PNNL-6415 Rev. 18

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Hanford Site National Environmental Policy Act (NEPA) Characterization

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September 2007

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RL01830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401.

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161

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Preface

This document describes the U.S. Department of Energy's (DOE) Hanford Site environment. It is intended to provide a consistent description of the Hanford Site for the many environmental documents being prepared by DOE contractors in accordance with the National Environmental Policy Act (NEPA). No statements regarding significance or environmental consequences are provided. This year's report is the eighteenth revision of the original document published in 1988 and is (until replaced by the nineteenth revision) the only version that is relevant for use in the preparation of Hanford NEPA, State Environmental Policy Act (SEPA), and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) documents.

Two chapters are included in this document (Chapters 4 and 6), numbered to correspond to chapters typically presented in environmental impact statements (EISs) and other Hanford Site NEPA or CERCLA documentation. Chapter 4.0 (Affected Environment) describes Hanford Site climate and meteorology; air quality; geology; hydrology; ecology; cultural, archaeological, and historical resources; socioeconomics; noise; and occupational health and safety. Sources for extensive tabular data related to these topics are provided in the chapter. When possible, subjects are divided into a general description of the characteristics of the Hanford Site, followed by site-specific information, where available, for the 100, 200, 300 and other areas. This division allows the reader to go directly to those sections of particular interest. When specific information on each of these separate areas is not complete or available, the general Hanford Site description should be used.

Chapter 6.0 (Statutory and Regulatory Requirements) describes federal and state laws and regulations, DOE directives and permits, and presidential executive orders that are applicable to NEPA documents prepared for Hanford Site activities. Information in Chapter 6 can be adapted and supplemented with specific information covering statutory and regulatory requirements for use in an environmental assessment or environmental impact statement.

When preparing environmental assessments and EISs, authors must consult with the Hanford Site NEPA compliance officer. Also consult the DOE *National Environmental Policy Act Implementing Procedures* (10 CFR 1021) and *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* published by the DOE Office of NEPA Oversight (DOE 2004). Additional direction and guidance on the preparation of DOE NEPA documents can be found at http://tis.eh.doe.gov/nepa/guidance.html. Individuals seeking baseline data on the Hanford Site and its past activities may also use the information contained in this document to evaluate projected activities and their impacts.

Pacific Northwest National Laboratory (PNNL) staff prepared individual sections of this document, with input from Hanford Site contractors with the best available information through May 2007. More detailed data are available from reference sources cited or from the authors. The following personnel are responsible for the various sections of this document and can be contacted with questions:

Document Editor	J.P. Duncan	(509) 371-7211	joanne.duncan@pnl.gov
Climate and Meteorology	K.W. Burk	(509) 373-3215	ken.burk@pnl.gov
Air Quality	B.G. Fritz	(509) 371-7119	bradley.fritz@pnl.gov
Geology	M.A. Chamness M.D. Sweeney	(509) 371-7221 (509) 371-7069	Mickie.chamness@pnl.gov Mark.sweeney@pnl.gov
Hydrology	P.D. Thorne G.V. Last	(509) 371-7220 (509) 371-7080	paul.thorne@pnl.gov george.last@pnl.gov
Ecology	T.M. Poston M.R. Sackschewsky	(509) 371-7068 (509) 371-7187	ted.poston@pnl.gov Michael.sackschewsky@pnl.gov
Cultural, Archaeological, and Historical Resources	E.P. Kennedy	(509) 371-7105	ellen.prendergast@pnl.gov
Socioeconomics	R.A. Fowler M.J. Scott	(509) 372-4332 (509) 372-4273	richard.fowler@pnl.gov michael.scott@pnl.gov
Noise	B.G. Fritz	(509) 371-7119	bradley.fritz@pnl.gov
Occupational Safety	S.F. Snyder	(509) 375-6684	sandra.snyder@pnl.gov
Statutory and Regulatory Requirements	P.L. Hendrickson	(509) 372-4294	paul.hendrickson@pnl.gov

The suggested citation for this document is Duncan, J.P., ed. 2007. *Hanford Site National Environmental Policy Act (NEPA) Characterization*. PNL-6415, Rev. 18. Pacific Northwest National Laboratory, Richland, Washington.

A copy of the document is available, upon request, from Joanne P. Duncan at (509) 371-7211. The document is also available electronically at http://www.pnl.gov/main/publications/external/technical_reports/PNNL-6415Rev18.pdf.

Acknowledgements

As editor of Revision 18 of the National Environmental Policy Act Characterization report, I would like to thank Duane A. Neitzel, who retired from Pacific Northwest National Laboratory during 2006, for his past endeavors and contributions to this document. I would also recognize the authors of the individual sections for their efforts and cooperation in preparing this description of the Hanford Site environment. Appreciation is extended to the PNNL, DOE, and other Hanford contractor staff for their review of the document. This year's reviewers include Theresa Aldridge, Bruce Bjornstad, Dennis Bowser, Kali Brandt, Bob Carosino, Doug Chapin, Cliff Clark, Kevin Clarke, Katie Cort, Dave Geist, Tom Ferns, Ken Gano, Mike Jansky, Tom Marceau, Kathy Rhoads, Connie Smith, Darby Stapp, Regan Weeks, and Jaime Zeisloft. Special thanks go to Woody Russell and Annabelle Rodriguez of DOE for their support and to Terri Gilbride and Brian Miller of PNNL for their assistance.

J.P. Duncan

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Acronyms, Abbreviations, and Symbols

AAS	Associate in Applied Science
ACL	Administrative Control Level
ADT	Average daily traffic
AEA	Atomic Energy Act
ALE	Arid Lands Ecology Reserve Unit
ANSS	Advanced National Seismic System
ARAR	Applicable or Relevant and Appropriate Requirements
ARPA	Archaeological Resources Protection Act
BCAA	Benton Clean Air Authority
BCRFD	Benton County Rural Fire Department
BFCOG	Benton Franklin Council of Governments
BFT	Benton Franklin Transit
BLM	U.S. Bureau of Land Management
BLS	Bureau of Labor Statistics
BNI	Bechtel National Inc.
BNSF	Burlington Northern and Santa Fe Railway
BPA	Bonneville Power Administration
BWIP	Basalt Waste Isolation Plant
CAA	Clean Air Act
CBC	Columbia Basin College
CCP	Comprehensive Conservation Plan
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CNG	Cascade Natural Gas Corporation
Corps	U.S. Army Corps of Engineers
CREHST	Columbia River Exhibition of History, Science and Technology
CRITFC	Columbia River Inter-Tribal Fish Commission
CWA	Clean Water Act
dB	Decibels
dBA	A-weighted sound level
DCG	Derived concentration guides
DNR	Washington State Department of Natural Resources
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
DOE-ORP	U.S. Department of Energy, Office of River Protection
DOE/RL	U.S. Department of Energy, Richland Operations Office
DOH	Washington State Department of Health
DOI	U.S. Department of the Interior

Acronyms, Abbreviations, and Symbols (cont'd.)

DOL	U.S. Department of Labor
DWS	Drinking water standards
E/Q	Atmospheric dispersion estimates
EA	Environmental assessment
EC	Environmental concern
Ecology	Washington State Department of Ecology
EDNA	Environmental designation for noise abatement
EIS	Environmental Impact Statement
EJ	Environmental justice
EM	Office of Environmental Management (U.S. Department of Energy)
EMT	Emergency medical technician
EO	Environmental Objections
E.O.	Executive Order
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-To-Know Act
ERDA	U.S. Energy Research and Development Administration
ESA	Endangered Species Act
EU	Environmentally unsatisfactory
FEMA	Federal Emergency Management Agency
FFTF	Fast Flux Test Facility
FR	Federal Register
FY	Fiscal Year
GENII	Generation II Model for Environmental Dose Calculations
GIS	Geographic Information System
HAER	Historic American Engineering Record
HAMMER	Hazardous Materials Management and Emergency Response
Historic District	Hanford Site Manhattan Project and Cold War Era Historic District
HMS	Hanford Meteorology Station
HT	Tritium in the form of incondensable gas
HTO	Tritium in the form of condensable water vapor
Hz	Hertz
I	Interstate
kWh	Kilowatt-hour
L_{eq}	Equivalent sound level
LIGO	Laser Interferometer Gravitational Wave Observatory
LLC	Limited Liability Corporation
LLWPA	Low-Level Radioactive Waste Policy Act
LMEA	Labor Market and Economic Analysis
LO	Lack of objections
LWC	Lost workday cases

Acronyms, Abbreviations, and Symbols (cont'd.)

MCL	Maximum contaminant levels
MEI	Maximally exposed individual
MMI	Modified Mercalli intensity
MW	Megawatt
NAAQS	National Ambient Air Quality Standards
National Register	National Register of Historic Places
ND	Not detected
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NM	Not measured
NPCC	Northwest Power and Conservation Council
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPR	New Production Reactor
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
OFM	Office of Financial Management (Washington State)
ORP	Office of River Protection (Department of Energy)
OSHA	Occupational Safety and Health Administration
OSPI	Office of Superintendent of Public Instruction
OTED	Washington State Office of Trade and Economic Development
PCB	Polychlorinated biphenyls
PFP	Plutonium Finishing Plant
PL	Public law
$PM_{2.5}$	Particulate matter (2.5 µm or less)
PM_{10}	Particulate matter (10 µm or less)
PNNL	Pacific Northwest National Laboratory
PNSO	DOE Office of Science Pacific Northwest Site Office
PSD	Prevention of significant deterioration
PSPL	Puget Sound Power and Light Company
PUREX	Plutonium-uranium extraction
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
REIS	Regional Economic Information System
RL	Richland Operations Office (U.S. Department of Energy)
RM	River mile
ROD	Record of Decision
SALDS	State-approved land disposal structure
SARA	Superfund Amendments and Reauthorization Act

Acronyms, Abbreviations, and Symbols (cont'd.)

SC	Office of Science (U.S. Department of Energy)
SDWA	Safe Drinking Water Act
SEPA	State Environmental Policy Act (Washington)
SESP	Surface Environmental Surveillance Project
SIP	State Implementation Plan
SR	State route
TCAR	Tri-City Association of Realtors
TCP	Traditional Cultural Place
TEDE	Total effective dose equivalent
TEDF	Treated Effluent Disposal Facility
TRC	Total recordable cases
Tri-Cities	Kennewick, Pasco, and Richland, Washington
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
TSCA	Toxic Substances Control Act
TSD	Treatment, storage, and/or disposal
UO_3	Uranium trioxide
USC	United States Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WCH	Washington Closure Hanford
WCRER	Washington Center for Real Estate Research
WDFW	Washington State Department of Fish and Wildlife
WHC	Westinghouse Hanford Company
WMP	Waste processing and management facilities
WNHP	Washington Natural Heritage Program
WNP	Washington nuclear plant
WSDOT	Washington State Department of Transportation
WSU-TC	Washington State University, Tri-Cities
WTP	Waste Treatment and Immobilization Plant
X/Q'	Atmospheric dispersion coefficient

Acronyms, Abbreviations, and Symbols (cont'd.)

Names and Symbols for Units of Measure, Radioactivity, Time, and Mathematical Terms

Length

cm	centimeter
ft	foot
in.	inch
km	kilometer
m	meter
mi	mile
mm	millimeter

Area

km^2	square kilometer
mi^2	square mile
ac	acre
ha	hectare

Volume

m^3	cubic meter
gal	gallon
L	liter
km^3	cubic kilometer
yd^3	cubic yard

Time/Speed

s	second
hr	hour
yr	year
mph	miles per hour
m/s	meters per second

Radioactivity/ Radiation Dose

Ci	curie
pCi	picocurie
mrem	millirem
Bq	becquerel
Sv	sievert
Gy	gray

Temperature

°C	degrees Celsius
°F	degrees Fahrenheit

Chemical

M	molar

Mathematical

<	less than
>	greater than
≤	less than or equal to
≥	greater than or equal to
~	approximately
avg	average
max	maximum
min	minimum

Mass

g	gram
kg	kilogram
mg	milligram
µg	microgram

Concentration

ppm	parts per million

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Glossary

Accrete. To grow or fuse together.

Ambient air. Any unconfined portion of the atmosphere: open air, surrounding air.

Anisotropic. The condition in which hydraulic properties of an aquifer are not equal when measured in all directions.

Anticline. A fold in rocks that brings rocks up from depth, forming a ridge or arch-like structure. The rocks in the center of an anticline are the older rocks.

Aquatic ecosystem. Ecological system containing species that live in water.

Aquifer. A water-bearing geologic formation below the surface of the earth that can supply water for a well or spring.

Atmospheric dispersion. The transport and diffusion of gases and particles within the atmosphere.

Benthic organism. A form of aquatic plant or animal life that is found on or near the bottom of a stream, lake, or ocean.

Biomass. All of the living material in a given area; often refers to vegetation.

Biota. Living organisms.

Clastic dike. An intrusion of sediment forced into fractures in rock or sediments.

Crib: An underground chamber used to dispose of large volumes of low level, radioactive liquid waste. They were often constructed of loosely spaced timbers several feet below ground level which allowed liquid percolation to the underlying soil.

Ecoregion. Areas where the geology, vegetation, land use, and topography are similar and where similar groups of organisms might be expected to live.

Ephemeral stream. Streams containing water only a fraction of the time, usually during and immediately after precipitation.

Evapotranspiration. Combined loss of water to the atmosphere via the processes of evaporation and transpiration.

Fossorial. Adapted for burrowing or digging.

Groundwater. Water that occurs below the Earth's surface. It is found within the pores of sand and gravel or the cracks of fractured rock beneath the land and is invisible to the naked eye.

Habitat. The place where an organism lives or is expected to occur; habitat type is a grouping of similar habitats.

Meteoric water. Groundwater derived primarily from precipitation.

Plankton. Small or microscopic organisms, including algae and protozoans, that float or drift in great numbers in water, especially at or near the surface, and serve as food for fish and other larger organisms.

Plant community. A habitat description based on the dominant plant species present.

Pre-contact. The period prior to the arrival of European explorers and settlers.

Redds. Nests fish make in gravel and/or small cobble in the riverbed to lay their eggs.

Return period. The frequency with which you would expect, on average, a given event to recur.

Riparian areas. Vegetated areas found on each side of streams and rivers.

Rough fish. Species of fish that are neither sport fish nor important food fish.

Shrub-steppe. A plant community characterized by a dominant shrub and grasslands that has hot dry summers, cold winters, and little rainfall.

Syncline. A fold in rocks in which the layers are bowed downward, resulting in a valley or bowl-shaped structure. The younger rocks are toward the center of a syncline.

Transpiration. The process of water loss from plants.

Unconfined aquifer. An aquifer containing groundwater that is not confined above by relatively impermeable rocks. The pressure at the top of the unconfined aquifer is equal to that of the atmosphere.

Vadose zone. The hydrogeologic region between the surface of the land and the water table.

Vernal pond. Temporary ponds that fill with water in the spring as a result of snowmelt, spring rains, and/or elevated ground water tables and dry up later in the year.

Water table. Theoretical surface represented by the elevation of water surfaces in wells penetrating only a short distance into the unconfined aquifer.

Wetlands. Lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface.

Zooplankton. Animal constituent of plankton; mainly small crustaceans and fish larvae.

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4.0 Affected Environment

Introduction

The U.S. Department of Energy (DOE) Hanford Site lies within the semiarid Pasco Basin of the Columbia Plateau in south-central Washington State (Figure 4.0-1). The Site, spanning approximately 50 km (30 mi) north to south and 40 km (24 mi) east to west, occupies an area of about 1,517 km^2 (586 mi^2) north of the confluence of the Yakima River with the Columbia River. The Hanford Site has restricted public access, providing a buffer for areas currently used for storage of nuclear materials, waste treatment, and waste storage and/or disposal.

The Columbia River flows through the northern part of the Hanford Site, before turning south to form part of the Site's eastern boundary. The Yakima River, which joins the Columbia River at the city of Richland, runs near the southern boundary of the Hanford Site. Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge form the southwestern and western boundaries, and Saddle Mountain forms the northern boundary. Two small east-west ridges, Gable Butte and Gable Mountain, rise above the plateau of the central part of the Hanford Site. Adjoining lands to the west, north, and east are principally range and agricultural land. The cities of Kennewick, Pasco, and Richland (the Tri-Cities), West Richland, and Benton City constitute the nearest population centers and are located south-southeast of the Hanford Site.

The U.S. Army Corps of Engineers (Corps) began construction of the Hanford Site in 1943 to produce plutonium for national defense; it was the first nuclear production facility in the world. The region was selected because of its remoteness and because it had abundant electrical power from Grand Coulee Dam, a functional railroad, clean water from the Columbia River, and available sand and gravel for construction.

The Hanford Site is divided into a number of operational areas. These include

- **100 Areas**. The 100 Areas, situated along the shore of the Columbia River in the northern portion of the Site, were the location of nine nuclear reactors. The first eight reactors were constructed between 1944 and 1955. The ninth reactor, N Reactor, was completed in 1963. The irradiated fuel produced in the 100 Areas reactors was transported by rail to the 200 Areas. The 100 Areas occupy a region of approximately 11 km^2 (4 mi^2).
- **200 Areas**. The 200 East and 200 West Areas are located on a plateau about 11 and 8 km (7 and 5 mi), respectively south of the Columbia River. These areas housed facilities called separations plants that separated plutonium from dissolved irradiated fuel. Wastes were neutralized and stored in large underground tanks. Wastes containing fission products, activation products, and nitrate were discharged to cribs. Low-level wastes and cooling water from the plants were distributed by open ditch to surface ponds for evaporation and percolation into the ground.

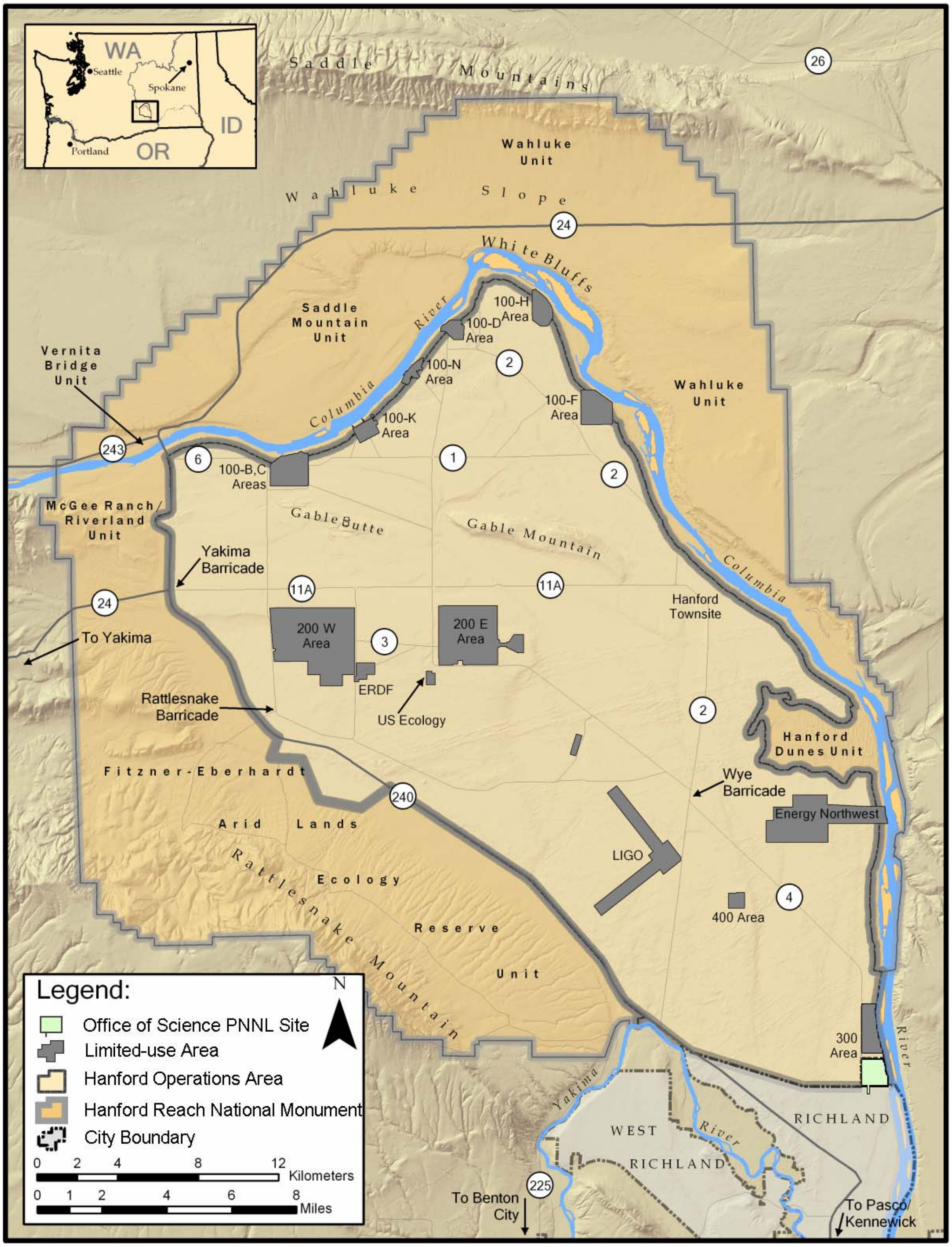

Figure 4.0-1. U.S. Department of Energy's Hanford Site, Washington

- **300 Area**. The 300 Area, encompassing approximately 1.5 km^2 (0.6 mi^2), is located just north of Richland, and was the location of nuclear fuel fabrication and research and development activities. Nuclear fuel in the form of pipe-like cylinders (fuel slugs) was fabricated from purified uranium shipped in from offsite production facilities. The fabricated fuel slugs were shipped by rail from the 300 Area to the nuclear reactors in the 100 Areas.
- **400 Area**. The 400 Area is located northwest of the 300 Area and covers approximately 0.61 km^2 (0.23 mi^2). It is the location of the Fast Flux Test Facility (FFTF), a 400-megawatt thermal, liquid-metal (sodium) cooled nuclear research and test reactor owned by the DOE. The facility, which operated for about ten years, has been shut down since 1993 and is currently being deactivated.
- **600 Area**. The 600 Area includes the Hanford Reach National Monument and all the land not included in the 100, 200, 300, and 400 Areas. The Hanford Reach National Monument, established in 2000 (65 FR 37253), totals 792.6 km^2 (306 mi^2) and includes Fitzner-Eberhardt Arid Lands Ecology Reserve Unit, Saddle Mountain Wildlife Refuge Unit, McGee Ranch/Riverlands Unit, and land 0.40 km (0.25 mi) inland from the mean high-water mark on the south and west shores of the 82 km (51 mi)-long Hanford Reach of the Columbia River. It also includes the federally owned islands in the Hanford Reach and the sand dune area northwest of the Energy Northwest site. This designation establishes the protection and management of the land encompassing the monument. A separate memorandum allows for the incorporation of additional Hanford Site lands into the monument as the land is remediated. The U.S. Fish and Wildlife Service manages approximately 67,000 ha (166,000 ac) of monument lands that are within the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit and the Wahluke Slope (Wahluke Unit and Saddle Mountain Unit) under permit from DOE. DOE manages the remainder of the monument. In December 2006, the U.S. Fish and Wildlife Service (USFWS), as lead agency, issued the Draft Comprehensive Conservation Plan (CCP) Environmental Impact Statement (EIS) (71 FR 74929) for management of the Hanford Reach National Monument. The document is in the finalization process.
- **Former 700 Area**. The 700 Area was the original location for administrative activities for the Hanford Site and was located where the Federal Building is located today (DOE 1997a). It is no longer part of the Hanford Site.
- **Former 1100 Area**. The former 1100 Area was the location of general stores and transportation maintenance facilities for the Hanford Site. The 1100 Area was located between the 300 Area and the city of Richland, encompassing an area of approximately 311 hectares (768 acres). In September 1996, the 1100 Area was declared remediated and the U.S. Environmental Protection Agency issued a delisting of this area of the Site from the National Priorities List (DOE 1998a). Most of the 1100 Area has been incorporated into the city of Richland and is no longer a part of the Hanford Site (DOE 2002a).

The Hanford Site encompasses more than 2,963 waste management units and groundwater contamination plumes that have been grouped into 75 operable units. Each operable unit has complementary characteristics such as geography, waste content, type of facility, and relationship of contaminant plumes. The grouping into operable units allows for economies of scale to reduce the cost and number of characterization investigations and remedial actions required to complete environmental cleanup (WHC 1989). The 75 operable units are located in four areas: 17 in the 100 Areas, 52 in the 200 Areas, two in the 300 Area, and four in the former 1100 Area (DOE 2007a). Those persons contemplating National Environmental Policy Act (NEPA)-related activities on the Hanford Site should be aware of the existence and location of the operable units. Detailed information concerning the operable units and current maps showing the locations of the operable units can be obtained from the *Hanford Site Waste Management Units Report* (DOE 2007a).

The Hanford Site is managed by DOE's Richland Operations Office and Office of River Protection. Each oversees separate contracts held by contractors and their subcontractors to support cleanup operations.

The DOE Office of Science manages and provides oversight to Pacific Northwest National Laboratory (PNNL), including the Environmental Molecular Sciences Laboratory, which is located on the PNNL site. It also oversees the operation of the Volpentest Hazardous Materials Management and Emergency Response (HAMMER) Training and Education Center, located in north Richland.

4.1 Climate and Meteorology

K. W. Burk

The Hanford Site lies within the semiarid shrub-steppe Pasco Basin of the Columbia Plateau in south-central Washington State. The region's climate is greatly influenced by the Pacific Ocean and the Cascade Mountain Range to the west, and other mountain ranges to the north and east. The Pacific Ocean moderates temperatures throughout the Pacific Northwest, and the Cascade Range generates a rain shadow that limits rain and snowfall in the eastern half of Washington State. The Cascade Range also serves as a source of cold air drainage, which has a considerable effect on the wind regime on the Hanford Site. Mountain ranges to the north and east of the region shield the area from the severe winter storms and frigid air masses that move southward across Canada.

Climatological data for the Hanford Site are compiled at the Hanford Meteorology Station (HMS), which is located on the Hanford Site's Central Plateau, just outside the northeast corner of the 200 West Area and about 4 km (3 mi) west of the 200 East Area. Meteorological measurements have been made at the HMS since late 1944. Before the HMS was established, local meteorological observations were made at the old Hanford townsite (1912 through late 1943) and in Richland (1943-1944). A climatological summary for Hanford is provided in Hoitink et al. (2005).[a]

Data from the HMS capture the general climatic conditions for the region and describe the specific climate of Hanford's Central Plateau. The size of the Hanford Site and its topography give rise to substantial spatial variations in wind, precipitation, temperature, and other meteorological characteristics. This is observed for the differences in the annual distribution of wind direction and speed measured at the HMS and at the 300 Area. To characterize meteorological differences accurately across the Hanford Site, the HMS operates a network of monitoring stations. These stations, which currently number 30, are situated throughout the Site and in neighboring areas (Figure 4.1-1). A 124-m (408-ft) instrumented meteorological tower operates at the HMS. A 61-m (200-ft) instrumented tower operates at each of the 100-N, 300, and 400 Area meteorology-monitoring sites. Most of the other network stations use instrumented towers with heights of about 9.1 m (30 ft). The data collected at each tower vary with at least three variables collected at all towers and up to seven collected at some (Table 4.1-1). Data are collected and processed at each station, and information is transmitted to the HMS every 15 minutes. This monitoring network has been in full operation since the early 1980s.

For the following descriptions in this section the seasons are defined as follows: winter, December through February; spring, March through May; summer, June through August; and autumn, September through November.

(a) Hanford climatological data summaries have been updated annually since 1995. Earlier climatological reports that have been cited extensively include Glantz et al. (1990) and Stone et al. (1983).

