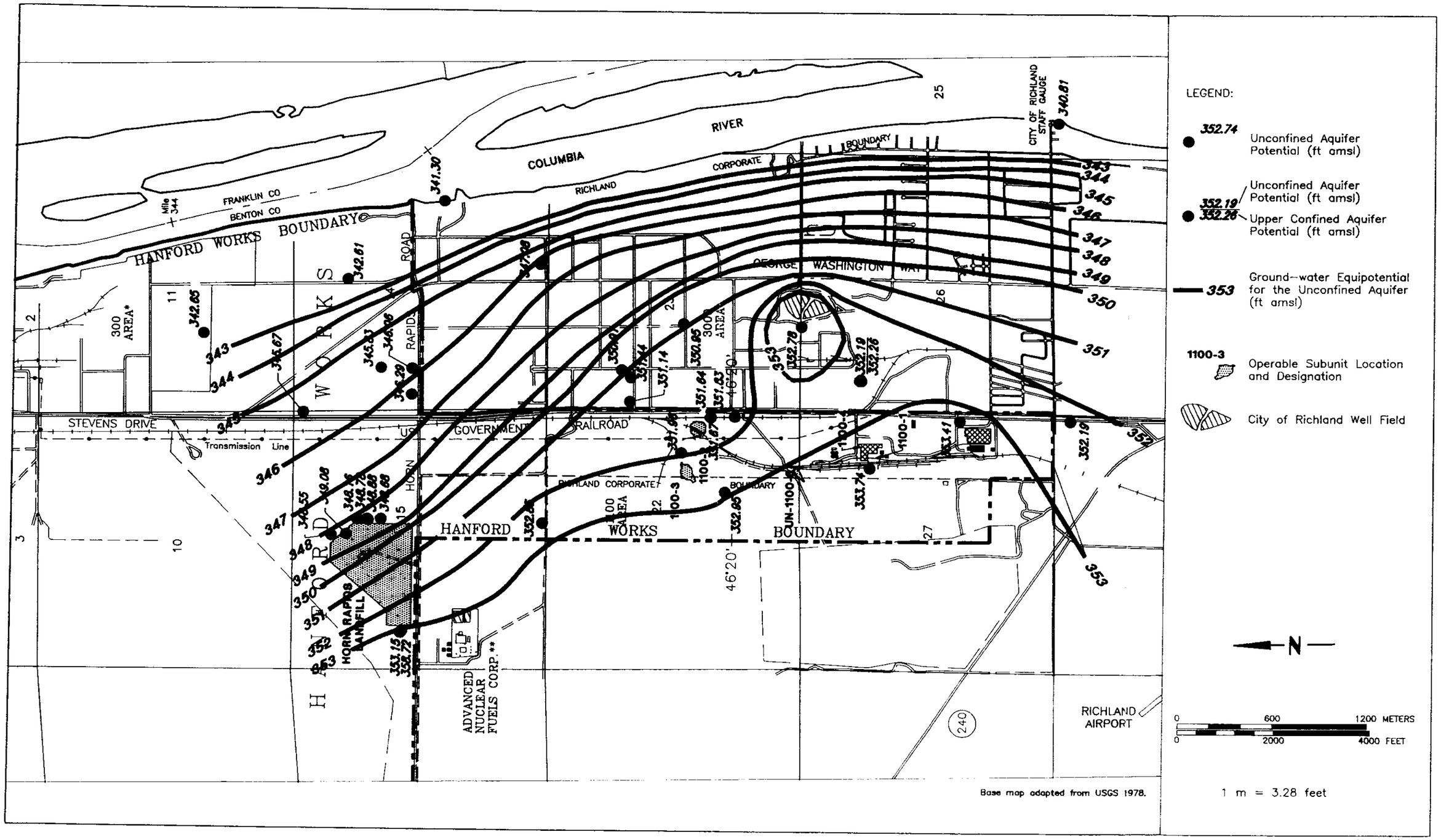

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Figure 3-39. Ground-Water Potentiometric Surface for the Unconfined Aquifer on March 5, 1990.

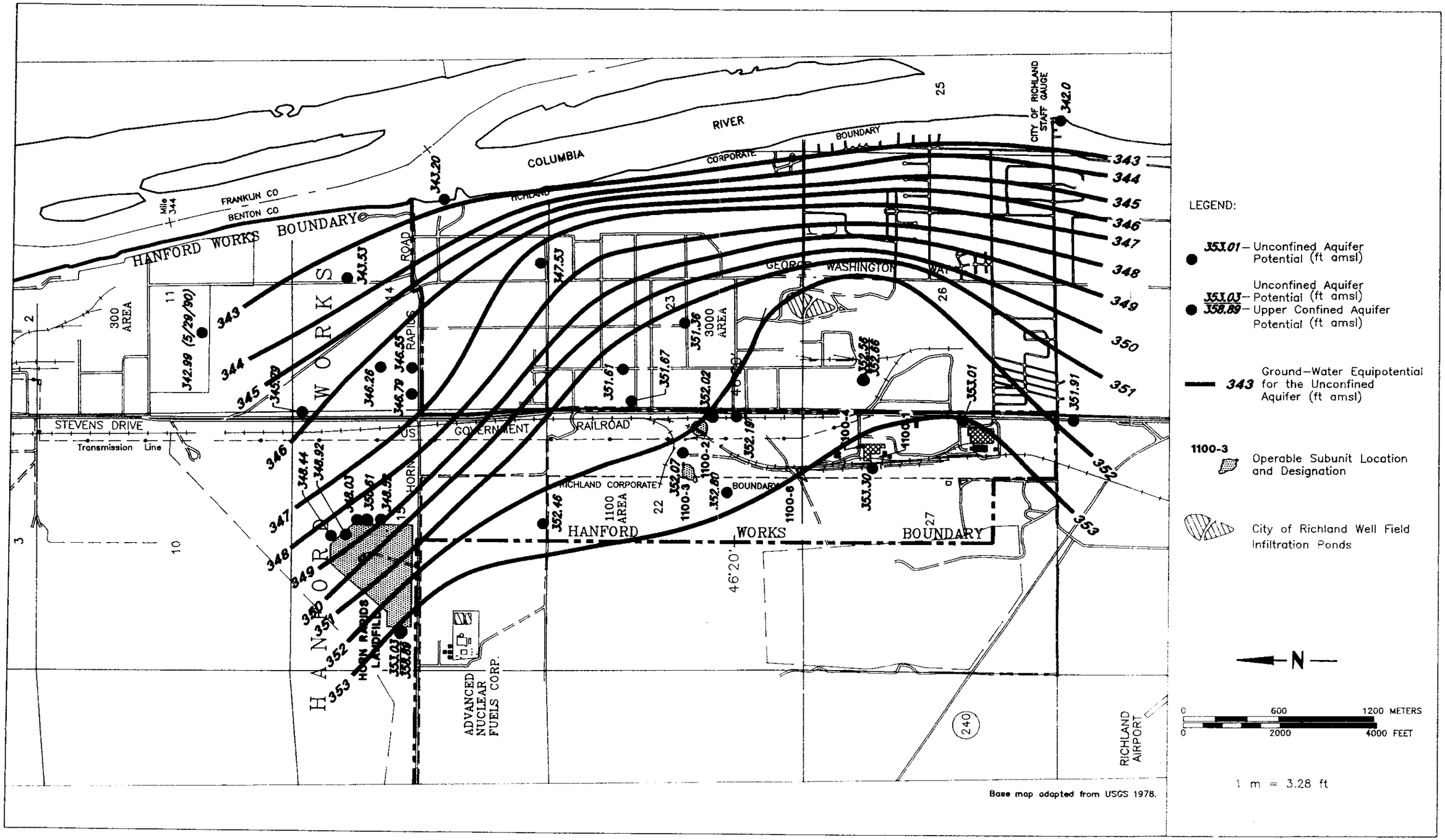

Figure 3-40. Ground-Water Potentiometric Surface for the Unconfined Aquifer on May 23,1990.

one to about eight during this period, the system was likely dominated by recharge on May 23, when the ground-water potentials were measured.

On March 2, 1990, the well field does not appear to have significant influence on the aquifer, as neither a depression or mound is observed at the well field (see Figure 3-38). The perturbation in the 107-m (352-ft) equipotential near the well field possibly indicates the onset of pumping, prior to when recharging waters reached the saturated zone. The flow field is otherwise generally undisturbed with no indication of a remnant ground-water mound from the well field activities one week earlier. The area of reduced gradient in the vicinity of the 1100-2 and 1100-3 subunits is likely due to the occurrence of greater transmissivity resulting from the increase in aquifer thickness observed in this area (see Figure 3-37).

On March 5, 1990, artificial recharge at the well field built a ground-water mound below the recharge ponds (see Figure 3-38). The mound had a height of approximately 0.15 m (1.5 ft) relative to the elevation prior to recharge, and a radius of about 130 m (500 ft). The consequence of the mound is that ground-water flow is diverted from the well field. Immediately west of the well field, the ground-water flow direction is actually reversed, flowing east to west rather than west to east. Eastward-flowing ground water that normally passes through the well field diverts toward the north and south.

Ground-water potentials observed about two months later, on May 23, 1990 (see Figure 3-40), are similar to those observed on March 5, 1990; a low ground-water mound appears to be present below the City of Richland well field on both dates. Ground-water potentials elsewhere in the 1100-EM-1 Operable Unit vicinity appear to be similar to those observed during March. The elevation of the Columbia River is also similar for both months, ranging from only 103.9 to 104.4 m (341.0 to 342.5 ft) amsl.

Based on the presently available ground-water potential measurements, the following conclusions regarding ground-water flow below the 1100-EM-1 Operable Unit can be made:

- Under undisturbed ground-water flow conditions and during conditions when pumping creates drawdown at the City of Richland well field, ground water passing below the southern portion of the 1100-EM-1 Operable Unit flows through the well field. This portion of the operable unit includes the 1100-1, 1100-4, and UN-1100-6 subunits.

- Under conditions when ground-water mounding prevails at the well field, the well field does not receive westerly ground-water inflow and ground water passing below the southern portion of the operable unit is diverted either north or south of the well field.

- Ground-water flow north of approximately latitude 46°20'N (near the location of MW-7) does not pass through the well field at any time based on presently available ground-water potential data. Rather, ground-water flow in this portion of the 1100-EM-1 Operable Unit, which includes the Horn Rapids Landfill, 1100-2, and 1100-3 subunits, flows east to northeast toward the Columbia River.

- Unless pumped from the aquifer by the City of Richland or other well owners, ground water flowing below the 1100-EM-1 Operable Unit flows to the Columbia River.

Continued ground-water potential measurements are needed to confirm these conclusions. There is potential that under conditions when pumping at the well field creates substantial drawdown, ground-water flow could be temporarily directed toward the well field from the 1100-2 and 1100-3 subunits. However, pumping influence of this magnitude on the unconfined aquifer is unlikely, because the aquifer's high transmissivity responds to pumping with little drawdown and the well field operations schedule attempts to maintain a local flow system dominated by ground-water recharge.

Discharge

Ground-water discharge from the unconfined aquifer occurs primarily into the Columbia River and to wells in the City of Richland well field, depending on the well field operations. Hydraulic connection between the aquifer and the river is shown by the continuity of the formation materials toward the river (see Figures 3-24 and 3-25), and the similarity between river stage and the observed ground-water potential in the unconfined aquifer near the river (see Figures 3-38 and 3-39).

This hydraulic connection was further demonstrated by the response of many monitoring wells to a 0.3-m (1-ft) decline in Columbia River stage from March 2 to 5, 1990. During this period, ground-water potential measured in monitoring wells nearest the river also declined approximately 0.3 m (1 ft).

Hydraulic Properties

The unconfined aquifer hydraulic conductivity varies spatially within the 1100-EM-1 Operable Unit. The spatial variation is a result of textural variation within the host strata, which is described in detail in Section 3.4.3 (Local Geology). Hydraulic conductivity was measured in 15 of the new monitoring wells using a rising head slug test. Results from these tests are presented in Table 3-2 and the well response curves are provided in Appendix L.

The hydraulic conductivity range obtained from the slug tests spanned an interval of approximately two orders of magnitude. The lowest test result was 7E-04 cm/s (2E+00 ft/d) and the highest was 7E-02 cm/s (2E+00 ft/d). In general, this range of hydraulic conductivity is slightly lower than the typical range for the unconfined aquifer at the Hanford Site. Test results are potentially biased toward low values due to limitations of the test method or the small slot size of the well screen materials.

For those wells screened entirely within the Pasco gravel unit (Hanford formation), the geometric mean hydraulic conductivity is 4E-03 cm/s (1E+01 ft/d) (n = 3). For wells screened entirely within the middle Ringold, a slightly lower but essentially equivalent geometric mean of 1E-03 cm/s (3E+00 ft/d) (n = 7) is obtained. Elsewhere on the Hanford Site the Pasco gravel unit generally has a greater hydraulic conductivity than the Ringold Formation; however, such a difference is not well defined by the slug test technique.

Table 3-2. Rising Head Hydraulic Conductivity Analysis Results.

Well ID	Hydraulic Conductivity (cm/s)[a]	Screened Saturated Thickness (ft)[b]	Percentage Hanford Formation[c]	Percentage Ringold Formation[c]	Type of Screen[d]
MW-1	3E-03 - 7E-03	7.9	100	0	CP
MW-2	8E-03 - 1E-02	12.1	75	25	10-S
MW-3	3E-02 - 5E-02	13.1	85	15	10-S
MW-4	1E-02	11.2	36	64	CP
MW-5	3E-03	15.1	0	100	CP
MW-6	1E-02 - 2E-02	9.8	100	0	CP
MW-7	9E-03	9.8	70	30	CP
MW-8	2E-02 - 5E-02	11.2	82	18	20-S
MW-9	4E-04	9.8	0	100	CP
MW-10	1E-03	11.2	0	100	10-S
MW-11	1E-03	11.2	100	0	CP
MW-12	6E-03	9.8	0	100	CP
MW-14	7E-04	9.8	0	100	CP
MW-15	2E-02 - 4E-02	7.9	0	100	10-S
MW-17	1E-04	9.8	0	100	CP

[a]1 ft/d = 2,835 cm/s.
[b]1 m = 0.3048 ft.
[c]The portion of either formation occurring in the screened saturated thickness.
[d]CP = 10-slot channel pack; 10-S = 10-slot wire wrapped; 20-S = 20-slot wire wrapped.

An earlier pumping test completed at the City of Richland well field provided a single hydraulic conductivity estimate of 5.3E-01 cm/s (1E+03 ft/d), which is more typical for the unconfined aquifer (CWC-HDR, Inc. 1988). At the well field, the unconfined aquifer occurs within both the Hanford formation and middle Ringold unit. During this test, water was withdrawn from the aquifer at a rate of 5,070 L/min (1,340 gal/min). Although the test continued for a total of 98 h, all observed drawdown occurred in the first 24 h. A total of 1.2-m (4-ft) drawdown was measured in the pumping well. In an observation well 107 m (350 ft) away, the total drawdown was only 0.20 m (0.66 ft).

3.6.2.4 Silt Aquitard. The silt aquitard was identified during drilling throughout the 1100-EM-1 Operable Unit, and is also recognized in the logs of previous workers (Newcomb et al. 1972; Lindberg and Bond 1979; Bryce and Goodwin 1989; CWC-HDR, Inc. 1988). The aquitard was encountered within the interval from 91 to 102 m (299 to 333 ft) amsl. Wells drilled deeper than 91 m (299 ft) amsl invariably intercepted the aquitard. There is, however, uncertainty regarding the continuity of the aquitard. Potential exists for the aquitard to be discontinuous due to erosion which may have occurred before the overlying sediments were deposited.

Aquitard Thickness

The thickness of the silt aquitard ranges from 1.2 to 10.1 m (4 to 33 ft). The thickness of only 1.2 m (4 ft) was observed in MW-6 and suggests that windows through the aquitard may occur. Greater thicknesses were observed north and south from MW-6. On the west side of Horn Rapids Landfill, in MW-9, the silt aquitard thickness is 10.1 m (33 ft). A short distance west of the City of Richland well field, in MW-17, the aquitard is 5.5 m (18 ft) thick. Within the City of Richland well field, no wells penetrated through the silt aquitard; however, several logs indicate a silt or clay interval being intercepted at the bottom of the borehole (CWC-HDR, Inc. 1988).

The change in thickness of the aquitard predominantly reflects undulations in its upper surface. This surface likely was subject to erosion based on the high-energy sand and gravel deposits which overly it. The lower surface of the silt, which is presumably conformable to the surface on which it was deposited, appears to be relatively flat (based on six data points), varying in elevation by less than 3 m (10 ft) over a 6-km (3-mi) north-south transect passing through the operable unit.

The similarity in elevations of the lower silt surface, as observed at different locations, suggests the aquitard may be formed by a continuous stratum; however, the undulating upper surface indicates that the stratum may have been completely eroded in localized areas. Below the 300 Area, a silt aquitard, which occurs at about the same elevation as that below the 1100-EM-1 Operable Unit, pinches out near the Columbia River channel (Lindberg and Bond 1979), an indication of complete erosion in this area.

Hydraulic Properties

Ten samples of the silt aquitard were used to measure the vertical hydraulic conductivity of this confining layer. These test results are shown in Table 3-3. The hydraulic conductivity estimates ranged from 3E-08 to 5E-05 cm/s (8E-04 to 1E-01 ft/d), a range orders of magnitude lower than in the overlying unconfined aquifer. The laboratory test results may not, however, be representative of the true hydraulic conductivities of the sediments due to disturbances that occur during sampling.

The confining ability of the aquitard is shown by comparison of the ground-water potentials in monitoring wells MW-8 and MW-9 on the west side of Horn Rapids Landfill. Well MW-9 is screened entirely within sediments underlying the silt aquitard and had ground-water potentials approximately 1.9 m (6.3 ft) greater than those in MW-8, which is screened above the aquitard, on March 2 and 5, 1990. Under these conditions, an upward hydraulic gradient across the aquitard exists.

At MW-17, which is the only other well screened below the aquitard, the ground-water potential difference across the aquitard was essentially zero. The absence of a potential gradient at MW-17 may be attributed to the occurrence of a window through the aquitard, mounding effects caused by recharge at the well field, or poor well construction. In general, an easterly decline in the hydraulic gradient across the aquitard is anticipated, as the aquitard likely pinches out in this direction (Lindberg and Bond 1979),

Table 3-3. Silt Aquitard Vertical Hydraulic Conductivity Analysis Results.

Well ID	Sample Number	Sample Midpoint Elevation (ft amsl)[a]	Vertical Hydraulic Conductivity (cm/s)[b]
MW-1	9	305.4	2E-07
MW-5	13	314.0	4E-07
MW-6	4	310.0	2E-06
MW-7	4	306.9	9E-07
MW-9	6	335.0	3E-08
MW-10	6	332.6	1E-07
MW-12	12	322.7	2E-05
MW-14	11	320.1	5E-05
MW-15	12	324.7	4E-05
MW-17	9	306.9	3E-07

[a]1 m = 3.28 ft.
[b]1 ft/d = 2,835 cm/s.

thereby allowing the unconfined aquifer to equilibrate with the ground-water zone below.

3.6.2.5 Upper Confined Aquifer. The upper confined aquifer occurs immediately below the silt aquitard, as shown on the hydrostratigraphic cross section presented previously (see Figure 3-35). Information on this aquifer is limited at present, as the 1100-EM-1 Phase I RI hydrogeological investigation focused primarily on the vadose zone and unconfined aquifer.

The upper confined aquifer is monitored by MW-9 and MW-17. The ground-water potentials measured in these wells indicate that flow was apparently easterly, the anticipated flow direction, on March 2 and 5, 1990. There is also flow upward into the silt aquitard of the overlying unconfined aquifer, at least in the vicinity of Horn Rapids Landfill. It is presently unknown if well field operations have significant affects on the flow observed in this aquifer.

The sediments encountered in the upper confined aquifer ranged from silty sand to sandy gravel. Rising head slug tests conducted in MW-9 and MW-17 yielded hydraulic conductivity estimates of 4E-04 cm/s (5E+00 ft/d) and 1E-04 cm/s (3E-01 ft/d), respectively, indicating that at least in these two locations, the hydraulic conductivity is generally lower than in the unconfined aquifer (see Table 3-2).

The horizontal and vertical extent of the upper confined aquifer is not presently well defined. Lindberg and Bond (1979) show the upper confined aquifer to merge with the unconfined aquifer near the Columbia River within the 300 Area, and Newcomb et al. (1972) report on a well drilled through the upper confined aquifer southwest of the 300 Area. During drilling for the initial phase of the 1100-EM-1 RI, the upper confined aquifer was identified

at Horn Rapids Landfill at MW-9, and to the south at MW-6 and MW-17. The vertical thickness of the upper confined aquifer may be on the order of a few meters (feet) or as thick as 10 m (30 ft), depending on the continuity of silt strata in the middle Ringold unit, as shown by the log of well 10/28-10G1 (see Figure 3-23). During the first phase of the RI, no explorations penetrated the upper confined zone to determine its thickness below the operable unit.

3.6.2.6 Deep Aquifers. Aquifers deeper than the upper confined aquifer were not explored during the Phase I RI and are not currently monitored in the vicinity of the 1100-EM-1 Operable Unit. However, earlier investigators (Newcomb et al. 1972) provide information on the intervening strata, based on a deep well drilled into the Columbia River Basalt 1.3 km (0.7 mi) north of the operable unit.

Generally, the Ringold sediments, consisting of interlayered gravelly sand, sandy gravel, and silt, continue downward to within approximately 8 m (25 ft) of the basalt. Based on the log for borehole 10/28-10G1 (see Figure 3-23), one or more confined-to-semi-confined aquifers are anticipated in this stratigraphic interval. Immediately overlying the basalt, a silt layer is present with an anticipated hydraulic conductivity on the order of E-06 cm/s (E-03 ft/d). The underlying basalt—encountered at approximately 60 m (200 ft) amsl, or about 58 m (190 ft) below ground surface—consists of the Ice Harbor flow of the Saddle Mountains Basalt Formation (DOE 1988).

3.7 ECOLOGICAL CHARACTERISTICS

This subsection provides a description of the potential receptor populations that exist in and around the 1100-EM-1 Operable Unit. Both human and non-human populations are respectively addressed in Sections 3.7.1 (Human Ecology) and 3.7.2 (Wildlife Ecology) below.

3.7.1 Human Ecology

The description of the human ecology associated with the operable unit focuses on issues pertaining to land use (Section 3.7.1.1), water use (Section 3.7.1.2), and cultural resources (Section 3.7.1.3). Demography is addressed within the land use discussion below.

3.7.1.1 Land Use. Land use, including a discussion of demographics, is presented below. Both regional and local aspects of this topic are addressed.

Regional Land Use

The Tri-Cities Region consists of the incorporated cities of Richland, Kennewick, and Pasco and the surrounding communities within Benton and Franklin Counties. Land use in the Tri-Cities Region is primarily agricultural, residential, and industrial. Recreational land use, such as hunting, is also important.

Most of the agricultural lands are located north and east of the Columbia River and south of the Yakima River. Such lands are used primarily for dry-land and irrigated crop production and livestock grazing. Principal agricultural products include hay, wheat, vegetables (primarily potatoes and

corn), apples, grapes and other soft fruits, and hops (DOE-RL 1987; Jacquish and Mitchell 1988). Prior to the establishment of the Hanford Site in the mid-1940's, the majority of what is now the site was used for agricultural purposes, primarily livestock grazing, with some areas used for orchards and irrigated crops.

Residential land use is concentrated around the incorporated areas; industrial lands are concentrated east of Kennewick along the Columbia River (Benton County Board of Commissioners 1985). Most industrial activities in the region are associated with either agriculture or energy production (DOE-RL 1987).

That portion of the Hanford Site located north of the Columbia River consists of two wildlife reserves—the Wahluke Slope Wildlife Area, a DOW wildlife management area, and the Saddle Mountain National Wildlife Refuge, managed by the USFWS. The northeast slope of the Rattlesnake Hills, along the southwestern boundary of the Hanford Site, is designated as the Arid Lands Ecology Reserve. This reserve is used for ecological research by DOE-RL; it is also designated a National Environmental Research Park (Jacquish and Mitchell 1988). Figure 3-41 shows the locations of these wildlife and ecological reserves, which cover approximately 45% of the Hanford Site surface.

The Benton County portion of the Hanford Site, including the eastern half of the 1100 Area, is currently zoned as unclassified (Benton County Planning Department undated). Land use is restricted for activities which are associated with the nuclear industry; non-nuclear related activities may be allowed upon the approval of DOE (Benton County Code, Title 11, Ordinance No. 62).

The estimated population for the Tri-Cities Region, as of 1988, was 150,700 (Rand McNally 1990). This represents an approximate 0.5% average annual growth rate since the 1980, when the population was determined to be 144,469 (United States Bureau of the Census 1982). The regional population is expected to remain somewhat stable for the near future; for the 5-yr period following 1988, Rand McNally (1990) projects an average annual population growth rate of approximately 0.09%. If this projection is correct, the population of the Tri-Cities Region will be approximately 151,400 in 1993.

Local Land Use

As noted in the regional land use discussion above, the eastern half of the 1100 Area is located within Benton County's land use jurisdiction, and is currently zoned unclassified. However, Benton County plans to zone the eastern-half of the 1100 Area, from its northern boundary south to and including the 1171 Building, for heavy industrial use; the remaining portion of the eastern half of the 1100 Area is to be zoned for light industrial use (Benton County Board of Commissioners 1985). A Heavy Industrial Use District is defined by the county to be an area that provides for the development of industrial and some commercial uses that may have an impact on surrounding land uses, whereas surrounding land uses are not to be significantly impacted within a Light Industrial Use District.

The areas immediately to the east, south, and west of the 1100 Area, and the western half of the 1100 Area itself, are located within the City of

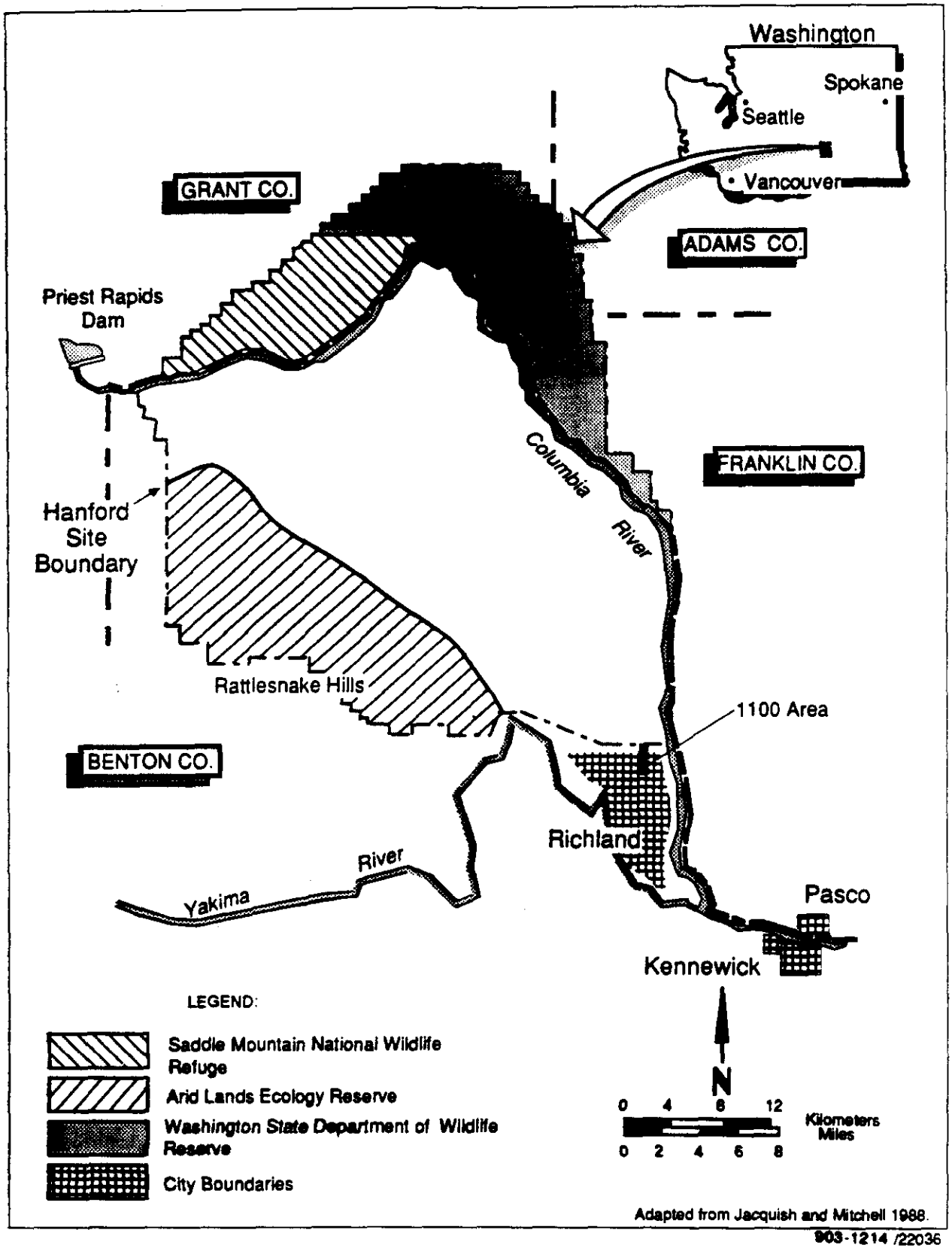

Figure 3-41. Locations of Wildlife and Ecological Land Reserves.

Richland. The city has zoned the majority of this area for industrial, commercial, and agricultural use. Residentially-zoned districts occur to the south and southeast of the 1100-EM-1 Operable Unit. Figure 3-42 shows the approximate zoning boundaries for the 1100-EM-1 Operable Unit vicinity. The zoning districts shown on the figure are described below (City of Richland Ordinance-Title 23):

- Agricultural Use (AG)—open land activities such as grazing or pasture, agriculture, small, part-time tract farming, and other compatible uses on land having favorable combinations of slope, climate, water-availability, and soil conditions

- Medium Industrial Use (I-M)—limited manufacturing, assembly, warehousing, and distribution operations and retail and wholesale sales of products manufactured on the premises or products allied thereto; also scientific administration and research and development facilities

- General Business Use (C-3)—commercial establishments having retail contact with the public and requiring either incidental shop work, storage, and warehousing or light manufacturing and extensive outdoor storage and display

- Limited Manufacturing Use (I-1)—manufacturing, warehousing, and distribution operations and commercial establishments satisfying the criteria for C-3

- Heavy Manufacturing Use (M-2)—heavy manufacturing and closely-related uses

- Central Business Use (C-2)—a wide range of retail business and services, occurring within enclosed buildings (except for parking and servicing), that are compatible with the core of the city and provide a focal point for city commerce

- Limited Business Use (C-LB)—professional and business offices, motels, hotels, and compatible uses

- Multiple-Family Residential Use (R-3)—high-density, multiple-family dwellings

- Medium-Density, Single-Family Residential Use (R-1M)—low-density, single-family detached residences, in areas offering a high degree of protection from hazards, objectional influences, and building congestion, while offering light, air, and privacy; certain essential and compatible public service facilities and institutions are permitted

- Low-Density Single-Family Residential Use (R-1L)—similar to R-1M, but provides for a lower population density

- Suburban Residential Use (R-1)—similar to R-1M and R-1L, but provides for the lowest population density within the city

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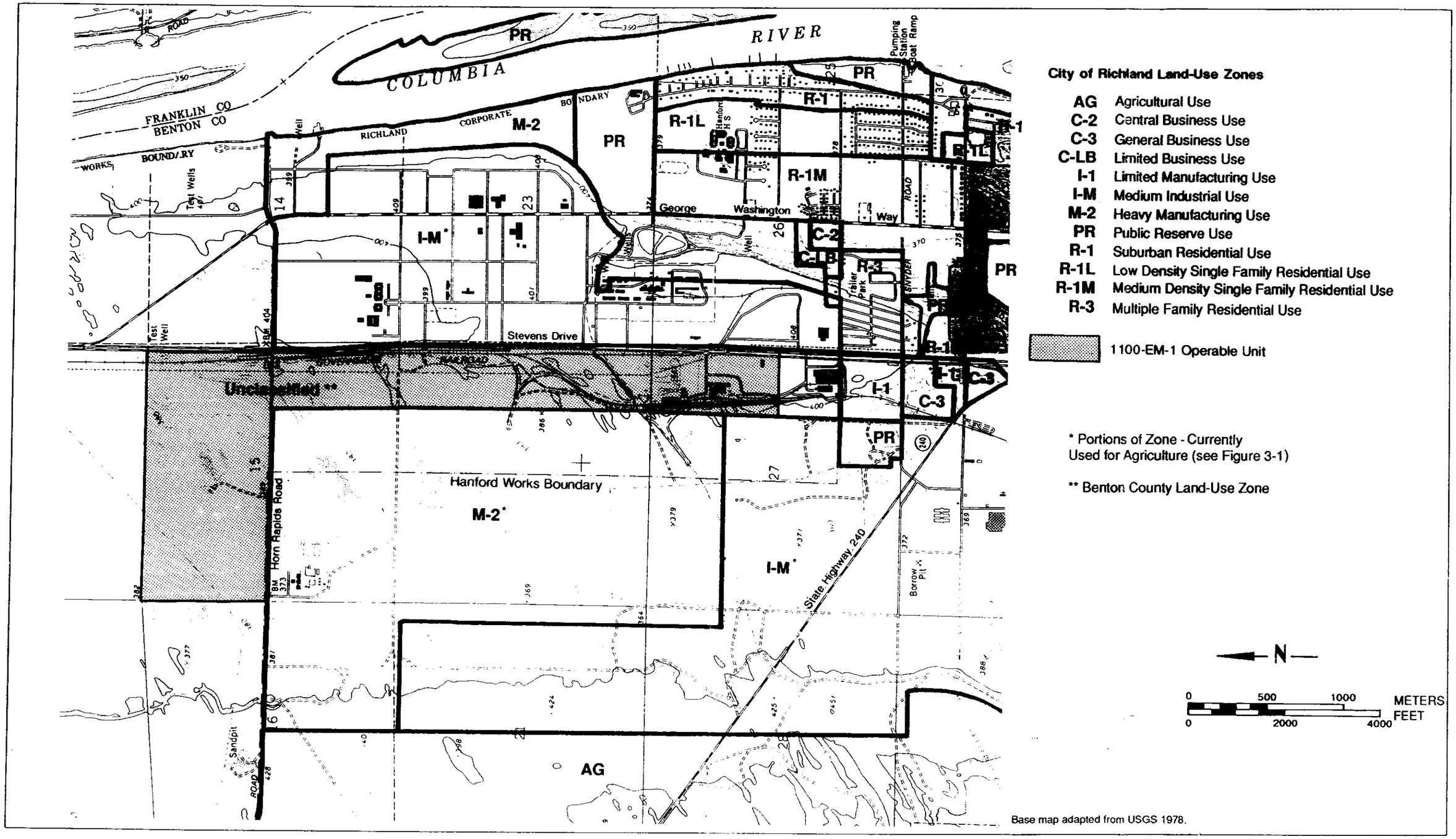

Figure 3-42. City of Richland and Benton County Land-Use Zoning for the 1100-EM-1 Operable Unit Vicinity.

- Public Reserve Use (PR)—open spaces, parks, playgrounds, and buildings and structures for public education, recreation, and other public and semi-public uses.

Before the Hanford Site was established, what is now the 1100 Area and its surroundings was predominantly used for agriculture. Relatively small areas of croplands and orchards still existed in the late 1940's (EPA 1989a). The area was served by a system of irrigation ditches, remnants of which are evident today (see Sections 3.1.2.2, 3.1.2.3, and 3.1.2.5).

Today the 1100 Area is used primarily for central warehousing, vehicle maintenance, and transportation distribution in support of the entire Hanford Site. Specific uses currently are:

- Vehicle, heavy equipment, bus, and railroad maintenance
- Bulk storage of petroleum products
- Gasoline station
- Bus system operations—main dispatch, holding, and transit center
- Rail system operations—main delivery, dispatch, and export center
- Warehousing operations
- Excess construction, maintenance, and administrative materials storage
- Hazardous and flammable construction and maintenance materials storage
- Classified materials destruction
- Administrative control for the above operations.

The construction of several new 1100 Area facilities is planned for the near future. These facilities will be consistent with current land use and include a new petroleum bulk storage plant, a new bus terminal, a new excess materials warehouse, and a new automobile and equipment maintenance and paint shop.

The workforce population within an approximate 1.6-km (1-mi) radius of the 1100-EM-1 Operable Unit can be partitioned into employees of Hanford Site contractors and non-site-related employers. Hanford Site contractors with facilities in the 1100 Area include Westinghouse Hanford, PNL, Kaiser Engineers, and HEHF. These organizations had a combined workforce at the area of approximately 900 in 1989, and this workforce is expected to grow by about 20% during the next three years; the Hanford Site contractor workforce stationed in the 3000 Area was approximately 2,700 in 1989, and is expected to grow by about 22% during the same time period (Seiler, S., WHC [Personal communication] February 12, 1990).

The non-site-related workforce in the 1100-EM-1 vicinity—as determined from various personal communications with representatives of the major

businesses, government offices, and schools in the vicinity—is presently 3,600. Near-term employment growth in this sector of the local economy is expected to be moderate.

The Horn Rapids Industrial Park is located south and west of the 1100-EM-1 Operable Unit. Although currently zoned for medium industrial use (I-M), the continued development of this industrial park is now oriented toward commercial office use, with an emphasis on science and technology. Therefore, further development of the industrial park may be related to Hanford Site activities.

The Port of Benton has indefinite plans for the development of their land within the nearby 3000 Area, which is referred to as the Richland Industrial Park. This development would include a new rail spur and docking facilities along the Columbia River that would serve to enhance transportation for agricultural commodities and light industrial products (Keller, S., Port of Benton [Personal communication] November 29, 1990).

The residential population within an approximate 1.6-km (1-mi) radius of the 1100-EM-1 Operable Unit is roughly 4,000 (United States Bureau of the Census 1982). The closest residence is located 0.8 km (0.5 mi) from the 1100-1 Battery Acid Pit; the nearby residential population is concentrated in a southeasterly direction from the operable unit.

In summary, the land use within and immediately adjacent to the 1100-EM-1 Operable Unit is of an industrial and commercial nature that is primarily associated with Hanford Site operations. Local county, city, and Hanford Site planning officials believe that this land use status will remain unchanged as long as the Hanford Site exists. If DOE, or the federal government in general, were to ever relinquish control and jurisdiction over the Hanford Site, an unlikely scenario according to local planning officials, land use in the immediate vicinity of the operable unit would likely remain unchanged due to the presence of established industrial and commercial facilities that could be readily utilized by the private sector.

3.7.1.2 **Water Use.** Water use in the general vicinity of the 1100-EM-1 Operable Unit is discussed below. Surface water is addressed first and is followed by a discussion of ground-water use.

Surface-Water Use

The Columbia River is the most significant surface-water body in the Tri-Cities Region. It is used as a source of drinking water, industrial process water, crop irrigation, and a variety of recreational activities, including hunting, fishing, boating, water skiing, and swimming (Jacquish and Mitchell 1988). Water intakes exist throughout the length of the Columbia River; however, it is appropriate to focus on that segment of the river that is most likely to be impacted by any operable unit contamination. As there are no significant surface-water bodies within or immediately adjacent to 1100-EM-1, the predominant contaminant transport mechanism is ground-water flow to the Columbia River.

Section 3.6.2 indicates that operable unit ground-water discharge to the Columbia River occurs within a 6.4-km (4-mi) reach. This reach extends from approximately the southern boundary of the 300 Area downstream to a point

about 0.8 km (0.5 mi) below the City of Richland water intake. The most significant intake is the city's, which supplies the municipal water-treatment plant and the ponds associated with the City of Richland well field. Appendix K contains recent monthly rates of water output supplied by the treatment plant and the well field. The annual output of the treatment plant is greater than the well field output by a factor of 3.5.

Several other irrigation intakes are located along this reach, including one operated by Washington State University, one operated by PNL, which is used to supply water to the forage crops grown within the 3000 Area, and one under construction, to supply water to the potato plot west of the operable unit (Gillian, M., City of Richland [Personal communication] February 15, 1990). The potato grower, Wiser Company Inc., is planning to expand their irrigated acreage, which is leased from the city, to increase crop production.

The Hanford Reach is a popular recreational sport fishery. Anadromous salmonids represent the majority of the sport fish harvested from the Hanford Reach. Other significant sport catches include white sturgeon, smallmouth bass, and walleye (Fiscus, H., Washington State Department of Fisheries [Personal communication] February 20, 1990; Foster, J., DOW [Personal communication] February 20, 1990).

Swimming and water skiing are popular recreational activities on the Columbia River. In the Tri-Cities Region, both of these activities are centered downstream in McNary Reservoir. However, a public swimming area has been established at Leslie R. Groves Park. This swimming area is located approximately 0.8 km (0.5 mi) downstream from the city water intake.

Ground-Water Use

Ground water in the vicinity of the 1100-EM-1 Operable Unit is used primarily for environmental monitoring, supplemental municipal water supply, irrigation, and domestic use (see Appendix J). All residential buildings near the operable unit have access to city water; therefore, it is unlikely that domestic wells are used to produce water for human consumption. Such wells are most likely used for domestic irrigation and heat pump systems. The irrigation wells for the potato field west of the operable unit will no longer be used once the surface-water irrigation supply is in operation (see the surface-water use discussion, above).

Several potential ground-water receptor points exist within the vicinity of the operable unit. As shown in Figure 3-43, there are about 40 wells, excluding known environmental monitoring wells, located within the area subject to potential ground-water contamination from the operable unit. This area is conservatively defined as all areas hydraulically downgradient from the operable unit to the Columbia River, and all areas hydraulically upgradient within a 0.8-km (0.5-mi) radius of the operable unit. The completed depth of these wells range from 3.7 to 57.9 m (12 to 190 ft) below ground surface (see Appendix J).The City of Richland well field and recharge basins are located approximately 0.8 km (0.5 m) east of the operable unit. The well field is used to supplement the City of Richland treatment plant during times of peak seasonal demand. Water is pumped from the Columbia River and allowed to percolate through the soil column, thus reducing the turbidity of the river water (CWC-HDR, Inc. 1988). The city's recharge to withdrawal rate is maintained at 3:1 (Bauer, M., City of Richland [Personal

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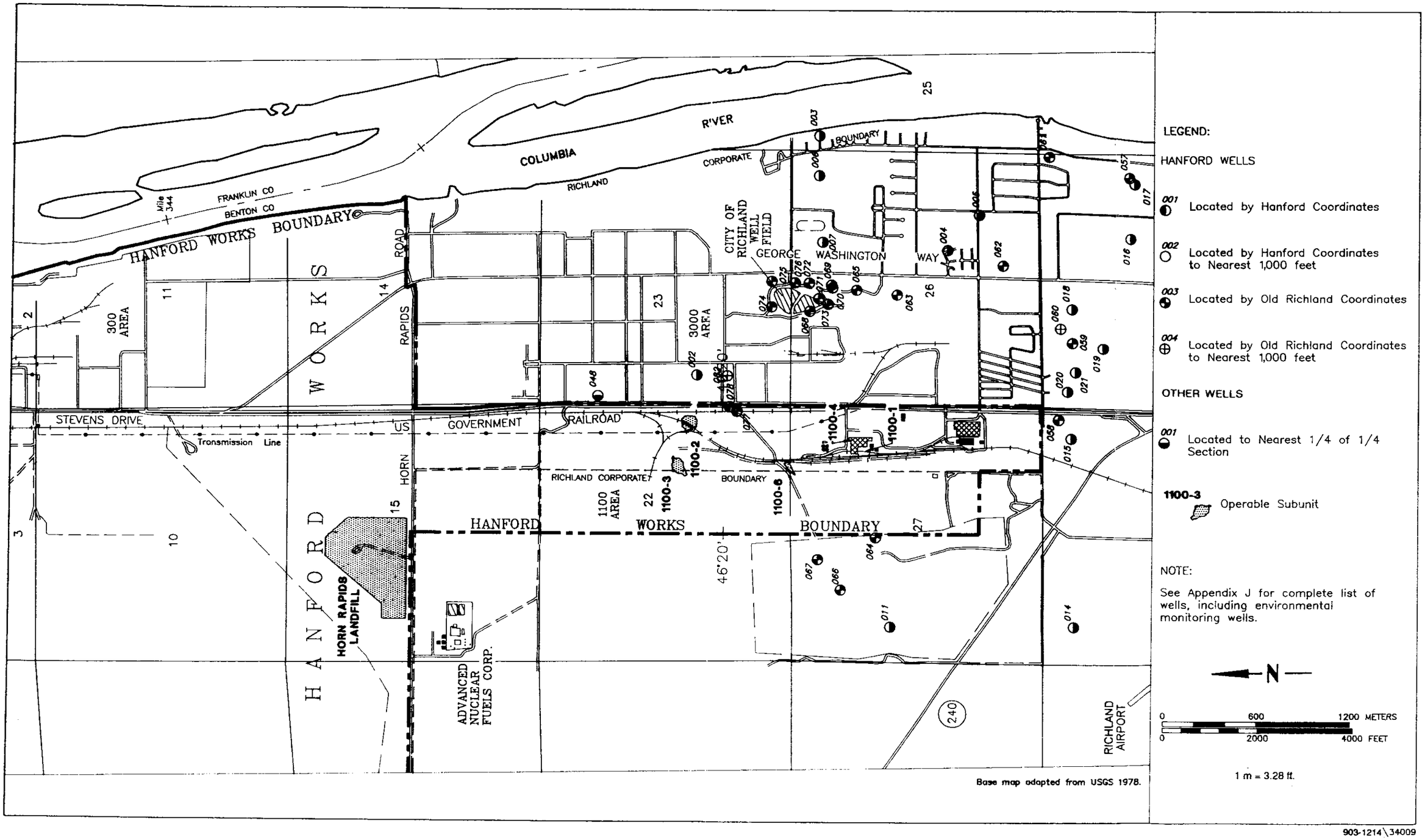


Figure 3-43. Potential Ground-Water Receptor Points.

communication] February 13, 1990). This practice ensures the withdrawal of the treated river water, which has a significantly lower hardness than the local ground water (Deju and Fecht 1979). Water output rates from the well field are contained in Appendix K and are summarized in Figure 3-44.

3.7.1.3 Cultural Resources. Several archeological districts and sites along the Hanford Reach of the Columbia River have been established and granted protection by the federal and state governments (Hanford Reach Study Task Force 1990). In addition, the first nuclear reactor constructed and operated at the Hanford Site, B Reactor, is being considered for designation as an historical site of national significance. However, no significant cultural resource sites exist within the immediate vicinity of the 1100-EM-1 Operable Unit.

3.7.2 Wildlife Ecology

Wildlife, as used in this report, refers to non-domesticated populations of plants and animals, both terrestrial and aquatic. The description of wildlife ecology associated with 1100-EM-1 focuses on terrestrial ecology, aquatic ecology, and sensitive environments.

3.7.2.1 Terrestrial Ecology. The terrestrial ecology of the 1100-EM-1 Operable Unit, on both the regional and local scales, is presented below. The flora and fauna are described, focusing on major and protected species.

Flora

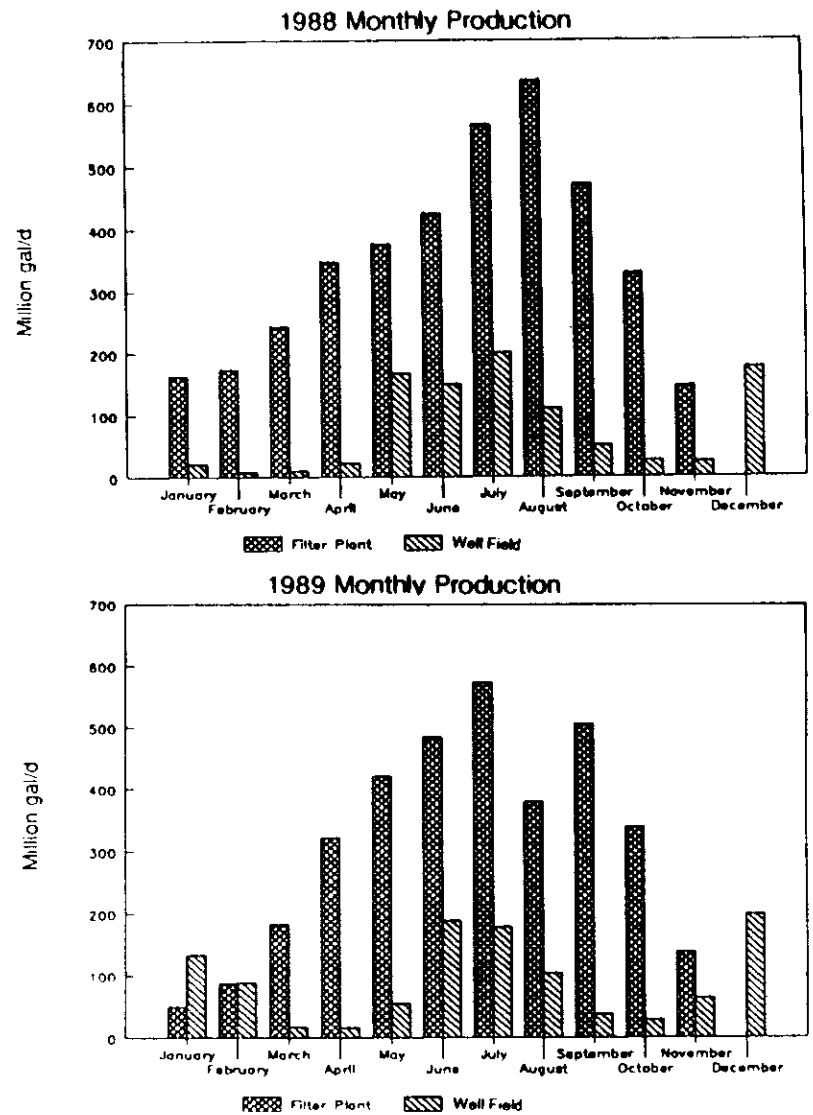
The Pasco Basin is located in the central, arid-to-semiarid portion of the Columbia Basin physiographic province, a shrub-steppe vegetational zone. This zone is characterized by the presence of sagebrush and bunchgrass communities growing upon desertic soils. The specific, natural climax community of the Hanford Site is the big sagebrush (*Artemisia tridentata*)/bluebunch wheatgrass (*Agropyron spicatum*) zonal association (Franklin and Dyrness 1988).

The dominant vegetation species of this community, both in terms of constancy of occurrence and percentage of canopy coverage, are the perennial grasses, bluebunch wheatgrass and Sandberg's bluegrass (*Poa sandbergii*). Big sagebrush is the medium shrub that dominates this community with respect to occurrence and coverage. Other major plant species in this community include (Franklin and Dyrness 1988):

- Medium shrubs—tall green rabbitbrush (*Chrysothamnus viscidiflorus*)
- Low shrubs—longleaf phlox (*Phlox longifolia*) and threadleaf fleabane (*Erigeron filifolius*)
- Perennial grasses—Cusick bluegrass (*Poa cusickii*) and needle and thread (*Stipa comata*)
- Perennial forbs—Spalding's milkvetch (*Astragalus spaldingii*), false agoseris (*Microseris troximoides*) and green-banded mariposa lily (*Calachortus macrocarpus*)

Year	Month	Filter Plant (million gal/d)	Well Field (million gal/d)
1988	January	163.53	21.52
	February	172.71	8.13
	March	242.60	10.00
	April	347.40	22.80
	May	376.00	167.20
	June	425.10	150.10
	July	565.60	200.80
	August	635.90	110.50
	September	471.70	51.00
	October	329.00	26.20
	November	147.00	24.40
	December	0.00	175.80
	Total	**3,876.54**	**968.45**
1989	January	49.50	133.40
	February	87.60	89.00
	March	182.10	17.70
	April	321.80	16.70
	May	422.00	54.90
	June	484.50	188.20
	July	573.40	178.00
	August	379.50	103.50
	September	505.90	38.00
	October	339.90	28.30
	November	138.30	64.10
	December	0.00	198.30
	Total	**3,484.50**	**1,110.10**
	2 Yr Total	**7,361.04**	**2,078.55**

Adapted from Appendix K



903-1214

Figure 3-44. City of Richland Filter Plant and Well Field Monthly Water Production for 1988 and 1989.

- Annuals-Indianwheat (*Plantago patagonica*), Nuttall's fescue (*Festuca microstachys*), cheatgrass brome (*Bromus tectorum*), pinnate tansymustard (*Descurainia pinnata*), and vernal draba (*Draba verna*).

Much of the Hanford Site vegetation has been disturbed by agricultural activities prior to the establishment of the reservation (Hanford Reach Study Task Force 1990), and by site construction and operations activities. Such disturbances alter the plant community, but typically, once the disturbance has ceased, the community successionally returns to its climax state. However, the introduction of an exotic, well-adapted species-cheatgrass brome-has altered the natural successional patterns in the region (Franklin and Dyrness 1988).

Cheatgrass brome, an annual grass, quickly colonizes an overgrazed area and competes successfully with the native perennial grasses-bluebunch wheatgrass and Sandberg's bluegrass. Once established, it rarely relinquishes an area. Tall gray rabbitbrush (*Chrysothamnus nauseosus*), a native, medium-height shrub, often increases to dominant proportions on disturbed areas invaded by cheatgrass. Areas subject to more intensive disturbances are dominated initially by tumbleweeds (*Salsola kali* and *Sisymbrium altissimum*) prior to the establishment of a dominant cheatgrass population (Franklin and Dyrness 1988).

A local biological survey of the 1100-EM-1 Operable Unit was conducted in the spring of 1989 (see Section 2.7.2.2). The biological diversity observed varied from subunit to subunit (Landeen, D., WHC [Memo to M. Adams, WHC] May 4, 1989). Certain operable subunits, specifically 1100-1 and 1100-4, were virtually devoid of wildlife due to extensive habitat alteration and the proximity of human industrial-related activities. As expected, the Horn Rapids Landfill contained the highest observed diversity due to its larger size, relatively remote location, and absence of current operational activities.

During the biological survey of the 1100-EM-1 Operable Unit, the following major plant species were observed: sagebrush (*Artemisia* spp.), rabbitbrush (*Chrysothamnus* spp.), tumbleweed, pinnate tansymustard, cheatgrass brome, plantain (*Plantago* spp.), and Sandberg's bluegrass (Landeen, D., WHC [Memo to M. Adams, WHC] May 4, 1989).

A list of state-designated endangered and threatened plant species that could potentially occur at the Hanford Site is contained in Table 3-4. It should be noted that Washington State designations, in all cases, are as strict or stricter than the corresponding federal designations. No endangered or threatened plant species were encountered during the biological survey of the operable unit.

The DNR performed a review of their database files, containing documented sightings of endangered and threatened plant species, for the 1100-EM-1 vicinity (Sprague, N., DNR [Letter to L. Johnson, GAI] February 6, 1990). No protected species, including those listed in Table 3-4 as having the potential to occur on the Hanford Site, are known to exist in the vicinity of the operable unit. No high-quality native plant communities or native wetlands were identified either.

Table 3-4. Endangered and Threatened Species Potentially Associated with the Hanford Site. (Sheet 1 of 2)

Endangered Vascular Plants

persistentsepal yellowcress (*Rorippa columbiae*): Known to have a scattered distribution due to specialized habitat requirements or habitat loss; generally occurs in moist to marshy places and is known to inhabit the wetted shoreline of the Hanford reach of the Columbia River in Benton County.

Threatened Vascular Plants

Columbia milk-vetch (*Astragalus columbianus*): Locally endemic to the area in the immediate vicinity of Priest Rapids Dam, including a portion of Benton County; could potentially occur along the Columbia River in the northwestern portion of the Hanford Site.

eatonella (*Eatonella nivea*): Known to occur along the Columbia River in Grant County; could potentially occur along the river in the northern portion of the Hanford Site.

Hoover's desert parsley (*Lomatium tuberosum*): Locally endemic to southcentral Washington, including Benton County; known to inhabit rocky hillsides.

Endangered Birds

Aleutian Canada goose (*Branta canadensis leucopareia*): Nests in the Aleutian Islands of Alaska and winters in California; has been occasionally sighted, as a migrant, in Benton County; a potential seasonal user of the Columbia River valley, feeding on grasses, sedges, and berries.

American white pelican (*Pelecanus erythrorhynchus*): Winters along the southern Pacific Coast and the Gulf Coast and nests in northern prairie and intermontane lakes; no longer nests in Washington; migrates through eastern Washington; flocks are common in the Columbia Basin during the summer; known to occasionally winter on the Columbia River, foraging on fish, amphibians, and crustaceans and roosting on islands.

peregrine falcon (*Falco peregrinus*): Breeds and winters in eastern Washington, inhabiting open marshes, river shorelines, wide meadows and farmlands; nests on undisturbed cliff faces; an erratic visitor at the Hanford Site, feeding on songbirds, shorebirds, and waterfowl.

sandhill crane (*Grus canadensis*): Inhabits open prairies, grainfields, shallow lakes, marshes, and ponds, nesting in drier grassy and marshy areas; common migrant during the spring and fall in Washington; some known and suspected nesting sites in eastern Washington; unlikely visitor at the Hanford Site.

Table 3-4. Endangered and Threatened Species Potentially Associated with the Hanford Site. (Sheet 2 of 2)

Endangered Birds (continued)

upland sandpiper (*Bartramia longicauda*): Inhabits ungrazed and lightly grazed prairies, upland meadows, and fields that are usually located near lakes or rivers; breeds in the northern and central portions of North America and winters in South America; uncommon in eastern Washington; a potential migratory visitor at the Hanford Site, feeding on insects, worms, and some vegetation.

western snowy plover (*Charadrius alexandrus*): A coastal species rarely observed in eastern Washington.

Threatened Birds

bald eagle (*Haliaeetus leucocephalus*): A regular winter visitor to the Columbia River, feeding on spawning salmon and perhaps waterfowl and small mammals; roosting areas are known to exist in the 100 Areas of the Hanford Site (roost sites and winter feeding areas constitute critical habitats for this species).

ferruginous hawk (*Buteo regalis*): Inhabits open prairies and sagebrush plains, usually with rocky outcrops or scattered trees, located well away from human disturbance; known to nest in Benton and Franklin counties, with Franklin County possessing the majority of the nests within Washington; known to nest in the Hanford Site on the Arid Lands Ecology Reserve; rarely winters in Washington; known to occasionally forage on small mammals, birds, and reptiles on sagebrush plains in the Hanford Site.

Threatened Mammals

pygmy rabbit (*Sylvilagus idahoensis*): May be extirpated from Washington; inhabits undisturbed areas of sagebrush having soils soft enough to dig burrows in; once known to exist on the Hanford Site near springs in the Snively Basin, west of the 200 Area plateau.

[a]State designations are as strict or stricter than federal designations.

Adapted from DOE-RL 1987, DOW 1987, DNR 1987, and Hitchcock and Cronquist 1973.

Fauna

The fauna of the Hanford Site is characteristic of the shrub-steppe plant community, with additional diversity occurring due to the ecotonal influence of the Columbia River. The most abundant fauna on the Hanford Site are the grasshopper (Ornithoptera), horned lark (*Eremophila alpestris*), western meadowlark (*Sturnella neglecta*), Great Basin pocket mouse (*Perognathus parvus*), cottontail rabbit (*Sylvilagus nuttallii*), and jackrabbit (*Lepus* spp.). Various species of raptors, the coyote (*Canis latrans*), and mule deer (*Odocoileus hemionus*) forage in this habitat (DOE-RL 1987; Jacquish and Mitchell 1988).

The Columbia Basin is a popular recreational hunting area, where deer, rabbits, waterfowl, and upland game birds are harvested. Furbearing mammals are also trapped in this area (Ware, D., DOW [Personal communication] February 21, 1990). However, no hunting or trapping is allowed on the Hanford Site except within the Wahluke Slope Wildlife Area, located north of the Columbia River (see Figure 3-41).

Because of the mobility of most animals and the seasonal, migratory nature of many species, an early spring survey of the operable unit is insufficient to allow a determination of the major animal species present. However, bird species observed during the spring-time operable unit survey included the white-crowned sparrow (*Zonotrichia leucophrys*), western meadowlark, horned lark, starling (*Sturnus vulgaris*), ring-billed gull (*Larus delawarensis*), killdeer (*Charadrius vociferus*), raven (*Corvus corax*), marsh hawk (*Circus cyaneus*), and long-billed curlew (*Numenius americanus*).

Mammal species observed, or identified by tracks, included the Townsend's ground squirrel (*Spermophilus townsendi*), Great Basin pocket mouse, cottontail rabbit, coyote, mule deer, and badger (*Taxidea taxus*). Because of the large number of abandoned badger burrows and the relative absence of human activity, the Horn Rapids Landfill may provide potential habitat for the burrowing owl (*Athene cunicularia*) (Landeen, D., WHC [Memo to M. Adams, WHC] May 4, 1989); however, this species was not sighted.

Table 3-4 also includes state-designated endangered and threatened animal species that could potentially occur at the Hanford Site. None of the endangered or threatened animal species listed in this table, nor any others, were encountered during the biological survey.

The DOW conducted an operable-unit-specific review of their database files of documented sightings of endangered and threatened animal species (Cyra, T., DOW [Letter to L. Johnson, GAI] February 12, 1990). No protected species, including those listed in Table 3-4 as having the potential to occur on the Hanford Site, are known by the department to exist in the vicinity of the operable unit. However, DOW does report two bird species in the vicinity—the Swainson's hawk (*Buteo swainsoni*) and the long-billed curlew (*Numenius americanus*)—that are regarded by the department as sensitive, but not formally protected in the sense of being endangered or threatened.

3.7.2.2 Aquatic Ecology. As there are no significant surface-water bodies within or immediately adjacent to the operable unit (see Section 3.3.2), this discussion of aquatic ecology will briefly address predominant aquatic and semiaquatic species known to inhabit the Hanford Reach of the Columbia River,

which is approximately 1.5 to 1.8 km (0.9 to 1.1 mi) east of the operable unit.

The major fish species using the Hanford Reach for spawning grounds, nursery areas, foraging areas, and as a migratory corridor include chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), and steelhead trout (*O. mykiss*). American shad (*Alosa sapidissima*) and white sturgeon (*Acipenser transmontanus*) may also use the Hanford Reach as a spawning ground (NOAA 1988).

The anadromous salmonids—chinook, coho, and sockeye salmon and steelhead trout—represent the majority of the sport fish harvested from the Hanford Reach. White sturgeon, smallmouth bass (*Micropterus dolomieui*), and walleye (*Stizostedion vitreum*) also represent a significant portion of the sport catch for the reach (Fiscus, H., Washington State Department of Fisheries [Personal communication] February 20, 1990; Foster, J., DOW [Personal communication] February 20, 1990).

The DOW flies the Hanford Reach of the Columbia River each fall and winter to count migratory waterfowl. The majority of such birds counted during 1989 were either the Canada goose (*Branta canadensis*), one of several species of ducks (Anatidae), or the coot (*Fulica* americana). Other semiaquatic bird species identified along the Hanford Reach in small numbers were the trumpeter swan (*Olor buccinator*), American white pelican (*Pelecanus erythrorhynchos*), common loon (*Gavia immer*), and common merganser (*Mergus merganser*). Two species of eagle, the bald eagle (*Haliaeetus leucocephalus*) and the golden eagle (*Aquila chrysaetos*), were also encountered in small numbers (Ware, D., DOW [Personal communication] February 21, 1990).

There are no aquatic species inhabiting the Hanford Reach of the Columbia River that are designated as either endangered or threatened by the State of Washington. However, some semiaquatic or riparian species could potentially occur within or along the segment of the reach east of the operable unit (see Table 3-4). Such species include the endangered persistentsepal yellowcress (*Rorippa columbiae*), a riparian plant known to inhabit the shoreline of the Benton County portion of the Hanford Reach, and the endangered American white pelican, which occasionally winters on the Hanford Reach. The threatened bald eagle, a regular visitor to the 100 Areas of the Hanford Site in the winter, where it feeds on spawning salmon, could also potentially be encountered in the more southern portions of the reach.

3.7.2.3 Sensitive Environments. The NCP defines a sensitive environment, from a CERCLA-perspective, to consist of either a critical habitat of an endangered species or a wetland habitat of 2 ha (5 ac) or greater in area (40 CFR 300, Appendix A). No endangered species inhabit the 1100-EM-1 Operable Unit vicinity (see Sections 3.7.2.1 and 3.7.2.2); however, about 3 ha (7 ac) of wetlands exist approximately (0.5 mi) west of the operable unit (see Figure 3-1). In addition, the Columbia River and certain animal species could be regarded as valued habitat and ecosystem components, respectively. This habitat and these species could therefore be deemed sensitive for the purposes of this project. The wetlands, the Columbia River, and the animal species are discussed in further detail below.

The nearby wetland habitat is actually a cluster of four small and discrete wetlands situated within natural depressions which together cover an

area of approximately 3 ha (7ac). These wetlands are located within the western-half of Section 27 in Township 10 North, Range 28 East, just to the west of the western boundary of the 1100 Area and approximately 0.8 km (0.5 mi) west of the operable unit (see Section 3.1.1 and Figure 3-1). Wetland habitats are generally deemed sensitive because of the importance of their ecosystem roles relative to the proportion of land area covered. Wetlands are often zones of ground-water recharge and sediment stabilization. Because they generally impart an ecotonal influence and serve as zones of nutrient accumulation, biological diversity and productivity are usually enhanced (EPA 1989b).

The USFWS (1976) has classified each of the four wetland areas as seasonal palustrine habitats. The three southern wetlands are categorized as supporting a forested-emergent vegetational community; the northernmost and smallest of the wetlands supports a emergent-scrub/shrub community.

The Columbia River is a valued resource for the Tri-Cities Region and the State of Washington as a whole. That portion of the river south of Grand Coulee Dam to the Washington-Oregon border is designated a Class A (Excellent) surface water by the state (WAC 173-201-080 (20)). This designation requires that water quality be maintained at certain specified levels for: fish migration, rearing, spawning, and harvesting; shellfish rearing, spawning, and harvesting; domestic, industrial, and agricultural water supply; recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment); and commerce and navigation (WAC 173-201-045(2)(b)).

The Hanford Reach of the Columbia River provides habitat, at least seasonally, for several endangered or threatened species, e.g., the riparian persistentsepal yellowcress, and the transient American white pelican and bald eagle (see Section 3.7.2.2). The overall environmental value of the Hanford Reach—the last non-tidal free-flowing Columbia River reach of any substantial length within the United States—is demonstrated by the fact that efforts are underway to determine whether or not the reach merits protective designation as a federal wild and scenic river (Hanford Reach Study Task Force 1990).