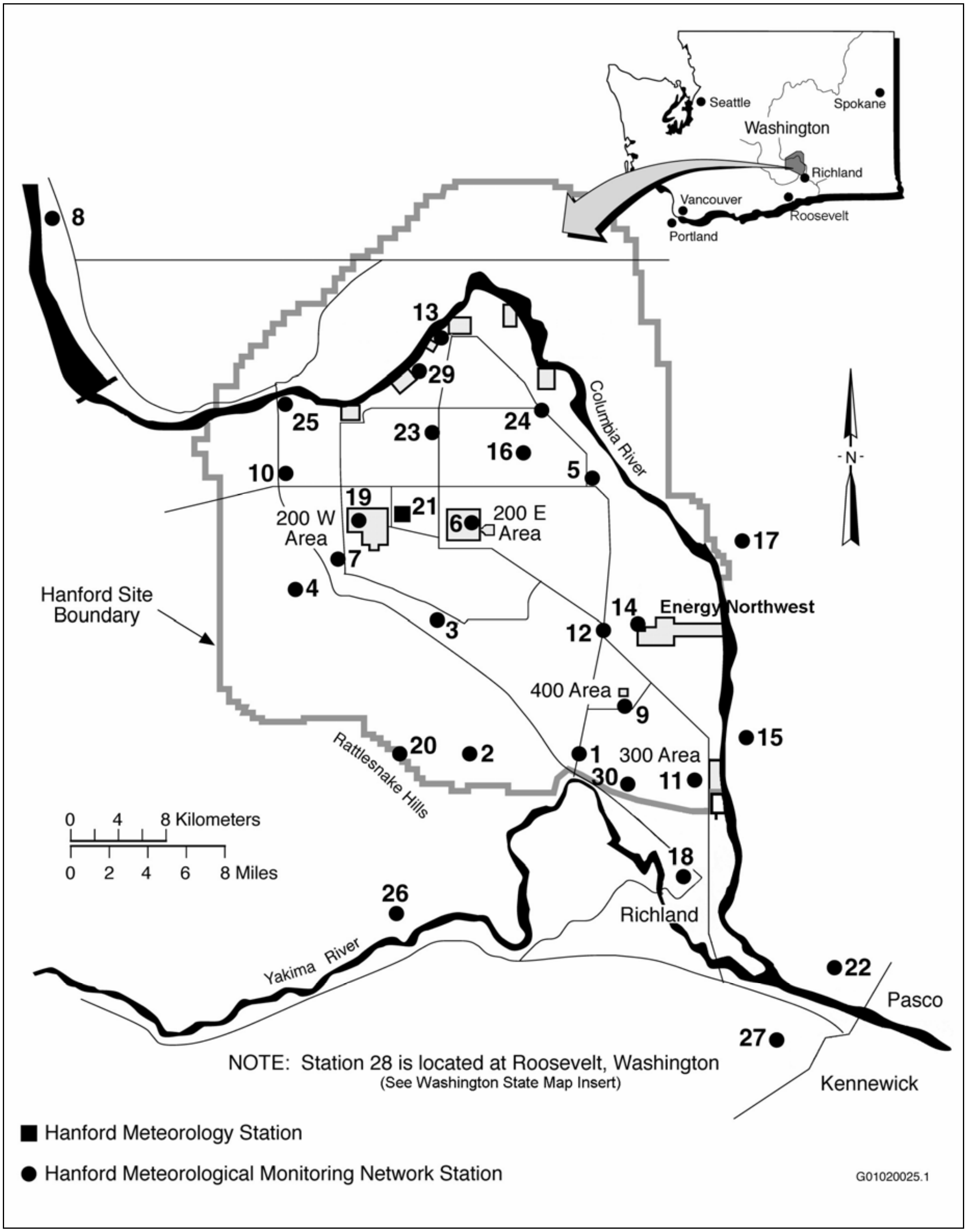

Figure 4.1-1. Hanford Meteorological Monitoring Network, Hanford Site, Washington

Table 4.1-1. Station Numbers, Names, and Meteorological Data Measured at each Station in the Hanford Meteorological Monitoring Network in Washington State

Site Number	**Site Name**	**Meteorological Data**
1	Prosser Barricade	WS, WD, T, P
2	Emergency Operations Center	WS, WD, T, P
3	Army Loop Road	WS, WD, T, P
4	Rattlesnake Springs	WS, WD, T, P
5	Edna Railroad Crossing	WS, WD, T
6	200 East Area	WS, WD, T, P, AP
7	200 West Area	WS, WD, T, P
8	Beverly, Washington	WS, WD, T, P
9	Fast Flux Test Facility (61 m or 200 ft)	WS, WD, T, TD, DP, P, AP
10	Yakima Barricade	WS, WD, T, P, AP
11	300 Area (61 m or 200 ft)	WS, WD, T, TD, DP, P, AP
12	Wye Barricade	WS, WD, T, P
13	100-N Area (61 m or 200 ft)	WS, WD, T, TD, DP, P, AP
14	Energy Northwest	WS, WD, T, P
15	Franklin County	WS, WD, T
16	Gable Mountain	WS, WD, T
17	Ringold, Washington	WS, WD, T, P
18	Richland Airport	WS, WD, T, AP
19	Plutonium Finishing Plant	WS, WD, T, AP
20	Rattlesnake Mountain	WS, WD, T, P
21	Hanford Meteorology Station (124 m or 408 ft)	WS, WD, T, P, DP, AP
22	Tri-Cities Airport	WS, WD, T, P
23	Gable West	WS, WD, T
24	100-F Area	WS, WD, T, P
25	Vernita Bridge	WS, WD, T
26	Benton City, Washington	WS, WD, T, P
27	Vista	WS, WD, T, P
28[a]	Roosevelt, Washington	WS, WD, T, P, AP
29	100-K Area	WS, WD, T, P, AP
30	Hazardous Material Management and Emergency Response Training Center	WS, WD, T

Legend:

AP - Atmospheric Pressure
DP - Dew Point Temperature
P - Precipitation
T - Temperature
TD - Temperature Difference (between 10-m and 60-m Tower Levels)
WD - Wind Direction
WS - Wind Speed

(a) Roosevelt is located on the Columbia River 92 km (57 mi) west/southwest of the Hanford Site.

4.1.1 Wind

Wind data at the HMS are collected 2.1 m (7 ft) above the ground and at the 15.2-, 61.0-, and 121.9-m (50-, 200-, and 400-ft) levels on the 124-m (408-ft) tower. Each of the three 61-m (200-ft) towers has wind-measuring instrumentation at the 10-, 25-, and 60-m (33-, 82-, and 197-ft) levels. The short towers measure winds 9.1 m (30 ft) above ground level.

The prevailing surface winds on Hanford's Central Plateau are from the northwest (Figure 4.1-2) and occur most frequently during the winter and summer. Winds from the southwest also have a high frequency of occurrence on the Central Plateau. During the spring and fall, there is an increase in the frequency of winds from the southwest and a corresponding decrease in winds from the northwest.

In the southeastern portion of the Hanford Site (including the 300 [Station 11] and 400 [Station 9] Areas), the prevailing wind direction near the surface is from the southwest during most months; winds from the northwest are much less common (Figure 4.1-2). In the 100 Areas and along the Columbia River, local winds are strongly influenced by the topography near the river. At the 100-K (Station 29) and 100-N (Station 13) Areas, the prevailing wind direction is from the west. At the 100-F Area (Station 24) and near the old Hanford townsite (Edna Railroad crossing [Station 5]), winds often have a northwesterly or southeasterly component.

Stations that are relatively close together can exhibit significant differences in wind patterns. For example, the stations at Rattlesnake Springs (Station 4) and the 200 West Area (Station 7) are separated by only about 5 km (3 mi) yet the wind patterns at the two stations are very different (Figure 4.1-2). Care should be taken when assessing the appropriateness of the wind data used in estimating environmental impacts. When possible, wind data from the closest representative station should be used for estimating local dispersion conditions.

Monthly and annual joint-frequency distributions of wind direction versus wind speed for the HMS are reported in Hoitink et al. (2005). Monthly average wind speeds 15.2 m (50 ft) above the ground are lower during the winter months, averaging 2.7 to 3.1 m/s (6 to 7 mph) and faster during the spring and summer, averaging 3.6 to 4.0 m/s (8 to 9 mph) (Table 4.1-2). The fastest wind speeds at the HMS are usually associated with flow from the southwest (Table 4.1-2). However, the summertime drainage winds from the northwest frequently exceed speeds of 13 m/s (30 mph). The maximum speed of the drainage winds (and their frequency of occurrence) tends to decrease as one moves toward the southeast across the Hanford Site. The HMS averages 156 days per year with peak wind gusts greater than or equal to 11 m/s (25 mph) (ranging from a low of about 7 in December to a high of nearly 20 in June and July) and 57 days with peak gusts greater than or equal to 16 m/s (35 mph) (from a low of about 3 days in September and October to a high of about 6 days during the months of April through July) (Table 4.1-3).

Surface features have less influence on winds aloft than on winds near the surface. However, substantial spatial variations are found in the wind distributions across Hanford 60 m (197 ft) above ground level (Figure 4.1-3). For releases at greater heights, the most representative data may come from the closest representative 61-m (200-ft) tower rather than the nearest 9.1-m (30-ft) tower.

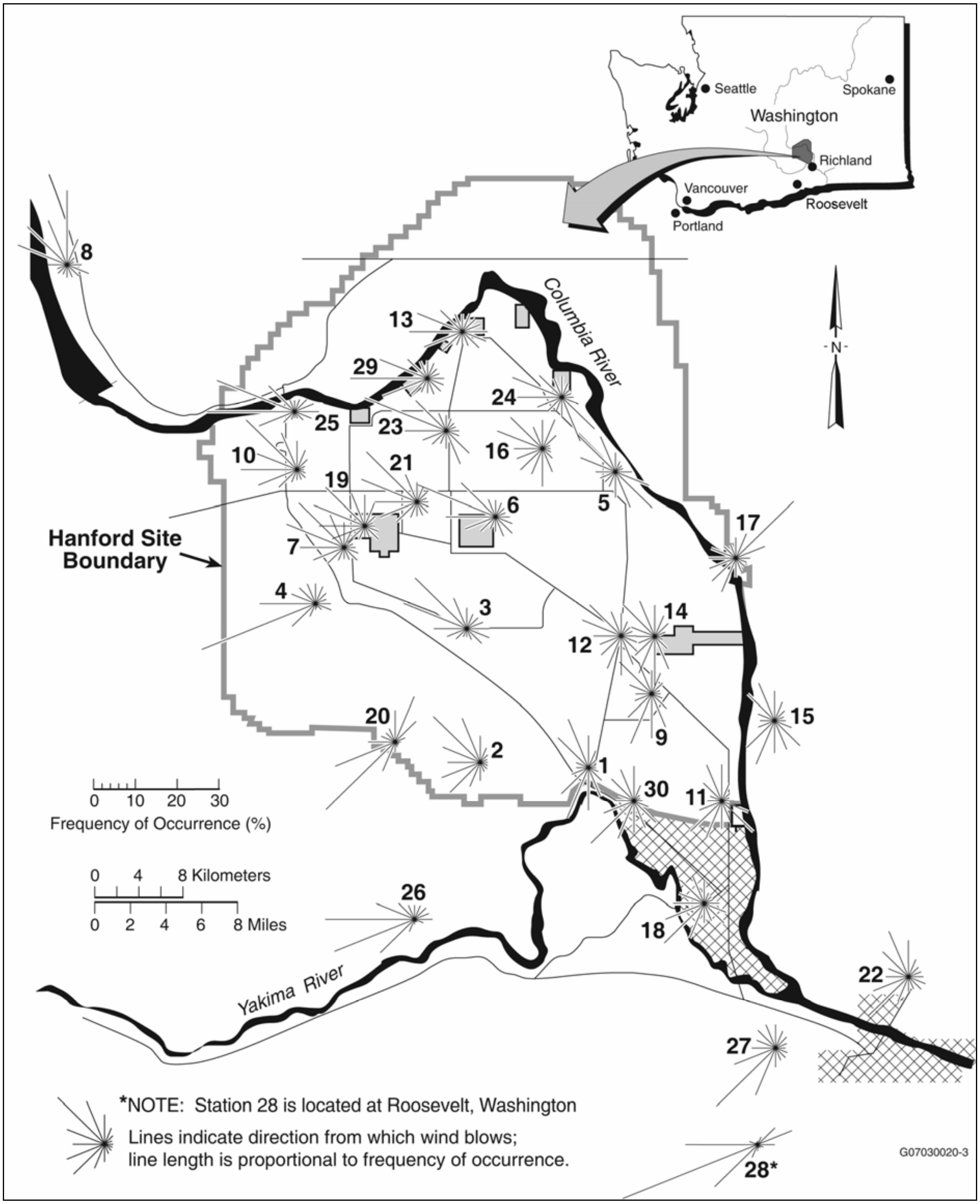

Figure 4.1-2. Wind Roses at the 9.1 m (30 ft) Level of the Hanford Meteorological Monitoring Network, Washington, 1982 through 2006

Table 4.1-2. Monthly and Annual Wind-Related Data Collected at the 15-m (50-ft) Level, 1945 through 2006, Hanford Meteorology Station

Month	Prevailing Direction	Average Speed (mph)[a]	Highest Average Speed (mph)	Year	Lowest Average Speed (mph)	Year	Peak Gust Speed (mph)	Direction	Year
January	NW	6.3	10.3	1972	2.9	1985	80	SW	1972
February	NW	7.0	11.1	1999	4.6	1963	65	SSW	1999[b]
March	WNW	8.2	10.7	1977[b]	5.9	1958	70	SW	1956
April	WNW	8.8	11.1	1972[b]	7.4	1989[b]	73	SSW	1972
May	WNW	8.8	10.7	1983	5.8	1957	71	SSW	1948
June	NW	9.1	10.7	1983[b]	7.7	1950[b]	72	SW	1957
July	NW	8.6	10.7	1983	6.8	1955	69	WSW	1979
August	WNW	7.9	9.5	1996	6.0	1956	66	SW	1961
September	WNW	7.5	9.2	1961	5.4	1957	65	SSW	1953
October	NW	6.6	9.1	1946	4.4	1952	72	SW	1997
November	NW	6.4	10.0	1990	2.9	1956	67	WSW	1993
December	NW	6.0	8.3	1968	3.3	1985	74	SW	2006
Annual	NW	7.6	8.8	1999	6.2	1989	80	SW	1972

(a) 1 mph = 1.61 km/hr or 0.447 m/s
(b) Most recent of multiple occurrences

Table 4.1-3. Number of Days with Peak Gusts above Specific Thresholds at the 15-m (50-ft) Level, 1945 through 2004, Hanford Meteorology Station, Washington

	Days with Peak Gusts ≥11 m/s (25 mph)					Days with Peak Gusts ≥16 m/s (35 mph)				
Month	Avg	Max	Year	Min	Year	Avg	Max	Year	Min	Year
January	7.5	21	1953	0	1985[a]	4.0	14	1953	0	1985[a]
February	8.5	17	1976[a]	2	2004[a]	3.7	14	1976	0	2004[a]
March	13.2	21	1977	4	1992	5.5	14	1997	0	1992
April	16.9	26	1954	8	1946	6.3	12	1972	1	1967
May	18.8	26	1978	9	1945	6.1	13	2002	0	1957
June	19.7	26	1963	11	1950[a]	6.4	12	2002[a]	1	1982
July	19.6	26	1995	11	1955	5.7	11	1994[a]	1	1982[a]
August	15.9	24	2000	7	1945	4.3	12	1996	0	1978[a]
September	11.4	17	2002[a]	7	1975[a]	3.4	7	2003[a]	0	1975
October	9.0	19	2003	3	1987[a]	3.2	12	2003	0	1993[a]
November	8.4	16	1990	0	1979	3.9	10	2006[a]	0	1997[a]
December	7.3	15	1968	0	1985	4.1	11	1957	0	1985[a]
Annual	156.2	192	1999	123	1952	56.6	86	2002	31	1978

(a) Most recent of multiple occurrences

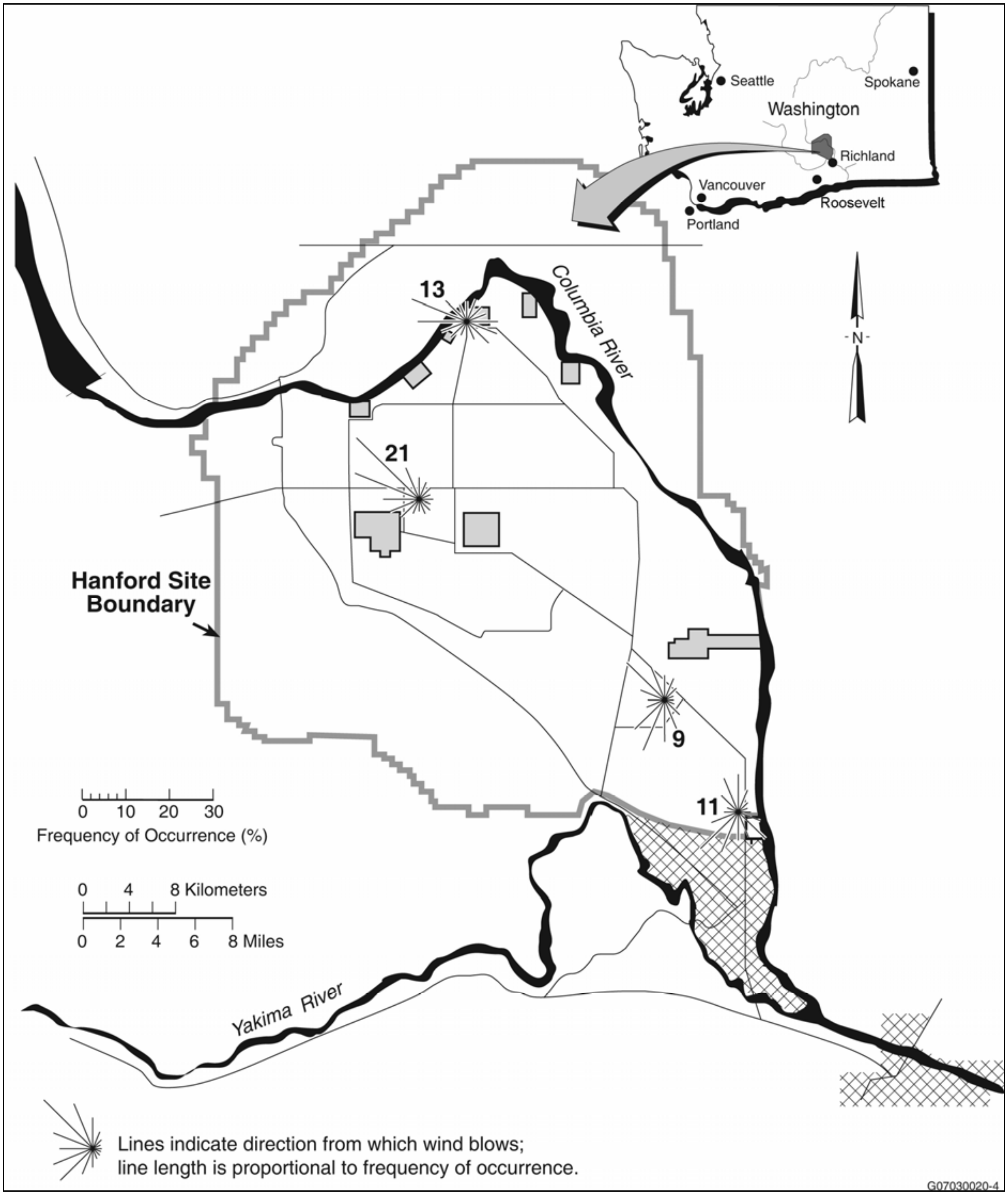

Figure 4.1-3. Wind Roses at the 60-m (197-ft) Level of the Hanford Meteorological Monitoring Network, Washington, 1986 through 2006

4.1.2 Temperature and Humidity

The 124-m (408-ft) tower at the HMS has temperature-measuring instrumentation at the following levels: 0.9, 9.1, 15.2, 30.5, 61.0, 76.2, 91.4, and 121.9 m (3, 30, 50, 100, 200, 250, 300, and 400 ft). The three 61-m (200-ft) towers have temperature-measuring instrumentation at the 2-, 10-, and 60-m (approximately 6.5-, 33-, and 197-ft) levels. Temperatures are measured at the 2-m (6.5-ft) level on the 9-m (30-ft) towers. Relative humidity/dew point temperature measurements are made at the HMS and at the three 61-m (200-ft) tower locations.

Monthly averages and extremes of temperature, dew point, and humidity are presented in Hoitink et al. (2005). Based on data collected from 1946 through 2004, the average monthly temperatures at the HMS range from a low of -0.7°C (31°F) in January to a high of 24.7°C (76°F) in July. The highest winter monthly average temperature was 6.9°C (44°F) in February 1958 and February 1991, and the lowest average monthly temperature was -11.1°C (12°F) in January 1950. The highest monthly average temperature was 27.9°C (82°F) in July 1985 and the lowest summer monthly average temperature was 17.2°C (63°F) in June 1953.

Daily maximum temperatures at the HMS vary from an average of 2°C (35°F) in late December and early January to 36°C (96°F) in late July. There are, on average, 52 days during the summer months with maximum temperatures greater than or equal to 32°C (90°F) and 12 days with maxima greater than or equal to 38°C (100°F). The largest number of consecutive days on record with maximum daily temperatures greater than or equal to 32°C (90°F) is 32 days. The record maximum temperature, 45°C (113°F) occurred at the HMS on July 23, 2006, July 13, 2002, and August 4, 1961.

From mid-November through early March, the average daily minimum temperature is below freezing; the daily minimum in late December and early January is -6°C (21°F). On average, the daily minimum temperature of less than or equal to -18°C (approximately 0°F) occurs only 3 days per year; however, only about one winter in two experiences such low temperatures. The greatest number of consecutive days on record with minimum daily temperatures of less than or equal to -18°C (0°F) is 11 days. The record minimum temperature, -31°C (-23°F) occurred on both February 1 and 3, 1950.

The annual average relative humidity at the HMS is 55 percent. It is highest during the winter months, averaging about 76 percent, and lowest during the summer, averaging about 36 percent. The annual average dewpoint temperature at the HMS is 1°C (34°F). In the winter, the dewpoint temperature averages about -3°C (27°F), and in the summer it averages about 6°C (43°F).

4.1.3 Precipitation

Average annual precipitation at the HMS is 17 cm (6.8 in.). During 1995, the wettest year on record, 31.3 cm (12.3 in.) of precipitation was measured; during 1976, the driest year, only 7.6 cm (3 in.) was measured. The wettest season on record was the winter of 1996-1997 with 14.1 cm (5.4 in.) of precipitation; the driest season was the summer of 1973, when only 0.1 cm (0.03 in.) of precipitation was measured. Most precipitation occurs during the late autumn and winter, with more than half of the annual amount occurring from November through February. Days with greater than 1.3 cm (0.50 in.) precipitation occur on average less than one time each year.

Average snowfall ranges from 0.25 cm (0.1 in.) during October to a maximum of 13.2 cm (5.2 in.) during December and decreases to 1.3 cm (0.5 in.) during March. The record monthly snowfall of 59.4 cm (23.4 in.) occurred during January 1950. The seasonal record snowfall of 142.5 cm (56.1 in.) occurred during the winter of 1992-1993. Snowfall accounts for about 38 percent of all precipitation from December through February.

4.1.4 Fog and Visibility

Fog has been recorded during every month of the year at the HMS; however, 89 percent of the occurrences are from November through February, with less than 3 percent from April through September (Table 4.1-4). The average number of days per year with fog (visibility less than or equal to 9.6 km [6 mi]) is 48, while those with dense fog (visibility less than or equal to 0.4 km [0.25 mi]) number 25. The greatest number of days with fog was 84 days during 1985–1986, and the least was 22 during 1948–1949. The greatest number of days with dense fog was 42 during 1950–1951, and the least was 9 during 1948–1949. The greatest persistence of fog was 114 hours (December 1985) and the greatest persistence of dense fog was 47 hours (December 1957).

Other phenomena causing restrictions to visibility (i.e., visibility less than 9.6 km [6 mi]) include dust, blowing dust, and smoke from field burning. There are few such days; an average of 5 days per year have dust or blowing dust, and less than 1 day per year, on average, has reduced visibility from smoke.

Table 4.1-4. Number of Days with Fog by Season, Hanford Site, Washington

Category	Winter	Spring	Summer	Autumn	Total
fog	32	3	≤1	12	48
dense fog	17	1	≤1	7	25

4.1.5 Severe Weather

Concerns about severe weather usually focus on hurricanes, tornadoes, and thunderstorms. Fortunately, Washington does not experience hurricanes; tornadoes are infrequent and generally small in the northwestern portion of the United States. The National Climatic Data Center maintains a database that provides information on the incidence of tornados reported in each county in the United States. This database can be accessed via the Internet at: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms.

This database reports that in the ten counties closest to the Hanford Site (Benton, Franklin, Grant, Adams, Yakima, Klickitat, Kittitas, and Walla Walla counties in Washington and Umatilla and Morrow counties in Oregon), there have been only 28 tornadoes recorded from 1950 through December 2006. Of these, 21 tornadoes had maximum wind speeds estimated to be in the range of

18 to 32 m/s (40 to 72 mph), four had maximum wind speeds in the range of 33 to 50 m/s (73 to 112 mph), and three had maximum wind speeds in the range of 51 to 71 m/s (113 to 157 mph). There were no deaths or substantial property damage (in excess of $50,000) associated with any of these tornadoes.

Ramsdell and Andrews (1986) report that for the 5° block centered at 117.5° west longitude and 47.5° north latitude (where the Hanford Site is located), the expected path length of a tornado is 7.6 km (5 mi), the expected width is 95 m (312 ft), and the expected area is about 1.5 km^2 (1 mi^2). The estimated probability of a tornado striking a point on the Hanford Site is 9.6 x 10^{-6}/yr (Ramsdell and Andrews 1986). The probabilities of extreme winds associated with tornadoes striking a point can be estimated using the distribution of tornado intensities for the region (Table 4.1-5).

Table 4.1-5. Estimate of the Probability of Extreme Winds Associated with Tornadoes Striking a Point at Hanford, Washington (after Ramsdell and Andrews 1986)

Wind Speed (m/s)	Wind Speed (mph)	Probability Per Year
28	62	2.6 x 10^{-6}
56	124	6.5 x 10^{-7}
83	186	1.6 x 10^{-7}
111	249	3.9 x 10^{-8}

The average occurrence of thunderstorms in the vicinity of the HMS is ten per year. They are most frequent during the summer; however, they have occurred in every month. Thunderstorms can generate high-speed winds and hail. Using the National Weather Service criteria for classifying a thunderstorm as “severe” (i.e., hail with a diameter greater than or equal to 19 mm [3/4 in.] or wind gusts greater than or equal to 25.9 m/s [58 mph]), only 1.9 percent of all thunderstorm events surveyed at the HMS have been “severe” storms, and all met the criteria based on their wind gusts. High-speed winds at Hanford are more commonly associated with strong, cold frontal passages. In rare cases, intense low-pressure systems can generate winds of near hurricane force (Table 4.1-6).

Table 4.1-6. Estimates of Extreme Winds at the Hanford Site, Washington (Hoitink et al. 2005)

	Peak Gusts			
Return Period (yr)	15.2 m (50 ft) above Ground (m/s)	15.2 m (50 ft) above Ground (mph)	61 m (200 ft) above Ground (m/s)	61 m (200 ft) above Ground (mph)
2	27	60	30	67
10	32	71	36	80
100	38	85	43	96
1000	44	98	50	111

4.2 Air Quality

B. G. Fritz

A variety of atmospheric monitoring is done on and around the Hanford Site, allowing a relatively detailed analysis of air quality. The primary air pollutant of concern for the Hanford Site is radiological contamination. Radiological contamination becomes airborne as a result of stack emissions, diffuse emissions, and re-suspension of contaminated material from the ground. Dust is another air quality parameter of particular interest on and around the Hanford Site. Although the dust (or particulate matter) concentrations are generally low, the local environment experiences periodic windblown dust storms, raising the interest in particulate matter concentrations. Emissions of other nonradiological gaseous compounds are measured, but due to the low regional concentrations, these compounds are generally of less concern. The following sections summarize the ambient air monitoring programs and emissions measurements that occur and provide a general synopsis of regional air quality.

4.2.1 Atmospheric Dispersion

Atmospheric dispersion is a function of wind speed, duration and direction of wind, intensity of atmospheric turbulence, and mixing depth. Atmospheric turbulence is not directly measured at the Hanford Site; instead, the impact of turbulence on atmospheric dispersion is characterized using atmospheric stability. Atmospheric stability describes the thermal stratification or vertical temperature structure of the atmosphere. Generally, six or seven different classes of atmospheric stability are used to describe the atmosphere. These classes range from extremely unstable (when atmospheric turbulence is greatest) to extremely stable (when atmospheric mixing is at a minimum). When the atmosphere is unstable, pollutants can rapidly diffuse through a large volume of the atmosphere. When the atmosphere is stable, pollutants will diffuse much more slowly in a vertical direction. Horizontal dispersion may be limited during stable conditions; however, plumes may also fan out horizontally during stable conditions, particularly when the wind speed is low. Most major pollutant incidents have been associated with stable conditions when inversions can trap pollutants near the ground.

Conditions likely to increase dispersion are most common in the summer when neutral and unstable stratification exists, about 56 percent of the time (Stone et al. 1983). Conditions less likely to promote dispersion are most common during the winter when moderately to extremely stable stratification exists, about 66 percent of the time (Stone et al. 1983). Low dispersion conditions also occur periodically for surface and low-level releases in all seasons from about sunset to about an hour after sunrise as a result of ground-based temperature inversions and shallow mixing layers. Occasionally, there are extended periods of poor dispersion conditions associated with stagnant air in stationary high-pressure systems. These instances tend to occur during the winter months (Stone et al. 1983).

Stone et al. (1972) estimated the probability of extended periods of poor dispersion conditions. The probability of an inversion, once established, persisting more than 12 hours varies from a low of about 10 percent in May and June to a high of about 64 percent in September and October. These probabilities decrease rapidly for durations of more than 12 hours and are associated with extended surface-based inversions (Table 4.2-1).

Many simple dispersion models use the joint frequency distribution of atmospheric stability, wind speed, and wind direction to compute diffusion factors for both chronic and acute releases. Joint frequency distributions for atmospheric stability, wind speed, and transport direction have been estimated for the data collected at the 100-N, 200, 300, and 400 Areas from two release heights (9.1 m and 60 m [30 ft and 197 ft]) (Tables A1 through A8, Appendix A). For each station, the joint frequency distributions were determined using wind measurements and calculated stability collected during the 1983 to 2006 time period.

The annual sector-average atmospheric dispersion coefficients (X/Q') where X is the air concentration (Ci/m^3) and Q' is the emission rate (Ci/s) were estimated for ground level and 60-m (197-ft) releases (Tables A9 through A16, Appendix A). The 95 percent centerline atmospheric dispersion estimates (E/Q') for the four major Hanford operating areas (100, 200, 300, and 400 Areas) were estimated from atmospheric data (Tables A17 through A24, Appendix A). These dispersion factors are presented as a function of direction and distance from the release point and are based on meteorological data collected during the years 1983 through 2006.

Table 4.2-1. Percent Probabilities for Extended Periods of Surface-Based Inversions, Hanford Site, Washington (after Stone et al. 1972)

	Inversion Duration		
Months	**12-hr**	**24-hr**	**48-hr**
January-February	54.0	2.5	0.28
March-April	50.0	<0.1	<0.1
May-June	10.0	<0.1	<0.1
July-August	18.0	<0.1	<0.1
September-October	64.0	0.11	<0.1
November-December	50.0	1.2	0.13

4.2.2 Nonradiological Air Quality

The Clean Air Act (CAA) is the basis for federal regulation of air quality in the United States (42 USC 7401). The CAA was first passed during 1967 and was comprehensively amended in 1970, 1977, and 1990. Section 108 of the CAA calls for the U.S. Environmental Protection Agency (EPA) to promulgate a list of air pollutants that are emitted by numerous or diverse sources and whose presence in the atmosphere may reasonably be expected to endanger public health or welfare. In response to this mandate, EPA has issued regulations in 40 CFR 50 setting national ambient air quality standards. These standards are not directly enforceable, but other enforceable regulations are based on these standards. The states have primary responsibility for ensuring that their air quality meets the national ambient air quality standards through implementation plans that are approved by EPA. Areas that meet ambient air quality standards are said to be “in attainment.” Areas that fail to meet one or more ambient air standards are designated as "nonattainment areas." The CAA also establishes a permitting program for construction or modification of large sources of air pollutants in both attainment and nonattainment areas and an operating permit program.

Section 176 of the CAA states that federal agencies are not to engage in, support in any way, provide financial assistance for, license, permit, or approve any activity that does not conform to an applicable state implementation plan. The DOE has guidance (DOE 2000) on how to apply the CAA conformity requirements and associated EPA regulations in a NEPA document and how to coordinate the CAA and NEPA public participation requirements.

Ambient air quality standards define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health (primary standards) and the public welfare (secondary standards). "Ambient air" is that portion of the atmosphere, external to buildings, to which the general public has access (40 CFR 50.1). EPA has issued ambient air standards for sulfur oxides (measured as sulfur dioxide), nitrogen dioxide, carbon monoxide, lead, ozone, and PM_{10}, which is an air pollutant consisting of small particles with an aerodynamic diameter less than or equal to 10 µm. The standards specify the maximum pollutant concentrations and frequencies of occurrence that are allowed for specific averaging periods. The averaging periods vary from 1 hour to 1 year, depending on the pollutant.

State and local governments have the authority to impose standards for ambient air quality that are more restrictive than the national standards (Table 4.2-2). Washington State has established more stringent standards for sulfur dioxide. In addition, Washington has established standards for total suspended particulates (WAC 173-470) and fluorides (WAC 173-481) that are not covered by national standards. The state standards for carbon monoxide, nitrogen dioxide, PM_{10}, and lead are identical to the national standards. Benton County and the Hanford Site are "in attainment" for all standards outlined in Table 4.2-2.

On July 18, 1997, EPA issued new air quality standards for particulate matter with a diameter of 2.5 µm or less ($PM_{2.5}$) and an 8-hour ozone standard. Decisions on violations of the new particulate matter and ozone standard were delayed to give states time to set up monitoring networks and obtain 3 years of data (Ecology 1997). Revised standards for $PM_{2.5}$ were implemented in 2006. The revised standards lowered the allowable annual average $PM_{2.5}$ concentration from 65 µg/m^3 to 35 µg/m^3. In addition, the annual average PM_{10} standard was revoked (71 FR 61144).

4.2.2.1 Prevention of Significant Deterioration

Prevention of significant deterioration permits apply to new major sources of pollutants located in attainment areas which are subject to EPA National Ambient Air Quality Standards (NAAQS). The Plutonium-Uranium Extraction (PUREX) and Uranium Trioxide (UO_3) facilities were issued a prevention of significant deterioration permit for nitrogen oxide emissions during 1980. These facilities were permanently shut down in the late 1980s and deactivated in the 1990s. None of the currently operating Hanford facilities have nonradiological emissions of sufficient magnitude to warrant consideration under prevention of significant deterioration regulations.

Table 4.2-2. U.S. Environmental Protection Agency (EPA) and Washington State Ambient Air Quality Standards [(a)]

Pollutant	EPA Primary	EPA Secondary	Washington State
Total Suspended Particulates			
Annual geometric mean	NS[(b)]	NS	60 μg/m^3
24-hr average	NS	NS	150 μg/m^3
PM_{10}[(c)]			
Annual arithmetic mean	NS	NS	50 μg/m^3
24-hr average	150 μg/m^3	150 μg/m^3	150 μg/m^3
$PM_{2.5}$[(d)]			
Annual arithmetic mean	15 μg/m^3	15 μg/m^3	NS
24-hr average	35 μg/m^3	35 μg/m^3	NS
Sulfur Dioxide			
Annual average	0.03 ppm (≅80 μg/m^3)	NS	0.02 ppm (≅50 μg/m^3)
24-hr average	0.14 ppm (≅365μg/m^3)	NS	0.10 ppm (≅260 μg/m^3)
3-hr average	NS	0.50 ppm (≅1.3 mg/m^3)	NS
1-hr average	NS	NS	0.40 ppm (≅1.0 mg/m^3)[(e)]
Carbon Monoxide			
8-hr average	9 ppm (≅10 mg/m^3)	9 ppm (≅10 mg/m^3)	9 ppm (≅10 mg/m^3)
1-hr average	35 ppm (≅40 mg/m^3)	35 ppm (≅40 mg/m^3)	35 ppm (≅40 mg/m^3)
Ozone			
8-hr average	0.08 ppm (~157 μg/m^3)	0.08 ppm (~157 μg/m^3)	NS
1-hr average	0.12 ppm (≅235 μg/m^3)	0.12 ppm (≅235 μg/m^3)	0.12 ppm (≅235 μg/m^3)
Nitrogen Dioxide			
Annual average	0.053 ppm (≅100 μg/m^3)	0.053 ppm (≅100 μg/m^3)	0.053 ppm (≅100 μg/m^3)
Lead			
Quarterly average	1.5 μg/m^3	1.5 μg/m^3	1.5 μg/m^3
Fluorides			
12-hr average	NS	NS	3.7 μg/m^3
24-hr average			2.9 μg/m^3
7 day average			1.7 μg/m^3
30 day average			0.84 μg/m^3

Abbreviations: ppm = parts per million; μg/m^3 = micrograms per cubic meter; mg/m^3 = milligrams per cubic meter.

(a) Source: 40 CFR 50 and WAC 173-470 – 173-481. Annual standards are never to be exceeded; short-term standards are not to be exceeded more than once per year unless otherwise noted. Particulate pollutants are in micrograms per cubic meter. Gaseous pollutants are in parts per million and equivalent micrograms (or milligrams) per cubic meter.

(b) NS = no standard.

(c) PM_{10} - small particles in the air with an aerodynamic diameter less than or equal to 10 micrometers.

(d) $PM_{2.5}$ - small particles in the air with an aerodynamic diameter less than or equal to 2.5 micrometers. Currently the $PM_{2.5}$ standard is not enforced by the EPA.

(e) 0.25 ppm not to be exceeded more than twice in any 7 consecutive days.

4.2.2.2 Emissions of Nonradiological Pollutants

Nonradiological pollutants are mainly emitted from power-generating and chemical-processing facilities in the 200 and 300 Areas on the Hanford Site (Table 4.2-3). The 100, 400, and 600 Areas do not have any nonradiological emission sources of concern (Poston et al. 2007).

4.2.2.3 Offsite Monitoring

During 1998, the Washington State Department of Ecology (Ecology) conducted offsite monitoring near the Hanford Site for PM_{10} (Ecology 1999, 2000). PM_{10} was monitored at one location in Benton County, the Tri-Tech Vocational Center near the Hanford meteorological monitoring network's Vista Field site in Kennewick. The Benton Clean Air Authority currently conducts particulate monitoring at Tri-Tech Vocational Center to demonstrate compliance with EPA and Washington State standards (Table 4.2-2). During 2006, the maximum measured PM_{10} concentration was 88 $\mu g/m^3$ and the second highest measured concentration was 36 $\mu g/m^3$ (EPA 2007). The annual average PM_{10} concentration reported for Benton County was 18 $\mu g/m^3$ (EPA 2007). $PM_{2.5}$ data was not available for 2006 in Benton County. The maximum measured $PM_{2.5}$ concentration for Benton County during 2005 was 29 $\mu g/m^3$ and the 2004 annual average $PM_{2.5}$ concentration was 6.9 $\mu g/m^3$ (EPA 2007). These measured concentrations were less than EPA and Washington State standards. It should be noted that in 2006 there were instances of PM_{10} concentrations measured in Benton County in excess of 150 $\mu g/m^3$. However, these exceedences were attributed to natural events and were not considered in determining the attainment status for the county.

4.2.2.4 Background Monitoring

During the last 10 years, carbon monoxide, sulfur dioxide, and nitrogen dioxide have been monitored periodically in communities and commercial areas south-southeast of Hanford. These urban measurements are typically used to estimate the maximum background pollutant concentrations for the Hanford Site because of the lack of specific onsite monitoring.

Particulate concentrations can reach relatively high levels in eastern Washington because of exceptional natural events (i.e., dust storms and large brushfires) that occur in the region. During June 1996, EPA adopted the policy that allows dust storms to be treated as uncontrollable natural events (EPA 1996). This means that EPA will not designate areas affected by dust storms as nonattainment. However, states are required to develop and implement a natural events action plan.

Areas that require more strict controls on air quality impacts are regions that have been determined to be nonattainment areas by the EPA. There are currently no non-attainment areas near the Hanford Site. Federal Class I areas include certain national parks and wilderness areas. Actions on the Hanford Site are unlikely to have any effect on these types of areas. The nearest Federal Class I areas to the Hanford Site are Mount Rainer National Park, 160 km (100 mi) west of the Site; Goat Rocks Wilderness Area, approximately 145 km (90 mi) west of the Site; Mount Adams Wilderness Area, approximately 150 km (95 mi) southwest of the Site; and Alpine Lakes Wilderness Area, approximately 175 km (110 mi) northwest of the Site (40 CFR 81.434). Operations at the Hanford Site should have no discernable effects on these areas because of their distance from the Site and because topography and prevailing winds tend to prevent Hanford emissions from reaching these Class I areas.

Table 4.2-3. Nonradioactive Constituents Discharged to the Atmosphere during 2006, Hanford Site, Washington (Rokkan et al. 2007)

Constituent	Release, kg	(lb)
Particulate matter-total	3,700	(8,200)
Particulate matter-PM_{10}	2,800	(6,200)
Particulate matter-$PM_{2.5}$	1,000	(2,200)
Nitrogen oxides	11,000	(24,000)
Sulfur oxides	2,900	(6,400)
Carbon monoxide	13,000	(28,000)
Lead	0.44	(0.97)
Volatile organic compounds[a, b]	10,000	(22,000)
Ammonia[c]	5,500	(12,000)
Other toxic air pollutants[d]	4,500	(9,900)
Total criteria pollutants[e]	40,000	(89,000)

(a) The estimate of volatile organic compounds does not include emissions from certain laboratory operations.
(b) Produced from burning fossil fuel for steam and electrical generators and calculated estimates from the 200 East and 200 West Area tank farms, evaporative losses from fuel dispensing, operation of the 242-A Evaporator, the 200 Area Effluent Treatment Facility, the Central Waste Complex, the T Plant Complex, and the Waste Receiving and Processing Facility.
(c) Ammonia releases are calculated estimates from the 200 East Area and 200 West Areas tank farms and operation of the 242-A Evaporator and the 200 Area Effluent Treatment Facility, and produced from burning fossil fuel for steam and electrical generators.
(d) Releases are a composite of calculated estimates of toxic air pollutants, excluding ammonia, from the 200 East and 200 West Areas tank farms, operation of the 242-A Evaporator, the 200 Area Effluent Treatment Facility, the Central Waste Complex, the T Plant Complex, and the Waste Receiving and Processing Facility.
(e) Criteria pollutants include particulate matter – total, nitrogen oxides, sulfur oxides, carbon monoxide, lead, and volatile organic compounds.

4.2.2.5 Onsite Monitoring

Monitoring of particulate matter mass concentrations in air on the Hanford Site began during February 2001. PM_{10} data have been collected at the HMS since February 2001, while $PM_{2.5}$ data collection began during October 2001. The observed annual average PM_{10} concentration at the HMS during 2006 was 13 µg/m^3. Daily average PM_{10} concentrations on the Hanford Site did not exceed the EPA standard for any days when measurements were conducted. However, due to instrument failures throughout the year, data was only recorded for 149 days during 2006. The Benton Clean Air Authority (BCAA) conducts air monitoring that is responsible for determining Benton County's compliance with the EPA NAAQS, so concentrations on the Hanford Site are not considered for determining compliance. For comparison, the annual average PM_{10} concentration in 2006 measured in Kennewick at the BCAA monitoring location was 18 µg/m^3. The measured annual average $PM_{2.5}$

concentration at the HMS during 2006 was 4.5 µg/m^3, while the highest 24-hr average concentration observed was 8.1 µg/m^3. Both of these concentrations were less than EPA standards of 15 µg/m^3 and 35 µg/m^3, respectively (Table 4.2-2). However, $PM_{2.5}$ monitoring at the HMS only occurred 73 days during 2006.

4.2.3 Radiological Air Quality

Airborne effluents that may contain radioactive constituents are continually monitored at the Hanford Site. Samples are analyzed for gross alpha and gross beta activity as well as selected radionuclides. Radioactive emissions during 2006 originated in the 100, 200, 300, and 400 Areas (Table 4.2-4). Emissions from the 100 Areas originated from the K Basins (irradiated fuel stored in two water-filled storage basins) and the Cold Vacuum Drying Facility, where fuel from the K Basins was prepared for storage. The 200 Areas emissions originated from the PUREX Plant, the Waste Encapsulation and Storage Facility, the Plutonium Finishing Plant, T Plant, 222-S Laboratory, underground storage tanks, and waste evaporators. Emissions from the 300 Area originated from the 324 Waste Technology Engineering Laboratory, 325 Radiochemical Processing Laboratory, 327 Post-Irradiation Laboratory, and 340 Vault and Tanks. 400 Area emissions originated at the Fast Flux Test Facility (FFTF) and Maintenance and Storage Facility (Rokkan et al. 2007).

4.2.3.1 Radiological Emissions

Standards for emissions of radionuclides to air from DOE facilities have been established by EPA (40 CFR 61) and Washington State (WAC 173-480 and WAC 246-247). Emissions may not exceed quantities that would result in a dose of 10 mrem in a year to a maximally exposed individual (MEI) of the public. Dose to an MEI is calculated through computer modeling that uses radiological emissions to the atmosphere as one input parameter.

4.2.3.2 Dose Assessments

Each year dose assessments are conducted to determine doses from Hanford emissions. Different assessments are done to comply with various regulations. A hypothetical MEI dose with contributions from all potential pathways is calculated to satisfy the requirements of DOE Order 5400.5 (DOE 1993). This dose estimate is made to ensure that no member of the public receives a dose exceeding 100 mrem (1,000 µSv) per year from emissions to air and water combined with direct radiation sources. Similarly, dose estimates are made to satisfy the requirements of the Clean Air Act, which stipulates that no member of the public can receive an annual dose that exceeds 10 mrem (100 µSv) from radionuclide emissions to air.

The annual dose to the Hanford Site maximally exposed individual is estimated using GENII (Napier et al. 1998). It estimates dose based on exposure from all potential pathways including emissions to air and water. For 2006, this MEI dose was calculated to be 0.068 mrem (0.68 µSv) per year (Poston et al. 2007). The MEI was modeled to reside at the Sagemoor location in Franklin County, just across the Columbia River from the 300 Area.

Table 4.2-4. Radionuclides Discharged to the Atmosphere at the Hanford Site, Washington, 2006 (Rokkan et al. 2007)

Radionuclide	Releases, Ci[(a)]					
	100 Areas	**200 East Area**	**200 West Area**	**300 Area**	**400 Area**	**Total**
^{3}H (as HT)[(b)]	NM	NM	NM	6.95E+01	NM	**7.0E+01**
^{3}H (as HTO)[(c)]	NM	NM	NM	2.6E+02	3.7E-01	**2.6E+02**
^{90}Sr	2.3E-05	4.3E-05	3.2E-05	1.2E-06	NM	**9.9E-05**
^{129}I	NM	1.5E-03	NM	NM	NM	**1.5E-03**
^{137}Cs	NM	1.3E-05	1.2E-07	6.0E-06	7.2E-06	**2.6E-05**
^{220}Rn	NM	NM	NM	3.0E+01	NM	**3.0E+01**
^{222}Rn	NM	NM	NM	9.1E-01	NM	**9.1E-01**
^{238}Pu	2.2E-06	2.1E-11	6.0E-07	7.4E-10	NM	**2.8E-06**
$^{239/240}Pu$	1.5E-05	1.3E-06	3.2E-05	1.1E-07	1.2E-06	**5.0E-05**
^{241}Pu	8.3E-05	ND	2.5E-05	ND	NM	**1.1E-04**
^{241}Am	1.3E-05	1.8E-07	6.6E-06	4.7E-07	NM	**2.0E-05**
^{243}Am	NM	NM	NM	3.0E-09	NM	**3.0E-09**
^{131m}Xe	NM	NM	NM	3.1E-08	NM	**3.1E-08**
^{135}Xe	NM	NM	NM	1.0E-08	NM	**1.0E-08**

(a) 1 Ci (curie) = 3.7 E+10 becquerels (Bq); ND = not detected (i.e., either the radionuclide was not detected in any sample during the year or the average of all the measurements for that given radionuclide or type of radioactivity made during the year was below background levels); NM = not measured.

(b) HT = tritium in the form of incondensable gas.

(c) HTO = tritium in the form of condensable water vapor.

(d) This release value includes gross beta data, assumed to be ^{90}Sr in dose calculations.

(e) For dose modeling, this value had added to it the value of 9.2 E–06 Ci of gross beta activity, assumed to be ^{137}Cs in dose calculations.

(f) This release value derives entirely from FFTF gross beta data, assumed to be ^{137}Cs in dose calculations.

(g) Calculated release based on inventory and project process.

(h) This release value includes gross alpha data, assumed to be $^{239/240}Pu$ in dose calculations.

(i) For dose modeling, this value had added to it the value of 7.8 E–07 Ci of gross alpha, assumed to be ^{241}Am in dose calculations.

The Clean Air Act requires the implementation of an EPA-approved dispersion model to be used in order to estimate dose based on measured stack emissions. For the Hanford Site, the annual dose to an offsite MEI at Sagemoor from air emissions in 2006 was calculated to be 0.066 mrem (0.66 μSv) (Poston et al. 2007; Rokkan et al. 2007). Based on guidance from EPA Region 10 and the Washington State Department of Health, a dose to a non-DOE worker on the Hanford Site from Hanford emissions was also calculated. This dose was estimated to be 0.0028 mrem (0.028 μSv) per year to an employee of the Laser Interferometer Gravitational Wave Observatory (LIGO) facility (Poston et al. 2007). Finally, using environmental measurements at the Hanford Site perimeter and CAP88-PC environmental radiological assessment computer code results, a dose to an offsite member of the public from diffuse and fugitive sources is calculated. For 2006, this dose was calculated to be 0.038 mrem (0.38 μSv) per year at the Sagemoor area (Poston et al. 2007; Rokkan et al. 2007).

4.2.3.3 Environmental Monitoring

Both the Surface Environmental Surveillance Project (SESP) and the near-facility environmental monitoring project conduct Hanford Site environmental monitoring. The SESP conducts monitoring at locations across the Hanford Site, as well as at upwind and downwind locations. The near-facility monitoring project primarily collects samples near known effluent sources. Summaries of the 2006 monitoring data from both of these projects are available in the annual Hanford Site Environmental Report (Poston et al. 2007). The spatial coverage of these two monitoring networks is sufficient to identify some Hanford sources. However, the amount of radiological materials in air is so small that there is no difference between upwind and downwind samples for most radionuclides. Atmospheric dispersion reduces Hanford atmospheric emissions to background levels before those emissions leave the Site (Poston et al. 2007).

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4.3 Geology

M. A. Chamness and M. D. Sweeney

Geologic considerations for the Hanford Site include physiography, stratigraphy, structural geology, tectonics, and soil characteristics. Much of the information in this section is available from Reidel and Chamness (2007), who summarized and updated earlier works concerning the geology of the Hanford Site.

4.3.1 Physiography

The Hanford Site is located in the Columbia Basin of the Pacific Northwest. The Columbia Basin is an intermontane basin between the Cascade Range and the Rocky Mountains and forms the northern part of the Columbia Plateau physiographic province and the Columbia River flood-basalt province. Most of the geologic features visible in the Basin occurred during the last 18 million years of the Cenozoic Era, but events as far back as the late Precambrian (2.3 billion years ago) have had significant influence on the Cenozoic history of the area.

The Columbia Basin has four structural subdivisions or subprovinces, two of which are important to the Pasco Basin and the Hanford Site: the Yakima Fold Belt and the Palouse Slope (Figure 4.3.1). The Yakima Fold Belt is a series of anticlinal ridges and synclinal valleys in the western part of the Columbia Basin that has predominantly an east-west structural trend. The Palouse Slope is the eastern part of the Columbia Basin and shows little deformation with only a few faults and low-amplitude, long wavelength folds on an otherwise gently westward-dipping paleoslope.

The Hanford Site lies within the Pasco Basin, which is a smaller basin in the Yakima Fold Belt along the western margin of the Palouse Slope (Figure 4.3.1). The Saddle Mountains forms the northern boundary of the Pasco Basin while Rattlesnake Mountain forms part of the southern boundary. The main Hanford Site waste management areas, located in the 200 East and 200 West Areas, lie in the Cold Creek syncline between Yakima Ridge and Umtanum Ridge in the central portion of the Pasco Basin (Figure 4.3.2).

The physiographic setting of the Hanford Site is relatively low-relief resulting from river and stream sedimentation filling the synclinal valleys and basins between the anticlinal ridges. Surface topography has been modified within the past several million years by Pleistocene cataclysmic flooding, Holocene eolian activity, and landsliding. Cataclysmic floods during the Pleistocene eroded sediments and scoured basalt bedrock, forming “scabland” topography visible north of the Pasco Basin. Branching flood channels, giant current ripples, ice rafted erratics, and giant flood bars are among the landforms created by the floods and readily seen on the Hanford Site.

Since the end of the Pleistocene (about 10,000 years ago), winds have locally reworked the flood sediments, depositing dune sands in the lower elevations and windblown silt around the margins of the Pasco Basin. Most sand dunes have been stabilized by vegetation. Active dunes exist north of the 300 Area in the Hanford Reach National Monument. Some dunes elsewhere on the Hanford Site were temporarily reactivated by removal of vegetation resulting from the June-July 2000 range fire.

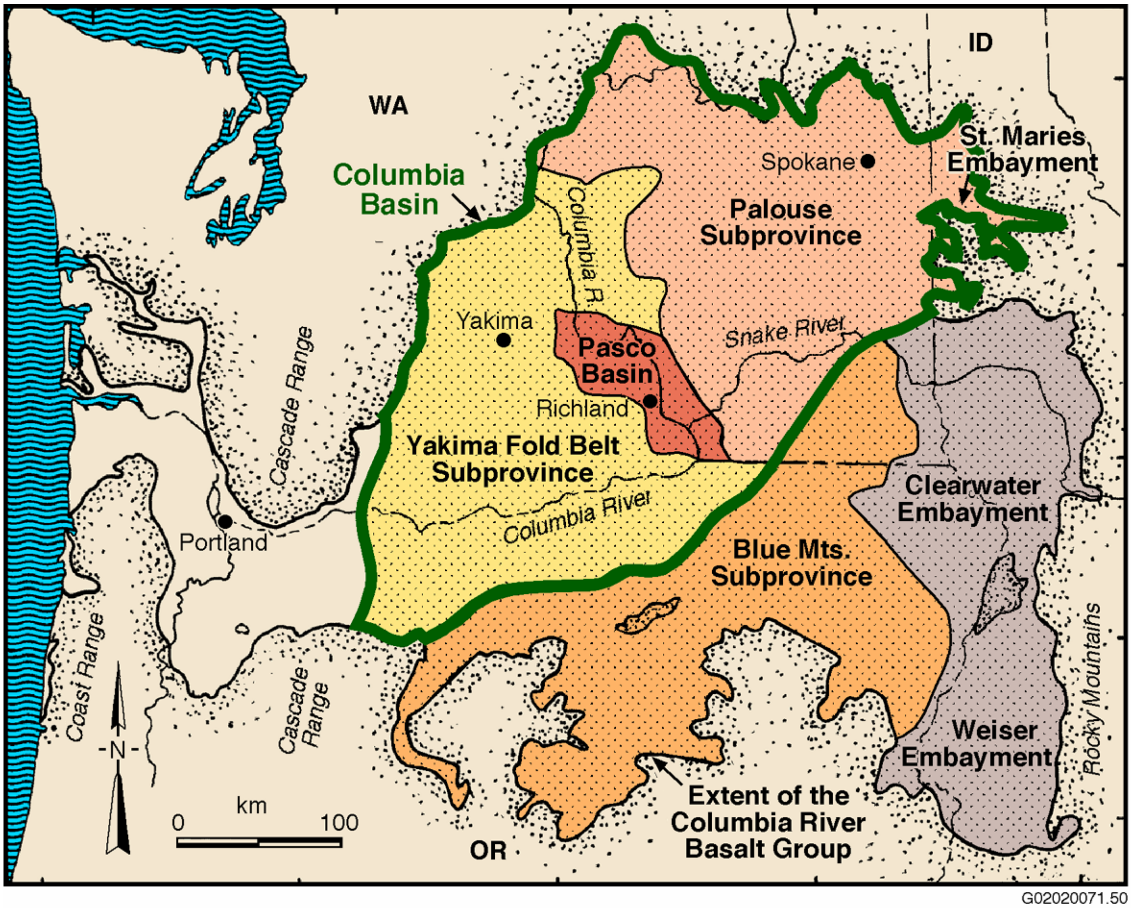

Figure 4.3.1. Geologic Setting of the Pasco Basin and Extent of the Columbia River Basalt Group (Reidel et al. 2002)

4.3.2 Stratigraphy

Within the Yakima Fold Belt, the Columbia River Basalt Group overlies Tertiary continental sedimentary rocks and is overlain by late Tertiary and Quaternary fluvial and glaciofluvial deposits (Figure 4.3.3).

The Columbia River Basalt Group and interbedded sedimentary rocks of the Ellensburg Formation define the fundamental stratigraphy of the Columbia Basin and have the greatest overall influence on the geology and waste disposal activities on the Hanford Site. Younger sedimentary rocks that include the Ringold Formation, Cold Creek unit, Pleistocene cataclysmic flood deposits of the Hanford formation, and Holocene strata overly the basalt and are found mainly in the structural lows (Figure 4.3.3). The rocks that underlie the basalt are varied but have influenced the geologic development of the Hanford Site. The following sections describe the stratigraphy based on its age relative to the Columbia River Basalt Group.

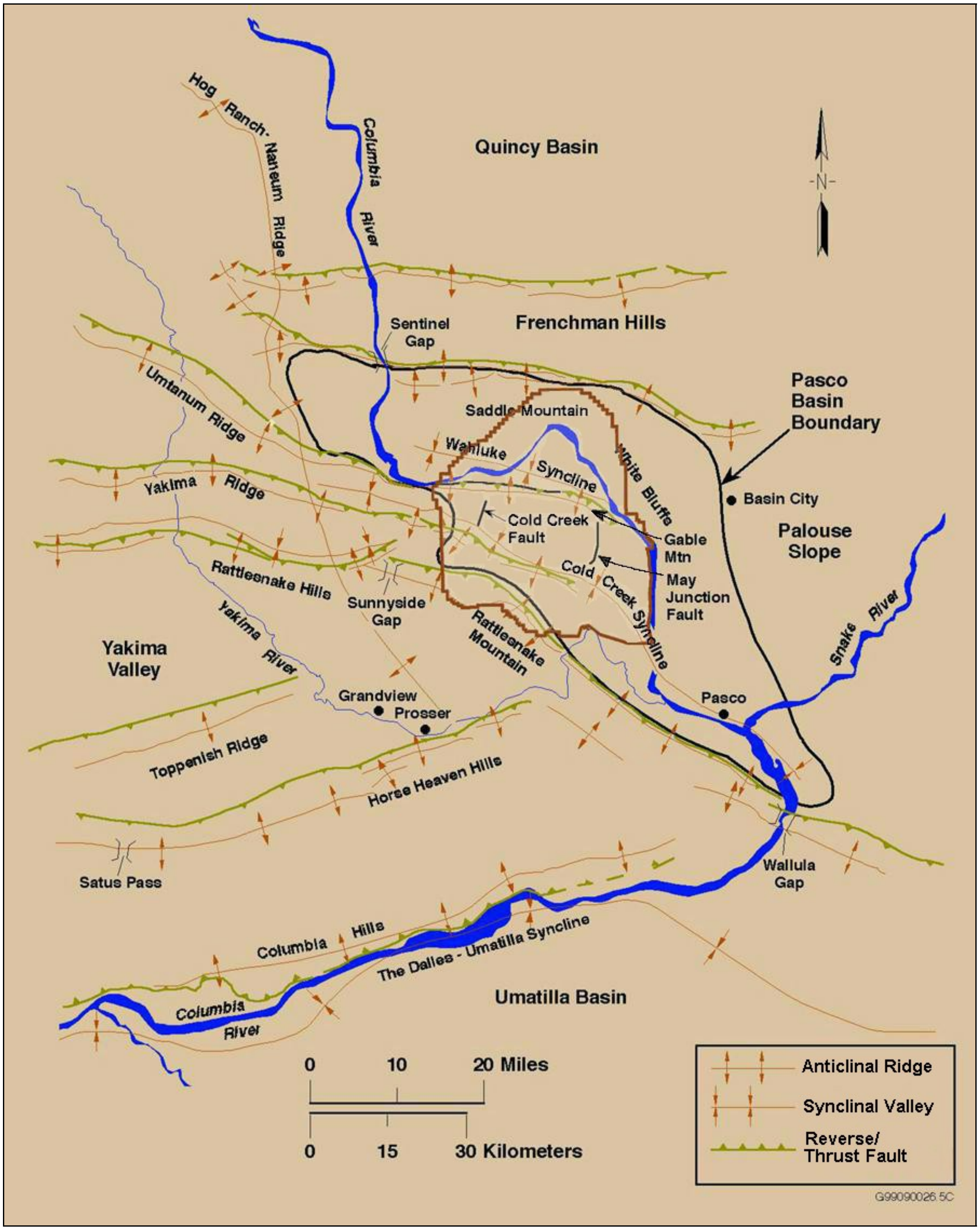

Figure 4.3.2. Physical and Structural Geology of the Hanford Site

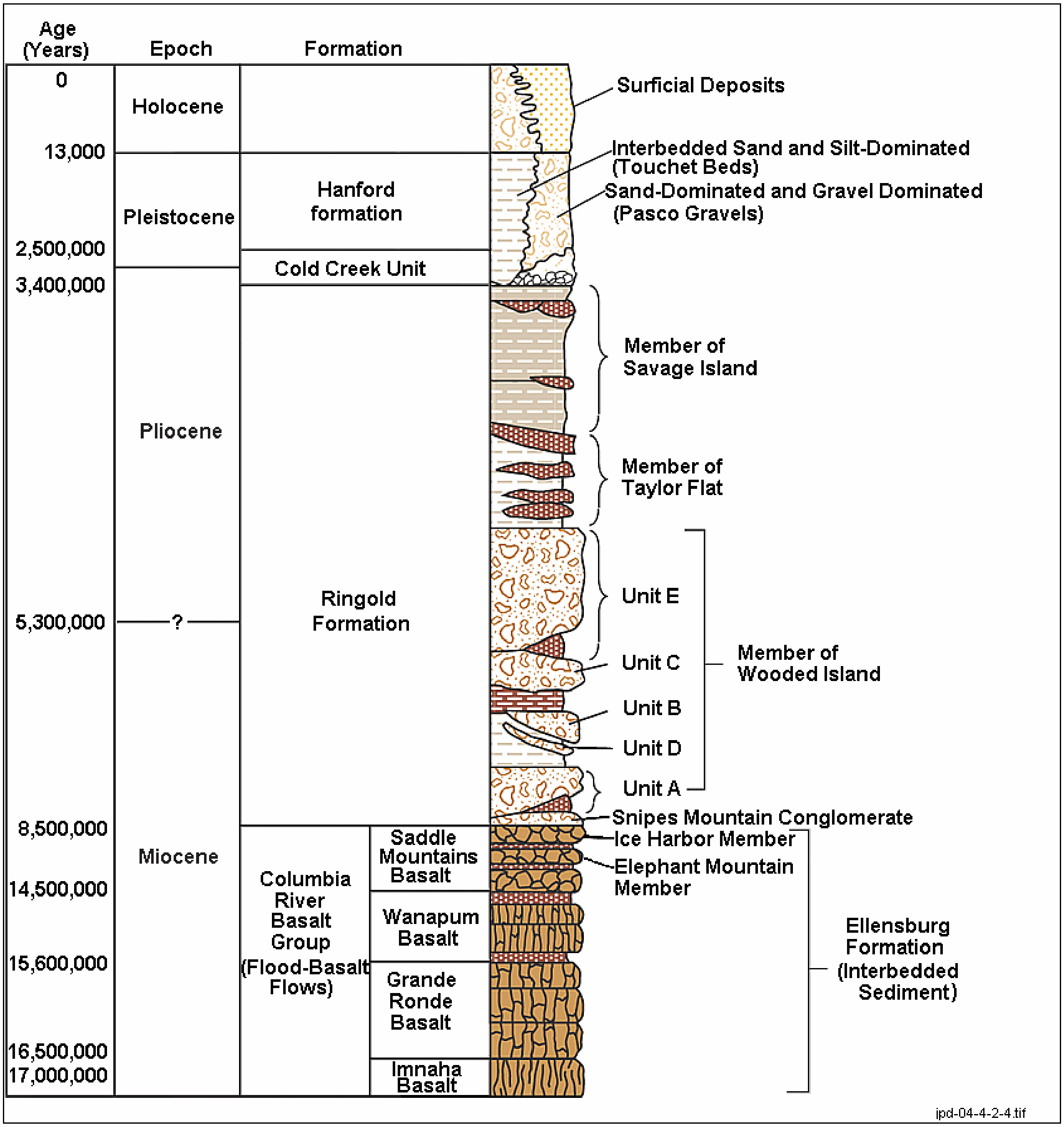

Figure 4.3.3. Generalized Stratigraphy of the Pasco Basin and Vicinity

4.3.2.1 Stratigraphy of Rocks Older than the Columbia River Basalt Group

Rocks older than the Columbia River Basalt Group are exposed primarily along the margin of the Columbia Basin, but are important to understanding the history of the Hanford Site because many are thought to extend under the basalt and form the foundation of the area.