While no endangered or threatened species inhabit or are known to utilize the 1100-EM-1 Operable Unit, several species do that may be regarded as valued. Game animals, such as the cottontail rabbit and the mule deer (see Section 3.7.1.1), are components of the human food chain. However, the range of a cottontail rabbit is generally limited to a single acre of land (Larrison 1970). As no hunting is allowed on the Hanford Site, nor within the corporate boundary of the adjacent City of Richland, the likelihood of human consumption of an operable-unit-resident cottontail is extremely low. Mule deer range much more widely, but are only transient within the operable unit itself. They are herbivorous, primarily browsing on shrubs; they also graze on grasses and forbs.

Species identified by DOW as sensitive, the Swainson's hawk and the long-billed curlew (see Section 3.7.1.1), also merit consideration. The Swainson' hawk is a summer resident that preys primarily upon large insects (mostly grasshoppers and crickets), small rodents, rabbits, and rarely young birds (Terres 1980). An active Swainson's hawk nest is located about 1.5 km (0.9 mi) west of the Horn Rapids Landfill, far enough away such that normal remedial activities within the landfill should not disturb its inhabitants (Rickard, B., PNL [Memo to R. Gephart, PNL] December 8, 1988).

The long-billed curlew is also a migrant that nests in the summer within and adjacent to the Horn Rapids Landfill. The nests are located on the ground in sparse stands of cheatgrass (Rickard, B., PNL [Memo to R. Gephart, PNL] December 8, 1988). During the nesting season, long-billed curlews feed primarily on large insects—mostly grasshoppers, beetles, and caterpillars (Terres 1980).

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4.0 NATURE AND EXTENT OF 1100-EM-1 OPERABLE UNIT CONTAMINATION

This section provides a description of the nature and extent of contamination at the 1100-EM-1 Operable Unit. The focus of Section 4 is on the empirically-determined chemical and contaminant characteristics of the operable unit. A description of the physical characteristics of 1100-EM-1 is provided in Section 3; an analysis of the environmental fate and transport of the operable unit contaminants is provided in Section 5.

Section 4.1 describes the known and suspected information about the contaminant sources for each operable subunit and briefly characterizes other waste streams in the operable unit vicinity. Results of the surface radiation and soil gas surveys conducted at the operable subunits are also discussed in Section 4.1. The empirically-determined nature and extent of operable unit contamination is addressed in Sections 4.2 (air), 4.3 (surface waters and associated sediments), 4.4 (soil), 4.5 (ground water), and 4.6 (biota). The section concludes with a summary of operable unit contaminants of potential concern and their respective environmental distributions in Section 4.7.

4.1 CONTAMINANT SOURCES

Known and suspected wastes for the six operable subunits within the 1100-EM-1 Operable Unit are described below. Disposal records were not maintained during the operational periods of these subunits; therefore, the following waste characterizations have obvious limitations. The actual characterization of the nature and extent of 1100-EM-1 contamination is primarily dependent upon the findings of the meteorological, surface hydrological, pedological, hydrogeological, and ecological investigations, which are presented below in Sections 4.2 through 4.6, respectively. The information presented in this subsection has been used to assist in validating the findings of the other environmental-medium-specific investigations. Section 4.7 (Nature and Extent of Contamination Summary) provides a general comparison of the actual nature of contamination encountered during the Phase I RI against that anticipated.

For each waste facility general types of wastes with major anticipated chemical constituents, the period of waste disposal, and the estimated volumes of wastes disposed are reported. A detailed description of the physical characteristics of each facility is provided in Section 3.1 (Source Facility Characteristics). Each of the six operable subunits is addressed in Section 4.1.1; other nearby waste facilities, not directly associated with 1100-EM-1, are addressed in Section 4.1.2.

4.1.1 Operable Subunits

The known and suspected waste characteristics of each of the six operable subunits—1100-1, 1100-2, 1100-3, 1100-4, UN-1100-6, and the Horn Rapids Landfill—are presented below. Major toxic chemical constituents for each waste type identified are presented in Table 4-1. The physical characteristics of the operable subunits are described in Section 3.1.2.

Table 4-1. Major Toxic Constituents in 1100-EM-1 Operable Unit Potential Waste Products. (Sheet 1 of 2)

Waste Product	Toxic Element
antifreeze	ethylene glycol, propylene glycol
automotive cleaners[1]	cresol, ethylene dichloride, sodium chromate, petroleum distillates, 1,1,1-trichloroethane
battery acid[2]	lead, sulfuric acid, arsenic, cadmium
contact cement[1]	toluene, hexane, methyl ethyl ketone, trichloroethene
degreasers	1,1,1-trichloroethane, trichloroethene
gasoline	C_3-C_{12} aliphatic hydrocarbons, xylene, benzene
hydraulic oils	PCBs
industrial lubricants[1]	trichloroethene, lead naphthenate
lacquer thinners[1]	ethyl acetate, butyl acetate, butyl alcohol, toluene, xylene, aliphatic hydrocarbons
metal cleaners[1]	potassium carbonate, trisodium phosphate, tetrachloroethene, trichloroethene, kerosene[b], chromic acid
paints, latex[3]	ethylene glycol, zinc
paints, oil-based[4]	linseed oil[c], mineral spirits[d], lead, zinc
paints, other[3,4]	toluene, methyl ethyl ketone, chromium, zinc, lead
paint removers	dichloromethane, methyl ethyl ketone
paint thinners	mineral spirits[d]
penetrating oils[1]	kerosene[b], xylene, carbon tetrachloride
roof patching sealants[1]	kerosene[b], gasoline, mineral spirits[d]
solvents	acetone, carbon tetrachloride, gum turpentine, methanol, 1,1,1-trichloroethane, stoddard solvent[e]
stains[1]	mineral spirits[d], aniline dyes

Table 4-1. Major Toxic Constituents in 1100-EM-1 Operable Unit Potential Waste Products. (Sheet 2 of 2)

Waste Product	Toxic Element
undercoating material[1]	aromatic hydrocarbons, aliphatic hydrocarbons, phenolic resins, methyl isobutyl ketone
vinyl adhesives[1]	benzene, toluene
waste oil[5]	C_{10}-C_{16} alkanes, toluene, 1,1,1-trichloroethane, polycyclic aromatic hydrocarbons (PAHs)

[a]Petroleum distillates are hydrocarbon fractions such as gasoline and kerosene.
[b]Kerosene contains aromatic hydrocarbons and C_5-C_{16} aliphatic hydrocarbons.
[c]Linseed oil contain flaxseed oil and additives such as lead, manganese, and cobalt.
[d]Mineral spirits contains benzene, toluene, hexane, and cyclohexane.
[e]Stoddard solvent contains C_9-C_{12} aliphatic hydrocarbons, naphthene, and aromatic hydrocarbons.

[1] Gosselin et al. 1984.
[2] Eckroth 1981.
[3] Ash and Ash 1978.
[4] Myers and Long 1975.
[5] EPA 1974.

4.1.1.1 1100-1 (Battery Acid Pit). The Battery Acid Pit was a circular unlined sump or French drain approximately 1.8 m (6 ft) in both diameter and depth (see Section 3.1.2.1). This pit was operated from the mid-1950's until it was backfilled upon retirement in 1977.

Battery acid wastes from vehicle maintenance activities were disposed in this pit. Anecdotal information indicates that acid was drained from batteries directly into the pit. The primary chemical constituents and other common toxic contaminants of the lead-acid battery (the most common battery used in vehicles) are listed in Table 4-1. The maximum volume of acid disposed, over the operational period of the pit, is estimated to be 57,000 L (15,000 gal) (Clark 1990a).

Other wastes are suspected of having been disposed in the Battery Acid Pit, especially waste oils, solvents, and antifreeze, because of the proximity of the 1171 Building, the vehicle service, maintenance, and repair facility (DOE-RL 1989a). However, the soil gas survey for this operable subunit detected no VOCs (Evans 1989) (a list of target VOCs is provided in Appendix C); the surface radiation survey results were also negative for the Battery Acid Pit (Clark 1990b).

Based on the above information, cadmium, lead, and sulfuric acid appear to be the anticipated contaminants of concern associated with 1100-1.

4.1.1.2 1100-2 (Paint and Solvent Pit). The Paint and Solvent Pit is the remains of a roughly circular gravel pit which covers approximately 0.4 ha (1 ac). Subsequent to its use as a gravel pit, from 1954 through the mid-1980's, it was used for the disposal of construction debris and, reportedly, for the occasional disposal of paint and solvent waste from the 1100 Area vehicle service, maintenance and repair facility, the 1171 Building. The disposal volume of such shop wastes is estimated to be about 11,000 L (3,000 gal) for the 30-year operational period of the pit (Clark 1990a). Concerns about the potential disposal of bulk volumes of liquid wastes in 55-gal drums were not substantiated by the results of the geophysical survey (Sandness et al. 1989). Backfill material, of a depth ranging from 1.2 to 4.9 m (4 to 16 ft), currently covers the pit (see Section 3.1.2.2).

The types of paints in common use during the period of reported disposal most likely were latex, oil-based, and miscellaneous metal paints and enamels. Such products, along with paint removers, paint thinners, and paint solvents, include a variety of different chemicals. The typical toxic constituents of these representative paint products are listed in Table 4-1.

A variety of products other than paints are used in vehicle body shops, such as undercoating materials, metal cleaners, solvents, and various epoxies and resins. These products, in addition to penetrating oils, lacquer thinners or strippers, roof patching sealant, contact cement, vinyl adhesives, industrial lubricants, phosphoric acid, tung oil, and stains, were reportedly used at the 1171 Building during the operational period of 1100-2. Representative major toxic constituents of these products are listed in Table 4-1.

The soil gas survey for the 1100-2 operable subunit detected measurable concentrations of tetrachloroethene (Evans 1989). The results of this survey are displayed in Figure 4-1; data are contained in Appendix C. No detectable radioactivity was encountered during the surface radiation survey for this operable subunit (Clark 1990b).

Based upon probable product disposal and toxicity information, and the results of the soil gas survey, the anticipated contaminants of concern for 1100-2 are:

- acetone
- chromium
- lead
- methanol
- tetrachloroethene.

4.1.1.3 1100-3 (Antifreeze and Degreaser Pit). The Antifreeze and Degreaser Pit is currently a shallow, subcircular depression approximately 0.8 ha (2 ac) in size. The subunit was originally a sand and gravel pit that was subsequently used for the disposal of approximately 23 m^3 (30 yd^3) of used roofing gravel and 0.8 m^3 (1 yd^3) of concrete rubble from 1979 through 1985. Approximately 1.5 m (5 ft) of backfill material currently covers portions of the subunit (see Section 3.1.2.3).

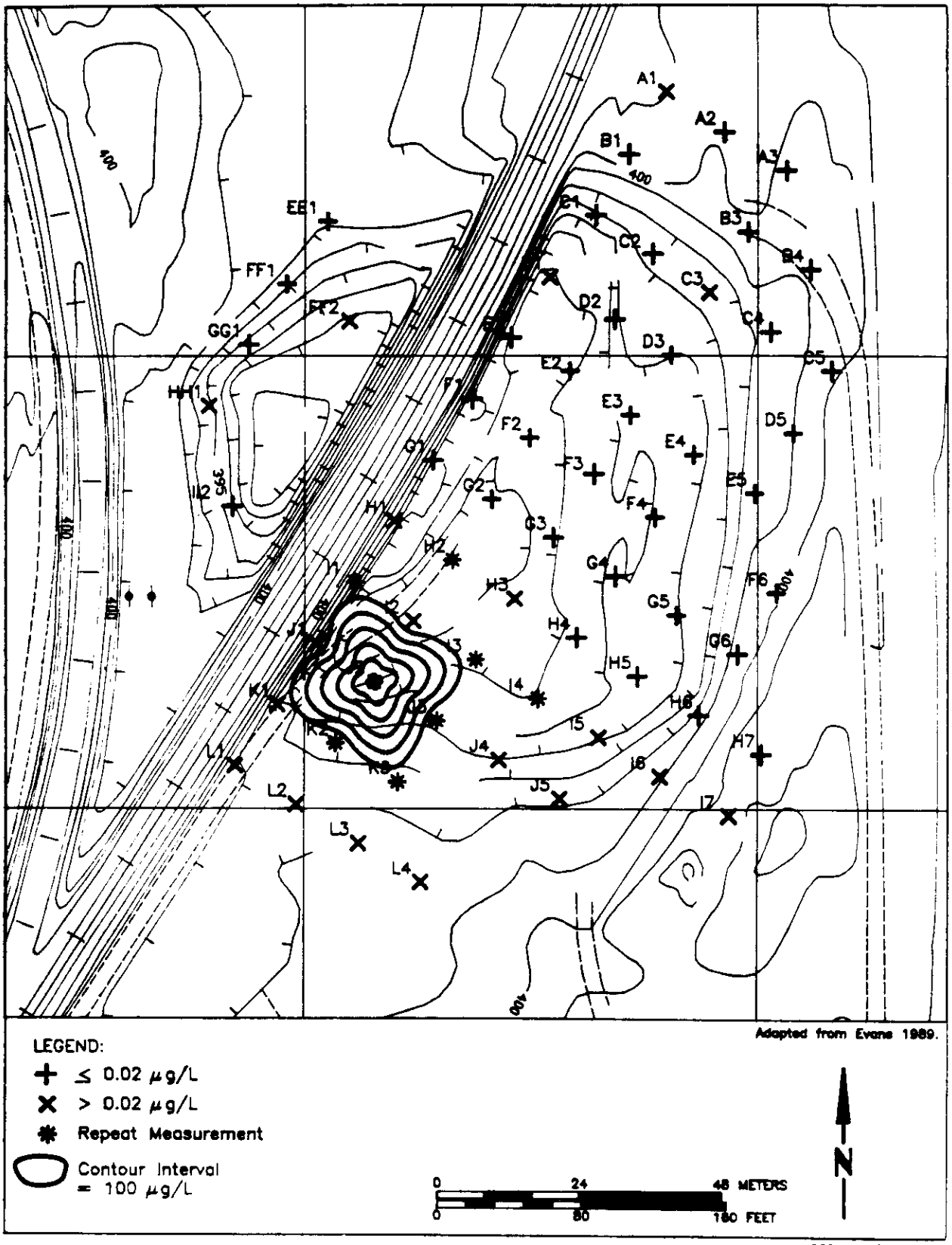

Figure 4-1. Distribution of Tetrachloroethene in Soil Gas at the 1100-2 Operable Subunit.

Anecdotal information indicates that the pit was also used for the disposal of waste generated in the 1171 Building. It is estimated that this garage serviced about 80% of the light automotive fleet for the Hanford Site during the 1100-3 operational period (Clark 1990a).

Primary products used in the garage include gasoline, hydraulic fluid and oil, motor oil, grease, freon gas, antifreeze (ethylene glycol), and other miscellaneous solvents, degreasers, and cleaners. Typical major toxic constituents of each of these products are presented in Table 4-1. Past practices included collecting all petroleum and organic-based liquid wastes in storage tanks to be used as "road oil" for dust control in the spring and summer. Clark (1990a) estimates an annual volume of 38,000 to 47,000 L (10,000 to 12,500 gal) of organic waste that could have potentially been disposed at 1100-3.

Evans (1989) states that no detectable or significant concentrations of VOCs were encountered during the 1100-3 operable subunit soil gas survey. Results of the surface radiation survey for 1100-3 were also negative (Clark 1990b).

Based on the above information, anticipated contaminants of concern for 1100-3 consist of chromium, ethylene glycol, lead, petroleum naphthas, and waste oil constituents.

4.1.1.4 1100-4 (Antifreeze Tank Site). The waste antifreeze disposal tank, removed in 1986, was located inside the northeastern corner of the 1171 Building, the vehicle service, maintenance, and repair facility for the Hanford Site (see Section 3.1.2.4). The 19,000-L (5,000-gal) tank was used for storage of waste antifreeze from before 1978 through 1986. The tank was removed when it was suspected of leaking, although no evidence of leakage was found during the tank removal (Cramer, K., PNL [Memo to file] August 6, 1987).

Because of the relatively non-volatile nature of antifreeze, a soil gas survey of the 1100-4 operable subunit was not conducted. The surface radiation survey for the 1171 Building vicinity, including the location of the antifreeze tank, detected no measurable amounts of radioactivity (Clark 1990b).

Ethylene glycol, and to a smaller extent propylene glycol, are the primary constituents of antifreeze. In general, ethylene glycol is rapidly and completely biodegraded and toxicity is limited unless high, local concentrations are present (Eckroth 1981).

4.1.1.5 UN-1100-6 (Discolored Soil Site). The Discolored Soil Site consists of a patch of stained soil in an elongated natural depression. It covers an area of less than 0.2 ha (0.4 ac) (see Section 3.1.2.5). This subunit appears to be the location of at least one, and possibly several, incidents where containers of liquid organic material were emptied directly on the ground. A grab sample of surface soils taken from this subunit, while the 1100-EM-1 RI/FS work plan was under development, was found to contain measurable concentrations of phthalates and nine unknown SVOCs; an elevated TOC value was also noted (DOE-RL 1989a). Soil gas and surface radiation surveys were not conducted for UN-1100-6.

4.1.1.6 Horn Rapids Landfill. The Horn Rapids Landfill covers an area of approximately 20 ha (50 ac) (see Section 3.1.2.6). The landfill was operated as a solid waste disposal facility from approximately 1950 through 1970. It is reported to have received waste asbestos, used tires, and construction debris. Various types of debris, such as paint cans, steel cables, sheet metal, concrete rubble, and miscellaneous materials, lie scattered over much of the landfill; broken laboratory glassware is located along the east-central boundary of the operable subunit. Anecdotal information indicates past disposal of waste liquids, including sewage sludge, slurried fly ash, and, possibly, various unidentified liquids contained within 55-gal drums.

The source of the sewage sludge is unknown. Thus, it is difficult to specify toxic constituents of such material; however, sewage sludge often contains various metals, especially if it is an end product of an industrial waste stream. Fossil fuel power plants on the Hanford Site generate fly ash (Coony et al. 1988). Fly ash commonly contains volatile metals such as arsenic, bismuth, lead, mercury, selenium, and tin (EPA 1988d).

The Horn Rapids Landfill was used by a variety of Hanford Site contractors; unauthorized dumping by both on-site and off-site parties was a frequent problem. Indeterminate quantities of hazardous chemicals, including drums of carbon tetrachloride and small amounts of explosive compounds (e.g., picric acid and ethers), are suspected of having been disposed at this subunit (DOE-RL 1989a).

The soil gas survey detected measurable concentrations of trichloroethene, tetrachloroethene, and 1,1,1-trichloroethane (Evans 1989). The results of this survey are contained in Appendix C and displayed in Figures 4-2, 4-3, and 4-4, respectively. Surface radiation survey results for the Horn Rapids Landfill were negative (Clark 1990b).

The lack of disposal records for the Horn Rapids Landfill makes it difficult to identify likely contaminants of concern. However, based on the soil gas survey results and reported disposal practices, potential contaminants include:

- asbestos
- carbon tetrachloride
- tetrachloroethene
- 1,1,1-trichloroethane
- trichloroethene
- various metals.

4.1.2 Other Potential Contaminant Sources in the 1100-EM-1 Operable Unit Vicinity

Several nearby waste facilities, not directly related to the 1100-EM-1 Operable Unit, have been identified. These include the waste management units assigned to the 1100-EM-2 and 1100-EM-3 Operable Units, the Lamb-Weston, Inc. potato processing plant, the Advanced Nuclear Fuels Corp.'s nuclear fuel fabrication facility, the 300 Area nuclear fuel fabrication and research and development complex, and the Richland Municipal Landfill. The physical characteristics of each of these facilities is briefly summarized in Section 3.1.3; the locations of all of the facilities, with the exception of the

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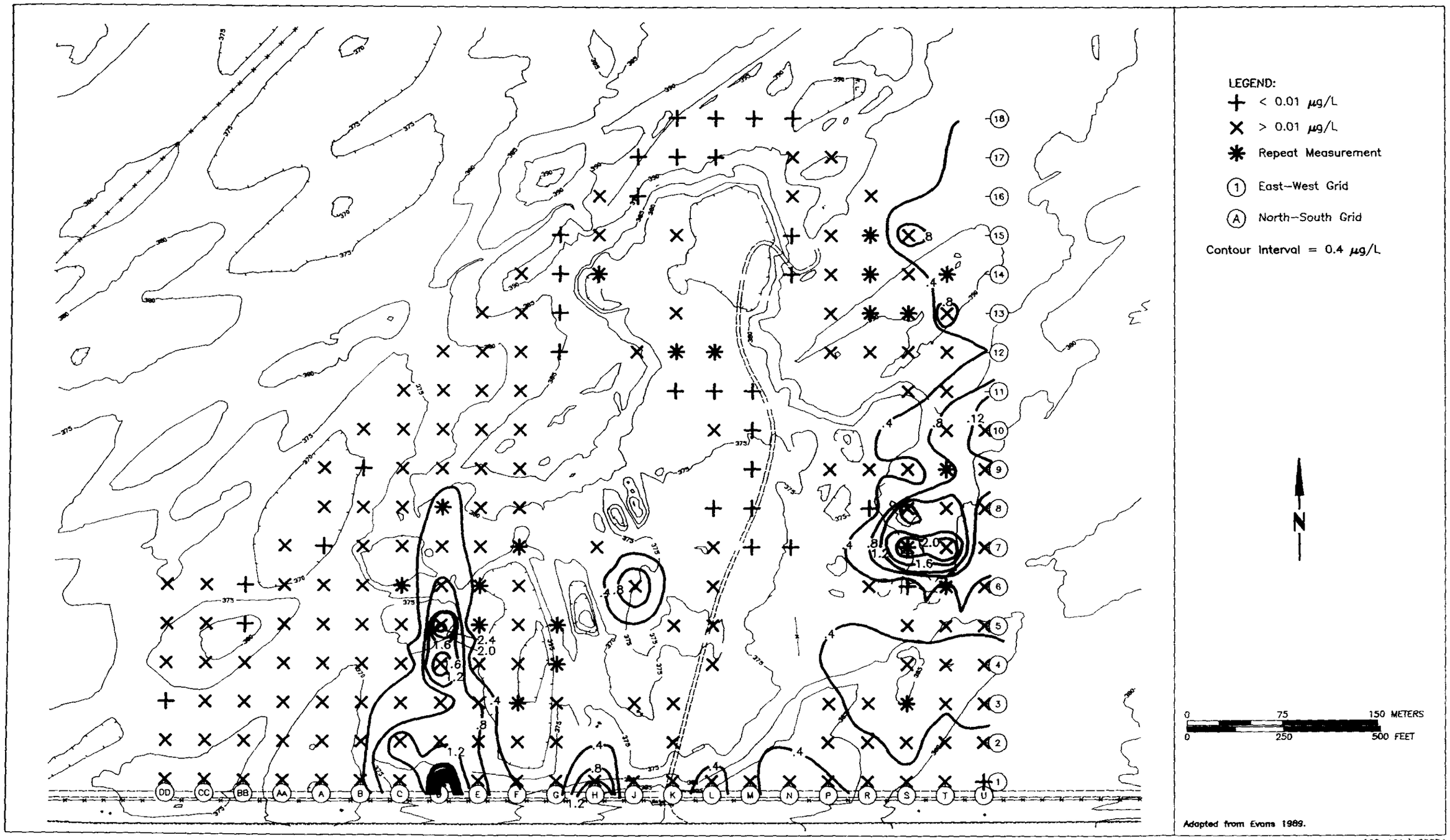

Figure 4-2. Distribution of Trichloroethene in Soil Gas at the Horn Rapids Landfill Operable Subunit .

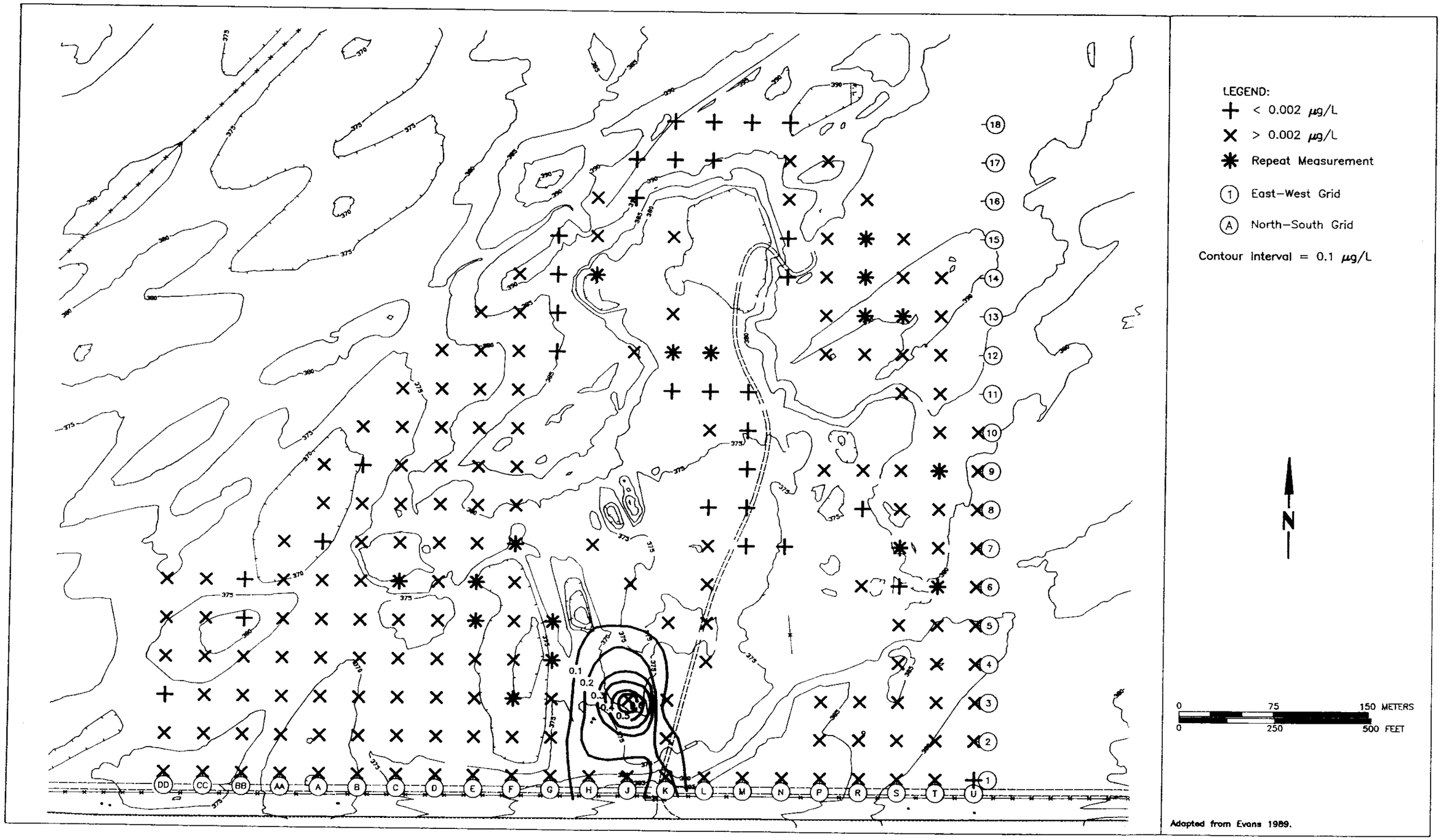

Figure 4-3. Distribution of Tetrachloroethene in Soil Gas at the Horn Rapids Landfill Operable Subunit .

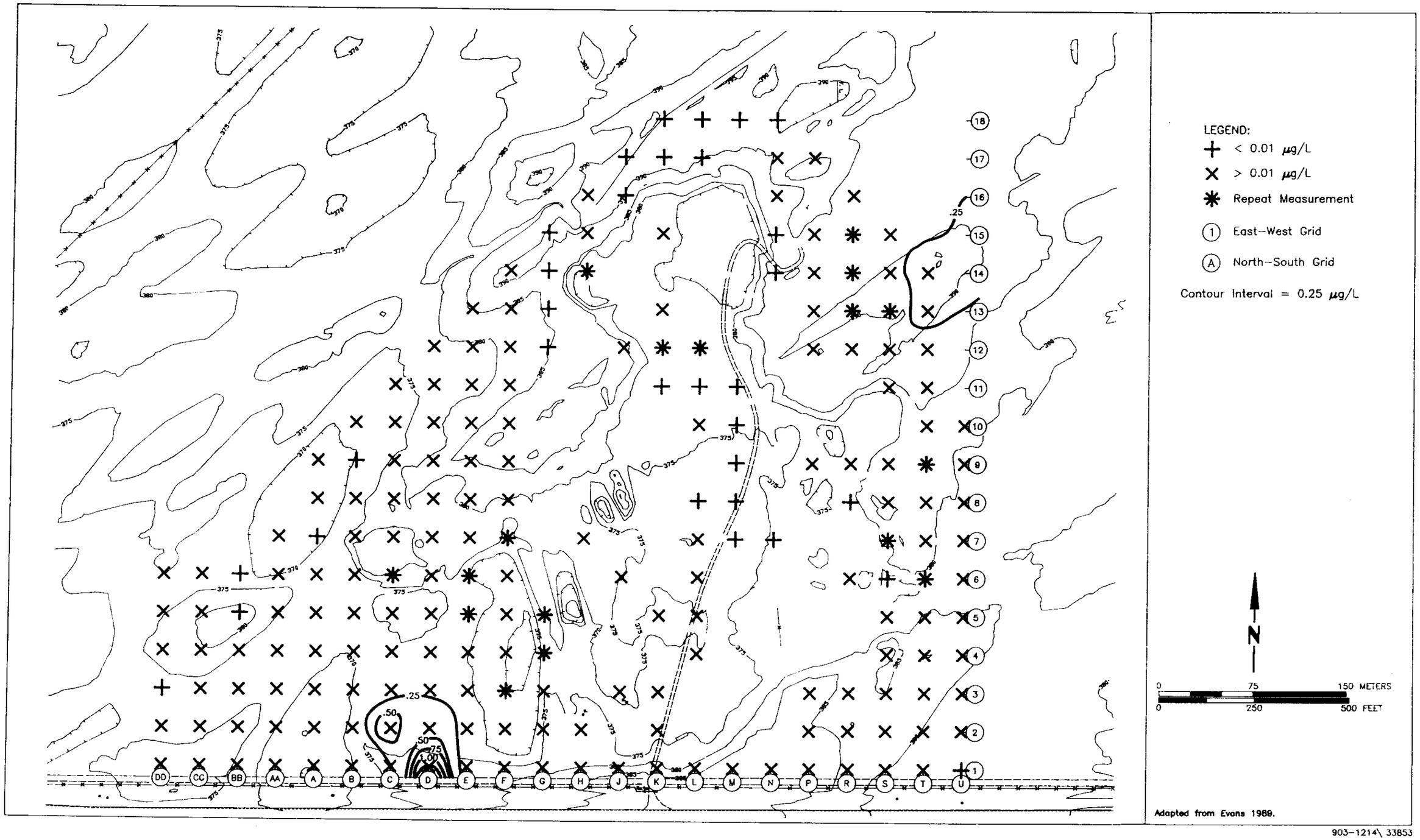

Figure 4-4. Distribution of 1,1,1-Trichlorothane in Soil Gas at the Horn Rapids Landfill Operable Subunit.

Richland Municipal Landfill, are shown in Figure 3-1. Known information on the characteristics of the wastes for each of these facilities is briefly summarized below.

4.1.2.1 1100-EM-2 Operable Unit. The 1100-EM-2 Operable Unit, with the exception of one remote facility, consists of active maintenance facilities (e.g., equipment maintenance areas, cleaning stations, and used oil storage tanks) located in or adjacent to the 1171 Building. Seven waste management units assigned to 1100-EM-2 are located in or adjacent to the 1171 Building (DOE-RL 1989b). These waste units are described in Table 4-2. No documented releases have occurred in this operable unit, although minor spills are likely around such facilities (WHC 1989).

4.1.2.2 1100-EM-3 Operable Unit. The 1100-EM-3 Operable Unit consists of seven waste management units located to the east of 1100-EM-1 in the 3000 Area. Most of the waste management units within this operable unit, which are listed in Table 4-3, function as hazardous waste staging areas that store relatively small amounts of waste (WHC 1989).

4.1.2.3 Lamb-Weston, Inc. Lamb-Weston processes potatoes to produce frozen french fries. Potatoes are washed and cooked during the process, and the waste water generated is routed to basins for clarification prior to disposal by land application. Hazardous substances are not anticipated to comprise a significant portion of this waste stream; however, food processing waste waters typically have high oxygen demands.

4.1.2.4 Advanced Nuclear Fuels Corp. Advanced Nuclear Fuels manufactures nuclear reactor fuel rods at a facility west of 1100-EM-1. Approximately 1,900,000 L (500,000 gal) of waste water is generated and disposed to the City of Richland sewage system each day. Prior to disposal, pretreatment for uranium and ammonia recovery occurs on-site. Six liquid waste lagoons, one solids leach pit, and one dry sand storage pit are located along the eastern boundary of the facility.

The six lagoons have a combined storage capacity of 43,500,000 L (11,500,000 gal) and are double-lined and monitored with a system of leak detection devices. Ground water is monitored at the facility with a network of approximately 20 wells. Combustible wastes are incinerated in a controlled-air unit and the resulting ash is sorted and packaged for off-site disposal. Noncombustible materials are drummed and disposed off-site as well. Non-radioactive hazardous waste is collected, stored, and disposed off-site in accordance with federal and state regulations (Advanced Nuclear Fuels Corp. 1987).

A plume of contaminated ground water exists downgradient from the Advanced Nuclear Fuels pretreatment lagoons because of past leakage. The first of these lagoons started operating in about 1971 (Malody, C., Advanced Nuclear Fuels Corp. [Personal communication] August 9, 1990). Initially, the lagoons were lined single liners which were discovered to be cracked and leaking around 1973 or 1974. After several attempts to repair the liners proved unsuccessful, all lagoons liners were replaced with double liners around 1979 or 1980.

In 1983, the plume that emanated from the lagoons was estimated to be approximately 300 to 3,400 m (1,000 to 11,000 ft) long, 150 to 180 m (500 to

Table 4-2. Waste Management Units Assigned to the 1100-EM-2 Operable Unit (DOE-RL 1989b).

Waste Unit	Waste Type	Waste Volume	Other Information
1100 Area Hazardous Waste Staging Area	waste acid waste paint	500 kg/yr 1,000 kg/yr	Stored within a fenced perimeter on a gravel bed.
1100 Area Bus Shop Underground Hoist Rams	non-PCB hydraulic oil	Tank 1: 689-L (182-gal) capacity Tank 2: 689-L (182-gal) capacity Tank 3: 923-L (244-gal) capacity	Replaced 1986 due to leakage; all tanks have secondary containment systems.
1100 Area Underground Steam Pad #2	oily waste water	15,000-L (4,000-gal) capacity	Waste water in pads #2 and #3 is from bus and equipment washing operations.
1100 Area Underground Steam Pad #3	oily waste water	15,000-L (4,000-gal) capacity	1988 disposal volume for pads #2 and #3 was 98,000 L (26,000-gal)[2].
1100 Area Used Oil Tank #4	waste oil	15,000-L (4,000-gal) capacity	Stored for off-site recycling.
1100 Area Used Oil Tank #5	waste oil	3,800-L (1,000-gal) capacity	Stored for off-site recycling.
1100 Area Used Oil Tank #6	waste oil	7,600-L (2,000-gal) capacity	Stored for off-site recycling.

[1]The 700 Area Waste Solvent Tank is not listed because it is not located within the vicinity of the 1100-EM-1 Operable Unit.
[2]Coony et al. 1988.

Table 4-3. Waste Management Units Assigned to the 1100-EM-3 Operable Unit (DOE-RL 1989b). (Sheet 1 of 2)

Waste Unit	Waste Type	Waste Volume	Other Information
1100 Area Paint Shop	waste solvents waste paints	1,100 (300 gal)/yr	Stored in containers or 55-gal drums on a concrete pad while awaiting disposal.
1100 Area Automotive Shop	waste oils, solvents, antifreeze, and degreasers	1,100 L (300 gal)/yr	Stored in containers or 55-gal drums on a concrete pad while awaiting disposal.
1100 Area Machine Shop	waste lubricating and cutting oils, solvents, and degreasers	760 L (200 gal)/yr	Stored in containers or 55-gal drums on a concrete pad while awaiting disposal.
1100 Area Storage Yard	radioactive wastes nitrate-containing wastes extraction-procedure-toxic wastes	350 114-L (30-gal) containers/yr	Temporary storage of containers on pallets on a gravel pad.
3000 Area Jones Yard	nonregulated oil antifreeze and paint-reacted materials	200 55-gal drums 14 55-gal drums	All drums stored on pallets.
3000 Area Underground Tank	waste oil	7,600 L (2,000 gal)/yr	Temporary storage in 1,900-L (500-gal) tank for off-site recycling.

Table 4-3. Waste Management Units Assigned to the 1100-EM-3 Operable Unit (DOE-RL 1989b). (Sheet 2 of 2)

Waste Unit	Waste Type	Waste Volume	Other Information
UN-3000-1	cesium-134	1.65 L (0.4 gal) of solution	Unplanned release into the City of Richland sewer system.

600 ft) wide, and 12 to 15 m (40 to 50 ft) deep, and traveling in a northeasterly direction. Ecology has determined that this plume poses no threat to public health or the environment due to the restricted nature of the local land use. Ecology did, however, require corrective action in the form of double-lining the pretreatment lagoons and increasing the ground-water monitoring effort (Milton, J. and D. Bowhay, Ecology [Memo to R. Taylor, Ecology] October 31, 1986). Contaminant levels in the ground water are known to exceed drinking-water standards for nitrate, fluoride, sulfate, and gross-alpha and gross-beta radiation; elevated concentrations of ammonia are also documented (Milton, J. and D. Bowhay, Ecology [Memo to R. Taylor, Ecology] October 31, 1986; Lockhaven, S., Advanced Nuclear Fuels Corp. [Letter to C. Cline, Ecology] January 12, 1990).

4.1.2.5 300 Area. The 300 Area is the nuclear fuel manufacturing and research and development complex for the Hanford Site. The 300 Area, in conjunction with the 400 Area, has also been designated as an NPL site. Numerous waste management units exist at the 300 Area, including many soil column disposal facilities for process, laboratory, and sanitary sewage streams, hazardous and hazardous/radioactive mixed waste landfills, various other active and inactive TSD facilities, and many documented unplanned releases of diverse types of contamination.

The nature of the most significant contamination at the 300 Area can be described briefly as including metallic and nonmetallic inorganic substances, VOCs, and radioactive substances. Perhaps the most significant contaminant is uranium, which was disposed in high volumes in the process sewage stream. A plume of uranium-contaminated ground water currently underlies the 300 Area. The plume travels in a east-southeasterly direction and discharges into the adjacent Columbia River. The known extent of this plume, which is monitored by an extensive network of ground-water monitoring wells (a total of approximately 50 wells exist within and near the 300 Area), is downgradient and within 1.6 km (1 mi) of the Horn Rapids Landfill.

4.1.2.6 Richland Municipal Landfill. No formal investigations for contamination have been conducted at the Richland Municipal Landfill except for the installation of four ground-water monitoring wells to satisfy state

solid waste landfill regulations. Recent monitoring results at the Richland Municipal Landfill show that underlying ground water meets drinking-water standards (Gillum, M., City of Richland Water and Utilities Department [Letter to Benton-Franklin Health Department] July 21, 1989).

4.2 AIR CONTAMINATION

Two rounds of ambient air monitoring were conducted during the Phase I RI for the 1100-EM-1 Operable Unit. The results of these two monitoring rounds are reported in Glantz and Laws (1990a and 1990b). The first round consisted of upwind and downwind monitoring episodes, one each at the 1100-1 Battery Acid Pit, the 1100-2 and 1100-3 disposal pits, and the Horn Rapids Landfill; the second round consisted of monitoring during the drilling of two soil borings in the Horn Rapids Landfill and one boring at 1100-2.

The results of the second round of ambient air monitoring are provided in Glantz and Laws (1990b). Their report concludes that:

> Several [VOCs] were detected in extremely low concentrations near each of the borehole drilling sites . . . . Differences in pollutant concentrations between upwind and downwind monitoring locations were not statistically significant. [SVOCs] were not detected in the atmosphere near the waste sites . . . .

Given these conclusions, and the objective of assessing the potential of occupational safety and health impacts to drilling and sampling personnel (as opposed to operable unit characterization), the results of the second round of air monitoring are not given further consideration in this report.

For each first-round monitoring episode, analyses were conducted for particulate elements, VOCs, and SVOCs; analyses were conducted for VOCs and SVOCs during second-round monitoring. The specific target parameters used be Glantz and Laws (1990a) are listed below; during the second round, a greatly expanded list of target VOC parameters was used for the sampling at the Horn Rapids Landfill (see Glantz and Laws 1990b for details).

- Particulate elements
  - aluminum
  - antimony
  - arsenic
  - barium
  - bromine
  - cadmium
  - calcium
  - cerium
  - cesium
  - chlorine
  - chromium
  - cobalt
  - copper
  - gallium
  - indium
  - iodine

- iron
- lanthanum
- lead
- manganese
- mercury
- molybdenum
- nickel
- niobium
- palladium
- phosphorus
- potassium
- rhodium
- ruthenium
- selenium
- silicon
- silver
- strontium
- sulfur
- tellurium
- tin
- titanium
- uranium
- vanadium
- yttrium
- zinc
- zirconium

■ VOCs

- benzene
- carbon tetrachloride
- octane
- tetrachloroethene
- toluene
- 1,1,1-trichloroethane
- trichloroethene

■ SVOCs

- chlorobenzene
- cresol
- 1,2-dichlorobenzene
- 1,3-dichlorobenzene
- p-dichlorobenzene
- hexachlorobenzene
- hexachlorophene
- kerosene
- maleic hydrazide
- naphthalene
- nicotinic acid
- pentachlorobenzene
- pentachlorophenol
- phenol
- strychnine
- 1,2,3,4-tetrachlorobenzene

- 1,2,3,5-tetrachlorobenzene
- 1,2,4,5-tetrachlorobenzene
- tributylphosphate
- 1,2,4-trichlorobenzene
- 1,3,5-trichlorobenzene

In addition to the above target parameters, a separate sampling episode was conducted for asbestos fiber analysis at the Horn Rapids Landfill (Glantz and Laws 1990a). Samples analyzed for the target SVOCs were also analyzed for several PCB and pesticide parameters. The PCB and pesticide data are not provided in Glantz and Laws (1990a), but the results section of their report summarizes the findings. The fact that vapor phase samples were used for SVOC analyses limits the utility of these data. By their very nature, SVOCs are not highly volatile; therefore, one would expect to encounter such compounds primarily in the particulate phase, rather than the vapor phase, of the ambient air (Glantz and Laws 1990a).

Because of the fluid and changing nature of the atmosphere, the limited number of sampling stations employed, and the short duration of the sampling intervals ($\leq$ 3 h), the results of the first round of ambient air monitoring are of limited value. The data generated are provided in Appendix E. As several errors were found in the data set, corrections were made and noted. For example, data were subjected to validation criteria specified by Bleyler (1988a and 1988b). Such validation showed many analytical results to be insignificantly above levels detected in associated blanks. In addition, several errors were noted in the results section of Glantz and Laws (1990a); actual results, based upon the corrected data, are summarized below by operable subunit. Sampling locations for each first-round sampling episode are shown in Figure 2-10.

4.2.1 1100-1 (Battery Acid Pit)

Particulate sampling for elemental analysis was not conducted at the 1100-1 operable subunit, "because the heavy metals contained in the liquids that were dumped into the pit are currently buried beneath fill material" (Glantz and Laws 1990a). Trichloroethene was the only VOC detected at the Battery Acid Pit, but the upwind concentration was higher than that found at the downwind sampling station. Therefore, there is no indication of any atmospheric VOC contamination emanating from the 1100-1 operable subunit.

The 1100-1 SVOC data were omitted from Glantz and Laws (1990a). However, the results section of their report states the following:

> Several SVOCs were detected in roughly equivalent concentrations at the upwind, downwind, and blank samples. Pesticides and PCBs were not detected on any . . . sample.

4.2.2 1100-2 (Paint and Solvent Pit) and 1100-3 (Antifreeze and Degreaser Pit)

The particulate elements detected at the 1100-2 and 1100-3 operable subunits were barium, chlorine, chromium, copper, lanthanum, lead, manganese, mercury, nickel, palladium, phosphorous, potassium, sulfur, titanium, and

zinc. Of these elements, barium, chromium, copper, manganese, mercury, palladium, and zinc were detected only in the upwind background sample. The estimated upwind and downwind concentrations for the remaining elements—reported to one significant digit, due to the high degree of uncertainty associated with the particulate element data set—are presented in Table 4-4. As all of the remaining detected elements are below, at, or near apparent background sample quantitation limits, there is no substantial evidence of any particulate contamination associated with either 1100-2 or 1100-3. The results may indicate random, low-level fluctuations in ambient particulate air quality, or, because of the absence of substantial departures from apparent sample quantitation limits and the extremely low concentrations reported, they may be artifacts of the sampling and analytical methods.

During the sampling episode for the 1100-2 and 1100-3 operable subunits, the pump for the 1100-2 downwind VOC sampling apparatus failed. Thus, available results are specific to the Antifreeze and Degreaser Pit only. All four VOCs that were detected during this monitoring episode, however, were found only upwind from both operable subunits at extremely low concentrations. There is, therefore, no empirical evidence of atmospheric VOC contamination associated with either subunit. If anything, an upwind source can be inferred to exist.

Several unknown PAHs, unknown hydrocarbons, and other unknown SVOCs were detected at low concentrations in the 1100-2/1100-3 samples. Estimated total PAH concentrations downwind of 1100-2 were less than those found upwind; total PAH concentrations downwind of 1100-3 were approximately twice that found in the upwind background sample (about 6,000 versus about 3,000 ng/m^3, respectively). Estimated total unknown hydrocarbon concentrations were about 1,000 and 3,000 ng/m^3 downwind of 1100-2 and 1100-3, respectively. Unknown hydrocarbons were not found in the upwind background sample. The estimated total concentrations for other unknown SVOCs were higher in the upwind background than downwind of either 1100-2 or 1100-3.

The SVOC results seem to indicate that the 1100-2 and 1100-3 subunits may be minor contributors of semi-volatile hydrocarbon and semi-volatile hydrocarbon and PAH emissions, respectively, to the atmosphere. Toxicity associated with the unknown hydrocarbons can not be assessed without specific compound identification, and the current body of toxicity data for PAH mixtures is insufficient to develop a carcinogenic slope factor (SF) (EPA 1984). However, the United States Occupational Safety and Health Administration (OSHA) has established a permissible exposure limit (PEL) for occupational exposures to mixtures of carcinogenic PAHs such as coal tar volatiles.

The OSHA PEL for coal tar PAH mixtures is 200,000 ng/m^3 (29 CFR 1910.1000). For screening purposes, this PEL is divided by a factor to adjust from an occupational to a conservative surrogate residential exposure limit. The term conservative is used here and throughout the remainder of the report to indicate that biased assumptions are employed such that interpretative results are protective of human health and the environment. The adjustment factor takes into account exposure lifetime (75-yr residential versus 47-yr occupational lifetime), weekly exposure time (168 h/wk versus 40 h/wk), and sensitive subpopulations (an order of magnitude safety factor):

Surrogate Residential Exposure Limit = (PEL)(47/75)(40/168)(0.1).

Table 4-4. Concentrations of Those Particulate Elements Detected in Ambient Air Downwind of the 1100-2 and 1100-3 Operable Subunits.

Element	Concentration (ng/m^3)[a]		
	Upwind[b]	Downwind of 1100-2[b]	Downwind of 1100-3[b]
chlorine	200	200	300
lanthanum	< 1,000	< 1,000	900
lead	< 100	< 80	60
nickel	< 30	30	< 30
phosphorous	200	< 200	200
potassium	300	300	300
sulfur	1,000	600	900
titanium	300	200	90

[a]Calculated from Glantz and Laws (1990a) data contained in Appendix E.
[b]Location of monitoring stations shown in Figure 2-10.

After adjustment, the conservative surrogate residential exposure limit for PAH becomes 3,000 ng/m^3. As the maximum downwind PAH value was twice the calculated screening criterion, PAH could be regarded as a contaminant of potential concern for the 1100-3 operable subunit. On the other hand, the apparent overall inconsistency of the SVOC results may indicate random, low-level fluctuations in ambient air quality, or artifacts of the sampling and analytical methods. Confirmation from soil data findings is necessary (see Section 4.4.4).

4.2.3 Horn Rapids Landfill

The particulate elements detected at the Horn Rapids Landfill were chromium, lead, mercury, nickel, niobium, potassium, rhodium, ruthenium, silicon, strontium, sulfur, titanium, and zirconium. Of these, chromium, mercury, rhodium, and strontium were found only in the upwind background sample. The estimated upwind and downwind concentrations for the remaining elements are presented in Table 4-5. Titanium appears to be the most significant landfill contaminant in the particulate fraction of the air. Overall, however, the results indicate random, low-level fluctuations in ambient particulate air quality, or insensitivity of the sampling and analytical methods employed.

Table 4-5. Concentrations of Those Particulate Elements Detected in Ambient Air Downwind of the Horn Rapids Landfill.

	Concentration (ng/m^3)[a]		
Element	Upwind[b]	Western Downwind Station[b]	Eastern Downwind Station[b]
lead	< 200	200	200
nickel	< 60	< 60	40
niobium	< 200	< 200	90
potassium	300	500	300
ruthenium	< 2,000	2,000	< 2,000
silicon	< 8,000	< 9,000	8,000
sulfur	800	900	700
titanium	200	6,000	600
zirconium	< 200	< 200	200

[a]Calculated from Glantz and Laws (1990a) data contained in Appendix E.
[b]Location of monitoring stations shown in Figure 2-10.

Titanium is physiologically inert, and is therefore regarded as essentially non-toxic (Klaassen et al. 1986). No chronic reference dose (RfD), a threshold dose for which no adverse toxicological response is anticipated, has been published for this substance (EPA 1989c and 1990a). The PEL for titanium is 10,000,000 ng/m^3 (29 CFR 1910.1000). A conservative surrogate residential exposure limit (see Section 4.2.2) can be estimated to be 150,000 ng/m^3, well above the maximum observed downwind concentration of 6,000 ng/m^3 (see Table 4-5).

Five VOCs—carbon tetrachloride, octane, tetrachloroethene, 1,1,1-trichloroethane, and trichoroethene—were detected in low concentrations at the Horn Rapids Landfill. However, only octane and perhaps tetrachloroethene were detected at higher concentrations in one or both of the downwind samples.

Octane was effectively undetected in the upwind sample at a concentration of 1,700 ng/m^3 (based on the highest amount of octane found in an associated sample blank). No effective amount of octane was detected in one of the downwind samples, while the other downwind sample—the one furthest to the east—contained the compound at a concentration of 20,000 ng/m^3. The upwind concentration of tetrachloroethene was reported to be ≥ 450 ng/m^3; the

downwind concentrations were ≥ 2,400 ng/m^3 at the westernmost station and 2,800 ng/m^3 at the easternmost station.

The Horn Rapids Landfill may, therefore, be a source of slight octane contamination in the local ambient atmosphere. The tetrachloroethene data, because of quantitative uncertainties, are far too tentative to make any kind of an interpretative conclusion. However, when the overall VOC data set for the landfill is viewed, the results appear to suggest an upwind source, albeit a minor one, of air contamination.

Data are currently insufficient to allow for the determination of an RfD for octane, but the PEL is 1,450,000,000 ng/m^3 (29 CFR 1910.1000). For the purpose of screening, the conservative surrogate residential exposure limit (see Section 4.2.2) is therefore 22,000,000 ng/m^3, far greater than the maximum downwind concentration encountered.

No target SVOCs were detected in any of the upwind or downwind ambient air samples obtained at the Horn Rapids Landfill. Glantz and Laws (1990a) state that no pesticides or PCBs were detected either. Two tentatively identified SVOCs—2,6-bis(1,1-dimethylethyl)-4-methylphenol and benzoic acid—were found in the landfill air samples. The methylphenol derivative was found at 1,600 ng/m^3 in the upwind sample and at concentrations at or barely above background in the two downwind samples (1,600 ng/m^3 at the easternmost sample station and 1,800 ng/m^3 at the westernmost station). Once again, therefore, an upwind source of contamination could be inferred. The benzoic acid was found only in the westernmost downwind sample at 11,000 ng/m^3; thus, the landfill is an implied minor source of this contaminant.

Toxicity associated with the inhalation of benzoic acid is not well characterized, but oral ingestion of this compound is considered to have a low toxicity potential (Eckroth 1981). Inhalation of highly concentrated vapors (much higher than detected) may be irritating to the nose and throat due to the acidic nature of the substance.

Asbestos monitoring results for the Horn Rapids Landfill were negative (< 2 fibers/cm^3), with no fibers being detected in either of the downwind samples.

4.3 SURFACE-WATER AND AQUATIC-SEDIMENT CONTAMINATION

Because of the absence of significant surface-water bodies within and adjacent to the operable unit, no formal field investigation of surface water or associated sediment quality was conducted during the first phase of the RI. Potential operable unit impacts on the Columbia River are addressed in Section 5 (Contaminant Fate and Transport). The surface-water discussion in Section 5 is based upon predicted contaminant transport in ground water.

The small ephemeral pool formed from parking lot runoff during high-intensity precipitation events was sampled during the first phase of the RI, even though it is not a designated waste management unit within the 1100-EM-1 Operable Unit or any other operable unit in the 1100 Area NPL Site. The results of the analyses of these samples are discussed in Section 4.4 (Soil Contamination).

4.4 SOIL CONTAMINATION

Surface and subsurface soils were sampled and chemically analyzed during the 1100-EM-1 Operable Unit Phase I RI, as described in Section 2.5.2. Locations of the soil sampling stations are displayed aerially in Figures 2-11 through 2-17; a detailed summary of the subsurface sampling scheme for the operable unit soils is presented in Appendix G. A total of approximately 260 discrete locations was sampled for chemical analysis during the Phase I RI soil investigation. The results of this soil contamination investigation are provided in Appendix I.

Operable-unit-specific background soils were characterized, along with potentially-impacted soils at each of the five operable subunits. In addition, surface soils were characterized at two miscellaneous locations within the operable unit—Pit 1, an operational gravel pit, and the location of an ephemeral pool that develops from parking lot runoff during intense precipitation events. The results for these two miscellaneous locations are reported in Appendix I and summarized below, even though these locations are not directly related to any of the designated operable subunits.

All soil samples were analyzed for TAL and TCL parameters. In addition, samples obtained from the 1100-4 Antifreeze Tank Site were analyzed for ethylene glycol, and certain samples from the Horn Rapids Landfill were analyzed for asbestos fibers. Appendix I provides results for all detected target parameters and tentatively-identified compounds (TICs). A list of target parameters analyzed for but not detected, with the accompanying range of sample quantitation limits (SQLs) for each, is also provided in Appendix I.

The data in Appendix I are "blank validated" with respect to sample delivery group (SDG) blanks only. In accordance with EPA data validation guidelines (Bleyler 1988a and 1988b), validation should be based on all blanks associated with the sample case, (i.e., all blanks associated with 1100-EM-1 Phase I RI soil investigation samples). Significant concentrations of inorganic TAL parameters were not found in any of the blanks associated with the 1100-EM-1 soil case; therefore, no further validation adjustments are required for these parameters. However, significant concentrations of several organic TCL parameters were encountered in case blanks.

The TCL parameters detected in these blanks and their corresponding maximum blank concentrations are presented in Table 4-6. This information was used to finalize the validation of the data presented in Appendix I, in accordance with Bleyler (1988a) (i.e., a parameter must be detected at a concentration exceeding five times—ten times for common laboratory contaminants—the highest amount detected in a blank associated with the sample case; if the parameter concentration does not exceed this criterion, the parameter is regarded as undetected at the concentration reported). Final validated data are used in the descriptions of background soils and soil contamination for each operable subunit and the miscellaneous locations below.

Appendix I contains numerous TICs which have not been subjected to final validation. Final validation procedures for these TICs, and a final validated list of TIC occurrences by operable subunit, are presented in Appendix O. A preliminary toxicological review of the final validated TIC list for soils was conducted. None of the TICs are known carcinogens and no associated RfDs were

Table 4-6. Highest Detected Organic Blank Concentrations Associated With 1100-EM-1 Soil Samples.

	Parameter	Sample ID/SDG	Concentration (µg/kg with qualifier)	
Volatiles	methylene chloride *	A1801WDL/A1615S	81,000	D
	acetone *	AH216SDL/AH206S	170	D
	chloroform	A0305W/A0301S	11	
	2-butanone *	A0701W/A0608S	55	
	4-methyl-2-pentanone	A0701W/A0608S	38	
	2-hexanone	VBLKS1/A0608S	6.0	J
	toluene *	A0701W/A0608S	6.0	
Semivolatiles	diethylphthalate *	A0701W/A0608S	3.0	J
	bis(2-ethylhexyl)phthalate *	SBLKS1/S6150A	17,000	E
	di-n-octyl phthalate *	SBLKS2/A1501W	820	
	benzoic acid	SBLKS1/A1312S	81	J
	phenol	SBLKS1/A2139S	15	J
	2-chlorophenol	SBLKS1/A2139S	9.0	J
	pyrene	SBLKS1/A2139S	2.0	J
	butylbenzylphthalate *	SBLKS1/A2139S	22	J
	di-n-butylphthalate *	SBLKS1/A2139S	3.0	J
	benzo(k)fluoranthene	SBLKS1/A2139S	8.0	J
Pesticides	heptachlor	PBLK2/A0301S	0.0038	J
	aldrin	PBLK1/A1201S	5.2	J
	endrin	A2001W/A1901S	0.018	J

*Common laboratory contaminant according to Bleyler (1988a).
D: Result obtained from the analysis of a diluted sample.
J: The associated value is an estimated quantity.
E: Concentration exceeds instrument calibration range.

found (EPA 1989c and 1990a). Because of the uncertainties in the identities and quantities of these compounds, the lack of EPA-endorsed toxicological data for them, the relatively low estimated concentrations, and the fact that they are encountered, for the most part, in association with target compounds, TICs in soil are eliminated from further consideration in this report.

Operable-unit-specific background soil quality is described in Section 4.4.1. Preliminary analysis of background soils indicated that several parameters have statistically significant differences in concentration with depth from ground surface. In particular, aluminum, arsenic, calcium, lead, magnesium, manganese, potassium, sodium, and zinc concentrations from depths less than 1.5 m (5 ft) differ significantly (as determined by analysis of variance, $\alpha = 0.05$) from their respective concentrations at lower depths.

Because the downhole soil sampling scheme was inconsistent from borehole to borehole with respect to depth intervals sampled (see Appendix G), and concentration differences could not be correlated with identifiable geological strata, surface soils are considered to be those within the uppermost 0.6 m (2 ft) of the ground surface, while subsurface samples are those that were obtained from below 0.6 m (2 ft) for the purpose of the following discussions. Such stratification is supported by the statistical findings and is consistent with subsequent exposure pathway analyses (i.e., subsurface soils pose little if any exposure potential by means of direct contact, ingestion, or fugitive dust inhalation).

Soil contamination conditions are addressed for each operable subunit and miscellaneous locations in Sections 4.4.2 through 4.4.8. These discussions are presented in terms of those parameters which are found at concentrations exceeding operable-unit-specific background levels. Such elevated parameters are regarded as contaminants. Each contaminant is then subjected to a conservative preliminary toxicity screening to determine if it is present at a level which could conceivably pose a significant threat to human health or the environment.

Risk-based calculations, or regulatory guidelines, where available, are utilized during the preliminary screening to develop a conservative, contaminant-specific, toxicity screening criterion. Comparison of maximum concentrations encountered against this criterion ensures the retention of all contaminants of potential concern for further consideration. For the purposes of risk analysis, each contaminant within an operable subunit or miscellaneous location is identified as either a non-toxic substance, a systemic toxin, or a carcinogen. Non-toxic contaminants are disregarded, and systemic toxins and carcinogens are subjected to further evaluation.

Systemic toxins are evaluated in terms of their published EPA RfDs. Soil concentrations resulting in an oral or inhalation dose equivalent to the applicable RfD are calculated. The resulting concentration is that which would represent a hazard quotient (HQ) equal to unity. An HQ less than unity is considered to indicate the lack of a systemic toxic hazard. Carcinogens are evaluated in terms of their contaminant-specific incremental cancer risk (ICR), based on published EPA carcinogenic SFs. An ICR of 1E-06 or less is regarded as an indication of an insignificant carcinogenic hazard. Both oral and inhalation RfDs and SFs are taken into account, as appropriate.

Therefore, the screening criteria used are those concentrations that would be necessary to attain an intake equivalent to the RfD, for systemic toxins, or an intake equivalent to an ICR of 1E-06 (i.e., 1E-06/SF), for carcinogens. The generic equation for calculating each screening criterion concentration is:

$$\text{Screening Criterion} = \frac{\text{(Intake)(Body Weight)(Averaging Time)}}{\text{(Contact Rate)(Exposure Duration and Frequency)}}$$

All soil screening criteria concentrations are derived using conservative risk assessment assumptions from EPA (1989d) and EPA-Region X (1990). For oral soil ingestion of systemic toxins, conservative assumptions used for calculations are a body weight of 16 kg, a soil ingestion contact rate of 200 mg/d (converted to kg/d), an exposure frequency and duration of every day for 6 yr (converted to d), and an averaging period of 6 yr (converted to d).

For carcinogens, the conservative assumptions are a body weight of 70 kg, a soil ingestion contact rate of 100 mg/d (converted to kg/d), a daily exposure frequency for a duration of 75 yr, and a 75 yr averaging time (the latter two converted to d).

Soil criteria are similarly derived for the inhalation of fugitive dust generated from contaminated soil. Intake assumptions of a body weight of 70 kg, an inhalation contact rate of 20 m^3/d for a lifetime exposure duration of 75 yr, and an averaging period of 75 yr (converted to d) are assumed. Published inhalation RfDs and SFs and conservative assumptions regarding particulate concentrations in air are also utilized. The airborne particulate concentrations are conservatively assumed to be at the maximum annual national ambient air quality standard of 0.075 mg/m^3 (40 CFR 50). In accordance with Cowherd et al. (1985), 25% of this concentration (i.e., 0.019 mg/m^3) is assumed to be respirable. The contaminant concentration in the respirable fraction is assumed to correspond to the concentration of the contaminant found in the parent soil and all respirable particulate is assumed to be derived entirely from the parent soil. Appropriate conversion factors are used as necessary.

The dermal exposure route rarely, if ever, represents a significant risk relative to those posed by the oral and inhalation routes under environmental exposure scenarios when conservative ingestion and inhalation parameters are used. In addition, the present analytical techniques for quantifying dermal absorption risks are not well developed. Consequently, the dermal exposure route is not used to screen 1100-EM-1 Operable Unit contaminants.

An exceedance of a conservative screening criterion does not necessarily establish the existence of a significant risk. A criterion exceedance, at this point in the overall analysis, simply indicates the need to retain a given contaminant for further evaluation with respect to contaminant fate and transport and risk assessment, taking more realistic assumptions into account, in Sections 5 and 6, respectively. On the other hand, if a contaminant does not exceed the conservative screening criterion, it may be eliminated from further consideration, on an environmental-medium- and operable-subunit-specific basis, with a high degree of confidence that the contaminant poses either no or only insignificant risk to human health and the environment. Consequently, conservative toxicity screening at this point in the process is useful and meaningful in that it serves to focus attention and effort on those contaminants that could potentially pose such risks.

4.4.1 Background Soil Quality

Project-specific background soil samples were obtained from, or near in the case of actual surface samples, three boreholes located in and near the western portion of 1100-EM-1 in areas that appeared to be undisturbed by operable unit activities. No discernable differences in parameter concentrations exist between locations; therefore, all samples were combined to provide a description of operable-unit-specific background conditions. After stratifying by depth, nine samples are available to describe surface soil background (≤ 0.6 m or 2 ft) and 12 (after excluding soil samples obtained from beneath the water table) are available to describe subsurface background (> 0.6 m or 2 ft) (see Appendix I). The exclusion of saturated soil samples for the purposes of defining background conditions is appropriate

in that it is not possible to take the potential for lateral contaminant contributions into account. Therefore, the focus of Section 4.4 is on contaminant conditions in unsaturated soils of the vadose zone.

Surface and subsurface soil background conditions are characterized in Tables 4-7 and 4-8 for inorganic and organic target parameters, respectively, by means of the one-sided upper tolerance limit (UTL) of the 95th percentile ($\alpha = 0.05$) for the distribution of each parameter (a normal distribution is conservatively assumed, as data are of insufficient quantity to prove non-normality). The method for the calculation of this value is provided in EPA (1989e).

All inorganic concentrations are reported in terms of mg/kg (parts per million), while all organic results are reported in µg/kg (parts per billion); these are the units reported by the analytical laboratories. If a parameter was not detected in a given sample, one-half the SQL was used as a surrogate value in the statistical calculation. If a given parameter was never detected in a respective set of background samples, the highest reported SQL for the parameter is substituted for the UTL, as noted in Tables 4-7 and 4-8.

In the following operable subunit characterizations, an exceedance of the respective values presented in Tables 4-7 or 4-8 is regarded as evidence of contamination above operable-unit-specific background.

4.4.2 1100-1 (Battery Acid Pit) Soil Quality

Soil samples from the Battery Acid Pit were obtained from a single borehole drilled through the operable subunit (see Figure 2-11). A total of eight samples was obtained, only one of which was within the upper 0.6 m (2 ft) to characterize surface soil conditions (see Appendices G and I).

Elevated contaminants within the surface and subsurface soils at the Battery Acid Pit are listed below. The concentrations of these parameters are shown in Appendix P. This appendix also indicates the concentrations and depths of elevated inorganic parameters in the subsurface soils of operable subunit.

- 1100-1 Surface Soil Contaminants

  - Inorganic contaminants

    calcium
    copper
    lead
    magnesium
    mercury
    nickel
    sodium
    zinc

  - Organic contaminants

    none encountered

Table 4-7. Inorganic UTLs for Background Soils.