The oldest rocks in the Pacific Northwest are found along the northeast and east margins of the Columbia Basin. These are late Precambrian and early Paleozoic metamorphosed volcanic and sedimentary rocks (2.3 billion-300 million years before present). These older rocks represent the ancient North American continent and the remnants of a one-billion-year-old supercontinent that broke apart 750 million years ago to form the Pacific Ocean. The boundary of that rifted margin occurs east of the eastern border of the Hanford Site.

Younger meta-volcanic and meta-sedimentary rocks from the late Paleozoic, Mesozoic, and early Cenozoic are exposed along the south and western margins of the Columbia Basin. These are the rocks that were added onto the North America Plate between 200 and 50 million years ago as ocean islands and microcontinents carried on the oceanic plate collided with the North American Plate. During the collision process these ocean islands and microcontinents were accreted onto North America and resulted in the westward growth of North America. Similar accreted terrain rocks are thought to occur deep beneath the Hanford Site.

A series of sedimentary basins formed during early Tertiary time along the west and northwest margins of the Columbia Basin. The Tertiary rocks extend under the Columbia Basin and Hanford Site and were the targets of oil exploration in the later half of the 20th Century. These rocks include volcanic and sedimentary rocks that are 50 to 20 million years old and were derived from the erosion of highlands in the Pacific Northwest.

4.3.2.2 Columbia River Basalt Group

The Columbia River Basalt Group forms the main bedrock of the Columbia Basin and Hanford Site. The Columbia River Basalt Group consists of over 200,000 km^3 (262,000 yd^3) of tholeiitic flood-basalt flows that were erupted between 17 and 6 million years before present and now cover approximately 230,000 km^2 (88,800 mi^2) of eastern Washington and Oregon and western Idaho (Camp et al. 2003). Individual eruptions had volumes up to 5,000 km^3 (6,500 yd^3) (Reidel et al. 1989) and more than 98 percent by volume of the Columbia River Basalt Group were erupted in a 2.5 million-year period (16.5 to 14.5 million years ago). These flows are the structural framework of the Columbia Basin and their distribution pattern reflects the tectonic history of the area over the past 16 million years.

Columbia River basalt flows were erupted from north-northwest trending fissures or linear vent systems mostly in north-central and northeastern Oregon, eastern Washington, and western Idaho. The Columbia River Basalt Group has been divided into five formations, the Picture Gorge Basalt, the Imnaha Basalt, the Grande Ronde Basalt, the Wanapum Basalt, and the Saddle Mountains Basalt. Only the last three are exposed on or beneath the Hanford Site (Figure 4.3.3). There is a minimum of 50 basalt flows beneath the Hanford Site with a combined thickness of greater than 3,000 m (1.9 mi)

(DOE 1988). The Elephant Mountain Member and the Ice Harbor Member of the Saddle Mountains Basalt are the youngest basalt flows at the Hanford Site.

Basalt flows at the Hanford Site have been eroded to various degrees in localized areas (Reidel and Chamness 2007). North of the 200 Areas near Gable Gap, the Saddle Mountains Basalt has been eroded down to the Umatilla Member.

Interbedded with, and in some places overlying the Columbia River Basalt Group, are sedimentary rocks of the Ellensburg Formation (Swanson et al. 1979). In the western Columbia Basin, the Ellensburg Formation is mostly volcanic-derived sediment; in the central and eastern basin, fluvial mainstream and overbank sediments of the ancestral Clearwater-Salmon and Columbia Rivers form the dominant lithologies (Fecht et al. 1987).

4.3.2.3 Post-Columbia River Basalt Stratigraphy

Ellensburg Formation

Contemporaneous with eruption of the basalt flows, river and lake sediments were deposited along the edges and eventually across the top of the flat flood basalt flows. Older sediments were buried by successive basalt flows, while sediments deposited after the last basalt eruption are preserved in the basins and valleys. The dominant source of this upper Miocene to middle Pliocene (10 to 3 million years ago) sediment is the Columbia River system and its tributaries. The Ellensburg Formation and the Ringold Formation are the main sediment packages that contain this history and record the migration of rivers and streams into their present channels (Fecht et al. 1987).

The lower, older Ellensburg Formation at the Hanford Site mainly records the path of the ancestral Clearwater-Salmon River system as it flowed from the Rocky Mountains west to its confluence with the Columbia River near Priest Rapids Dam. The upper, younger Ellensburg Formation interbedded with the Saddle Mountains Basalt reflects changes in river courses, with sediments from the Columbia River becoming dominant as developing anticlinal ridges pushed the Columbia River east and basalt flows pushed the Clearwater-Salmon system to the south. During this time the Columbia River flowed west from Priest Rapids Dam to the western margin of the Columbia Basin near Goldendale. The upper Ellensburg Formation consists of sand and gravel marking mainstream deposits and sand, silt, and clay overbank deposits that are sandwiched between basalt flows. Along with the more permeable basalt flow bottoms and flowtops, these sediments form the uppermost confined basalt aquifer system beneath the Hanford Site.

Ringold Formation

Most post-Columbia River Basalt Group sediments are confined to the synclinal valleys and basins of the Yakima Fold Belt. Sediments of the Ringold Formation represent the evolution of the ancestral Columbia River as it was forced to change course across the Columbia Basin by the growth of the Yakima Fold Belt. Ridges of the Yakima Fold Belt were growing continuously, creating small ridges and folding existing basalt flows before being almost completely buried by the next new basalt flow. As time between eruptions increased, the ridges began to have more influence on river and subsequent basalt flow locations. After the last major basalt eruption, the ridges began to develop significant topography. Continued uplift of the ridges forced the Columbia River and its confluence with the Salmon-Clearwater River eastward.

About 8.5 million years ago, the Columbia River abandoned Sunnyside Gap north of Sunnyside and started flowing across the Hanford Site to the Yakima River water gap near Benton City. The river meandered across a gravelly braided plain, depositing the extensive gravel and interbedded sand of the oldest Ringold sediments - unit A, Ringold Formation Member of Wooded Island (Figure 4.3.3) (Fecht et al. 1987; Reidel et al. 1994; Lindsey 1995).

Between 5 and 7 million years ago, the Columbia River abandoned the Yakima River water gap and began to exit the Pasco Basin through Wallula Gap. Around 6.7 million years ago the Columbia River became a sandy alluvial system, depositing extensive lake and stream overbank sediments known as the Ringold Formation lower mud unit (Fecht et al. 1987; Reidel et al. 1994; Lindsey 1995). The lower mud unit is present under much of the Hanford Site and is a nearly continuous feature beneath 200 West Area and the southern half of 200 East Area. Where present, the lower mud unit forms the base of the unconfined aquifer at the Hanford Site and acts as an aquitard, separating groundwater in the underlying Ringold unit A from the unconfined aquifer. The lower mud unit was covered by another extensive sequence of mainstream gravels and sands in the central Pasco Basin and fine-grained overbank deposits near the 100 Areas. The most extensive of the course sediments, unit E, Ringold Formation Member of Wooded Island, underlies much of the 200 Areas. Other sequences (e.g., units C and D) are also locally recognized.

The Columbia River sediments became more sand-dominated about 5 million years ago when over 90 meters of interbedded fluvial sand and overbank deposits accumulated at the Hanford Site. These deposits are collectively called the Member of Taylor Flat (Lindsey 1995). The fluvial sands of the Member of Taylor Flat dominate the lower cliffs of the White Bluffs (Figure 4.3.4) but have been subsequently eroded from most of the Hanford Site.

The last Ringold unit was deposited between 4.8 and 3.4 million years ago in the form of lake deposits (Reidel and Chamness 2007). A series of three successive lakes are recognized along the White Bluffs and elsewhere along the margin of the Pasco Basin (Lindsey 1995). The lakes may have resulted from damming of the Columbia River farther downstream, possibly near the Columbia Gorge. The lakes and related deposits in the Pasco Basin are collectively called the Ringold Formation Member of Savage Island.

At the end of Ringold time, western North America underwent regional uplift resulting in a change in base level for the Columbia River system. Uplift, probably related to the rising Cascade Mountains to the west, caused a change from sediment deposition to sediment removal. This is especially apparent in the Pasco Basin where nearly 100 m (330 ft) of Ringold Formation are visible in the White Bluffs that have been eroded from the central Hanford Site. This regional erosion marks the beginning of Cold Creek time and the end of major deposition by the Columbia River.

Figure 4.3.4. White Bluffs East of the Hanford Site, Washington, Display River and Lake Deposits Left from the Ancestral Columbia River

Cold Creek Unit

The Cold Creek unit is the main sediment that records the geologic events between the extensive erosion by the Columbia River and the next major event, the catastrophic Ice Age floods. Early during the Cold Creek interval, the Columbia River flowed through various channels between Umtanum Ridge and Gable Mountain, eroding a wide swath to the south across the middle of the Hanford Site before gradually shifting course to the east, where it continued to erode the eastern half of the Site. At this time the uppermost Ringold Formation was removed from much of the Pasco Basin and the development of White Bluffs began. North of the 200 East Area, the ancestral Columbia River was able to erode completely through the Ringold Formation to the top of the basalt. The eroded channel can be traced from Gable Gap across the eastern part of 200 East Area and to the southeast; it is important in defining the distribution of contaminants in the unconfined aquifer.

Lower Cold Creek unit sediments include a series of extensively weathered, carbonate-rich, cemented, ancient soil profiles called paleosols. The surface of the Ringold Formation was eroded less in the 200 West Area than elsewhere; consequently, it is at a higher elevation and is more weathered than in other parts of the Hanford Site. Paleosols and small side stream drainages were developing in the 200 West Area while the Columbia River was still eroding the 200 East Area. The paleosols and side stream sediments, which are referred to as the lower Cold Creek unit, are consequently more numerous and heavily cemented in the 200 West Area (DOE 2002b).

Wind-derived sediments and minor fine-grained stream deposits were deposited on the lower Cold Creek unit, resulting in a wide variety of sediments that are called the upper Cold Creek unit. The thickness and type of sediment was highly variable due to several localized environments. Because of their fine-grained and/or cemented nature, the upper and lower Cold Creek units play important roles in the movement of water and contaminants through the vadose zone.

During Cold Creek time in the central Pasco Basin, the Columbia River flowed through Gable Gap, depositing gravels of mixed lithologies in a sand matrix. These mainstream gravel deposits, informally called the “pre-Missoula gravels” (PSPL 1981), overlie the Ringold Formation. However, the contacts and differences between Ringold, pre-Missoula, and Hanford gravels are often difficult to differentiate in drilled samples. This difficulty and uncertainty in distinguishing among these similar units is reflected in the differences among authors in geologic contacts and their descriptions.

The Hanford Formation

During the Pleistocene (between about 1.8 million and 15,000 years ago), ice dams in northern Washington failed a number of times, inundating the Pasco Basin with cataclysmic floods (Baker et al. 1991; Bjornstad 2006). At least three major episodes of cataclysmic flooding (each composed of numerous floods) are recognized in the Pasco Basin. Based on the magnetic polarity of the flood deposits, the oldest cataclysmic flood deposits are at least 770,000 years old and could be as old as 1.76 million years (Pluhar et al. 2006). The most recent major glacial flood cycle is thought to have occurred between 15,000 and 30,000 years ago (Bjornstad 2006). Fine-grained deposits associated with the last floods commonly contain Mount St. Helens volcanic ash, dated approximately 15,000 calendar years ago.

Current interpretations suggest as many as 40 individual flooding events occurred during the most recent glacial cycle, as ice dams holding back glacial Lake Missoula repeatedly formed and burst. In addition to flood episodes from Lake Missoula, there was also at least one flood from glacial Lake Bonneville in Utah, and possibly floods from other ice dammed lakes in northern Washington and Idaho. Temporary lakes were created when flood waters were hydraulically dammed resulting in the formation of the short-lived Lake Lewis behind Wallula Gap. Evidence for these temporary lakes includes high-water marks inferred from ice-rafted boulders and sediments along the basin margins at elevations between 370 and 385 m (1,214 to 1,261 ft) above sea level, far above the present Pasco Basin bottom.

Sediments deposited by the cataclysmic flood waters have been informally called the Hanford formation. Three major types of flood deposits are recognized: coarse sand- and gravel-dominated, sand-dominated, and interbedded sand- and silt-dominated (DOE 2002b).

The gravel-dominated flood deposits are generally confined to tracts within or adjacent to flood channels. A major depositional feature called the Cold Creek bar underlies the 200 Areas on the Hanford Site and was deposited just south of one such channel. Gravel-dominated flood sediments deposited on the north side of the bar grade into sand-dominated sediments on the south side.

The gravel- and sand-dominated sediments make up most of the vadose zone beneath the Hanford Site. Interbedded sand- and silt-dominated sediments, often referred to as rhythmite deposits, occurred in slackwater areas around the margins of the basin and are rarely encountered during Hanford operations.

Since the end of the Pleistocene, the dominant geologic process has been wind. After the last Ice Age flood drained from the Pasco Basin, winds moved the loose, unconsolidated material until vegetation was able to stabilize it. Stabilized sand dunes cover much of the Pasco Basin but there are areas such as along the Hanford Reach National Monument where active sand dunes remain (Figure

4.3.5). Recent range fires removed stabilizing vegetation, causing reactivation of old sand dunes in localized areas until vegetation was reestablished.

4.3.3 Clastic Dikes

Clastic dikes, vertical to sub-vertical tabular structures usually filled with multiple layers of unconsolidated sediments, cross-cut normal sedimentary layers and have the potential to influence the movement of soil moisture and contaminants. They are common in the Hanford Site vadose zone sediments (Figure 4.3.6). Clastic dikes on the Hanford Site have been described in detail by Fecht et al. (1999).

Figure 4.3.5. Active Dune Field in the Hanford Reach National Monument

Clastic dikes typically occur in swarms and in plan view may appear as regularly shaped polygonal patterns, irregularly shaped polygonal patterns, or as random occurrences. Regular polygonal networks resemble four- to eight-sided polygons. Individual clastic dikes are known to extend vertically from as little as 30 cm (1 ft) to greater than 55 m (180 ft) deep. Clastic dikes have been reported at several single-shell tank farms, the Environmental Restoration and Disposal Facility, the Integrated Disposal Facility, and throughout the Cold Creek Valley (Fecht et al. 1999; Reidel and Chamness 2007).

Clastic dikes have the potential to act as preferential pathways and/or barriers to the movement of soil moisture in the vadose zone. Infiltration studies, ongoing for several years, are examining the influence these structures have on water flow in the vadose zone. A recent finding indicates that at low water fluxes typical of vegetated areas on the Hanford Site, flow is dominated by the relatively finer-grained dikes. At high input fluxes, the coarser-grained host sediments dominate flow suggesting clastic dikes containing fine sediment may actually retard vertical flow rather than act as conduits for fluids through the vadose zone (Ward et al. 2004). It also suggests that such features may act as cutoff walls, limiting the lateral spread of fluids, which otherwise could move significant distances laterally.

4.3.4 Structure and Tectonics

The Yakima Fold Belt subprovince covers about 14,000 km^2 (5,410 mi^2) of the western Columbia Basin (extending into the Pasco Basin) and formed as basalt flows and interbedded sediments were folded and faulted under north-south compression. Most of the present structural relief in the Columbia Basin has developed within about the last 10.5 million years when the last massive outpouring of lava buried much of the central Columbia Basin. Almost all of the present structural relief is post-basalt.

The Yakima Fold Belt consists of a series of narrow, asymmetrical anticlinal ridges separated by broad synclines or basins that, in many cases, contain thick accumulations of Pliocene to Quaternary-age sediments (5.3 million years to present). The northern limbs of the generally east-west trending anticlines dip steeply to the north or are vertical. The southern limbs generally dip at relatively shallow angles to the south. Thrust faults, or high-angle reverse faults with fault planes that strike parallel or subparallel to the axes of the folds, are principally found on the north sides of these anticlines (Figure 4.3.2 and Figure 4.3.7). The amount of vertical stratigraphic offset associated with these faults varies but commonly exceeds hundreds of meters.

Figure 4.3.6. Clastic Dike in the Hanford Formation

Deformation of the Yakima folds occurred under north-south compression and was contemporaneous with the eruption of the basalt flows. The fold belt was growing during the eruption of the Columbia River Basalt Group and continued to enlarge through the Pliocene Epoch (5.3 to 1.8 million years before present), into the Pleistocene Epoch, and probably to the present.

The Umtanum Ridge-Gable Mountain uplift and the Yakima Ridge are two of the Yakima folds that enter the Hanford Site from the west (Figure 4.3.2). The Cold Creek syncline lies between the Umtanum Ridge-Gable Mountain uplift and the Yakima Ridge and is an asymmetric and relatively flat-bottomed structure. The 200 Areas lie on the northern flank of the syncline, and the bedrock dips gently (approximately 5^{o}) to the south (Reidel and Chamness 2007). The 300 Area lies at the eastern end of the Cold Creek syncline where it merges with the Pasco syncline.

The Wahluke syncline, north of Gable Mountain, is the principal structural unit that contains the 100 Areas (Figure 4.3.2). The Wahluke syncline is an asymmetric and relatively flat-bottomed structure similar to the Cold Creek syncline. The northern limb dips gently (approximately 5^{o}) to the south. The steepest limb is adjacent to the Umtanum-Gable Mountain structure.

Figure 4.3.7. Rattlesnake Mountain Anticline in the Yakima Fold Belt. Note fault zone at the base of the steeply dipping limb.

4.3.5 Geology Specific to the Major Hanford Site Areas

This section briefly describes the geology of the major operational areas on the Hanford Site. Additional and more detailed information can be found in the references cited.

4.3.5.1 Geology of the 100 Areas

The 100 Areas extend along the Columbia River in the northern portion of the Pasco Basin. With the exception of the 100-B/C Area, the 100 Areas lie on the northern limb of the Wahluke syncline. The 100-B/C Area lies over the axis of the syncline. The top of the basalt in the 100 Areas ranges in elevation from 46 m (150 ft) near the 100-H Area to -64 m (-210 ft) below sea level near the 100-B/C Area. The Ringold Formation and Hanford formation occur throughout this area; the Cold Creek unit may be present near the 100-B/C and 100-K Areas but is not readily distinguished from the Ringold and Hanford sediments.

The Ringold Formation shows a marked west-to-east variation in the 100 Areas (Lindsey 1992). The main channel of the ancestral Columbia River flowed along the front of Umtanum Ridge and through the 100-B/C and 100-K Areas, before turning south to flow along the front of Gable Mountain and/or through Gable Gap. This main channel deposited coarse-grained sand and gravel of the Ringold Formation (Units A, B, C, and E) in the western and southern parts of the Wahluke synclinal valley. Farther to the north and east, however, the Ringold formation sediments gradually become dominated by the lake and river overbank deposits and associated paleosols of the Ringold Formation lower mud unit, with the 100-H Area showing almost none of the gravel sediments (Lindsey 1995, 1996).

The Hanford formation in the 100 Areas consists primarily of coarse sand and gravel sediments, with local minor occurrences of the sand-dominated sediments. Several hydrogeologic reports provide information specific to each of the 100 Areas: 100-B/C Area – Lindberg (1993a), 100-D Area – Lindsey and Jaeger (1993), 100-F Area – Raidle (1994), 100-H Area – Lindsey and Jaeger (1993); 100-K Area – Lindberg (1993b), and 100-N Area – Hartman and Lindsey (1993).

4.3.5.2 Geology of the 200 Areas

The uppermost basalt flow beneath the 200 Areas is the Elephant Mountain Member of the Saddle Mountains Basalt. Between the 200 East Area and Gable Gap to the north, several basalt flows have been eroded to expose the Umatilla basalt. There is also a suspected window eroded through the Elephant Mountain Member near the northeast corner of the 200 East Area.

Unit A of the Ringold Formation overlies the basalt beneath much of the 200 Areas. The unit is thickest to the north and south of the 200 West Area. Generally, unit A is a conglomerate with clasts of basalt and other lithologies in a silty sand matrix interbedded with sand and silt layers. The sediments are well compacted and/or cemented in places.

The Ringold Formation lower mud unit has had a more complex history in the 200 Areas. The lower mud is eroded or was never deposited from beneath most of the 200 East Area. There is also a poorly defined channel cut through the lower mud unit in the northeastern corner of the 200 West Area. The lower mud unit consists primarily of lake bed silt and clay deposits, with at least one well-developed paleosol at the top of the sequence noted in the 200 West Area.

Unit E of the Member of Wooded Island is by far the thickest of the Ringold Formation units present beneath the 200 Areas. It consists of bimodal well-rounded gravel in a sand and silt matrix deposited by major rivers. Erosion by the Columbia River during Cold Creek time and cataclysmic floods through Gable Gap during Hanford formation time has removed unit E from most of the northeastern part of the 200 East Area.

The Ringold Formation Member of Taylor Flat consists of a sequence of fluvial sands and overbank deposits. The Member of Taylor Flat has been eroded from beneath all of the 200 East Area. Erosional remnants of the Member of Taylor Flat are found beneath parts of the 200 West Area (Lindsey 1995).

The laterally discontinuous Cold Creek unit overlies the tilted and eroded Ringold Formation in the vicinity of the 200 West Area. The lower Cold Creek unit in the 200 West Area is a highly weathered paleosurface that developed on top of the Ringold Formation. The lower Cold Creek unit consists of basaltic to quartzitic gravels, sands, silt, and clay that are cemented with one or more layers of calcium carbonate. Also included in the lower Cold Creek unit are basaltic gravel and calcic fine-grained sediments deposited by local side streams with sources in the nearby basalt ridges.

The upper Cold Creek unit consists of a distinctive silt-rich interval representing wind blown deposits in the 200 West Area. Locally, interbedded layers of fine sand and silt, more characteristic of stream deposits, are found with the wind blown deposits. The silt-dominated deposits can be correlated across most of the 200 West Area.

The Cold Creek unit in the 200 East Area may be represented by the mainstream "pre-Missoula gravels" (Reidel and Chamness 2007). The exact origin of the sedimentary deposits overlying the Columbia River Basalt Group and underlying the Hanford formation is uncertain and still open to interpretation. Wood et al. (2000) show two Cold Creek unit sediment types beneath some of the 200 East tank farms: fine-grained silt up to 10 m (33 ft) thick and sandy gravel to gravelly sand.

The Hanford formation is the main stratigraphic unit at the surface for both the 200 Areas. The Hanford formation is thickest in the vicinity of the 200 East Area, where it is over 100 m (330 ft) thick. Gravel-dominated sediments make up most of the Hanford formation in the northern part of the 200 East and 200 West Areas and were deposited by high energy water in or immediately adjacent to the main cataclysmic flood channels. The sand-dominated sediments are most common in the central to southern parts of the 200 Areas and were deposited adjacent to the main flood channels during the waning stages of flooding. Rhythmite deposits are primarily found south and west of the 200 Areas.

More detailed information about the geology of the 200 Areas can be found in Reidel and Chamness (2007) and DOE (2002b).

4.3.5.3 Geology of the 300 Area

The 300 Area, located in the southeastern portion of the Hanford Site, lies above the gentle eastern extension of the Cold Creek syncline (Figure 4.3.2). Over most of the Hanford Site, the uppermost basalt flows belong to the Elephant Mountain Member, but near the 300 Area younger flows belonging to the Ice Harbor Member are present, causing a relatively high region in the top of the basalt surface (Schalla et al. 1988).

The Ringold Formation overlies the basalt in the 300 Area. The lower 17 meters (56 ft) of Ringold Formation is composed of the lower mud sequence and is laterally extensive in the area. This is overlain by about 10 meters (33 ft) of gravel that is correlated to Ringold Formation units B, C, and E of the Member of Wooded Island (Lindberg and Chou 2001). There is evidence of erosion and formation of one or more channels in the top of the Ringold Formation throughout the 300 Area. The eroded surface of the Ringold Formation is approximately 3 to 9 meters (10 to 30 ft) lower in these channels (Lindberg and Chou 2001).

The Hanford formation in the vicinity of the 300 Area is about 15 meters (49 ft) thick and consists of both gravel-dominated and sand-dominated sediment. Locally, the gravel-dominated sediment can be divided into pebble to cobble gravel and boulder gravel. The pebble to cobble gravel is the most abundant Hanford formation sediment type beneath the 300 Area (Lindberg and Chou 2001).

4.3.6 Soils

Hajek (1966) describes 15 different soil types on the Hanford Site, varying from sand to silty and sandy loam (Figure 4.3.8). The soil classifications given in Hajek (1966) have not been updated to reflect current reinterpretations of soil classifications. Until soils on the Hanford Site are resurveyed, the descriptions presented in Hajek (1966) will continue to be used.