Parameter	Surface (n=9) (mg/kg)	Subsurface (n=12) (mg/kg)
aluminum	7,870	6,235
antimony	3.7 *	3.1 *
arsenic	3.21	2.92
barium	97.9	236
beryllium	0.65	0.28
cadmium	0.78	0.36 *
calcium	4,530	7,830
chromium	11.7	47.3
cobalt	15.3	16.8
copper	16.3	19.5
iron	27,000	29,400
lead	13.6	5.03
magnesium	5,760	4,680
manganese	472	355
mercury	0.1 *	0.1 *
nickel	15.2	25.9
potassium	1,790	967
selenium	0.39 *	0.41 *
silver	2.3	0.54 *
sodium	112	420
thallium	0.39 *	0.41 *
vanadium	73.5	115
zinc	53.3	50.5
cyanide	0.52 *	0.51 *

*Parameter was never detected in the respective background samples; therefore, the highest reported respective background SQL is substituted as a surrogate UTL.

Table 4-8. Organic UTLs for Background Soils.
(Sheet 1 of 4)

Parameter	Surface (n=9) (mg/kg)		Subsurface (n=12) (mg/kg)	
Volatiles				
chloromethane	11	*	11	*
bromomethane	11	*	11	*
vinyl chloride	11	*	11	*
chloroethane	11	*	11	*
methylene chloride	5	*	5	*
acetone	43	*	22	*
carbon disulfide	5	*	5	*
1,1-dichloroethene	5	*	5	*
1,1-dichloroethane	5	*	5	*
1,2-dichloroethene (total)	5	*	5	*
chloroform	5	*	5	*
1,2-dichloroethane	5	*	5	*
2-butanone	11	*	11	*
1,1,1-trichloroethane	5	*	5	*
carbon tetrachloride	5	*	5	*
vinyl acetate	11	*	11	*
bromodichloromethane	5	*	5	*
1,2-dichloropropane	5	*	5	*
cis-1,3-dichloropropene	5	*	5	*
trichloroethene	5	*	5	*
dibromochloromethane	5	*	5	*
1,1,2-trichloroethane	5	*	5	*
benzene	5	*	5	*
trans-1,3-dichloropropene	5	*	5	*
bromoform	5	*	5	*
4-methyl-2-pentanone	11	*	11	*
2-hexanone	11	*	11	*
tetrachloroethene	5	*	5	*
1,1,2,2-tetrachloroethane	5	*	5	*
toluene	5	*	5	*
chlorobenzene	5	*	5	*
ethylbenzene	5	*	5	*
styrene	5	*	5	*
xylene (total)	5	*	5	*
Semivolatiles				
phenol	38,100		350	*
bis(2-chloroethyl)ether	690	*	350	*
2-chlorophenol	690	*	350	*
1,3-dichlorobenzene	690	*	350	*
1,4-dichlorobenzene	690	*	350	*
benzyl alcohol	690	*	350	*

Table 4-8. Organic UTLs for Background Soils.
(Sheet 2 of 4)

Parameter	Surface (n=9) (mg/kg)		Subsurface (n=12) (mg/kg)	
Semivolatiles (cont.)				
1,2-dichlorobenzene	690	*	350	*
2-methylphenol	690	*	350	*
bis(2-chloroisopropyl)ether	690	*	350	*
4-methylphenol	690	*	350	*
N-nitroso-di-n-propylamine	690	*	350	*
hexachloroethane	690	*	350	*
nitrobenzene	690	*	350	*
isophorone	690	*	350	*
2-nitrophenol	690	*	350	*
2,4-dimethylphenol	690	*	350	*
benzoic acid	3,300	*	1,700	*
bis(2-chloroethoxy)methane	690	*	350	*
2,4-dichlorophenol	690	*	350	*
1,2,4-trichlorobenzene	690	*	350	*
naphthalene	690	*	350	*
4-chloroaniline	690	*	350	*
hexachlorobutadiene	690	*	350	*
4-chloro-3-methylphenol	690	*	350	*
2-methylnaphthalene	690	*	350	*
hexachlorocyclopentadiene	690	*	350	*
2,4,6-trichlorophenol	690	*	350	*
2,4,5-trichlorophenol	3,300	*	1,700	*
2-chloronaphthalene	690	*	350	*
2-nitroaniline	3,300	*	1,700	*
dimethylphthalate	690	*	350	*
acenaphthylene	690	*	350	*
2,6-dinitrotoluene	690	*	350	*
3-nitroaniline	3,300	*	1,700	*
acenaphthene	690	*	350	*
2,4-dinitrophenol	3,300	*	1,700	*
4-nitrophenol	3,300	*	1,700	*
dibenzofuran	690	*	350	*
2,4-dinitrotoluene	690	*	350	*
diethylphthalate	690	*	350	*
4-chlorophenyl-phenylether	690	*	350	*
fluorene	690	*	350	*
4-nitroaniline	3,300	*	1,700	*
4,6-dinitro-2-methylphenol	3,300	*	1,700	*
N-nitrosodiphenylamine (1)	690	*	350	*
4-bromophenyl-phenylether	690	*	350	*
hexachlorobenzene	690	*	350	*
pentachlorophenol	3,300	*	1,700	*
phenanthrene	690	*	350	*

Table 4-8. Organic UTLs for Background Soils.
(Sheet 3 of 4)

Parameter	Surface (n=9) (mg/kg)		Subsurface (n=12) (mg/kg)	
Semivolatiles (cont.)				
anthracene	690	*	350	*
di-n-butylphthalate	690	*	350	*
fluoranthene	690	*	350	*
pyrene	690	*	350	*
butylbenzylphthalate	690	*	350	*
3,3'-dichlorobenzidine	1,400	*	710	*
benzo(a)anthracene	690	*	350	*
chrysene	690	*	350	*
bis(2-ethylhexyl)phthalate	690	*	350	*
di-n-octylphthalate	690	*	350	*
benzo(b)fluoranthene	690	*	350	*
benzo(k)fluoranthene	690	*	350	*
benzo(a)pyrene	690	*	350	*
indeno(1,2,3-cd)pyrene	690	*	350	*
dibenz(a,h)anthracene	690	*	350	*
benzo(g,h,i)perylene	690	*	350	*
Pesticides				
alpha-BHC	17	*	17	*
beta-BHC	17	*	17	*
delta-BHC	14		17	*
gamma-BHC (lindane)	17	*	17	*
heptachlor	17	*	17	*
aldrin	17	*	17	*
heptachlor epoxide	17	*	17	*
endosulfan I	17	*	17	*
dieldrin	33	*	34	*
4,4'-DDE	33	*	34	*
endrin	33	*	34	*
endosulfan II	33	*	34	*
4,4'-DDD	33	*	34	*
endosulfan sulfate	33	*	34	*
4,4'-DDT	33	*	34	*
methoxychlor	170	*	170	*
endrin ketone	33	*	34	*
alpha-chlordane	170	*	170	*
gamma-chlordane	160		170	*
toxaphene	330	*	340	*
aroclor-1016	170	*	170	*
aroclor-1221	170	*	170	*
aroclor-1232	170	*	170	*
aroclor-1242	170	*	170	*

Table 4-8. Organic UTLs for Background Soils.
(Sheet 4 of 4)

Parameter	Surface (n=9) (mg/kg)		Subsurface (n=12) (mg/kg)	
Pesticides (cont.)				
aroclor-1248	170	*	170	*
aroclor-1254	330	*	340	*
aroclor-1260	330	*	340	*

*Parameter was never detected in the respective background samples; therefore, the highest reported respective background SQL is substituted as a surrogate UTL.

- 1100-1 Subsurface Soil Contaminants
  - Inorganic contaminants

    arsenic
    copper
    iron
    lead
    mercury
    potassium
    sodium
    vanadium
    zinc

  - Organic contaminants

    none encountered

Calcium, iron, magnesium, potassium, and sodium are essential human nutrients considered to be non-toxic at the concentrations encountered within the operable subunit soils (EPA 1989d). Toxicity data are currently insufficient to estimate an RfD for copper, and the substance is not a known carcinogen (EPA 1989c). However, copper is an essential plant micronutrient and the maximum concentration encountered does not exceed its normal range in soils (5 to 150 mg/kg) within the United States (Brady 1974). Copper is therefore eliminated from further consideration as a contaminant of potential concern for the 1100-1 operable subunit.

The preliminary toxicity screening for the remaining soil contaminants at the operable subunit is summarized in Table 4-9. The only contaminant of potential concern is arsenic, found one time at approximately 2 m (6 ft) below the ground surface (at a concentration that barely exceeds background, see

Table 4-9. Preliminary Toxicity Screening for Soil Contaminants at the 1100-1 Operable Subunit.

Parameter	Maximum Soil Concentration (mg/kg)	Oral RfD (mg/kg/d)	Soil Concentration at the Oral RfD (mg/kg)	Inhalation RfD (mg/kg/d)	Soil Concentration at the Inhalation RfD (mg/kg)	Oral SF $(mg/kg/d)^{-1}$	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Inhalation SF $(mg/kg/d)^{-1}$	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
arsenic	1.2	1.0E-03[b]	77	--	--	1.7[d]	0.41	5.0E+01[a]	3.6	--
lead	266.0	--	--	--	--	--	--	--	--	500-1,000[c]
mercury	0.25	3.0E-04[b]	23	--	--	--	--	--	--	--
nickel	20.9	2.0E-02[a]	1,500	--	--	--	--	8.4E-01[a]	220	--
vanadium	118.0	7.0E-03[b]	540	--	--	--	--	--	--	--
zinc	100.0	2.0E-01[b]	15,000	--	--	--	--	--	--	--

[a]EPA 1990a.
[b]EPA 1989c.
[c]EPA 1989f.
[d]Surrogate based on proposed arsenic unit risk of 5E-05 µg/L (EPA 1990a).
-- Not available.

Note: Shaded areas indicate screening criterion exceeded.

Appendix P). Two anticipated contaminants of concern—lead and cadmium (see Section 4.1.1.1)—do not pose a problem in the soils of the Battery Acid Pit. Lead does not exceed its screening criterion, and no elevated cadmium was found.

4.4.3 1100-2 (Paint and Solvent Pit) Soil Quality

Four boreholes were drilled at the Paint and Solvent Pit. These boreholes yielded 33 discrete soil samples, four of which were from the surface stratum and 29 from the subsurface. In addition, soil samples were obtained from 20 locations on the surface of the operable subunit, providing a total of 24 samples for characterization of surface soil conditions (see Appendix I). Borehole locations are shown in Figure 2-12 and vertical sampling locations within each borehole are described in Appendix G. Locations of the additional surface sampling stations within the operable subunit are also shown in Figure 2-12.

Elevated surface and subsurface contaminant parameters at the 1100-2 operable subunit are listed below. Specific locations and concentrations of these soil contaminants are shown in Appendix P.

- 1100-2 Surface Soil Contaminants
  - Inorganic contaminants

    aluminum
    calcium
    chromium
    copper
    lead
    potassium
    sodium
    thallium
    zinc

  - Organic contaminants

    chlorobenzene
    4,4'-DDE
    4,4'-DDT
    1,1-dichloroethene

- 1100-2 Subsurface Soil Contaminants
  - Inorganic contaminants

    calcium
    copper
    lead
    magnesium
    manganese
    potassium
    sodium
    zinc

- Organic contaminants

  4,4'-DDE
  4,4'-DDT
  tetrachloroethene

Calcium, magnesium, potassium, sodium, and copper are eliminated from further evaluation for the reasons specified in Section 4.4.2 above. Aluminum toxicity data are currently insufficient to determine an RfD and the substance is not a known carcinogen. Because the aluminum concentrations encountered at 1100-2 do no exceed the normal range of concentrations found in surface soils in the temperate regions of the United States (24,000 to 70,000 mg/kg) (Brady 1974), aluminum is not given further consideration.

For the purposes of this and later evaluations, DDT is defined as the sum of 4,4'-DDT, 4,4'-DDD, and 4-4'-DDE. Whenever individual contaminant parameters, such as these, are combined into a contaminant class for further evaluation, the sum of the highest respective concentrations encountered for each individual parameter is used for conservative preliminary toxicity screening purposes. For the sake of simplicity, differences in molecular weights (which are insignificant) are disregarded whenever such contaminants are combined.

As insufficient data are available to ascertain speciation, chromium is conservatively assumed to be in the hexavalent (most toxic) state for the purposes of toxicological evaluation throughout this report.

Table 4-10 summarizes the preliminary toxicity screening at the operable subunit. The only contaminant of potential concern for the 1100-2 operable subunit is chromium. Elevated chromium is found within only a single surface soil sample from borehole DP-9 (see Figure 2-12), at a concentration not greatly in excess of background levels (see Appendix P).

It should be noted that operable unit surface soil background levels for chromium exceeds inhalation toxicity criteria (see Tables 4-10 and Appendix P). This observation attests to the conservative nature of the preliminary toxicity screening process.

4.4.4 1100-3 (Antifreeze and Degreaser Pit) Soil Quality

Thirty-seven soil locations were sampled at the Antifreeze and Degreaser Pit during the first phase of the RI-27 from four boreholes and 10 additional surface samples (see Figure 2-13 for areal locations and Appendix G for downhole locations of borehole samples). Of these samples, 13 are available for the characterization of surface soil quality and 24 are available for subsurface characterization (see Appendix I).

Appendix P provides locations and concentrations of elevated inorganic and organic target parameters in the surface and subsurface soils of the 1100-3 operable subunit. The soil contaminants are listed below. No organic target compounds were encountered in either the surface or subsurface soils at the 1100-3 operable subunit. The lack of detectable organic compounds in

Table 4-10. *Preliminary* Toxicity Screening for Soil Contaminants at the 1100-2 Operable Subunit.

Parameter	Maximum Soil Concentration (mg/kg)	Oral RfD (mg/kg/d)	Soil Concentration at the Oral RfD (mg/kg)	Inhalation RfD (mg/kg/d)	Soil Concentration at the Inhalation RfD (mg/kg)	Oral SF $(mg/kg/d)^{-1}$	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Inhalation SF $(mg/kg/d)^{-1}$	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
chromium	16.8	5.0E-03[a]	380	--	--	--	--	4.1E+01[a]	4.4	--
lead	94.6	--	--	--	--	--	--	--	--	500-1,000[c]
manganese	366.0	2.0E-01[b]	15,000	3.0E-04[b]	55,000	--	--	--	--	--
thallium	0.48	7.0E-05[b]	5.4	--	--	--	--	--	--	--
zinc	56.6	2.0E-01[b]	15,000	--	--	--	--	--	--	--
chlorobenzene	0.006	2.0E-02[a]	1,500	--	--	--	--	--	--	--
DDT	0.124	5.0E-04[a]	38	--	--	3.4E-01[a]	2.1	3.4E-01[a]	530	--
1,1-dichloroethene	0.005	9.0E-03[a]	690	--	--	6.0E-01[a]	1.2	1.2E+00[a]	150	--
tetrachloroethene	0.016	1.0E-02[b]	770	--	--	5.1E-02[b]	14	3.3E-03[b]	55,000	--

[a]EPA 1990a.
[b]EPA 1989c.
[c]EPA 1989f.
-- Not available.

Note: Shaded areas indicate screening criterion exceeded.

subunit soils is inconsistent with the ambient air monitoring results which imply the existence of PAH contamination at this subunit (see Section 4.2.2).

- 1100-3 Surface Soil Contaminants

  - Inorganic contaminants

    aluminum
    arsenic
    barium
    calcium
    chromium
    copper
    lead
    magnesium
    sodium
    thallium
    zinc

  - Organic contaminants

    none encountered

- 1100-3 Subsurface Soil Contaminants

  - Inorganic contaminants

    aluminum
    antimony
    calcium
    cobalt
    copper
    iron
    magnesium
    manganese
    sodium
    zinc

  - Organic contaminants

    none encountered

Calcium, iron, magnesium, potassium, and sodium are non-toxic essential elements (see Section 4.4.2), and copper and aluminum concentrations do not exceed their normal soil concentrations (see Sections 4.4.2 and 4.4.3, respectively). In addition, cobalt is an essential micronutrient found in soil at normal concentrations of 1 to 50 mg/kg (Brady 1974). As concentrations at 1100-3 do not exceed this range, and insufficient data are available to develop an RfD and the substance is not a known carcinogen, cobalt is given no further consideration as a potential operable subunit contaminant of concern for the soil medium.

Table 4-11 summarizes the results of the preliminary toxicity screening for the remaining contaminants at the Antifreeze and Degreaser Pit. Arsenic

Table 4-11. Preliminary Toxicity Screening for Soil Contaminants at the 1100-3 Operable Subunit.

Parameter	Maximum Soil Concentration (mg/kg)	Oral RfD (mg/kg/d)	Soil Concentration at the Oral RfD (mg/kg)	Inhalation RfD (mg/kg/d)	Soil Concentration at the Inhalation RfD (mg/kg)	Oral SF $(mg/kg/d)^{-1}$	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Inhalation SF $(mg/kg/d)^{-1}$	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
antimony	22.6	4.0E-04[a]	31	--	--	--	--	--	--	--
arsenic	3.4	1.0E-03[b]	77	--	--	1.7[c]	0.41	5.0E+01[a]	3.6	--
barium	106.0	5.0E-02[a]	3,800	1.0E-04[b]	18,000	--	--	--	--	--
cadmium	14.0	5.0E-03[a]	380	--	--	--	--	4.1E+01[a]	4.4	--
lead	26.4	--	--	--	--	--	--	--	--	500-1,000[d]
manganese	381.0	2.0E-01[b]	15,000	3.0E-04[b]	55,000	--	--	--	--	--
thallium	0.40	7.0E-05[b]	5.4	--	--	--	--	--	--	--
zinc	60.0	2.0E-01[b]	15,000	--	--	--	--	--	--	--

[a]EPA 1990a.
[b]EPA 1989c.
[c]Surrogate based on proposed arsenic unit risk of 5E-05 µg/L (EPA 1990a).
[d]EPA 1989f.
-- Not available.

Note: Shaded areas indicate screening criterion exceeded.

and chromium exceed their screening criteria. These two substances are thus regarded as contaminants of potential concern.

Arsenic was encountered in elevated concentrations in only one surface sample (S2139A, see Figure 2-13) at a concentration that barely exceeds background (see Appendix P). Chromium was encountered in concentrations exceeding background levels at only two surface locations. Figure 4-5 shows the surface distribution of chromium. Neither substance was encountered at elevated levels in the subsurface stratum of the 1100-3 subunit soils (see Appendix P).

4.4.5 1100-4 (Antifreeze Tank Site) Soil Quality

One borehole was drilled through the Antifreeze Tank Site, and additional soil samples were obtained for chemical analysis from a nearby ground-water monitoring well (MW-3). A total of 19 discrete locations were sampled from these two borings, all of which in the subsurface stratum. The locations of the two borings are shown on Figure 2-11, and the distribution of the specific downhole sampling locations are tabulated in Appendix G.

Elevated contaminant parameters in the subsurface soils at and near the 1100-4 operable subunit are listed below and categorized by location and concentration in Appendix P. Aluminum and potassium are the only two contaminants associated with the actual location of the former antifreeze disposal tank; the remaining parameters were detected at elevated concentrations only in the nearby ground-water monitoring well. No organic parameters were detected at elevated levels in samples from either boring.

- 1100-4 Subsurface Soil Contaminants
  - Inorganic contaminants

    aluminum
    arsenic
    beryllium
    calcium
    copper
    lead
    potassium
    silver
    sodium
    thallium
    zinc

  - Organic contaminants

    none encountered

Calcium, potassium, and sodium are non-toxic essential nutrients (see Section 4.4.2). Copper and aluminum concentrations at 1100-4, while elevated, do not exceed their normal soil concentration ranges (see Sections 4.4.2 and 4.4.3, respectively). Preliminary toxicity screening for the remaining contaminants, displayed in Table 4-12, indicates that arsenic is the only parameter that exceeds its screening criterion. However, this substance was

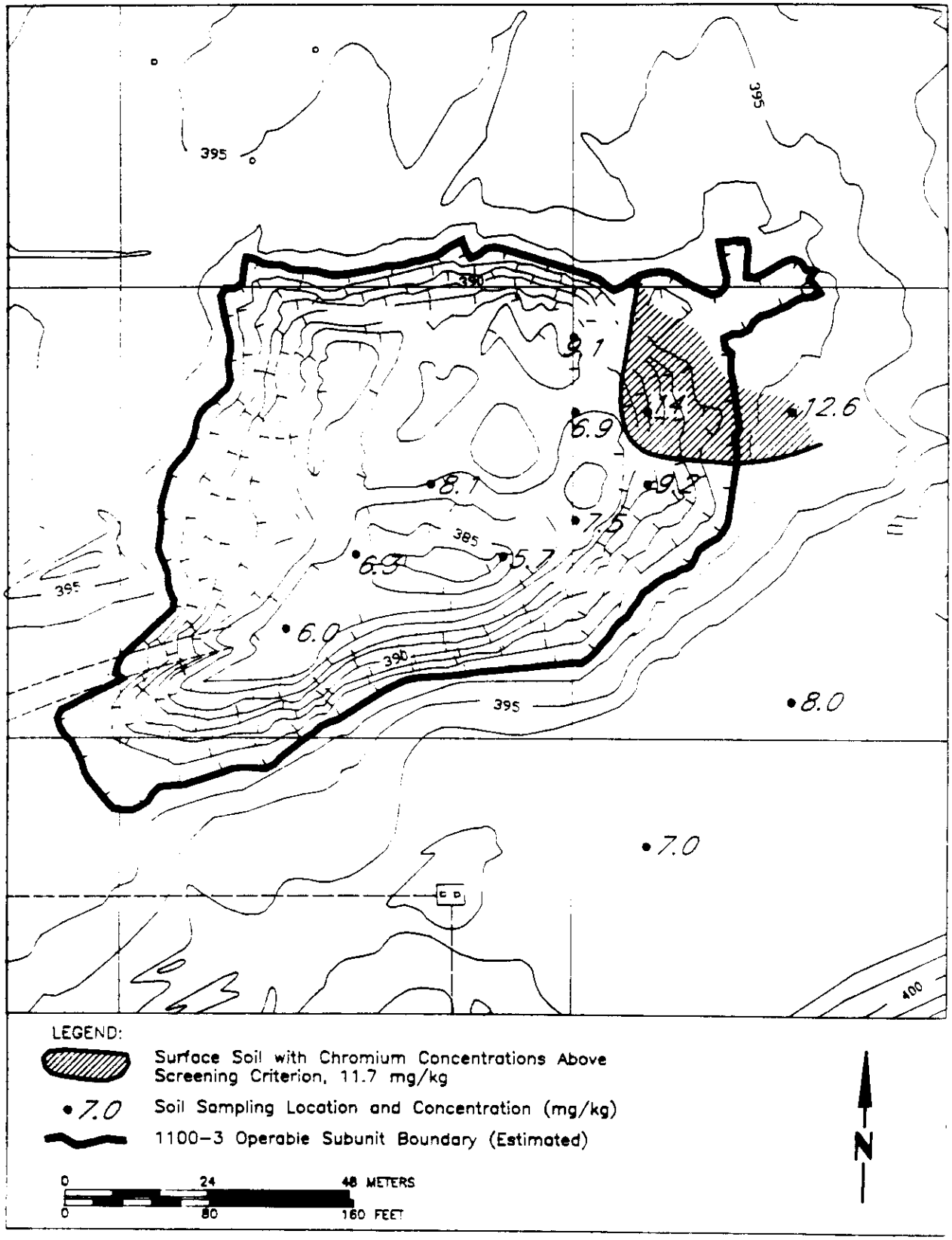

Figure 4-5. Chromium Distribution in the Surface Soil of the 1100-3 Operable Subunit.

Table 4-12. Preliminary Toxicity Screening for Soil Contaminants at the 1100-4 Operable Subunit.

Parameter	Maximum Soil Concentration (mg/kg)	Oral RfD (mg/kg/d)	Soil Concentration at the Oral RfD (mg/kg)	Inhalation RfD (mg/kg/d)	Soil Concentration at the Inhalation RfD (mg/kg)	Oral SF (mg/kg/d)[1]	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Inhalation SF (mg/kg/d)[1]	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
arsenic	5.8	1.0E-03[b]	77	--	--	1.7[c]	0.41	5.0E+01[a]	3.6	--
beryllium	0.93	5.0E-03[a]	380	--	--	--	--	8.4E+00[a]	22	--
lead	5.7	--	--	--	--		--	--	--	500-1,000[d]
silver	2.0	3.0E-03[a]	230	--	--	--	--	--	--	--
thallium	0.48	7.0E-05[b]	5.4	--			--	--	--	--
zinc	63.8	2.0E-01[b]	15,000	--	--			--	--	--

[a]EPA 1990a.
[b]EPA 1989c.
[c]Surrogate based on proposed arsenic unit risk of 5E-05 µg/L (EPA 1990a).
[d]EPA 1989f.
-- Not available.

Note: Shaded areas indicate screening criterion exceeded.

encountered at an elevated estimated concentration in only a single saturated sample below the water table in MW-3 (see Figure 2-11), at a depth of approximately 15 m (50 ft) below ground surface (see Appendix P). Further evaluation of potential arsenic contamination at 1100-4 is therefore deferred to Section 4.5 (Ground-Water Contamination).

4.4.6 UN-1100-6 (Discolored Soil Site) Soil Quality

No soil borings were drilled at UN-1100-6; however, 15 discrete surface soil samples were obtained at the operable subunit. The locations of the surface soil sampling stations for the Discolored Soil Site are shown in Figure 2-14.

Inorganic and organic contaminants present in the surface soils of the UN-1100-6 operable subunit are listed below. Appendix P indicates that organic contamination is much more prevalent at the Discolored Soil Site than is inorganic contamination: some of the concentrations of bis(2-ethylhexyl)phthalate (BEHP) are in the low percent range.

- UN-1100-6 Surface Soil Contaminants
  - Inorganic contaminants

    aluminum
    barium
    lead
    potassium
    sodium
    zinc

  - Organic contaminants

    alpha-chlordane
    gamma-chlordane
    4,4'-DDE
    BEHP
    heptachlor
    2-hexanone
    di-n-octyl phthalate
    1,1,1-trichloroethane

Potassium and sodium are excluded from further consideration because they are non-toxic essential nutrients (see Section 4.4.2); aluminum is excluded because it is present at concentrations normally found in soils (see Section 4.4.4). Because there are insufficient data to develop an RfD for di-n-octyl phthalate and the substance is not a known carcinogen, this compound is combined and evaluated with the carcinogen, BEHP. Insignificant concentrations of di-n-octyl phthalate, as compared with BEHP, provide further justification for combining these two substances for the purposes of further evaluation. The alpha- and gamma-isomers of chlordane are also combined for further evaluation within this report.

Table 4-13 summarizes the preliminary toxicity screening for the UN-1100-6 operable subunit. The potential contaminants of concern for the

Table 4-13. Preliminary Toxicity Screening for Soil Contaminants at the UN-1100-6 Operable Subunit.

Parameter	Maximum Soil Concentration (mg/kg)	Oral RfD (mg/kg/d)	Soil Concentration at the Oral RfD (mg/kg)	Inhalation RfD (mg/kg/d)	Soil Concentration at the Inhalation RfD (mg/kg)	Oral SF (mg/kg/d)$^{-1}$	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Inhalation SF (mg/kg/d)$^{-1}$	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
barium	99.2	5.0E-02[a]	3,800	1.0E-04[b]	18,000	--	--	--	--	--
lead	22.1	--	--	--	--	--	--	--	--	500-1,000[c]
zinc	111.0	2.0E-01[b]	15,000	--	--	--	--	--	--	--
BEHP	25,046.0	2.0E-02[a]	1,500	--	--	1.4E-02[a]	50	1.4E-02[e]	13,000	--
chlordane	1.86	6.0E-05[a]	4.6	--	--	1.3E+00[a]	0.53	1.3E+00[a]	140	--
DDT	0.17	5.0E-04[a]	38	--	-	3.4E-01[a]	2.1	3.4E-01[a]	530	--
heptachlor	0.065	5.0E-04[a]	38	--	--	4.5E+00[a]	0.16	4.5E+00[a]	40.0	--
2-hexanone	0.053	5.2E-02[b,d]	4,000	2.0E-02[b,d]	3,600,000	--	--	--	--	--
1,1,1 trichloroethane	0.035	9.0E-02[b]	6,900	3.0E-01[b]	55,000,000	--	--	--	--	--

[a]EPA 1990a.
[b]EPA 1989c.
[c]EPA 1989f.
[d]Surrogate based on 2-butanone (EPA 1990a).
[e]Surrogate inhalation SF assumed equal to BEHP oral SF.
-- Not available.

Note: Shaded areas indicate screening criterion exceeded.

Discolored Soil Site—BEHP and chlordane—were each encountered in several samples. Figure 4-6 shows the areal distribution of BEHP. The chlordane distribution is not shown, as it is directly correlated with the distribution of BEHP (see Appendix P).

4.4.7 Horn Rapids Landfill Soil Quality

Nine boreholes were drilled at the Horn Rapids Landfill. These boreholes yielded 63 discrete soil samples, eight of which were from the surface stratum and 55 from the subsurface. Forty-two additional soil samples were obtained from the surface of the landfill, thereby providing a total of 50 discrete samples for characterization of surface soil conditions at the operable subunit (see Appendix I). Borehole locations are shown in Figure 2-15 and vertical sampling locations within each borehole are described in Appendix G. Locations of the additional surface sampling stations within the operable subunit are also shown in Figure 2-15.

It should be noted that boreholes were intentionally situated to avoid drilling through known and suspected waste deposits, the locations of which were determined during scoping, and implementation of the landfill geophysical and soil gas surveys. This decision was made for reasons of safety and health concerns; however, the biased subsurface sampling design places substantial limitations on the representativeness of the subsurface soil quality results summarized in the discussion below.

As shown in Appendix P, numerous inorganic contaminants were encountered in the surface and subsurface soils of the Horn Rapids Landfill. These contaminants, along with the organic contaminants, are listed below. The only subsurface organic contaminant encountered, in one borehole (HRL-4) at a single depth (approximately 2 m [7 ft] below ground surface), was the PCB mixture, aroclor-1248. Appendix P contains specific information regarding elevated contaminant locations and concentrations.

- Horn Rapids Landfill Surface Soil Contaminants
  - Inorganic contaminants

    aluminum
    arsenic
    barium
    beryllium
    cadmium
    calcium
    chromium
    cobalt
    copper
    cyanide
    iron
    lead
    magnesium
    mercury
    nickel
    potassium
    selenium

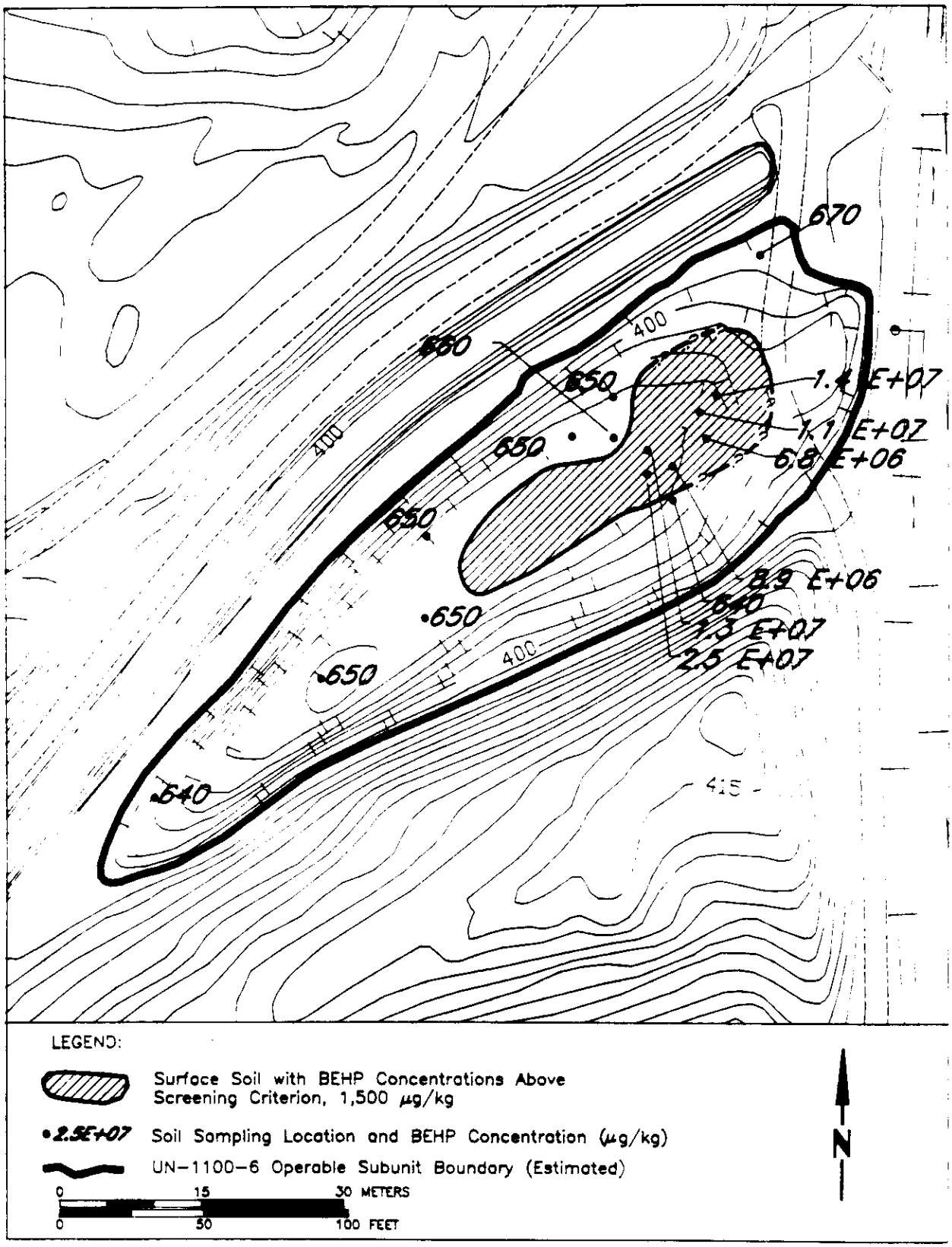

Figure 4-6. BEHP Distribution in the Surface Soil of the UN-1100-6 Operable Subunit.

silver
sodium
thallium
vanadium
zinc

- Organic contaminants

aroclor-1248
aroclor-1254
alpha-chlordane
4,4'-DDD
4,4'-DDE
4,4'-DDT
heptachlor
2-methylnaphthalene
naphthalene
tetrachloroethene

- Horn Rapids Landfill Subsurface Soil Contaminants

  - Inorganic contaminants

aluminum
antimony
arsenic
beryllium
cadmium
calcium
chromium
cobalt
copper
cyanide
iron
lead
magnesium
mercury
nickel
potassium
silver
sodium
thallium
zinc

  - Organic contaminants

aroclor-1248

The essential nutrients that are regarded as non-toxic—calcium, iron, magnesium, potassium, sodium—are not given further consideration (see Section 4.4.2). Copper, aluminum, and cobalt are also excluded for reasons previously specified (see Sections 4.4.2, 4.4.3, and 4.4.4, respectively). For the purposes of preliminary toxicity screening and further evaluation within this report, all PCB congeners are combined and evaluated as total PCB, and naphthalene and 2-methylnaphthalene are combined and evaluated as naphthalene,

as insufficient toxicity data currently exist to quantitatively evaluate the methylated derivative of this substance.

Table 4-14 summarizes the results of the preliminary toxicity screening for soil contaminants at the Horn Rapids Landfill. The following four contaminants exceed their respective screening criteria:

- PCB
- chromium
- arsenic
- nickel.

However, the only soil sample that fails the nickel inhalation screening criterion of 220 mg/kg was located approximately 4.8 m (15.8 ft) below ground surface (see Appendix P). As soil at this depth can not contribute to a release of fugitive dust and its oral criterion was not exceeded, nickel is not retained as a contaminant of potential concern for the Horn Rapids Landfill soils. The three contaminants of potential concern for the Horn Rapids Landfill are therefore PCB, chromium, and arsenic.

Figures 4-7 and 4-8, respectively, display the distribution of PCB contamination in the surface soils and subsurface soils (at borehole HRL-4) of the Horn Rapids Landfill. Surface and subsurface distributions of chromium contamination at the landfill are plotted in Figures 4-9 and 4-10, respectively. Arsenic occurrences within the surface and subsurface landfill soils are shown in Figures 4-11 and 4-12, respectively.

4.4.8 Soil Quality at Miscellaneous Locations

Surface soil samples were taken at two locations within the operable unit that are not directly associated with any recognized waste management unit assigned to the 1100 Area NPL Site. This sampling effort was conducted outside of the planned scope of the 1100-EM-1 Operable Unit RI/FS, but the results are summarized below. Six samples were obtained from Pit 1, an operational gravel pit within the 1100 Area. Another two samples were obtained from the location of an ephemeral pool that forms infrequently and for brief periods during intense precipitation events. The locations of the gravel pit and the ephemeral pool are shown in Figure 2-16. Exact locations of the sampling stations within each location were not surveyed or recorded.

The concentrations of elevated inorganic and organic target parameters for Pit 1 are contained in Appendix P. The elevated contaminants present within the gravel pit are listed below.

- Pit 1 Surface Soil Contaminants
  - Inorganic contaminants

    calcium
    copper
    lead
    sodium
    zinc

Table 4-14. Preliminary Toxicity Screening for Soil Contaminants at the Horn Rapids Landfill Operable Subunit.

Parameter	Maximum Soil Concentration (mg/kg)	Oral RfD (mg/kg/d)	Soil Concentration at the Oral RfD (mg/kg)	Inhalation RfD (mg/kg/d)	Soil Concentration at the Inhalation RfD (mg/kg)	Oral SF (mg/kg/d)[-1]	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Inhalation SF (mg/kg/d)[-1]	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
antimony	3.2	4.0E-04[a]	31	--	--	--	--	--	--	--
arsenic	6.6	1.0E-03[b]	77	--	--	1.7[c]	0.41	5.0E+01[a]	3.6	--
barium	1,320.0	5.0E-02[a]	3,800	1.0E-04[b]	18,000	--	--	--	--	--
beryllium	1.3	5.0E-03[a]	380	--	--	--	--	8.4E+00[a]	22	--
cadmium	2.0	1.0E-03[a]	77	--	--	--	--	6.1E+00[a]	30	--
chromium	1,250.0	5.0E-03[a]	380	--	--	--	--	4.1E+01[a]	4.4	--
lead	482.0	--	--	--	--	--	--	--	--	500-1,000[d]
manganese	496.0	2.0E-01[b]	15,000	3.0E-04[b]	55,000	--	--	--	--	--
mercury	1.3	3.0E-04[b]	23	--	--	--	--	--	--	--
nickel	557.0	2.0E-02[a]	1,500	--	--	--	--	8.4E-01[a]	220	--
selenium	0.92	3.0E-03[b]	230	--	--	--	--	--	--	--
silver	7.7	3.0E-03[a]	230	--	--	--	--	--	--	--
thallium	3.1	7.0E-05[b]	5.4	--	--	--	--	--	--	--
vanadium	87.3	7.0E-03[b]	540	--	--	--	--	--	--	--
zinc	408.0	2.0E-01[b]	15,000	--	--	--	--	--	--	--
cyanide	0.56	2.0E-02[a]	1,500	--	--	--	--	--	--	--
chlordane	0.18	6.0E-05[a]	4.6	--	--	1.3E+00[a]	0.53	1.3E+00[a]	140	--
DDT	1.9	5.0E-04[a]	38	--	--	3.4E-01[a]	2.1	3.4E-01[a]	534	--
heptachlor	0.02	5.0E-04[a]	38	--	--	4.5E+00[a]	0.16	4.5E+00[a]	40	--
naphthalene	8.2	4.0E-03[b]	300	--	--	--	--	--	--	--
PCBs	65.29	--	--	--	--	7.7E+00[e]	0.090	7.7E+00[f]	24	1-25[e]
tetrachloroethene	0.006	1.0E-02[b]	770	--	--	5.1E-02[b]	14	3.3E-03[b]	55,000	--

[a]EPA 1990a.
[b]EPA 1989c.
[c]Surrogate based on proposed arsenic unit risk of 5E-05 µg/L (EPA 1990a).
[d]EPA 1989f.
[e]40 CFR 761.
[f]Surrogate inhalation SF assumed equal to PCB oral SF.
-- Not available.

Note: Shaded areas indicate screening criterion exceeded.

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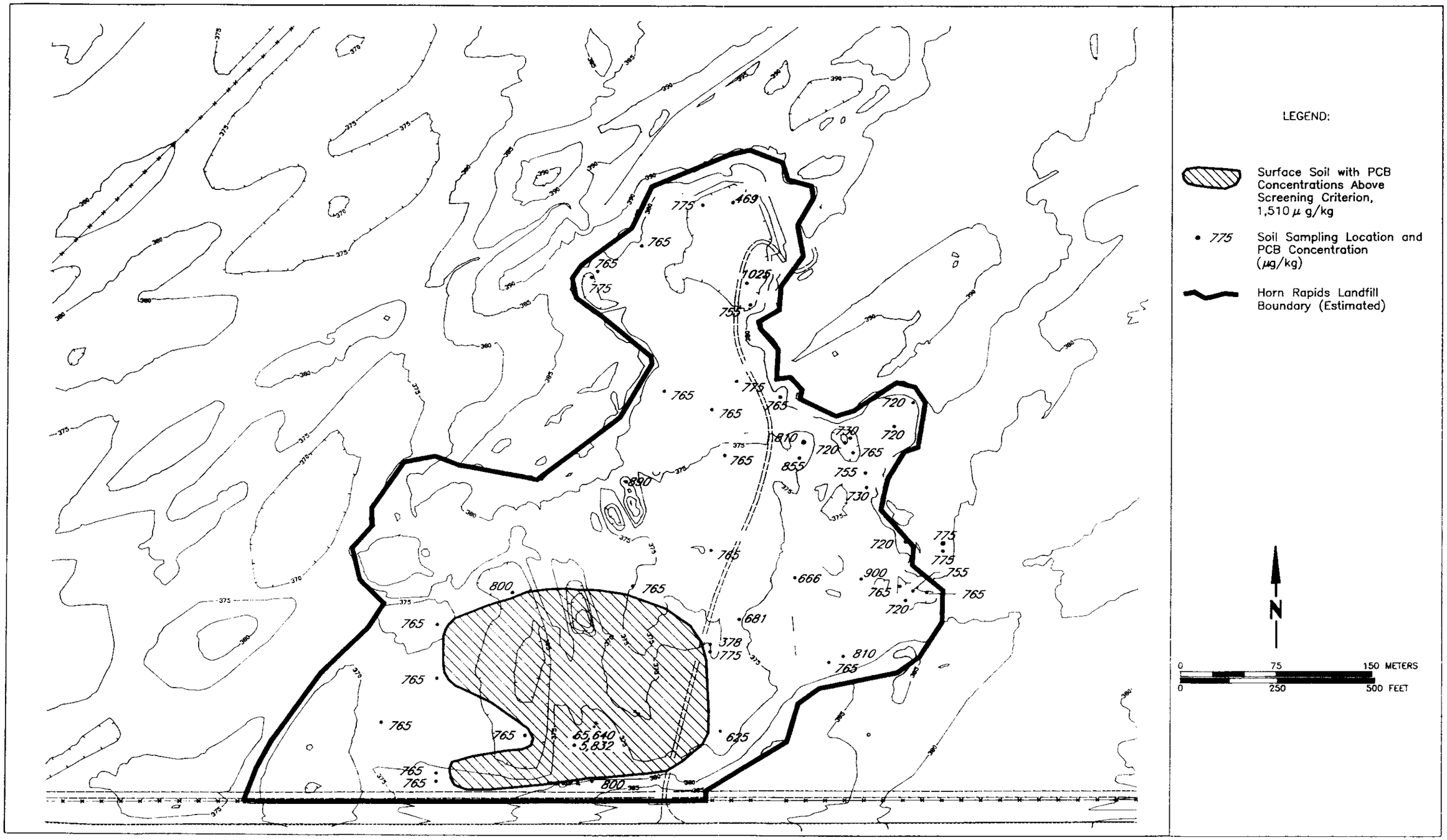
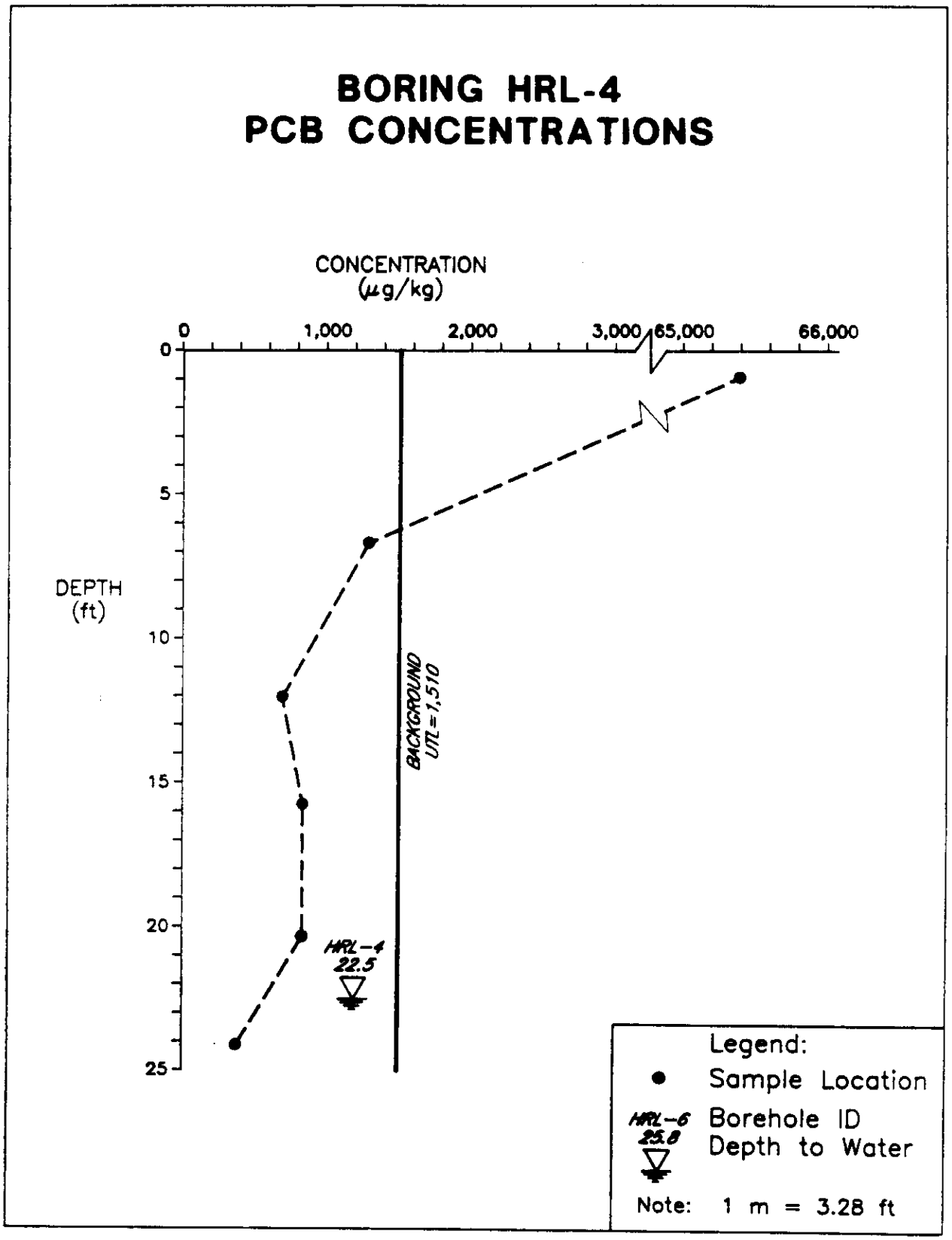


903-1214\33845

Figure 4-7. Total PCB Distribution in Surface Soil of the Horn Rapids Landfill Operable Subunit.



903-1214\33848

Figure 4-8. Vertical Distribution of PCB in Soil from Borehole HRL-4 at the Horn Rapids Landfill Operable Subunit.

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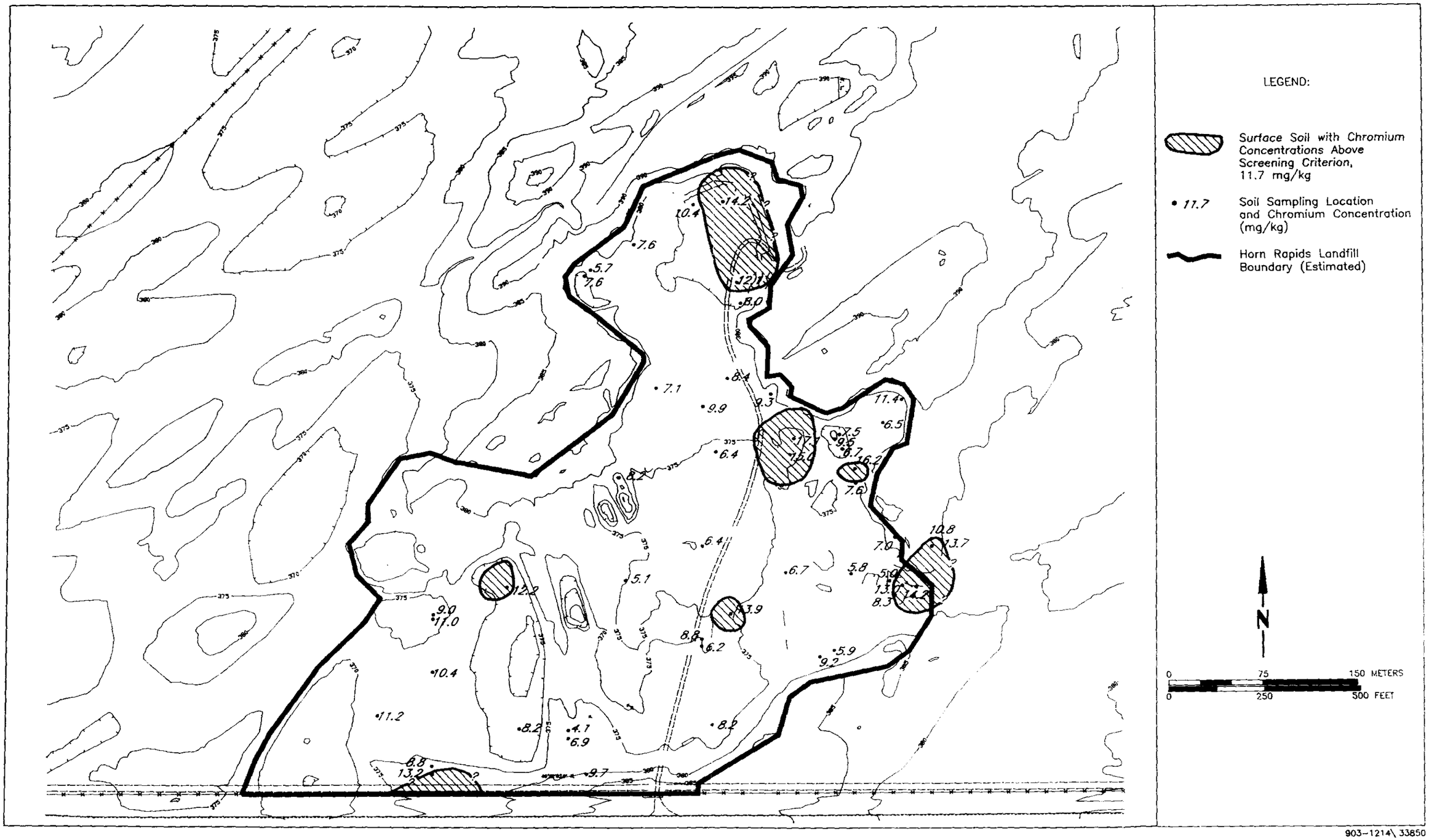

903-1214\ 33850

Figure 4-9. Chromium Distributions in the Surface Soil of the Horn Rapids Landfill Operable Subunit.

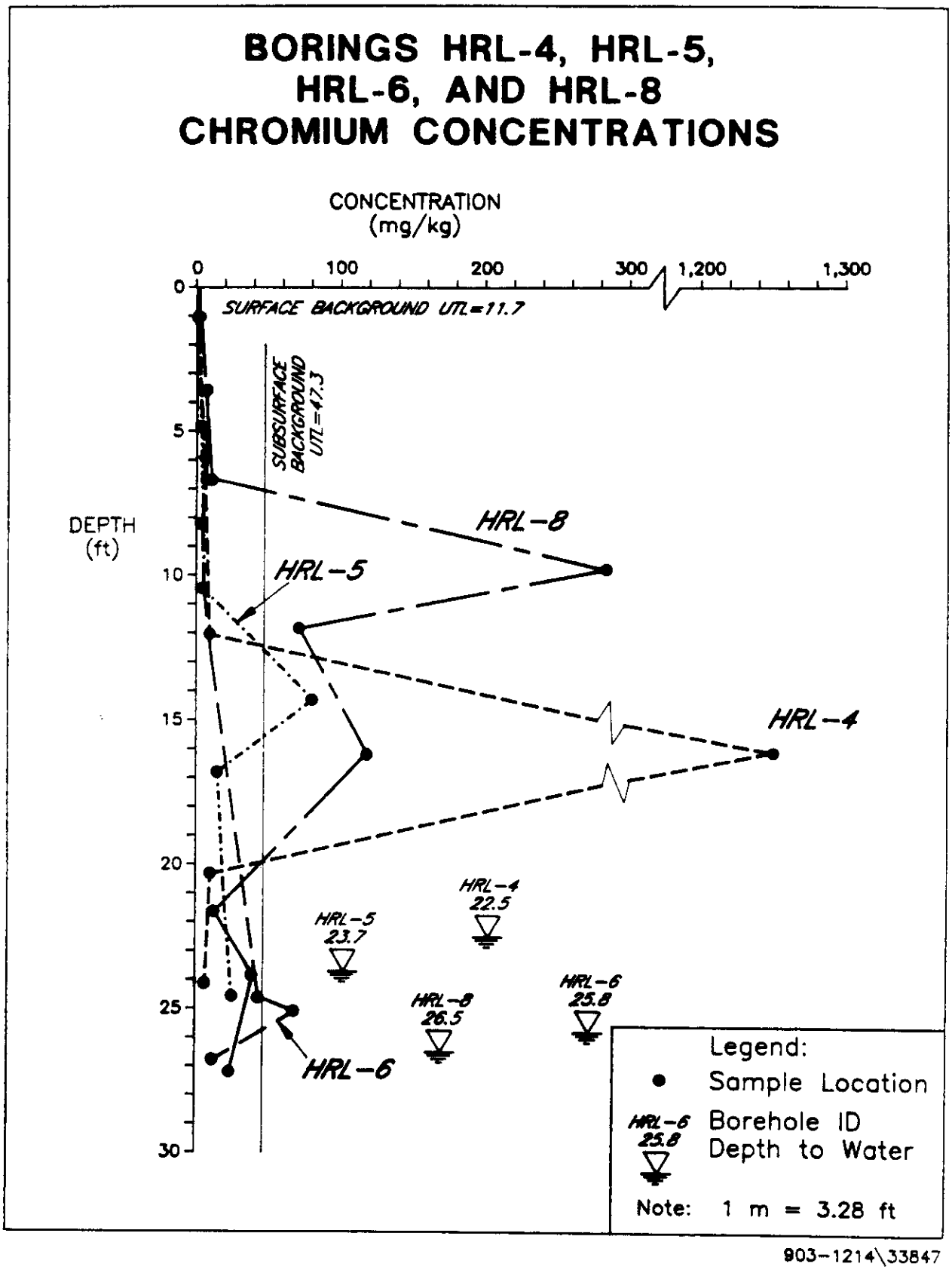

Figure 4-10. Vertical Distribution of Chromium in Soil from Boreholes HRL-4, HRL-5, HRL-6, and HRL-8 at the Horn Rapids Landfill Operable Subunit.

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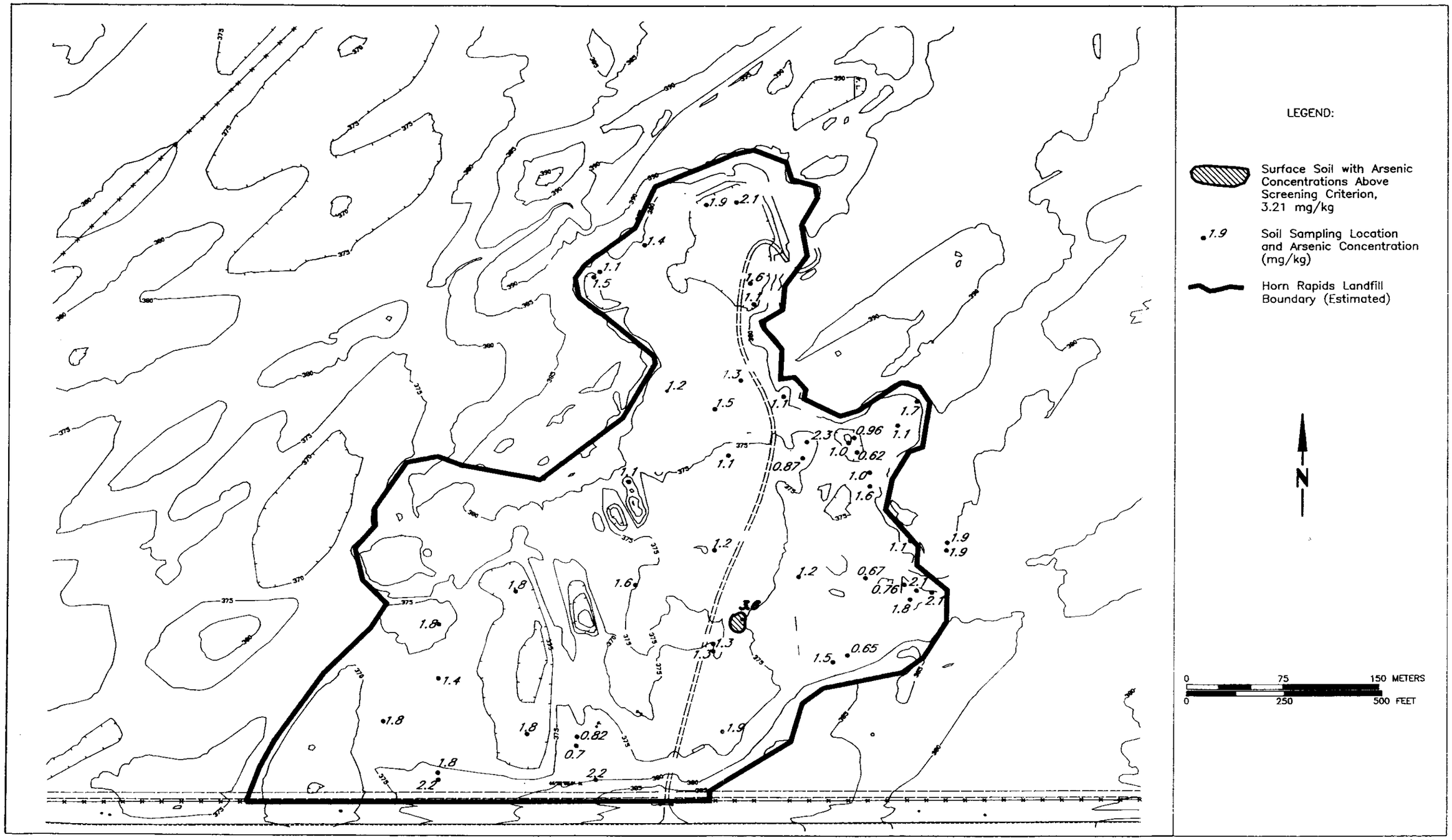

903-1214\33844

Figure 4-11. Arsenic Distributions in the Surface Soil of the Horn Rapids Landfill Operable Subunit.

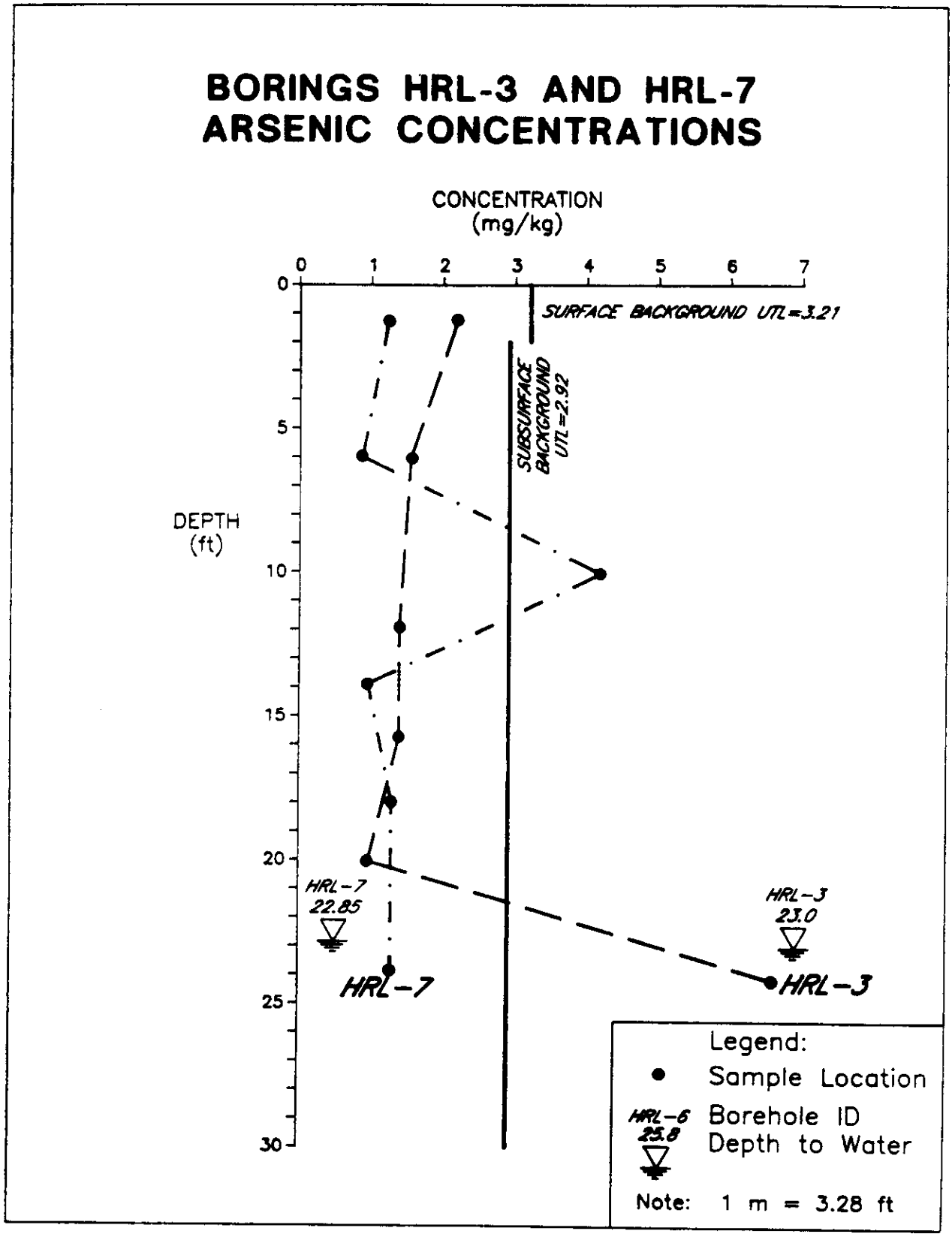

Figure 4-12. Vertical Distribution of Arsenic in Soil from Boreholes HRL-3, and HRL-7 at the Horn Rapids Landfill Operable Subunit.

- Organic contaminants

  aroclor-1260

The inorganic and organic target contaminants for the ephemeral pool are also contained in Appendix P. The contaminants present at this location are:

- Ephemeral Pool Surface Soil Contaminants

  - Inorganic contaminants

    lead
    sodium
    zinc

  - Organic contaminants

    aroclor-1260
    alpha-chlordane
    gamma-chlordane
    endosulfan II
    endrin
    heptachlor

Calcium and sodium are eliminated from further consideration because they are non-toxic essential nutrients, and copper is eliminated because it does not exceed its typical soil concentration range (see Section 4.4.2). The preliminary toxicity screening for the remaining contaminants is presented in Table 4-15.

The sole contaminant of potential concern for Pit 1 is PCB, detected in elevated concentration (440 µg/kg at only one of the six locations sampled. The presence of potential contaminants of concern—PCB and chlordane—at the ephemeral pool indicates a potential parking lot runoff problem with the precise source of the contamination unknown. Chlordane was found at both locations sampled, while PCB was encountered at only one of these two locations.

4.5 GROUND-WATER CONTAMINATION

The local unconfined and confined aquifers were sampled and chemically analyzed, in two rounds, during the first phase of the 1100-EM-1 Operable Unit RI (see Section 2.6.4). Monitoring well locations are shown in Figures 2-18 and 2-19, and well completion information is provided in Table 2-1. A total of 21 monitoring well samples and two composite samples from the City of Richland well field distribution lines were obtained for chemical analysis during the first round of the Phase I RI hydrogeological investigation; eight wells were added for the second round of sampling. The results of this ground-water contamination investigation are provided in Appendix N.

All ground-water samples were analyzed for conventional water quality, TAL, and TCL parameters. Appendix N provides results for all detected target parameters and TICs. A list of target parameters analyzed for but not

Table 4-15. Preliminary Toxicity Screening for Soil Contaminants at Pit 1 and the Ephemeral Pool.

Parameter	Maximum Soil Concentration (mg/kg)	Oral RfD (mg/kg/d)	Soil Concentration at the Oral RfD (mg/kg)	Inhalation RfD (mg/kg/d)	Soil Concentration at the Inhalation RfD (mg/kg)	Oral SF $(mg/kg/d)^{-1}$	Soil Concentration at Oral ICR = 1E-06 (mg/kg)	Inhalation SF $(mg/kg/d)^{-1}$	Soil Concentration at Inhalation ICR = 1E-06 (mg/kg)	Regulatory Soil Cleanup Guidelines (mg/kg)
[illegible]	4.7	--	--	--	--	7.7+00[a]	0.090	7.7E+00[d]	24	1-25[e]
[illegible]dane	1.81	6.0E-05[a]	4.6	--	--	1.3+00[a]	0.54	1.3E+00[a]	140	--
endosulfan II	0.16	5.0E-05[b]	3.8	--	--	--	--	--	--	--
endrin	0.039	3.0E-04[b]	23	--	--	--	--	--	--	--
heptachlor	0.029	5.0E-04[a]	38	--	--	4.5+00[a]	0.16	4.5E+00[a]	40	--
zinc	54.0	2.0E-01[b]	15,000	--	--	--	--	--	--	--

[a]EPA 1990a.
[b]EPA 1989c.
[c]40 CFR 761.
[d]Surrogate inhalation SF assumed to be equal to PCB oral SF.
-- Not available.

Note: Shaded areas indicate screening criterion exceeded.

detected, along with the range of SQLs for each such parameter, is also provided in Appendix N.

The ground-water chemical data in Appendix N are "blank validated" with respect to SDG blanks only. In accordance with EPA data validation guidelines (Bleyler 1988a and 1988b), validation should be based on all blanks associated with the sample case. The pertinent blanks in this instance are all blanks associated with 1100-EM-1 Phase I RI ground-water investigation samples. As was the case for soils (see Section 4.4), some organic TCL parameters were encountered in ground-water-associated blanks that were detected in high enough concentrations to require further validation adjustment.

Table 4-16 presents the TCL parameters detected in these blanks and their corresponding maximum blank concentrations. This information was used, in the manner specified in Section 4.4 for soil data, to finalize the validation of the ground-water data presented in Appendix N. Final validated data are used in the descriptions of operable unit ground-water quality presented below.

Appendix N also contains TICs which have not been subjected to final validation. Final validation procedures for ground-water TICs, along with soil TICs, and a final validated list of TIC occurrences within each of these operable unit media, are presented in Appendix O. After validation, no TICs remain in the ground-water data set.

The ground-water TAL parameters were analyzed in both unfiltered and filtered samples. Results from such analyses are generally representative of total and dissolved ground-water concentrations, respectively. To maintain comparability among the ground-water samples from different wells (i.e., to factor out variability attributable to among-well differences in construction, development, and sampling), only filtered TAL analyses are used to evaluate ground-water contamination. The turbidity of samples obtained from operable unit wells chemically analyzed varied from < 0.10 to 60 NTU (see Appendix N). Such variability causes a comparability problem for unfiltered samples. In addition, unfiltered results from samples with turbidities > 5 NTU are considered unacceptable by EPA (1986d and 1986e). Filtered TAL analytical results are much more representative of actual ground-water quality, as particulate ground-water transport (ignoring colloidal material) does not occur under typical laminar aquifer flow conditions (Freeze and Cherry 1979).

Turbulent flow conditions necessary for particulate transport in ground water are artificially imposed upon an aquifer during sampling. As a result, particulate concentrations observed in ground-water samples are not representative of actual aquifer conditions, but are a reflection of human disturbance of the system in the course of obtaining a sample. The filter diameter used to obtain filtered water samples is 0.45 μm. This pore size lies near the mid-point of the colloidal size range (Stumm and Morgan 1981). Therefore, a filtered sample overestimates the dissolved fraction of a constituent in a water medium, as (at a first approximation) about half of all colloidal particles present (i.e., those less than 0.45 μm in size) are represented in the sample.

Operable-unit specific background ground-water quality is described in Section 4.5.1. For the purposes of this report, background ground-water quality is stratified by the unconfined and confined aquifer zones. Following the characterization of background conditions, ground-water contamination

Table 4-16. Highest Detected Organic Blank Concentrations Associated With 1100-EM-1 Ground-Water Samples.

	Parameter	Sample ID/SDG	Concentration (µg/L with qualifier)	
First Sampling Round				
Volatiles	acetone *	B00028/B00028	3	
	2-butanone *	B00028/B00028	43	
	chloroform	B0063T/B0048D	7	
	methylene chloride *	B00037/B00028	5	
	trichloroethene	B00018/A2401W	1	
Semivolatiles	bis(2-ethylhexyl)phthalate *	SBLKW2/B0048D	7	J
Second Sampling Round				
Volatiles	acetone *	B00082/B00070	14	
	2-butanone *	B00082/B00070	66	
	chloroform	B000G8/B000G0	3	
	methylene chloride *	B00082/B00070	5	
	trichloroethene	B00099/B00070	1	

Note: No organic contaminants (other than TICs) were found in blanks associated with the Advanced Nuclear Fuels Corp. sampling conducted concurrently with the Second Sampling Round.
*Common laboratory contaminant according to Bleyler (1988a).
J: The associated value is an estimated quantity.

conditions are assessed for the operable unit as a whole to identify contaminants of potential concern. Such contaminants are identified and their distributions are discussed in Section 4.5.2.

As with the soil contamination presentations in Section 4.4, those parameters that exceed their respective operable-unit-specific background levels are regarded as contaminants. Each contaminant is then subjected to a conservative preliminary toxicity screening, the process for which is described in detail within Section 4.4. In lieu of cleanup guidelines, few of which are available for soils, many regulatory water quality standards and criteria are employed for the ground-water toxicity screening:

- Primary maximum contaminant levels (1° MCLs) (40 CFR 141 and WAC 248-54-175)
- Maximum contaminant level goals (MCLGs) (40 CFR 141)

- Human water quality health criteria, based on the consumption of both water and fish (HWQHC) (EPA 1986a and WAC 173-201-035(12))
- Chronic freshwater quality criteria (CFWQC) (EPA 1986a and WAC 173-201-035(12))
- Secondary maximum contaminant levels (2° MCLs) (40 CFR 143 and WAC 248-54-175)
- Human water quality welfare criteria (HWQWC) (EPA 1986a and WAC 173-201-035(12)).

Conservative intake assumptions used for calculating water concentrations at the RfD or the ICR of 1E-06, as appropriate, are an ingestion rate of 2L/d, a body weight of 70 kg, a daily exposure duration of 75 yr (converted to d) and a 75-yr averaging time (converted to d). For volatile substances (i.e., tetrachlorethene), inhalation intakes are conservatively estimated by assuming that they are equivalent to two times the drinking water ingestion intakes on a mass per body weight per time basis, in accordance with EPA-Region X (1990). For radionuclides, the screening criterion (i.e., the concentration of the ICR of 1E-06) is set equal to 1E-06/(Unit Risk) in accordance with EPA (1989c).

4.5.1 Background Ground-Water Quality

Ground-water samples which provide operable-unit-specific background data for the unconfined aquifer were obtained from three of the Phase I RI monitoring wells; a single well was used to characterize operable-unit-specific background data for the uppermost unconfined aquifer. The particular wells selected for operable-unit-specific background characterization are located either hydraulically upgradient or in a position that is not impacted by potential 1100-EM-1 or adjacent contaminant sources (see the evaluations of available ground-water potential data in Figures 3-38 through 3-40). Using this criterion, wells MW-2, MW-7, and MW-8 are designated as operable-unit-specific unconfined aquifer background wells, while MW-9 is designated the operable-unit-specific background well for the upper confined aquifer (see Figure 2-18 and Table 2-1).

A plume of contaminated ground-water is known to have emanated from the Advanced Nuclear Fuels Corp. facility located to the southwest of, and hydraulically upgradient from, the Horn Rapids Landfill (see Figures 3-38 through 3-40). This plume is known to contain elevated concentrations of nitrate, fluoride, sulfate, gross-alpha and gross-beta radiation, and ammonia (see Section 4.1.2.4). Horn-Rapids-Landfill-specific background data for the unconfined aquifer were therefore obtained from three existing upgradient wells (ANF-14, -15, and -16) located on Advanced Nuclear Fuels property (see Figure 2-19 and Table 2-1).

The background monitoring system for the unconfined aquifer is generally adequate, except for the absence of any wells to the southeast of the Horn Rapids Landfill (see Figures 2-19 and 3-38 through 3-40). Without ground-water samples from this location, the contaminant plume known to have originated from the nearby, upgradient Advanced Nuclear Fuels Corp. facility can not be fully characterized with respect to its nature and extent.

There is a possibility that MW-7 may not be representative of project-specific background conditions for the unconfined aquifer. Under conditions of ground-water mounding below the City of Richland well field, ground water intercepted by this well may be influenced by contamination originating at the 1100-2, 1100-3, and UN-1100-6 operable subunits. At present, the results for MW-7 agree well with those for MW-2 and MW-8, and available ground-water potential data (see Figures 3-38 and 3-39) indicate that MW-7 is hydraulically upgradient from the three operable subunits mentioned.

Two additional wells, MW-1 and 699-S43-E12, could potentially be regarded as background wells. However, both wells are immediately adjacent to potential sources of ground-water contamination within the 1100-EM-1 Operable Unit, so they are not regarded as background wells for the purposes of this report.

Operable-unit-specific and Horn-Rapids-Landfill-specific unconfined and operable-unit-specific confined aquifer water quality conditions are characterized in Tables 4-17, 4-18, and 4-19 for conventional, TAL, and TCL parameters, respectively. For the operable-unit-specific unconfined aquifer background data (n = 6), a one-sided UTL is presented for each parameter (both upper and lower tolerance limits are provided for pH) in accordance with the procedure utilized for background soil characterization (see Section 4.4.1). A sample size of three was generally available for characterizing the Horn-Rapids-Landfill-specific background conditions, and the sample size used for the operable-unit-specific confined aquifer conditions was generally two.

When a data point is missing from the unconfined aquifer data set, the available data are then insufficient (n = 1) to allow for a statistical characterization of background conditions. In such situations, a surrogate UTL for confined aquifer parameters is reported—the single concentration observed in MW-9 multiplied by 10. If a given parameter was analyzed for but never detected in a particular background well or set of wells, its SQL is used as a surrogate UTL for the appropriate background type.

4.5.2 1100-EM-1 Operable Unit Ground-Water Quality

In the following characterization of ground-water quality, an exceedance of the respective background threshold values, presented in Tables 4-17 through 4-19, for a particular parameter is regarded as evidence of contamination. Monitoring well MW-17, which is completed within the uppermost confined aquifer (see Table 2-1) is compared to operable-unit-specific confined aquifer background; MW-10, -11, -12, -13, -14, -15, 699-S27-E14, and 699-S29-E12 are compared to Horn-Rapids-Landfill-specific unconfined aquifer background (see Figures 3-38 through 3-40); and, the remaining non-background wells are compared to operable-unit-specific background.

Parameters detected at concentrations exceeding their corresponding background thresholds are:

- 1100-EM-1 Ground-Water Contaminants
  - Conventional contaminant parameters

    alkalinity

Table 4-17. Conventional Parameter UTLs for Background Ground Waters.

Parameter	Operable-Unit-Specific Background: Unconfined Aquifer (n=6) (mg/L)	Operable-Unit-Specific Background: Confined Aquifer (n=2) (mg/L)	Horn-Rapids-Landfill-Specific Background: Unconfined Aquifer (n=3) (mg/L)
alkalinity (as calcium carbonate)	199	94	--[a]
ammonium	0.15	0.87	--
bromide	1 *	1 *	--
chloride	22.1	4.3	111
COD	15[b]	80	--
coliform (MPN/100 mL)	2.2[c] *	2.2[d] *	2 *
fluoride	0.5	1.2	39.1
gross alpha radiation (pCi/L)	8.2[c]	13[d]	--
gross beta radiation (pCi/L)	18[c]	64[d]	--
hydrogen-3 (pCi/L)	1,000[c,f] *	1,000[d,f] *	--
nitrate	54.4	0.5 *	895
nitrite	1[c] *	1[d] *	0.2 *
pH (standard pH units)	7.5 - 8.7[b]	[e]	--
phosphate	1.0 *	1.0 *	0.5 *
radium-226/228 (pCi/L)	1.7[c]	4.0[d]	--
strontium-90 (pCi/L)	2[c,f] *	2[d,f] *	--
sulfate	42.5	242	311
SC (μmhos/cm)	659	1,200	--
TDS	433	2,000	--
TOC	3.9	15.4	--
TOX	0.22	2.1	--

*Parameter was never detected in the respective background samples; therefore, the highest reported respective background SQL is substituted as a surrogate UTL.

[a]--indicates value was not reported.

[b]n=5.

[c]n=3.

[d]n=1; if the parameter is detected, 10 times the reported value is substituted as a surrogate UTL.

[e]Upper and lower tolerance limits far exceed plausible environmental values.

[f]Parameter not detected; SQLs for hydrogen-3 and strontium-90 not reported, but assumed to be 1,000 and 2 pCi/L, respectively (40 CFR 141.25(c)(2)).

Table 4-18. TAL Parameter UTLs for Background Ground Waters.

Parameter	Operable-Unit-Specific Background: Unconfined Aquifer (n=6) (µg/L)	Operable-Unit-Specific Background: Confined Aquifer (n=2) (µg/L)	Horn-Rapids-Landfill-Specific Background: Unconfined Aquifer (n=3) (µg/L)
aluminum	152 *	192 *	147 *
antimony	21 *	21 *	32 *
arsenic	10.9	1	18
barium	60.5	259	550
beryllium	1 *	1 *	1 *
cadmium	3 *	23	2 *
calcium	74,600	77,900	257,000
chromium	7.8 *	6.1 *	4 *
cobalt	3 *	3 *	21.2 *
copper	5.22 *	2 *	15.2 *
iron	820	2,860	10,900
lead	13.7	42.6 *	7.9
magnesium	20,200	18,400	56,800
manganese	390	415	596
mercury	0.2 *	0.2 *	0.2[a] *
nickel	15 *	15 *	22.9 *
potassium	7,140	40,000	46,500
selenium	5.29	2 *	2 *
silver	4.0	3 *	12.8 *
sodium	29,500	242,000	122,000
thallium	4 *	2 *	3 *
vanadium	18.1	3 *	33.4 *
zinc	8.3	2 *	217
cyanide	10 *	10 *	10 *

*Parameter was never detected in the respective background samples; therefore, the highest reported respective background SQL is substituted as a surrogate UTL.

[a]n=2

Table 4-19. TCL Parameter UTLs for Background Ground Waters.
(Page 1 of 4)

Parameter	Operable-Unit-Specific Background: Unconfined Aquifer (n=6) (µg/L)		Operable-Unit-Specific Background: Confined Aquifer (n=2) (µg/L)		Horn-Rapids-Landfill-Specific Background: Unconfined Aquifer (n=3) (µg/L)	
Volatiles						
chloromethane	2	*	2	*	10	*
bromomethane	2	*	2	*	10	*
vinyl chloride	2	*	2	*	10	*
chloroethane	2	*	2	*	10	*
methylene chloride	1	*	1	*	5	*
acetone	10	*	10	*	10	*
carbon disulfide	1	*	1	*	5	*
1,1-dichloroethene	1	*	1	*	5	*
1,1-dichloroethane	1	*	1	*	5	*
1,2-dichloroethene (total)	1	*	1	*	5	*
chloroform	1	*	1	*	5	*
1,2-dichloroethane	1	*	1	*	5	*
2-butanone	2	*	2	*	10	*
1,1,1-trichloroethane	1.2		1	*	22	
carbon tetrachloride	1	*	1	*	5	*
vinyl acetate	2	*	2	*	10	*
bromodichloromethane	1	*	1	*	5	*
1,2-dichloropropane	1	*	1	*	5	*
cis-1,3-dichloropropene	1	*	1	*	5	*
trichloroethene	1	*	1	*	194	
dibromochloromethane	1	*	1	*	5	*
1,1,2-trichloroethane	1	*	1	*	5	*
benzene	1	*	1	*	5	*
trans-1,3-dichloropropene	1	*	1	*	5	*
bromoform	1	*	1	*	5	*
4-methyl-2-pentanone	10	*	10	*	10	*
2-hexanone	10	*	10	*	10	*
tetrachloroethene	1	*	1	*	5	*
1,1,2,2-tetrachloroethane	1	*	1	*	5	*
toluene	1	*	1	*	5	*
chlorobenzene	1	*	1	*	5	*
ethylbenzene	1	*	1	*	5	*
styrene	1	*	1	*	5	*
xylene (total)	1	*	1	*	5	*
Semivolatiles						
phenol	10	*	10	*	10	*
bis(2-chloroethyl)ether	10	*	10	*	10	*
2-chlorophenol	10	*	10	*	10	*
1,3-dichlorobenzene	10	*	10	*	10	*
1,4-dichlorobenzene	10	*	10	*	10	*

Table 4-19. TCL Parameter UTL Concentrations for Background Ground Water
(Page 2 of 4)

Parameter	Operable-Unit-Specific Background Unconfined Aquifer (n=6) (µg/L)		Operable-Unit-Specific Background Confined Aquifer (n=2) (µg/L)		Horn-Rapids-Landfill-Specific Background Unconfined Aquifer (n=3) (µg/L)	
Semivolatiles (cont.)						
benzyl alcohol	10	*	10	*	10	*
1,2-dichlorobenzene	10	*	10	*	10	*
2-methylphenol	10	*	10	*	10	*
bis(2-chloroisopropyl)ether	10	*	10	*	10	*
4-methylphenol	10	*	10	*	10	*
N-nitroso-di-n-propylamine	10	*	10	*	10	*
hexachloroethane	10	*	10	*	10	*
nitrobenzene	10	*	10	*	10	*
isophorone	10	*	10	*	10	*
2-nitrophenol	10	*	10	*	10	*
2,4-dimethylphenol	10	*	10	*	10	*
benzoic acid	50	*	50	*	48	*
bis(2-chloroethoxy)methane	10	*	10	*	10	*
2,4-dichlorophenol	10	*	10	*	10	*
1,2,4-trichlorobenzene	10	*	10	*	10	*
naphthalene	10	*	10	*	10	*
4-chloroaniline	10	*	10	*	10	*
hexachlorobutadiene	10	*	10	*	10	*
4-chloro-3-methylphenol	10	*	10	*	10	*
2-methylnaphthalene	10	*	10	*	10	*
hexachlorocyclopentadiene	10	*	10	*	10	*
2,4,6-trichlorophenol	10	*	10	*	10	*
2,4,5-trichlorophenol	50	*	50	*	48	*
2-chloronaphthalene	10	*	10	*	10	*
2-nitroaniline	50	*	50	*	48	*
dimethylphthalate	10	*	10	*	10	*
acenaphthylene	10	*	10	*	10	*
2,6-dinitrotoluene	10	*	10	*	10	*
3-nitroaniline	50	*	50	*	48	*
acenaphthene	10	*	10	*	10	*
2,4-dinitrophenol	50	*	50	*	48	*
4-nitrophenol	50	*	50	*	48	*
dibenzofuran	10	*	10	*	10	*
2,4-dinitrotoluene	10	*	10	*	10	*
diethylphthalate	10	*	10	*	10	*
4-chlorophenyl-phenylether	10	*	10	*	10	*
fluorene	10	*	10	*	10	*
4-nitroaniline	50	*	50	*	48	*
4,6-dinitro-2-methylphenol	50	*	50	*	48	*
N-nitrosodiphenylamine (1)	10	*	10	*	10	*
4-bromophenyl-phenylether	10	*	10	*	10	*
hexachlorobenzene	10	*	10	*	10	*

Table 4-19. TCL Parameter UTL Concentrations for Background Ground Water
(Page 3 of 4)

Parameter	Operable-Unit-Specific Background: Unconfined Aquifer (n=6) (µg/L)		Operable-Unit-Specific Background: Confined Aquifer (n=2) (µg/L)		Horn-Rapids-Landfill-Specific Background: Unconfined Aquifer (n=3) (µg/L)	
Semivolatiles (cont.)						
pentachlorophenol	50	*	50	*	48	*
phenanthrene	10	*	10	*	10	*
anthracene	10	*	10	*	10	*
di-n-butylphthalate	10	*	10	*	12	
fluoranthene	10	*	10	*	10	*
pyrene	10	*	10	*	10	*
butylbenzylphthalate	10	*	10	*	10	*
3,3'-dichlorobenzidine	20	*	20	*	19	*
benzo(a)anthracene	10	*	10	*	10	*
chrysene	10	*	10	*	10	*
bis(2-ethylhexyl)phthalate	23	*	10	*	67	
di-n-octylphthalate	10	*	10	*	10	*
benzo(b)fluoranthene	10	*	10	*	10	*
benzo(k)fluoranthene	10	*	10	*	10	*
benzo(a)pyrene	10	*	10	*	10	*
indeno(1,2,3-cd)pyrene	10	*	10	*	10	*
dibenz(a,h)anthracene	10	*	10	*	10	*
benzo(g,h,i)perylene	10	*	10	*	10	*
Pesticides						
alpha-BHC	0.05	*	0.05	*	0.048	*
beta-BHC	0.05	*	0.05	*	0.048	*
delta-BHC	0.05	*	0.05	*	0.048	*
gamma-BHC (lindane)	0.05	*	0.05	*	0.048	*
heptachlor	0.05	*	0.05	*	0.048	*
aldrin	0.05	*	0.05	*	0.048	*
heptachlor epoxide	0.05	*	0.05	*	0.048	*
endosulfan I	0.05	*	0.05	*	0.048	*
dieldrin	0.10	*	0.10	*	0.095	*
4,4'-DDE	0.10	*	0.10	*	0.095	*
endrin	0.10	*	0.10	*	0.095	*
endosulfan II	0.10	*	0.10	*	0.095	*
4,4'-DDD	0.10	*	0.10	*	0.095	*
endosulfan sulfate	0.10	*	0.10	*	0.095	*
4,4'-DDT	0.10	*	0.10	*	0.095	*
methoxychlor	0.50	*	0.50	*	0.48	*

Table 4-19. TCL Parameter UTL Concentrations for Background Ground Water
(Page 4 of 4)

Parameter	Operable-Unit-Specific Background Unconfined Aquifer (n=6) (µg/L)	Operable-Unit-Specific Background Confined Aquifer (n=2) (µg/L)	Horn-Rapids-Landfill-Specific Background Unconfined Aquifer (n=3) (µg/L)
Pesticides (cont.)			
endrin ketone	0.10 *	0.10 *	0.095*
alpha-chlordane	0.50 *	0.50 *	0.48 *
gamma-chlordane	0.50 *	0.50 *	0.48 *
toxaphene	1.0 *	1.0 *	0.95 *
aroclor-1016	0.50 *	0.50 *	0.48 *
aroclor-1221	0.50 *	0.50 *	0.48 *
aroclor-1232	0.50 *	0.50 *	0.48 *
aroclor-1242	0.50 *	0.50 *	0.48 *
aroclor-1248	0.50 *	0.50 *	0.48 *
aroclor-1254	1.0 *	1.0 *	0.95 *
aroclor-1260	1.0 *	1.0 *	0.95 *

* Parameter was never detected in the respective background samples; therefore, the highest reported respective background SQL is substituted as a surrogate UTL.

ammonium
chloride
coliform bacteria
fluoride
gross alpha radiation
gross beta radiation
nitrite
pH
phosphate
radium-226/228
specific conductance (SC)
total dissolved solids (TDS)

- Inorganic (TAL) contaminant parameters

aluminum
antimony
arsenic
barium
cadmium
calcium
chromium
copper
iron

magnesium
nickel
potassium
selenium
sodium
zinc

- Organic (TCL) contaminant parameters

  BEHP
  1,1,1-trichloroethane
  tetrachloroethene

The occurrence of each elevated detection, by well, is tabulated in Tables 4-20 through 4-22 (conventional, TAL, and TCL parameters, respectively).

Phosphate is encountered at an elevated level in only one well, MW-17, at the low concentrations of no more than 2.5 mg/L. This substance is an essential nutrient and is regarded as non-toxic. It is therefore eliminated from further consideration. Calcium, magnesium, potassium, and sodium are also essential nutrients, and are thus also eliminated from further consideration. No EPA-endorsed toxicity values are available for aluminum (EPA 1989c and 1990a). Furthermore, aluminum is currently known to be associated with toxicity related to medical therapy only (Klaassen 1986). Therefore, aluminum is eliminated from further consideration as a contaminant of potential concern in operable unit ground waters.

A preliminary toxicity screening for the remaining contaminants encountered in operable unit ground waters is summarized in Table 4-23. The screening evaluation for radium is conservatively based on the more toxic radium-226. The contaminants (or contaminant parameters) exceeding screening criteria for the 1100-EM-1 ground-water medium are:

- coliform bacteria
- fluoride
- gross alpha radiation
- nitrite
- radium-226/228
- SC
- TDS
- antimony
- arsenic
- cadmium
- copper
- iron
- nickel
- BEHP
- tetrachloroethene.

Each of these contaminants or contaminant parameters is discussed further below.

Coliform bacteria: Elevated numbers of coliform bacteria were encountered only within the western City of Richland well field distribution lines and well 699-S40-E14, which is located immediately adjacent to the well

Table 4-20. Conventional Ground-Water Parameters Exceeding Background.

Location	Concentration (mg/L)[a]																									
	Alkalinity[b]		Ammonium[b]		Chloride		Fluoride		Gross Alpha[b]		Gross Beta[b]		Coliform		Nitrite		pH[b]		Phosphate		SC[b]		TDS[b]		Radium-226/228[b]	
	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2
Unconfined Aquifer (relative to operable-unit-specific background)																										
MW-1	261	200			58	28.4			8.4	--[d]		--									720					--
MW-2										--		--														--
MW-3	303	225			173	127			17	--		--					7.3				1,280	1,100	648	695	2.4	--
MW-4										--		--														
MW-5[c]										--		--														
MW-6										--		--														
MW-7										--		--														
699-S30-E15A	--	202	--		--		--		--	--	--	--					--		--		--		--		--	--
699-S31-E13	--	230	--		--		--		--	--	--	--					--		--		--		--		--	--
699-S32-E13A	--	223	--		--		--		--	--	--	--					--		--		--		--		--	--
699-S37-E14								3.7		--		--													2	--
699-S40-E14										--		--		16												--
699-S41-E13A										--		--														--
699-S41-E13B	221	215								--		--														--
699-S43-E12		240			31.7	51.8				--		--												450		--
NRWF-E										--		--														--
NRWF-W										--		--		16												--
Unconfined Aquifer (relative to Horn-Rapids-Landfill-specific background)																										
MW-10			0.98[e]						11.9[e]	--	30.2[e]	--									870[e]	850[e]	511[e]	580[e]	2[e]	--
MW-11[c]			1.55[e]	0.970[e]					12.2[e]	--	35.2[e]	--									880[e]	880[e]	516[e]	580[e]	2.6[e]	--
MW-12[c]			0.8[e]							--	34.6[e]	--				4.0					990[e]	980[e]	611[e]	485[e]		--
MW-13			0.32[e]	0.216[e]					9.1[e]	--	28.8[e]	--									920[e]	910[e]	553[e]	620[e]		--
MW-14			1.18[e]	1.13[e]						--	25.1[e]	--				7.6					930[e]	950[e]	588[e]	700[e]		--
MW-15									9.3[e]	--	23.2[e]	--									800[e]	696[e]	477[e]	540[e]		--
699-S27-E14	--		--		--		--		--	--	--	--					--		--		--		--		--	--
699-S29-E12	--		--		--		--		--	--	--	--					--		--		--		--		--	--
Confined Aquifer (relative to operable-unit-specific background)																										
MW-17	113	110								--		--							1.4	2.5						--

[a]The units for gross alpha, gross beta, and radium-226/228, are pCi/L; the units for pH are standard units; the units for SC are µmho/cm.
[b]No Horn-Rapids-Landfill-specific background data available.
[c]Analtyical results for Round 1 from MW-5 and MW-11, and the Round 2 from MW-12, are the average of two duplicate samples.
[d]-- indicates no analysis was performed.
[e]Value exceeds operable-unit-specific background.

Table 4-21. TAL Ground-Water Parameters Exceeding Background.

Location	Concentration (µg/L)																													
	Aluminum		Antimony		Arsenic		Barium		Cadmium		Calcium		Chromium		Copper		Iron		Magnesium		Nickel		Potassium		Selenium		Sodium		Zinc	
	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2	Rnd 1	Rnd 2
Unconfined Aquifer (relative to operable-unit-specific background)																														
MW-1			21.4				97.7				85,300											73.8	8,510							
MW-2																														
MW-3	1,350						65.8	111				125,000					1,820 J			27,600		47.9		10,000				40,700		
MW-4																														
MW-5							63.6	63.1														17.3								
MW-6									3.6																					
MW-7																														
699-S30-E15A	–		–		–		–		–		–		–		–		–		–		–		–		–		–		–	
699-S31-E13	–		–		–		–	79	–		–	81,700	–		–		–		–		–		–		–		–		–	
699-S32-E13A	–		–		–		–	70.9	–		–		–		–		–		–		–		–		–		–		–	
699-S37-E14																														
699-S40-E14																														
699-S41-E13A																						21.8								
699-S41-E13B									4																					
699-S43-E12								65.6				98,700																		
NRWF-E																23.9														
NRWF-W																12.8													29.1	
Unconfined Aquifer (relative to Horn-Rapids-Landfill-specific background)																														
MW-10	166																								2.2					
MW-11																														
MW-12																														
MW-13																									2.3 J					
MW-14														7.9											2.7 J					
MW-15																														
699-S27-E14																														
699-S29-E12																									2.2 J	2.25				
Confined Aquifer (relative to operable-unit-specific background)																														
MW-17	276				2.5																									

[a]Analytical results for Round 1 from MW-5 and MW-11, and Round 2 from MW-12, are the average of two duplicate samples.
[b]– indicates no analysis was performed.

Table 4-22. TCL Ground-Water Parameters Exceeding Background.

Location	Concentration (µg/L)					
	BEHP		1,1,1-Trichloroethane		Tetrachloroethene	
	Round 1	Round 2	Round 1	Round 2	Round 1	Round 2
Unconfined Aquifer (relative to operable-unit-specific background)						
MW-1						
MW-2						
MW-3						
MW-4			3 J[a]	2	1 J	1
MW-5[b]			4	4		
MW-6						
MW-7						
699-S30-E15A	--[c]	27	--		--	
699-S31-E13	--	130,000	--		--	
699-S32-E13A	--		--		--	
699-S37-E14						
699-S40-E14						
699-S41-E13A						
699-S41-E13B						
699-S43-E12						
NRWF-E						
NRWF-W						
Unconfined Aquifer (relative to Horn-Rapids-Landfill-specific background)						
MW-10						
MW-11[b]						
MW-12[b]						
MW-13						
MW-14						
MW-15						
699-S27-E14						
699-S29-E12						
MW-17						

[a]J = estimated value.
[b]Analytical results for Round 1 from MW-5 and MW-11, and Round 2 from MW-12, are the average of two duplicate samples.
[c]-- indicates no analysis was performed.

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Table 4-23. Preliminary Toxicity Screening for Ground-Water Contaminants at the 1100-EM-1 Operable Unit.

Parameter	Maximum Ground-Water Concentration (mg/L)	Oral RfD (mg/kg/d)	Ground-Water Concentration at Oral RfD (mg/L)	Oral SF $(mg/kg/d)^{-1}$	Ground-Water Concentration at Oral ICR = 1E-06 (mg/L)	1° MCL[a,b] (mg/L)	MCLG[a,c] (mg/L)	HVOHC[d,e] (mg/L)	CFVOC[d,e] (mg/L)	2° MCL[b,f] (mg/L)	HVOUC[d,e] (mg/L)
alkalinity	303[i]	--	--	--	--	--	--	--	> 20[j]	--	--
ammonium	1.55	--	--	--	--	--	--	--	1.8[g]	--	--
chloride	173	--	--	--	--	--	--	--	--	250	250
fluoride	3.7	6.0E-02[h]	2.1	--	--	4.0	--	--	--	2.0	--
nitrite	7.6	1E-1[h]	3.4	--	--	--	3.3	1	--	--	--
pH	7.3[a]	--	--	--	--	--	--	--	6.5 - 9.0[a]	6.5 - 8.5[a]	5 - 9[a]
SC	1,280[l]	--	--	--	--	--	--	--	--	700[l,v]	--
TDS	695	--	--	--	--	--	--	--	--	500	500
antimony	0.0214	4.0E-04[c]	0.014	--	--	--	--	0.146	1.6	--	--
arsenic	0.0025	1.0E-03[h]	0.034	1.7[j]	0.00002	0.05	--	0.0000022	0.190	--	--
barium	0.111	5.0E-02[c]	1.7	--	--	1.0	1.5	1	--	--	--
cadmium	0.004	5.0E-04[c]	0.017	--	--	0.010	0.005	0.010	0.00081[k]	--	--
chromium	0.0079	5.0E-03[c]	0.172	--	--	0.05	0.12[l]	0.050	0.011	--	--
copper	0.0239	--	--	--	--	--	1.3	--	0.0082[k]	1.0	1
iron	1.82	--	--	--	--	--	--	--	1.0	0.3	0.3
nickel	0.0738	2.0E-02[c]	0.69	--	--	--	--	0.0134	0.069[k]	--	--
selenium	0.0027	3.0E-03[c]	0.103	--	--	0.01	--	0.010	0.035	--	--
zinc	0.0291	2.0E-01[h]	6.9	--	--	--	--	--	0.074[k]	5.0	5
BEHP	130	2.0E-02[c]	0.69	1.4E-02[c]	0.0025	--	--	15	0.003	--	--
tetrachloroethene	0.001	1.0E-02[h]	0.11[m]	5.1E-02[h]	0.0002[m]	--	0[r]	0.00080	0.840	--	--
1,1,1-trichloroethane	0.004	9.0E-02[c]	1.03[m]	--	--	0.20	0.20	18.4	--	--	--
gross alpha	17[p]	--	--	--	--	15[n,p]	--	--	--	--	--
gross beta	35.2[p]	--	--	--	--	50[o,p]	--	--	--	--	--
radium-226/228	2.6[p]	--	--	6.1E-06[u]	0.164[p]	5[p]	--	--	--	--	--
coliforms	16[q]	--	--	--	--	1[q]	--	--	--	--	--

[a]40 CFR 141.
[b]WAC 248-54-175.
[c]EPA 1990a.
[d]EPA 1986a.
[e]WAC 173-201-035(12).
[f]40 CFR 143.
[g]Assumes an average pH of 7.9 and an average temperature of 12°C for the Hanford Reach (Jacquish and Mitchell 1988).
[h]EPA 1989c.
[i]Expressed as µmhos/cm at 25°C.
[j]Surrogate based on proposed arsenic unit risk of 5E-05 µg/L (EPA 1990a).
[k]Assumes an average hardness of 65 mg $CaCO_3$/L for the Hanford Reach (Jacquish and Mitchell 1988).
[l]Based on total chromium.
[m]Concentration based on intake from a combined oral and inhalation exposure for volatile substances (EPA-Region X 1990).
[n]Includes radium-226 but excludes radon and uranium.
[o]Standard applies if hydrogen-3 and strontium-90 standards are met and total dose is < 4 mrem/yr.
[p]Expressed as pCi/L.
[q]Expressed as MPN/100 mL.
[r]Based on 40 CFR 300.430 (e)(2)(i)(C), a zero MCLG is not used as a screening criterion.
[s]Expressed as standard units.
[t]Expressed as calcium carbonate.
[u]Unit risk for radium-226 (1989c)
[v]WAC 248-54-175 only.
--Not available.
Note: Shaded areas indicate screening criterion exceeded.

field (see Table 4-20 and Figure 2-18). As no known or suspected sources of bacterial contamination (e.g., sewage disposal facilities) are associated within the 1100-EM-1 Operable Unit, other wells located between the operable unit and the well field displayed no bacterial contamination, and the abundant amounts of untreated Columbia River water (a likely source of bacterial contamination) are infiltrated at the well field, coliform bacteria are not regarded as an operable unit ground-water contaminant of concern.

Fluoride: This parameter was encountered in only a single well, 699-S37-E14, during the second round of monitoring at a concentration exceeding the 2°, but not the 1°, MCL (see Table 4-23). Well 699-S37-E14 is located in the middle of the 3000 Area, well to the east of the 1100-EM-1 operable unit (see Figure 2-19). As other wells within the operable unit did not display elevated fluoride levels, and no source of such contamination is known to exist within 1100-EM-1, this parameter is given no further consideration in this report.

Gross Alpha Radiation: Elevated concentrations of gross alpha radiation that are of potential concern were found in two wells located in the vicinity of the 1171 Building (MW-1 and -3), and in several wells located in the vicinity of the Horn Rapids Landfill (MW-10, -11, -13, and -15) (see Table 4-23 and Figure 2-19).

No Horn-Rapids-Landfill-specific ground-water background data are available for gross alpha (see Table 4-17), but the contaminated plume of ground water upgradient from the landfill is known to contain gross alpha in concentrations above the 15 pCi/L 1° MCL (see Section 4.1.2.4). Once appropriate landfill-specific background data are obtained, it is likely that an upgradient source for the elevated alpha radiation will be confirmed. In addition, the surface radiation survey for the Horn Rapids Landfill gave no evidence of radioactive contamination at this subunit (see Section 4.1.1.6). For these reasons, gross alpha radiation is not regarded as a ground-water contaminant of concern at the landfill.

No source of radiation is known to exist at either 1100-1 or 1100-4, the two operable subunits assigned to 1100-EM-1 that are located in the immediate vicinity of the 1171 Building. Surface radiation surveys conducted at both sites showed no evidence of radiation (see Sections 4.1.1.1 and 4.1.1.4, respectively). Although radiation analyses were not conducted on the subsurface soils at these subunits, routine radiation monitoring during drilling and sampling, for the purposes of occupational safety and health protection, showed no cause for concern. Therefore, gross alpha radiation near the 1171 Building is not regarded as a contaminant parameter of concern in the remainder of this report, except for a recommendation in Section 7 (Summary and Conclusions) to obtain radiation readings from archived soil samples obtained from the 1100-1 and 1100-4 operable subunits during the first phase of the RI.

Nitrite: Nitrite concentrations in excess of the MCLG and the HWQHC were encountered during the second round of monitoring in only two wells located in the vicinity of the Horn Rapids Landfill, MW-12 and -14 (see Table 4-23 and Figure 2-19). While the nitrite levels in MW-12 and MW-14 exceed landfill-specific background, they could potentially be explained by the high levels of nitrate and ammonia contamination found upgradient of the landfill (see Section 4.1.2.4 and Table 4-17). Ammonia can be oxidized to nitrate in the

nitrification process; nitrite is an intermediate product of this process (EPA 1986a). Under typical environmental conditions, nitrite is unstable and readily transformed; as a result, significant nitrite concentrations are usually associated with heavily polluted waters (EPA 1986a).

Given the unstable nature of nitrite under most environmental conditions, and the presence of a contaminant plume with an upgradient origin that could explain the presence of the observed elevated nitrite, this substance is not regarded as a contaminant of concern for the ground-water medium at the 1100-EM-1 Operable Unit.

Specific Conductance and Total Dissolved Solids: Table 4-20 indicates that two correlated parameters, SC and TDS, are elevated in wells associated with the Horn Rapids Landfill (MW-10, -11, -12, -13, -14, and -15) and at MW-1 and MW-3, in the 1171 Building vicinity (see Figure 2-19). No landfill-specific background data are available, but the SC and TDS readings at the landfill are indicators of a more specific problem, as evidenced by the high UTLs for many landfill-specific background parameters (see Tables 4-17 through 4-19). Thus, SC and TDS are not regarded as contaminant parameters of concern for the landfill ground waters.

In the vicinity of the 1171 Building, the elevated SC and TDS also seem to be associated with localized deteriorated ground-water quality. Tables 4-20 through 4-22 indicate that MW-1 and MW-3 contain several parameters higher (or lower in the case of pH and [see Appendix N] dissolved oxygen) than operable-unit-specific background levels: alkalinity, chloride, gross alpha radiation, pH, SC, TDS, radium-226/228, aluminum, antimony, barium, calcium, iron, magnesium, nickel, potassium, sodium, and dissolved oxygen. Due to the nonspecific nature of SC and TDS, they are also not regarded as contaminants of concern in 1100-EM-1 ground waters near the 1171 Building.

Radium-226/228: Elevated levels of radium were found at MW-3, near the vicinity of the 1171 Building, at MW-10 and -11, in the vicinity of the Horn Rapids Landfill, and at well 699-S37-E14, in the 3000 Area (see Table 4-23 and Figure 2-19). Although no operable unit soil samples were analyzed for specific radium isotopes, surface radiation surveys conducted in 1100-EM-1 operable subunits failed to detect any areas of radiation contamination (see Section 4.1.1). Thus, there are no known sources of radium contamination within the operable unit.

For analogous reasons specified above under fluoride, the radium found in well 699-S37-E14 is not regarded as an operable unit contaminant of concern. The radium in the vicinity of the Horn Rapids Landfill is likely correlated with the gross alpha radiation present in the area. As no landfill-specific background data are available, and the plume that emanated from an upgradient direction is known to contain elevated radiation (see Section 4.1.2.4), the radium encountered near the landfill is not treated as an operable unit contaminant of concern.

The radium in MW-3 appears to be associated with the localized deterioration in ground-water quality in the 1171 Building vicinity (see the above discussion on SC and TDS). For reasons specified in the preceding discussion on gross alpha radiation, radium in the vicinity of the 1171 Building is not considered further in this report, except for a recommendation

in Section 7 to obtain radium readings from archived soil samples obtained from the 1100-1 and 1100-4 operable subunits during the first phase of the RI.

Antimony: Elevated antimony was encountered only during the first round of monitoring in a single well, MW-1, which is located west of the 1100-1 operable subunit (see Figure 2-18). The concentration observed was barely above discernable background levels (see Table 4-18). As available ground-water potential data indicate that this well is hydraulically upgradient of the Battery Acid Pit (see Figures 3-38 through 3-40), and no antimony was detected within the soil column of the operable subunit, the source of this contamination can not currently be determined. Antimony was detected within the saturated soils beneath the 1100-3 operable subunit (see Section 4.4.4), but was not present in elevated concentrations in any of the wells located near the subunit (see Table 4-21).

As no operable unit source of antimony contamination can be documented with existing data, the substance is eliminated from further consideration as a contaminant of potential concern for 1100-EM-1 ground waters.

Arsenic: Elevated arsenic ground-water concentrations were found, in the first round of monitoring only, in the confined aquifer well, MW-17, at a level of 2.5 mg/L (see Table 4-21). Only one background well, MW-9, was used to characterize conditions in the confined aquifer (see Section 4.5.1), and the UTL for arsenic is calculated to be 1 mg/L (see Table 4-18). However, Appendix N indicates that the arsenic results for MW-9 were 1 and 2 U mg/L for the first and second monitoring rounds, respectively. Because half the SQL is substituted for nondetected values in the statistical calculations in this report (see Section 4.4.1), the arsenic distribution in MW-9 becomes artificially invariable. Any variability at all in the MW-9 arsenic data (e.g., 1 and 0.9 mg/L) would have yielded a UTL above the concentration detected at MW-17 in the first round of sampling.

Given the above information, the lack of verification from the second round monitoring results, and the lack of elevated arsenic in any of the unconfined aquifer wells in the vicinity of MW-17, arsenic is not regarded as a ground-water contaminant of concern for the 1100-EM-1 Operable Unit. Elevated arsenic (with respect to vadose-zone soils) was found in a single saturated soil sample obtained at the 1100-4 operable subunit (see Section 4.4.5). Given the absence of any positive evidence of elevated arsenic in ground water in the vicinity of the Antifreeze Tank Site, arsenic is also not regarded as a soil contaminant of concern for this operable subunit.

Cadmium: Cadmium was detected at elevated concentrations that exceed the CFWQC, during only the first round of monitoring, in wells MW-6 and 699-S41-E13B (see Tables 4-21 and 4-23). Both of these wells are screened within the unconfined aquifer (see Table 2-1). The 1100-3 operable subunit is monitored primarily by MW-6. Well MW-6 is also located near the 1100-2 operable subunit; however, it is hydraulically upgradient from this subunit, based on presently available ground-water potential data (see Figures 3-38 through 3-40). Elevated cadmium was not found within the soil column of either subunit (see Sections 4.4.3 and 4.4.4).

Monitoring well 699-S41-13B is located approximately 450 m (1,500 ft) downgradient from the 1100-1 operable subunit (see Figures 3-38 through 3-40).

However, unconfined wells MW-3 and 699-S41-E13A do not display cadmium contamination (see Table 4-21).

The source of cadmium ground-water contamination is therefore unknown and can not be attributed to the operable unit with existing data. Cadmium, therefore, is not regarded as a contaminant of potential concern for the 1100-EM-1 ground-water medium.

Copper: Elevated copper, in concentrations exceeding the CFWQC, was encountered only within the City of Richland well field distribution lines (see Tables 4-18 and 4-23). There is no known operable unit source of the copper found in the well field. The well field is generally downgradient from the 1100-1, 1100-4, and UN-1100-6 operable subunits (see Figures 3-38 through 3-40).

However, copper was not identified as a soil contaminant at any of these subunits (see Sections 4.4.2, 4.4.5, and 4.4.6). In addition, none of the wells located between these subunits and the well field show any indication of copper contamination (see Table 4-21). This information indicates that the copper may have originated from the well field systemfe.g., from metals in structures such as wells, pumps, or affiliated pipingfrather than from the ground water. As a result, copper is not regarded as an operable unit ground-water contaminant of concern.

Iron: Iron was found at concentrations exceeding background levels, the CFWQC, the 2° MCL, and the HWQWC in a single well, MW-3, during the first round of monitoring only (see Tables 4-21 and 4-23). Some elevated iron was encountered in the subsurface soils of the Battery Acid Pit (1100-1, see Section 4.4.2). However, it is likely that the increased levels of iron observed in MW-3 are associated with the generally deteriorated ground-water quality in the vicinity of the 1171 Building, as mentioned above in the SC and TDS discussion.

Given that iron is an essential nutrient, the relatively small magnitude of the elevated concentration, that the 2° MCL and HWQWC were established on a strictly welfare basis (EPA 1986a) (e.g., to prevent discoloration of plumbing fixtures and laundry), the distance to the Columbia River, the volume of discharge to the river, and the absence of confirmation from the second round monitoring results, iron is not regarded as an 1100-EM-1 Operable Unit ground-water contaminant of concern.

Nickel: Four wellsfMW-1, -3, -5, and 699-S41-E13A (see Table 4-21)fwere found to contain elevated levels of nickelfall in excess of the HWQHC, and one in excess of the CFWQC (see Table 4-23). However, no operable unit source of this substance is known, as no elevated nickel concentrations were found in the soils at any of the operable subunits except for the Horn Rapids Landfill (see Section 4.4.7) and the Battery Acid Pit (1100-1, see Section 4.4.2). Since the elevated nickel concentrations at the 1100-1 subunit were confined to the surface soils, and the Horn Rapids Landfill is not in the vicinity of any of the wells displaying nickel contamination (see Figures 2-19 and 3-38 through 3-40), nickel is not considered to be a ground-water contaminant of concern for the operable unit.

bis(2-Ethylhexyl)phthalate: The phthalate ester BEHP was observed at elevated levels in two wells, 699-S30-15A and 699-S31-E13, that are located

well to the east of the operable unit, between the 3000 and 300 Areas (see Figure 2-19 and Table 4-22). Both observations exceed the concentration at the oral ICR of 1E-06 and the CFWQC, and the concentration in the latter well also far exceeds the concentration at the oral RfD and the HWQHC (see Table 4-23).

The UN-1100-6 operable subunit is the only 1100-EM-1 subunit or location known to contain BEHP in soils (see Section 4.4.6). As the two wells in question are approximately 2.4 km (1.5 mi) and mostly crossgradient from UN-1100-6 (see Figures 3-38 through 3-40), and none of the intervening wells display BEHP contamination (see Table 4-22), BEHP is not regarded as an operable unit ground-water contaminant of concern.

Tetrachloroethene: A single well, MW-4, shows indications of low level tetrachloroethene contamination. A concentration of 1 mg/L was observed during both monitoring rounds (see Table 4-22); this concentration exceeds both the concentration at the oral ICR of 1E-06 and the HWQHC (see Table 4-23).

Well MW-4 is screened within the upper portion of the unconfined aquifer, mostly crossgradient of the Paint and Solvent Pit (1100-2) (see Table 2-1 and Figures 2-18 and 3-38 through 3-40). Tetrachloroethene was also found at significant concentrations in the soil gas in a localized portion of the 1100-2 operable subunit (see Section 4.1.1.2 and Figure 4-1). The Paint and Solvent Pit may therefore be the source of this contamination, but the extent is by no means yet defined.

All of the above information indicates that tetrachloroethene, near the 1100-2 Paint and Solvent Pit, is the sole contaminant of potential concern for 1100-EM-1 ground waters (i.e., it is the only contaminant failing the preliminary screening criteria that appears, on the basis of existing data, to be attributable to waste management units assigned to the 1100-EM-1 Operable Unit). There are two other areas of ground-water contamination in the vicinity of the operable unit that may well not be associated with the operable unit, and can not, with existing data, be so attributed. These two areas include a general deterioration of ground-water quality in the vicinity of the 1171 Building (i.e., the 1100-EM-2 Operable Unit, see Sections 1.3, 3.1.3.1, 4.1.2.1, and Figure 1-2), and a known contaminant plume originating upgradient of the Horn Rapids Landfill, possibly from facilities associated with the Advanced Nuclear Fuels Corp. complex (see Section 4.1.2.4).

The area of deteriorated ground water near the 1171 Building, the source and extent of which has yet to be defined, is not considered further in this report, other than for recommendations in Section 7 for Phase II RI activities to confirm that nearby 1100-EM-1 operable subunits are not associated with the problem. An evaluation of the known plume in the Horn Rapids Landfill vicinity is provided below and in subsequent sections of this report. This evaluation was conducted immediately after the first round of ground-water monitoring data became available; landfill-specific background data were not available at that time. Without such data, two substances, trichloroethene and nitrate, were identified as contaminants of potential concern.

The landfill vicinity plume evaluation is preserved in this report for information purposes only. Although the evaluation is based on the assumption of a contributing landfill source of trichloroethene and nitrate, its

inclusion should not be construed, on the basis of existing data, to indicate either an 1100-EM-1 Operable Unit source, or any other DOE-RL source, of this contamination.

Within the plume, both trichloroethene and nitrate, greatly exceed their respective 1° MCLs of 0.005 and 44 mg/L (40 CFR 141, see Appendix N). Thus, the plume is discussed in relation to these two contaminants, on the basis of first round monitoring data only. Appendix N shows that the concentrations for both contaminants observed in the wells located downgradient from the Horn Rapids Landfill were not appreciably different in the second round as compared to the first.

Trichloroethene and nitrate contamination, as shown respectively in Figures 4-13 and 4-14, are encountered only within the vicinity of the Horn Rapids Landfill. The Horn Rapids Landfill is monitored on its northeastern, hydraulically-downgradient side by six monitoring wells, MW-10 through MW-15 (see Figure 2-18). Each of these wells is screened within the water table with the exception of MW-14, which is screened toward the bottom of the unconfined aquifer (see Table 2-1). The trichloroethene concentrations encountered near the landfill in the first round of sampling ranged up to 92 mg/L; the nitrate concentrations up to 217 mg/L (see Appendix N).

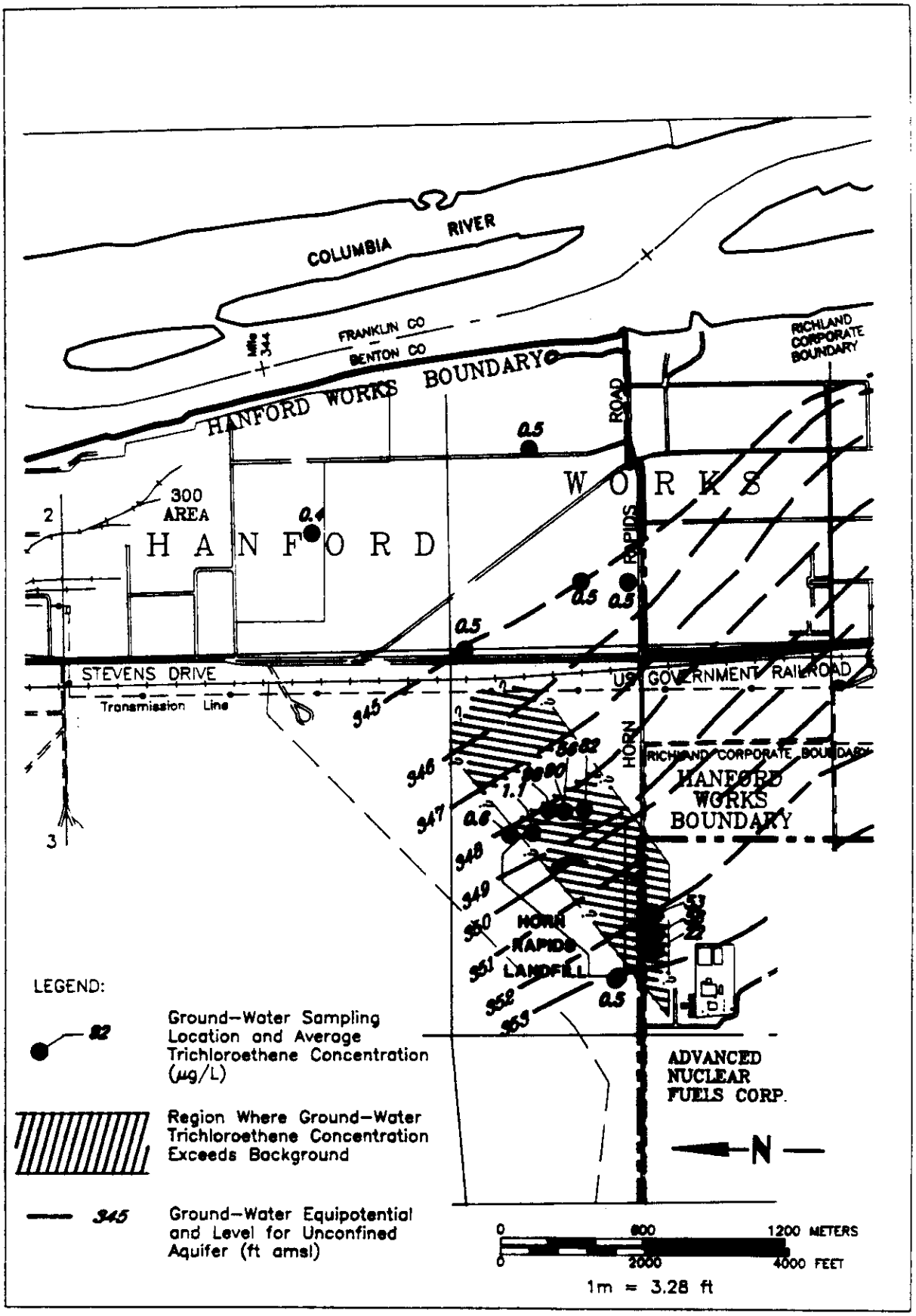
4.6 BIOTIC CONTAMINATION

A formal biotic contamination field investigation was not conducted during the first phase of the RI. Potential operable unit impacts on the major sensitive terrestrial species identified in Section 3.7.2.1 and 3.7.2.3fthe Swainson's hawk and the long-billed curlewfare addressed in Sections 5 (Contaminant Fate and Transport) and 6 (Baseline Risk Assessment). Potential contaminant impacts on aquatic species within the Columbia River, and on humans consuming potentially contaminated venison, are also discussed in Sections 5 and 6.

4.7 NATURE AND EXTENT OF CONTAMINATION SUMMARY

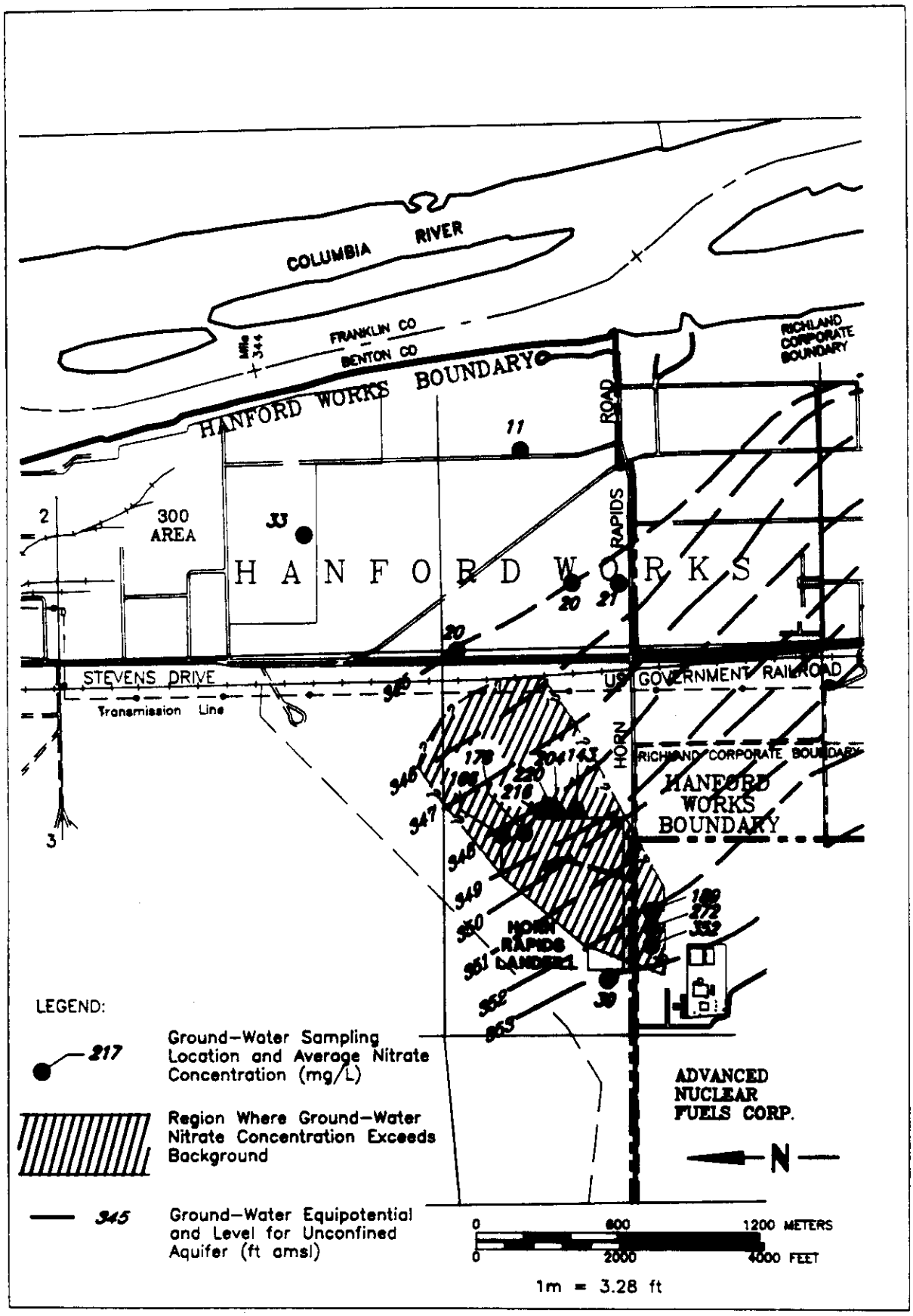
This subsection provides a summary of the known nature and extent of operable unit contamination within the three environmental mediafair, soil, and ground waterfsubjected to field investigation during the first phase of the RI. Contaminants of potential concern are identified for each environmental medium. Contaminants of potential concern are those attributable to operable unit operations which were encountered at concentrations, elevated above local natural and anthropogenic background, that could potentially cause significant adverse human health or environmental impacts. In general, the contaminants of potential concern for each operable subunit are subsets of those anticipated, based on reviews of scoping information and early soil gas survey results (see Section 4.1.1).

Table 4-24 provides a matrix of contaminant of potential concern occurrence by environmental medium subjected to empirical evaluation (i.e., air, soil, and ground water).



903-1214\34212

Figure 4-13. Trichloroethene Distribution in Unconfined Aquifer, in the Vicinity of the Horn Rapids Landfill, January - March, 1990.



903-1214\34211

Figure 4-14. Nitrate Distribution in Unconfined Aquifer, in the Vicinity of the Horn Rapids Landfill, January - March, 1990.

Table 4-24. Summary of Contaminant-of-Potential-Concern Distribution at the 1100-EM-1 Operable Unit.

	Contaminant	Environmental Medium		
		Air	Soil	Ground Water
Inorganics	arsenic	--	X	--
	chromium	--	X	--
Organics	BEHP	--	X	--
	chlordane	--	X	--
	PCB	--	X	--
	tetrachloroethene	--	X[a]	X
	1,1,1-trichloroethane	--	X[a]	--
	trichloroethene	--	X[a]	--

[a]Contaminant of potential concern in soil gas.

4.7.1 Air Contamination Summary

The quantity and quality of the first round of ambient air monitoring data are too low, and the functional objectives of the second round of monitoring too restricted, to be of much use (see Section 4.2). However, some generalized, tentative hypotheses can be formed.

First, while data tentatively indicate that PAH could be a contaminant of potential concern for the 1100-3 operable subunit, soil data and ground-water data do not support the air results (i.e., no PAH was detected in subunit soils or ground water; therefore, there is no apparent source of this contaminant). This substantiates the fact that the ambient air monitoring data are of limited quality and indicates that the data set may be affected by sampling or analytical methodology artifacts.

Second, under moderate wind conditions, there seems to be no indication of substantial deterioration of ambient air quality in the vicinity of the 1100-EM-1 Operable Unit, and certainly no such deterioration that can be attributed to the operable unit. This hypothesis is tested by use of air dispersion modeling in Section 5 (Contaminant Fate and Transport Analysis).

Third, the highest concentrations of potential contaminant parameters were usually found in the upwind background samples. This may indicate a potential source of air pollution to the west of the operable unit. Such potential sources in this direction do exist; however, the testing of this hypothesis falls well outside of the scope of the 1100-EM-1 RI/FS.

4.7.2 Soil Contamination Summary

The eight potential contaminants of concern for the soil medium at the 1100-EM-1 Operable Unit (including soil gas contaminants) are arsenic, BEHP, chlordane, chromium, PCB, tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene. These contaminants of potential concern can be partitioned among operable subunits in the following manner:

- 1100-1 (Battery Acid Pit)

  arsenic

- 1100-2 (Paint and Solvent Pit)

  chromium
  tetrachlorethene

- 1100-3 (Antifreeze and Degreaser Pit)

  arsenic
  chromium

- UN-1100-6 (Discolored Soil Site)

  BEHP
  chlordane

- Horn Rapids Landfill

  PCB
  chromium
  arsenic
  trichloroethene
  tetrachlorethene
  1,1,1-trichloroethane

- Miscellaneous Locations

  Pit 1fPCB
  Ephemeral PoolfPCB, chlordane.

No soil contaminants of potential concern are identified for the 1100-4 (Antifreeze Tank Site) operable subunit. The fate and transport of the above soil contaminants and the human health and environmental risks associated with them, are assessed in Sections 5 and 6, respectively.

4.7.3 Ground-Water Contamination Summary

Current data indicate that there is a single contaminant of potential concern for the 1100-EM-1 Operable Unit ground-water medium: tetrachloroethene (see Table 4-24). This substance is present near the 1100-2 Paint and Solvent Pit, but the extent and magnitude of the tetrachloroethene ground-water contamination have yet to be determined. The ground-water

contamination findings seem to correlate with the soil gas contamination findings for the Paint and Solvent Pit (see Section 4.7.2).

Although existing data do not suggest operable unit sources, two other areas of ground-water contamination are present within the vicinity of the 1100-EM-1 Operable Unit. One is an area of generally deteriorated ground-water quality in the vicinity of the 1171 Building that contains elevated concentrations of several contaminant parameters. The other appears to be a contaminant plume that originated upgradient from, and is passing beneath, the Horn Rapids Landfill. This plume is characterized primarily by the presence of high concentrations of trichloroethene and nitrate.

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5.0 CONTAMINANT FATE AND TRANSPORT ANALYSIS

This section provides an analysis of the environmental fate of the operable unit contaminants of potential concern that were identified in Section 4 (Nature and Extent of 1100-EM-1 Operable Unit Contamination). The transport of these contaminants, through various pertinent environmental media, is also analyzed within this section. Thus, the known nature and extent of contamination, as determined from empirical observation (see Sections 4.2, 4.4, and 4.5), is extrapolated to provide a detailed conceptual model of the types and distributions of the operable unit contaminants within the environment. This information is used in Section 6 (Baseline Risk Assessment) to evaluate the threats posed, to human health and the environment, by contaminant releases at the 1100-EM-1 Operable Unit.

Section 5.1 discusses potential contaminant migration pathways and identifies those that may be significant at the 1100-EM-1 Operable Unit. Contaminant fate is discussed in Section 5.2. This discussion addresses the anticipated physical, chemical, or biochemical transformations a particular contaminant is subjected to under environmental conditions. The section concludes with an analysis of contaminant transport through each significant migration pathway in Section 5.3.

5.1 POTENTIAL PATHWAYS OF CONTAMINANT MIGRATION

A contaminant migration pathway is a specific chemical transport process, often involving multiple environmental media, that terminates (in terms of a hazardous substance response perspective) in human or environmental contaminant exposure, or at least the potential for such exposure. Each exposure pathway consists of the following five elements (EPA 1986b):

- A contaminant source
- A contaminant release mechanism
- An environmental transport medium (or media)
- An exposure route
- A receptor.

Contaminant sources at the 1100-EM-1 Operable Unit are described in Sections 3.1 and 4.1 from a respective physical and chemical perspective. Receptor populations are described in Section 3.7, and this information will be analyzed in the context of potential exposure pathways, along with potential routes of exposure, in Section 6 (Baseline Risk Assessment). Therefore, this subsection focuses on contaminant release mechanisms and environmental transport media of concern for the operable unit.

Each potential contaminant migration pathway at the 1100-EM-1 Operable Unit is discussed qualitatively below by the predominant environmental medium involved: air (Section 5.1.1), surface water (Section 5.1.2), surface soil (Section 5.1.3), subsurface soil and ground water (Section 5.1.4), and biota (Section 5.1.5). Later subsections provide information on the environmental fate and transport characteristics of specific contaminants (Section 5.2) and quantitative analysis, as feasible, of contaminant transport to estimate contaminant concentrations at potential exposure points (Section 5.3).

5.1.1 Air Pathways

For an air pathway to be operative, at least one of two release mechanisms must exist: emission of volatile vapors or emission of fugitive dust from surface soils. Each of the operable subunits within the 1100-EM-1 Operable Unit is assessed below, in terms of the nature and extent of contamination data provided in Section 4, to determine whether or not the air transport pathway is potentially operative. As the quality of the ambient air monitoring data is not considered adequate (see Section 4.2), the following air pathway assessments are based on the findings from other environmental media.

5.1.1.1 1100-1 (Battery Acid Pit). No VOCs were encountered within the soil column at the Battery Acid Pit, in either actual soil samples or soil gas, and no contaminants of potential concern are present within the surface soils of the operable subunit (see Sections 4.1.1.1 and 4.4.2, and Appendix P). Therefore, the air pathway is considered inoperative at the 1100-1 operable subunit.

5.1.1.2 1100-2 (Paint and Solvent Pit). The soil gas survey for the 1100-2 operable subunit detected tetrachloroethene, which was also detected within the subsurface portion of the soil column along with chlorobenzene and 1,1-dichloroethene (see Sections 4.1.1.2 and 4.4.3, respectively). Preliminary screening demonstrates that the concentrations of VOCs within the soil column are insufficient to pose an inhalation hazard by means of fugitive dust generation (see Section 4.4.3); however, the screening process does not take volatilization into account. As tetrachloroethene is present in soil gas within the operable subunit, further analysis of the transport of this contaminant, assuming the soil gas as the emission source, is conducted in Section 5.3 below.