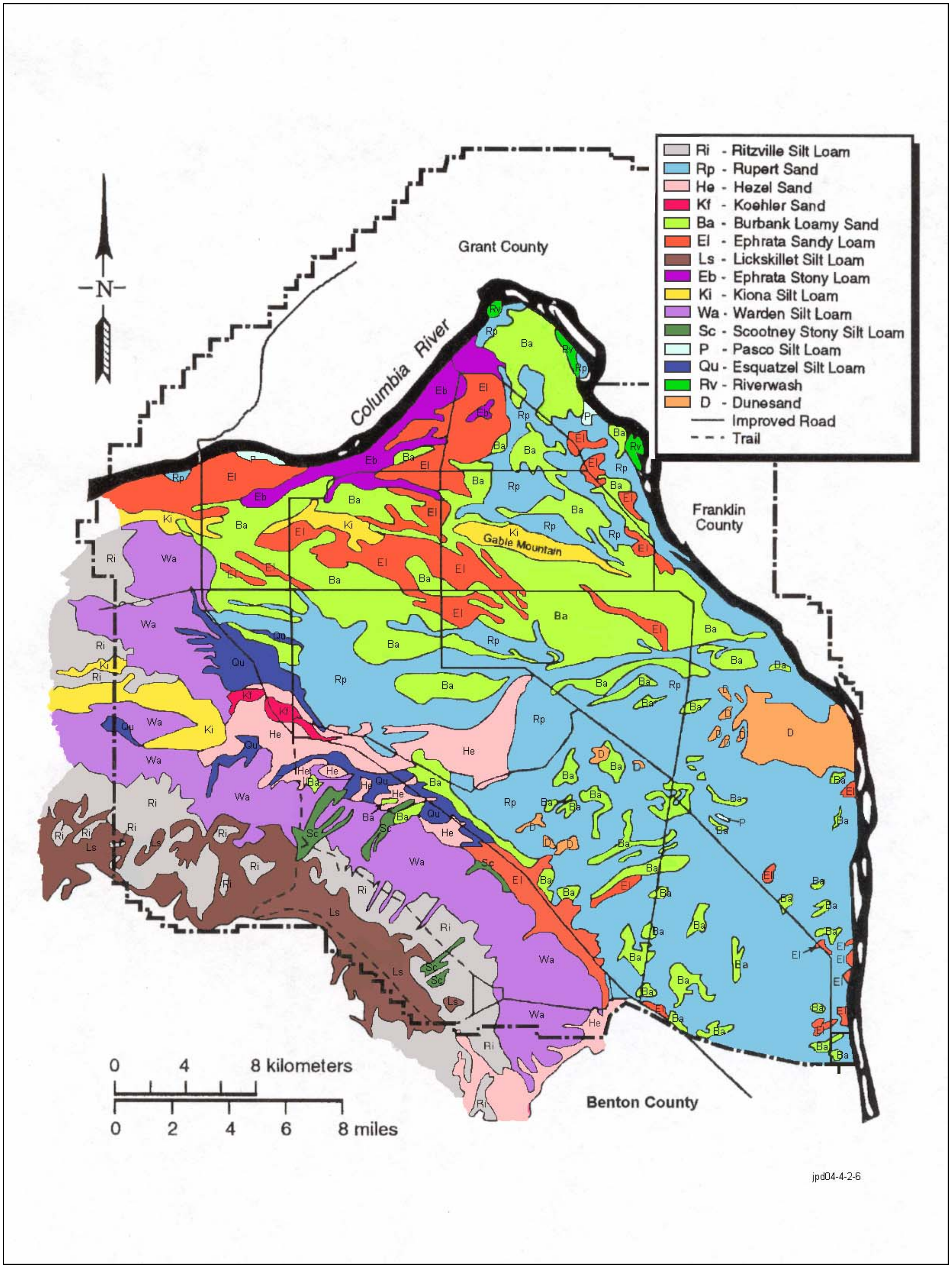

Figure 4.3.8. Soil Map for the Hanford Site (modified from Hajek 1966)

Soil types found on the Hanford Site include the following:

Ritzville Silt Loam. Ritzville silt loam, a dark-colored silt loam soil, is found midway up the slopes of the Rattlesnake Hills. It was formed under bunch grass from silty wind-laid deposits mixed with small amounts of volcanic ash. Characteristically greater than 150 cm (60 in.) deep, Ritzville silt loam may be separated by bedrock that occurs between 75 and 150 cm (30 and 60 in.).

Rupert Sand. Rupert sand, brown-to grayish-brown coarse sand grading to dark grayish-brown at a depth of 90 cm (35 in.), is one of the most extensive soil types on the Hanford Site. Rupert sand developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits that were mantled by wind-blown sand and formed hummocky terraces and dune-like ridges.

Hezel Sand. Hezel sand, similar to Rupert sands, is laminated grayish-brown strongly calcareous silt loam subsoil usually encountered within 100 cm (39 in.) of the surface. When found as surface soil it is very dark brown. Hezel sand was formed in wind-blown sands that mantled lake-laid sediment.

Koehler Sand. Koehler sand is similar to other sandy soil found on the Hanford Site, differing in that it mantles a lime-silica cemented hardpan layer. It was developed in a wind-blown sand mantle, exhibits a very dark grayish-brown surface layer, and is somewhat darker than Rupert sand. Its calcareous subsoil is usually dark grayish-brown at about 45 cm (18 in.).

Burbank Loamy Sand. Burbank loamy sand is a dark-colored, coarse-textured soil underlain by gravel. Its surface soil is usually about 40 cm (16 in.) thick but may be as much as 75 cm (30 in.) thick. The gravel content of its subsoil ranges from 20 percent to 80 percent.

Ephrata Sandy Loam. Ephrata sandy loam is found on level topography on the Hanford Site. Its surface is darkly colored and its subsoil is dark grayish-brown medium-textured soil underlain by gravelly material that may continue for many feet.

Lickskillet Silt Loam. Lickskillet silt loam occupies the ridge slopes of Rattlesnake Hills and slopes greater than 765 m (2,509 ft) elevation. It is similar to Kiona silt loam except the surface soil is darker. Lickskillet silt loam is shallow over basalt bedrock and exhibits numerous basalt fragments throughout the profile.

Ephrata Stony Loam. Ephrata stony loam is similar to Ephrata sandy loam. It differs in that many large, hummocky ridges are made up of debris released from melting glaciers. Areas of Ephrata stony loam located between hummocks contain many boulders several feet in diameter.

Pasco Silt Loam. Pasco silt loam is poorly drained very dark grayish-brown soil formed in recent alluvial material. Its subsoil is variable, consisting of stratified layers. Only small areas of Pasco silt loam are found on the Hanford Site, located in low areas adjacent to the Columbia River.

Kiona Silt Loam. Kiona silt loam occupies steep slopes and ridges. Its surface soil is very dark grayish-brown, is about 10 cm (4 in.) thick, and has dark-brown subsoil containing basalt fragments 30 cm (12 in.) and larger in diameter. Many basalt fragments are found in its surface layer and basalt rock outcrops are often present. Kiona silt loam is a shallow stony soil normally occurring in association with Ritzville and Warden soil.

Warden Silt Loam. Warden silt loam is dark grayish-brown soil with a surface layer usually 23 cm (9 in.) thick. Its silt loam subsoil becomes strongly calcareous at about 50 cm (20 in.) and becomes lighter in color. Granitic boulders are found in many areas. Warden silt loam is usually greater than 150 cm (60 in.) deep.

Scootney Stony Silt Loam. Scootney stony silt loam developed along the north slope of the Rattlesnake Hills and is usually confined to floors of narrow draws or small fan-shaped areas where draws open onto plains. It is severely eroded with numerous basaltic boulders and fragments exposed and the surface soil is usually dark grayish-brown grading to grayish-brown within the subsoil.

Esquatzel Silt Loam. Esquatzel silt loam is a deep dark-brown soil formed in recent alluvium derived from loess and lake sediment. Its subsoil grades to dark grayish-brown in many areas, but the color and texture of the subsoil are variable because of the stratified nature of the alluvial deposits.

Riverwash. Riverwash is wet, periodically flooded areas of sand, gravel, and boulder deposits that make up overflowed islands in the Columbia River and adjacent land.

Dunesand. Dunesand is a miscellaneous land type that consists of hills or ridges of sand-sized particles drifted and piled up by wind. They are either actively shifted or so recently fixed or stabilized that no soil layers have developed.

4.3.7 Seismicity

The historic record of earthquakes in the Pacific Northwest dates from about 1840. The early part of this record is based on newspaper reports of human perception of shaking and structural damage as classified using the Modified Mercalli Intensity (MMI) scale; the early record is probably incomplete because the region was sparsely populated. The historical record appears to be complete since 1905 for MMI V and since 1890 for MMI VI (Rohay 1989). Seismograph networks did not start providing earthquake locations and magnitudes of earthquakes in the Pacific Northwest until about 1960. A comprehensive network of seismic stations that provides accurate locating information for most earthquakes of magnitude greater than 2.5 was installed in eastern Washington during 1969. DOE (1988) provides a summary of the seismicity of the Pacific Northwest, a detailed review of the seismicity in the Columbia Plateau region and the Hanford Site, and a description of the seismic networks used to collect the data.

Large earthquakes (magnitude M greater than or equal to 7) in the Pacific Northwest have occurred near Puget Sound, Washington, and near the Rocky Mountains in eastern Idaho and western Montana. Two large earthquakes occurred beneath Vancouver Island. The first occurred during 1918 and had a maximum MMI VII (estimated magnitude M 7.0). The second earthquake occurred in 1946 and had a maximum MMI VII (over a wider area) and magnitude M 7.3. The depth of these early, large earthquakes beneath Vancouver Island is uncertain. Another large earthquake occurred at a depth of 53 km (33 mi) near Olympia, Washington, in 1949; it had a maximum MMI VIII and a magnitude M equal 7.1. A smaller (M 6.5), deep (63 km [39 mi]) earthquake occurred during 1965 between Seattle and Tacoma. These events may all be related to deformation within the subducting Juan de Fuca Plate at depth beneath the Vancouver Island/Puget Sound region.

Two large events occurred on the eastern boundary of the Pacific Northwest in the Rocky Mountains. These were the 1959 Hebgen Lake earthquake in western Montana, which had a Richter magnitude of 7.5 and an MMI X, and the 1983 Borah Peak earthquake in eastern Idaho, which had a Richter magnitude of 7.3 and an MMI IX.

Closer to the Hanford Site, a significant, large earthquake of uncertain location occurred in north-central Washington in 1872. This event was estimated to have a maximum MMI ranging from VIII to IX and an estimated Richter magnitude of approximately 7.4. The distribution of intensities suggests a location within a broad region between Lake Chelan, Washington, and the British Columbia border. Evidence of landslides near Lake Chelan suggests a location near there. A recent study indicates that the maximum MMI for this event was VIII and its magnitude was 6.8, with a location at the south end of Lake Chelan (Bakun et al. 2002).

On February 28, 2001, there was a moderate (M less than 7), deep earthquake near Olympia in Puget Sound called the Nisqually earthquake. This earthquake occurred at a depth of 52 km (32 mi) and had a magnitude of 6.8; reported ground-shaking effects reached MMI VIII. This event is similar to those in 1949 and 1965 described above. The Nisqually earthquake was recorded by a network of strong motion accelerographs at the Hanford Site. Peak horizontal accelerations measured from 0.0016 to 0.0055g (1g is the acceleration of gravity). These levels of ground shaking are considerably less than design and evaluation values (PNNL Seismic Monitoring Team 2001).

The seismicity of the Columbia Plateau, as determined by the rate of earthquakes per area and the historical magnitude of these events, is relatively low compared with other regions of the Pacific Northwest, the Puget Sound, and western Montana/eastern Idaho. The largest known earthquake in the Columbia Plateau occurred in 1936 near Milton-Freewater, Oregon. This earthquake had a Richter magnitude of 5.75 and a maximum MMI of VII, and it was followed by a number of aftershocks indicating a northeast-trending fault plane. Bakun et al. (2002) concluded that the magnitude of this earthquake was a lower value of 5.35.

Other earthquakes with Richter magnitudes greater than or equal to 5 and/or MMIs of VI occurred along the boundaries of the Columbia Plateau in a cluster near Lake Chelan in 1872 and extended into the northern Cascade Range, northern Idaho and Washington, and along the boundary between the western Columbia Plateau and the Cascade Range. Three MMI VI earthquakes have occurred within the Columbia Plateau, including one in the Milton-Freewater, Oregon, region in 1921; one near Yakima, Washington, in 1892; and one near Umatilla, Oregon, in 1893 (Figure 4.3-9). In the central portion of the Columbia Plateau, the largest earthquakes near the Hanford Site are two that occurred during 1918 and 1973. These two events were magnitude 4.4 and intensity V and were located north of the Hanford Site near Othello.

Earthquakes often occur in spatial and temporal clusters in the central Columbia Plateau and are termed “earthquake swarms.” The region north and east of the Hanford Site is a region of concentrated earthquake swarm activity, but earthquake swarms have also occurred in several locations within the Hanford Site. The frequency of earthquakes in a swarm tends to gradually increase and decay with no one outstanding large event within the sequence. Roughly 90 percent of the earthquakes in swarms have Richter magnitudes of 2 or less. These earthquake swarms are

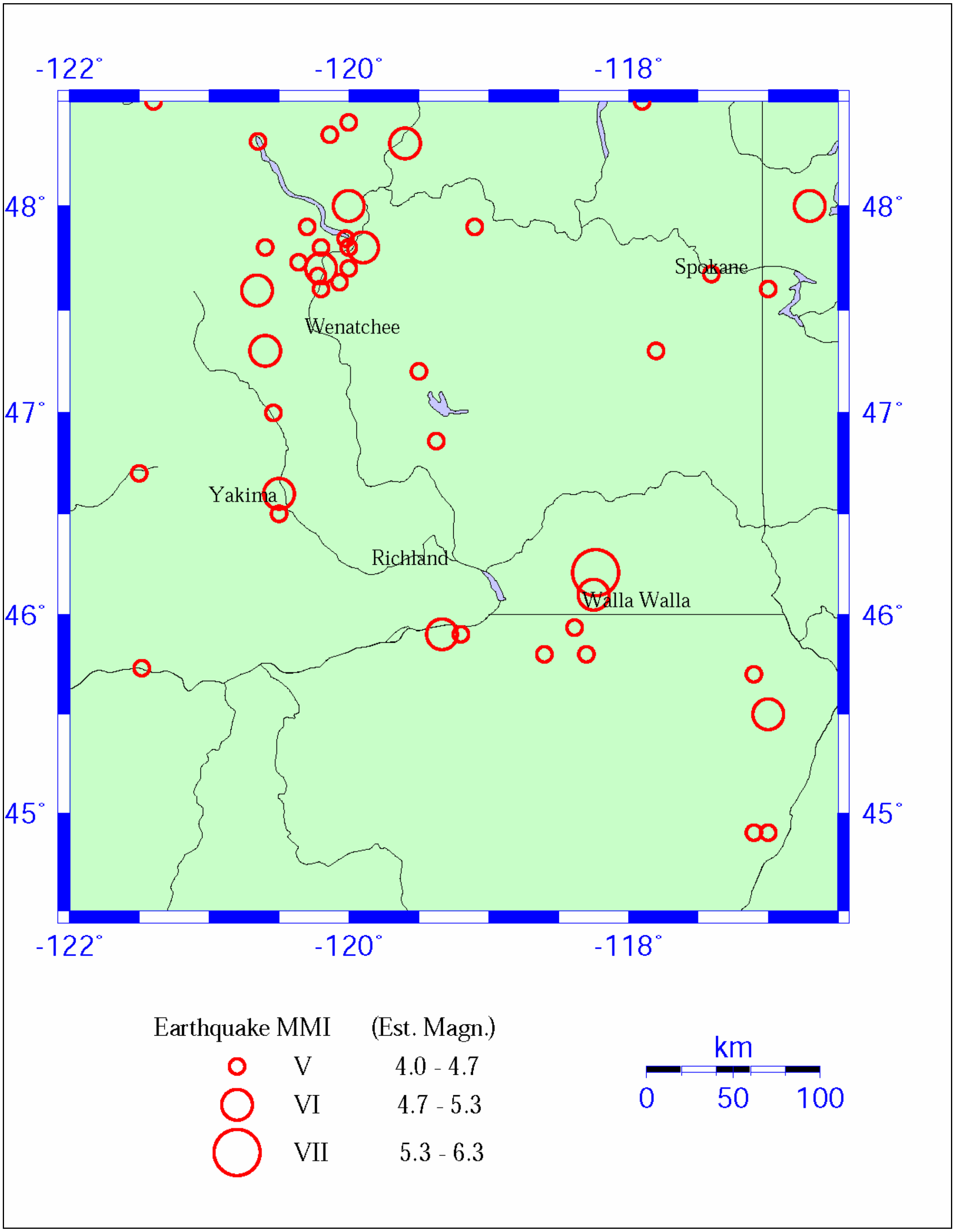

Figure 4.3-9. Historical Earthquake Activity of the Columbia Basin, Washington, and Surrounding Areas. All earthquakes between 1890 and 1970 with a Modified Mercalli Intensity (MMI) V or larger and/or a magnitude 4 or larger are shown (Rohay 1989).

generally shallow; 75 percent of the events are at depths less than 4 km (2.5 mi). However, several recent swarm sequences have occurred at greater depths (PNNL Seismic Monitoring Team 2003). Each earthquake swarm typically lasts several weeks to months, consists of several to 100 or more earthquakes, and is clustered in an area 5 to 10 km (3 to 6 mi) in lateral dimension. Often, the longest dimension of the swarm area is in an east-west direction. However, detailed locations of swarm earthquakes indicate that the events occur on fault planes of variable orientation and not on a single throughgoing fault plane.

Earthquakes in the central Columbia Plateau also occur to depths of about 30 km (18.6 mi). These deeper earthquakes are less clustered and occur more often as isolated events. Based on seismic refraction surveys in the region, the shallow earthquake swarms occur in the Columbia River basalts and the deeper earthquakes occur in crustal layers below the basalts.

The spatial pattern of seismicity in the central Columbia Plateau suggests an association of the shallow swarm activity with the east-west oriented Saddle Mountain anticline. However, this association is complex, and the earthquakes do not delineate a throughgoing fault plane that would be consistent with the faulting observed on this structure.

Earthquake focal mechanisms in the central Columbia Plateau generally indicate reverse faulting on east-west planes, consistent with a north-south-directed maximum compressive stress and with the formation of the east-west oriented anticlinal folds of the Yakima Fold Belt (Rohay 1987, 2003). However, earthquake focal mechanisms indicate faulting on a variety of fault plane orientations.

Earthquake focal mechanisms along the western margin of the Columbia Plateau also indicate north-south compression, but here the minimum compressive stress is oriented east to west, resulting in strike-slip faulting (Rohay 1987). Geologic studies indicate an increased component of strike-slip faulting in the western portion of the Yakima Fold Belt. Earthquake focal mechanisms in the Milton-Freewater region to the southeast indicate a different stress field, one with maximum compression directed east-west instead of north-south.

Estimates for earthquake potential of structures and zones in the central Columbia Plateau have been developed during the licensing of nuclear power plants at the Hanford Site. In reviewing the operating license application for the Washington Public Power Supply System Washington Nuclear Plant (WNP)-2 (now Energy Northwest Columbia Generating Station), the U.S. Nuclear Regulatory Commission (NRC) concluded that four earthquake sources should be considered for seismic design: the Rattlesnake-Wallula alignment, Gable Mountain, a floating earthquake in the tectonic province, and a swarm area (NRC 1982).

For the Rattlesnake-Wallula alignment, which passes along the southwest boundary of the Hanford Site, the NRC estimated a maximum Richter magnitude of 6.5; for Gable Mountain, an east-west structure that passes through the northern portion of the Hanford Site, a maximum Richter magnitude of 5.0 was estimated. These estimates were based on the inferred sense of slip, the fault length, and/or the fault area. The floating earthquake for the tectonic province was developed from the largest event located in the Columbia Plateau, the Richter magnitude 5.75 Milton-Freewater earthquake. The maximum swarm earthquake for the Columbia Generating Station seismic design was a Richter magnitude 4.0 event based on the maximum swarm earthquake in 1973 (Figure 4.3-10). (The NRC concluded that the actual magnitude of this event was smaller than previously estimated.)

Probabilistic seismic hazard analyses have been used to determine the seismic ground motions expected from multiple earthquake sources, and these are used to design or evaluate facilities on the Hanford Site. A Hanford Site-specific hazard analysis conducted by Geomatrix (1996) estimated that 0.10 g horizontal acceleration would be experienced on average every 500 years (or with a 10 percent chance every 50 years). This study also estimated that 0.2 g would be experienced on average every 2,500 years (or with a 2 percent chance in 50 years). These estimates are in approximate agreement with the results of national seismic hazard maps produced by the U.S. Geological Survey (USGS 1996, 2002).

Construction of the Hanford Tank Waste Treatment and Immobilization Plant (WTP), located in the 200 East Area of the Hanford Site and intended to facilitate tank waste cleanup, began in 2002. The seismic design was based on Geomatrix analyses and was approved in 1999 by the DOE Office of River Protection following revalidation reviews by British Nuclear Fuels, Ltd., and independent reviews by seismologists from the U.S. Army Corps of Engineers and Lawrence Livermore National Laboratory. In 2002, the Defense Nuclear Facilities Safety Board, a DOE oversight panel, raised questions concerning assumptions used in the Waste Treatment Plant seismic design basis.

In response, a site-specific ground response model for the WTP was conducted (Rohay and Reidel 2005). Results indicated increased ground motions for the design basis of this facility by up to 40 percent to include greater conservatism. The DOE developed the revised ground motion spectra to address concerns by the Defense Nuclear Facilities Safety Board about local soil characterization and attenuation (Corps 2006). Four deep boreholes were drilled, cored, and geophysically sampled during fiscal years 2005 through 2007. A final site response model will be issued in mid-2007.

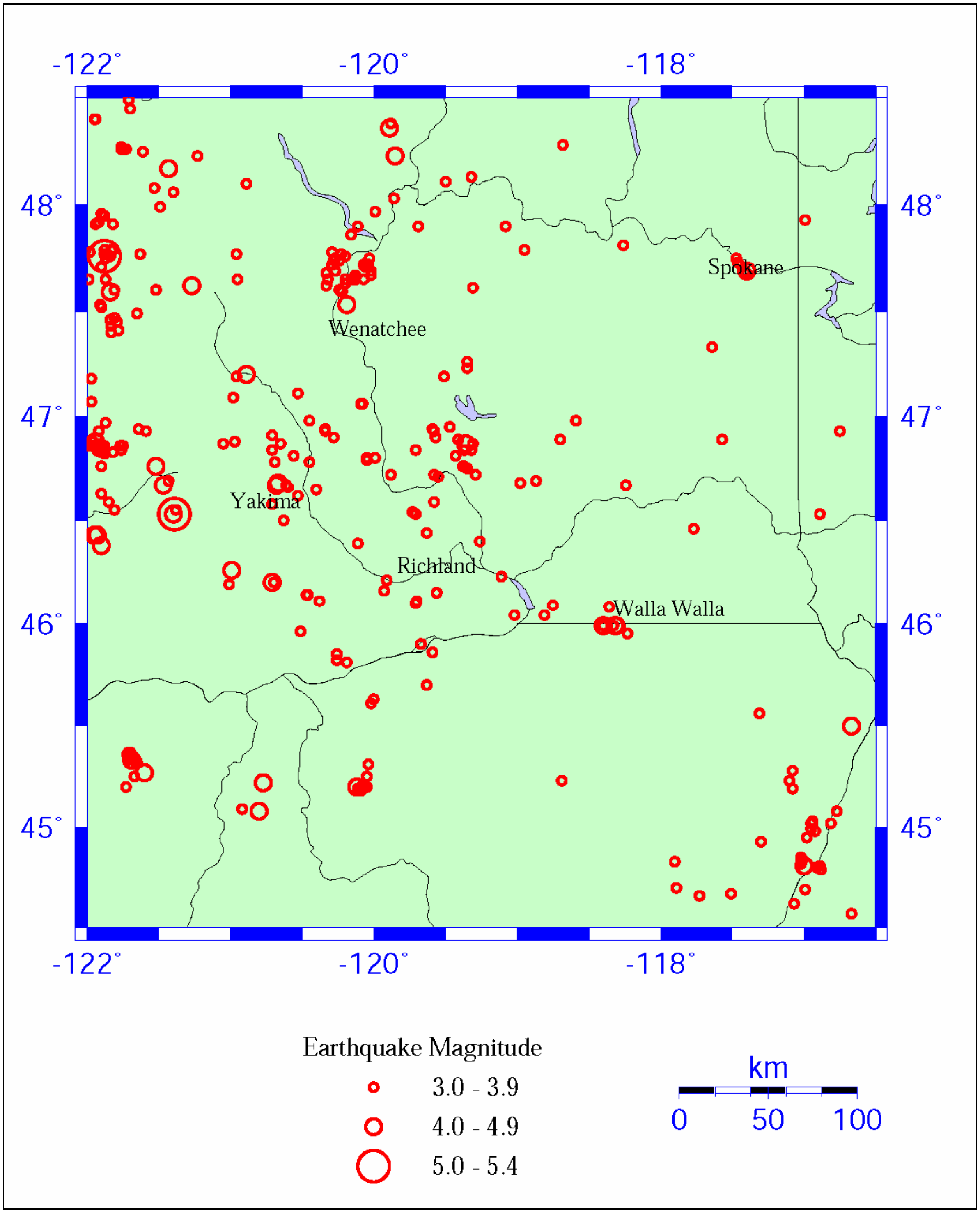

Figure 4.3-10. Earthquake Activity of the Columbia Basin, Washington, and Surrounding Areas as Measured by Seismographs. All earthquakes between 1970 and 2005 with Richter magnitudes of 3 or larger are shown (ANSS 2005).

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4.4 Hydrology

P. D. Thorne and G. V. Last

Characterization of hydrology at the Hanford Site includes surface water, the vadose zone, and groundwater. The vadose zone is the unsaturated or partially saturated region between the ground surface and the saturated zone. Water in the vadose zone is called soil moisture. Groundwater refers to water within the saturated zone. Permeable saturated units in the subsurface are called aquifers.

4.4.1 Surface Water

Surface water at Hanford includes the Columbia River, springs, and ponds. Intermittent surface streams, such as Cold Creek, may also contain water after large precipitation or snowmelt events. In addition, the Yakima River flows along a short section of the southern boundary of the Hanford Site (Figure 4.4-1) and there is surface water associated with irrigation east and north of the Site.

4.4.1.1 Columbia River

The Columbia River is the fourth largest river in the contiguous United States in terms of total flow and is the dominant surface-water body on the Hanford Site. The original selection of the Hanford Site for plutonium production and processing was based, in part, on the abundant water provided by the Columbia River. The existence of the Hanford Site has precluded development of this section of the river for hydroelectric production and barge transportation.

Originating in the Canadian Rockies of southeastern British Columbia, Canada, the Columbia River drains a total area of approximately 680,000 km^2 (262,480 mi^2) en route to the Pacific Ocean. Most of the Columbia River is impounded by 11 dams within the United States: seven upstream and four downstream of the Hanford Site. Priest Rapids is the nearest upstream dam, and McNary is the nearest downstream dam. Lake Wallula, the impoundment created by McNary Dam, extends upstream past Richland, Washington, to the southern part of the Hanford Site. Except for the section between Bonneville Dam and the ocean, the only unimpounded stretch of the Columbia River in the United States is the Hanford Reach, which extends from Priest Rapids Dam downstream approximately 82 km (51 mi) to Lake Wallula, north of Richland. The Hanford Reach of the Columbia River was recently incorporated into the land area established as the Hanford Reach National Monument.

Flows through the Hanford Reach fluctuate significantly and are controlled primarily by releases from three upstream storage dams: Grand Coulee in the United States, and Mica and Keenleyside in Canada. Flows in the Hanford Reach are directly affected by releases from Priest Rapids Dam; however, Priest Rapids operates as a run-of-the-river dam rather than a storage dam. Flows are controlled for purposes of power generation and to promote salmon egg and embryo survival. [(a)]

(a) The Vernita Bar Agreement (signed in 1988 and expanded in 2004, by the U.S. DOE, federal and state agencies, Tribal governments, and public utility districts in Grant, Chelan, and Douglas counties) was created to prevent redds (salmon nests) from being left high and dry when river flows fluctuate to meet peak power demands.

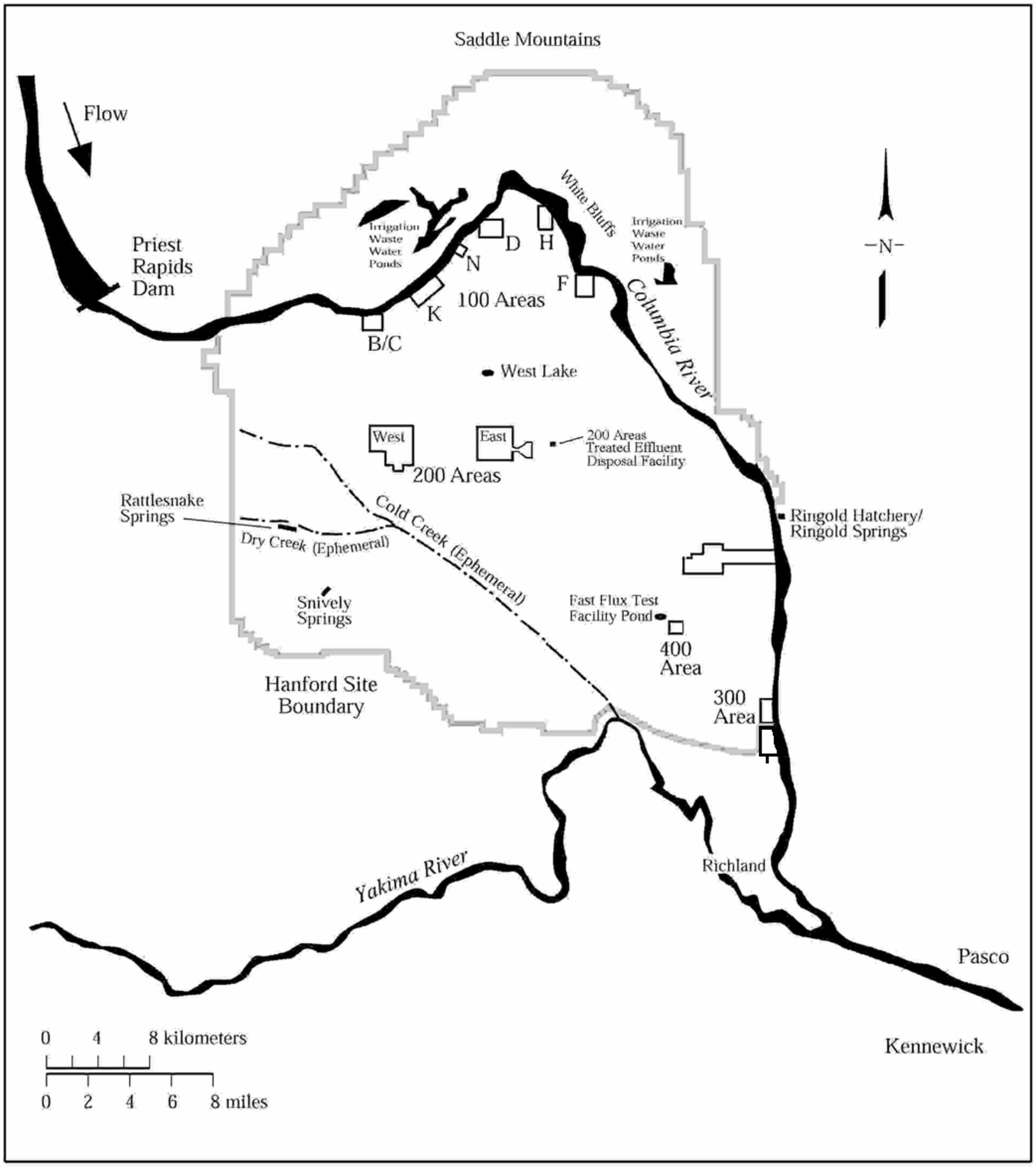

Figure 4.4-1. Surface Water Features on the Hanford Site, Washington, including Rivers, Ponds, Major Springs, and Ephemeral Streams

Columbia River flow rates near Priest Rapids during the 90-year period from 1917 to 2007 averaged about 3,330 m^3/s (117,550 ft^3/s). Daily average flows during this period ranged from 570 to 19,500 m^3/s (20,000 to 690,000 ft^3/s). The lowest and highest flows occurred before the construction of upstream dams. During the 10-year period from 1997 through 2006, the average flow rate was also about 3,300 m^3/s (116,500 ft^3/s). Daily average flows through the Hanford Reach for 1995 through April 2007 are plotted in Figure 4.4-2. Storage dams on tributaries of the Columbia River also affect flows.

During 1996 and 1997, exceptionally high spring runoff resulted from larger than normal snowpacks. The highest daily average flow rate during 1997 was nearly 11,750 m^3/s (415,000 ft^3/s) (USGS 2007). Peak daily average flow during 2006 was 7,731 m^3/s (273,000 ft^3/s) (Figure 4.4-3). Columbia River flows typically peak from April through June during spring runoff from snowmelt and are lowest from September through October. As a result of daily discharge fluctuations from upstream dams, the depth of the river varies over a short time period. River stage changes of up to 3 m (10 ft) during a 24-hr period may occur along the Hanford Reach (Poston et al. 2006). The width of the river varies from approximately 300 m (1,000 ft) to 1,000 m (3,300 ft) within the Hanford Reach. The width also varies with the flow rate, which causes repeated wetting and drying of an area along the shoreline.

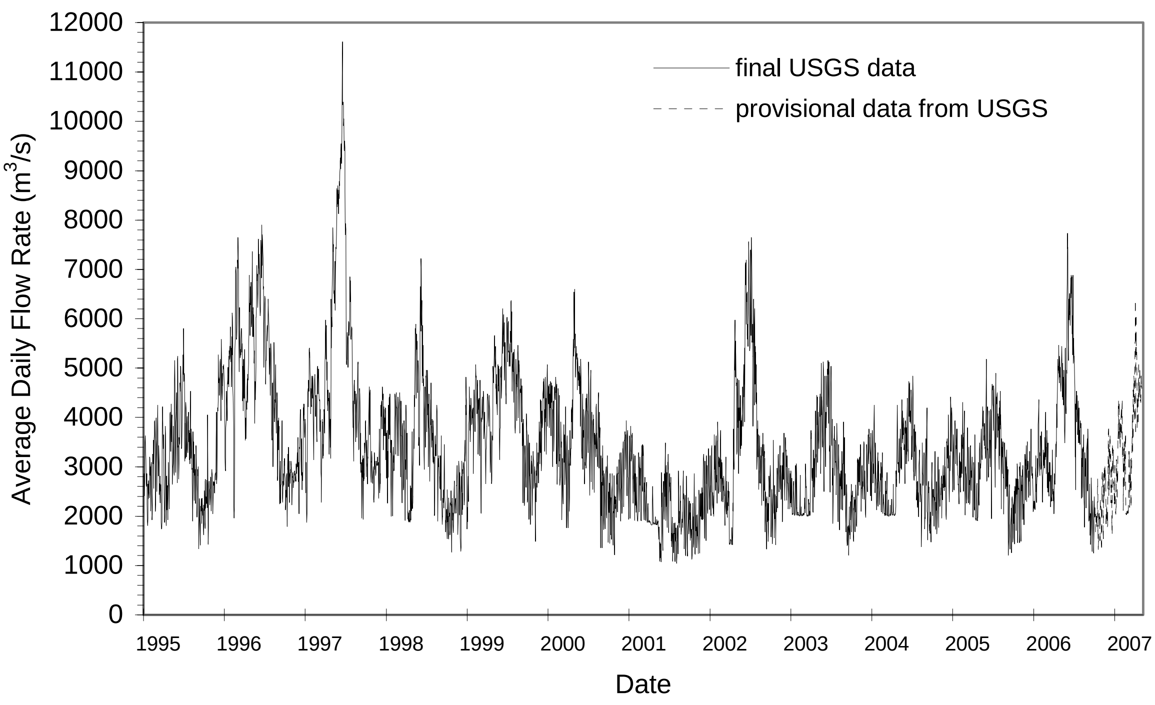

Figure 4.4-2. Average Daily Flow for the Hanford Reach, Columbia River, Washington, from January 1995 through April 2007 (data from USGS 2007, provisional data not yet reviewed and subject to change) (1 m^3/s = 35.3 ft^3/s)

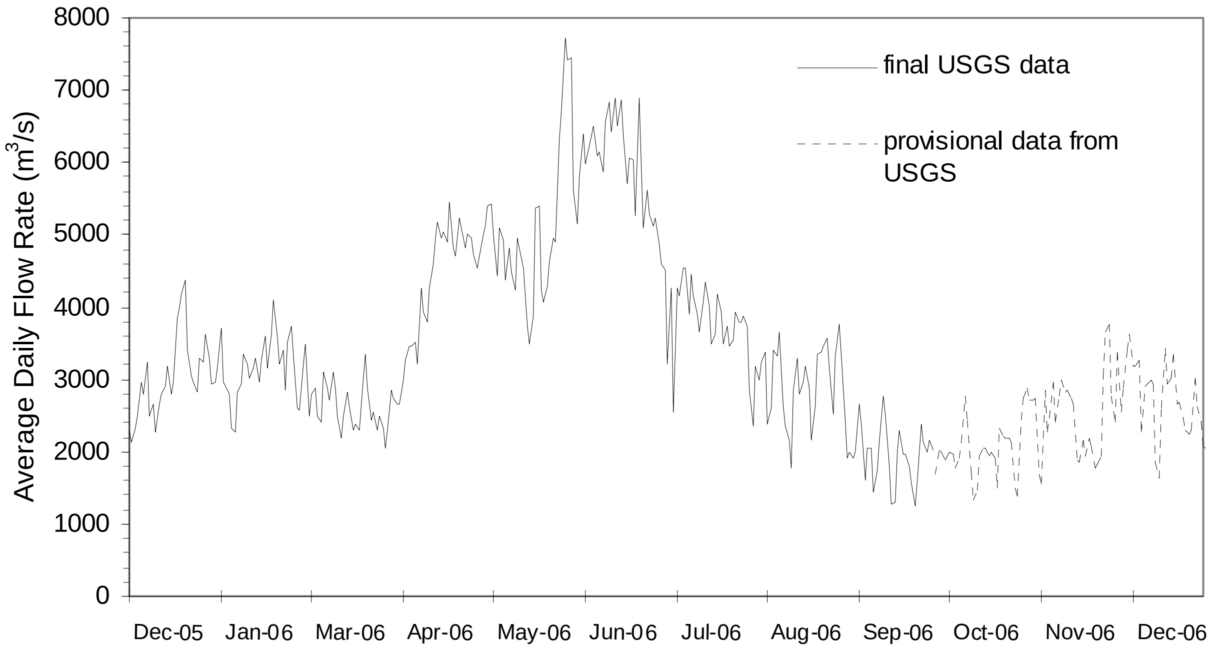

Figure 4.4-3. Average Daily Flow for the Columbia River during Calendar Year 2006 (data from USGS 2007, provisional data not yet reviewed and subject to change) (1 m^3/s = 35.3 ft^3/s)

The primary uses of the Columbia River include the production of hydroelectric power, irrigation of cropland in the Columbia Basin, and transportation of materials by barge. The Hanford Reach is the upstream limit of barge traffic on the mainstem Columbia River. Barges are used to transport reactor vessels from decommissioned nuclear submarines to Hanford for disposal. Several communities along the Columbia River rely on the river as their source of drinking water. The Columbia River is also used as a source of both drinking water and industrial water for several Hanford Site facilities (Poston et al. 2006). In addition, the Columbia River is used extensively for recreation, including fishing, hunting, boating, sailing, water-skiing, diving, and swimming.

4.4.1.2 Water Quality of the Columbia River

The water quality of the Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford Reach, has been designated as Class A, Excellent (WAC 173-201A) by Washington State (Poston et al. 2006). Class A waters are suitable for essentially all uses, including raw drinking water, recreation, and wildlife habitat. State and federal drinking water standards apply to the Columbia River (Section 6.2.2). In 2003, the Washington State Department of Ecology revised the surface-water quality standards and submitted them to EPA for approval (WAC 173-201A). Under the submitted surface water quality standards, the Class A (Excellent) designated uses criteria were replaced with separate designations for aquatic life uses, recreational uses, water supply uses, and miscellaneous uses. For the Columbia River downstream from Grand Coulee Dam, the aquatic life designation is “salmon and trout spawning, noncore rearing, and migration,” which provides for the protection of spawning, noncore rearing, and migration of salmon and trout, and other associated aquatic life. The recreational uses designation for the Columbia River downstream from Grand Coulee Dam is “primary contact,” which provides for activities that may involve complete submersion by the participant. The entire Columbia River is designated for all water supply and miscellaneous uses by the state of Washington (Poston et al. 2006).

During 2005, Columbia River water samples were collected from fixed-location monitoring stations at Priest Rapids Dam and Richland, Washington, and from cross-river transects and near-shore locations near the Vernita Bridge, 100-N Area, 100-F Area, Hanford townsite, 300 Area, and the city of Richland, Washington. Samples from Priest Rapids Dam and the Vernita Bridge, upstream from Hanford Site facilities, were collected to provide background data from locations unaffected by Site operations. Samples were collected from all other locations to identify any increase in contaminant concentrations attributable to Hanford Site operations, including a municipal drinking water supply and points of withdrawal for irrigation water downstream of the Hanford Site. In addition to water quality monitoring for potential Hanford contaminants conducted by the Pacific Northwest National Laboratory (PNNL), water quality monitoring for basic parameters (e.g., pH, dissolved oxygen, turbidity) was performed by the U.S. Geological Survey for PNNL. Samples were collected three times per year along Columbia River transects at the Vernita Bridge and Richland. Sample locations are shown in Figure 4.4-4.

Radionuclide concentrations monitored in Columbia River water were low throughout 2005. Tritium, strontium-90, iodine-129, uranium-234, uranium-238, plutonium-239/240, and naturally occurring beryllium-7 and potassium-40 were consistently measured in river water at levels greater than their reported minimum detectable concentrations. The concentrations of all other radionuclides were typically below the minimum detectable concentrations. Tritium, strontium-90, iodine-129, and plutonium-239/240 exist in worldwide fallout from historical nuclear weapons testing as well as in effluent from Hanford Site facilities. Tritium and uranium occur naturally in the environment, in addition to being present in Hanford Site effluent.

Columbia River water sample data show a statistical increase in tritium, nitrate, uranium, and iodine-129 between samples taken at Vernita Bridge and at the Richland pump house (Poston et al. 2006). These constituents are known to be entering the river from contaminated groundwater beneath the Hanford Site (Section 4.4.3). Measurements of strontium-90 at the Richland pump house were not statistically higher than those at the Vernita Bridge even though strontium-90 is known to enter the river through groundwater inflow at 100-N Area. Transect measurements for tritium showed higher concentrations near the shoreline relative to mid-river for samples from the 100-N Area and the Richland pump house. The highest tritium concentration measured in water samples from cross-river transects during 2005 was 95 ± 9.5 pCi/L (3.5 ± 0.35 Bq/L), which was detected along the shoreline at the Richland pump house (Poston et al. 2006). The highest total uranium concentration (1.5 ± 0.23 pCi/L [0.056 ± 0.0085 Bq/L]) was measured for the Richland transect at the southern boundary of the 300 Area on the Benton County shoreline (Poston et al. 2006).

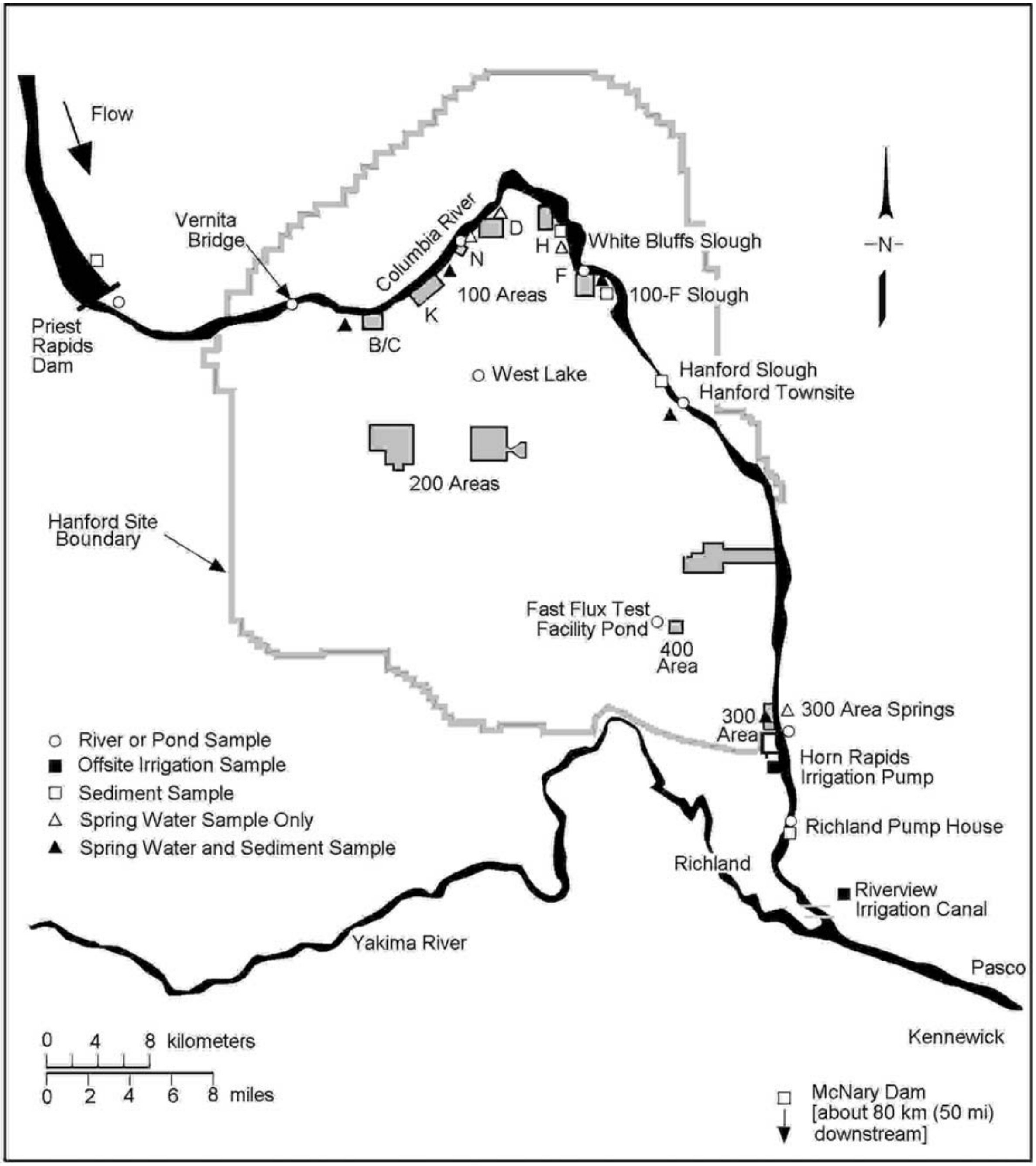

Figure 4.4-4. Surface Water and Sediment Monitoring Locations, Hanford Site, Washington (Poston et al. 2006)

Columbia River water quality data for 2005, collected by the U.S. Geological Survey (USGS), are comparable to those reported during the previous 5 years (Poston et al. 2006). Applicable standards for a Class A-designated surface-water body were met. During 2005, there was no indication of deterioration of water quality resulting from Hanford Site operations or from other sources of pollutants entering the river, which include irrigation return flows and groundwater seepage associated with irrigated agriculture. Groundwater contamination from nitrates has been documented in Franklin County and along the Hanford Reach (USGS 1995).

4.4.1.3 Yakima River

The Yakima River follows a portion of the southwestern boundary of the Hanford Site and has much lower flows than the Columbia River. The average flow, based on 72 years of daily flow records, is about 100 m^3/s (3,530 ft^3/s), with an average monthly maximum of 497 m^3/s (17,550 ft^3/s) and minimum of 4.6 m^3/s (165 ft^3/s) (USGS 2007). Exceptionally high flows were observed during 1996 and 1997; the highest average daily flow rate during 1996 was nearly 1,300 m^3/s (45,900 ft^3/s) (Figure 4.4-5). Average daily flow during 2000, a low water year, was 89.9 m^3/s (3,176 ft^3/s).

Average daily flow during 2006 was 100 m^3/s (3,530 ft^3/s) (USGS 2007). The Yakima River system drains surface runoff from approximately one-third of the Hanford Site. Groundwater is expected to flow from the Yakima River into the aquifer underlying the Site rather than from the aquifer into the river because, based on well water-level measurements, the elevation of the river surface is higher than the adjacent water table (Thorne et al. 1994). Therefore, groundwater contaminants from the Hanford Site do not reach the Yakima River.

4.4.1.4 Springs and Streams

Springs are found on the slopes of the Rattlesnake Hills along the western edge of the Hanford Site (DOE 1988). There is also an alkaline spring at the east end of Umtanum Ridge (Hall 1998). Rattlesnake and Snively springs form small surface streams. Water discharged from Rattlesnake Springs flows in Dry Creek for about 3 km (1.6 mi) before disappearing into the ground (Figure 4.4-1). Cold Creek and its tributary, Dry Creek, are ephemeral streams within the Yakima River drainage system in the southwestern portion of the Hanford Site. These streams drain areas to the west of the Hanford Site and cross the southwestern part of the Site toward the Yakima River. When surface flow occurs, it infiltrates rapidly and disappears into the surface sediments in the western part of the Site. The quality of water in these springs and streams varies depending on the source. However, they are up-gradient of Hanford waste sites and groundwater contamination plumes.

4.4.1.5 Columbia Riverbank Springs

Riverbank springs were documented along the Hanford Reach long before Hanford operations began (Jenkins 1922). During the early 1980s, researchers identified 115 springs along the Benton County shoreline of the Hanford Reach (McCormack and Carlile 1984). The presence of shoreline springs varies with river stage, which is controlled by upriver conditions and operations at upriver dams. Seepage occurs both below the river surface and on the exposed riverbank, particularly at low-river stage. Water flows into the aquifer (resulting in “bank storage”) as the river stage rises and then

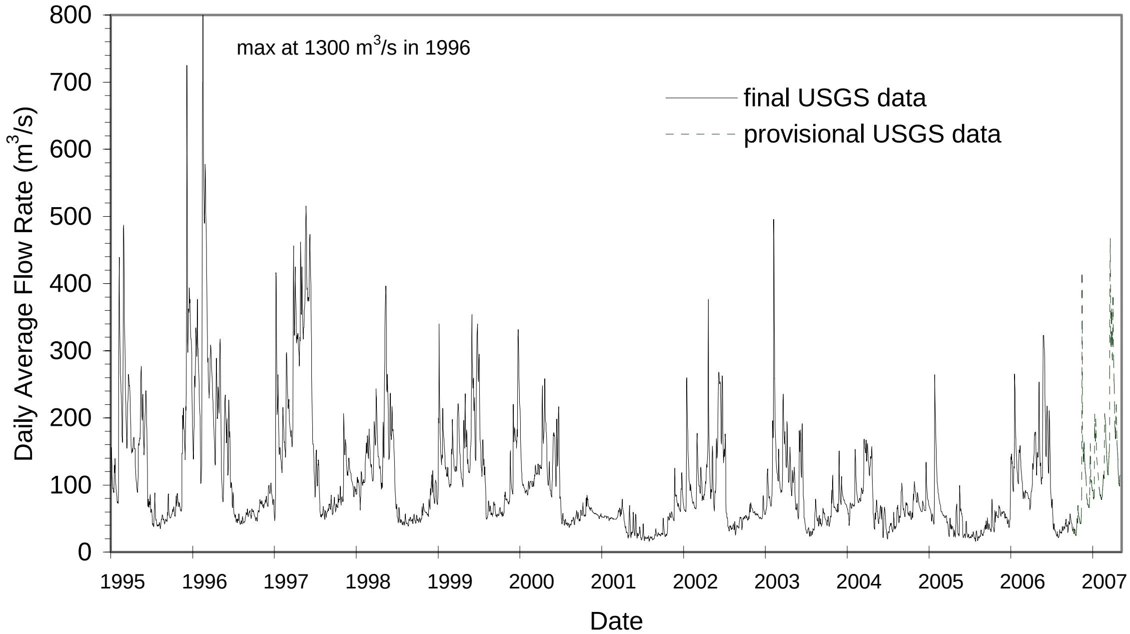

Figure 4.4-5. Average Daily Flow for the Yakima River, Washington, from 1995 through April 2007 (data from USGS 2007, provisional data not yet reviewed and subject to change) (1 m^3/s = 35.3 ft^3/s)

discharges from the aquifer in the form of shoreline springs as the river stage falls. Following an extended period of low river flow, groundwater discharge zones located above the water level of the river may cease to exist once the level of the aquifer comes into equilibrium with the level of the river. Thus, springs are most readily identified immediately following a decline in river stage. Bank storage of river water also affects the contaminant concentration of the springs. Spring water discharged immediately following a river stage decline generally consists of river water or a mixture of river water and groundwater. The percentage of groundwater in the spring water discharge increases over time following a drop in river stage.

In areas of contaminated groundwater, riverbank springs are also generally contaminated. However, concentrations in seeping water along the riverbank may be lower than groundwater because of the bank-storage phenomenon. Contamination has also been detected in near shore samples downstream from riverbank springs (Poston et al. 2006). Riverbank springs are monitored for radionuclides at each of the 100 Areas, the Hanford townsite, and the 300 Area (Figure 4.4-4). Contaminants originating from the Hanford Site occur in some of these springs (Poston et al. 2006). Detected radionuclides include strontium-90, technetium-99, iodine-129, uranium-234, -235, and -238, tritium, arsenic, chromium, chloride, fluoride, nitrate, and sulfate. Volatile organic compounds were below detection limits (Poston et al. 2006). Regulatory standards for groundwater are presented in Table 4.4-1.

Table 4.4-1. Regulatory Drinking Water Standards for Groundwater

Contaminant, Units	Drinking Water Standard	Contaminant, Units	Drinking Water Standard
arsenic (filtered), µg/L	10	gross beta, pCi/L	50
cadmium (filtered), µg/L	5	iodine-129, pCi/L	1
carbon tetrachloride, µg/L	5	nickel (filtered), µg/L	100
carbon-14, pCi/L	2,000	nitrate, mg/L	45
cesium-137, pCi/L	200	nitrite, mg/L	3.3
chloroform, µg/L	100	plutonium-239/240, pCi/L	not applicable
chromium (dissolved), µg/L	100	strontium-90, pCi/L	8
cis-1,2-dichloroethene, µg/L	70	technetium-99, pCi/L	900
cobalt-60, pCi/L	100	trichloroethene, µg/L	5
cyanide, µg/L	200	tritium, pCi/L	20,000
fluoride, mg/L	4	uranium, µg/L	30
gross alpha, pCi/L	15		

The highest strontium-90 concentration detected in riverbank springs during 2005 occurred at the 100-K Area (2.7 ± 0.41 pCi/L [0.10 ± 0.015 Bq/L]). This value was 34 percent of the ambient surface-water quality criterion of 8 pCi/L (0.30 Bq/L). Samples from a spring at the 100-N Area have historically had the highest strontium-90 concentrations. However, because of decreased groundwater elevations, no flow has been observed at this spring since 1997 (Poston et al. 2006). Tritium concentrations in riverbank springs varied widely with location. The highest tritium concentration detected in riverbank springs during 2005 was 39,000 ± 2,800 pCi/L [1,400 ± 100 Bq/L]) at the Hanford townsite (Poston et al. 2006). During 2000 to 2004 the highest iodine-129 concentration of 0.25 pCi/L (0.0093 Bq/L) was found in a Hanford townsite spring. Iodine-129 results were not yet available for 2005 (Poston et al. 2006).

Non-radioactive contaminants of Hanford-origin continued to be detected in water from shoreline springs entering the Columbia River along the Hanford Site during 2005. Metals and anions (chloride, fluoride, nitrate, and sulfate) were detected in spring water. Concentrations of volatile organic compounds were near or below their detection limits in all samples. Trichloroethene was detected (1.4 µg/L) in one sample from the 300 Area and was the only analyte detected at all shoreline spring sampling locations. Trichloroethene has been consistently detected at low concentrations in 300 Area shoreline spring water (Poston et al. 2006).

4.4.1.6 Runoff and Net Infiltration

Total estimated precipitation over the Pasco Basin is about 9 x10^8 m^3 (3.2 x 10^{10} ft^3) annually, calculated by multiplying the average annual precipitation averaged over the Pasco Basin by the 4,900 km^2 (1,900 mi^2) basin area (DOE 1988). Precipitation varies both spatially and temporally with higher amounts generally falling at higher elevations. Annual precipitation measured at the HMS has varied from 7.6 cm (3 in.) to 31.3 cm (12.3 in.) since 1945. Most precipitation occurs during the late autumn and winter, with more than half of the annual amount occurring from November through February. Mean annual runoff from the Pasco Basin is estimated at 3.1×10^7 m^3/yr (1.1×10^9 ft^3/yr), or approximately 3 percent of the total precipitation (DOE 1988). Most of the remaining precipitation is lost through evapotranspiration; however, a portion of the precipitation that infiltrates the soil is not lost to evaporation or transpiration and eventually recharges the groundwater flow system. The amount of recharge varies spatially based primarily on soil texture and vegetation (Gee et al. 1992; Fayer and Walters 1995). Recharge also varies temporally with the majority occurring in the winter and spring. There is some evidence that the most significant recharge events are associated with rapid melting of relatively large snowpacks, which may only occur a few times in a decade (Fayer and Szecsody 2004).

4.4.1.7 Flooding

Large Columbia River floods have occurred in the past (DOE 1987), but the likelihood of recurrence of large-scale flooding has been reduced by the construction of several flood control/water-storage dams upstream of the Hanford Site (Figure 4.4-6). Major floods on the Columbia River are typically the result of rapid melting of the winter snowpack over a wide area augmented by above-normal precipitation. The maximum historical flood on record occurred June 7, 1894, with a peak discharge at the Hanford Site of 21,000 m^3/s (742,000 ft^3/s). The floodplain associated with the 1894 flood was modeled based on topographic cross-sections of the river channel (ERDA 1976) (Figure 4.4-7). The largest recent flood took place during 1948 with an observed peak discharge of 20,000 m^3/s (700,000 ft^3/s) at the Hanford Site. The exceptionally high runoff during the spring of 1996 resulted in a maximum discharge of nearly 11,750 m^3/s (415,000 ft^3/s) (USGS 2007). There are no Federal Emergency Management Agency (FEMA) floodplain maps for the Hanford Reach of the Columbia River. FEMA only maps developing areas, and the Hanford Reach has been specifically excluded because the adjacent land is primarily under federal control.

Evaluation of flood potential is conducted in part through the concept of the probable maximum flood, which is determined from the upper limit of precipitation falling on a drainage area and other hydrologic factors such as antecedent moisture conditions, snowmelt, and tributary conditions that could result in maximum runoff. The probable maximum flood for the Columbia River downstream of Priest Rapids Dam has been calculated to be 40,000 m^3/s (1.4 million ft^3/s) and is greater than the 500-year flood (Figure 4.4-8). This flood would inundate parts of the 100 Areas adjacent to the Columbia River, but the central portion of the Hanford Site would remain unaffected (DOE 1986).

The U.S. Army Corps of Engineers (Corps) (1989) has derived the Standard Project Flood with both regulated and unregulated peak discharges given for the Columbia River downstream of Priest Rapids Dam. Frequency curves for both unregulated and regulated peak discharges are also given for the same portion of the Columbia River. The regulated Standard Project Flood for this part of the river is given as 15,200 m^3/s (54,000 ft^3/s) and the 100-year regulated flood as 12,400 m^3/s (440,000 ft^3/s) (DOE 1998b). Impacts to the Hanford Site are negligible and would be less than the probable maximum flood (Figure 4.4-8).