Chromium is the only contaminant of potential concern encountered in the surface soils at 1100-2 (see Section 4.4.3). The conservative screening toxicity process used in Section 4.4.3 is unable to eliminate chromium from further consideration. Therefore, the air transport of chromium by fugitive dust generation is evaluated under more realistic conditions in Section 5.3.

5.1.1.3 1100-3 (Antifreeze and Degreaser Pit). A volatilization release from the Antifreeze and Degreaser Pit is ruled out as no VOCs were encountered during the 1100-3 soil gas survey or within the operable subunit soil column (see Sections 4.1.1.3 and 4.4.4, respectively). Two contaminants of potential concern, arsenic and chromium, are present in the surface soils at concentrations that can not be disregarded after conducting a conservative screening for inhalation risks (see Section 4.4.4). The transport of arsenic and chromium by fugitive dust is therefore evaluated in Section 5.3.

5.1.1.4 1100-4 (Antifreeze Tank Site). A soil gas survey was not conducted for the Antifreeze Tank Site (see Section 4.1.1.4), and no VOCs were detected in the soil column at or near the operable subunit (see Section 4.4.5). Thus, a volatilization release mechanism is not applicable to 1100-4. No contaminants of potential concern are present within the vadose-zone soils at this subunit. Although the surface stratum of the soil column (uppermost 0.6 m [2 ft]) was not sampled at this subunit, the subunit location, beneath the concrete floor of the 1171 Building (see Section 3.1.2.4), precludes a fugitive dust generation release mechanism. Therefore, the air pathway is

inoperative at the Antifreeze Tank Site and is given no further consideration in this report.

5.1.1.5 UN-1100-6 (Discolored Soil Site). While no soil gas survey was conducted for UN-1100-6 (see Section 4.1.1.5), two VOCs—1,1,1-trichloroethane and 2-hexanone—were encountered within the surface soils of the subunit, but at concentrations so low as to pose no hazard associated with the inhalation of fugitive dust (see Section 4.4.6). Of the two contaminants of potential concern in the surface soil—BEHP and chlordane—conservative toxicity screening in Section 4.4.6 demonstrates that only the former poses a potential significant inhalation risk. Therefore, the transport of BEHP through the air pathway is evaluated in Section 5.3 for the UN-1100-6 operable subunit.

5.1.1.6 Horn Rapids Landfill. The soil gas survey conducted for the Horn Rapids Landfill detected tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene (see Section 4.1.1.6). However, tetrachloroethene was the only VOC detected within the soil column at the landfill (see Section 4.4.7). Preliminary screening demonstrates that the soil tetrachloroethene concentrations encountered pose no fugitive dust inhalation hazard (see Section 4.4.7). While preliminary screening demonstrates that inhalation of VOC-contaminated fugitive dust from the Horn Rapids Landfill poses no significant hazard, further analysis of the transport of tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene—assuming the soil gas as the emission source—is conducted in Section 5.3 below.

Conservative toxicity screening (see Table 4-14) indicates that arsenic, chromium, and PCB inhalation risks must be characterized further with respect to fugitive dust generation potential. These substances are therefore evaluated further in Section 5.3.

5.1.1.7 Miscellaneous Locations. Volatilization is not a release mechanism of concern, as no VOCs were encountered at either Pit 1 or the ephemeral pool (see Section 4.4.8). While two contaminants of potential concern are present at both locations (PCB at Pit 1 and PCB and chlordane at the ephemeral pool), screening conducted in Section 4.4.8 shows that neither substance poses a significant risk via the inhalation of fugitive dust. Therefore, the air pathways at both locations are considered inoperative and are given no further consideration in this report.

5.1.2 Surface-Water Pathways

Surface-water pathways associated with the 1100-EM-1 Operable Unit can be assessed in two parts to determine whether they require further consideration. The first assessment considers the immediate vicinities of the operable subunits. The topography and semiarid climate associated with the operable unit preclude, for the most part, significant contaminant transport by surface-water runoff; the absence of significant surface-water bodies adjacent to the operable subunits supports this conclusion (see Section 3.3.2). The presence of contamination in the ephemeral pool, however, indicates transportation by runoff from the 1100 Area parking lot (see Sections 4.3 and 4.4.8). Due to the ephemeral nature of this pool, however, it is more appropriate to address this contamination in the discussions of surface soil and subsurface soil and ground-water pathways (see Sections 5.1.3 and 5.1.4).

The second part of this assessment considers the Columbia River as a potential migration pathway for 1100-EM-1 contaminants. Potential threats to the aquatic environment and human health need to be evaluated. As no empirical investigation was conducted on the Columbia River, this assessment is contingent upon the results of the analysis of contaminant transport in the soil and ground-water media (see Section 5.1.4). Therefore, the surface-water analysis in Section 5.3 is based upon the subsurface transport evaluation contained within the same subsection. The only contaminant of potential concern for the operable unit ground waters is tetrachloroethene; however, evaluations for trichloroethene and nitrate, associated with the plume of apparent upgradient origin in the Horn Rapids Landfill vicinity, are also presented for informational purposes (see Section 4.7.3).

5.1.3 Surface Soil Pathways

The assessment of risks associated with direct contact of soils in Section 6 (Baseline Risk Assessment) is not dependent upon a contaminant transport analysis and relies on empirical surface soil data reported in Section 4.4. The actual transport of surface soil contaminants is addressed under air transport in Section 5.1.1. However, each operable subunit, or miscellaneous location, is evaluated below to determine whether the direct contact exposure pathway is potentially operative.

Surficial contamination, within the upper 0.6 m (2 ft) of the soil column, at concentrations of potential concern is present at all operable subunits except for two. No surficial contamination of concern was encountered at the 1100-1 operable subunit (see Section 4.4.2); therefore, direct contact pathway at this location is inoperative and is not given further consideration.

While no soil samples were obtained for analysis within the surface stratum of the 1100-4 operable subunit, no contamination attributable to a leaking antifreeze disposal tank has been encountered in the subsurface stratum, and the location of the subunit—beneath the concrete floor within the 1171 Building—eliminates the possibility of direct contact of surface soils. Therefore, the direct soil contact pathway for the 1100-4 operable subunit is given no further consideration in this report.

Contamination at levels of potential concern is also present within both miscellaneous locations—Pit 1 and the ephemeral pool. These two locations and the four remaining operable subunits—1100-2, 1100-3, UN-1100-6, and Horn Rapids Landfill—are evaluated further in Section 5.3 below.

5.1.4 Subsurface Soil and Ground-Water Pathways

The subsurface contaminant migration pathways can be viewed in two parts: vadose-zone and ground-water migration. Contaminants transported downward through the vadose zone eventually reach the water table and are transported further through the ground-water medium. Thus, for the subsurface pathway to be operative (ignoring the possibility of injection well disposal, which is not known to have occurred at the 1100-EM-1 Operable Unit), there must first be a release to the soil, with a sufficient amount of subsequent infiltration to allow contaminants to reach the water table.

The potential for upward migration of VOCs by gaseous diffusion through the soil (originating from either waste deposits within the soil column or from volatilization from contaminated ground water) is not addressed within this sub-subsection, because it is taken into consideration during the evaluation of air pathways in Section 5.1.1. Lateral transport of VOCs within the soil gas medium at 1100-EM-1 is anticipated to be insignificant due to the unconsolidated and porous nature of the Hanford formation (see Sections 3.4.2.1 and 3.5.2.2), and the lack of impermeable surfaces over or within the operable subunits exhibiting VOC contamination.

Each of the operable subunits within the 1100-EM-1 Operable Unit is assessed below, within the context of the contaminant nature and extent data provided in Section 4, to determine whether or not the subsurface migration pathway is potentially operative. The evaluation of the surface-water transport pathway in the Columbia River is dependent upon the results of the subsurface pathway analysis (see Section 5.1.2).

As contaminants of potential concern are present within the soil columns of operable subunits 1100-1, 1100-2, 1100-3, UN-1100-6, Horn Rapids Landfill, and the two miscellaneous locations, and no impermeable covers are present at these locations, their subsurface transport pathways must be deemed to be potentially operative.

Each of these six subunits or locations also contains contaminants of potential concern within the surface stratum of their soil columns; therefore, the potential for direct soil contact exposure exists. Further evaluation of subsurface contaminant transport for each of these subunits or locations is conducted in Section 5.3; risks associated with direct contact of surface contamination are assessed in Section 6.

The subsurface contaminant migration pathway at the 1100-4 operable subunit is not operative. No contamination attributable to a leaking antifreeze disposal tank has been encountered at this subunit, and the location of the subunit—beneath the concrete floor within the 1171 Building—eliminates the possibility of vertical contaminant migration through the vadose zone. The subsurface transport pathway for the 1100-4 operable subunit is therefore given no further consideration in this report.

Although no plume has been defined with respect to extent or magnitude, tetrachloroethene contamination, apparently attributable to the 1100-2 operable subunit, is present in the unconfined aquifer. Due to the lack of information, the subsequent evaluations of ground-water transport and risks associated with this substance (presented in Sections 5.3 and 6, respectively) are qualitative in nature. However, quantitative ground-water transport and risk evaluations for trichloroethene and nitrate, which are present in the vicinity of the Horn Rapids Landfill are provided for informational purposes. As noted earlier (see Section 4.5.2), existing data can not attribute these contaminants to the landfill or any other potential operable unit source.

5.1.5 Biotic Pathways

The evaluation of biotic pathways of contaminant transport is difficult due to ecosystem complexity. However, the NCP provides guidance by indicating

that CERCLA environmental evaluations, in order to determine ultimate remedial action objectives, shall focus on sensitive habitats and critical habitats of endangered and threatened species (40 CFR 300.430(e)(2)(i)(G)).

As demonstrated in Section 3.7.2, no such habitats exist within the 1100-EM-1 Operable Unit. However, the presence of two bird species near the Horn Rapids Landfill (the Swainson's hawk and the long-billed curlew)—identified by DOW as being of interest to that agency (see Section 3.7.2.3)—indicates the need to further evaluate contaminant transport through the food chains of these species in Section 5.3 below. The occasional use of the Horn Rapids Landfill by mule deer, a game species consumed by humans (see Section 3.7.2.3), indicates a need to include this species in the biotic transport pathway evaluation, as well.

Operable subunits other than the Horn Rapids Landfill do not provide valid habitat for the above terrestrial species because of their proximity to human activities. The degree of disturbance at the 1100-1 Battery Acid Pit and the 1100-4 Antifreeze Tank Site has virtually eliminated wildlife habitat at these locations. The other subunits have also been subjected to considerable human disturbance and are insignificantly small, with respect to the Horn Rapids Landfill. Therefore, the terrestrial biotic pathway evaluation in Section 5.3 focuses on the landfill.

Potential aquatic biological contaminant uptake associated with the operable unit as a whole are also be assessed in Section 5.3, based upon the results of the surface-water pathway analysis presented in the same subsection.

5.2 CONTAMINANT FATE

This subsection provides information on the environmental fate of the 1100-EM-1 Operable Unit contaminants of potential concern, which are identified in Section 4.7. The organic and inorganic contaminants of potential concern are discussed separately within Sections 5.1.1 and 5.1.2, respectively.

5.2.1 Organic Contaminants of Potential Concern

The 1100-EM-1 Operable Unit organic contaminants of potential concern and the environmental media in which they are found are:

trichloroethene	soil gas
tetrachloroethene	soil gas, ground water
1,1,1-trichloroethane	soil gas
BEHP	soil
PCB	soil
chlordane	soil

The physical properties and partitioning factors of these compounds that relate to their environmental fate are presented in Table 5-1. Each contaminant is discussed further below.

Table 5-1. Physical Properties of the Organic Contaminants of Potential Concern at the 1100-EM-1 Operable Unit.

Table 5-1. Physical Properties of the Organic Contaminants of Potential Concern at the 1100-EM-1 Operable Unit.

Contaminant	Mole. wt. (g/mole)	Density (g/cm^3)	Melting Point (°C)	Boiling Point (°C)	Vapor Pressure (mm Hg)	Solubility in Water (mg/L)	Henry's K (atm m^3/mole)	Log K_{ow}	K_{oc} (ml/g)	$T^{1/2}_{Soil}$ (d)	$T^{1/2}_{Chem-Water}$ (d)	$T^{1/2}_{Air}$ (d)	$T^{1/2}_{Bio-Water}$ (d)	Fish Bioaccum. Factor (L/kg)
BEHP	391	--	-50	387	2.0E-07	0.4 to 1.3	3E-07	8.7 to 5.3	10,000 to 100,000	--	730,000	high	14 to 30	high
trichloroethene	131.4	1.46	-87, -73	87	5.8E+01	1,100	9.1E-3	2.38	41 to 126	--	320	3.7	variable	10.6 to 17
1,1,1-trichloroethane	133.4	1.34	-31	71 to 76	1.23E+02	1,500 to 4,400	0.6 to 1.7E-02	2.49	105 to 152	--	0.14 to 7	803 to 1,752	variable	5.6 to 9
tetrachloroethene	166	1.63	-22.7	121.4	1.78E+01	1,500	1.2E-02	2.6	364	--	1 to 30	47	variable	31
PCBs (1248, 1254, 1260)	330	1.41 to 1.58	--	--	7.7E-05	0.0027 to 0.54	1.1E-03 to 7.1E-03	6 to 7	530,000	high	high	58 to 500	high	100,000
chlordane	410	1.6	107	175	1E-05	0.56	9.6E-06	3.32	140,000	1,200	>1,500	.25 to 40	high	3,500 to 14,000

Sources: Callahan et al. 1979.
Clement Associates 1988.
EPA 1986b.
NSDB Scientific Review Panel 1990.
Syracuse Research Corp. 1989a.
Syracuse Research Corp. 1989b.
Verschueren 1983.

5.2.1.1 Trichloroethene. Trichloroethene is a common solvent used for the degreasing of metals. It is a liquid at room temperature and has a density greater than water. It has a propensity to volatize due to its relatively high vapor pressure. Solubility in water is moderate.

Trichloroethene is relatively mobile within the soil, as indicated by measured soil-water partition coefficients (K_{oc}s). As a pure phase liquid, trichloroethene has a lower viscosity and higher density than water; these properties facilitate rapid migration through soils. Infiltrating rain water can solubilize trichloroethene and transport it to the water table. Volatilization could be a dominant fate in soils, initially to the soil gas phase of the vadose zone then ultimately to the atmosphere.

Trichloroethene is also mobile in ground-water and surface-water systems. As a pure phase solvent it can sink to the bottom of an aquifer then migrate along the surface of the aquitard as a dense non-aqueous liquid phase. Trichloroethene can migrate within aqueous systems as a solute. Volatilization accounts for the majority of trichloroethene losses from surface-water environments, but is unlikely to be a significant process for the reduction of the substance within ground-water systems. The relatively low K_{oc} indicates that trichloroethene will not partition significantly from the water phase to sediments in natural bodies of water. Bioconcentration of trichloroethene is not considered to be significant, as evidenced by the substance's lipidphobic nature and low fish bioaccumulation factors.

The relatively high vapor pressure of trichloroethene suggests that the atmosphere may be the most dominant sink for most environmental releases (Syracuse Research Corp. 1989a). The substance has been detected in numerous rain water samples within the United States, although it exists mainly in the vapor phase within the atmosphere. Atmospheric degradation by photo-produced hydroxyl reactions is estimated to have a half life of 6.8 d. The degradation products of these atmospheric reactions include phosgene, dichloroacetyl chloride, and formyl chloride. Reaction of trichloroethene with ozone in the atmosphere is too slow to be environmentally significant.

In natural water and soil systems, biodegradation may be the most important transformation process (Syracuse Research Corp. 1989a). The rates of aerobic and anaerobic biodegradation are sensitive to various environmental factors. The biodegradation products from trichloroethene are dichloroethene and vinyl chloride. Hydrolysis, oxidation, and direct photolysis are not usually environmentally important transformation process, although half lives for hydrolysis reactions have been reported to be 10.7 mo (Callahan et al. 1979).

5.2.1.2 Tetrachloroethene. The physical properties of tetrachloroethene are very similar to that of trichloroethene (Verschueren 1983). Having four chlorine atoms per molecule instead of three gives tetrachloroethene a higher density, higher boiling point, and lower vapor pressure, however. Tetrachloroethene has a slightly higher affinity for soils and organic substances relative to water, and has a slightly higher fish bioaccumulation factor. In general, the environmental behavior of tetrachloroethene is similar to that described for trichloroethene in Section 5.2.1.1 above. Tetrachloroethene commonly degrades, either biologically or chemically, to trichloroethene.

5.2.1.3 1,1,1-Trichloroethane. The physical properties of 1,1,1-trichloroethane are again similar to those of trichloroethene; however, the former substance contains a single carbon-carbon bond as compared to the double bond in the latter. As a result, 1,1,1-trichloroethane has a higher vapor pressure, is very volatile, and is slightly more mobile in soil and water systems. The bioaccumulation propensity of 1,1,1-trichloroethane is less than that of trichloroethene.

The most significant environmental sink for 1,1,1-trichloroethane appears to be the atmosphere, where degradation occurs by interaction with photochemically produced hydroxyl radicals (Syracuse Research Corp. 1989b). Products arising from this reaction are not known, nor can they be accurately predicted. Due to such degradation, the half life in the atmosphere has been estimated to be between 2.26 and 6 yr.

Biological and chemical processes degrade 1,1,1-trichloroethane within aquatic systems. Microbial degradation normally results in a dechlorination to 1,1-dichloroethane, and eventually to chloroethane (Cline and Viste 1985). Researchers have discovered hydrolysis degradation pathways that can transform the single carbon-carbon bond of the ethene portion of the molecule with accompanying dehalogination. Such reactions have been observed to transform 1,1,1-trichloroethane to 1,1-dichloroethene and acetic acid.

5.2.1.4 bis(2-Ethylhexyl)phthalate. The compound BEHP is used as a plasticizer for polyvinylchloride and other polymers products in large quantities. It is a high molecular weight liquid with a low vapor pressure and low solubility in water. The substance is very hydrophobic and has a high affinity for organic matter, as indicated by its high octanol-water partition coefficient (K_{ow}) and high K_{oc}.

In the soil, BEHP is relatively immobile because it does not appreciably volatilize, nor does it leach—it has a high affinity to soil particles and organic matter (Hazardous Substances Data Base, HSDB, Scientific Review Panel 1990). Limited data suggest that BEHP may biodegrade in soil under aerobic conditions following bacterial acclimation. A degradation half life of about 14 d under specific experimental conditions has been observed. An intermediate in the biodegradation process is 1,2-dihydroxybenzene (Callahan et al. 1979).

In water systems, BEHP strongly adsorbs to sediments. Volatilization and hydrolysis within aquatic systems are not significant removal processes for the compound. Biodegradation of BEHP under aerobic aqueous conditions has been observed to be fairly rapid, and, following bacterial acclimation, a half life of 2 to 3 wk has been measured. Aquatic organisms are known to bioaccumulate BEHP (Callahan et al. 1979).

Little is known about the atmospheric fate of BEHP, which can be released to the atmosphere in the form of fugitive dust even though the volatilization rate is negligible. Atmospheric processes such as photolysis or photo-oxidation are unlikely to significantly reduce BEHP in the atmosphere. Washout by rain or particulate fallout appear to be the most significant atmospheric removal processes for the compound. The substance, which has been detected in the troposphere over both the Atlantic and Pacific Oceans, is known to be atmospherically transported long distances (HSDB Scientific Review Panel 1990).

5.2.1.5 Polychlorinated Biphenyls. Several PCB mixtures (aroclors 1248, 1254, and 1260) were detected within soil media at the 1100-EM-1 Operable Unit. Each aroclor is a mixture of different congeners of chlorobiphenyl, and the relative importance of the environmental fate mechanisms generally depends on the degree of chlorination. In general, the persistence of PCB increases with an increase in the degree of chlorination (HSDB Scientific Review Panel 1990). Aroclors 1248, 1254, and 1260 are resistant to biodegradation in natural soil and water systems.

This group of compounds strongly adsorb to soil, and adsorption generally increases with a greater degree of chlorination. Solubilities for PCB are low and decrease with increasing chlorination. Altogether, the higher chlorinated forms do not readily leach nor are they significantly mobile within soils under typical environmental conditions (Callahan et al. 1979; Verschueren 1983).

In the presence of organic solvents, PCB may leach quite rapidly through soil. Volatilization of PCB from soil surfaces, although slow, may be an important ultimate fate mechanism. Volatilization potential increases with decreasing chlorination.

Within natural water systems, PCB readily adsorbs to sediments and suspended matter. Although adsorption appears to immobilize the substance (especially the higher chlorinated congeners), eventual redissolution into the water phase does occur. The migration rate, particularly within ground water, can be very slow. In the absence of adsorption, PCB volatilizes relatively rapidly from water (HSDB Scientific Review Panel 1990). However, strong PCB adsorption to sediment and soil competes significantly with volatilization, with the higher chlorinated congeners volatilizing less readily.

Atmospheric releases of PCB can be in the form of either vapors or fugitive dust to which the chemical is adsorbed. The dominant atmospheric transformation process is probably vapor-phase reaction with photochemically produced hydroxyl radicals. Estimated atmospheric half lives range from 12.9 d for monochlorobiphenyl to 1.3 yr for heptachlorobiphenyl. Physical removal of PCB from the atmosphere is accomplished by particulate-phase fallout or rain washout of vapor-phase and particulate-phase components.

Bioaccumulation in aquatic organisms is known to be significant. Fish bioaccumulation factors are high—approximately 100,000 L/kg (EPA 1986b).

5.2.1.6 Chlordane. Chlordane is an insecticide, consisting of a mixture of alpha- and gamma-isomers, that was primarily used for underground termite control. It is a solid at standard atmospheric conditions in pure phase with a melting point slightly over 100°C.

Chlordane in soils may persist for long periods of time. The degradation rate in soils is estimated to occur with a half life of about 3.3 yr (Clement Associates 1988). Field studies, leaching studies, and K_{OC} determinations indicate that chlordane is generally immobile in soil. However, chlordane has been detected in ground waters under certain situations which indicate that leaching can occur in association with more mobile organic liquids.

With a vapor pressure of 1E-05 mm of mercury, chlordane is not highly volatile; but, it can volatize from soil surfaces onto which it has been applied, particularly when such surfaces are moist. Incorporation into subsurface soils has been found to greatly restrict volatilization (HSDB Scientific Review Panel 1990), possibly due to the substance's strong affinity to soil particles. Insufficient data exists to understand biodegradation rates of chlordane, but such processes are expected to be slow.

Chlordane released in water systems is not expected to undergo significant hydrolysis, oxidation, or direct photolysis (HSDB Scientific Review Panel 1990). Volatilization of chlordane from ground water is insignificant. A significant fate of chlordane in surface waters can be volatilization to the atmosphere, as evidenced by Henry's Law constants. The volatilization half life from a 1-m deep river flowing 1 m/s with an overlying wind velocity of 3 m/s has been estimated to be 7 to 8 h at 23°C; volatilization half lives for ponds or lakes are estimated to be 18 to 26 d (HSDB Scientific Review Panel 1990).

Adsorption to sediments can significantly attenuate the importance of volatilization, and sediment adsorption is considered the major fate of chlordane in aqueous systems (Clement Associates 1988). The presence of chlordane in loose sediment samples (HSDB Scientific Review Panel 1990) suggests that it may be very persistent in the adsorbed state in aquatic environments.

Chlordane vapors in the atmosphere react with photochemically produced hydroxyl radicals. The estimated half life for atmospheric vapors is 6.2 h, and this degradation process is the dominant means of removal from the vapor phase. Chlordane is not subject to direct photolysis. The most abundant form of chlordane in the atmospheric reservoir is the sorbed particulate state. Particulate-phase chlordane may be removed from the atmosphere by wet and dry deposition processes. The detection of chlordane in the ambient atmosphere in remote locations over the Pacific, Atlantic, and Arctic Oceans indicates that long-range transport does occur. Chlordane's presence in rain water demonstrates that wet deposition does occur (Clement Associates 1988; HSDB Scientific Review Panel 1990).

Bioconcentration of chlordane in the environment is expected to be significant, based on experimentally determined bioconcentration factors. Most estimated values are above 35,000 L/kg (HSDB Scientific Review Panel 1990).

5.2.2 Inorganic Contaminants of Potential Concern

The inorganic contaminants of potential concern for the 1100-EM-1 Operable Unit, and their corresponding distributions with the environmental media, are:

chromium	soil
arsenic	soil

A discussion of the environmental fate of each is presented below. Nitrate properties are also discussed.

5.2.2.1 Chromium. Chromium is a naturally occurring element in the earth's crust; however, there are many anthropogenic sources that account for much of the current chromium in the environment. Chromium is a transition metal having multiple valence states. Of the three common valence states, only the trivalent form occurs naturally; hexavalent and metallic chromium are produced through industrial processes (Syracuse Research Corp. 1989c). Hexavalent chromium rarely occurs naturally because it is readily reduced in the presence of oxidizable organic matter. However, hexavalent chromium, in the form of chromate and dichromate ions, is stable in many aqueous systems if there is a low concentration of reducing matter. In general, the trivalent chromium compounds are generally insoluble in water, whereas the hexavalent forms are more soluble.

The fate of chromium in soils is dependent on the form and quantity of the substance and many environmental factors. Hexavalent chromium in the form of chromate or dichromate is water soluble and mobile in soils. However, these common forms of hexavalent chromium are readily reduced in soils to the relatively insoluble trivalent oxide form. Residual chromium in soils is expected to be in the trivalent state because the most hexavalent chromium salts are readily dissolved and transported. Chromium in soils may be released to the atmosphere as a component of fugitive dust. Volatilization of chromium is not considered a significant fate mechanism for either naturally occurring or anthropogenic forms of the substance.

Chromium in aqueous systems does not volatilize either. Most trivalent chromium eventually precipitates into aquifer or surface-water sediments. Small amounts of trivalent chromium may remain mobile in aqueous systems as colloidal particles or soluble organic complexes. Hexavalent chromium is present predominantly as a solute in aqueous systems and may be sufficiently stable to experience significant transport. Hexavalent chromium is eventually transformed to the trivalent state by reducing processes in natural aqueous systems (Syracuse Research Corp. 1989c).

Chromium releases to the atmosphere are only feasible in the form of fugitive dust emissions. The residence time in the atmosphere is dependent on the size of the particulates and meteorological conditions. Particulate chromium is removed from the atmosphere by both rain washout and dry fallout deposition. Chromium particulates of aerodynamic diameters (< 20 μm) may remain airborne for long periods and be transported long distances (Syracuse Research Corp. 1989c).

The bioaccumulation of chromium in aquatic species is highly variable. One bioconcentration factor for hexavalent chromium in fish is reported to be about 1 L/kg (Syracuse Research Corp. 1989c), while another value is reported as 16 L/kg (EPA 1986b). In shellfish, the bioconcentration factors for trivalent and hexavalent chromium range from 86 to 192 (Syracuse Research Corp. 1989c). Chromium has not been observed to bioconcentrate in plants.

5.2.2.2 Arsenic. Arsenic is a naturally occurring element in the earth's crust; however, there are many anthropogenic sources of arsenic that account for much of the current arsenic in the environment. Arsenic is a semi-metal having multiple valence states. Of the three common valence states, pentavalent arsenic is the predominant form under normal environmental conditions. Trivalent arsenic and metallic arsenic are produced through industrial processes (HSDB Scientific Review Panel 1990). Arsenic in the

environment may undergo a complex cycle of chemical conversions and transfers between media.

Arsenic fate in soils is a function of quantity, valence state, chemical speciation, and many environmental factors. In general, arsenic in soil occurs predominantly in an insoluble, absorbed form (Life Systems, Inc. 1987). Some clays are particularly effective at adsorbing arsenate by anion exchange. Complexation and chelation by organic material, iron, or calcium are important processes that can fix arsenic in insoluble forms. Leaching of arsenic is usually important only in the top 30 cm (12 in) of soil, although coarse sandy soils, such as those present at the 1100-EM-1 Operable Unit, encourage deeper migration. Life Systems, Inc. (1987) reports that leached arsenic could not be detected below a soil depth of 90 cm (35 in) in a number of studies conducted by EPA.

Soluble forms of arsenic interact with soil and are readily transported with ground water and surface water. Arsenic chemistry is complex; shifts in oxidation states in either direction can dramatically alter solubility and mobility. Arsenic can exhibit high mobility depending on the prevailing equilibrium-controlling reactions (Callahan et al. 1979). The environmental factors controlling arsenic mobility in aqueous systems include: oxidation-reduction potential, pH, sulfide concentration, iron concentration, presence of phosphorus minerals, temperature, salinity, and type of biota present. Arsenic can readily adsorb onto clays, iron oxides, and manganese salts, and organic material. Adsorption can temporarily immobilize arsenic or enhance migration if the material is suspended in a colloidal state. Arsenic volatilization can occur under environmental conditions, but extreme reducing conditions are needed to methylate the substance at environmental temperatures.

Arsenic can be released to the atmosphere in the form of fugitive dust from contaminated surface soils. The residence time in the atmosphere depends on particle size and meterological conditions, but an average residence time of 9 d is estimated (Life Systems, Inc. 1987). Arsenic, in particulate form, is removed by rain washout and dry fallout from the atmosphere.

Bioconcentration of arsenic occurs in aquatic organisms, primarily in algae and invertebrates, but significant biomagnification does not appear to occur in aquatic food chains (Callahan et al. 1979; Life Systems, Inc. 1987). Some fish and invertebrate species do contain high levels of arsenic compounds, but these are relatively inert from a toxicological perspective (Life Systems, Inc. 1987). Fish bioconcentration factors are reported to be 44 L/kg (EPA 1986b).

Plants may accumulate arsenic via root uptake from soil solution, and certain species may accumulate substantial levels in this manner (Life Systems, Inc. 1987). In addition to species differences, the amount of arsenic taken up depends on soil arsenic concentration, soil characteristics, and other environmental factors.

5.2.2.3 Nitrate. Nitrogen in the form of dissolved nitrate is a major nutrient for vegetation and the element is essential to all life. Nitrate is naturally produced by numerous natural and anthropogenic processes. Nitrates are formed by the process of nitrification, where ammonium is oxidized to nitrate.

Most common forms of nitrate are soluble in water and are mobile in soils. Some nitrate is utilized by plants, where it remains fixed until the plant dies. Nitrate is not volatile, but under low oxidation-reduction potentials can undergo denitrification, where the gas nitrous oxide and gaseous nitrogen are formed.

Nitrates in ground water are mobile and their concentrations are rarely limited by solubility constraints. Nitrates can also be converted to ammonium, but the rate of this biochemical transformation is insignificant. Nitrate migrates through many ground-water and surface-water systems with no transformation and little or no retardation (Freeze and Cherry 1979). Some clays displaying high anion exchange capacities can retard the migration of nitrate slightly.

Little information exists on the bioconcentration potential of nitrates in animals. However, because nitrogen is readily metabolized, bioconcentration is not expected to occur.

5.3 CONTAMINANT TRANSPORT

The environmental transport of operable unit contaminants of potential concern is analyzed below. The analysis is conducted by contaminant within potentially operative exposure pathway—air (Section 5.3.1), surface soil (Section 5.3.2), subsurface (Section 5.3.3), surface water (Section 5.3.4), and biota (Section 5.3.5)—as dictated by the needs specified in Section 5.1. The purpose of the following analysis is to provide conservative estimates of contaminant concentrations in various environmental media at points of potential receptor exposure. The data generated are used in Section 6 (Baseline Risk Assessment) to assess the nature and magnitude of the threats to human health and the environment posed by contaminant releases emanating from the 1100-EM-1 Operable Unit.

5.3.1 Air Transport

Section 5.1.1 indicates that the air exposure pathway may be operative at the 1100-EM-1 Operable Unit. Two release mechanisms, volatilization and fugitive dust generation, are discussed below in Sections 5.3.1.1 and 5.3.1.2, respectively.

Volatile contaminants of potential concern present at the operable unit, in the form of soil vapors, are tetrachloroethene at the 1100-2 operable subunit, and trichloroethene, 1,1,1-trichloroethane, and tetrachloroethene at the Horn Rapids Landfill. Nonvolatile surface soil contaminants of potential concern that could pose a threat via inhalation of fugitive dust are chromium at the 1100-2 operable subunit, arsenic and chromium at the 1100-3 operable subunit, BEHP at the UN-1100-6 operable subunit, and arsenic, chromium, and PCB at the Horn Rapids Landfill.

5.3.1.1 Volatile Emissions. A volatile emission rate can be conservatively estimated using the following formula (EPA 1989g):

$$J = D_i P_T^{4/3} C_S / L$$

where J is the volatilization vapor flux through the soil surface ($\mu g/cm^2/s$), D_i is the chemical- and temperature-specific vapor diffusion coefficient in air (cm^2/s), P_T is the total soil porosity (unitless), C_S is the concentration of the volatile substance is the soil gas ($\mu g/cm^3$), and L is the depth of the soil layer to the point of the soil gas measurement (cm).

Sixty-three locations within the 1100-2 operable subunit were sampled for soil gas (see Section 2.1.4). Tetrachloroethene was detected at an average concentration of 1.1E-02 $\mu g/cm^3$ (one-half the SQL substituted for results below detection), with a standard deviation of 8.0E-02 $\mu g/cm^3$) (see raw data in Appendix C). A conservatively biased estimate of the mean concentration of tetrachloroethene in soil gas is 2.8E-02 $\mu g/cm^3$ (one-sided confidence limit, $\alpha = 0.05$). Soil gas measurements were obtained from a depth of approximately 120 cm (see Section 2.1.4). Mean annual temperature at the Hanford Site is estimated to be 15°C (see Section 3.2.1.2); therefore, the air diffusion coefficient for tetrachloroethene is approximately 7.2E-02 cm^2/s (EPA 1988e). Total soil porosity is conservatively estimated to be 0.55 (EPA 1988e).

Therefore, the tetrachloroethene emission rate per unit area for the 1100-2 operable subunit is conservatively estimated to be 7.6E-06 $\mu g/cm^2/s$. The area of the subunit is approximately 4E+07cm^2 (see Section 3.1.2.2); thus, the integrated emission rate is 0.3 mg/s.

The number of discrete soil gas samples from the Horn Rapids Landfill totaled 207 (see Section 2.1.4). The average trichloroethene concentration at 120 cm depth was 2.8E-04 $\mu g/cm^3$, with a standard deviation of 5.9E-04 $\mu g/cm^3$ (calculated from data in Appendix C). The upper one-sided confidence limit of the mean trichloroethene concentration is 3.4E-04 $\mu g/cm^3$ ($\alpha = 0.05$). The air diffusion coefficient at 15°C is approximately 7.9E-02 cm2/s (EPA 1988e).

With the same soil porosity assumption used for 1100-2, the trichloroethene emission rate for the Horn Rapids Landfill is approximately 1.0E-07 $\mu g/cm^2/s$. The area of the landfill is approximately 2E+09 cm^2 (see Section 3.1.2.6). The resulting trichloroethene total emission rate for the landfill is then 0.2 mg/s.

The one-sided upper confidence limits of the mean 1,1,1-trichloroethane and tetrachloroethene soil gas concentrations at the Horn Rapids Landfill ($\alpha = 0.05$) are 5.3E-05 and 2.9E-05 $\mu g/cm^3$, respectively, as calculated from data contained in Appendix C. The 15°C air diffusion coefficients for 1,1,1-trichloroethane and tetrachloroethene are 7.7E-02 and 7.2E-02 cm^2/s, respectively (EPA 1988e). The respective estimated landfill emission rates are 1.5E-08 and 7.8E-09 $\mu g/cm^2/s$; the respective emission rates for the entire landfill area are 0.03 and 0.02 mg/s.

A downwind air concentration for each substance can be conservatively estimated with a simple infinite line source dispersion model (Turner 1969):

$$C(x) = 2QW/L\sigma_Z\mu(2\pi)^{1/2}$$

where C(x) is the air concentration at x m from the emission point, Q is a total substance emission rate (mg/s), W is the maximum frequency at which the wind blows in any given direction, L is the length of the line source in m, σ_Z is the vertical dispersion coefficient in m, and μ is the mean wind speed in

m/s. This model is invalid at distances closer than 100 m. This is termed an infinite line source model because the line emission source is assumed to extend infinitely far; lateral dispersion is therefore ignored.

The mean wind speed for the 1100-EM-1 Operable Unit is approximately 2.9 m/s (see Section 3.2.2.2). The maximum frequency at which operable unit winds blow in a given direction (conservatively regarded as any 60° azimuth, regardless of actual orientation) is approximately 33% (interpolated from Figure 3-10). The length of the line source is conservatively assumed to be the operable subunit area divided by the subunit length. This estimate provides L values of 36 and 310 m, respectively, for the 1100-2 and Horn Rapids Landfill subunits (see Sections 3.1.2.2 and 3.1.2.6).

The vertical dispersion coefficient is dependent upon the atmospheric stability category, which is approximated from wind speed, solar radiation, and cloud cover data (EPA 1988e). Due to the semiarid climate, cloud cover is assumed to be less than 50%, solar radiation is conservatively assumed to be slight, and day and night conditions are given equal weight and a conservative geometric mean value used. Graphs in EPA (1988e) provide σ_z estimates as a function of downwind distance. Concentrations at three distances at each subunit are used in Section 6 to assess potential occupational exposures on the subunit, at the nearest permanent occupational facility, and at the nearest residential location. For the sake of conservatism and simplicity, actual wind direction frequencies are not taken into consideration.

For exposures in close proximity to an operable subunit, x = 100 m, the minimum distance at which the model is valid. Wind frequency, W, is assumed to be unity for estimating air concentrations at this distance. The nearest permanent occupational facilities to the 1100-2 subunit are located to the east of Stevens Drive, approximately 460 m away (see Section 3.1.2.2 and Figure 3-1). The nearest residentially zoned area is located approximately 1,100 m to east-southeast (see Figure 3-42). The permanent occupational facility nearest to the Horn Rapids Landfill is the Advanced Nuclear Fuels Corp. complex, located approximately 610 m southwest of the center of the landfill (see Section 3.1.2.6 and Figure 3-1). The residentially zoned area nearest to the landfill is located approximately 3,000 m to the southeast (see Figure 3-42).

Graphs in EPA (1988e) provide σ_z estimates for x = 100, 460, 610, 1,100, and 3,000 m of 4.2, 15, 20, 32, and 66 m, respectively. Conservative downwind VOC air concentrations at the respective distances specified above for the 1100-2 and Horn Rapids Landfill operable subunits are provided in Table 5-2.

5.3.1.2 Fugitive Dust Emissions. The estimation of a fugitive dust emission rate is conducted in two steps. First, a wind erosion analysis is conducted, in accordance with EPA (1988e) and Skidmore and Woodruff (1968), to determine total soil loss in tons/ac/yr. This method determines soil loss as a function of a soil erodibility index (I′, tons/ac), a soil ridge roughness factor (K′, unitless), a climatic factor (C′, as a percentage), unsheltered field length along the prevailing wind erosion direction (L′, ft), and a vegetative cover factor (V, lb/ac).

The variable I′ is determined from soil grain-size distribution data. The fraction > 0.84 mm is assumed to be non-wind-erodible, and a table in Skidmore and Woodruff (1968) is used to convert this information to I′.

Table 5-2. Estimated Downwind Air Concentrations.

Area	Contaminant	Estimated Air Concentration (mg/m^3) Operable Subunit Employees	Closest Permanent Employee Population	Closest Residential Population
Volatiles				
1100-2 (Paint and Solvent Pit)	tetrachloroethene	5E-04	5E-05	2E-05
Horn Rapids Landfill	trichloroethene	4E-05	3E-06	9E-07
	tetrachloroethene	4E-06	3E-07	9E-08
	1,1,1-trichloroethane	6E-06	4E-07	1E-07
Fugitive Dusts				
1100-3 (Antifreeze and Degreaser Pit)	arsenic	1E-08	7E-10	4E-10
	chromium	2E-09	1E-10	9E-11
UN-1100-6 (Discolored Soil Site)	BEHP	2E-03	2E-04	1E-04
Horn Rapids Landfill	arsenic	6E-08	4E-09	1E-09
	chromium	4E-07	3E-08	9E-09
	PCB	2E-06	1E-07	4E-08

Conservatively biased estimates of the > 0.84 mm fractions of the surface soils for the 1100-2, 1100-3, UN-1100-6, and Horn Rapids Landfill operable subunits are provided in Section 3.5.2.2 (35, 37, 5, and 29%, respectively). These values respectively convert to I′ values of 65, 62, 180, and 76 tons/ac.

For the sake of simplicity and conservatism, the surface of each operable subunit is assumed to be flat. This assumption maximizes the value of K′ at 1. Figures provided in Skidmore and Woodruff (1968) are used to provide an estimate of the annual mean for C′ ($\bar{x}$ = 24%; s = 12%; n = 12 monthly estimates). A conservative upper bound estimate of this value, rounded to the nearest 10% (preserving the number of significant digits used by Skidmore and Woodruff), is 30% (one-sided upper confidence limit of the mean, α = 0.05).

The field length for each operable subunit is assumed to be equivalent to the maximum length, regardless of orientation, and the entire length is assumed to be unsheltered. The resulting L′ values for the 1100-2, 1100-3, UN-1100-6, and Horn Rapids Landfill operable units are 360, 430, 340, and 2,100 ft, respectively (see Sections 3.1.2.2, 3.1.2.3, 3.1.2.5, and 3.1.2.6). Vegetative cover is conservatively assumed to be nonexistent at each subunit.

In accordance with Skidmore and Woodruff (1968), a series of calculations and nomographs are used to obtain the following total soil loss rates, which take into account the approximate surface areas of 1, 2, 0.4, and 50 ac, respectively, (see Sections 3.1.2.2, 3.1.2.3, 3.1.2.5, and 3.1.2.6) for each operable subunit:

- 1100-2 (Paint and Solvent Pit) 10 tons/yr
- 1100-3 (Antifreeze and Degreaser Pit) 20 tons/yr
- UN-1100-6 (Discolored Soil Site) 20 tons/yr
- Horn Rapids Landfill 1,000 tons/yr.

Appendix H contains grain-size distribution data for surface soils at each of the subunits (n = 4 for 1100-2 and 1100-3, n = 3 for UN-1100-6, and n = 6 for the Horn Rapids Landfill). A conservative estimate of the mean fraction of respirable particulates (< 10 μm, EPA 1988e) in the surface soils at each operable subunit is calculated by t-test to obtain the one-sided upper 95% confidence limit of the mean (grain-size data for the three UN-1100-6 samples are not available for the respirable fraction; the respirable fraction is estimated by extrapolation from the larger fractions). The resulting upper confidence limits for the mean respirable fractions are:

- 1100-2 (Paint and Solvent Pit) 7% ($\bar{x}$ = 5%; n = 4)
- 1100-3 (Antifreeze and Degreaser Pit) 4% ($\bar{x}$ = 3%; n = 4)
- UN-1100-6 (Discolored Soil Site) 13% ($\bar{x}$ = 7%; n = 3)
- Horn Rapids Landfill 12% ($\bar{x}$ = 7%; n = 6).

The annual average emission rates of respirable particulates from each subunit, converted to mg/s, are therefore:

- 1100-2 (Paint and Solvent Pit) 2E+01 mg/s
- 1100-3 (Antifreeze and Degreaser Pit) 2E+01 mg/s
- UN-1100-6 (Discolored Soil Site) 7E+01 mg/s
- Horn Rapids Landfill 3E+03 mg/s.

The potential particulate inhalation contaminant of concern concentrations in the respirable fraction are assumed to be identical to the concentrations for the entire fraction of soil analyzed. Chromium concentrations in the surface soil samples (those within 0.6 m [2 ft] of the ground surface) obtained from the 1100-2 operable subunit are contained in Appendix I along with all other surface soil chemistry results. A conservative estimate of the mean concentration of chromium, attributable to contamination, in the Paint and Solvent Pit surface soils is calculated to be -0.1 mg/kg (one-sided upper confidence limit of the mean, α = 0.05, less the mean surface background concentration). As the chromium content of the surface soils of the 1100-2 subunit is not discernable from background levels, the subunit is disregarded as a potential source of particulate contaminant emissions.

Arsenic and chromium are the particulate inhalation contaminants of potential concern in the surface soils of the 1100-3 operable subunit. Evaluations of the data in Appendix I show the respective one-sided upper confidence limits of the means (n = 14, α = 0.05)—adjusted for background to determine the amount attributable to operable subunit contamination—for each substance to be 0.5 and 0.1 mg/kg. The respective respirable emission rates for arsenic and chromium at 1100-3 are therefore 1E-05 and 2E-06 mg/s.

The particulate inhalation contaminant of potential concern for the UN-1100-6 operable subunit is BEHP. Statistical calculations based on the data contained in Appendix I provide a conservatively biased estimate of the mean BEHP concentration of 8,700 mg/kg (one-sided upper confidence limit, α = 0.05, n = 15, less estimated background contribution of 0.5 SQL [one-half the SQL was used as a surrogate value, in both background and impacted areas, whenever a substance was not detected]). Using this value, a reasonable maximum mean emission rate for BEHP from UN-1100-6 is estimated to be 6E-01 mg/s.

The particulate inhalation contaminants of potential concern for the Horn Rapids Landfill surface soils are arsenic, chromium, and PCB. Statistical analysis of the appropriate data in Appendix I indicate that the one-sided upper confidence limits of the means (n = 52, α = 0.05)—less background contributions—are 0.1, 0.8, and 3.5 mg/kg for arsenic, chromium, and PCB, respectively. Therefore, the respective respirable emission rates for these substances are estimated to be 3E-04, 2E-03, and 1E-02 mg/s.

Calculated conservative downwind particulate air concentrations at the distances specified for each subunit, using the atmospheric dispersion model described in Section 5.3.1.1, are displayed in Table 5-2. Air dispersion parameters for the Horn Rapids Landfill are specified in Section 5.3.1.1 above. The closest permanent work facility to the 1100-3 operable subunit is located 610 m to the southeast, and the nearest residentially zoned area is approximately 1,200 m to the east-southeast (see Section 3.1.2.3, and Figures 3-1 and 3-42). The respective distances applicable to the UN-1100-6 operable subunit are 370 m and 1,200 m (see Section 3.1.2.5, and Figures 3-1 and 3-42). Estimates of the vertical dispersion coefficient, σ_z, for x = 370, 610, and 1,200 m are 13, 20, and 35 m, respectively (EPA 1988e); estimates for x = 100 m (for determinations of within subunit exposures) are provided above in Section 5.3.1.1. The line source lengths (L) for 1100-3 and UN-1100-6 are 61 and 19 m, respectively (area divided by length; see Sections 3.1.2.3 and 3.1.2.5).

5.3.2 Surface Soil

Although not an actual transport medium (with the exception of fugitive dust generation potential, which is quantified in Section 5.3.1.2), surface soils provide a point of potential contaminant exposure that is evaluated in Section 6. Section 5.1.3 indicates that operable subunits 1100-2, 1100-3, UN-1100-6, Horn Rapids Landfill, along with Pit 1 and the ephemeral pool, display potentially hazardous quantities of contamination within their respective surface strata.

Conservatively biased means for each contaminant of potential concern within each subunit or location are provided below. For the purposes of statistical calculations, one-half the reported SQL is used as a surrogate concentration value whenever the contaminant in question was not detected in a given sample. Those SQLs inflated by sample dilution in the laboratory are not used; one-half of the typical non-diluted SQL is used instead. The same rules are applied for subtracting background contributions (estimated as one-half the mean background SQL for each parameter not detected in background surface soils).

Chromium is the only contaminant of potential concern within the surface soils of the 1100-2 operable subunit (see Section 4.4.3); however, Section 5.3.1.2 demonstrates that the subunit surface chromium levels are not distinguishable from, in fact they are less than, background levels. There are two contaminants of potential concern in the 1100-3 operable subunit surface soils—arsenic and chromium (see Section 4.4.4); their respective conservatively biased mean values are 0.5 and 0.1 mg/kg (see Section 5.3.1.2).

At the UN-1100-6 operable subunit, BEHP and chlordane are the two contaminants of potential concern known to exist within the surface soil stratum (see Section 4.4.6). A conservatively biased estimate of the mean BEHP concentration is 8,700 mg/kg (see Section 5.1.3.2). An equivalent value for chlordane, using the data provided in Appendix I, is calculated to be 0.65 mg/kg (one-sided upper confidence limit, $\alpha = 0.05$, $n = 15$, less background).

The surface soils of the Horn Rapids Landfill contain arsenic, chromium, and PCB as contaminants of potential concern (see Section 4.4.7). Section 5.3.1.2 provides conservatively biased mean values of 0.1, 0.8, and 3.5 mg/kg, respectively, for each substance.

The only surface soil contaminant of potential concern at Pit 1 is PCB (see Section 4.4.8). The one-sided upper 95% confidence limit of the mean PCB concentration for the gravel pit is 0.18 mg/kg ($n = 5$, less background). Two contaminants of potential concern—PCB and chlordane—are present within the surface soils of the ephemeral pool location. The respective one-sided upper 95% confidence limits for these two substances are 13 and 5.1 mg/kg ($n = 2$, less estimated background contributions).

5.3.3 Subsurface Transport

Section 5.1.4 indicates that subsurface exposure pathways may be operative at the 1100-1, 1100-2, 1100-3, UN-1100-6, and Horn Rapids Landfill operable subunits, and at Pit 1 and the ephemeral pool, as well. The potential for downward migration of contaminants through the vadose zone at each of these locations is evaluated in Section 5.3.3.1. The ground-water component of the subsurface transport pathway is evaluated in Section 5.3.3.2.

5.3.3.1 Vadose-Zone Transport. The vadose-zone transport pathway may be operative at the 1100-EM-1 Operable Unit as indicated in Section 5.1.4. There are two potential pathways associated with the vadose-zone: percolation of contaminants through the vadose zone to ground water, and upward and lateral migration of VOCs by gaseous diffusion. The upward migration of VOCs by gaseous diffusion through soil is not addressed here because it is taken into consideration during the evaluation of air transport in Section 5.3.1. Lateral migration of VOCs is assumed to be negligible (see Section 5.1.4). This evaluation focuses on vertical transportation of contaminants through the vadose zone.

The rate of vertical migration is a function of water recharge through infiltration and the solubility of specific contaminants (EPA 1988e). Hydraulic testing and surface mapping to evaluate vadose zone recharge to ground water was not conducted during the initial phase of the 1100-EM-1 Operable Unit RI. Recharge through the vadose zone is anticipated to vary between 0 and 11 cm/yr (0 to 4.5 in/yr) (see Section 3.6.2.2). The highest

recharge is expected in the disturbed areas of the operable unit, where little or no vegetation exists to decrease infiltration through transpiration.

The main source of ground-water recharge at the 1100-EM-1 Operable Unit is precipitation. The vast majority of precipitation that falls is lost through evapotranspiration, leaving little water to either infiltrate or generate surface runoff (see Section 3.3.2). The ephemeral pool does receive parking lot runoff during high-intensity precipitation events. Therefore, the infiltration rate at this location would be increased during such events.

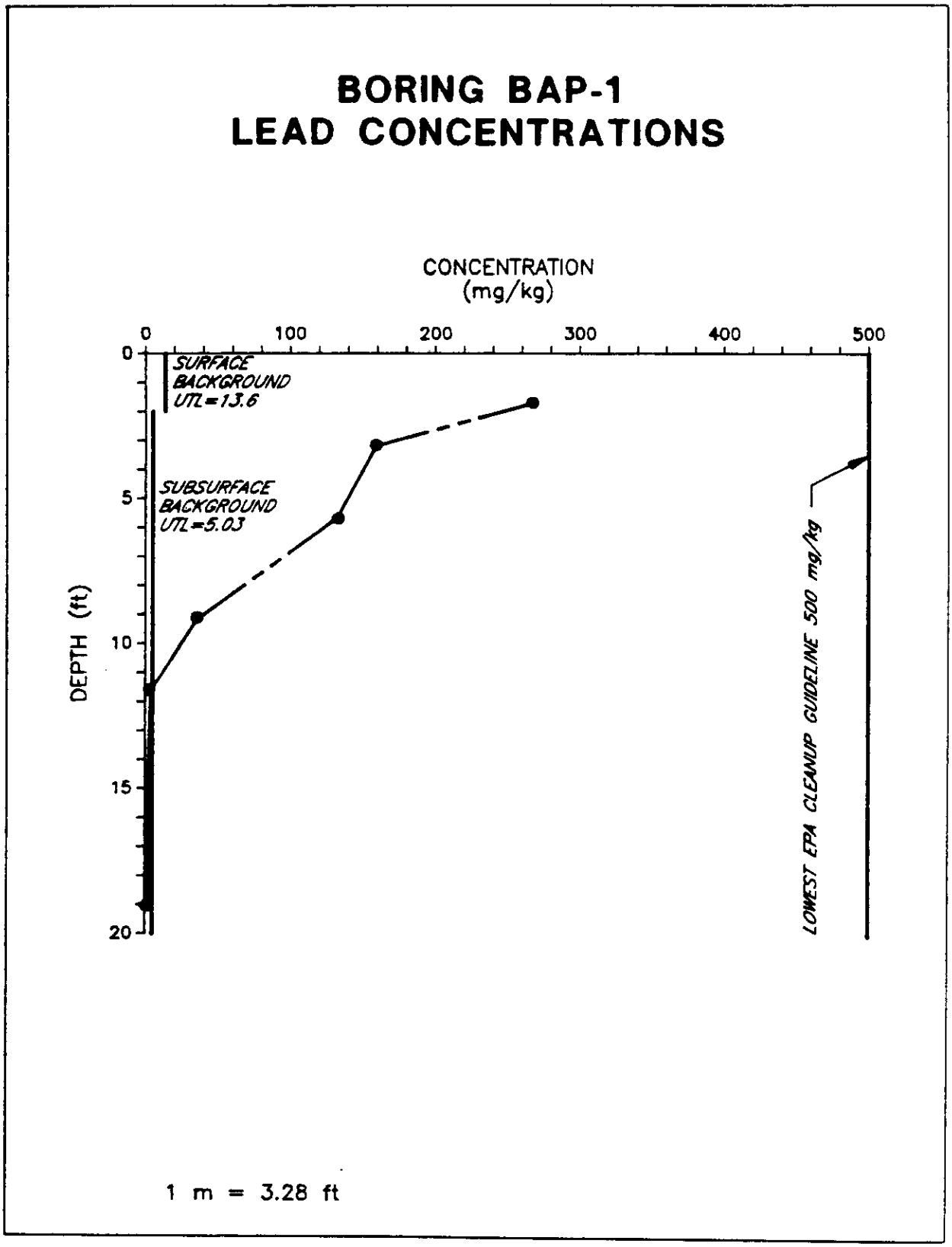
The thickness of the vadose zone varies throughout the operable unit: at the Horn Rapids Landfill, 6 to 8 m (20 to 25 ft) on the west side and 8 m (25 ft) on the east side; 15 m (50 ft) at the 1100-2 and 1100-3 operable subunits; and 14 to 15 m (45 to 50 ft) at the 1100-1 and UN-1100-6 operable subunits. The unsaturated soils above the water table are part of the porous Hanford formation (see Section 3.5.2.2).

The operable unit soil column organic contaminants of potential concern—BEHP, chlordane, and PCB—are hydrophobic (see Section 5.2.1). Such substances have high affinities for organic matter and are thus relatively immobile in soils. Soil gas contaminants known to exist at the operable unit are trichloroethene, tetrachloroethene, and 1,1,1-trichloroethane. The vadose-zone transport characteristics of these VOCs are similar in that all have relatively high mobilities. However, trichloroethene is the only VOC detected at elevated concentrations in operable unit ground waters and the source of this contamination has not been defined.

The inorganic soil contaminants of potential concern are chromium and arsenic. The hexavalent form of chromium is generally soluble and mobile in soils. However, hexavalent chromium is often readily reduced under environmental conditions to the relatively insoluble (and much less toxic) trivalent form (see Section 5.2.2). Arsenic occurs predominantly in an insoluble form. Complexation and chelation by organic material, iron, or calcium are important processes that can fix arsenic in insoluble forms (see Section 5.2.2). Nitrate is the only inorganic contaminant of potential concern in the operable unit ground waters. While the source of this contamination has not been determined, nitrate salts are highly soluble and as a result have relatively high transport rates through vadose-zone soils.

The 1100-1 operable subunit is the only waste management unit in the 1100-EM-1 Operable Unit known to have repeatedly received liquid wastes at the same location. Waste battery acids (up to 57,000 L [15,000 gal]) were disposed here for over 20 yr (see Section 1.3.2.1), and supposedly, the contaminated soils at the bottom of the pit were removed and replaced from time to time.

The current distribution of lead, a common battery constituent, in the soil column at the 1100-1 subunit is shown in Figure 5-1. The elevated concentrations of lead at the surface rapidly decrease to background levels at a depth of approximately 3.5 m (11.5 ft). The log for soil boring BAP-1 (see Appendix F) also indicates that prominent soil discoloration, attributable to acid disposal, occurs only to a depth of about 5 m (16 ft) (although a minor degree of staining was found throughout the borehole to its maximum depth of 6 m [20 ft]). Thus, the vast majority, if not all, of the contamination



803-1214 \34057

Figure 5-1. Vertical Distribution of Lead at the 1100-1 Operable Subunit.

appears to be restricted to those portions of the soil column that are well above the local water table depth of approximately 14 m (45 ft).

The pit is estimated to have had an approximate 2-m (6-ft) depth at the time of operations, the lead was disposed in an acidic liquid matrix which greatly enhances mobility, and a percolation period of more than 35 yr has transpired since the pit was first placed in service (see Section 1.3.2.1). Given these adverse factors, the soils have quite effectively retarded the rate of downward contaminant migration (only 2 to 3 m [6 to 10 ft]).

It is possible that the pit has been used since its supposed retirement in 1977—the lead concentrations in the surface soil stratum appear to be too high for, and its vertical distribution inconsistent with, a 2-m (6-ft) pit that was supposedly covered with clean soils upon retirement. Even under a post-1977 unauthorized use scenario, significant contamination has occurred only to a depth of 4 to 5 m (13 to 16 ft) over approximately 10 yr.

As a result of this evaluation, the downward migration rate of soil column contaminants at the 1100-EM-1 Operable Unit is considered to be insignificant throughout the remainder of this report. There is the potential that such contaminants could migrate in sufficient quantity provided sufficient time is allowed or man-made influences result to increase water infiltration rates at the operable subunits. In any event, the current operable unit data are insufficient to predict contaminant transport kinetics within the vadose zone, and the potential for downward migration is readily eliminated through standard engineering controls such as capping or runoff diversion.

5.3.3.2 Ground-Water Transport. As noted in Section 5.1.4, the ground-water contaminant transport pathway is potentially operative at the 1100-EM-1 Operable Unit. With the possible exception of one contaminant, tetrachloroethene associated with the 1100-2 subunit, the potential for the downward migration of soil column contaminants through the vadose-zone to the water table currently appears to be insignificant.

Currently, the magnitude and extent of the tetrachloroethene contamination in the unconfined aquifer is unknown, as the substance has been found in but a single well (see Section 4.5.2). Therefore, a quantitative hydrogeological transport evaluation is not feasible at the present time. The risks to human health and the environment to potential tetrachloroethene exposure in Section 6 will therefore be assessed qualitatively on the basis of the results of the quantitative trichloroethene transport evaluation provided, in conjunction with a nitrate evaluation, below.

Trichloroethene and nitrate are the characteristic contaminants that appear to be associated with the plume known to exist in the vicinity of the Horn Rapids Landfill. This plume appears to have an origin upgradient of the landfill (see Section 4.5.2).

Hydrostratigraphic Structure and Aquifer Intercommunication

The uppermost aquifers below the operable unit are an unconfined sand and gravel water-table aquifer and a confined-to-semi-confined sand aquifer, with an intervening silt aquitard (see Section 3.6.2 and Figure 3-35). Verification of this hydrostratigraphic sequence has not been confirmed in the

direction hydraulically downgradient from the Horn Rapids Landfill; however, the regional surface of the silt aquitard appears to be declining in a downgradient direction (see Section 3.4.3.1 and Figure 3-24). There is some evidence to suggest that the silt aquitard may not exist in proximity to the Columbia River (see Section 3.6.2.4). If this is true, then the unconfined and upper confined aquifers are in hydraulic communication prior to their confluence with the Columbia River.

For the purpose of this ground-water transport evaluation, only flow within the unconfined aquifer is considered. This simplifying assumption conservatively biases the results of the evaluation by disregarding intercommunication between the unconfined and upper confined aquifers.

Hydraulic Parameters

The most important hydraulic parameters used for estimating aquifer flow characteristics are hydraulic conductivity, hydraulic gradient, and effective porosity. Table 5-3 provides a summary of existing knowledge of these parameters. Estimates for hydraulic conductivity assume that the horizontal component is larger than the vertical component, a condition typical of sediments deposited by water (Freeze and Cherry 1979). Effective porosities have also been estimated. Flow calculations are usually relatively insensitive to inaccuracies in effective porosity in coarser unconsolidated aquifer matrices.

The horizontal ground-water flow velocities estimated from the data in Table 5-3 are also provided in the table. The resulting velocities are directly proportional to the hydraulic conductivity of the corresponding aquifer. The estimates of conductivity values have over an order-of-magnitude range. Slug test measurements of the hydraulic conductivity of the unconfined aquifer have a geometric mean of approximately 5E-03 cm/s (see Section 3.6.2.3). This value is lower than normally expected for middle unit Ringold Formation and Hanford formation water-table aquifers; although, conductivities have been reported as low as E-03 cm/s for aquifers within the Ringold Formation (see Section 3.6.1.1 and Table 3-1).

A pump test conducted by the City of Richland well field at their nearby well field—located about 3 km (2 mi) from the landfill, see Figure 3-1—yielded much higher conductivity values. The city well field is believed to be receiving much of its water through the Hanford formation which typically exhibits higher conductivities than the underlying Ringold Formation. The Phase I RI monitoring wells near the Horn Rapids Landfill appear to be receiving ground water from the Ringold Formation (see Section 3.6.2.3 and Table 3-2).

Slug tests, at best, provide estimates of hydraulic conductivity that display only order-of-magnitude accuracy. In addition, the well screens on many of the Phase I RI monitoring wells are 10-slot size with fine-grained screen packs. Such construction may bias results from slug tests to lower values. Therefore, the higher slug tests results are believed to be more representative of the unconfined aquifer in the area of the landfill. Hydraulic conductivities between 5E-03 and 5E-02 cm/s are used in the ground-water transport evaluation below, although much uncertainty exists in the representativeness of this range of values.

Table 5-3. Summary of Major Hydraulic Parameters and Ground-Water Flow Estimates.

	Horizontal Hydraulic Conductivity (cm/s)	Vertical Hydraulic Conductivity (cm/s)[a]	Horizontal Hydraulic Gradient	Vertical Hydraulic Gradient	Effective Porosity	Horizontal Average Linear Velocity (cm/s)	Vertical Average Linear Velocity[d] (cm/s)
Unconfined Sand and Gravel Aquifer	5E-03 to 5E-02	1E-03 to 1E-02	-0.0013	N/A	0.2[c]	3E-05 to 3E-04	N/A
Silt Aquitard	5E-05	1E-06 to 1E-07	N/A	-0.17[b]	0.1[c]	N/A	2E-07 to 2E-06
Upper Confined Sand Aquifer	5E-04	1E-04	-0.003	N/A	0.2[c]	8E-06	N/A

[a]Assumed vertical hydraulic conductivity is one-fifth the horizontal hydraulic conductivity.
[b]Vertical hydraulic gradients represent the gradient through the silt aquitard from the upper confined aquifer to the unconfined aquifer (upward flow).
[c]Assumed values.
[d]Assumed hydraulic connection between the unconfined and upper confined aquifers in the vicinity of well 699-S29-E12.

Contaminant Source Characteristics

The following evaluation of the characteristics of the ground-water contaminant sources is based on information that was available prior to the receipt of the second round monitoring data, which provided Horn-Rapids-Landfill-specific background data. As noted earlier, the source location of the trichloroethene and nitrate contamination in the ground-water near the landfill can not be attributed to the operable subunit with existing data; neither can source quantities be defined.

A ground-water plume appears to have migrated from the Advance Nuclear Fuels Corp. property in a north-northeasterly direction (see Section 4.1.2.4), and is flowing under the landfill. Trichloroethene and nitrate are the characteristic constituents of this plume.

Trichloroethene has been detected in the soil gases within the Horn Rapids Landfill. While existing data indicate an upgradient source of the trichloroethene in the ground water, there is some uncertainty regarding the source contributions of this substance. The presence of trichloroethene in the landfill soil gas can be attributed to volatilization from either contaminated ground water or from sources within the landfill. Trichloroethene was detected, albeit at low concentrations, in soil column samples from within the landfill (see Section 4.4.7).

Without delineation of the sources of trichloroethene and nitrate, the quantities remaining in the sources cannot be estimated. For conservative transport evaluation, an infinite source of each is assumed. The release rates are assumed to be constant, continuous, and equal to their respective fluxes observed through the unconfined aquifer cross section formed by the line of wells downgradient of the landfill (MW-10 through MW-15). The assumed width of the impacted aquifer is the observed transverse boundary of the respective plume or the edge of the landfill if the plume is not bounded by the existing monitoring well network. The continuous source flux is dependent on the hydraulic conductivity and associated ground-water flow rate.

As trichloroethene has a density greater than water (see Table 5-1), there is a possibility that a dense non-aqueous phase separation of this substance may be present within the unconfined aquifer that is contributing to the concentrations observed in the landfill vicinity. If a phase separation exists in significant quantities, it would be expected to accumulate along the top of the silt aquitard. Ground water flowing past the product phase would dissolve the trichloroethene and transport the substance as a solute. For purposes of evaluating ground-water transport, the distinction between a phase separation and a vadose-zone source is immaterial as long as the solubilized trichloroethene remains constant within the unconfined aquifer at the observed concentrations.

A possible source of a dense non-aqueous phase separation of trichloroethene at the Horn Rapids Landfill is buried bulk containers of the substance. The possibility of drum disposal of carbon tetrachloride at the landfill has been stated in DOE-RL (1989a). If such drums were in fact buried intact and their integrity subsequently breached, the impacts to ground water could be significantly increased and the source assumptions used in the transport evaluation would need to be reevaluated.

Contaminant Transport Properties

In addition to the aquifer properties controlling ground-water flow (discussed above), the major parameters affecting net transport of trichloroethene and nitrate solutes in the ground water are hydrodynamic dispersion, solute retardation, solute degradation, and solute volatilization. These parameters were not measured nor were relevant data obtained for their estimation during the Phase I 1100-EM-1 Operable Unit RI. Reasonable bounded estimates for these parameters can be provided from experience, but error associated with such estimation results in uncertainty in the contaminant transport results. Because nitrate is a conservative solute in most hydrochemical environments, solute retardation, degradation, and volatilization is assumed to be non-existent. For trichloroethene, solute volatilization and degradation are considered.

Although operative, the loss of VOCs from aquifers is generally regarded to be insignificant (see Section 5.2). The volatilization process from aquifers is complex, involving vapor pressure equilibrium and diffusion through various hydrostratigraphic layers (Hutchins et al. 1985). The rate of volatilization and ultimate loss to the atmosphere is controlled by the slowest diffusion rate in the overall process. Assuming a simple two-layer system consisting of the vadose zone and capillary fringe, applying Fick's Law of diffusion at steady state, and assuming inter-layer equilibrium in accordance with Henry's Law, the rate-controlling step is diffusion through the capillary fringe using a two-film theory as presented in Hutchins et al. (1985).

The model applied to trichloroethene loss assumes that the capillary fringe is saturated, stagnant, and about 3-cm (1-in) thick, and that the vadose zone is about 10-m (3-ft) thick. The model ignores reactions occurring between the vadose-zone aqueous and gaseous phases, by assuming equilibrium is maintained and is relatively constant. Porosity and tortuosity terms are included for the media through which the trichloroethene is diffusing. Kinetics for reaching equilibrium in accordance with Henry's Law is rapid and assumed to be instantaneous. The atmosphere at the ground surface is assumed to have a zero concentration of trichloroethene. The ground water in the aquifer immediately below the capillary fringe is assumed to maintain a constant trichloroethene concentration. This latter assumption, although untrue, may be a close approximation where advection and hydrodynamic dispersion due to aquifer dispersivity dominate over diffusion (Freeze and Cherry 1979).

The results of this simple model provide an estimate of the trichloroethene volatilization half life to be 30 yr, or longer if a concentration gradient is present at the surface of the aquifer. Furthermore, the half life is shown to be independent of trichloroethene concentrations in the aquifer and is directly proportional to the thickness of the capillary fringe. The actual trichloroethene volatilization half life for the Horn Rapids Landfill vicinity is assumed to range between 30 and 100 yr. Whether such loss rates are significant depends on the actual contaminant residence time in the aquifer.

Degradation of trichloroethene in aquifers occurs primarily by hydrolysis and microbial biodegradation processes that can occur under either aerobic or anaerobic conditions. Hydrolysis reactions are reportedly observed at rates

that result in a half life of 320 d (Syracuse Research Corp. 1989a). Actual reaction rates are dependent on the hydrochemical environment and temperature. Biodegradation rates are highly variable and are dependent primarily on temperature, nutrient availability, dissolved oxygen content, and microbial species present (Torpy et al. 1989).

Degradation, both biological and chemical, involves successive dechlorination that first transforms trichloroethene to either cis- or trans-1,2-dichloroethene or 1,1-dichloroethene, then to vinyl chloride (Cline and Viste 1985). Vinyl chloride and trichloroethene primary MCLs are .002 mg/L and 0.005 mg/L, respectively (40 CFR 141). Because of the difference in molecular weights, these regulatory limits represent similar molar concentrations.

The molecular weights of trichloroethene and vinyl chloride are 131.4 g/mole and 62.4 g/mole, respectively. Therefore, total degradation of trichloroethene to vinyl chloride results in a 52.5% reduction in mass concentration of hazardous substance—i.e., water containing 0.0050 mg of trichloroethene would, ignoring volatilization, eventually contain 0.0024 mg of vinyl chloride. A dichlorinated chemical product in the transformation chain—1,1-dichloroethene—has a higher primary MCL (0.007 mg/L) than do trichloroethene and vinyl chloride (40 CFR 141). As all transformations involved result in a reduction of hazardous substance mass, the intermediate reactions reduce total hazardous substance concentrations to levels resulting in an unchanged regulatory status as compared to that posed by the initial concentrations of trichloroethene. The most conservative trichloroethene degradation evaluation considers total dechlorination of the substance. Vinyl chloride appears to be more resistant than higher chlorinated ethenes to hydrolysis and microbial degradation. The hydrolytic half life of vinyl chloride is estimated to be < 10 yr (Syracuse Research Corp. 1989d).

Considering available volatilization rate data (half life of 30 to 100 yr) and degradation rate data (total dechlorination half life of < 10 yr), along with the uncertainties associated with this information, a conservative estimate of the overall loss rate for trichloroethene in the unconfined aquifer in the Horn Rapids Landfill vicinity, expressed as a half life, appears to be approximately 30 yr. However, the ground-water transport evaluation below is conducted under various half-life assumptions—10, 30, and 100 yr and infinity (i.e., the worst-case scenario of no degradation)—to evaluate the sensitivity of this parameter.

Trichloroethene solutes react with the aquifer matrix. Such interactions retard the migration rate relative to the ground-water flow. Many types of reactions are possible. The retardation reaction considered in the ground-water transport evaluation is adsorption to the surface of organic matter in aquifer sediments. Sufficient amounts of organic matter exist in aquifer matrices to dominate over less-efficient adsorption to mineral surfaces (Griffin and Roy 1985). Natural and other anthropogenic organic solutes and colloids can enhance mobility of trichloroethene within the aquifer. Such reactions offset some of the retardation effects of matrix materials; however, operable unit ground waters contain only trace amounts of dissolved organic carbon (see Appendix N).

The K_{OC} for trichloroethene is reported to be between 41 and 126 mL/g, and more recent studies support the validity of the lower values of this range

(Syracuse Research Corp. 1989a). Retardation is expressed as a factor relating the ratio of the ground-water velocity to the plume velocity as (Freeze and Cherry 1979):

$$R_f = (V/V_c) - 1 + (\rho_b k_d/\eta)$$

where R_f is the retardation factor (unitless), V is the mean linear ground-water velocity (cm/s), V_c is the mean linear velocity of the solute plume (cm/s), ρ_b is the bulk mass density of the porous medium (g/cm^3), η is the total porosity of the porous medium (unitless), and k_d is the distribution coefficient for the solute between the medium and the ground water (mL or cm^3/g).

For a sand and gravel matrix, ρ_b/η usually ranges between 5 and 7 g/cm^3 (Mercer et al. 1982). The k_d for trichloroethene is estimated from its K_{oc} and the amount of organic matter in the porous medium (Griffin and Roy 1985):

$$k_d = (\%\ \text{organic carbon})(K_{oc})$$

where the percentage of organic carbon is expressed as a fraction. This equation assumes that the Freundlich isotherm is linear and the adsorption reaction is rapid and reversible. Slight deviations in linearity of the isotherm in the observed concentration range are not expected to significantly alter the outcome of the k_d calculations.

Organic carbon was not measured in the aquifer soil matrix. Given the depositional history of the sediments and the semiarid nature of the climate, the organic content of the porous medium is expected to be low. Typically, the organic content of aquifer sediments are greater than 1%. Aquifers in the vicinity of Spokane (a semiarid region with high energy sediment deposits) have organic carbon contents ranging from 0.1 and 2% (GAI 1987).

Assuming values between 0.1 and 0.5% carbon content and a K_{oc} of 41 mL/g, k_d ranges between 0.04 and 0.2 cm^3/g. The resulting retardation factor has values between 1.2 and 2.4. The largest uncertainty in the actual retardation factor is the unknown aquifer sediment organic carbon content.

Hydrodynamic dispersion affects plume geometry and concentrations within an aquifer. It is dependent on flow velocities, the heterogeneity of the aquifer (expressed as dispersivity), and molecular diffusion. Many researchers have noted a scale dependency for hydrodynamic dispersion (the larger the extent of an aquifer, the greater the dispersion). Such a dependency is likely due greater differences in geologic depositional histories over larger areas. The best means of estimating hydrodynamic dispersion is to observe a plume of a conservative solute in the aquifer of concern. The source concentration and contaminant flux must be well known.

Significant plumes of nitrate and tritium, both relatively conservative parameters, are known to occur at the 200 Areas. However, there is substantial uncertainty regarding the source term (i.e., disposal amounts, concentrations, times, and periodicities) for both parameters. In addition, the more significant nitrate and tritium plumes have resulted from anthropogenic recharge of such rates that substantial ground-water mounding has occurred and has, in some cases, altered regional ground-water flows. Finally, hydraulic conductivities of the unconfined aquifer in the Ringold

Formation at the 200 Areas may not be similar to such conductivities characteristic of the unconfined aquifer at the 1100-EM-1 Operable Unit.

Therefore, due to large uncertainties associated with dispersivity estimates that could be obtained from 200 Area plumes, and a lack of operable-unit-specific data, such an extrapolation analysis for the Horn Rapids Landfill ground-water transport evaluation is not warranted. Instead, a range of hydrodynamic dispersion values is used for evaluating the sensitivity of this parameter. Based on experience (GAI 1987), the values used are 21 and 37 m for longitudinal dispersivity, and 3 and 9 m for transverse dispersivity; molecular diffusion is assumed to be 2E-10 m^2/s (Freeze and Cherry 1979).

Numerical Transport Modeling

Ground-water flow and solute transport modeling was conducted using PORFLO-3, Version 1.0 (Runchal and Sagar 1989). PORFLO-3 is a numerical model for fluid flow, heat, and mass transport in porous media. Development of the code was initiated in 1979, and validation is currently being undertaken at DOE's Idaho National Engineering Laboratory. The code was compiled and executed on a MicroVAX II computer for the simulations presented below. Prior to conducting the simulations, the code was verified for correct installation and compilation by comparing test case output, provided by the author of the code, to the MicroVAX II output. The outputs compared identically with respect to the numerical results.

Solute transport simulations were run under steady state and transient conditions within a two-dimensional steady state ground-water flow field. The model mesh, which is shown on Figure 5-2, was constructed from elements 61 by 61 m (200 by 200 ft) in area and 9 m (30 ft) in depth. Hydraulic head and chemical concentrations are calculated at the center of each element. The mesh was oriented so that the principal direction of ground-water flow would generally coincide with one of the model coordinate axes over the area of interest. This orientation is favorable for accurately modeling solute dispersion and for assigning ground-water flow boundary conditions to the model. Transient simulations were run using a constant time increment of five years, which is within a factor or two of the advective and diffusive time scales and ensured stability of the numerical solution.

The model boundary conditions were not changed for the various simulations and are shown on Figure 5-2 for both ground-water flow and solute transport. For ground-water flow, the western and eastern boundaries of the mesh were set to fixed hydraulic heads of 107.0 and 104.3 m (351 and 342 ft), respectively, whereas the northern and southern boundaries were set to zero hydraulic gradient (i.e., no flow). The fixed hydraulic head boundaries controlled all flow into and out of the model as water was not allowed to enter the model domain by either precipitation or upward discharge from deeper aquifers.

The fixed head ground-water boundary conditions are generally appropriate for the physical system based on the presently available data. The western boundary coincides with the 107 m (351 ft) ground-water equipotential (see Figures 3-38 through 3-40), and the eastern boundary along the Columbia River is generally at an elevation of 104.3 m (342 ft), as observed in March 1990. Fluctuations of 0.1 to 3 m (1 to 10 ft) may periodically occur along these boundaries, which would effect hydraulic gradients and, consequently, local

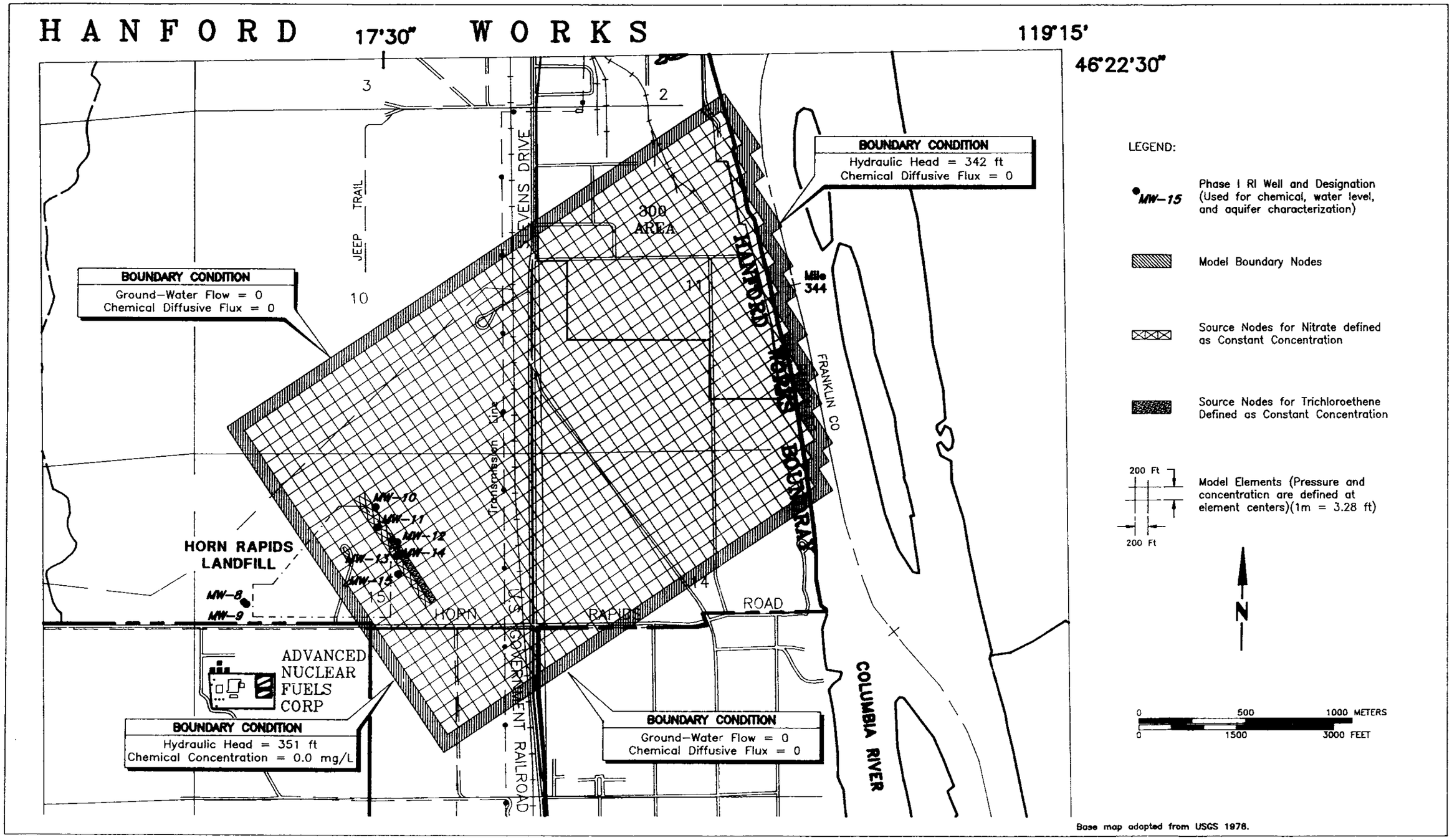


Figure 5-2. Numerical Discritization Scheme for Ground-Water Flow and Chemical Transport Modeling.

ground-water flow velocities. Further ground-water and river stage monitoring is needed to evaluate fluctuations in these boundary conditions.

The zero hydraulic gradient boundaries on the north and south of the model mesh are also appropriate for the physical system. In the vicinity of Horn Rapids Landfill, the north and south boundaries were selected along streamlines; therefore, by definition, they are not flow boundaries. East of the landfill, however, the equipotentials become parallel to the Columbia River. In these areas, some flow occurs across the northern boundary into the model domain and across the southern boundary out of the model domain. The shift in the equipotentials is generally small, however, and the flow occurs predominantly parallel to the north and south boundaries.

Model boundaries for solutes are more difficult to determine, due to the diffusion component of chemical transport, which may occur in directions across flow paths, as well as opposite to the flow direction. For the transport simulations, the western boundary was fixed at a concentration of 0.0 mg/L to represent clean ground water entering the model domain. The north, south, and eastern boundaries were set to zero gradient, although it is possible for chemical gradients to occur along these boundaries. The advantage to using zero gradient boundaries, however, is that mass may leave the domain by advection. Under the conditions of advection-dominated transport, little if any error occurs in the model results. Transport for the simulations was found to be dominated by advection, hence, the boundary conditions appear adequate.

Source terms for chemical species were designated by fixing the concentration at nodes along the eastern border of the Horn Rapids Landfill, as shown on Figure 5-2. Each node was assigned a concentration equal to the arithmetic mean of concentrations measured in samples from the wells at this location. For nitrate, a source concentration of 189 mg/L was assigned to each node and determined by averaging concentrations measured, in samples from MW-10 through MW-15. For trichloroethene, a source concentration of 0.077 mg/L was assigned to each node. Only samples from MW-12 through MW-15 were used to compute this value, because the concentrations observed in samples from MW-10 and -11 were much lower and considered to represent the periphery of the plume.

Both trichloroethene and nitrate source terms were computed from the first round of ground-water monitoring data to meet the project schedule. Incorporation of the second round ground-water data changes the source terms, at the locations specified above, very little (nitrate, 190 mg/L; trichloroethene, 0.082 mg/L). These minor differences are anticipated to have negligible effects on the simulation results presented below.

Two ground-water flow fields in homogeneous isotropic media were generated for the chemical transport simulations. The flow fields are simplified representations of the unconfined aquifer and differ from each other by only hydraulic conductivity. A low velocity flow field was simulated using an hydraulic conductivity of 5E-03 cm/s (2E-04 ft/s), and a higher velocity flow field was simulated using an hydraulic conductivity of 5E-02 cm/s (2E-02 ft/s). The corresponding average linear ground-water flow velocities were 0.005 and 0.05 m/d (0.02 and 0.2 ft/d), respectively.

The ground-water potentiometric surface for the two flow fields is shown on Figure 5-3. Because both flow fields use the same model boundary conditions and the model domain is assumed homogenous and isotropic, the potentiometric surface is invariant to hydraulic conductivity. The simulated equipotentials differ from those observed during the Phase I RI field activities (see Figures 3-38 and 3-39). The main difference is that the simulated hydraulic gradient fails to flatten near the Columbia River, possibly suggesting an increase in aquifer transmissivity in that area.

Results of Simulations

Steady state transport simulations were conducted to understand the sensitivity of input parameters to the transport of nitrate and trichloroethene. Steady state transport with a continuous source represents the maximum extent a plume can migrate, since the source is assumed continuous and time of transport is infinite. In reality, the source is finite and may deplete prior to the plume achieving a steady state configuration.

Transient simulations were conducted to understand sensitivity of input parameters, and to evaluate the potential travel time for contaminants to reach the Columbia River and intervening distances. These simulations also utilized constant source terms. Therefore, the transient results became identical to the steady state results after long simulation times.

Two factors not included within the transport configurations include: (1) infiltrating rainfall that recharges the aquifer; and (2) vertical ground-water flow due to upward hydraulic gradients. These factors, if included, would not significantly affect the flux of contaminants, but would reduce the concentrations predicted for the steady state plume configurations. It is recommended that these factors be simulated in the future for evaluating their influence on the potential contaminant concentrations.

The assumption of an absence of flow across the northeast and southeast boundaries, respectively into and out of the model domain, is anticipated to have little effect on the predicted solute plumes. If such flows were modeled as they actually exist in the ground-water flow system (Smith et al. 1990), a slight southward shift in the extents of the contaminant plumes near the Columbia River, and slightly lower solute concentrations, relative to those predicted would result.

Presented below is a summary of the more relevant results of ground-water transport simulations for nitrate and trichloroethene.

Nitrate: Nitrate is usually considered conservative and was modeled assuming no retardation, no degradations, and no volatilization. The source, as in all the simulations, is assumed to be constant and continuous. Hydrodynamic dispersion and horizontal hydraulic conductivity are the variable input parameters. Figures 5-4, 5-5, and 5-6 illustrate the results of steady state simulations. These represent the maximum potential concentration distributions and fluxes of nitrate to the Columbia River with available data. The figures provide the calculated fluxes of nitrate to the Columbia River, which vary between 60 and 600 mg/s.

The steady state simulations indicate that ground water having concentrations in excess of the 1° MCL (44 mg/L) will reach the river.

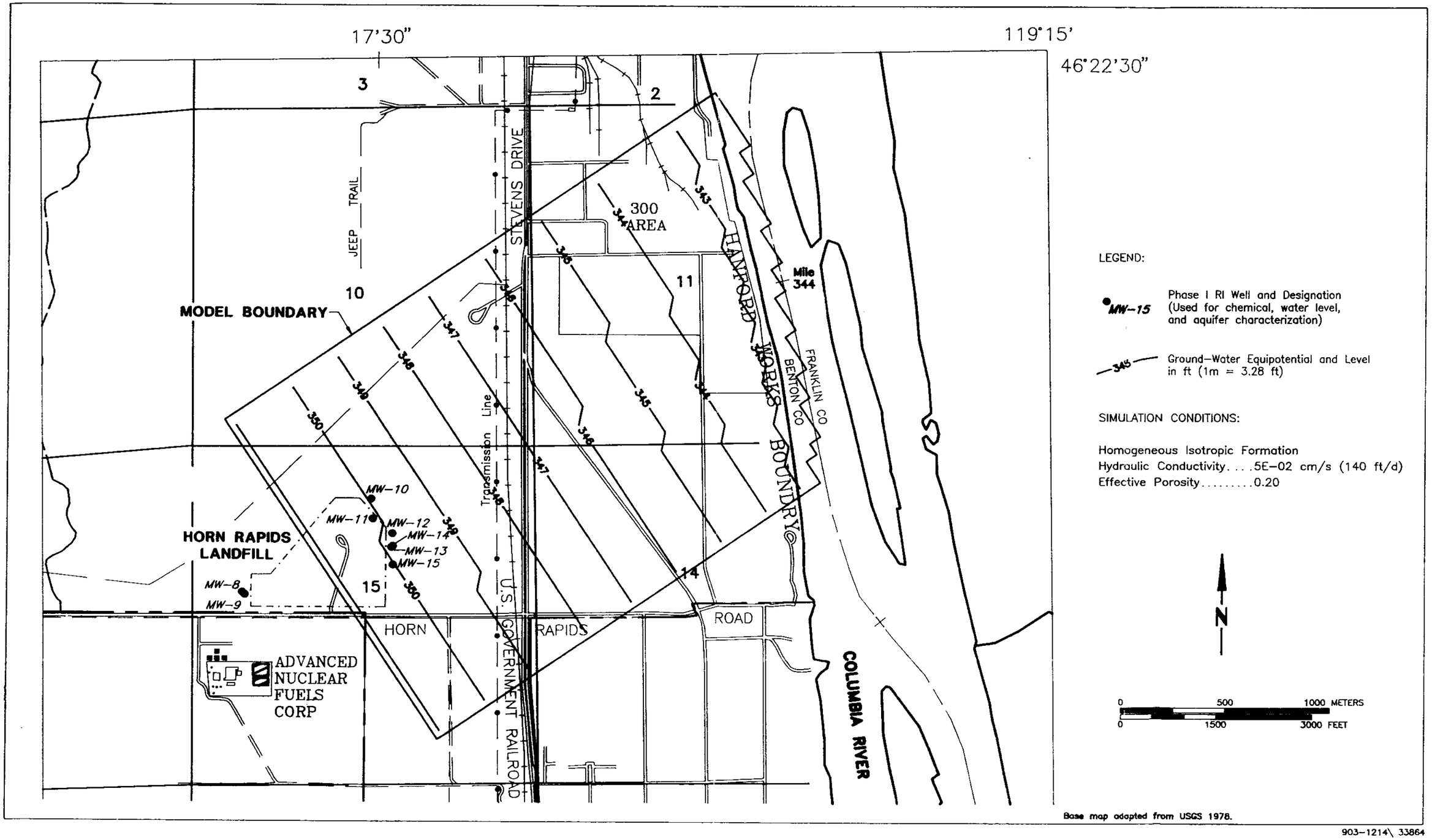


Figure 5-3. Simulated Steady State Potentiometric Surface for the Unconfined Aquifer.

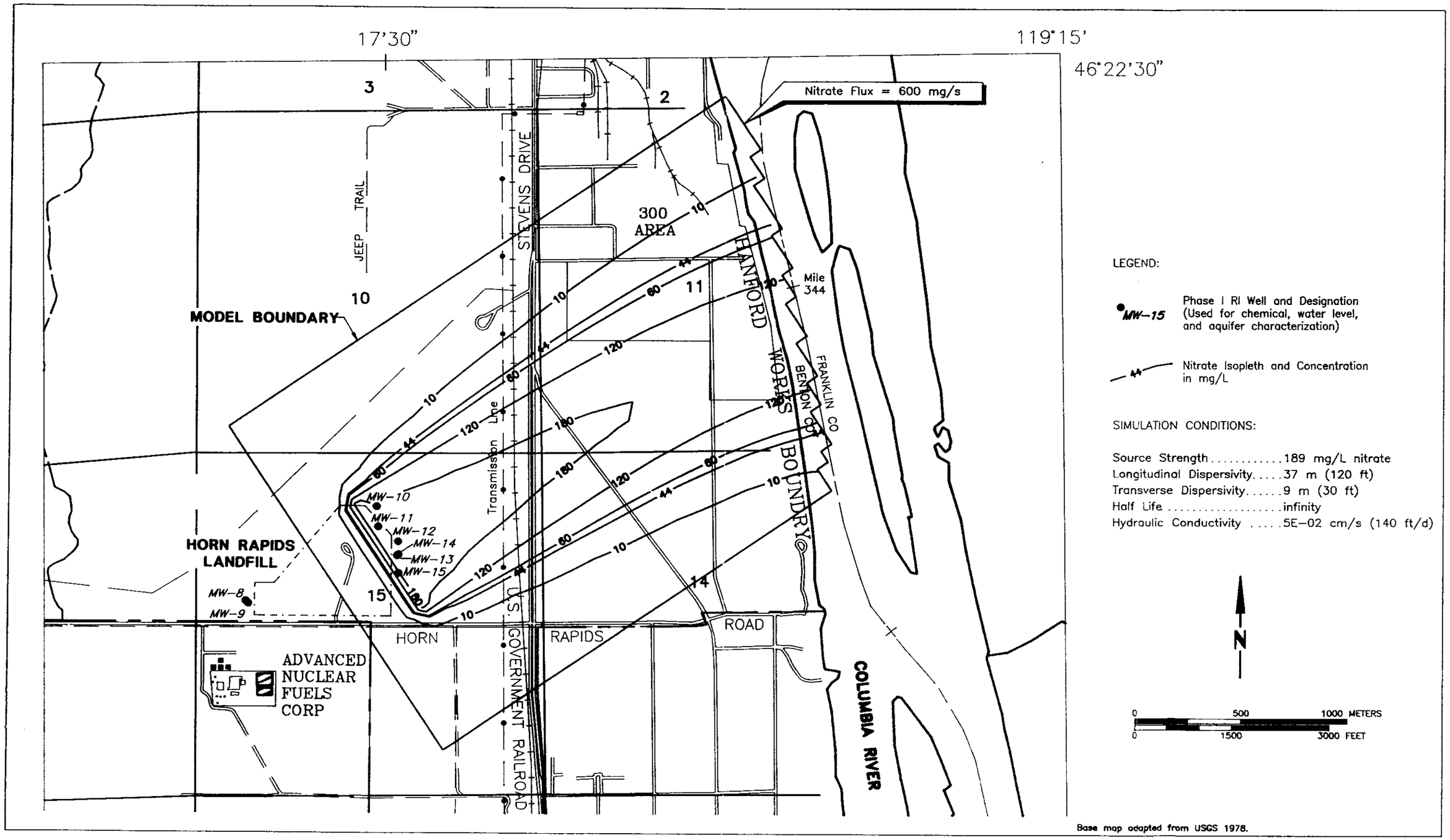


Figure 5-4. Steady State Simulation of Nitrate Concentrations in the Unconfined Aquifer - High Velocity Flow Field, Large Dispersion.

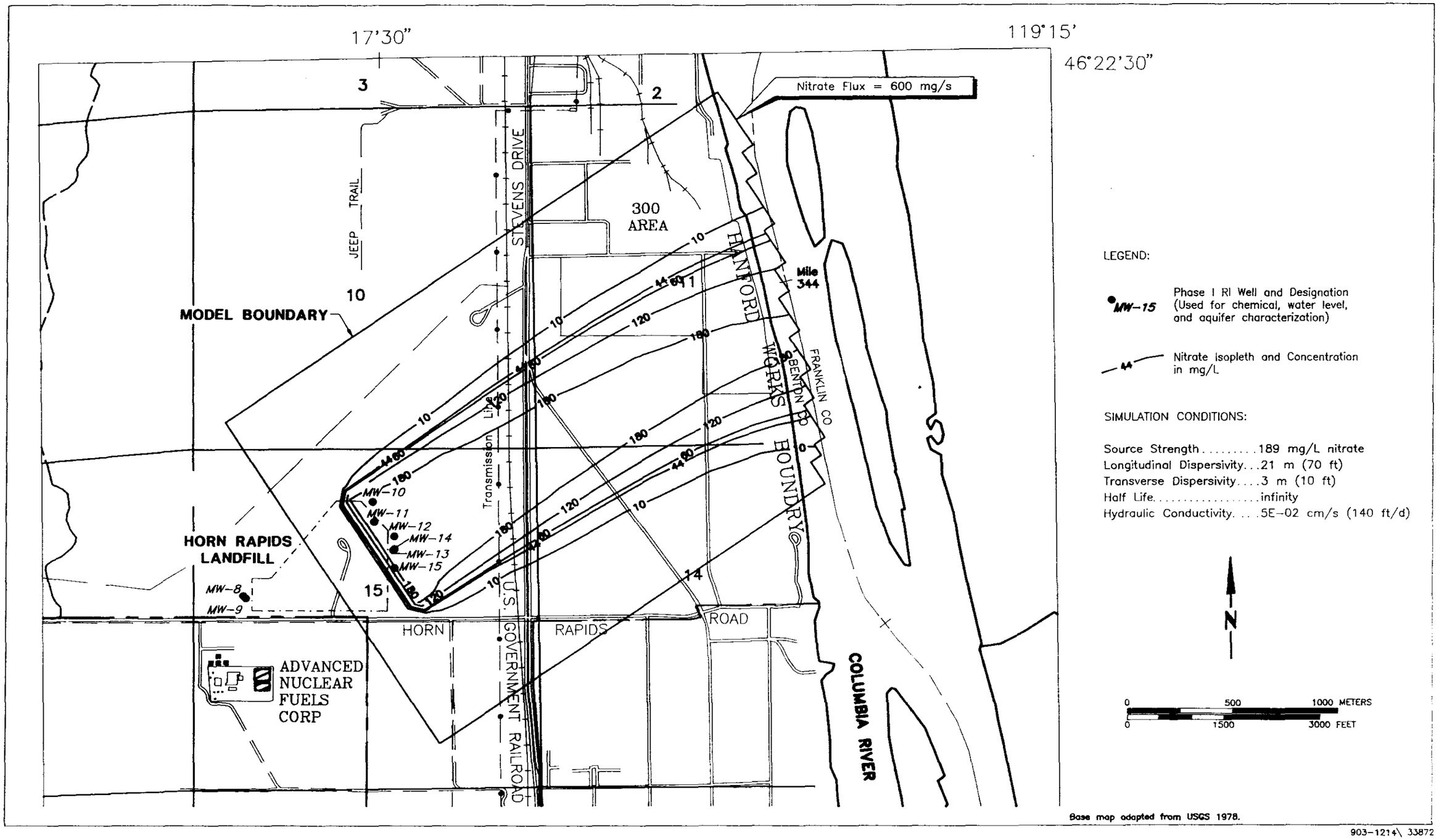


Figure 5-5. Steady State Simulation of Nitrate Concentrations in the Unconfined Aquifer - High Velocity Flow Field, Small Dispersion.

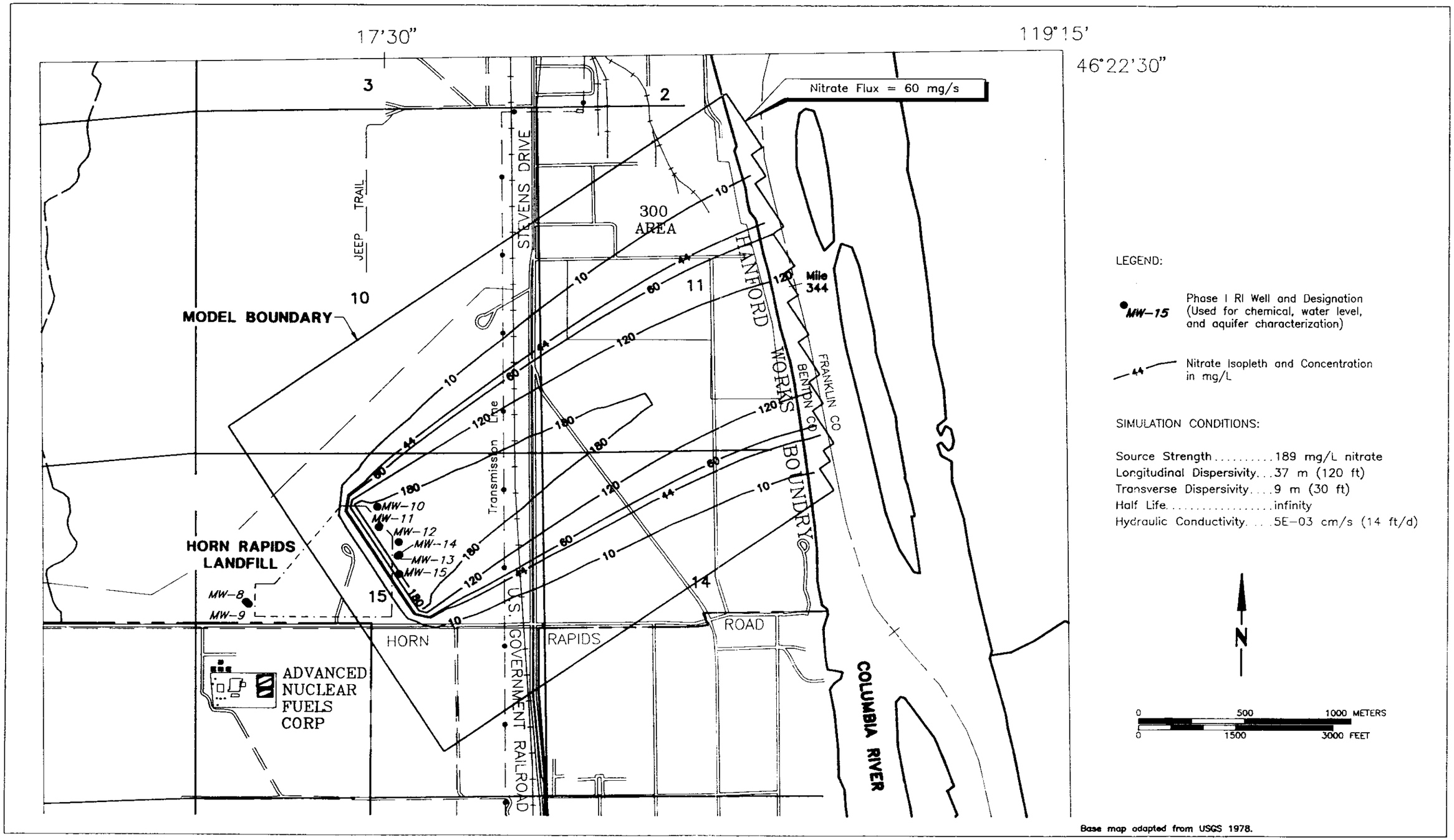


Figure 5-6. Steady State Simulation of Nitrate Concentrations in the Unconfined Aquifer -Low Velocity Flow Field, Large Dispersion.

Transient simulations of the higher velocity flow field, as shown in Figure 5-7, indicate that the 1° MCL is exceeded at the river after approximately 100 yr; simulations assuming the lower velocity flow field indicate that the time period required to exceed the MCL at the river is in excess of 1,000 yr.

The results illustrate the conservative nature of nitrate in that the flux to the river is proportional to the ground-water flow rate which is dependent on the hydraulic conductivity of the aquifer. Uncertainty exists for the best representation of hydraulic conductivity for the unconfined aquifer.

The simulations presented in Figures 5-4 and 5-5 differed only by changing the hydrodynamic dispersion. Hydrodynamic dispersion, although changing the general geometry of the plume, does not have a significant influence on the flux of nitrate entering the river. This again reflects the conservative nature of nitrate and the impact of the continuous source assumption. Both longitudinal and transverse dispersion were changed by approximately 70%. The resulting change in longitudinal length of the plume was greater than 70%, but the transverse width only changed by about 17%.

Trichloroethene: Trichloroethene is not considered conservative in hydrologic systems. Steady state simulations of trichloroethene transport are illustrated in Figures 5-8 through 5-11, with half lives of 10 yr, 30 yr, 100 yr and infinite half life, respectively. All other transport parameters are held constant. The values of the other transport variables are provided on the figures. Half lives dramatically affect the configuration of the trichloroethene plume, particularly in determining whether the plume, in a practical sense, reaches the Columbia River. The steady state simulation with infinite half life (i.e., no degradation or volatilization) is used as a baseline comparison to the effects of half lives. Fluxes of trichloroethene to the river are also provided on the respective figures and range between 5E-04 to 1E-01 mg/s.

The travel time of trichloroethene in ground water between two point generally exceeds that of the ground water itself due to the adsorption onto and desorption from the aquifer matrix. In PORFLO-3, these processes are modeled as linear and reversible via a retardation coefficient (Freeze and Cherry 1979). Figure 5-12 shows results for a transient trichloroethene simulation, with the assumption of an infinite half life and an average retardation coefficient of 1.75. Steady state conditions are realized after approximately 200 yr. Under the assumption of the higher flow field, the 1° MCL of 0.005 is observed at the Columbia River after a period of about 80 yr. Additional simulations indicated that travel times are not very sensitive to the retardation factor.

Figure 5-13 illustrates the steady state plume configuration when the 30-yr half life is kept constant and the flow velocity is decreased, relative to the simulation results presented in Figure 5-9, by lowering the assumed hydraulic conductivity. The velocity of ground water has a dramatic effect on the ultimate size of the trichloroethene plume. Figure 5-13 indicates that a detectable plume will not enter the river (calculated flux of 6E-10 mg/s). Although the ground-water flow velocity is only one order of magnitude less than that used in the simulation illustrated in Figure 5-9, a reduction of almost seven orders of magnitude in flux of trichloroethene to the river is

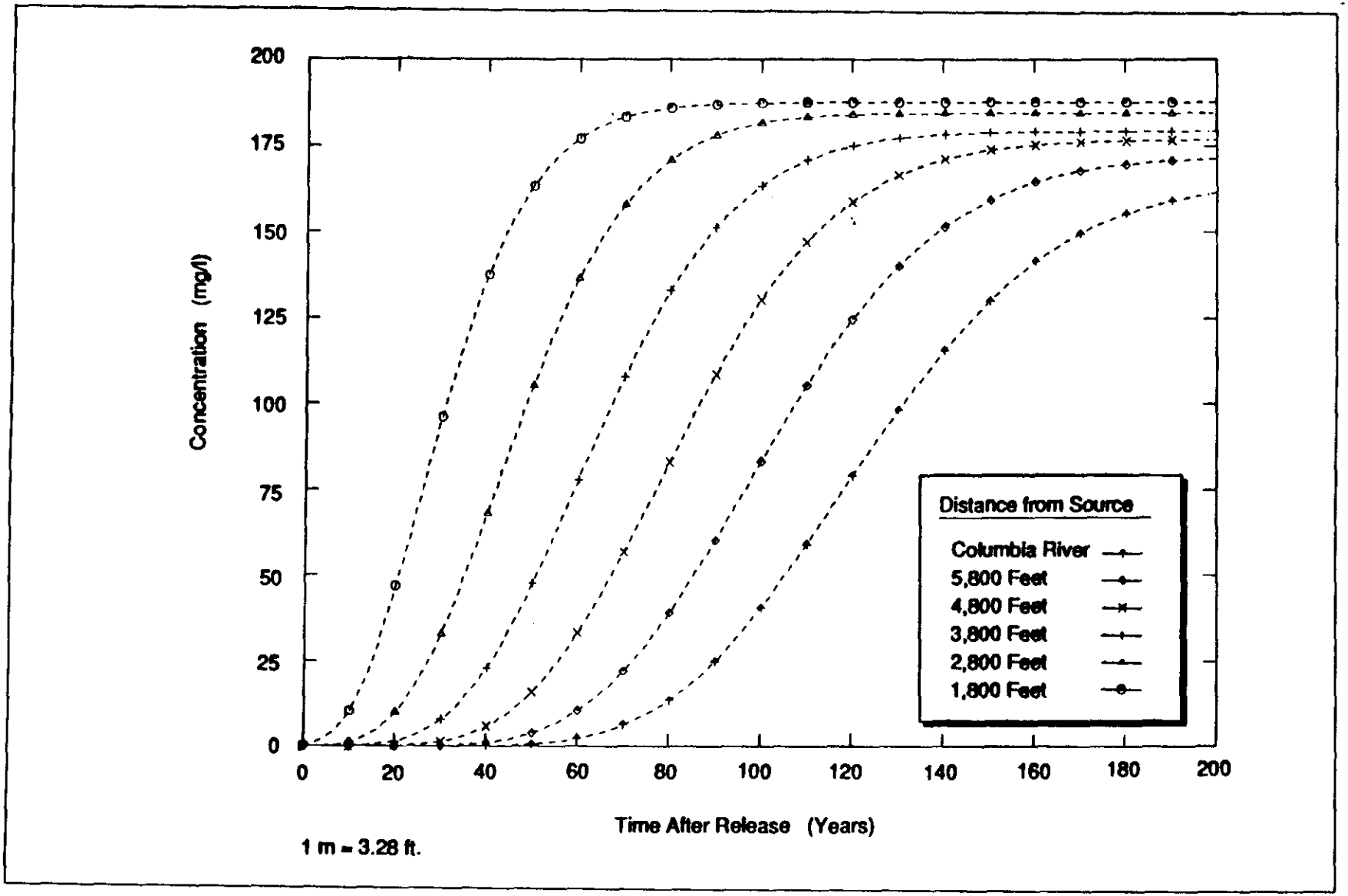


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Figure 5-7. Simulated Nitrate Concentrations at Selected Locations in the Unconfined Aquifer - High Velocity Flow Field and Large Dispersion

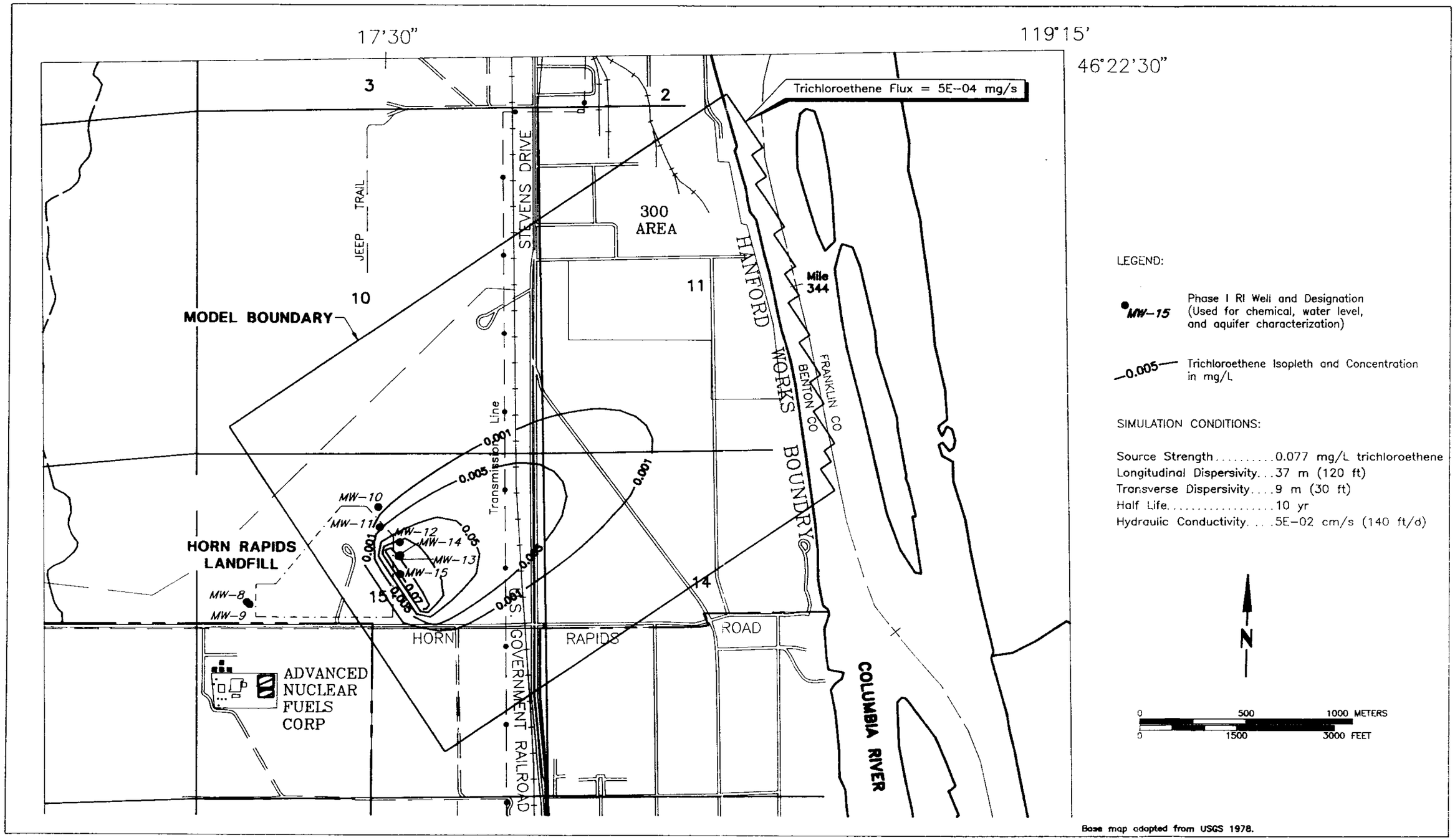

Figure 5-8. Steady State Simulation of Trichloroethene Concentrations in the Unconfined Aquifer - 10 - yr. Half Life, High Velocity Flow Field, Large Dispersion.

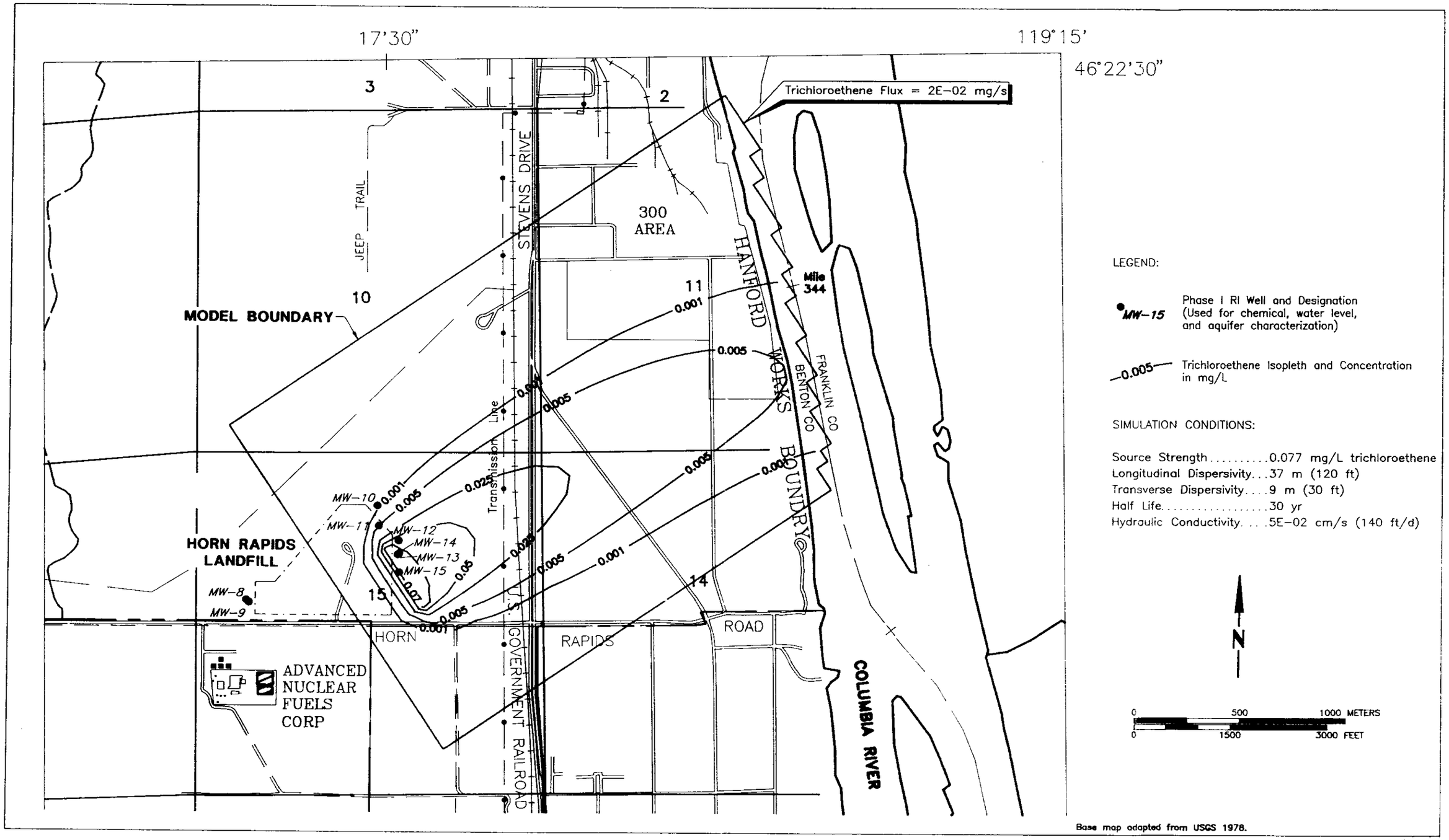

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Figure 5-9. Steady State Simulation of Trichloroethene Concentrations in the Unconfined Aquifer - 30 - yr. Half Life, High Velocity Flow Field, Large Dispersion.

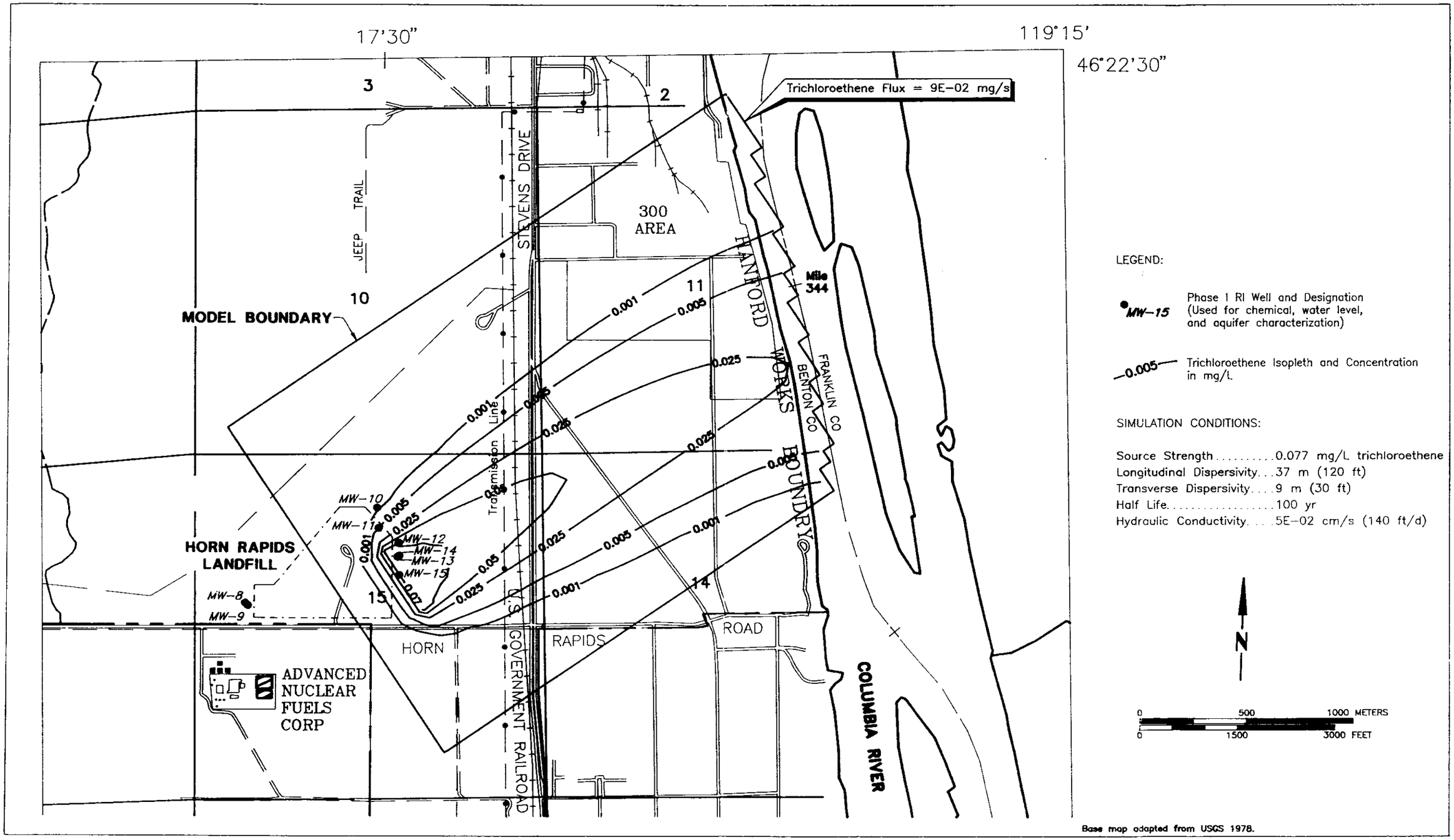

Figure 5-10. Steady State Simulation of Trichloroethene Concentrations in the Unconfined Aquifer - 100 - yr. Half Life, High Velocity Flow Field, Large Dispersion.

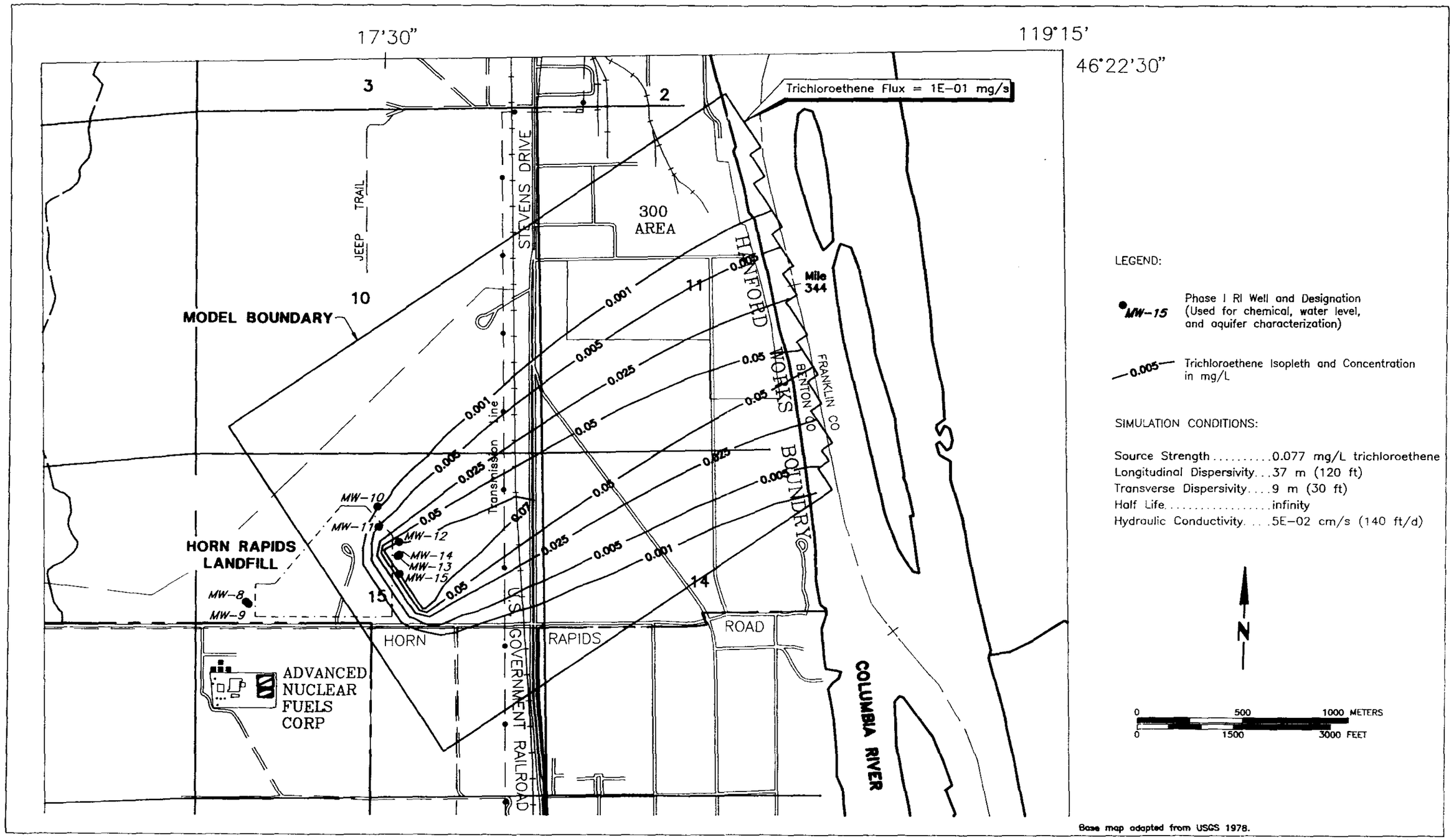

Figure 5-11. Steady State Simulation of Trichloroethene Concentrations in the Unconfined Aquifer - Infinite Half Life, High Velocity Flow Field, Large Dispersion.

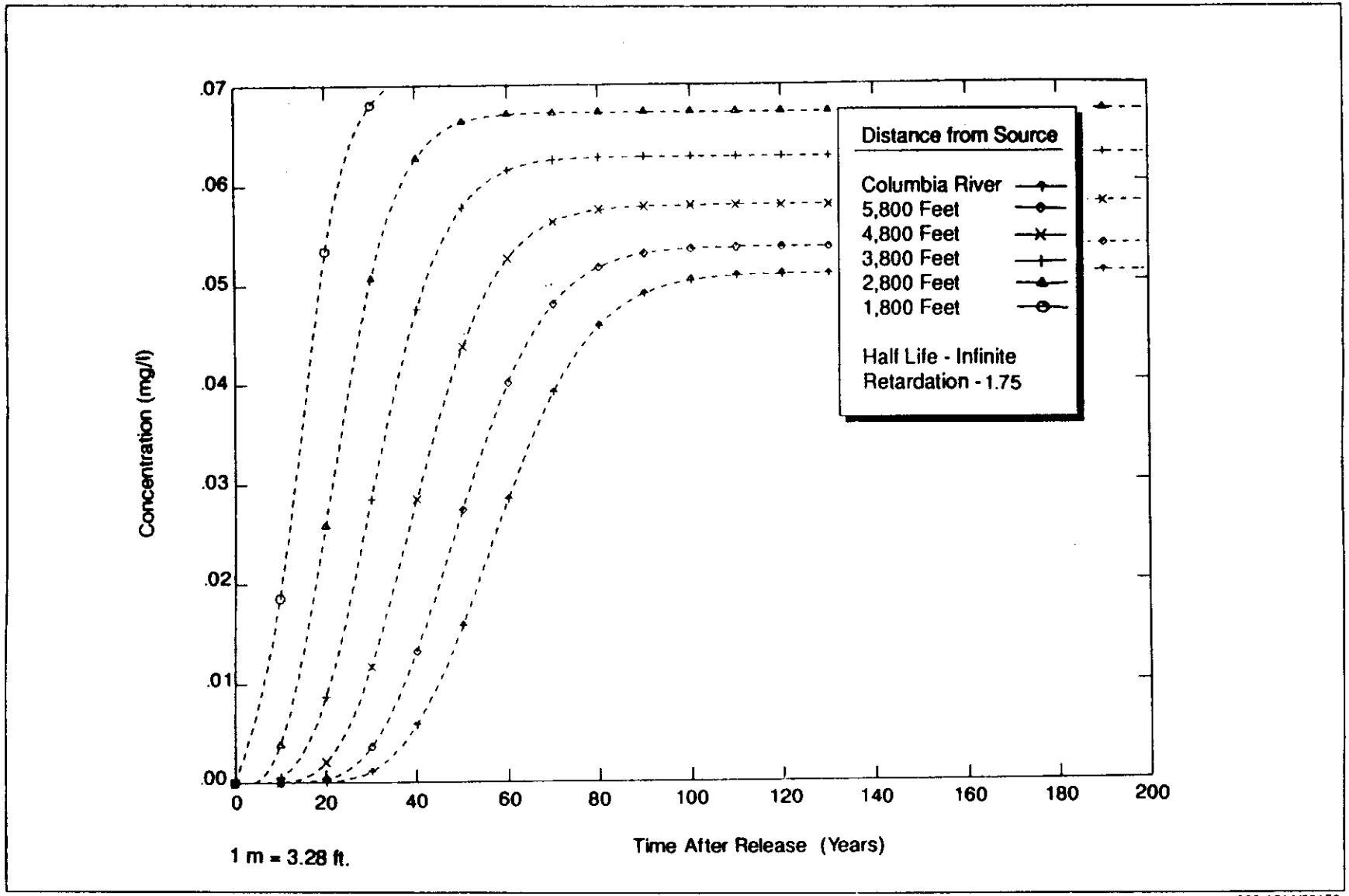

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Figure 5-12. Simulated Trichloroethene Concentrations at Selected Locations in the Unconfined Aquifer - Infinite Half Life, Retardation of 1.75, High Velocity Flow Field, and Large Dispersion.

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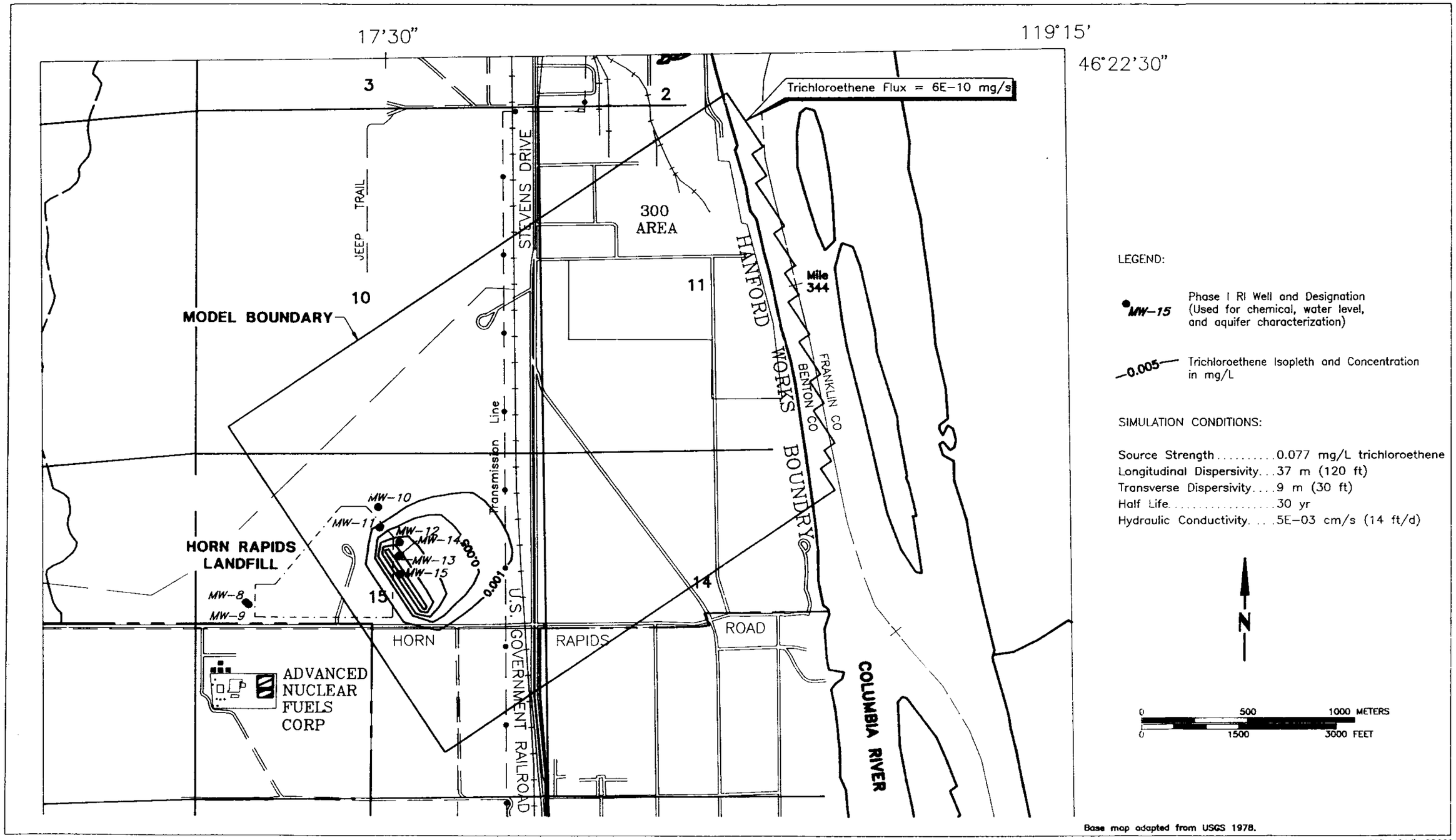

Figure 5-13. Steady State Simulation of Trichloroethene Concentrations in the Unconfined Aquifer - 30 - yr. Half Life, Low Velocity Flow Field, Large Dispersion.

realized. Clearly, the migration of trichloroethene in ground water is very sensitive to residence time and ground-water flow velocities.

Figure 5-14 illustrates the steady state plume configuration when longitudinal and transverse hydrodynamic dispersion are decreased relative to the conditions in the simulation illustrated in Figure 5-9. The width and length of each corresponding concentration isopleth in the simulation illustrated in Figure 5-14 are about 24% less broad and about 0.3% larger than those presented in the former simulation. As the differences in the assumed transverse and longitudinal dispersion values are about a 70% between simulations, these results suggest that the plume configuration and contaminant migration are not highly sensitive to dispersion.