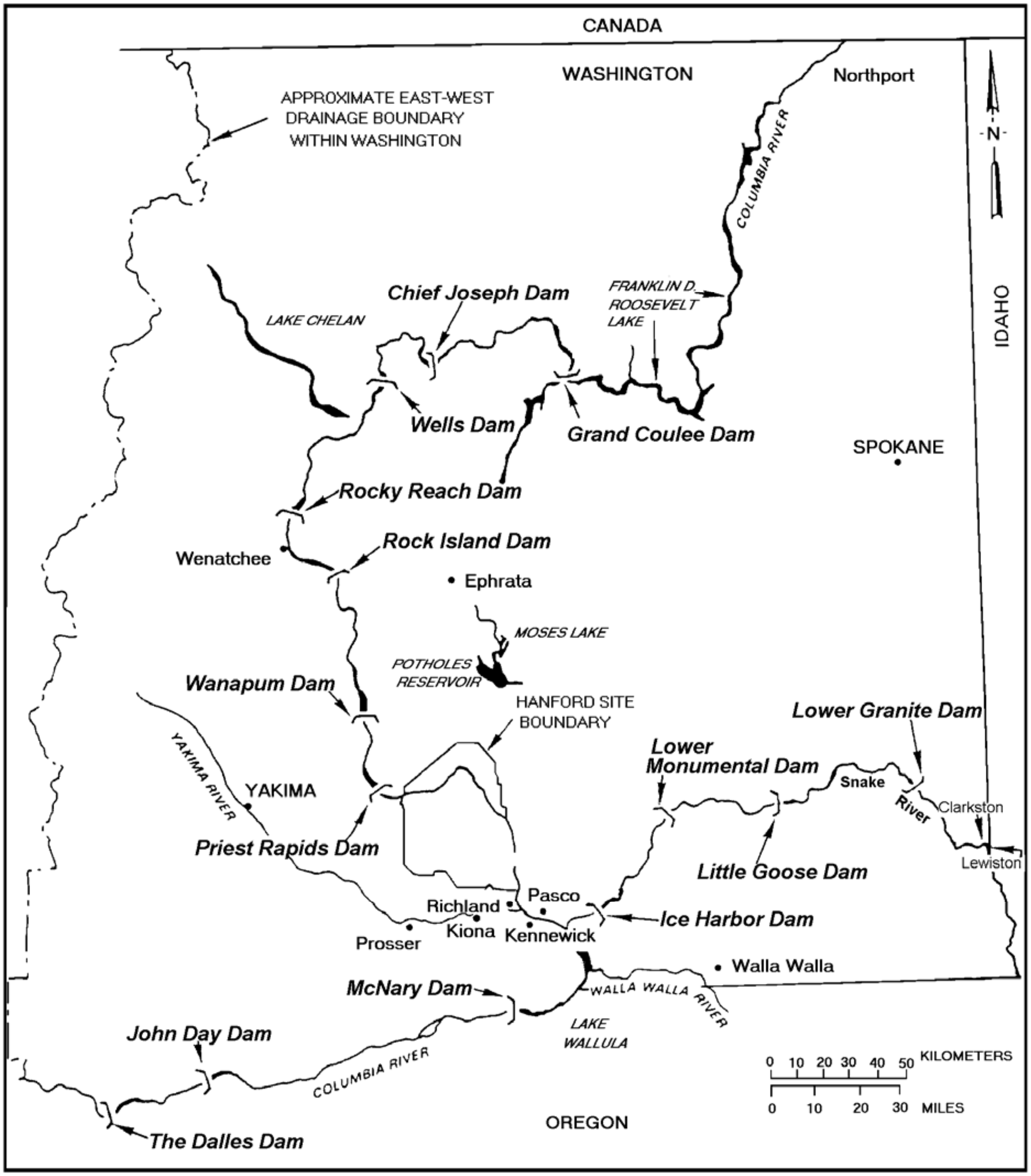

Figure 4.4-6. Locations of Principal Dams within the Columbia Plateau, Washington and Oregon (DOE 1988)

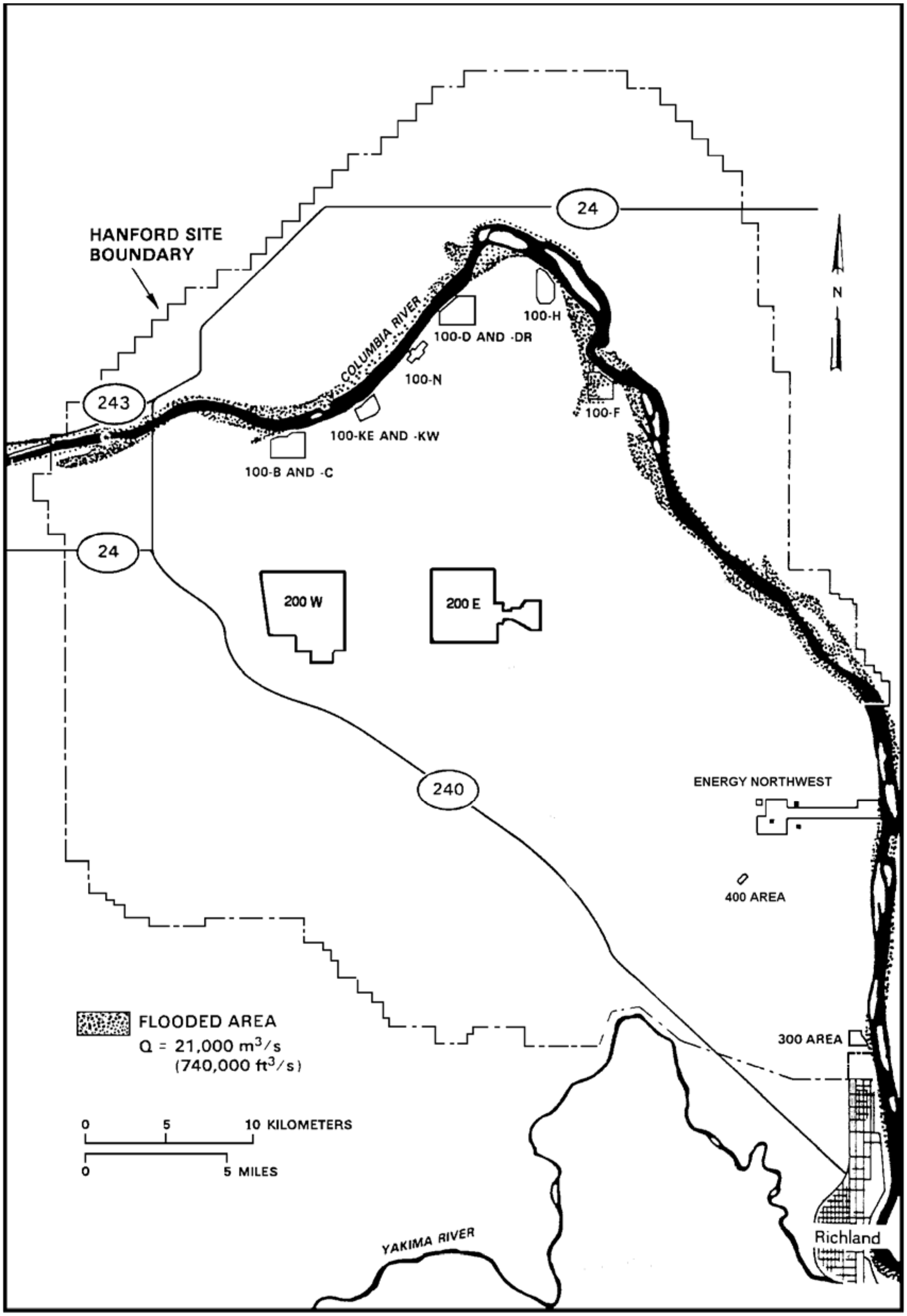

Figure 4.4-7. Flood Area on the Hanford Site, Washington, during the 1894 Flood Based on Modeled Topographic Cross Sections (DOE 1986)

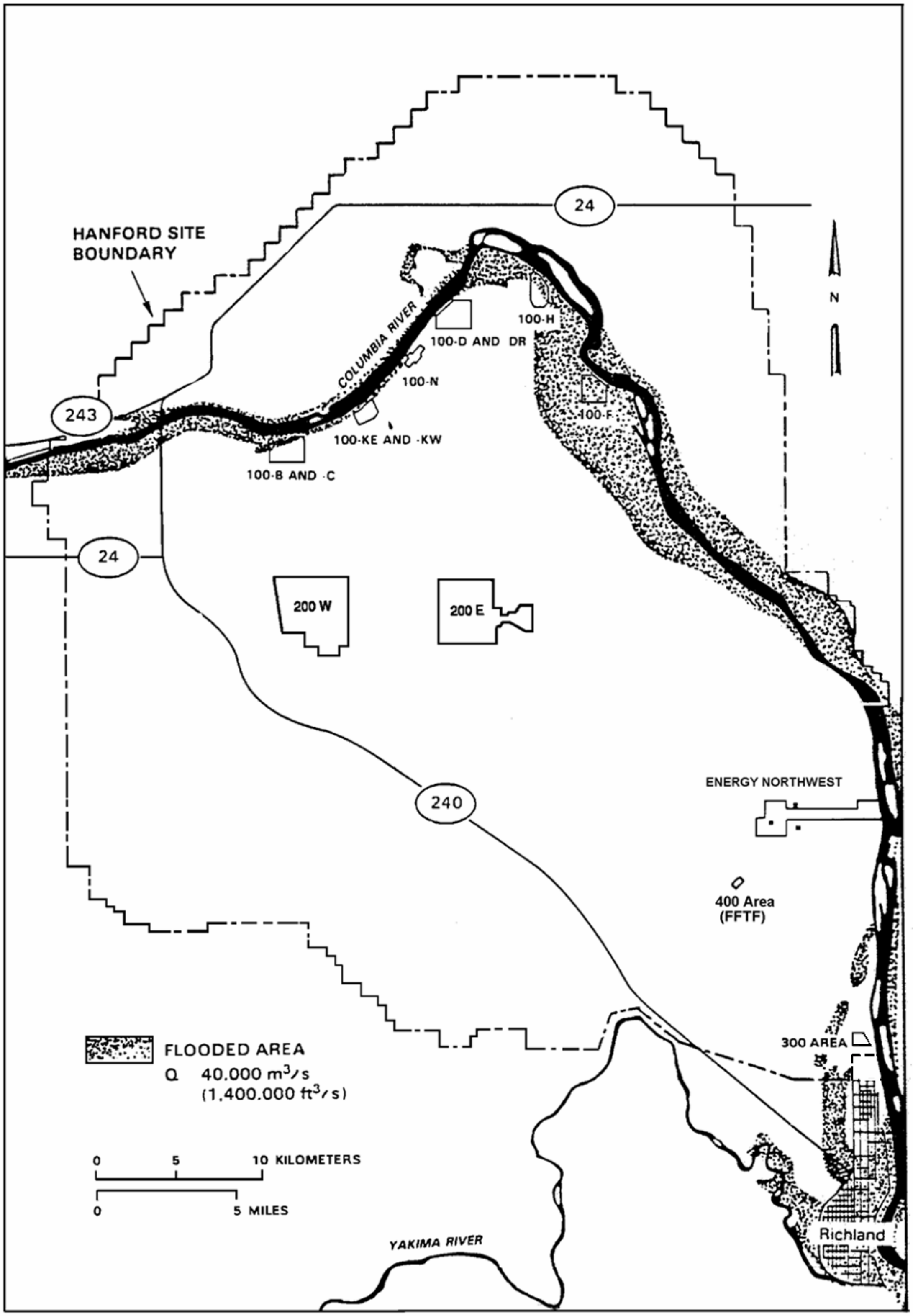

Figure 4.4-8. Flood Area for the Probable Maximum Flood on the Hanford Site, Washington, as Determined by the Upper Limit of Precipitation and Maximum Runoff (DOE 1986)

Potential dam failures on the Columbia River have been evaluated. Upstream failures could arise from a number of causes, with the magnitude of the resulting flood depending on the degree of breaching at the dam. The Corps evaluated a number of scenarios on the effects of failures of Grand Coulee Dam, assuming flow conditions of 11,000 m^3/s (400,000 ft^3/s). For emergency planning, they hypothesized that 25 and 50 percent breaches, the "instantaneous" disappearance of 25 or 50 percent of the center section of the dam, could result from the detonation of explosives. The discharge or floodwave resulting from such an instantaneous 50 percent breach at the outfall of the Grand Coulee Dam was determined to be 600,000 m^3/s (21 million ft^3/s). In addition to the areas inundated by the probable maximum flood (Figure 4.4-8), the remainder of the 100 Areas, the 300 Area, and nearly all of Richland would be flooded (DOE 1986; ERDA 1976). No determinations were made for failures of dams upstream, for associated failures downstream of Grand Coulee or for breaches greater than 50 percent of Grand Coulee Dam. The 50 percent scenario was believed to represent the largest realistically conceivable flow resulting from either a natural or human-induced breach (DOE 1986). It was also assumed that a scenario such as the 50 percent breach would occur only as the result of direct explosive detonation, not because of a natural event such as an earthquake, and that even a 50 percent breach under these conditions would indicate an emergency situation in which there might be other overriding major concerns.

The possibility of a landslide resulting in river blockage and flooding along the Columbia River has been examined for an area bordering the east side of the river upstream of the city of Richland. The possible landslide area considered was the 75-m- (250-ft-) high bluff generally known as White Bluffs. Calculations were made for an 8×10^5 m^3 (1×10^6 yd^3) landslide volume with a concurrent flood flow of 17,000 m^3/s (600,000 ft^3/s) (a 200-year flood), resulting in a floodwave crest elevation of 122 m (400 ft) above mean sea level. Areas inundated upstream of such a landslide event would be similar to those occurring during the probable maximum flood (DOE 1986).

There have been fewer than 20 major floods on the Yakima River since 1862 (DOE 1986). The most severe occurred during November 1906, December 1933, May 1948, and February 1996; discharge magnitudes at Kiona, Washington, were 1,870 m^3/s (66,000 ft^3/s), 1,900 m^3/s (67,000 ft^3/s), 1,050 m^3/s (37,000 ft^3/s), and 1,300 m^3/s (45,900 ft^3/s), respectively. The average flow of the Yakima River is 104 m^3/s (165 ft^3/s), and the average monthly maximum is 490 m^3/s (17,500 ft^3/s). The recurrence intervals for the 1933 and 1948 floods are estimated at 170 and 33 years, respectively. The development of irrigation reservoirs within the Yakima River Basin has considerably reduced the flood potential of the river. The southern border of the Hanford Site could be susceptible to a 100-year flood on the Yakima River (Figure 4.4-9).

During 1980, a flood risk analysis of Cold Creek was conducted as part of the characterization of a basaltic geologic repository for high-level radioactive waste. Such design work is usually done according to the criteria of Standard Project Flood or probable maximum flood, rather than the worst-case or 100-year flood scenario. Therefore, in lieu of 100- and 500-year floodplain studies, a probable maximum flood evaluation was performed based on a large rainfall or combined rainfall/snowmelt event in the Cold Creek and Dry Creek watershed (Skaggs and Walters 1981). The probable maximum flood discharge rate for the lower Cold Creek Valley was 2,265 m^3/s (80,000 ft^3/s),

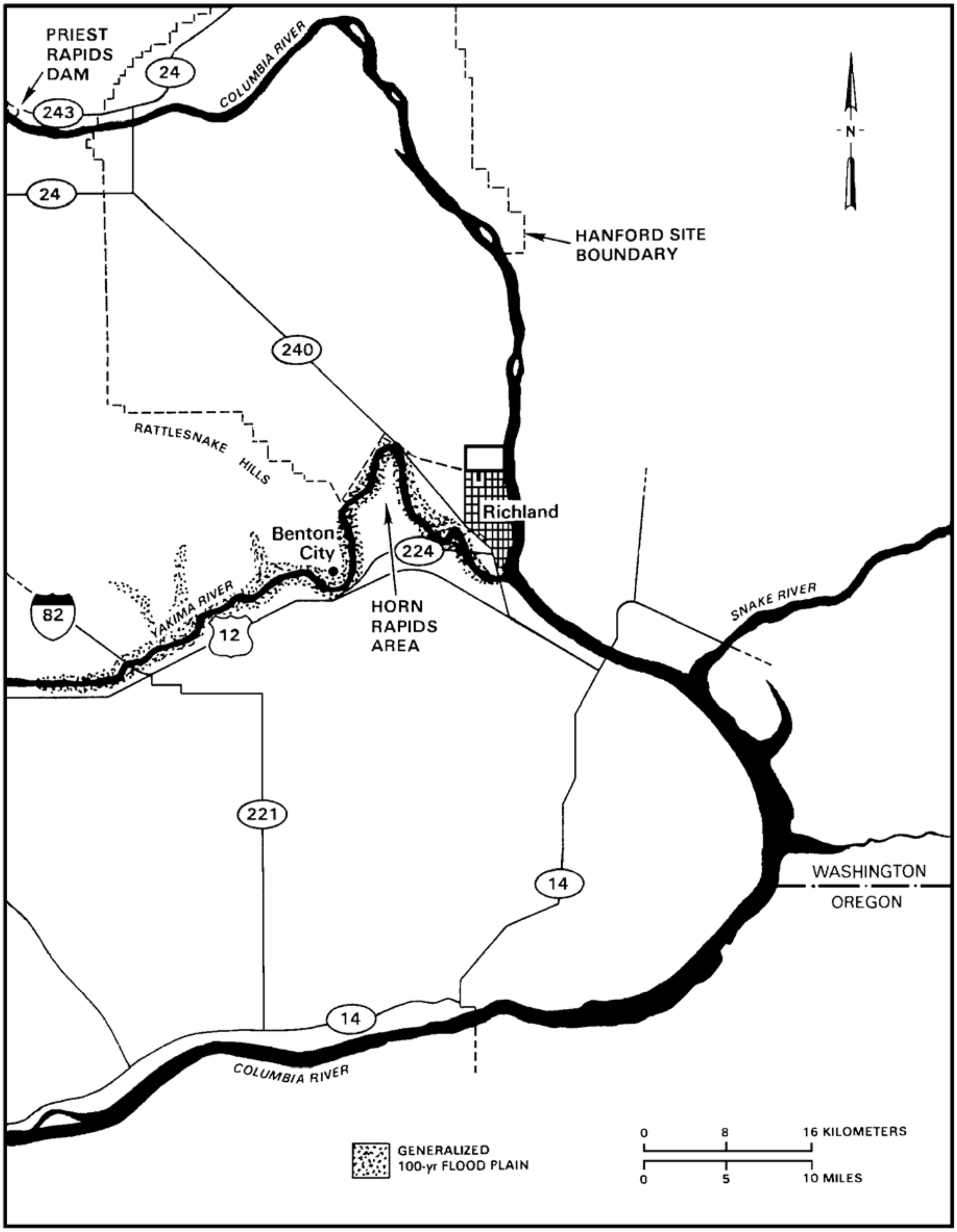

Figure 4.4-9. Flood Area from a 100-Year Flood of the Yakima River near the Hanford Site, Washington (DOE 1986)

compared to 564 m^3/s (19,900 ft^3/s) for the 100-year flood (Figure 4.4-10). Modeling indicated that State Route (SR) 240 along the Site's southwestern and western areas would be unusable.

4.4.1.8 Non-Riverine Surface Water

Active ponds on the Hanford Site include West Lake and the 200 Area Treated Effluent Disposal Facility (TEDF) disposal ponds (Figure 4.4-1). West Lake is north of the 200 East Area and is a natural feature recharged from groundwater (Gephart et al. 1976; Poston et al. 1991). West Lake has not received direct effluent discharges from Site facilities; rather, its existence is caused by the intersection of the elevated water table with the land surface in the topographically low area. Water levels of West Lake fluctuate with water table elevation, which is influenced by wastewater discharge in the 200 Areas. The water level and size of the lake has been decreasing over the past several years because of reduced wastewater discharge (Section 4.4.3.2). There is unsubstantiated information that sewage sludge may have been dumped in the vicinity of West Lake during the 1940s, and this has been cited as the reason for elevated dissolved solids and nitrate in the lake water (Emery and McShane 1978; Meinhardt and Frostenson 1979). However, it is possible that the concentration of salts resulted from evaporation of groundwater at the lake, which has no outlet. Total dissolved solids are approximately 15,000 mg/L and pH is greater than 9. Nitrate and ammonia concentrations of about 1.8 and 2.6 mg/L, respectively, have been reported, which are greater than freshwater lakes, but lower than other alkaline lakes in Washington such as Soap Lake and Lake Lenore. West Lake contains relatively high levels of uranium that are thought to be from natural sources concentrated by evaporation in the lake (Poston et al. 1991, 2006).

TEDF, located east of the 200 East Area, consists of two disposal ponds. These ponds are each 0.02 km^2 (0.008 mi^2) in size and receive industrial wastewater permitted in accordance with the Washington State Department of Ecology's State Waste Discharge Permit Program (WAC 173-216). The wastewater evaporates into the air or percolates into the ground from the disposal ponds.

There are several naturally occurring vernal ponds near Gable Mountain and Gable Butte (Hall 1998). These ponds appear to occur where a depression is present in a relatively shallow buried basalt surface. Water collects within the depression over the winter resulting in a shallow pond that dries during the summer months. The formation of these ponds in any particular year depends on the amount and temporal distribution of precipitation and snowmelt events. The vernal ponds range in size from about 6.1 m x 6.1 m to 45.73 m x 30.5 m (20 ft x 20 ft to 150 ft x 100 ft) and are found in three clusters. Approximately ten have been documented at the eastern end of Umtanum Ridge, seven were observed in the central part of Gable Butte, and three were found at the eastern end of Gable Mountain (Figure 4.0-1).

Other than rivers and springs, there are no naturally occurring bodies of surface water adjacent to the Hanford Site. There are wetlands caused by irrigation on the east and west sides of the Wahluke Slope, which lies north of the Columbia River and on the White Bluffs east of the Columbia River. Hatcheries and irrigation canals constitute the only other surface water in the Hanford Site vicinity. The Ringold Hatchery is located just south of the Hanford Site boundary on the east side of the Columbia River (Figure 4.4-1).

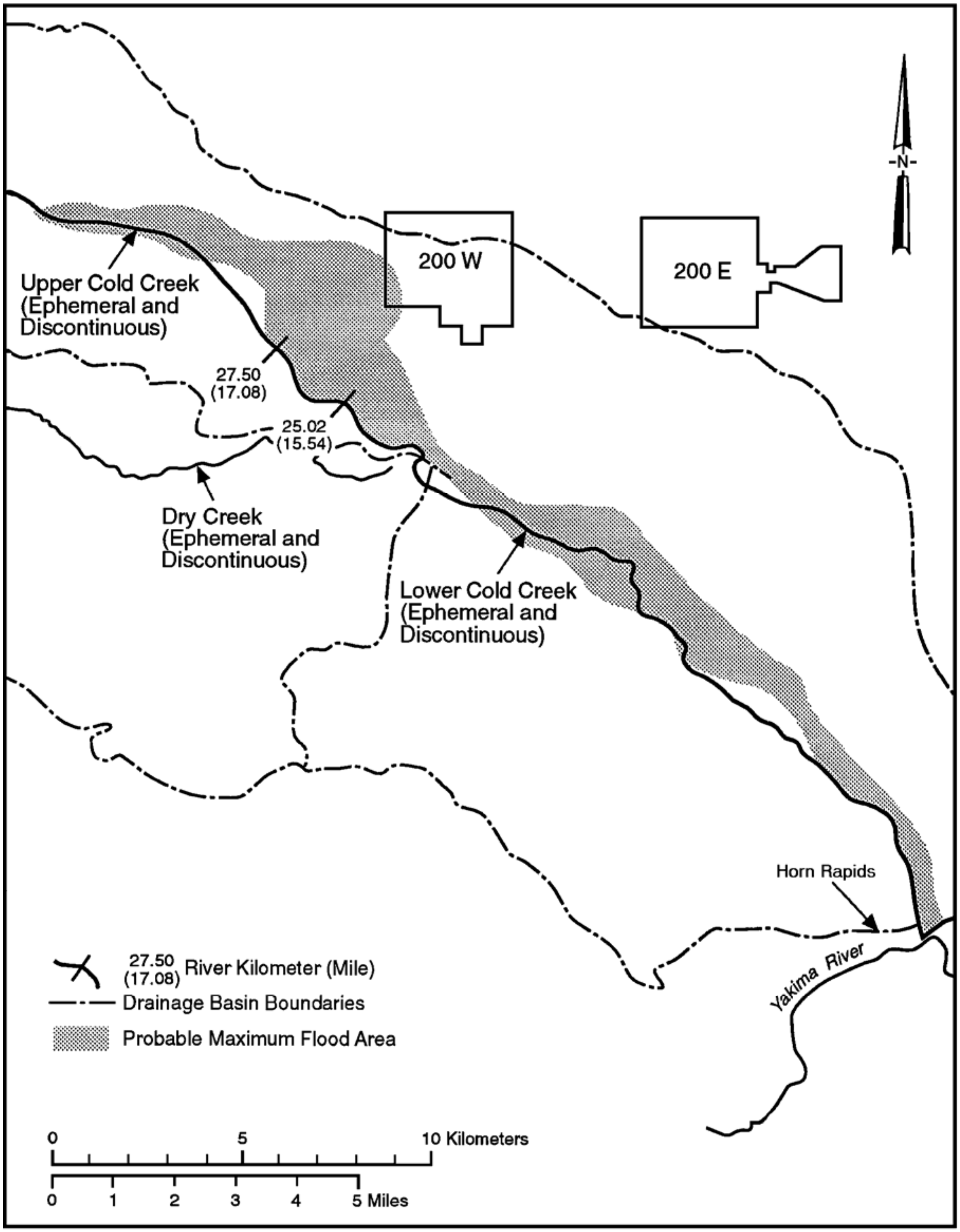

Figure 4.4-10. Extent of Probable Maximum Flood in Cold Creek Area, Hanford Site, Washington, delineated using the U.S. Army Corps of Engineers' HEC-2 Water Surface Profiles model (Skaggs and Walters 1981)

4.4.2 Hanford Site Vadose Zone

The vadose zone is that part of the geologic media which extends from the earth's surface to the water table. At the Hanford Site, the thickness of the vadose zone ranges from 0 m (0 ft) near the Columbia River to greater than 100 m (330 ft) beneath parts of the central plateau (Hartman 2000). Unconsolidated glacio-fluvial sands and gravels of the Hanford formation make up most of the vadose zone. In some areas, such as most of the 200 West Area and in some of the 100 Areas, the fluvial-lacustrine sediments of the Ringold Formation make up the lower part of the vadose zone. The Cold Creek unit also makes up part of the vadose zone. The integrated knowledge obtained from previous and on-going studies provides a conceptual understanding of the geologic, hydraulic, and geochemical environment and its controls on the distribution and movement of contaminants within the vadose zone (DOE 1999a; Last et al. 2004).

Moisture movement through the vadose zone is important because it is the driving force for migration of most contaminants to the groundwater. Radioactive and hazardous wastes in the soil column from liquid-waste disposals, unplanned leaks, solid waste burial, and underground tank storage are potential sources of continuing and future vadose zone and groundwater contamination. Contaminants may continue to move downward for long periods (tens to hundreds of years depending on recharge rates and the distribution coefficient of the contaminant) after termination of liquid waste disposal.

Except for the State Approved Land Disposal Site (SALDS), the 200 Area TEDF ponds (Figure 4.4-1), and septic drain fields, liquid discharges to the vadose zone ended during the mid-1990s. Currently, the major source of moisture to the vadose zone is precipitation. Infiltration and deep drainage of meteoric water in the vadose zone causes older pre-existing water to be displaced downward by newly infiltrated water. The amount of deep drainage (below the root zone) at any particular site is dependent on the total amount of water available at the time of the event, soil type, and the presence of vegetation. Usually, vegetation reduces the amount of deep drainage through the biological process of transpiration.

The vadose-zone stratigraphy influences the movement of liquid through the soil column. Where conditions are favorable, lateral spreading of liquid effluent and/or local perched water zones may develop. Lateral spreading can occur along any strata with contrasting conductivity. Perched water zones form where downward-moving moisture accumulates on top of less-permeable soil lenses or highly cemented horizons. Even in relatively uniform sediments, the influence of grain orientation is important and can give rise to anisotropic hydraulic properties, causing significant lateral movement of contaminant plumes (Ward et al. 2002a, b; Zhang et al. 2003). Lateral spreading can delay the arrival of contaminants at the water table but may cause mixing of the subsurface plume at one site with that of an adjacent site. Spreading may also require increasing the area of surface barriers to cover wider plumes.

Preferential flow may also occur along discontinuities, such as clastic dikes and fractures. Clastic dikes are a common geologic feature in the suprabasalt sediments at the Hanford Site. Their most important feature is their potential to either enhance or inhibit vertical and lateral movement of contaminants in the subsurface, depending on textural relationships (Fecht et al. 1999).

4.4.2.1 Vadose Zone Contamination

The Hanford Site has more than 800 past-practice liquid-disposal facilities. Radioactive liquid waste was discharged to the vadose zone through reverse (injection) wells, French drains, cribs, ponds, trenches, and ditches. From 1944 through the late 1980s, 1.5 to 1.7 billion m^3 (396 to 449 billion gal) of effluent were disposed to the soils (Gephart 1999). Most effluent was released in the 200 Areas. The major groundwater contaminant plumes emanating from the 200 Areas are those of tritium and nitrate. The major source for both was discharges from chemical processing of irradiated nuclear fuel rods.

Also present are technetium-99 and iodine-129 which, like tritium and nitrate, are mobile in both the vadose zone and groundwater. The major sources of technetium-99 and iodine-129 were discharges to liquid disposal facilities. Vadose zone sources for these contaminants remain beneath many past-practice disposal facilities. However, other than physical sampling and laboratory analysis, there are few direct ways to monitor tritium, nitrate, technetium-99, and iodine-129 in the vadose zone.

Liquid wastes generated during plutonium recovery processes at Z Plant in the 200 West Area contained carbon tetrachloride. These wastes were discharged to nearby subsurface liquid waste disposal facilities from 1955 to 1973 (Rohay et al. 1994; Swanson et al. 1999). Soil vapor extraction is being used to remove carbon tetrachloride from the vadose zone in the 200 West Area (Hartman et al. 2007).

Approximately 280 unplanned releases in the 200 Areas also contributed contaminants to the vadose zone (DOE 1997b). Many of these were from underground tanks and have contributed significant contamination to the vadose zone. In addition, approximately 50 active and inactive septic tanks and drain fields and numerous radioactive and non-radioactive landfills and dumps have impacted the vadose zone (DOE 1997b). The landfills are and were used to dispose of solid wastes, which, in most instances, are easier to locate, retrieve, and remediate than are liquid wastes.

One hundred and forty-nine single-shell tanks and 28 double-shell tanks have been used to store high-level radioactive and mixed wastes in the 200 Areas. The wastes resulted from uranium and plutonium recovery processes and, to a lesser extent, from strontium and cesium recovery processes. Sixty-seven of the single-shell tanks are assumed to have leaked an estimated total of 2,839 to 3,975 m^3 (750,000 to 1,050,000 gal) of contaminated liquid to the vadose zone (Hanlon 2001). The three largest tank leaks were 435,320 L (115,000 gal), 37,850 to 1,048,560 L (10,000 to 277,000 gal), and 265,980 L (70,365 gal). The average tank leak was between 41,640 and 60,565 L (11,000 and 16,000 gal) (Hanlon 2001). Brown et al. (2006) describes detailed analyses of vadose zone sediments from boreholes adjacent to a single-shell tank in the C tank farm. Data includes sediment types, the vertical extent of contamination, the migration potential of the contaminants, and the likely source of the contamination in the vadose zone below the C Tank Farm.