5.3.4 Surface-Water Transport

Section 5.3.3.2 demonstrates that a conservative nitrate flux rate to the Columbia River, resulting from the discharge of contaminated ground water present in the vicinity of the Horn Rapids Landfill, is approximately 6E+02 mg/s (see Figure 5-4). The theoretical maximum nitrate concentration at the infinitesimally thin boundary layer adjacent to the point of ground-water discharge would be approximately 140 mg/L under the ground-water transport scenario presented in Figure 5-4. This value provides an artificially high bounding concentration for any given point in the Columbia River water column.

For trichloroethene, the conservative estimate of flux to the river is shown to be approximately 1E-01 mg/s (see Section 5.3.3.2 and Figure 5-10). The theoretical maximum concentration of trichloroethene at the point of entry into the river under the circumstances presented in Figure 5-10 is indicated to be approximately 0.05 mg/L.

Upon reaching the river, both substances will be substantially diluted due to the high discharge rate of the river. Even at low stages, the Columbia River discharges about 1,000 m^3/s (35,000 ft^3/s) (see Section 3.3.1.1). Therefore, after complete mixing at low river stage (ignoring plant assimilation of nitrate, volatilization of trichloroethene, and additional dilution volume provided by the Yakima and Snake Rivers further downstream), the concentrations of nitrate and trichloroethene corresponding to the flux rates specified above are 6E-04 and 1E-07 mg/L, respectively. These values aid in bounding the low end of the surface-water contaminant concentration spectrum.

Reasonable yet conservative concentrations are required to assess impacts to the human populations utilizing Columbia River water and aquatic communities within the river. The nearest point of human exposure below the predicted ground-water discharge zone is the City of Richland water intake (see Figure 3-1). This intake is approximately 5 km (3 mi) below the discharge zone. Figure 3-1 shows several irrigation intakes located along this particular reach of the river, but any elevated nitrates would serve as an effective fertilizer to the crops to which it is applied, and irrigation application would effectively treat the trichloroethene through the enhancement of volatilization and microbial degradation. Therefore, any human and environmental impacts associated with potentially contaminated irrigation water are assumed to be negligible and the remainder of this evaluation focuses on the city intake.

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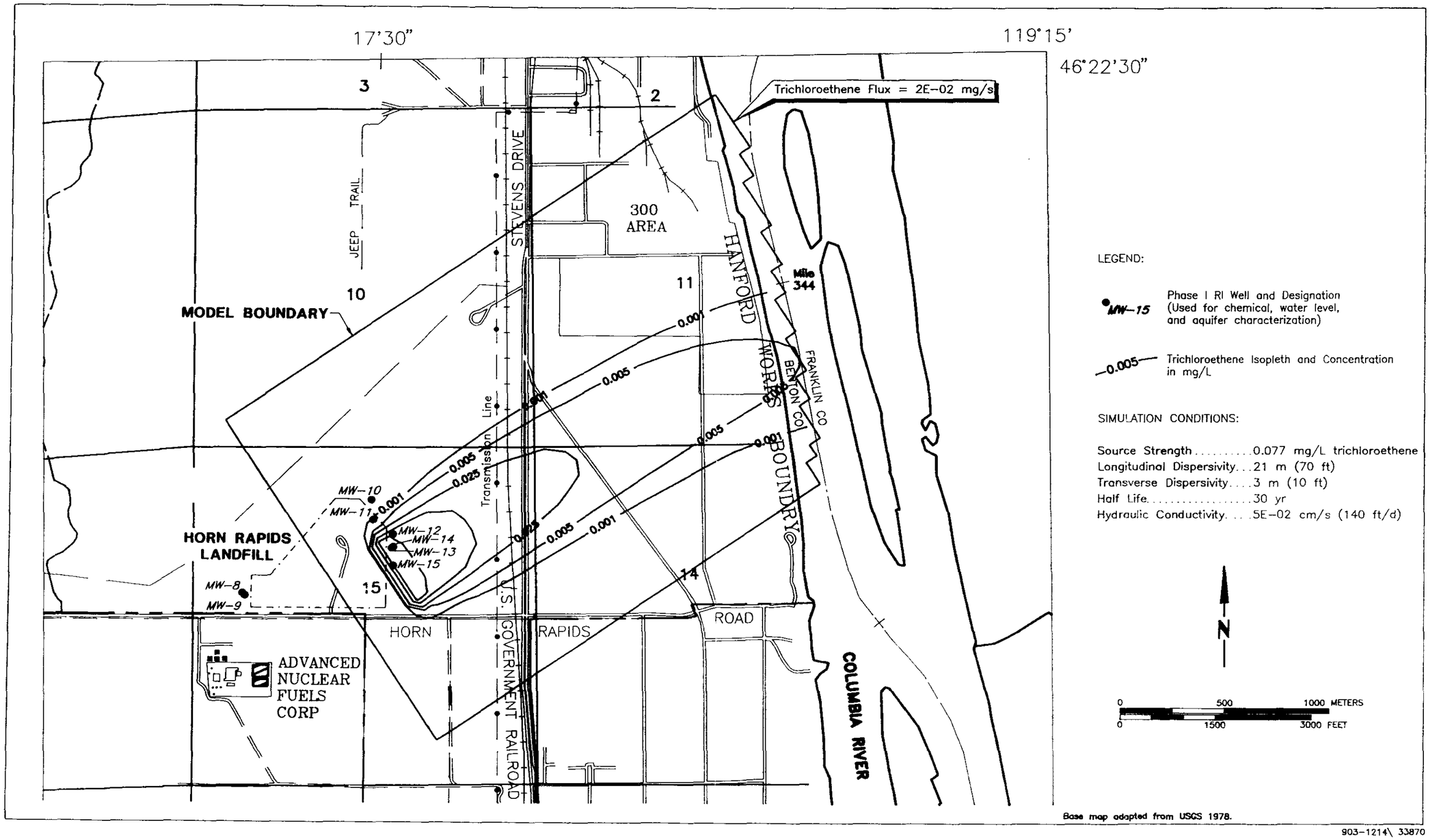

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Figure 5-14. Steady State Simulation of Trichloroethene Concentrations in the Unconfined Aquifer - 30 - yr. Half Life, High Velocity Flow Field, Small Dispersion.

With the knowledge that the city's water intake is located approximately 4.6 m (15 ft) beyond the shoreline, and about the same distance below the water surface (Gillum, M., City of Richland Water and Waste Utilities Department [Personal communication] May 18, 1990), a reasonable yet conservative dilution factor can be estimated. The cross sectional area of that portion of the river water column bounded by the shoreline and the location of the intake, assuming a constantly sloping river bed, is:

$$A_1 = (4.6\ m)(4.6\ m)/2 = 11\ m^2.$$

If it is further assumed that the intake derives one-half of its water from this segment of the river and the other half from the segment extending another 4.6 m from shore, and that the depth of the river does not increase, then:

$$A_2 = (4.6\ m)(4.6\ m) = 21\ m^2$$

and:

$$A = A_1 + A_2 = 33\ m^2.$$

If contaminant mixing is restricted entirely to this portion of the water column, and complete mixing within this portion is assumed to occur by the time the surface-water plume reaches the intake, the estimated concentration at the intake is then:

$$C_I = F/AV(1{,}000\ L/m^3)$$

where C_I is the contaminant concentration at the intake (mg/L), F is the flux rate estimated above (mg/s), A is the cross sectional area derived above (m^3), V is the mean velocity of the portion of the river under consideration. Section 3.3.1.1 indicates that the velocity of the Columbia River at low stage is approximately 1 m/s. A conservative estimate of the mean velocity within the portion of the river defined above is assumed to be 0.5 m/s (accounting for the fact that slower velocities are generally encountered near shore). Therefore, the estimated intake concentrations for nitrate and trichloroethene are 4E-02 and 6E-06 mg/L, respectively.

There are currently insufficient data to quantitatively estimate river concentrations of the single 1100-EM-1 ground-water contaminant of potential concern, tetrachloroethene (see Section 4.5.2). However, by analogy to the trichloroethene and nitrate evalations above, the concentrations of tetrachloroethene in the Columbia River can be expected to be very low.

5.3.5 Biological Transport

As noted in Section 5.1.5, there is a potential for contaminant transport to and through the terrestrial and aquatic biological media at and near the 1100-EM-1 Operable Unit. The evaluation of such transport is taken into account in the baseline risk assessment in Section 6 because of the potential harmful effects to humans, when they are the ultimate receptors in the food chain, and to the wildlife community, itself.

The only terrestrial organism that is a direct component of the human food chain having a likelihood of contributing to human contaminant exposures, and that is known to utilize the operable unit (i.e., the Horn Rapids Landfill), is the mule deer (see Section 3.7.2.3). Contaminant transport through this species is addressed below in Section 5.3.5.1. The DOW identified two sensitive migrant bird species, of concern to the agency (i.e., the Swainson's hawk and the long-billed curlew), that are known to nest in the vicinity of the Horn Rapids Landfill (see Section 3.7.2.3). These two birds are therefore regarded as sensitive terrestrial ecosystem indicators and are evaluated, with respect to their potential for being harmed by landfill contamination, in Section 5.3.5.1.

Contaminant transport to and through the aquatic community in the Columbia River is evaluated below in Section 5.3.5.2.

Contaminant transport through an ecosystem is difficult to characterize due to lack of system- and species-specific data. Conservative simplifying assumptions and surrogate uptake factors are used liberally in the terrestrial and aquatic biological transport pathway evaluations that follow. While the results are useful in assessing potential risks in Section 6, they must be regarded as semiquantitative at best.

5.3.5.1 Terrestrial Biological Transport. Contaminants of potential concern within the soil column of the Horn Rapids Landfill are arsenic, chromium, and PCB (see Section 4.4.7). The conservatively biased mean concentrations for landfill surface soils for each contaminant (see Section 5.3.1.2) are respectively 0.1, 0.8, and 3.5 mg/kg. Surface soils are used because of the biased nature of the subsurface soil sampling design for the landfill—areas of known and suspected waste deposition were intentionally avoided because of occupational safety and environmental concerns (see Section 4.4.7). Thus, for the purpose of this analysis, deep root contaminant uptake by plants (> 0.6 m [2 ft]) is considered insignificant.

Consumption of contaminated venison must be assessed to determine whether it poses a potential human health problem. A generalized contaminant transport pathway for human consumption of mule deer (see Section 3.7.2.3) can be represented as:

Soil → Plant Leaves → Mule Deer → Man

Plant leaf uptake factors (dry leaf tissue weight/dry soil weight) for arsenic, chromium, and PCB are estimated to be 0.04, 0.2, and 0.4, respectively. These are conservative values, based on leafy vegetable uptake, obtained from EPA (1986c), for arsenic and PCB; the value for chromium, obtained from Kabata-Pendias and Pendias (1984), is based on uptake in corn leaves.

Uptake factors for beef fat are used as surrogates for deer. On a dry weight basis (deer fat/leaf tissue), the PCB uptake factor for deer is thus 4 and, in the absence of element-specific data, a surrogate deer uptake value for arsenic and chromium of 0.1 is derived from the average of conservative values for cadmium, mercury, selenium, and zinc (EPA 1986c).

A conservative mule deer home range of 3,170 ha (7,830 ac)—the lower one-tailed 95% confidence limit of the mean mule deer home range at the Hanford

Site (Eberhardt et al. 1984)—is used, along with the assumption that the browsing rate is uniform throughout the range. As the area of the Horn Rapids Landfill is approximately 20 ha (50 ac) (see Section 3.1.2.6), a mule deer residing in the vicinity would obtain only about 0.6% of its food from the landfill. For the purpose of this evaluation, the incidental ingestion rate of soil for deer—estimated to be 0.15% of the total diet for white tails (Paustenbach 1989)—is assumed to be negligible.

Thus, the concentrations of arsenic, chromium, and PCB in Horn Rapids Landfill vicinity mule deer venison are conservatively determined to be 2E-06, 1E-04, and 3E-02 mg/kg (on a dry weight basis), respectively. These values are used semiquantitatively in Section 6 to assess the potential risk posed to humans due to venison consumption.

The Swainson's hawk and the long-billed curlew are sensitive bird species that are used to assess potential environmental impacts due to contaminant releases at the Horn Rapids Landfill. Generalized contaminant transport pathways for these species (see Section 3.7.2.3) can be represented as:

```
Soil → Plant Leaves → Insects → Long-Billed Curlew
          |                  ↘
          |                   Swainson's Hawk
          └→Small Mammals——↗
```

The surface soil contaminant concentrations and corresponding plant uptakes factors are assumed to be identical to those used in the mule deer analysis above. In lieu of specific data, the above deer uptake factors derived from cattle fat tissue are also applied to small mammals.

No insect intake factors are known to exist for the landfill contaminants of potential concern. One study indicates a grasshopper uptake factor of approximately 1 (on a dry weight basis relative to soil concentrations) for dioxin (Paustenbach 1989). Therefore, this surrogate value is used for all three landfill contaminants of potential concern.

Small mammals and insects are both assumed to reside entirely within the landfill boundaries. Thus, the estimated contaminant concentrations attributable to the landfill within each type of prey (on a dry weight basis) are estimated to be:

- Insect tissue

arsenic	1E-01 mg/kg
chromium	8E-01 mg/kg
PCB	4E+00 mg/kg

- Small mammal tissue

arsenic	4E-04 mg/kg
chromium	2E-02 mg/kg
PCB	6E+00 mg/kg.

These values are used in Section 6, in a semiquantitative manner, to assess the potential harm to local populations of the two sensitive bird species.

5.3.5.2 Aquatic Biological Transport. Section 5.3.4 demonstrates that the 1100-EM-1 Operable Unit ground-water contaminant of potential concern, tetrachloroethene, along with trichloroethene and nitrate, could be found in the water column of the Columbia River. As noted in Section 5.2.2, nitrate is an essential nutrient and is not expected to bioaccumulate. Tetrachloroethene and trichloroethene, however, do display a propensity to bioaccumulate.

Once the tetrachloroethene and trichloroethene reach the Columbia River, their concentrations will vary—decreasing from the point of entry into the river downstream to a point where they become uniformly mixed throughout the water column. As the discharge of the river is extremely high in comparison to the contaminant influx, the concentration upon complete mixing will be negligible (see Section 5.3.4). For the purposes of assessing the potential effects of aquatic biological transport of trichloroethene in the Columbia River, a conservatively biased estimated concentration at the City of Richland water intake is used—6E-06 mg/L. This concentration, derived in Section 5.3.4, is high in comparison to actual concentrations that would be encountered throughout the vast majority of the river water column; data are currently insufficient to allow for a quantitative assessment of the effects of tetrachloroethene.

As trichloroethene bioaccumulates, with a bioconcentration factor of 17 L/kg (on a wet weight basis), the resulting contaminant concentration in the tissue of fish inhabiting the vicinity of the city water intake is conservatively estimated to be 1E-04 mg/kg. Analogously, tetrachloroethene concentrations in fish tissue are expected to also be low. The trichloroethene value is used in the baseline risk assessment in Section 6 to quantitatively evaluate potential risks to human health that could arise through the consumption of contaminated fin fish.

6.0 BASELINE RISK ASSESSMENT

This section provides an assessment of the threats posed, to human health and the environment, by the contaminants that have been released from the 1100-EM-1 Operable Unit. Operable unit contaminants of potential concern are identified by environmental medium and operable subunit in Section 4 (Nature and Extent of 1100-EM-1 Operable Unit Contamination). The environmental fate and transport of these contaminants is analyzed in Section 5 (Contaminant Fate and Transport Analysis) to estimate the forms and concentrations of contaminants at various points along potential pathways of migration. This information is utilized within this section to characterize potential human health and environmental risks.

In addition to the operable unit contaminants of potential concern, risks related to trichloroethene and nitrate, which are associated with the plume that apparently originates upgradient of the Horn Rapids Landfill, are also assessed. Risks associated with the only known operable unit ground-water contaminant of potential concern, tetrachloroethene at the 1100-2 Paint and Solvent Pit, are not quantitatively assessed due to a lack of information regarding the magnitude and extent of contamination (see Section 4.5.2).

The human health evaluation is presented in Section 6.1; the environmental evaluation is presented in Section 6.2. Both subsections are organized in the following manner:

- Exposure assessment
- Toxicity assessment
- Risk characterization.

6.1 HUMAN HEALTH EVALUATION

The assessments of contaminant exposures, toxicities, and overall risks from a human perspective are provided below in Sections 6.1.1, 6.1.2, and 6.1.3, respectively.

6.1.1 Human Exposure Assessment

The purpose of a human exposure assessment is to estimate the magnitude, frequency, duration, and route of exposure to the potential contaminants of concern that human receptor populations may experience. This exposure estimation can then be integrated with appropriate toxicity information to allow for an assessment of the nature and extent of any health threats from the contaminants of potential concern. The exposure assessment considers measured and estimated contaminant concentrations in various environmental media, presented in Sections 4 and 5, identifies potential human receptor populations, described in Section 3.7, and determines probable routes of contaminant intake.

Human populations having a reasonable potential of being exposed to 1100-EM-1 Operable Unit contamination are briefly characterized below in Section 6.1.1.1. Pathway exposures to such populations are estimated in Section 6.1.1.2, and pathway exposures are integrated into overall exposures

in Section 6.1.1.3. Uncertainties associated with the exposure assessment are discussed in Section 6.1.1.4, and a concise exposure assessment summary is provided in Section 6.1.1.5.

6.1.1.1 Potential Human Receptor Populations. Identification of the human populations at greatest risk from exposure to the contaminants of potential concern at the 1100-EM-1 Operable Unit is dependent on present and future land and water use. In addition to land- and water-use assumptions, the geographic distribution of the operable subunits, the location of worker and residential populations, and the opportunity for contact with transported contaminants all influence the identification of plausible human receptors.

Currently, the 1100-EM-1 Operable Unit is located in an area zoned for either industrial or restricted use, but agricultural and residential areas occur nearby. For the purposes of this risk assessment, it is assumed that future land- and water-use patterns will remain similar to the existing conditions, as county and city land-use plans, current construction plans for the 1100 Area, and the availability of city water to residential lots throughout the vicinity indicate no significant changes in the foreseeable future (see Sections 3.7.1.1 and 3.7.1.2).

The proposed human receptor populations for the contaminants of potential concern for the 1100-EM-1 Operable Unit include:

- Industrial workers with direct access to and work requirements at the operable subunits
- Workers at permanent facilities near the operable subunits (the closest worker populations in this category are shown in Figure 3-1 and discussed in Sections 3.7 and 5.3)
- Individuals living near the operable unit (the nearest residential populations are shown in Figure 3-1 and discussed in Sections 3.7 and 5.3).

6.1.1.2 Estimated Human Exposures. The following discussion provides the assumptions, information, and computational methods used to estimate chronic exposures to the three human receptor populations identified above. For all populations, several routes of exposure have been eliminated from further consideration. First, short-term, subchronic exposure is not evaluated further because the nature of the contaminant sources and releases precludes short-term fluctuations in contaminant concentrations that might produce acute or subchronic effects.

Second, the direct ingestion of, or dermal contact with, contaminated ground water is eliminated as a likely exposure for all populations. No wells downgradient of the 1100-2 operable subunit, the only waste management facility assigned to the 1100-EM-1 Operable Unit with known ground-water contamination, are used as sources of drinking water; the same is true for the Horn Rapids Landfill vicinity (see Section 3.7.1.2). Thus, no impacts to any wells downgradient of the operable unit are predicted (see Sections 5.3.3.1 and 5.3.3.2), other than via surface-water transport, which is evaluated below.

Third and finally, dermal contact with surface water is not evaluated further. Although the Columbia River is used for swimming, the duration of exposure through recreational activities and other types of dermal contact (e.g., washing and showering) is short. The risk from dermal contact with the surface water is considered negligible relative to the oral ingestion pathway for the contaminants that may reach surface waters.

A matrix provided in Table 6-1 summarizes the human receptor populations and potentially applicable contaminant exposure routes and pathways.

Employees with Direct Access to the Operable Subunits

The first receptor population, the industrial worker at the operable subunits, is assumed to have occasional access to the actual contaminated locations for some limited period of time each month to perform miscellaneous tasks (e.g., weed control, fence inspection, area surveillance, etc.). Such access suggests that the individual may be exposed to volatile or particulate contaminants by inhalation, contaminant ingestion through soil contact, and dermal absorption of contaminants through soil contact. The exposure duration and frequency for individuals in this population is assumed to 8 h/mo at each operable subunit for a working lifetime of 47 yr. It is assumed that this population does not use protective clothing or equipment.

Conservative assumptions are used for estimating remaining exposure factors. Such estimates are derived from EPA-Region X (1990), or, as necessary, modified along the lines of best professional judgement to provide reasonably maximum exposure parameters for this particular industrial scenario.

Applicable airborne concentrations of volatiles and particulates are presented in Section 5.3.1 and Table 5-2, and are protectively assumed to be those occurring at 100 m from a line source. An estimation of the chronic intake from inhaling volatile or particulate contaminants is computed as (EPA 1989d):

$$\text{Intake (mg/kg/d)} = \frac{(CA)(IR)(ET)(EF)(ED)}{(BW)(AT)}$$

where CA is the contaminant concentration in air (mg/m^3), IR is the inhalation rate of 1.25 m^3/h (30 m^3/d), ET is the exposure time of 8 h/d, EF is the exposure frequency of 3% (12 d/yr), ED is the exposure duration for a working lifetime (47 yr), BW is the body weight of 70 kg, and AT is the averaging time of 47 yr (converted to d for systemic toxins) or 75 yr (converted to d for carcinogens).

The estimated chronic contaminant inhalation intake for this industrial receptor population is presented in Table 6-2 for both carcinogens and systemic toxins of potential concern present at each operable subunit.

The ingestion of soil contaminants may occur incidental to contact with soil during work activities. It is conservatively assumed that 75% of the daily soil ingestion comes from a work exposure with the remainder of the daily ingestion from residential or food contact. Section 5.3.2 presents conservatively biased means for each contaminant of potential concern in the

Table 6-1. Matrix of Human Receptor Populations and Potential Exposure Routes for Contaminants of Potential Concern at the 1100-EM-1 Operable Unit.

Exposure Pathways and Routes	Industrial Worker at Subunits	Closest Employee Population	Closest Residential Population	Reason for Exclusion
Air				
inhalation of volatiles	X	X	X	--
inhalation of fugitive dusts	X	X	X	--
Ingestion				
soil	X	--	--	access to operable subunits is limited
venison	--	--	X	not an occupational exposure
fish	--	--	X	not an occupational exposure
food crops	--	--	--	no food crops grown on operable subunits
ground water	--	--	--	no ground-water wells available as drinking water source
surface water	X[a]	X[a]	X	contact limited to City of Richland water users
Dermal Contact				
soil	X	--	--	access to operable subunits is limited
ground water	--	--	--	no ground-water wells available for human use
surface water	--	--	--	potential for significant exposure negligible because of limited contact

[a]Evaluated under the residential exposure.

Table 6-2. Estimated Chronic Contaminant Intakes for Employees with Direct Access to the 1100-EM-1 Operable Subunits. (Sheet 1 of 3)

Area	Contaminant	Estimated Air Concentration (mg/m^3)	Contaminant Intake (mg/kg/d)
Inhalation Pathway - Carcinogens			
Volatiles			
1100-2 (Paint and Solvent Pit)	tetrachloroethene	5E-04	1E-06
Horn Rapids Landfill	trichloroethene	4E-05	1E-07
	tetrachloroethene	4E-06	1E-08
Fugitive Dusts			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	1E-08	3E-11
	chromium	2E-09	6E-12
UN-1100-6 (Discolored Soil Site)	BEHP	2E-03	6E-06
Horn Rapids Landfill	arsenic	6E-08	2E-10
	chromium	4E-07	1E-09
	PCB	2E-06	6E-09
Inhalation Pathway - Systemic Toxins			
Volatiles			
Horn Rapids Landfill	1,1,1-trichloroethane	6E-06	3E-08

Table 6-2. Estimated Chronic Contaminant Intakes for Employees with Direct Access to the 1100-EM-1 Operable Subunits. (Sheet 2 of 3)

Area	Contaminant	Soil Concentration (mg/kg)	Contaminant Intake (mg/kg/d)
Soil Ingestion Pathway - Carcinogens			
1100-3	arsenic	0.50	1E-08
UN-1100-6	BEHP	8,700	2E-04
	chlordane	0.65	1E-08
Horn Rapids Landfill	arsenic	0.10	2E-09
	PCB	3.5	8E-08
Pit 1	PCB	0.18	4E-09
Ephemeral Pool	PCB	13	3E-07
	chlordane	5.1	1E-07
Soil Ingestion Pathway - Systemic Toxins			
1100-3	arsenic	0.50	2E-08
	chromium	0.10	4E-09
UN-1100-6	BEHP	8,700	3E-04
	chlordane	0.65	2E-08
Horn Rapids Landfill	arsenic	0.10	4E-09
	chromium	0.80	3E-08
Ephemeral Pool	chlordane	5.1	2E-07

Table 6-2. Estimated Chronic Contaminant Intakes for Employees with Direct Access to the 1100-EM-1 Operable Subunits. (Sheet 3 of 3)

Area	Contaminant	Soil Concentration (mg/kg)	Absorbed Contaminant Dose (mg/kg/d)
Dermal Contact with Contaminated Soil - Carcinogens			
1100-3	arsenic	0.50	7E-10
UN-1100-6	BEHP	8,700	8E-06
	chlordane	0.65	9E-09
Horn Rapids Landfill	arsenic	0.10	1E-10
	PCB	3.5	5E-08
Pit 1	PCB	0.18	3E-09
Ephemeral Pool	PCB	13	2E-07
	chlordane	5.1	7E-08
Dermal Contact with Contaminated Soil - Systemic Toxins			
1100-3	arsenic	0.50	1E-09
	chromium	0.10	2E-10
UN-1100-6	BEHP	8,700	1E-05
	chlordane	0.65	1E-08
Horn Rapids Landfill	arsenic	0.10	2E-10
	chromium	0.80	2E-09
Ephemeral Pool	chlordane	5.1	1E-07

surface soils at each operable subunit. The chronic oral soil contaminant intake is computed as (EPA 1989d):

$$\text{Intake (mg/kg/d)} = \frac{(CS)(IR)(CF)(FI)(EF)(ED)}{(BW)(AT)}$$

where CS is the contaminant concentration in soil (mg/kg), IR is the soil ingestion rate of 100 mg/d, CF is a conversion factor of 1E-06 kg/mg, FI is the fraction ingested from the source under consideration (75%), EF is the

exposure frequency of 3% (12 d/yr), ED is the exposure duration for a working lifetime (47 yr), BW is the body weight of 70 kg, and AT is the averaging time of 47 yr (converted to d for systemic toxins) or 75 yr (converted to d for carcinogens).

Estimated chronic soil contaminant ingestion intakes are presented in Table 6-2 for both carcinogens and systemic toxins at each subunit.

Dermal absorption resulting from skin contact with soils may be a potentially important exposure pathway for some contaminants, especially organic compounds. To estimate the dermal absorption of the soil contaminants of potential concern, an absorption factor is derived based on the contact time of the soil with the skin (time between exposure and washing), the bioavailability of the contaminant from the soil matrix, and contaminant-specific absorption data, when available.

The contact time is conservatively assumed to be 8 hr and 80% of the contaminant is estimated to be absorbed during this time period (Shu et al. 1988). Contaminants bound to the soil are less bioavailable than pure or dilute solutions of contaminants applied directly to the skin. Of the total concentration of an organic contaminant in soil, only 10% is generally bioavailable; 1% of inorganic contaminant concentrations in soil is assumed to be bioavailable (Ryan et al. 1987). Contaminant-specific data are available for BEHP; studies in rats have shown that 6.9% of BEHP, applied as pure product, is dermally absorbed (Life Systems, Inc. 1989). Applying the appropriate time-specific and bioavailability corrections to the above information yields estimated absoprtion factors of 8% for chlordane and PCB, 0.8% for arsenic and chromium, and 0.55% for BEHP.

Using upperbound mean contaminant surface soil concentrations (see Section 5.3.2), absorbed contaminant doses are estimated from the following equation (EPA 1989d):

$$\text{Absorbed Dose (mg/kg/d)} = \frac{(CS)(CF)(SA)(AF)(AB)(EF)(ED)}{(BW)(AT)}$$

where CS is the contaminant concentration in soil (mg/kg), CF is a conversion factor of 1E-06 kg/mg, SA is the exposed surface area of the hands (820 cm^2 [EPA 1989d]), AF is the soil adherence factor conservatively assumed to be 0.7 mg/cm^2 (95% one-sided upper confidence limit for adherence of unsieved soil [Driver et al. 1989]), AB is the absorption factor (discussed above), EF is the exposure frequency of 3% (12 d/yr), ED is the exposure duration for a working lifetime (47 yr), BW is the body weight of 70 kg, and AT is the averaging time of 47 yr (converted to d for systemic toxins) or 75 yr (converted to d for carcinogens).

The estimated chronic absorbed doses from surface soil contact with contaminants at each of the operable subunits are presented in Table 6-2 for both carcinogens and systemic toxins.

Closest Permanent Employee Population

A second receptor population is composed of employee populations located at permanent occupational facilities near each operable subunit (e.g., Advance Nuclear Fuel Corp. employees located near the Horn Rapids Landfill). The only

exposure route applicable for this receptor group is the inhalation of volatile and particulate contaminants, as these individuals are not expected to have routine access to or duties at the operable subunits.

The chronic inhalation intake of contaminants of potential concern is estimated using the inhalation intake equation provided above. Conservative estimates of airborne contaminant concentrations are provided in Section 5.3.1 and Table 5-2. These concentrations are based on the approximate distance from each operable subunit to the closest permanent occupational facility. The exposure assumptions used for intake estimation for this population are identical to those provided with the equation, except that the exposure frequency is assumed to be 240 d/yr (average work year, excluding holidays and vacation), and exposure to outside airborne contaminants is assumed to occur 36% of the time during an 8-h shift.

The inhalation intakes for the worker receptor population at nearby permanent work stations for both carcinogenic contaminants of potential concern and systemic toxins are summarized in Table 6-3 by operable subunit.

Closest Residential Population

The third receptor population consists of residents living near the 1100-EM-1 Operable Unit. Potential exposure routes are the inhalation of volatile vapors or fugitive dusts derived from operable subunit emissions, the ingestion of venison and fish respectively contaminated at the Horn Rapids Landfill or the Columbia River, and the ingestion of Columbia River drinking water supplied by the City of Richland.

Because of the industrial setting of the 1100-EM-1 Operable Unit and the restricted access to the Hanford Site, direct contact with and ingestion of contaminated soils by the residential population is unlikely. Therefore, these exposure pathways are not considered further for the residential scenario. As no food crops are grown within the operable unit, human ingestion of contaminated food is limited to fish taken from the Columbia River and venison that could be potentially contaminated at the Horn Rapids Landfill.

To estimate inhalation exposures in the nearest residential population, contaminant concentrations derived in Section 5.3.1 are used. Conservative assumptions recommended by EPA-Region X (1990) are used for estimating all other inhalation parameters, and intakes are calculated using the inhalation equation provided above. For the residential scenario, the conservative assumptions are an inhalation rate of 30 m^3/d, an exposure time of 24 h/d for 365 d/yr for 75 yr. The body weight is assumed to be 70 kg, and the averaging time for both systemic toxins and carcinogens is 75 yr (converted to days). The inhalation intakes of airborne contaminants of concern for individuals living near the operable unit are presented in Table 6-4.

Mule deer may feed at the Horn Rapids Landfill (see Section 5.3.5). The estimated contaminant levels in fat for deer foraging on the landfill are 2E-06 mg/kg for arsenic, 1E-04 mg/kg for chromium, and 3E-02 mg/kg for PCB (see Section 5.3.5.). Although hunting is prohibited on the Hanford Site, animals occasionally visiting the landfill may wander to the adjacent Priest Rapids Game Management Unit (GMU 370, WAC 232.28.218) where hunting is legal,

Table 6-3. Estimated Chronic Contaminant Intake for Closest Permanent Employee Population.

Area	Contaminant	Estimated Air Concentration (mg/m^3)	Contaminant Intake (mg/kg/d)
Inhalation Pathway - Carcinogens			
Volatiles			
1100-2 (Paint and Solvent Pit)	tetrachloroethene	5E-05	1E-06
Horn Rapids Landfill	trichloroethene	3E-06	6E-08
	tetrachloroethene	3E-07	6E-09
Fugitive Dusts			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	7E-10	1E-11
	chromium	1E-10	2E-12
UN-1100-6 (Discolored Soil Site)	BEHP	2E-04	4E-06
Horn Rapids Landfill	arsenic	4E-09	8E-11
	chromium	3E-08	6E-10
	PCB	1E-07	2E-09
Inhalation Pathway - Systemic Toxins			
Volatiles			
Horn Rapids Landfill	1,1,1-trichloroethane	4E-07	1E-08

Table 6-4. Estimated Chronic Contaminant Intakes for Closest Residential Population to the 1100-EM-1 Operable Unit. (Sheet 1 of 2)

Area	Contaminant	Estimated Air Concentration (mg/m^3)	Contaminant Intake (mg/kg/d)
Inhalation Pathway - Carcinogens			
Volatiles			
1100-2 (Paint and Solvent Pit)	tetrachloroethene	2E-05	9E-06
Horn Rapids Landfill	trichloroethene	9E-07	4E-07
	tetrachloroethene	9E-08	4E-08
Fugitive Dusts			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	4E-10	2E-10
	chromium	9E-11	4E-11
UN-1100-6 (Discolored Soil Site)	BEHP	1E-04	4E-05
Horn Rapids Landfill	arsenic	1E-09	4E-10
	chromium	9E-09	4E-09
	PCB	4E-08	2E-08
Inhalation Pathway - Systemic Toxins			
Volatiles			
Horn Rapids Landfill	1,1,1-trichloroethane	1E-07	4E-08

Table 6-4. Estimated Chronic Contaminant Intakes for Closest Residential Population to the 1100-EM-1 Operable Unit. (Sheet 2 of 2)

Source	Contaminant	Estimated Concentration in Source (mg/kg)	Contaminant Intake (mg/kg/d)
Food and Water Ingestion Pathway - Carcinogens			
Venison	arsenic	2E-06[a]	3E-12
	PCB	3E-02[a]	5E-08
Fish	trichloroethene[d]	1E-04[b]	9E-09
Water	trichloroethene[d]	6E-06[c]	2E-07
Food and Water Ingestion Pathway - Systemic Toxins			
Venison	chromium	1E-04	2E-10
Water	nitrate[d]	4E-02[c]	1E-03

[a]Estimated concentration in deer fat.
[b]Based on wet weight.
[c]Expressed as mg/L.
[d]Not an operable unit contaminant of potential concern for this pathway.

resulting in a possible human exposure through ingestion of potentially contaminated venison.

Paustenbach (1989) proposes a venison fat consumption rate of 1,000 mg/d, based on one 45-kg deer per a two person family per year. However, it is not likely that all venison consumed over a lifetime would be from deer foraging on the Horn Rapids Landfill. Therefore, it is assumed that a deer, with a level of contamination noted above, is used as a food source 11% of the time over a 75-yr lifetime. This is based on an upperbound mean hunter success rate of 19% for GMU 370 (DOW 1989 and 1988; Washington State Department of Game 1987 and 1986), and the proportion of the 15.2 mi^2 home range of a mule deer foraging on the landfill (see Section 5.3.5.1) to the approximate 2,542 mi^2 area of GMU 370 (WAC 232.28.218). Thus derived, this ingestion fraction conservatively ignores the hunting ban at the Hanford Site. Further conservatism is added to the evaluation with the assumption that all contaminants in the venison are bioavailable.

Applying these conservative assumptions, the equation used to estimate intake from venison consumption is (EPA 1989d):

$$\text{Intake (mg/kg/d)} = \frac{(CB)(IR)(FI)(EF)(ED)}{(BW)(AT)}$$

where CB is the concentration of the contaminant in the food source (mg/kg), IR is the ingestion rate of 1,000 mg/d (fat), FI is the fraction ingested from the source (11%), EF is the exposure frequency of 365 d/yr, ED is the exposure duration for a lifetime of 75 yr, BW is the body weight of 70 kg, and AT is the averaging time of 75 yr (converted to d).

The fish ingestion exposure route addresses the direct consumption of fish taken from that portion of the Columbia River impacted by trichloroethene that appears to be associated with a ground-water plume in the vicinity of the Horn Rapids Landfill. Contaminant intake from ingestion of fish is derived using the same equation applied to venison, with a CB of 1E-04 mg/kg (see Section 5.3.5.2), an IR of 6,500 mg/d (EPA 1989d), and an FI of 100%.

The surface-water ingestion exposure route addresses the consumption of Columbia River water. Such water is supplied by the City of Richland, and is potentially impacted from the ground-water plume in the Horn Rapids Landfill vicinity. The venison intake equation is again used, with CW (contaminant concentration in water) replacing CB. The CW for trichloroethene is 6E-06 mg/L; for nitrate it is 4E-02 mg/L; insufficient data are available to conduct a quantitative evaluation for tetrachloroethene, the only known operable unit ground-water contaminant of concern (see Section 5.3.4). The IR is 2 L/d, the FI is 100%, and the remaining parameters are unchanged.

The estimated chronic contaminant intakes for individuals consuming venison, fish, and City of Richland water are also summarized in Table 6-4.

6.1.1.3 Human Exposure Integration. From the contaminant intakes derived in Section 6.1.1.2, the relative impact of various exposure pathways can be determined for the individual receptor populations. The inhalation pathway is the only pathway common to all three receptor populations, and estimated intakes are approximately the same order of magnitude for all groups, in spite of different exposure periods. The soil ingestion pathway and the dermal contact pathway appear to provide higher contaminant intakes than other pathways for most contaminants, and contact with the soils at either the UN-1100-6 operable subunit or the ephemeral pool is necessary for any exposure to one contaminant of potential concern, chlordane. Consumption of City of Richland water is necessary for intake of nitrate associated with the plume that appears to be originating upgradient from the Horn Rapids Landfill.

The intake information presented in Section 6.1.1.2 is integrated to estimate a reasonable maximum potential exposure that any one individual may experience from exposure to the contaminants of potential concern at the 1100-EM-1 Operable Unit. The most exposed individual would be a person who works near the operable unit, resides near the operable unit, and ingests potentially contaminated venison, fish, and water. It is also conservatively assumed that in addition to the normal 40-h work week, this individual spends 8 h/mo performing tasks within the operable subunits themselves that result in soil ingestion and dermal contact exposures. The 8 h/mo is assumed to be

evenly divided between the 1100-2, 1100-3, UN-1100-6, and Horn Rapids Landfill operable subunits and Pit 1 and the ephemeral pool.

The estimated inhalation intakes are based on airborne contaminant intakes calculated for the residential scenario adjusted to 128 h/wk to account for time spent on the job. These intakes are combined with occupational intakes at a work station located near the UN-1100-6 and Horn Rapids Landfill subunits only. These assumptions conservatively include exposure during the work week to the most significant airborne contaminants including the known inhalation carcinogens (arsenic and chromium) and BEHP, the highest-concentration contaminant found at the operable unit.

The soil ingestion intakes and dermal contact intakes are based on an exposure duration and frequency of 1.3 h/mo at each operable subunit with surface contamination at levels of potential concern. The venison, fish, and water ingestion intakes assumed are those estimated in Section 6.1.1.2 for residential exposures.

A summary of the estimated intakes for the theoretically most exposed individual is presented in Table 6-5.

6.1.1.4 Uncertainty Analysis. The uncertainty associated with the human exposure assessment is qualitatively addressed below. The potential for an overestimation or an underestimation of exposures can result from uncertainty surrounding the many variables utilized in the assessment process. The soil contaminant concentrations used are one-sided upper 95% confidence limits of mean values less background (see Section 5.3.2). The use of such concentrations contributes a conservative bias to the assessment.

Modeled air concentration values are used because of limited information provided by ambient air monitoring. The models employed conservatively overestimate actual exposure conditions and are expected to contribute a conservative bias to the assessment (see Section 5.3.1). Similar conservative estimates have also been used, resulting in a corresponding bias, in the ground-water and surface-water contaminant transport evaluations (see Sections 5.3.3.2 and 5.3.4). Overall, the contaminant concentrations assumed in exposure calculations result in very conservative, overestimated intakes.

Available data for the tetrachloroethene contamination near 1100-2 are currently insufficient for a quantitative exposure assessment. However, viewing especially the estimated trichloroethene ingestion intakes as an analog, tetrachloroethene intakes through the ingestion of potentially contaminated surface water and fish can be expected to be quite low.

Other exposure factors used contain intentionally conservative assumptions. Maximum exposure parameters suggested by EPA-Region X (1990) are used, with reasonable modification as necessary, to predict contaminant intakes (see Section 6.1.1.2). The one potential exception is the use of upperbound residential inhalation rates for occupational exposures. This may contribute to an underestimation of inhalation intakes for the most exposed individual. However, the upperbound residential inhalation rate is judged to be more realistic and the conservative natures of the other exposure assumptions are expected to offset the liberal bias from this factor.

Table 6-5. Estimated Contaminant Intakes for the Most Exposed Individual at the 1100-EM-1 Operable Unit. (Sheet 1 of 4)

Area	Contaminant	Estimated Air Concentration (mg/m^3)	Contaminant Intake (mg/kg/d)
Inhalation Pathway - Carcinogens			
Work Exposure Volatiles			
Horn Rapids Landfill	trichloroethene	3E-06	6E-08
	tetrachloroethene	3E-07	6E-09
Fugitive Dusts			
Horn Rapids Landfill	arsenic	4E-09	8E-11
	chromium	3E-08	6E-10
	PCB	1E-07	2E-09
UN-1100-6 (Discolored Soil Site)	BEHP	2E-04	4E-06
Residential Exposure Volatiles			
1100-2 (Paint and Solvent Pit)	tetrachloroethene	2E-05	6E-06
Horn Rapids Landfill	trichloroethene	9E-07	3E-07
	tetrachloroethene	9E-08	3E-08
Fugitive Dusts			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	4E-10	1E-10
	chromium	9E-11	3E-11
UN-1100-6 (Discolored Soil Site)	BEHP	1E-04	3E-05
Horn Rapids Landfill	arsenic	1E-09	3E-10
	chromium	9E-09	3E-09
	PCB	4E-08	1E-08

Table 6-5. Estimated Contaminant Intakes for the Most Exposed Individual at the 1100-EM-1 Operable Unit. (Sheet 2 of 4)

Area	Contaminant	Estimated Air Concentration (mg/m^3)	Contaminant Intake (mg/kg/d)
Inhalation Pathway - Systemic Toxins			
Work Exposure			
Horn Rapids Landfill	1,1,1-trichloroethane	4E-07	1E-08
Residential Exposure			
Horn Rapids Landfill	1,1,1-trichloroethane	1E-07	3E-08

Area	Contaminant	Soil Concentration (mg/kg)	Contaminant Intake (mg/kg/d)
Soil Ingestion Pathway - Carcinogens			
1100-3	arsenic	0.5	2E-09
UN-1100-6	BEHP	8,700	3E-05
	chlordane	0.65	2E-09
Horn Rapids Landfill	arsenic	0.10	4E-10
	PCB	3.5	1E-08
Pit 1	PCB	0.18	7E-10
Ephemeral Pool	PCB	13	5E-08
	chlordane	5.1	2E-08

Table 6-5. Estimated Contaminant Intakes for the Most Exposed Individual at the 1100-EM-1 Operable Unit. (Sheet 3 of 4)

Area	Contaminant	Soil Concentration (mg/kg)	Contaminant Intake (mg/kg/d)
Soil Ingestion Pathway - Systemic Toxins			
1100-3	arsenic	0.50	3E-09
	chromium	0.10	6E-10
UN-1100-6	BEHP	8,700	5E-05
	chlordane	0.65	4E-09
Horn Rapids Landfill	arsenic	0.10	6E-10
	chromium	0.80	5E-09
Ephemeral Pool	chlordane	5.1	3E-08

Area	Contaminant	Soil Concentration (mg/kg)	Absorbed Contaminant Dose (mg/kg/d)
Dermal Contact with Contaminated Soil - Carcinogens			
1100-3	arsenic	0.50	1E-10
UN-1100-6	BEHP	8,700	1E-06
	chlordane	0.65	1E-09
Horn Rapids Landfill	arsenic	0.10	2E-11
	PCB	3.5	8E-09
Pit 1	PCB	0.18	4E-10
Ephemeral Pool	PCB	13	3E-08
	chlordane	5.1	1E-08

Table 6-5. Estimated Contaminant Intakes for the Most Exposed Individual at the 1100-EM-1 Operable Unit. (Sheet 4 of 4)

Area	Contaminant	Soil Concentration (mg/kg)	Absorbed Contaminant Dose (mg/kg/d)
Dermal Contact with Contaminated Soil - Systemic Toxins			
1100-3	arsenic	0.50	2E-10
	chromium	0.10	4E-11
UN-1100-6	BEHP	8,700	2E-06
	chlordane	0.65	2E-09
Horn Rapids Landfill	arsenic	0.10	4E-11
	chromium	0.80	3E-10
Ephemeral Pool	chlordane	5.1	2E-08
Source	**Contaminant**	**Estimated Concentration in Source (mg/kg)**	**Contaminant Intake (mg/kg/d)**
Ingestion Pathway - Carcinogens			
Venison	arsenic	2E-06[a]	3E-12
	PCB	3E-02[a]	5E-08
Fish	trichloroethene[d]	1E-04[b]	9E-09
Water	trichloroethene[d]	6E-06[c]	2E-07
Ingestion Pathway - Systemic Toxins			
Venison	chromium	1E-04	2E-10
Water	nitrate[d]	4E-02[c]	1E-03

[a]Estimated concentration in deer fat.
[b]Based on wet weight.
[c]Expressed as mg/L.
[d]Not an operable unit contaminant of potential concern for this pathway.

6.1.2 Human Toxicity Assessment

The purpose of the toxicity assessment is to weigh available evidence regarding the operable unit contaminants of potential concern and the likelihood that these contaminants may cause adverse effects in human receptor populations. Appendix Q summarizes pertinent toxicology information and criteria for the 1100-EM-1 Operable Unit contaminants of potential concern listed in Table 4-24. The carcinogenicity of the contaminants is addressed in Section 6.1.2.1, and the chronic systemic toxic effects are addressed in Section 6.1.2.2.

Nitrate toxicity is addressed, in addition to the contaminants of potential concern; this substance can not be attributed to the operable unit with existing data, but is of interest because it is characteristic of the ground-water plume that appears to be originating upgradient from the Horn Rapids Landfill.

6.1.2.1 Carcinogenic Toxic Effects. Carcinogenic toxic effects are evaluated on the assumption that there is no threshold or level of exposure to a carcinogen that is risk free. The toxicity data used to evaluate potential human carcinogenic risks are based on the EPA weight-of-evidence (WOE) classification and the SF.

The WOE classification system for carcinogenicity characterizes the likelihood that a substance is a human carcinogen based on human epidemiological studies and studies in animals, and assigns a contaminant to a group based on supporting evidence. The classification groups are:

- A—human carcinogen
- B1—probable human carcinogen based on limited human data
- B2—probable human carcinogen based on sufficient data in animals
- C—possible human carcinogen
- D—not classified as to human carcinogenicity
- E—evidence of noncarcinogenicity in humans.

The SF is a toxicity value that quantitatively defines the relationship between dose and response. It is used to estimate the upperbound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen over a lifetime. Assessed in combination, the SF and WOE classification provide a means of evaluating the probability of a given contaminant exposure inducing cancer in humans.

Table 6-6 summarizes the carcinogenic toxicity data for the contaminants of potential concern at the 1100-EM-1 Operable Unit. Toxicity values are those published in EPA (1990a) or EPA (1989c), as recommended by EPA (1989d). Surrogate inhalation SFs conservatively considered to be the same as the respective oral SF are assigned for BEHP and PCB because no specific EPA-endorsed inhalation toxicity data are available for these two contaminants.

Two contaminants of interest are not considered carcinogenic, nitrate and 1,1,1-trichloroethane. Nitrate has not been classified by EPA as a carcinogen, and 1,1,1-trichloroethane is considered a WOE class D at this time.

Table 6-6. Summary of Carcinogenic Toxicity Information for the Contaminants of Potential Concern at the 1100-EM-1 Operable Unit.

Contaminant	Weight-of-Evidence Classification	Type of Cancer[a]	Oral SF $(mg/kg/d)^{-1}$	Oral SF Basis/Source	Inhalation SF $(mg/kg/d)^{-1}$	Inhalation SF Basis/Source
arsenic	A	lung cancer[b], skin cancer[c]	1.7E+00[d]	water/IRIS[d,e]	5.0E+01[e,f]	air/IRIS
DEHP	B2	--	1.4E-02[e]	food/IRIS[e]	1.4E-02[f]	surrogate[f]
chlordane	B2	--	1.3E+00[e]	food/IRIS[e]	1.3E+00[e]	food/IRIS[e]
chromium	A	lung cancer[b]	--	--	4.1E+01[e]	air/IRIS[e]
nitrate	--[h]	--	--	--	--	--
PCB	B2	--	7.7E+00[e]	food/IRIS[e]	7.7E+00[f]	surrogate[f]
tetrachloroethene	B2	--	5.1E-02[g]	gavage/HEAST[g]	3.3E-03[g]	air/HEAST[g]
1,1,1-trichloroethane	D	--	--	--	--	--
trichloroethene	B2	--	1.1E-02[g]	gavage/HEAST[g]	1.7E-02[g]	air/HEAST[g]

[a]Provided for Class A carcinogens only.
[b]Via inhalation route.
[c]Via ingestion of drinking water.
[d]Surrogate based on proposed unit risk of 5E-05 µg/L (EPA 1990a).
[e]EPA 1990a.
[f]Surrogate inhalation SF conservatively assumed to be equal to oral SF.
[g]EPA 1989c.
[h]Not evaluated for carcinogenicity.
[i]SF based on 30% absorption of inhaled arsenic.

Hexavalent chromium is known to be a human carcinogen by the inhalation route only and as such rates a WOE classification A. Arsenic is a known human carcinogen and produces lung cancer via inhalation exposures and skin cancer via the ingestion route. The remaining contaminants of concern—BEHP, chlordane, PCB, tetrachloroethene, and trichloroethene—are classified as B2 (probable human carcinogens). The primary type of cancer seen in animals for these latter five contaminants is liver cancer.

6.1.2.2 Chronic Systemic Toxic Effects. For systemic toxic effects, protective mechanisms are believed to exist that allow exposure to a contaminant based on the concept that a threshold must be reached before adverse toxic effects may occur. An RfD is the toxicity value used most often to evaluate such effects. Because the contaminant sources at the 1100-EM-1 Operable Unit are of the nature that acute or subchronic exposure is not plausible, only chronic exposures and chronic RfDs are used for comparisons of systemic toxic effects. The chronic RfD, as noted in Section 4.4, is a protective estimate of a daily exposure level for the human population, including sensitive subpopulations such as children, that is likely to be without an appreciable potential for deleterious effects over a lifetime.

Table 6-7 summarizes the systemic toxicity values for the contaminants of potential concern at the 1100-EM-1 Operable Unit. As noted above, toxicity values are those published in the preferred toxicity information sources (EPA 1990a and 1989c). Because carcinogens can also have systemic effects, RfDs are provided for such substances when available. However, the carcinogenic effects usually occur at levels significantly lower than those associated with the systemic toxic effects; thus, the cancer risk is the predominant adverse effect for carcinogens.

Nitrate is not classified as a carcinogen, but is well recognized for producing methemoglobinemia and limiting the ability of the blood to carry oxygen. Confidence in the RfD provided is high, because it is based on multiple studies in exposed infants, the most sensitive subpopulation.

1,1,1-Trichloroethane is also a noncarcinogen and RfDs for both the inhalation and oral routes are provided. The RfDs are based on inhalation studies in animals and confidence in these intake levels is medium. The inhalation of 1,1,1-trichloroethane may produce liver damage.

6.1.2.3 Uncertainty Analysis. Toxicity information is often limited, thus uncertainty is associated with the toxicity values provided in Sections 6.1.2.1 and 6.1.2.2. For the carcinogenic substances, only arsenic and chromium are known human carcinogens and their SFs are based on documented human exposures and contaminant levels. Dose-response information from animal studies is used for the other five carcinogenic contaminants of potential concern to predict effects in humans. Uncertainty also arises because the animal studies use dose-response information from effects observed at high doses to predict adverse effects that may occur due to relatively low environmental exposure levels. Another contribution to the uncertainty for all of the carcinogens is the application of the dose-response information from healthy humans or homogeneous animal populations to predict effects in the general population.

Two carcinogenic contaminants of potential concern, tetrachloroethene and trichloroethene, are under review by EPA, and toxicity values for these

Table 6-7. Summary of Systemic Toxicity Information for the Contaminants of Potential Concern at the 1100-EM-1 Operable Subunit.

Contaminant	Oral RfD (mg/kg/d)	Oral RfD Basis/ Source	Confidence Level[a]	Critical Effect	Uncertainty Factors[b]	Modifying Factors	Inhalation RfD (mg/kg/d)	Inhalation RfD Basis/ Source	Confidence Level	Critical Effect	Uncertainty Factors	Modifying Factors
arsenic	1.0E-03[e]	water/HEAST[c]	--	keratosis, hyperpigmentation	1	--	NA	--	--	--	--	--
DEHP	2.0E-02[d]	food/IRIS[d]	M	increase in relative liver weight	1,000 (H,A,S)	1	NA	--	--	--	--	--
chlordane	6.0E-05[d]	food/IRIS[d]	L	regional liver hypertrophy in female rats	1,000 (H,A,O)	1	NA	--	--	--	--	--
chromium	5.0E-03[d]	water/IRIS[d]	L	no adverse effects observed	500[e] (S,L)	1	NA	--	--	--	--	--
nitrate	1.0E+00[d]	water/IRIS[d]	M	methemoglobinemia	1	1	NA	--	--	--	--	--
PCB	NA	--	--	--	--	--	NA	--	--	--	--	--
tetrachloroethene	1.0E-02[d]	gavage/IRIS[d]	M	liver damage in mice and weight gain in rats	1,000 (H,A,S)	1	NA	--	--	--	--	--
1,1,1-trichloroethane	9.0E-02[d]	air/IRIS[d]	M	no adverse effects observed	1,000 (H,A,S)	1	3.0E-01[c]	air/HEAST[c]	--	hepatotoxicity	1,000 (H,A,S)	1
trichloroethene	NA	--	--	--	--	--	NA	--	--	--	--	--

[a]L (low), M (medium), H (high) as designated in IRIS (EPA 1990a).
[b]Uncertainty adjustments (factor of 10 for each adjustment unless otherwise indicated):
H = Variation in human sensitivity
A = Animal to human extrapolation
S = Extrapolation from subchronic to chronic no-observed-adverse-effect-level (NOAEL)
L = Extrapolation from lowest-observed-adverse-effect-level (LOAEL) to NOAEL
O = Other study deficiencies.
[c]EPA 1989c.
[d]EPA 1990a.
[e]Additional factor of 5 based on exposure duration of principal study.
NA = Not available.

contaminants have been withdrawn from EPA (1990a). For purposes of this assessment, the SFs are obtained from EPA (1989c) and may be revised as additional information becomes available.

Although there is uncertainty associated with the SFs, all of the carcinogenic contaminants of concern are WOE classification B2 or higher. The SFs are based on appropriate exposure routes (e.g., food ingestion used to determine an oral SF) and correspond to probable human exposure routes. The exceptions are the inhalation SF for chlordane and the surrogate inhalation SF for PCB that are both based on oral ingestion routes. The B2 carcinogen classifications, applicable to the relevant operable unit contaminants of potential concern, are based on multiple supporting animal studies. Appendix Q provides additional information on the confidence and uncertainty surrounding each particular contaminant.

A high level of confidence and very little uncertainty are associated with the RfD for nitrate, as noted in Section 6.1.2.2. The oral and inhalation RfDs for 1,1,1-trichloroethane have safety factors applied to account for variation in extrapolation from animals to humans, for variation in the general population to protect sensitive subpopulations, and for extrapolation from subchronic studies to chronic exposures. Thus, the published RfDs for 1,1,1-trichloroethane may overestimate the hazard associated with exposure to this contaminant.

6.1.3 Human Health Risk Characterization

The exposure and toxicity assessments presented in Sections 6.1.1 and 6.1.2 form the basis for the characterization of risks and health hazards posed by the contaminants of potential concern at the 1100-EM-1 Operable Unit. Carcinogenic risks will be addressed in Section 6.1.3.1, systemic toxicity hazards in Section 6.1.3.2, and the uncertainty surrounding this characterization will be presented in Section 6.1.3.3.

6.1.3.1 Carcinogenic Risks. Seven of the nine contaminants of interest evaluated for the 1100-EM-1 Operable Unit and vicinity are probable human carcinogens. These contaminants are arsenic, BEHP, chlordane, chromium, PCB, tetrachloroethene, and trichloroethene. The risk associated with these contaminants is presented as the likelihood of contracting some form of cancer over a lifetime as a result of exposure to these substances. An ICR in the range of E-06 to E-04 is, in accordance with the NCP, considered acceptable, with a risk of E-06 being regarded as a point of departure for determining remediation goals for NPL sites (40 CFR 300.430(e)(2)(i)(A)(2)). For the purposes of this report, a significant ICR is considered to be one in excess of 1E-06. One should note, however, that such a level of risk does not necessarily indicate a need for remediation unless the total operable unit ICR exceeds 1E-04.

The SF converts daily intakes averaged over a lifetime of exposure directly to the estimated incremental risk of an individual developing cancer. The equation for risk estimation is:

Risk = (Chronic Daily Intake)(SF).

This linear equation is only valid at low risk levels (i.e., below estimated risks of E-02), and is an upperbound estimate based on the upper 95th percent confidence limit of the SF. Thus, one can be reasonably confident that the actual risk is likely to be less than that predicted. Cancer risk is assumed to be additive, and risks from different contaminants and pathways can be summed to evaluate the overall cancer risk posed by a site.

The SFs for all contaminants are provided in Table 6-6. Chronic daily contaminant intakes are provided in Tables 6-2 through 6-5 for each exposure scenario. The SFs are specific for the route of intake. All SFs are based on contaminant intake except the inhalation SF for arsenic. The inhalation SF for arsenic is based on 30% absorption of inhaled arsenic. Therefore, exposure scenario intakes for inhaled arsenic are adjusted to reflect 30% pulmonary absorption for risk calculations.

Currently, SFs are not published for dermal routes of exposure. For the purposes of this risk assessment, the SF for dermal contact exposure is assumed to be equivalent to that for oral exposure, after the oral SF is corrected for absorption as recommended by EPA (1989d). The oral absorption efficiency is contaminant specific. Orally administered arsenic is 95% absorbed (Lifesystem, Inc. 1987), and the oral SF corrected for absorption is 1.8 $(mg/kg/d)^{-1}$. For chlordane and PCB, ranges of oral absorption efficiencies are published. An oral absorption efficiency, based on animal studies, of 80% for chlordane (Clayton and Clayton 1982), and one of 90% for PCB (Syracuse Research Corp. 1989e) are assumed appropriate. The absorption adjusted SF for chlordane is 1.6 $(mg/kg/d)^{-1}$; for PCB, 13 $(mg/kg/d)^{-1}$. Because limited information is available regarding the extent of BEHP absorption, the oral absorption efficiency is protectively assumed to be 11%, the lowest reported absorption in human studies. Thus, the oral SF adjusted for absorption for BEHP is 1.3 E-01 $(mg/kg/d)^{-1}$.

The estimates of contaminant-specific cancer risk for the three exposure scenarios and the most exposed individual are provided in Tables 6-8 through 6-11. For the employees with direct access to the operable subunits (Table 6-8), the overall inhalation risk is insignificant. Negligible risks are associated with the on-site occupational scenario for exposure to the two contaminants known to cause lung cancer in humans via inhalation, arsenic and chromium.

For the soil ingestion pathway and the dermal contact pathway, the primary risks are associated with BEHP and PCB. The risk from potential ingestion of BEHP found in soils at UN-1100-6 is 3E-06, and for PCB at the ephemeral pool the risk is 2E-06. The overall soil ingestion pathway risk for employees with direct access to the operable subunits is 6E-06.

The dermal contact pathway also contributes significantly to the overall risk for employees with direct access to the sites. However, the multiple conservative assumptions used to determine the intake and to evaluate the risk from dermal contact, and the uncertainty associated with converting oral SFs to dermal SFs, may overestimate the actual risks attributable to the dermal pathway. Due to the uncertainties inherent in dermal contact pathway analysis, and in accordance with current EPA-Region X policy (Sweeney, C., EPA-Region X [Personal communication] June 7, 1990), dermal absorption risks

Table 6-8. Estimates of Cancer Risk and Chronic Systemic Hazard Quotients for Employees with Direct Access to the 1100-EM-1 Operable Subunits. (Sheet 1 of 2)

Area	Contaminant	Contaminant Specific Risk	Systemic Toxicity Hazard Quotient
Inhalation Pathway			
Volatiles			
1100-2 (Paint and Solvent Pit)	tetrachloroethene	3E-09	--
Horn Rapids Landfill	trichloroethene	2E-09	--
	tetrachloroethene	3E-11	--
	1,1,1-trichloroethane	--	0.0000001
Fugitive Dusts			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	5E-10	--
	chromium	2E-10	--
UN-1100-6 (Discolored Soil Site)	BEHP	8E-08	--
Horn Rapids Landfill	arsenic	3E-09	--
	chromium	4E-08	--
	PCB	5E-08	--
TOTAL INHALATION RISK:		2E-07	0.0000001
Soil Ingestion Pathway			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	2E-08	0.00002
	chromium	--	0.0000003
UN-1100-6 (Discolored Soil Site)	BEHP	3E-06	0.02
	chlordane	1E-08	0.0003
Horn Rapids Landfill	arsenic	3E-09	0.000004
	chromium	--	0.000008
	PCB	6E-07	--

Table 6-8. Estimates of Cancer Risk and Chronic Systemic Hazard Quotients for Employees with Direct Access to the 1100-EM-1 Operable Subunits. (Sheet 2 of 2)

Area	Contaminant	Contaminant Specific Risk	Systemic Toxicity Hazard Quotient
Soil Ingestion Pathway (Cont.)			
Pit 1	PCB	3E-08	--
Ephemeral Pool	PCB	2E-06	--
	chlordane	1E-07	0.003
TOTAL SOIL INGESTION RISK:		**6E-06**	**0.02**
Dermal Contact with Contaminated Soil Pathway[a]			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	1E-09	0.000001
	chromium	--	0.0000008
UN-1100-6 (Discolored Soil Site)	BEHP	1E-06	0.005
	chlordane	1E-08	0.0002
Horn Rapids Landfill	arsenic	2E-10	0.0000002
	chromium	--	0.000008
	PCB	4E-07	--
Pit 1	PCB	3E-08	--
Ephemeral Pool	PCB	2E-06	--
	chlordane	1E-07	0.003
TOTAL DERMAL CONTACT RISK:		**4E-06**	**0.008**

[a]RFDs and SFs adjusted to reflect absorbed dose.
-- Current published toxicity data indicate that this is not a significant mechanism of toxicity for the contaminant.

Table 6-9. Estimates of Cancer Risk and Chronic Systemic Hazard Quotients for Closest Permanent Employee Population.

Area	Contaminant	Contaminant Specific Risk	Systemic Toxicity Hazard Quotient
Inhalation Pathway			
Volatiles			
1100-2 (Paint and Solvent Pit)	tetrachloroethene	3E-09	--
Horn Rapids Landfill	trichloroethene	1E-09	--
	tetrachloroethene	2E-11	--
	1,1,1-trichloroethane	--	0.00000003
Fugitive Dusts			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	2E-10	--
	chromium	8E-11	--
UN-1100-6 (Discolored Soil Site)	BEHP	6E-08	--
Horn Rapids Landfill	arsenic	1E-09	--
	chromium	2E-08	--
	PCB	2E-08	--
TOTAL INHALATION RISK:		**1E-07**	**0.00000003**

-- Current published toxicity data indicate that this is not a significant mechanism of toxicity for the contaminant.

Table 6-10. Estimates of Cancer Risk and Chronic Systemic Hazard Quotients for Closest Residential Population to the 1100-EM-1 Operable Unit.

Area	Contaminant	Contaminant Specific Risk	Systemic Toxicity Hazard Quotient
Inhalation Pathway			
Volatiles			
1100-2 (Paint and Solvent Pit)	tetrachloroethene	3E-08	--
Horn Rapids Landfill	trichloroethene	7E-09	--
	tetrachloroethene	1E-10	--
	1,1,1-trichloroethane	--	0.0000001
Fugitive Dusts			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	3E-09	--
	chromium	2E-09	--
UN-1100-6 (Discolored Soil Site)	BEHP	6E-07	--
Horn Rapids Landfill	arsenic	6E-09	--
	chromium	2E-07	--
	PCB	2E-07	--
TOTAL INHALATION RISK:		**1E-06**	**0.0000001**
Food and Water Ingestion			
Venison	arsenic	5E-12	0.000000003
	chromium	--	0.00000004
	PCB	4E-07	--
Fish	trichloroethene[a]	1E-10	--
Water	nitrate[a]	--	0.001
	trichloroethene[a]	2E-09	--
TOTAL INGESTION RISK:		**4E-07**	**0.001**

[a]Not an operable unit contaminant of potential concern for this pathway.
-- Current published toxicity data indicate that this is not a significant mechanism of toxicity for the contaminant.

Table 6-11. Estimates of Cancer Risk and Chronic Systemic Hazard Quotients for Most Exposed Individual at the 1100-EM-1 Operable Unit. (Sheet 1 of 2)

Area	Contaminant	Contaminant Specific Risk	Systemic Toxicity Hazard Quotient
Inhalation Pathway[a]			
Volatiles			
1100-2 (Paint and Solvent Pit)	tetrachloroethene	2E-08	--
Horn Rapids Landfill	trichloroethene	6E-09	--
	tetrachloroethene	1E-10	--
	1,1,1-trichloroethane	--	0.0000001
Fugitive Dusts			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	2E-09	--
	chromium	1E-09	--
UN-1100-6 (Discolored Soil Site)	BEHP	5E-07	--
Horn Rapids Landfill	arsenic	6E-09	--
	chromium	1E-07	--
	PCB	9E-08	--
TOTAL INHALATION RISK:		**7E-07**	**0.0000001**
Soil Ingestion Pathway			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	3E-09	0.000003
	chromium	--	0.0000001
UN-1100-6 (Discolored Soil Site)	BEHP	4E-07	0.003
	chlordane	3E-09	0.00007
Horn Rapids Landfill	arsenic	7E-10	0.0000006
	chromium	--	0.000001
	PCB	8E-08	--
Pit 1	PCB	5E-09	--
Ephemeral Pool	PCB	4E-07	--
	chlordane	3E-08	0.0005
TOTAL SOIL INGESTION RISK:		**9E-07**	**0.004**

Table 6-11. Estimates of Cancer Risk and Chronic Systemic Hazard Quotients for Most Exposed Individual at the 1100-EM-1 Operable Unit. (Sheet 2 of 2)

Area	Contaminant	Contaminant Specific Risk	Systemic Toxicity Hazard Quotient
Dermal Contact with Contaminated Soil Pathway[b]			
1100-3 (Antifreeze and Degreaser Pit)	arsenic	2E-10	0.0000002
	chromium	--	0.0000002
UN-1100-6 (Discolored Soil Site)	BEHP	1E-07	0.001
	chlordane	2E-09	0.00004
Horn Rapids Landfill	arsenic	4E-11	0.00000004
	chromium	--	0.000001
	PCB	7E-08	--
Pit 1	PCB	3E-09	--
Ephemeral Pool	PCB	3E-07	--
	chlordane	2E-08	0.0004
TOTAL DERMAL CONTACT RISK:		**5E-07**	**0.001**
Food and Water Ingestion Pathway			
Venison	arsenic	5E-12	0.000000003
	chromium	--	0.00000004
	PCB	4E-07	--
Fish	trichloroethene[c]	1E-10	--
Water	nitrate[c]	--	0.001
	trichloroethene[c]	2E-09	--
TOTAL INGESTION RISK:		**4E-07**	**0.001**

[a]Represents risk or systemic toxicity associated with combined work and residential inhalation exposures.
[b]RFDs and SFs adjusted to reflect absorbed dose.
[c]Not an operable unit contaminant of potential concern for this pathway.
-- Current published toxicity data indicate that this is not a significant mechanism of toxicity for the contaminant.

are not included in any characterization of overall risks; they are presented in this report for informational purposes only.

The contaminant-specific risks for employees at the closest permanent work stations are presented in Table 6-9. The risks associated with all contaminant exposures are negligible. The risks for residents living near the 1100-EM-1 Operable Unit are presented in Table 6-10. Individual contaminant specific risks are negligible, and the total operable unit risk does not exceed 1E-06. Because of the conservative exposure assumptions, the actual total residential risk is likely considerably less than this estimation.

The risks associated with the consumption of potentially contaminated fish, venison, and surface water are negligible (see Table 6-10). Although not directly evaluated, the inhalation of trichloroethene vapors emanating from the water can be estimated in accordance with EPA-Region X (1990) by multiplying the water ingestion intake by four (worst-case scenario). The resulting inhalation risk from volatilized trichloroethene is also insignificant.

Insufficient operable unit characterization data are currently available to allow for a quantitative assessment of the risks associated with tetrachloroethene, the sole contaminant of potential concern in 1100-EM-1 ground waters. By analogy with the trichloroethene assessment above, risks associated with the consumption and inhalation of tetrachloroethene through the surface water pathway are expected to be negligible.

The cancer risks for the most exposed individual are presented in Table 6-11. These risks reflect the integration of all reasonable, potential exposure routes for one individual and represent a lifetime exposure to all contaminants of potential concern at the 1100-EM-1 Operable Unit. Although no individual contaminant or exposure pathway poses a risk in excess of 1E-06, the sum of the individual pathway risks (i.e., inhalation, soil ingestion, and food and water ingestion), presented in Table 6-11, is 2E-06 (excluding dermal absorption risks in accordance with EPA-Region X policy). For all contaminants and pathways, because of the very conservative method of calculation, the risks computed under such theoretical upperbound conditions are expected to exceed actual risks.

6.1.3.2 Chronic Systemic Toxic Risks. Potential human health hazards associated with chronic systemic toxins are evaluated differently than carcinogenic risks. The chronic daily intake is divided by the RfD to compute an HQ. If an HQ exceeds unity, the possibility exists of systemic toxic effects. The HQ is not a mathematical prediction of the severity or incidence of the effects, but rather is an indication that effects may occur, especially in sensitive subpopulations. If contaminants have similar systemic toxic effects, their respective HQs can be summed to determine a hazard index for a pathway or a site. For the purposes of this report, an HQ in excess of unity is considered to be significant.

The chronic systemic HQs for the three human receptor populations and the most exposed individual are presented in Tables 6-8 through 6-11. The HQs are based on the contaminant intakes presented in Tables 6-2 through 6-5 and the systemic toxicity information provided in Table 6-7.

The RfDs are route specific—oral RfDs are used to compute HQs from ingestion intakes and inhalation RfDs are compared to inhalation intakes. Oral RfDs are adjusted for oral absorption efficiency, as described in Section 6.1.3.1, in order to evaluate dermally absorbed doses for potential systemic effects. Arsenic is considered 95% orally absorbed, chlordane 80%, PCB 90% BEHP 11%, and all other contaminants are conservatively estimated to be 5% absorbed as recommended by EPA (1989d).

Systemic toxicity is evaluated for all contaminants if systemic mechanisms of toxicity are recognized as a significant form of toxicity for the particular contaminant. Many of the carcinogenic contaminants are currently associated with oral systemic toxicity, but not with inhalation toxicity, as reflected in the availability of their RfDs.

For the employee with direct access to the operable subunits, the systemic toxicity is negligible for all contaminants of potential concern.

The estimates of systemic effects in the nearby occupational facility employee populations are presented in Table 6-9. These estimates indicate no significant systemic effects are likely to occur in this receptor population.

The potential for systemic effects from contaminant intake by the closest residential population is displayed in Table 6-10. All systemic toxic effects are insignificant for the residential exposure scenario.

No systemic toxic effects appear to be likely for the most exposed individual.

6.1.3.3 Uncertainty Analysis. A human risk characterization examines the sources of the contaminant, its dispersion and resulting exposure to humans, and the toxicological effects of such exposure. For many of the contaminants, there is little information regarding partitioning in the soil, water, and air, the uptake rates in plants and animals (which can result in indirect exposure to humans), the absorption rates in humans from various exposures, or the toxic effects of chronic, low dose exposure. As a result, the risks presented are not fully probabilistic estimates of risk, but rather are conditional estimates given multiple assumptions about exposures, toxicity, and other variables. This discussion focuses on the uncertainty surrounding the projected risks and hazards due to uncertainty in these variables.

The identification of contaminants of potential concern is based on empirical environmental data collected for various media at the 1100-EM-1 Operable Unit. Such data sets have uncertainty associated with them, but the sampling coverage of the most accessible medium—surface soils at each of the operable subunits (the exposure points for the soil contact and soil ingestion pathways, and the sources of particulate emissions for the air pathway)—seems sufficient to identify the predominant contaminants of potential concern at the operable unit. In addition, conservatively biased estimates of mean concentration values are used to evaluate levels of exposure.

For the ground-water medium, uncertainty about the magnitude and extent of the tetrachloroethene contamination in the vicinity of the 1100-2 subunit was too great to allow for a quantitative risk characterization. However, two other ground-water contaminants of interest, trichloroethene and nitrate associated with a plume in the vicinity of the Horn Rapids Landfill that does

not appear to be associated with the operable unit, provide analogous characterizations that can be used to qualitatively characterize the risks attributable to tetrachloroethene in ground water. Such risks are anticipated to be negligible.

The exposure scenarios developed assume that there will be no major change in current land and water use at the operable unit. Although this seems highly probable based on current information, any land or water use change that would increase exposures by workers or residents would result in a need to reevaluate the risks presented here.

Uncertainty can also be attributed to the toxicity information used to determine the risks and hazards in Section 6.1.3.2. Only two contaminants, arsenic and chromium, are known to be human carcinogens, and no significant risks are found to be associated with these two substances. All other carcinogenic contaminants are so designated because of evidence from animal studies only (see Section 6.1.2.3). The extrapolation of data from high-dose animal studies to low-dose human exposures may overestimate the risk in the human population because of metabolic differences, repair mechanisms, or differential susceptibility.

The contaminants administered in the animal carcinogenicity testing may have been in different forms than those found in the environment. The most obvious case in point is PCB, which occurs as variable mixtures of congeners. This contaminant is associated with a large portion of the overall operable unit risk. Considerable variation in PCB congener mixtures is found between pure product forms used in toxicological testing and environmental forms that have undergone degradation and decomposition. This variation imparts substantial uncertainty to the characterization of risks associated with PCB.

The RfDs and SFs also have multiple conservative calculations built into them (i.e., factors of 10 for up to four different levels of uncertainty for RfDs, and the use of an upperbound estimate derived from the linearized multi-stage carcinogenesis model for SFs) that can contribute to overestimations of actual risk.

The assumptions used in the risk assessment process to determine intakes are highly conservative and contribute to overestimations of risk. For all scenarios, it is unlikely that individuals will be exposed on a daily basis for 47 working years or a 75-yr lifetime. The application of average lengths of work at one job or in one residence may more accurately reflect actual risk than the use of the upperbound parameters. The uncertainty surrounding dermal exposures and absorption from dermal exposure is another significant source of uncertainty that is reflected in the estimated risks associated with this pathway for some compounds. The lack of toxicity information to adequately determine RfDs and SFs for dermal exposures forces extrapolation from oral RfDs and SFs and compounds the conservative bias associated with the calculations.

6.1.3.4 Human Risk Characterization Summary. Although there are many sources of uncertainty in the risk assessment process, it is likely that the significant contaminants of concern have been identified in this risk characterization and that the resulting characterization is conservative from a regulatory perspective. The contaminants of concern for the 1100-EM-1 Operable Unit are BEHP and PCB.

The BEHP poses a problem at the UN-1100-6 operable subunit, where it is present in surface soils in percentage concentrations. Dermal contact with and ingestion of these soils may increase an individual's risk of developing cancer by more than E-06 (see Table 6-8). Employees at the 1100 Area who have direct access to this operable subunit comprise the population at risk.

The ephemeral pool has surficial PCB soil contamination that poses significant risks to individuals having direct access to this location. Dermal contact with this soil may increase cancer risks by approximately E-06 at this location. Soil ingestion poses a potentially significant risk at the ephemeral pool, with an estimated increased cancer risk of about E-06 (see Tables 6-8).

The risks for the most exposed individual are presented in Table 6-11. These risks are based on the integration of all reasonable maximum exposure pathways for a single hypothetical individual. Although no individual contaminant or exposure pathway poses a significant risk, the sum of all pathway risks is 2E-06 (excluding dermal absorption risks in accordance with EPA-Region X policy). The majority of the risk, greater than 90%, is attributable to BEHP and PCB. This estimated risk is expected to exceed the actual risk because of the multiple conservative assumptions.

Exposure to contaminated ground water downgradient of 1100-2 or in the vicinity of the Horn Rapids Landfill, although dismissed as operative pathways under existing land- and water-use conditions, could pose a human health hazard. Depending upon where a withdrawal well was sited and how it was used, a significantly increased cancer risk could be associated with ingestion and inhalation of tetrachloroethene, at 1100-2, and trichloroethene, in the vicinity of the Horn Rapids Landfill; a systemic toxic hazard could be posed by the ingestion of nitrate-contaminated ground water in the vicinity of the landfill (see Table 4-23). However, existing ground-water data are not sufficient to prove the landfill, and thus the operable unit, to be the source of the trichloroethene and nitrate contamination.

6.2 ENVIRONMENTAL EVALUATION

Sections 6.2.1, 6.2.2, and 6.2.3 respectively provide the assessments of environmental exposures, toxicities, and overall risks that are attributable to operable unit contaminant releases. In addition to the operable unit contaminants of potential concern, exposures and risks related to the trichloroethene and nitrate associated with the plume near the Horn Rapids Landfill are also assessed. Exposures and risks associated with the only known operable unit ground-water contaminant of potential concern, tetrachloroethene at the 1100-2 operable subunit, are not quantitatively assessed due to a lack of information regarding the magnitude and extent of contamination (see Section 4.5.2).

6.2.1 Environmental Exposure Assessment

An environmental exposure assessment estimates contaminant intake by indicator receptor populations, allowing for an assessment of the nature and magnitude of any significant adverse environmental threats. Measured and

estimated contaminant concentrations in various environmental media, that are presented in Sections 4 and 5, are considered, along with the indicator receptor populations described in Section 3.7, to determine routes and magnitudes of contaminant intake.

Sensitive environmental indicator populations with a potential of operable unit contaminant exposure are characterized in Section 6.2.1.1. Potentially significant pathway exposures to such populations are estimated in Section 6.2.1.2, and such exposures are integrated in Section 6.2.1.3. Environmental exposure assessment uncertainties are addressed in Section 6.2.1.4, and a brief summary of the overall environmental exposure assessment is provided in Section 6.2.1.5.

6.2.1.1 Potential Environmental Receptor Populations. The DOW identified two sensitive bird species known to nest in the vicinity of the 1100-EM-1 Operable Unit—the Swainson's hawk and the long-billed curlew (see Section 3.7.2.3). These species are regarded as indicators for evaluating potential adverse terrestrial ecosystem impacts posed by contaminant releases from the operable unit. A Swainson's hawk nest is located approximately 1.5 km (0.9 mi) west of the Horn Rapids Landfill, and curlews are known to nest within the landfill (see Section 3.7.2.3).

The Columbia River supports populations of anadromous and residential salmonids. This cold-water fishery is used as an indicator, by means of comparison with water quality criteria established to protect freshwater aquatic life (EPA 1986a), to assess the potential for degradation of the aquatic environment.

For reasons specified in Section 6.1.1.1, both the terrestrial and aquatic environmental exposure evaluations are conducted under the assumption of no significant alteration of current land- and water-use conditions.

6.2.1.2 Estimated Environmental Exposures. Biological exposures to operable unit contaminants of potential concern are estimated below. The discussion is organized into two parts: exposure of terrestrial biota to Horn Rapids Landfill soil contamination, and exposure of aquatic biota to ground-water contaminants known to exist in the vicinity of the landfill. The exposure of aquatic biota to tetrachloroethene in ground water near the 1100-2 operable subunit can not be quantitatively assessed due to a lack of data on the magnitude and extent of contamination.

Terrestrial Biota

The respective average weights of Swainson's hawks and long-billed curlews are approximately 1.0 and 0.9 kg (Terres 1980). Both species are migratory and inhabit the landfill vicinity only while nesting during the summer months. Swainson's hawks spend approximately 5 mo each year in the area (Fitzner 1980). Long-billed curlews are present for approximately 4 mo each year (Allen 1980), but spend only about 2 mo within their nesting territories (Rickard, W., PNL [Personal communication] June 19, 1990). As the curlews are known to nest within the landfill boundaries, have small territories in relation to the size of the landfill, and feed within their territories, it is assumed that all their food, during the 2-mo nesting period, is contaminated to the extent described in Section 5.3.5.1.

Adult Swainson's hawks have territorial ranges, during the nesting period, that average approximately 3.4 and 9.1 km^2 (1.3 and 3.5 mi^2) for females and males, respectively (Fitzner 1980). Assuming a circular territory, the foraging radius becomes 1.1 and 1.7 km (0.7 and 1.1 mi), respectively, for females and males. As noted above, the known nesting site is located approximately 1.5 km (0.9 mi) west of the landfill. Therefore, females are unlikely to derive a significant portion of their diet from landfill contaminated prey. However, during the brooding period, the male provides food for female, who remains on the nest, and the nestlings (Fitzner 1980).

As the distance from the nest to the landfill is x = 1.5 km and the foraging radius is r = 1.7 km, the angle subtending the chord formed by the landfill boundary intersecting the male's foraging territory is:

$$2\cos^{-1}(x/r) = 56°.$$

The area between the chord and the circumference of the territory is:

$$\pi r^2(56°/360°) - x(r^2 - x^2)^{1/2} = 0.2\ km^2.$$

Thus, assuming that foraging intensity is uniform over the territory, approximately 2% of the Swainson's hawk prey is derived from the Horn Rapids Landfill.

Paustenbach (1989) states that birds weighing over 0.1 kg consume less than 20% (on a dry weight basis) of their body weight per day. Birds in their native habitat that weigh approximately 1 kg ingest approximately 10% to 15% (on a wet weight basis) of their body weight per day; 80% to 90% of which is water (Driver, C., PNL [Personal communication] June 28,1990). With the conservative wet weight ingestion rate of 15% and the conservative water content of 80%, a 3%/d dry weight ingestion rate is obtained.

Thus, it is conservatively assumed that Swainson's hawks consume 30,000 mg/d and long-billed curlews consume approximately 27,000 mg/d. The long-billed curlew diet is assumed to consist entirely of insects, while the Swainson's hawk diet is conservatively assumed to consist entirely of small mammals (which accumulate PCB more than insects).

The annual average long-billed curlew intakes for each of the landfill contaminants of potential concern, based on the prey tissue concentrations derived in Section 5.3.5.1, are:

- arsenic 5E-04 mg/kg/d
- chromium 4E-03 mg/kg/d
- PCB 2E-02 mg/kg/d.

Swainson's hawk contaminant intakes, averaged over a year, are estimated to be:

- arsenic 1E-07 mg/kg/d
- chromium 5E-06 mg/kg/d
- PCB 2E-03 mg/kg/d.

These estimated intake rates are used below in Section 6.2.3 to assist in determining the magnitude of the threat posed by landfill contamination to these sensitive species.

Aquatic Biota

Tetrachloroethene is the only known contaminant of potential concern present in operable unit ground waters; it will eventually discharge to the Columbia River. Trichloroethene and nitrate, two contaminants that characterize the plume present in the vicinity of the Horn Rapids Landfill, will also reach the river in time. The predicted contaminant fluxes to the river for the latter two contaminants are very small in relationship to the river discharge (see Section 5.3.4). Because of this, contaminant concentrations in the river water column will be negligible once complete mixing is achieved. While currently available data are insufficient data to quantitatively evaluate the flux of tetrachloroethene associated with the 1100-2 subunit, the eventual river concentration, upon complete mixing, is also expected to be negligible by analogy.

For the purposes of the aquatic biological assessment, however, conservatively biased concentrations for the City of Richland water intake are assumed to exist within the entire river. Therefore, the respective water column concentrations to which the aquatic community will be exposed are assumed to be 4E-08 and 1E-03 mg/L for trichloroethene and nitrate (see Section 5.3.4). These concentrations are compared to established water quality criteria in Section 6.2.3 to determine the potential for harm to the aquatic community in the Columbia River. Analogously, tetrachloroethene concentrations at the city water intake are also expected to be low.

6.2.1.3 Uncertainty Analysis. The exposure assessments for the Swainson's hawk and the long-billed curlew, while based on best available data, contain much uncertainty: the food chain for each species has been simplified; surrogate uptake factors are used liberally to estimate contaminant concentrations in prey species; adult exposures are estimated rather than focusing on their young, which are presumably more sensitive to potential toxic effects; and the only exposure route evaluated is food ingestion.

The EPA (1988e) recommends that biotic pathway assessments be regarded, at best, as semiquantitative due to a current lack of understanding of the general theoretical relationships among contaminants, ecosystems, and biological species. Errors of up to three to four orders of magnitude should be anticipated, and the intake values must be used in a qualitative sense.

As mentioned previously, the assumed river water column concentrations for nitrate and trichloroethene are very high, relative to what could realistically be anticipated. They are derived from conservative assumptions for both ground-water and surface-water transport pathways. Such concentrations in actuality apply to only a very minor portion of the Columbia River. Therefore, the degree of confidence in the aquatic biological exposure assessment, from an environmental regulatory perspective, is high in that the actual exposure is being overstated.

6.2.2 Environmental Toxicity Assessment

The purpose of an environmental toxicity assessment is to evaluate available toxicological data on the operable unit contaminants of potential concern so that a characterization of potential risks to sensitive terrestrial and aquatic species and communities can be made. Relevant environmental toxicological data are summarized in Appendix Q for the environmental contaminants of potential concern—arsenic, chromium, and PCB for terrestrial species at and near the Horn Rapids Landfill, and tetrachloroethene (plus two contaminants of interest, trichloroethene and nitrate) for aquatic communities in the Columbia River.

The known toxic effects of these contaminants are described below in Section 6.2.2.1, and the uncertainties associated with the environmental toxicity assessment are discussed in Section 6.2.2.2.

6.2.2.1 Toxic Effects. To assist in the qualitative evaluation of the Swainson's hawk and long-billed curlew contaminant intakes estimated in Section 6.2.1.2, lowest observed toxic doses (TDLos) from Sax (1984) are provided below. As no values for birds are published, each TDLo listed below is the lowest value found for any species for any sort of toxic effect.

- arsenic — 6.1E-01 mg/kg — administered orally as a single dose to rats
- chromium — 2.9E-02 mg/kg/d — administered as an implant over a 6-wk period to rats
- PCB — 7.4E+01 mg/kg — administered orally as a single dose to rats

For the purposes of assessing potential impacts to the aquatic environment of the Columbia River, nitrate is regarded as non-toxic. Nitrate is an essential nutrient that is usually rapidly assimilated by aquatic plants (Hynes 1970). The annual average nitrate concentration in the river at the city water intake is approximately 2E-01 mg/L (Jacquish and Mitchell 1988).

The EPA (1986a) has published chronic water quality criteria, based on the protection of freshwater organisms, for tetrachloroethene and trichloroethene—0.84 and 21.9 mg/L, respectively. The tetrachloroethene criterion is based on a lowest-observed-effects-level for an unspecified species; the trichloroethene criterion is based on an adverse behavioral effect noted for an unspecified nonsensitive species.

6.2.2.2 Uncertainty Analysis. As the TDLo data for arsenic, chromium, and PCB are not specific to birds, and (for arsenic and PCB) are based on acute rather than chronic exposures, the uncertainty associated with using them for comparison against gross estimates of Swainson's hawk and long-billed curlew contaminant intakes is great. As noted above, errors of three to four orders of magnitude can be expected.

As nitrate is an essential aquatic plant nutrient, its toxic potential in an aquatic environment, at normal environmental concentrations, can be disregarded with a high degree of confidence. Because the CFWQC for trichloroethene is based on studies for only one species, one that is regarded

as nonsensitive, moderate certainty can at best be attributed to this value. The EPA (1986a) also indicates that chronic toxicity of tetrachloroethene to freshwater aquatic life could be expected to occur at concentrations lower than the published criterion for species more sensitive than those evaluated.

6.2.3 Environmental Risk Characterization

An environmental risk characterization allows for an evaluation of the potential for and the magnitude of any threats posed to sensitive biological organisms by contaminant releases. Toxic risks are evaluated below in Section 6.2.3.1, uncertainties associated with the evaluation are discussed in Section 6.2.3.2, and a summary of the results of the environmental risk assessment process is provided in Section 6.2.3.3.

6.2.3.1 Toxic Risks. Estimated landfill soil contaminant intake rates for Swainson's hawks and long-billed curlews can be compared to TDLo data in Table 6-12. These values can be compared in only the most qualitative sense, because of the inherent uncertainty associated with the intake estimates and the difference in species, form of dose administration, and timeframes used to obtain the TDLos.

However, bearing in mind that a three to four order of magnitude error can be expected and arbitrarily dividing the TDLos for arsenic and PCB by 10 in an attempt to compensate for the acute nature of the dose administration, the hawk arsenic, chromium, and PCB intakes are approximately six, four, and four orders of magnitude, respectively, below what could be regarded as a toxic level. The curlew intakes are approximately two orders of magnitude less for arsenic, about one order of magnitude less for chromium, and about three orders of magnitude lower for PCB, with respect to their crudely derived toxicity criteria.

It appears that there is no qualitative reason to suspect significant adverse toxicological impacts to the Swainson's hawks nesting to the west of the landfill. While the above analysis indicates that the long-billed curlews nesting in the immediate vicinity of the landfill should not be impacted, the results do not lie outside of the anticipated error range. Therefore, the results are less clear for the curlews, and, according to the analysis, if any adverse impact to these organisms were to be suspected, chromium toxicity would be most likely.

Table 6-12 also contains a conservatively estimated trichloroethene concentration in the Columbia River at the location of the City of Richland water intake and the relevant CFWQC. The predicted concentration is approximately seven orders of magnitude lower than the criterion, thus indicating that adverse impacts to the aquatic community from potential trichloroethene contamination are highly unlikely. Tetrachloroethene impacts are also anticipated to be unlikely.

The plant nutrient nitrate is shown in comparison with the annual average nitrate concentration found at the water intake. It can be seen that the maximum incremental contribution from ground-water contamination that appears to have originated upgradient of the Horn Rapids Landfill is insignificant in comparison to normal river nitrate levels at the City of Richland water intake (approximately one order of magnitude less).

Table 6-12. Environmental Risk Characterization

Contaminant of Potential Concern	Lowest Published TDLo (see Section 6.2.2.1)	Estimated Annual Average Intake (mg/kg/d) (see Section 6.2.1.2)	
Terrestrial Biota:		Swainson's Hawk	Long-Billed Curlew
arsenic	6.1E-01 mg/kg (one-time dose)	1E-07	5E-04
chromium	2.9E-02 mg/kg/d (over a 6-wk period)	5E-06	4E-03
PCB	7.4E+01 mg/kg (one-time dose)	2E-03	2E-02

Contaminant of Potential Concern	CFWQC (mg/L) (see Table 4-23)	Annual Average River Concentration (mg/L) (see Section 6.2.2.1)	Estimated River Concentration Due to Ground-Water Contributions (mg/L) (see Section 5.3.4)
Aquatic Biota:			
nitrate[a]	--	2E-01	4E-02
tetrachloroethene	8.4E-01	--	insufficient data
trichloroethene[a]	2.19E+01	--	6E-06

[a]Not an operable unit contaminant of potential concern for this pathway.

6.2.3.2 Uncertainty Analysis. For reasons specified in Sections 6.2.1.3 and 6.2.2.2 above, the risk characterizations for the Swainson's hawk and the long-billed curlew have a high degree of associated uncertainty. For example, the food chains analyzed for the two sensitive bird species have been simplified. Swainson's hawks are assumed to exclusively consume herbivorous small mammals. In reality, snakes comprise a significant fraction of a Swainson's hawk's diet at the Hanford Site (Fitzner 1980), thereby increasing the length of the food chain and the potential for bioaccumulation of PCB. However, existing data suggest that PCB levels in snake tissue are similar to those found in their prey species (Eisler 1986). Thus, the simplification of the hawk's food chain is not expected to impart a significant bias to the results of the risk characterization.

The uncertainty associated with the prediction of essentially zero risk posed by trichloroethene and nitrate to the aquatic community of the Columbia River appears to be very low. The estimated surface-water concentrations of trichloroethene, along with the maximum concentration encountered in ground water (see Table 4-23) are insignificant in comparison to the relevant EPA water quality criterion. As the predicted incremental increase in the surface-water concentration of nitrate is insignificant, and this substance is

an essential nutrient, there is virtually no uncertainty associated with a prediction of an absence of risk to the aquatic community. While the maximum amount of tetrachloroethene encountered in operable unit ground waters is well below the CFWQC (see Table 4-23), the ground water immediately downgradient from the 1100-2 Paint and Solvent Pit, the likely source of this contamination, has yet to be characterized.

6.2.3.3 Environmental Risk Characterization Summary. While there is no evidence to support a conclusion of adverse contaminant impacts to the Swainson's hawks and long-billed curlews known to inhabit the Horn Rapids Landfill vicinity, such impacts to the curlews can not be ruled out. However, the evaluation presented for this sensitive terrestrial community is simplistic and far from certain. The annual reoccurrence of both migratory species suggests that they are successfully reproducing. Putting the operable unit contamination problems into perspective, normal human activities—e.g., clearing, construction, facility operations, pesticide application, and off-road vehicle use—probably pose the greater threat to both species and most other terrestrial organisms.

As nitrate is a readily assimilated essential nutrient for aquatic plants and the levels that could be contributed by the contamination source upgradient of the operable unit are insignificant, it poses no risk to aquatic life in the Columbia River. The comparison of a conservatively biased prediction of trichloroethene concentrations in the Columbia River indicates, with a fair degree of certainty, that no adverse impacts to aquatic communities will occur. Aquatic impacts attributable to tetrachloroethene are also unlikely, but quantitative evidence is lacking.

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7.0 SUMMARY AND CONCLUSIONS

An RI, by its very nature, is a complex, multiple-objective phase of an important regulatory process. It demands the use of a multi-disciplinary investigational approach to define the nature and extent of any threats to human health and the environment posed by releases of contaminants from a site, and any other information needed to support an evaluation of remedial alternatives during the FS phase of the project.

In this section, a summary of the findings of the initial phase of this complex process for the 1100-EM-1 Operable Unit is presented. This summary is presented in Section 7.1. Based on these findings, and the statutory requirements of CERCLA and the regulatory requirements of the NCP and the TPA, Section 7.2 is used to provide recommendations for further hazardous substance response work at the operable unit.

7.1 PHASE I REMEDIAL INVESTIGATION SUMMARY

The Phase I RI for the 1100-EM-1 Operable Unit is summarized below in terms of the physical characteristics (Section 7.1.1), the nature and extent of contamination (Section 7.1.2), the environmental fate and transport of operable unit contaminants (Section 7.1.3), and the risks posed to human health and the environment by the contaminants released from the operable unit (Section 7.1.4). Detailed discussions on these topics are provided in Sections 3, 4, 5, and 6, respectively.

7.1.1 Physical Characteristics

The 1100 Area—the central warehousing, vehicle maintenance, and transportation operations center for the Hanford Site—was designated an NPL site in July, 1989. This NPL site was divided into four operable units, and the first equipment maintenance unit, 1100-EM-1, was assigned the highest priority. A detailed presentation of the regional and local aspects of the physical characteristics of the operable unit is provided in Section 3. The following summary focuses on the major issues related to contaminant sources, meteorology, surface hydrology, geology, pedology, hydrogeology, and ecology.

The 1100-EM-1 Operable Unit contains eight distinct waste management units that can be regarded as operable subunits, and two miscellaneous locations:

- 1100-1 (Battery Acid Pit)—an unlined dry sump, or french drain, used for the disposal of waste acid from vehicle batteries (see Section 3.1.2.1)
- 1100-2 (Paint and Solvent Pit)—a former sand and gravel pit subsequently used for the disposal of construction debris and, reportedly, waste paints, thinners, and solvents (see Section 3.1.2.2)

- 1100-3 (Antifreeze And Degreaser Pit)—a former sand and gravel pit subsequently used for the disposal of roofing gravel, concrete rubble, and, reportedly, waste antifreeze and degreasers (see Section 3.1.2.3)

- 1100-4 (Antifreeze Tank Site)—the site of a former underground storage tank used for the disposal of waste vehicle antifreeze (see Section 3.1.2.4)

- UN-1100-5 (Radiation Contamination Incident)—the site of a former leak of short-lived radionuclides onto the bed of a truck parked within the 1100 Area (see Section 1.3.2.5)

- UN-1100-6 (Discolored Soil Site)—the location of an apparent disposal event onto the ground surface involving a container of organic waste liquids (see Section 3.1.2.4)

- Horn Rapids Landfill—a solid waste facility used primarily for the disposal of office and construction waste and the burning of classified documents; asbestos, sewage sludge, fly ash, and, potentially, drums of unidentified organic liquids were also disposed at this location (see Section 3.1.2.6)

- Hanford Patrol Academy Demolition Site—a pit used for the disposal of unstable chemicals by detonation (see Section 1.3.2.8)

- Pit 1—the 1100 Area gravel pit in current use (see Section 4.4)

- Ephemeral Pool—the location of 1100 Area parking lot runoff accumulation during infrequent, high-intensity precipitation events (see Section 3.3.2).

The UN-1100-5 operable subunit is considered to pose no significant contamination problem: no radioactivity was found on the 1100 Area parking lot surface, and enough time has elapsed since the release such that the radioisotopes involved are virtually completely decayed. For the purposes of this report, the Hanford Patrol Academy Demolition Site is not regarded as part of the 1100-EM-1 Operable Unit. This waste management unit is a TSD facility that, if necessary, will be addressed separately under Ecology's RCRA authority.

There are several other waste management facilities in the vicinity of the 1100-EM-1 Operable Unit (see Section 3.1.3). These include two of the remaining three operable units that comprise the 1100 Area NPL Site (the 1100-EM-2 and 1100-EM-3 Operable Units), a potato processing plant, a private nuclear fuel manufacturing facility, the Hanford Site nuclear fuel fabrication and research and development complex (the 300 Area), and the Richland Municipal Landfill.

The 1100-EM-1 Operable Unit is situated within an area possessing a relatively moderate semiarid climate characterized by low precipitation, high evapotranspiration, and light winds (see Section 3.2). No significant surface water bodies are located within or immediately adjacent to the operable unit, as the topography is relatively flat and the precipitation, combined with high evapotranspiration potential, provides little water to generate runoff (see

Section 3.3). However, the Columbia River—an important regional surface water resource—is located approximately 1.5 to 1.8 km (0.9 to 1.1 mi) to the east of the operable unit.

The operable unit is underlain by massive basalt flows that form a regional bedrock. The uppermost basalt flow in the area of the 1100-EM-1 Operable Unit is the Ice Harbor Member of the Saddle Mountains Basalt Formation (see Section 3.4.3.2). Overlying the bedrock is the Ringold Formation, an approximately 43- to 52-m (142- to 170-ft) thick deposit of mixed sediments of fluvial and lacustrine origin (see Section 3.4.3.1). The upper portion of this formation consists of sandy gravels, gravelly sands, silty sandy gravels, and silty gravelly sands, with discontinuous sand lenses. These coarse-grained sediments are underlain by finer-grained silts, clays, sandy silts, and sands.

Above the Ringold Formation is the Hanford formation, the dominant facies of which is the Pasco gravels—a variable mixture of boulders, cobbles, pebbles, sands, and silts of glaciofluvial origin (see Section 3.4.3.1). Most of this formation, which is approximately 8- to 17 m (25- to 56-ft) thick, can be classified as unconsolidated basaltic sandy gravels to gravelly sands and silty sandy gravels. Eolian deposits form a thin veneer (< 0.3-m to 6-m [1- to 20-ft] thick) over the Hanford formation in the area of the operable unit. These deposits consist of moderately-to-well sorted, very-fine-to-medium-grained sands or silty sands that were originally derived from the Hanford formation (see Section 3.4.3.1).

The soils of the operable unit are primarily classified as regosols, and are largely dominated by the characteristics of the parent materials from which they are derived. The moisture content of these soils ranges from 1 to 7%, and the soils contain only low amounts of organic matter (see Section 3.5.2).

An unconfined water-table aquifer, underlain by a silt aquitard formed by the finer-grained lower portion of the Ringold Formation, occurs below the entire operable unit (see Section 3.6.2). The aquitard, which was observed throughout the operable unit vicinity, separates the unconfined aquifer from lower confined-to-semi-confined aquifers. Regionally, the zone of recharge to the unconfined aquifer is located to the west of the operable unit, and the aquifer discharges to the east, in the Columbia River. Local ground-water flow, as measured in early March of 1990, is easterly below most of the operable unit, but northeasterly in the vicinity of the Horn Rapids Landfill (see Section 3.6.2.3). The easterly flow in the southern portion of the operable unit indicates that ground water passing beneath most of the operable subunits could pass through the City of Richland well field, which is located between the operable unit and the Columbia River.

This well field supplements the city's river-derived water supply during times of peak use; however, essentially all water obtained from the field is river water derived from large infiltration ponds around which the withdrawal wells are sited. When in use, large-volume infiltration creates a mound that diverts the regional ground-water flow around the field (see Section 3.6.2.3).

With the exception of the 1100 Area, the entire Hanford Site within Benton County is zoned for restricted uses that are subject to federal government approval (see Section 3.7.1.1). Approximately 45% of the Hanford Site is currently set aside as either wildlife or ecological reserves.

All land encompassing the 1100-EM-1 Operable Unit is currently zoned for either industrial or restricted land use (see Section 3.7.1.1). Adjacent lands are zoned for industrial and commercial use; however, agricultural use is currently being allowed in a heavy-manufacturing-use zone to the west of the operable unit and a medium-industrial-use zone to the east. The nearest agricultural-use zones are about 1.8 km (1.1 mi) to the west of the operable unit, and the closest residential zone is approximately 0.8 km (0.5 mi) to the southeast of the Battery Acid Pit. County and city land-use plans and 1100 Area construction plans indicate that no significant changes in local land use are envisioned.

The Columbia River is the most significant surface-water body in the region. It serves as a source of drinking, industrial process, and irrigation water, and is used for various recreational activities (see Section 3.7.1.2). Ground water in the vicinity of the operable unit is used primarily for environmental monitoring, irrigation, and limited domestic use; all residential areas in the vicinity have access to the city water supply (see Section 3.7.1.2). As mentioned earlier, ground water derived from infiltrated river water is used to supplement the City of Richland water supply during times of peak seasonal demand.

No cultural resources, of either an archeological or historical significance, are located within the 1100-EM-1 Operable Unit (see Section 3.7.1.3).

The operable unit is located in a shrub-steppe vegetational zone characterized by the presence of a sagebrush/bunchgrass plant community in undisturbed areas and a cheatgrass/rabbitbrush/tumbleweed community in areas disturbed by human activities, such as the operable unit. No endangered, threatened, or sensitive plant species or communities are known to inhabit the operable unit vicinity (see Section 3.7.2.1).

The most abundant fauna apparent in the region are the grasshopper, horned lark, western meadowlark, Great Basin pocket mouse, cottontail rabbit, jackrabbit, various raptor species, coyote, and mule deer. The primary animal species of interest that inhabit the operable unit vicinity are the mule deer and two sensitive birds—the Swainson's hawk and the long-billed curlew (see Section 3.7.2.1).

No aquatic ecosystems are located on or adjacent to the operable unit. However, the Columbia River, while not supporting any endangered or threatened aquatic species, does support important populations of game fish, including various species of anadromous salmonids (see Section 3.7.2.2).

7.1.2 Nature and Extent of Contamination

The nature and extent of contamination at the 1100-EM-1 Operable Unit are summarized below by the environmental media characterized during Phase I RI field activities: contaminant sources, air, soil, and ground water. A

detailed presentation of the nature and extent of operable unit contamination is found in Section 4.

7.1.2.1 Contaminant Sources. Six operable subunits and two miscellaneous locations are evaluated in detail with respect to their potential to be primary or secondary sources of significant environmental contamination at the 1100-EM-1 Operable Unit. These subunits and locations are: the 1100-1 Battery Acid Pit, the 1100-2 Paint and Solvent Pit, the 1100-3 Antifreeze and Degreaser Pit, the 1100-4 Antifreeze Tank Site, the UN-1100-6 Discolored Soil Site, the Horn Rapids Landfill, Pit 1, and the ephemeral pool. Each subunit and location is briefly described in Section 7.1.1 above. Two other operable subunits, UN-1100-5 and the Hanford Patrol Academy Demolition Site, are not given further detailed consideration for reasons specified in Section 7.1.1.

The original waste streams associated with each of the six operable subunits considered are no longer in existence. The same is most likely true for the two miscellaneous locations. Therefore, the soils of these subunits and locations are regarded as existing secondary sources of contamination. Soil contamination is summarized in Section 7.1.2.3 below.

Surface radiation surveys were conducted at each of the operable subunits, with the exception of UN-1100-6; the results of all such surveys were negative—no measurable radioactivity was encountered (see Section 4.1.1). Soil gas surveys were conducted at the 1100-1, 1100-2, 1100-3, and Horn Rapids Landfill operable subunits. Tetrachloroethene was encountered within the soil gas of 1100-2 and the Horn Rapids Landfill, and trichloroethene and 1,1,1-trichloroethane were also found at the landfill (see Section 4.1.1).

Of the other nearby waste management facilities mentioned in Section 7.1.1, one—the Advanced Nuclear Fuels Corp. complex—is known to have contributed significant levels of contamination to operable unit ground waters in the vicinity of the Horn Rapids Landfill (see Section 4.1.2.4). Contaminants known to have emanated from this facility are nitrate, fluoride, sulfate, ammonia, and gross-alpha and gross-beta radiation.

7.1.2.2 Air Contamination. One round of ambient air monitoring data is available for operable unit characterization; a second round of monitoring was conducted to assess potential occupational impacts during RI activities (see Section 4.2). The quantity and quality of these data are such that their utility is questionable. However, no indications of substantial deterioration of ambient air quality in the vicinity of the operable unit were found under the moderate wind conditions present at the time the monitoring was conducted (see Section 4.7.1).

7.1.2.3 Soil Contamination. Soils were sampled at each operable subunit and miscellaneous locations, and analyzed for TAL and TCL parameters; in addition, samples obtained from the 1100-4 subunit were analyzed for ethylene glycol, and certain samples from the Horn Rapids Landfill were analyzed for asbestos fibers (see Section 4.4). Results were compared to operable-unit-specific background concentrations to determine the contaminants present, and preliminary conservative toxicity screening was performed to determine contaminants of potential concern. Surface soils are conservatively considered to be those lying within 0.6 m (2 ft) of the ground surface. The findings for each subunit and location are summarized below:

- 1100-1 (Battery Acid Pit)-arsenic is the only contaminant of potential concern, encountered in the subsurface stratum one time at a concentration barely exceeding background levels (see Section 4.4.2)

- 1100-2 (Paint and Solvent Pit)-chromium is the only soil column contaminant of potential concern, encountered in a single surface sample at a concentration not greatly in excess of background (see Section 4.4.3); in fact, the mean surface chromium concentration at 1100-2 is lower than the mean background concentration (see Section 5.3.1.2); tetrachloroethene was encountered during the soil gas survey conducted under the source investigation (see Section 7.1.2.1)

- 1100-3 (Antifreeze and Degreaser Pit)-only two contaminants of potential concern are present, arsenic and chromium; arsenic was encountered in only a single surface sample at a concentration barely exceeding background, and chromium was encountered at elevated concentrations only in the surface stratum at two locations (see Section 4.4.4)

- 1100-4 (Antifreeze Tank Site)-the surface stratum of the soil column was not sampled at this subunit, but a concrete floor prevents direct contact with surface soils at this location; arsenic was found at elevated levels of potential concern, but only in a single sample obtained from below the water table (see Section 4.4.5)

- UN-1100-6 (Discolored Soil Site)-only surface soils were sampled and analyzed at this subunit; the two contaminants of potential concern identified are BEHP and chlordane (see Section 4.4.6); BEHP is present in percentage concentrations, and the distribution of the chlordane contamination is spatially correlated with the BEHP contamination

- Horn Rapids Landfill-both surface and subsurface soils were sampled and analyzed, but the subsurface sampling intentionally avoided areas of known and suspected waste deposition; the soil column contaminants of potential concern are PCB, chromium, and arsenic (see Section 4.4.7); PCB was detected a levels of potential concern at three surface and one subsurface location; arsenic was encountered at levels of potential concern at one surface and two subsurface locations; chromium is more widely distributed, being found in 11 surface and eight subsurface locations at levels of potential concern; trichloroethene, tetrachloroethene, and 1,1,1-trichloroethane were encountered in the gaseous phase of the landfill soils during the soil gas survey conducted for this subunit (see Section 7.1.2.1)

- Pit 1-surface soils only were sampled and analyzed at this location; PCB was encountered in one out of the six samples obtained (see Section 4.4.8)

- Ephemeral pool—only two surface soil samples were obtained at this location; two contaminants of potential concern, PCB and chlordane, are identified—chlordane in both samples, PCB in only one (see Section 4.4.8).

7.1.2.4 Ground-Water Contamination. Twenty-nine monitoring wells throughout the 1100-EM-1 Operable Unit vicinity, and two distribution lines from the nearby City of Richland well field, were sampled during the Phase I RI field activities. Twenty-one wells were sampled in the first round of monitoring, and 29 in the second round; the well field distribution lines were sampled in both monitoring rounds.

The samples obtained were analyzed for conventional, TAL, and TCL parameters (see Section 4.5). Results were compared to operable-unit- or Horn-Rapids-Landfill-specific background concentrations, as appropriate, to determine the contaminants present. The determination of landfill-specific background was necessary due to the presence of the reported, upgradient Advanced Nuclear Fuels Corp. plume (see Section 4.1.2.4). Preliminary conservative toxicity screening was performed to determine contaminants of potential concern.

The only operable unit ground-water contaminant of potential concern identified, tetrachloroethene, is present in a single well near the 1100-2 Paint and Solvent Pit (see Section 4.5.2). However, insufficient data are currently available to understand the magnitude and extent of this contamination.

Although existing data do not suggest operable unit sources, two other areas of ground-water contamination are present within the vicinity of the 1100-EM-1 Operable Unit. One is an area of generally deteriorated ground-water quality in the vicinity of the 1171 Building that contains elevated concentrations of several contaminant parameters, including gross alpha radiation at levels that may be of interest. The other appears to be a contaminant plume that originated upgradient from, and is passing beneath, the Horn Rapids Landfill. This plume is characterized primarily by the presence of high concentrations of trichloroethene and nitrate, which, along with the operable unit contaminants of concern, are regarded as contaminants of interest.

7.1.3 Contaminant Fate and Transport

The contaminant fate characteristics of nine contaminants of interest—arsenic, BEHP, chlordane, chromium, nitrate, PCB, tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene—are discussed in Section 5.2. These contaminants include the operable unit contaminants of potential concern and trichloroethene and nitrate, the two ground-water contaminants that characterize what appears to be a plume of upgradient origin with respect to the Horn Rapids Landfill. Potentially operative contaminant transport pathways for the operable unit are qualitatively identified in Section 5.1 and quantitatively evaluated, where feasible, in Section 5.3.

The potentially operative contaminant transport pathways for the 1100-EM-1 Operable Unit, taking preliminary toxicity screening results of Section 4 into account, are:

- Volatile emissions and atmospheric dispersion—tetrachloroethene from 1100-2; trichloroethene, tetrachloroethene, and 1,1,1-trichloroethane from the Horn Rapids Landfill (see quantitative evaluations provided in Section 5.3.1.1)

- Fugitive dust emissions and atmospheric dispersion—arsenic and chromium from 1100-3; BEHP from UN-1100-6; arsenic, chromium, and PCB from the Horn Rapids Landfill (see quantitative evaluations provided in Section 5.3.1.2)

- Direct contact of surface contamination—arsenic and chromium at 1100-3; BEHP and chlordane at UN-1100-6; arsenic, chromium, and PCB at the Horn Rapids Landfill; PCB at Pit 1; PCB and chlordane at the ephemeral pool (see quantitative evaluations provided in Section 5.3.2)

- Vadose-zone transport—considered to be insignificant (see qualitative evaluation provided in Section 5.3.3.1)

- Ground-water transport—trichloroethene and nitrate in the vicinity of the Horn Rapids Landfill (see quantitative evaluations provided in Section 5.3.3.2); available data are currently insufficient to evaluate tetrachloroethene contamination associated with 1100-2

- Surface-water transport—tetrachloroethene, trichloroethene, and nitrate in the Columbia River from contaminated ground-water discharge (see quantitative evaluations, for trichloroethene and nitrate, and qualitative evaluation, for tetrachloroethene, provided in Section 5.3.4)

- Terrestrial biological transport—arsenic, chromium, and PCB to humans through mule deer, and to Swainson's hawks and long-billed curlews at the Horn Rapids Landfill (see semiquantitative evaluations provided in Section 5.3.5.1)

- Aquatic biological transport—tetrachloroethene, trichloroethene, and nitrate uptake by fish in the Columbia River (see quantitative evaluation, for trichloroethene, and qualitative evaluations, for tetrachloroethene and nitrate, provided in Section 5.3.5.2).

7.1.4 Risks to Human Health and the Environment

Section 6 provides a detailed assessment of the baseline risks, under current land- and water-use conditions, posed to human health and the environment by contaminant releases from and near the 1100-EM-1 Operable Unit. Brief summaries of the human and environmental portions of this assessment are respectively provided in Sections 7.1.4.1 and 7.1.4.2 below.

7.1.4.1 Human Health Risks. Of the nine contaminants of interest at and near the 1100-EM-1 Operable Unit, none alone, on the basis of an assessment of a hypothetically most exposed individual, poses a significant threat to human health under current land- and water-use conditions (see Section 6.1). The overall risk associated with systemic toxicity is negligible; the overall risk

associated with carcinogenicity is approximately 2E-06 (see Table 6-11 and Section 6.1.3.4). These cumulative risks include not only all identified operable unit contaminants of potential concern, but also trichloroethene and nitrate associated with an apparent ground-water plume of upgradient origin with respect to the Horn Rapids Landfill.

Approximately 90% of the overall cancer risk to the most exposed individual can be attributed to two operable unit contaminants of concern—BEHP and PCB. Risk assessment indicates that the human population at risk for adverse effects of these two contaminants consists of workers having direct access to and job duties on the UN-1100-6 Discolored Soil Site, the Horn Rapids Landfill, and the ephemeral pool.

The BEHP poses a problem at the UN-1100-6 operable subunit, where it is present in surface soils in percentage concentrations. Ingestion and inhalation of these soils may increase cancer risks by about E-06. The ephemeral pool and the Horn Rapids Landfill have surficial PCB soil contamination. The ingestion and inhalation of contaminated soils at both facilities, and the consumption of venison potentially contaminated by the landfill, may also increase cancer risks by about E-06.

Exposure to contaminated ground waters downgradient of the 1100-2 operable subunit, or in the vicinities of the 1171 Building and the Horn Rapids Landfill, although dismissed as an operative pathway under existing land- and water-use conditions, could pose a human health hazard. Depending upon where a withdrawal well might be sited and how it may be used, a significantly increased cancer risk could be associated with tetrachloroethene and trichloroethene ingestion and inhalation, and a systemic toxic hazard could be posed by the ingestion of nitrate-contaminated ground water. Insufficient data exist to determine whether ingestion of gross alpha radiation could pose a significant risk.

The tetrachloroethene is associated with the 1100-2 Paint and Solvent Pit, and the trichloroethene and nitrate are associated with a plume in the vicinity of the Horn Rapids Landfill. However, existing ground-water data are not sufficient to prove the landfill, and thus the operable unit, to be the source of the latter two contaminants. The gross alpha radiation appears to be associated with the 1171 Building; existing data are also insufficient to prove an operable unit source of this contamination.

7.1.4.2 Environmental Risks. Two sensitive bird species known to inhabit the Horn Rapids Landfill vicinity—the Swainson's hawk and the long-billed curlew—were selected as indicator species for the terrestrial environmental evaluation (see Section 6.2). Arsenic, chromium, and PCB, due to their presence in landfill surface soils, are the contaminants of potential concern for these species.

While there is no evidence to support a conclusion of adverse contaminant impacts to the Swainson's hawks known to inhabit the landfill vicinity, a potential for such impacts, especially due to chromium, to the long-billed curlews that nest within and adjacent to the landfill can not be ruled out. However, the evaluation presented for this sensitive terrestrial community is simplistic and far from certain. The annual reoccurrence of both migratory species suggests that they are successfully reproducing. Putting the operable unit contamination problems into perspective, normal human activities—e.g.,

clearing, construction, facility operations, pesticide application, and off-road vehicle use—probably pose the greater threat to both species and most other terrestrial organisms.

An environmental evaluation is also performed for the aquatic community of the Columbia River (see Section 6.2). Tetrachloroethene, derived from the discharge of 1100-2 vicinity ground waters to the river, is the contaminant of potential concern for this community; trichloroethene and nitrate, derived from the discharge of Horn Rapids Landfill vicinity ground waters to the river, are additional contaminants of interest.

As nitrate is a readily assimilated essential nutrient for aquatic plants, and the levels that could be contributed to the river are insignificant, it poses no risk to aquatic life. The comparison of a conservatively biased prediction of trichloroethene concentrations in the Columbia River indicates, with a fair degree of certainty, that no adverse impacts to aquatic communities will occur. Operable unit characterization data are currently insufficient to allow for a quantitative evaluation of potential tetrachloroethene impacts, but, by analogy, it is unlikely that any adverse impact to aquatic life will occur.

7.2 PHASE I REMEDIAL INVESTIGATION CONCLUSIONS

The results of the Phase I RI for the 1100-EM-1 Operable Unit, as summarized above in Section 7.1, are used to develop recommendations for conducting and focusing further hazardous substance response activities needed to comply with the terms of CERCLA, the NCP, and the TPA. Section 7.2.1 provides recommendations for removal actions in accordance with the process outlined in 40 CFR 300. Section 7.2.2 provides recommendations for Phase II RI activities, in terms of both additional operable unit characterization and treatability investigation. Section 7.2.3 recommends remedial action objectives for use in the early stages of the FS for the 1100-EM-1 Operable Unit.

The Phase I RI data indicate that the following operable subunits require no further direct characterization due to an absence of contamination at levels that could be reasonably expected to pose a threat to human health or the environment:

- 1100-3 (Antifreeze and Degreaser Pit)
- UN-1100-5 (Radiation Contamination Incident)
- Pit 1.

These subunits are therefore not given further consideration; no further response actions pursuant to CERCLA, the NCP, and the TPA are recommended.

The following recommendations for additional response actions focus on 1100-1 (the Battery Acid Pit), 1100-2 (the Paint and Solvent Pit), 1100-4 (the Antifreeze Tank Site), UN-1100-6 (the Discolored Soil Site), the Horn Rapids Landfill, and the parking-lot-runoff ephemeral pool. The 1100 Area was designated an NPL site because of the potential for contamination problems at the 1100-1 and 1100-4 operable subunits (see Section 1.3.3). While both of these facilities were investigated for specific anticipated problems during the Phase I RI, none has yet to be identified.

7.2.1 Recommended Removal Actions

At the time of completion of the first phase of an RI, it is appropriate to conduct an NCP removal site evaluation in accordance with 40 CFR 300.410. This Phase I RI Report is used, in part, to document such an evaluation for the 1100-EM-1 Operable Unit. Taking the factors specified in 40 CFR 300.415(b)(2) into account, this sub-subsection is used to recommend appropriate removal actions consistent with the guidelines provided in 40 CFR 300.415(d).

An evaluation of the NCP guidelines referenced above indicates that removal actions at the 1100-EM-1 Operable Unit are not necessary at this time. There is no evidence of imminent and substantial endangerment to either human health or the environment from exposures to operable unit contaminants, no drinking-water supplies or sensitive ecosystems are known to be contaminated by the operable unit, and none of the 1100-EM-1 contaminants of concern are present in the form of bulk storage. Although there is some high level soil contamination, the contaminants of concern, BEHP and PCB, are not readily subject to migration. Nor are weather conditions expected to arise that would result in the migration of such contamination. There is also no known threat of fire or explosion, and it appears that the 1100-EM-1 RI/FS, and any subsequent necessary remediation, can be completed in a timely manner.

Therefore, it is recommended that no removal actions be implemented, at this time, for any of the 1100-EM-1 waste management units. It is recommended, however, that this evaluation be repeated at the conclusion of the Phase II RI and at other appropriate points in the remedial response process.

7.2.2 Recommended Further Work for the Remedial Investigation

A Phase II RI is generally used to complete site characterization, as necessary, and conduct a treatability investigation to assess the performance of potential remedial technologies, as necessary, to support the analysis of remedial alternatives during the FS (EPA 1988a). Based on the Phase I RI results presented within this report, additional operable unit characterization and treatability investigation activities are recommended below in Sections 7.2.2.1 and 7.2.2.2, respectively.

7.2.2.1 Additional Operable Unit Characterization. The purpose of additional operable unit characterization is to supplement the initial information contained in this report to provide a definitive characterization of the nature and extent of the human health and environmental threats posed by contaminant releases from the operable unit. Further characterization must proceed until a sufficient amount of information is available to complete the FS.

Recommendations for additional, necessary 1100-EM-1 Operable Unit characterization activities are provided below by environmental medium (i.e., contaminant sources, air, surface water and aquatic sediments, geology, soils, ground water, and biota). Direct consideration is provided to only the following operable subunits and miscellaneous location—1100-1, 1100-2, 1100-4, UN-1100-6, the Horn Rapids Landfill, and the ephemeral pool. The absence of

contaminants at levels of concern at 1100-3, UN-1100-5, and Pit 1 precludes the need to evaluate them further.

Contaminant Source Investigation

A soil gas survey at the Horn Rapids Landfill and at the UN-1100-6 Discolored Soil Site is recommended. The objective of the survey for the landfill is to determine whether trichloroethene contamination in ground water is related to the landfill. The purpose of the soil gas survey at the UN-1100-6 operable subunit is to determine the potential for 1,1,1-trichloroethane contamination in the soils and ground water. Low levels of this highly volatile contaminant were encountered in surface soils, in association with BEHP contamination. Such a finding suggests the need to determine the potential for subsurface VOC contamination. If such contamination is found, the soil gas survey should be expanded to preliminarily delineate any ground-water plume.

Additional information concerning a potential former waste disposal area, the South Pit, that may be associated with the Horn Rapids Landfill, surfaced during the development of this Phase I RI Report. Historical aerial photographs (EPA 1990b) indicate surface disturbances south of Horn Rapids Road, immediately across from the landfill. Compilation of existing information on this facility is needed. Soil gas and geophysical surveys could be conducted at this potential waste management unit. Pending the findings of such non-intrusive source characterization activities, a decision will need to be made as to whether the South Pit should be regarded as a Hanford Site waste management unit and, if so, to what operable unit it should be assigned.

Soil samples archived during the first phase of the RI—from the 1100-1, 1100-4, and Horn Rapids Landfill operable subunits—should be analyzed for gross radioactivity to determine the potential for source contributions to the elevated radiation observed in the vicinity of the 1171 Building. In lieu of analyzing archived surface soils from UN-1100-6, an initial surface radiation survey is recommended.

Ongoing geodetic survey activities will be required during the Phase II RI to support additional field sampling efforts and to allow for accurate modifications of existing operable unit maps.

Meteorological Investigation

No further direct meteorological investigation activities are required for the 1100-EM-1 Operable Unit. Adequate weather data are collected regionally and locally to provide any additional information that may be necessary to support remaining response activities.

Surface Hydrological Investigation

No direct investigation of the Columbia River, related to the 1100-EM-1 Operable Unit, is required. Conservative ground-water modeling results indicate that any significant contaminant impact to the river is unlikely.

Geological Investigation

No further direct geological investigation activities are necessary. However, compilation of any additional data obtained from soil borings or ground-water monitoring well installations should be conducted to allow for refinement of the 1100-EM-1 Operable Unit conceptual geological model.

Pedological Investigation

Definition of the lateral and vertical extents of SVOC contamination at the UN-1100-6 operable subunit is recommended. The information obtained will be of use in limiting remedial actions to the volume of soil actually contaminated.

The subsurface soil characterization of the Horn Rapids Landfill is substantially biased because areas of known and suspected waste deposits were intentionally avoided. Safety and environmental concerns, associated with the potential for puncturing containerized wastes, drove this decision; such concerns are still valid. When consideration of the prohibitive costs associated with obtaining an effective subsurface soil and waste deposit characterization in a landfill is added, a long-term monitoring strategy appears to be the only viable option.

It is recommended that the remedy for the landfill incorporate typical solid and hazardous waste closure measures, such as long-term ground-water and soil gas monitoring, to provide an early warning system for detecting any release of buried, containerized hazardous liquid substances. A contingency plan for further response to such a release should be considered part of the eventual landfill remedy.

The characterization of the lateral extent of the surficial PCB contamination at the Horn Rapids Landfill and the ephemeral pool is suggested. Given the relatively low levels of contamination detected, and the non-mobile nature of PCB, limited characterization of the vertical extent of contamination at both facilities should suffice.

Hydrogeological Investigation

Two rounds of ground-water monitoring data were used to develop this report. Additional strategically located existing wells should be included in subsequent sampling rounds. Additional sampling events will provide more data that can be used to better define ground-water background conditions specific to the operable unit. Further hydraulic testing of the unconfined aquifer may be necessary for use in the refinement of contaminant transport evaluations and the baseline risk assessment. This information may be needed to evaluate potential ground-water remedial alternatives and, perhaps, to design such an alternative.

Tetrachloroethene was detected in soil gas in a small portion of the 1100-2 operable subunit, and, at low levels, in a nearby, crossgradient monitoring well. This substance was not encountered in the soil column, even within samples obtained from boreholes drilled in the immediate vicinity of the positive soil gas findings. It is possible, however, that this substance is not effectively detected in the soil because of volatilization during the sampling process, or because of the very localized nature of any residual in

the soil column. As no wells are currently located immediately downgradient from this operable subunit, the installation of such a well is recommended. If significant tetrachloroethene or other contamination is encountered, additional wells may be needed to delineate the plume.

Background ground-water quality needs to be better defined upgradient from the Horn Rapids Landfill to determine whether the landfill is contributing to the ground-water contamination in the vicinity. If the landfill is found to be contributing to such contamination, additional wells are recommended to bound the lateral extent of the plume, and to define the plume's longitudinal and vertical extents. A soil gas survey should be used, if necessary, to preliminarily delineate the extent of ground-water contamination. The results of such a survey would aid in locating any additional wells needed for adequate plume delineation in a cost-effective manner.

If the proposed soil gas survey for UN-1100-6 results in positive findings for 1,1,1-trichloroethane or other hazardous VOCs, it would be appropriate to install a well immediately downgradient of the operable subunit.

If Phase II RI activities do not identify any of the 1100-EM-1 operable subunits to be a source of the ground-water contamination observed in the vicinity of the 1171 Building, it is recommended that the 1100-EM-2 Operable Unit, to which a number of waste management units within and adjacent to the 1171 Building are assigned, be reprioritized. Continued monitoring of the nearby City of Richland well field—in conjunction with future 1100-EM-1 response activities or 1100-EM-2 scoping activities, as appropriate—is also recommended.

Ecological Investigation

Two additional ecological investigation activities are suggested. Any available future land- and water-use projections for the Hanford Site in general, and the 1100 Area vicinity in particular, should be compiled. Such projections—by the land owner, DOE-RL, and local city and county planning officials—will provide focus to the final operable unit baseline risk assessment. The existing ground-water well inventory for the vicinity should be upgraded to definitively determine withdrawal points that could result in potential receptor exposures.

7.2.2.2 Treatability Investigation. The purpose of a treatability investigation is to assess the performance of specific remedial technologies, as appropriate, to provide information necessary to complete the FS (EPA 1988a). Such information is usually obtained through a review of existing engineering literature; however, bench- or pilot-scale treatability studies are sometimes required. The need for specific treatability studies is dependent on site-specific conditions and the remedial technologies under consideration in the FS.

It is premature to speculate on the need for treatability studies. Such studies are of an action-specific nature and are dependent on FS development. The determination of the need for any bench- or pilot-scale studies is therefore deferred to the Phase I/II FS Report. This report is scheduled to be available for review later in December, 1990.

7.2.3 Recommended Remedial Action Objectives for the Feasibility Study

The initial task of an FS is to develop remedial action objectives. Such objectives establish site remediation goals by taking specific contaminants, contaminated environmental media, and potential contaminant exposure pathways into account (40 CFR 300.430(e)(2)(i)). Remedial action objectives, which are subject to refinement throughout the FS, focus the development, screening, and analysis of remedial alternatives to ensure they are protective of human health and the environment.

Recommended remedial action objectives are provided below, by contaminant of concern, in terms of suggested target cleanup levels in each environmental medium of concern. The proposed target cleanup levels are based upon exposure, toxicity, and risk assessment analyses developed in Section 6, and upon preliminary toxicity screening information provided in Section 4.

The overall threat posed by operable unit and nearby contamination, under existing land- and water-use conditions, is conservatively estimated to be an approximately 2E-06 increased cancer risk. Virtually all of this risk is attributable to two operable unit contaminants of concern—BEHP in the surface soils of the UN-1100-6 Discolored Soil Site, and PCB in the surface soils of the Horn Rapids Landfill and the ephemeral pool (see Section 7.1.4.1).

The NCP requires that remediation attain all legally applicable, or relevant and appropriate, federal and state environmental standards, requirements, criteria, and limitations (ARARs). In addition, a site must be remediated to the extent such that the overall cancer risk does not exceed the range of E-06 to E-04. Because 1100-EM-1 is estimated to pose no more than a 2E-06 risk, the operable unit is already in compliance with this latter provision of the NCP. However, the remedial action objectives recommended below should reduce the current risk estimate to no more than 1E-06.

The surface soils of the UN-1100-6 operable subunit contain BEHP in percentage concentrations. No contaminant-specific ARARs were identified; therefore, the recommended remedial action objective is to prevent human exposure to soils having BEHP concentrations in excess of 50 mg/kg. This objective is based on an acceptable risk associated with typical soil ingestion rates (see Table 4-13).

The surface soils of the Horn Rapids Landfill and the ephemeral pool contain PCB contamination. The recommended remedial action objective is to prevent human exposure to soils containing PCB in concentrations greater than 25 mg/kg, for the Horn Rapids Landfill, and 10 mg/kg, for the ephemeral pool. These values are derived from EPA soil cleanup standards for sites with restricted access (i.e., the Horn Rapids Landfill), and for sites with unrestricted access (i.e., the ephemeral pool), respectively. The standards are promulgated under the Toxic Substances Control Act (15 USC 2601 et seq.) in 40 CFR 761 (see Table 4-14). It is recommended that these standards be regarded as the most relevant and appropriate for conditions at the 1100-EM-1 Operable Unit.

Ground-water contamination exists, in the form of tetrachloroethene, near the 1100-2 Paint and Solvent Pit, and, in the form of trichloroethene and nitrate, in the vicinity of the Horn Rapids Landfill; however, the landfill vicinity contamination can not be attributed to the operable unit with

existing data (see Section 4.5.2). No adverse downgradient ground-water or surface-water exposures to trichloroethene or nitrate can be anticipated under existing land- and water-use conditions, and adverse exposures to tetrachloroethene are also unlikely (see Section 6.1). In the event that land and water uses were to change, human exposure to existing concentrations of tetrachloroethene, trichloroethene, and nitrate could be unacceptable if a drinking water supply well were to be installed near 1100-2 or in the vicinity of the landfill.

Should radical changes in land and water uses occur (providing, in the case of trichloroethene and nitrate, that the contamination near the landfill can be attributed to the 1100-EM-1 Operable Unit), applicable remedial action objectives for ground water would be to prevent human exposure, at the tap, to water containing more than 0.005 mg/L of trichloroethene, 44 mg/L of nitrate, and 0.0002 mg/L of tetrachloroethene. The first two levels are primary federal and state MCLs (see Table 4-23); as such, they would be legally applicable to the operable unit if a sufficient number of taps were served from the hypothetical well (40 CFR 141). The objective for tetrachloroethene is based on an acceptable risk associated with typical water ingestion rates (see Table 4-23).

Data are currently insufficient to attribute the observed deterioration of ground-water quality in the area of the 1171 Building to the 1100-EM-1 Operable Unit. Although no adverse downgradient exposures are likely, the current understanding of the nature and extent of this contamination precludes an identification of potential remedial action objectives.

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