In addition to removing pumpable liquids from the single-shell tanks, interim measures have been taken to reduce the movement of tank farm contaminants in the vadose zone. Infiltration of water has been identified as the primary means by which contaminants are displaced beneath the farms. Surface water controls have been constructed to reduce surface water run-on from major meteorological events and from breaks in waterlines. Also, waterlines that were determined unnecessary have been isolated, cut, and capped. Waterlines that were found to be necessary for continued operations are being leak tested and any lines found to be leaking will be replaced.

Cooling water from the single-pass reactors along the Columbia River was routinely routed to retention basins in the 100 Areas prior to return to the river. Thermal shock from the hot cooling water cracked the basins so that much of the cooling water leaked into the vadose zone. In addition, trenches were used for disposal of cooling water from 100-KE, 100-KW, and 100-N Reactors. The disposed cooling waters contained fission and neutron activation products and some chemicals and actinides. Tritium, strontium-90, nitrate, and chromium migrate through the vadose zone to groundwater, and ultimately, to the Columbia River in the 100 Areas. Chromium is actively being remediated at the 100-K and 100-H Areas by pump-and-treat methods and in the 100-D/DR Area by pump-and-treat and in situ redox methods (Hartman et al. 2007).

Contaminated cooling water that had contacted broken fuel rods was routed to trenches rather than being directly returned to the river. These fluids contained large quantities of fission and neutron activation products. In addition, leakage from fuel-storage basins in the 100-K Area also contributed quantities of fission products, transuranics, and carbon-14 to the soil column (Johnson et al. 1995). Thus, both past-practice sites and fuel-storage basin leakage are potential vadose zone sources of contaminants in the 100 Areas. Groundwater monitoring data from wells near the 100-KE and 100-KW basins do not show any indication of current leakage from either basin.

The amount of contamination remaining in the vadose zone is uncertain. Several compilations of vadose zone contamination have been formulated through the past years. DOE (1997b), Kincaid et al. (1998, 2001, 2006), and Simpson et al. (2001) contain the most recent inventories of contaminants disposed to past-practice liquid disposal facilities in the 200 Areas. Dorian and Richards (1978) list contaminant inventories disposed to most 100 Areas past-practice facilities. Agnew (1997) and Anderson (1990) list inventories of effluents sent to single-shell tanks and Simpson et al. (2001) list the compositions of fluids leaked from single-shell tanks. Most recently, the Hanford Tank Farm Vadose Zone Project has issued a series of reports that estimate the curies of gamma-emitting radionuclides and the volumes of contaminated soil associated with each single-shell tank farm (http://www.gjo.doe.gov/programs/hanf/).

Further information on vadose zone characterization and monitoring activities on the Hanford Site is available online at http://vadose.pnl.gov and http://www.hanford.gov/cp/gpp/ as well as in the annually updated Hanford Site groundwater monitoring report (i.e., Hartman et al. 2007).

4.4.3 Hanford Site Groundwater

Groundwater at the Hanford Site originated as either recharge from rain and snowmelt, or from excess irrigation, canal seepage, and wastewater disposal. Most of this groundwater will eventually discharge to the Columbia River. Some will be brought to the surface through wells, or excavations, or through evaporation or transpiration in shallow water table areas.

Groundwater beneath the Hanford Site is found in both an upper unconfined aquifer system and deeper basalt-confined aquifers. The unconfined aquifer system is also referred to as the suprabasalt aquifer system because it is within the sediments that overlie the basalt bedrock. Portions of the suprabasalt aquifer system are locally confined. However, because the entire suprabasalt aquifer system is interconnected on a site-wide scale, it is referred to in this report as the Hanford unconfined aquifer system.

4.4.3.1 Basalt-Confined Aquifer System

Relatively permeable sedimentary interbeds and the more porous tops and bottoms of basalt flows provide the confined aquifers within the Columbia River Basalts. The horizontal hydraulic conductivities of most of these aquifers fall in the range of 10^{-10} to 10^{-4} m/s (3×10^{-10} to 3×10^{-4} ft/s). Saturated but relatively impermeable dense interior sections of the basalt flows have horizontal hydraulic conductivities ranging from 10^{-15} to 10^{-9} m/s (3×10^{-15} to 3×10^{-9} ft/s), about five orders of magnitude lower than some of the confined aquifers that lie between these basalt flows (DOE 1988). Hydraulic-head information indicates that groundwater in the basalt-confined aquifers generally flows toward the Columbia River and, in some places, toward areas of enhanced vertical interaquifer flow within the unconfined aquifer system (Hartman et al. 2007; DOE 1988; Spane 1987). The basalt-confined aquifer system is important because there is a potential for significant groundwater movement between the two systems. Head relationships presented in previous reports (DOE 1988) demonstrate the potential for such interaquifer flow. In addition, limited water chemistry data indicate that interaquifer flow has occurred in an area near the Gable Mountain anticlinal structure, north of the 200 East Area (Graham et al. 1984; Jensen 1987).

4.4.3.2 Unconfined Aquifer System

The unconfined aquifer system is composed primarily of the Ringold Formation and overlying Hanford formation (Section 4.3). In some areas, the coarse-grained multilithic facies of the Cold Creek unit (pre-Missoula gravels) lie between these formations and below the water table. The other subunits of the Cold Creek unit are generally above the water table.

Water table elevations (Figure 4.4-11) show that groundwater in the unconfined aquifer at Hanford generally flows from recharge areas in the elevated region near the western boundary of the Hanford Site toward the Columbia River on the eastern and northern boundaries. The Columbia River is the primary discharge area for the unconfined aquifer. The Yakima River borders the Hanford Site on the southwest and is generally regarded as a source of recharge. Along the Columbia River shoreline, daily river level fluctuations may result in water table elevation changes of up to 3 m (10 ft). During the high river stage periods of 1996 and 1997, some wells near the Columbia River showed water level changes of more than 3 m (10 ft). As the river stage rises, a pressure wave is transmitted inland through the groundwater. The longer the duration of the higher river stage, the farther inland the effect is propagated. The pressure wave is observed farther inland than the water actually moves. For the river water to flow inland, the river level must be higher than the groundwater surface and must remain high long enough for the water to flow through the sediments. Typically, this inland flow of river water is restricted to within several hundred feet of the shoreline (McMahon and Peterson 1992).

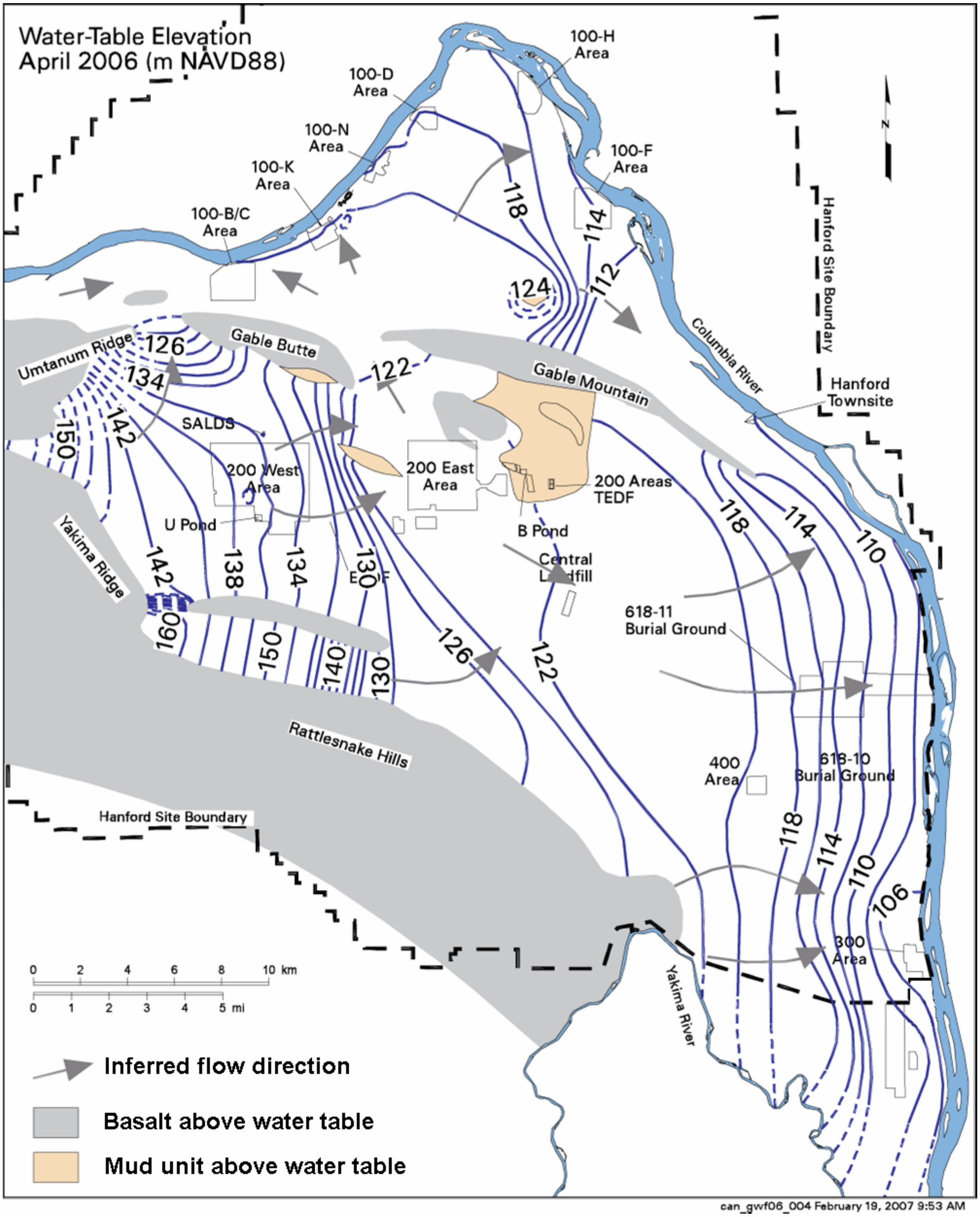

Figure 4.4-11. Water Table Elevations in Meters (1 m = 3.28 ft) and Inferred Groundwater Flow Directions for the Unconfined Aquifer at Hanford, Washington, March 2006 (Hartman et al. 2007)

Gee et al. (1992) and Fayer et al. (1996) estimate that recharge rates from precipitation across the Hanford Site range from near zero to over 100 mm/year (3.94 in./yr). Recharge is variable both spatially and temporally. It is greatest for coarse-textured soils bare of deep-rooted vegetation and in years with rapid snowmelt events and precipitation during cool months. The magnitude of recharge at a particular location is influenced by five main factors: climate, soils, vegetation, topography, and springs and streams. Events such as the fire that burned vegetation from a large portion of the Hanford Site during the summer of 2000 also affect recharge rates. Fayer et al. (1996) used several types of field data and computer modeling to estimate the areal distribution of mean recharge rates for the soil and vegetation conditions at the Hanford Site, including any disturbance by Hanford operations.

Between 1944 and the mid-1990s, the volume of artificial recharge from Hanford wastewater disposal was significantly greater than recharge from precipitation. An estimated 1.68×10^{12} L (4.44×10^{11} gal) of liquid was discharged to disposal ponds, trenches, and cribs during this period. Wastewater discharge has decreased since 1984 and currently contributes a volume of recharge in the same range as the estimated natural recharge from precipitation. Because of the reduction in discharges, groundwater levels are falling, particularly around the operational areas (Hartman et al. 2007).

After the beginning of Hanford operations during 1943, the water table rose about 27 m (89 ft) under the U Pond disposal area in the 200 West Area and about 9.1 m (30 ft) under disposal ponds near the 200 East Area (Figure 4.4-11). The volume of water that was discharged to the ground at the 200 West Area was actually less than that discharged at the 200 East Area. However, the lower hydraulic conductivity of the aquifer near the 200 West Area inhibited groundwater movement in this area resulting in a higher groundwater mound. The presence of the groundwater mounds locally affected the direction of groundwater movement, causing radial flow from the discharge areas. Zimmerman et al. (1986) documented changes in water table elevations between 1950 and 1980. Until about 1980, the edge of the mounds migrated outward from the sources over time. Groundwater levels have declined over most of the Hanford Site since 1984 because of decreased wastewater discharges (Hartman et al. 2007). Although the reduction of wastewater discharges has caused water levels to drop significantly, a residual groundwater mound beneath the 200 West Area is still shown by the curved water table contours near this area and small groundwater mounds exist near the 200 Area Treated Effluent Disposal Facility (TEDF) and SALDS wastewater disposal sites (Figure 4.4-11).

Horizontal hydraulic conductivities of sand and gravel facies within the Ringold Formation generally range from about 1 to 100 m/day (3 to 330 ft/day), compared to 10 to 3,000 m/day (33 to 10,000 ft/day) for the Hanford formation and the coarse-grained multilithic facies of the Cold Creek unit (pre-Missoula gravels) (DOE 1988; Cole et al. 2001; Thorne and Newcomer 2002). Because the Ringold Formation sediments are more consolidated and partially cemented, they are about 10 to 100 times less permeable than the sediments of the overlying Hanford formation. Before wastewater disposal operations at the Hanford Site, the uppermost aquifer was mainly within the Ringold Formation, and the water table extended into the Hanford formation at only a few locations

(Newcomb et al. 1972). However, wastewater discharges raised the water table elevation across the Site. The general increase in groundwater elevation caused the unconfined aquifer to extend upward into the Hanford formation over a larger area, particularly near the 200 East Area. This resulted in an increase in groundwater velocity because of both the greater volume of groundwater and the higher permeability of the newly saturated Hanford formation sediments.

4.4.3.3 Limitations of Hydrogeologic Information

The sedimentary architecture of the unconfined aquifer is very complex because of repeated deposition and erosion. Although hundreds of wells have been drilled on the Hanford Site, many penetrate only a small percentage of the total unconfined aquifer thickness, and there are a limited number of wells that can be used for defining the deeper sediment facies. A number of relatively deep wells were drilled in the early 1980s as part of a study for a proposed nuclear power plant (PSPL 1982), and these data are helpful in defining facies architecture. For most of the thinner and less extensive sedimentary units, correlation between wells is either not possible or uncertain. Major sand and gravel units of the Ringold Formation (e.g., Units A, B, C, D, and E) are separated by mud-dominated units (Figure 4.3-3). In some places the mud units act as aquitards that locally confine groundwater in deeper permeable sediments.

A limited amount of hydraulic property data is available from testing of wells. Hydraulic test results from wells on the Hanford Site have been compiled for the Hanford Groundwater Monitoring Project and for environmental restoration efforts (Kipp and Mudd 1973; Connelly et al. 1992 [a, b]; Thorne and Newcomer 1992, 2002; Spane and Thorne 1995, 2000; Spane et al. 2001[a, b]; Spane et al. 2002). Most hydraulic tests were conducted within the upper 15 m (49 ft) of the aquifer, and many were open to more than one geologic unit. In some cases, changes in water table elevation may have significantly changed the unconfined aquifer transmissivity at a well since the time of the hydraulic test. Few hydraulic tests within the Hanford Site unconfined aquifer system have yielded accurate estimates of aquifer-specific yield.

4.4.3.4 Groundwater Travel Times

Tritium and carbon-14 measurements indicate that groundwater residence time (time that ground water has been in the subsurface) is up to thousands of years for the unconfined aquifer and more than 10,000 years for groundwater in the shallow confined aquifer (Johnson et al. 1992). Chlorine-36 and noble gas isotope data suggest groundwater ages of greater than 100,000 years in the deeper confined systems (Johnson et al. 1992). These relatively long residence times are consistent with semiarid-site recharge conditions. However, groundwater travel time from the 200 East Area to the Columbia River has been shown to be much faster, in the range of 10 to 30 years (USGS 1987; Freshley and Graham 1988). This is because of large volumes of recharge from wastewater that was disposed in the 200 Areas between 1944 and the mid-1990s and the relatively high permeability of Hanford formation sediments, which are below the water table between the 200 East Area and the Columbia River. Travel time from the 200 West Area is greater because of the lower permeability of Ringold Formation sediments. Plume monitoring indicates that groundwater from the 200 West Area has moved about 6 km (3.7 mi) during the past 50 years. Groundwater travel times from the 200 Areas to the Columbia River are expected to decrease because of diminishing wastewater recharge in the 200 Areas and the resulting reduction of the hydraulic gradient.

4.4.3.5 Groundwater East and North of the Columbia River

The Hanford Site boundary extends east and north of the Columbia River. Hanford Site activities in these areas have not impacted the groundwater. However, the groundwater in this area is impacted by high recharge from irrigation and canal leakage. The South Columbia Basin Irrigation District manages surface water used to irrigate land east and north of the Columbia River. Recharge from irrigation water has increased water table elevations in large areas of the Pasco Basin by as much as 92 m (300 ft) (Drost et al. 1989).

There are two general hydrologic areas that impinge upon the Hanford Site boundaries to the east and north of the river. The eastern area extends from north to south between the lower slope of Saddle Mountain and the Esquatzel Diversion canal and includes the Ringold Coulee, White Bluffs area, and Esquatzel Coulee. The water table occurs in the Pasco gravels of the Hanford formation in both Ringold and Esquatzel Coulees. Brown (1979) reported that runoff from spring discharge at the mouth of Ringold Coulee is greater than 0.631 m^3/s (22.3 ft^3/s). Elsewhere in this area, the unconfined aquifer is in the less-transmissive Ringold Formation. Irrigation has also created perched aquifers and resulted in a series of springs issuing from perched water along the White Bluffs. The increased hydraulic pressure in these sediments has caused subsequent slumping and landslides (Brown 1979; Newcomer et al. 1991).

The other principal irrigated area is the northern part of the Pasco Basin on the Wahluke Slope, which lies between the Columbia River and the Saddle Mountain anticline. Irrigation return waste-water paths off of the Wahluke Slope have created ponds and springs in the Saddle Mountain Wildlife Refuge Unit. The direction of unconfined groundwater flow is southward from the basalt ridges toward the Columbia River. Bauer et al. (1985) reported that lateral water table gradients are essentially equal to or slightly less than the structural gradients on the flanks of the anticlinal fold mountains where the basalt dips steeply.

4.4.4 Groundwater Quality

The quality of groundwater at the Hanford Site, uncontaminated by Hanford activities, varies depending on the aquifer system and depth, which generally is related to residence time in the aquifer (DOE 1992a, 1997c; Hartman et al. 2007). DOE has conducted a study examining historical data and new data from wells in areas not affected by Hanford Site contaminants (DOE 1997c).

Groundwater chemistry in the basalt-confined aquifers displays a range depending on depth and residence time (DOE 1988). The chemical type varies from calcium- and magnesium-carbonate water to sodium- and chloride-carbonate water. Some of the shallower basalt-confined aquifers in the region (e.g., the Wanapum basalt aquifer) have exceptionally good water quality characteristics: less than 300 mg/L dissolved solids; less than 0.1 mg/L iron and magnesium; less than 20 mg/L sodium, sulfate, and chloride; and less than 10 ppb heavy metals (Johnson et al. 1992). However, deeper basalt-confined aquifers typically have high dissolved solids content and some have fluoride concentrations greater than the drinking water standard of 5 mg/L (DOE 1988).

Groundwater beneath large areas of the Hanford Site has been contaminated by radiological and chemical constituents resulting from past Hanford Site operations. These contaminants were primarily introduced through wastewater discharged to cribs, ditches, injection wells, trenches, and ponds (Kincaid et al. 1998). Additional contaminants from spills, leaking waste tanks, and burial grounds (landfills) have also entered groundwater in some areas. Contaminant concentrations in the existing groundwater plumes are expected to decline through radioactive decay, mineral adsorption, chemical degradation, and dispersion. However, contaminants also exist within the vadose zone beneath waste sites (Section 4.4.2) as well as in waste storage and disposal facilities. These contaminants have a potential to continue to move downward into the aquifer.

Some contaminants, including tritium and chloride, move at the same velocity as groundwater. The movement of other contaminants is slower because they react with or are sorbed on the surface of minerals within the aquifer or the vadose zone. The factor by which the velocity of a constituent is reduced compared to average groundwater flow velocity is called the “retardation factor.” Therefore, tritium in groundwater will move ten times faster than a contaminant with a retardation factor of ten. For Hanford sediments, it has been estimated that technetium and chromium have small retardation factors and move at nearly the same velocity as groundwater (Thorne 2004). Iodine, nitrate, uranium, and carbon tetrachloride were estimated to have median retardation factors between 3 and 12. Strontium, cesium, and plutonium were estimated to have median retardation factors between 290 and 27,000. Cantrell et al. (2002) and Serne and Kaplan (2000) offer additional information on retardation of chemicals transported in groundwater.

Groundwater contamination is being actively remediated through pump-and-treat operations at the 200 West Area, 100-F Area, and 100-K Area. These operations are summarized in Hartman et al. (2007). At the 100-N Area, pump-and-treat remediation has been terminated and a passive treatment barrier is being used to reduce contaminant migration.

Monitoring of radiological and chemical constituents in groundwater at the Hanford Site is performed to characterize physical and chemical trends in the flow system, establish groundwater quality baselines, assess groundwater remediation, and identify new or existing groundwater problems. Groundwater monitoring is also performed to verify compliance with applicable environmental laws and regulations. Samples were collected from 778 wells and 247 shoreline aquifer sampling tubes during FY 2006 to determine the distributions of radiological and chemical constituents in Hanford Site groundwater (Hartman et al. 2007).

To assess the quality of groundwater, concentrations measured in samples were compared with maximum contaminant levels (MCL) or interim Drinking Water Standards (DWS) and DOE’s Derived Concentration Guides (DCG). The MCL or DWS standards are legal limits for contaminant concentrations in public drinking water supplies enforceable by the Washington State Department of Health or EPA. Although these standards are only applicable at the point of consumption of the water, they provide a useful indicator of negative impacts to the groundwater resource. The DCG applies only to radionuclides and is based on the concentration that would result in a radiological dose of 1 mSv/year (100-mrem/year) effective dose equivalent, a calculation of dose that assumes ingestion under specified intake scenarios.

Radiological constituents including carbon-14, cesium-137, cobalt-60, iodine-129, strontium-90, technetium-99, gross alpha, gross beta, tritium, and uranium were detected at levels greater than the

DWS in one or more onsite wells. Concentrations of strontium-90 were detected at levels greater than DOE's DCG. Certain nonradioactive chemicals regulated by EPA and the State of Washington (nitrate, fluoride, antimony, arsenic, mercury, chromium, cyanide, carbon tetrachloride, chloroform, trichloroethylene, and tetrachloroethylene) were also present in Hanford Site groundwater during fiscal year 2006 (Table 4.4-2). The extent of radiological and non-radiological contamination in Hanford Site groundwater above the applicable DWS is determined annually (Figures 4.4-12 and 4.4-13). The area of contaminant plumes on the Hanford Site with concentrations exceeding drinking water standards was estimated to be 186 km^2 (87.3 mi^2) during fiscal year 2006.

4.4.5 100 Areas Hydrology

The hydrology of the 100 Areas is affected by its location adjacent to the Columbia River. The water table ranges in depth from near 0 m (0 ft) at the river edge to 30 m (107 ft). The groundwater flow direction is generally toward the river. However, during high river stage, the flow direction may reverse immediately adjacent to the river. The unconfined aquifer in the 100 Areas is composed of either the Ringold Unit E gravels or a combination of the Unit E gravels and the Hanford formation (Figure 4.3-5). There are two large areas where the water table is within the Ringold Formation (Lindsey 1992), and the Hanford formation is unsaturated (Figure 4.4-14). In the 100-H and 100-F Areas, the Ringold Unit E gravels are missing and the Hanford formation lies directly over the fine-grained Ringold lower-mud unit. In most of the 100 Areas, the lower Ringold mud forms an aquitard, and the Ringold gravels below the mud are locally confined. Additional information on the hydrology of the 100 Areas is available in Hartman and Peterson (1992) and Peterson et al. (1996). A number of studies of various sites in the 100 Areas present specific hydrologic information. These include: 100-B/C Area - Lindberg (1993a); 100-D Area - Lindsey and Jaeger (1993); 100-F Area - Lindsey (1992), Peterson (1992); 100-H Area - Liikala et al. (1988), Lindsey and Jaeger (1993); 100-K Area - Lindberg (1993b); and 100-N Area - Gilmore et al. (1992), Hartman and Lindsey (1993).

4.4.6 200 Areas Hydrology

In the 200 West Area, the water table occurs almost entirely in the Ringold Unit E gravels, while in the 200 East Area, it occurs primarily in the Hanford formation and in the Ringold Unit A gravels (Figure 4.3-5). Along the southern edge of the 200 East Area, the water table is in the Ringold Unit E gravels. The upper Ringold facies were eroded in most of the 200 East Area by the ancestral Columbia River and, in some places, by the Missoula floods that subsequently deposited Hanford gravels and sands on what was left of the Ringold Formation (DOE 2002b). Because the Hanford formation and possibly the Cold Creek unit sand and gravel deposits are much more permeable than the Ringold gravels, the water table is relatively flat in the 200 East Area, but groundwater flow velocities are higher. On the north side of the 200 East Area, there is evidence of erosional channels that may allow interaquifer flow between the unconfined and uppermost basalt-confined aquifer (Graham et al. 1984; Jensen 1987).

The hydrology of the 200 Areas has been strongly influenced by the discharge of large quantities of wastewater to the ground during a 50-year period. The discharges caused elevated groundwater

Table 4.4-2. Maximum Concentrations of Selected Groundwater Contaminants during Fiscal Year 2006 (Hartman et al. 2007)

Contaminant, units (alphabetical order)	DWS (DCG)[a]	100-BC-5		100-KR-4		100-NR-2		100-HR-3-D		100-HR-3-H		100-FR-3	
		Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells	Aquifer Tubes
Antimony (filtered), µg/L[b]	6									**34.1**			
Arsenic (filtered), µg/L	10				2.4			6.1					
Carbon tetrachloride, µg/L	5												
Carbon-14, pCi/L	2,000 (70,000)			**16,300**	519								
Cesium-137, pCi/L	200 (3,000)												
Chloroform, µg/L	100			0.74								0.58	
Chromium (dissolved), µg/L	100	40	48	**515**	80	**163**	57	**2,360**	**393**	**106**	43	83.3	8
cis-1,2-Dichloroethene, µg/L	70												
Cobalt-60, pCi/L	100 (5,000)												
Cyanide, µg/L	200												
Fluoride, mg/L	4	0.26	0.18	0.33	0.26	1.0	0.29	0.56	0.2	0.59	0.17	0.9	0.15
Gross alpha, pCi/L	15	1.74	1.02	6.11		8.83	2.15	3.51		9.64		9.05	
Gross beta, pCi/L	50	**54.1**	27.7	**4,480**	4.05	**34,100**	**6,650**	**200**		**76.9**	19.3	**99.1**	
Iodine-129, pCi/L	1 (500)												
Mercury, µg/l	2			0.1									
Nitrate, mg/L	45	25.2	28.8	**160**	**48.3**	**410**	26.1	**77**	41.6	**253**	**47.4**	**124**	31
Nitrite, mg/L	3.3		0.174	1.58		**4.6**[c]	0.125	3.28				0.099	
Plutonium-239/240, pCi/L[d]	NA (30)												
Strontium-90, pCi/L	8 (1,000)	**41.9**	**11.5**	***3,140***	1.03	***16,300***	***3,620***	**9**		**40**	6.83	**48.6**	2.5
Technetium-99, pCi/L	900 (100,000)		116	130						870	35.4		
Tetrachloroethene, µg/L	5												
Trichloroethene, µg/L	5			**2.9**								**14**	
Tritium, pCi/L	20,000 (2,000,000)	**125,000**	19,200	**669,000**	4,750	**26,500**	7,840	**32,500**	10,900	6,030		19,800	
Uranium, µg/L	30			6.49				5.08		**85.5**	1.17	14.5	

Note: Table lists highest concentration for FY 2006 in each groundwater interest area. Concentrations in **bold** exceed drinking water standards. Concentrations in ***bold italic*** exceed DOE derived concentration guides. Blank space indicates the constituent was undetected or not analyzed. (a) DWS = Drinking water standard; DCG = DOE derived concentration guide. See Tables 1.0-4 and 1.0-5 for more information on these standards.
(b) Detection limit is higher than DWS. Not a known contaminant of interest on the Hanford Site. (c) Suspected error. (d) There is no drinking water standard for plutonium-239/240. (e) From offsite contaminant sources..

Table 4.4-2. (cont'd)

Contaminant, units (alphabetical order)	DWS (DCG)[a]	200-ZP-1	200-UP-1	200-BP-5	200-PO-1		300-FF-5		1100-EM-1
		Wells	Wells	Wells	Wells	Aquifer Tubes	Wells	Aquifer Tubes	Wells
Antimony (filtered), µg/L[b]	6	44.3(c)							
Arsenic (filtered), µg/L	10	**10.8**	7.3	6.1	**10.5**				
Carbon tetrachloride, µg/L	5	**4,400**	**610**		0.44		0.65	0.19	0.27
Carbon-14, pCi/L	2,000 (70,000)	165							
Cesium-137, pCi/L	200 (3,000)			**902**					
Chloroform, µg/L	100	**144**	16	0.45	0.62		1.5	0.46	0.39
Chromium (dissolved), µg/L	100	**782**	**1,750**	58.3	41.1		23	4.3	
cis-1,2-Dichloroethene, µg/L	70	0.68					**160**	2	
Cobalt-60, pCi/L	100 (5,000)	23.6		**290**					
Cyanide, µg/L	200			**1,470**					
Fluoride, mg/L	4	**4.1**	0.75	0.83	**7.3**	0.21	1.4	0.33	0.88
Gross alpha, pCi/L	15	8.66	10.8	**476**	33.5		**74.2**		2.44
Gross beta, pCi/L	50	**22,900**	**20,700**	**10,700**	**2,020**	3.27	**86.2**		9.76
Iodine-129, pCi/L	1 (500)	**42.7**	**30.6**	**4.57**	**9.11**				
Mercury, µg/L	2	0.13	0.05	**3.1**	0.09				
Nitrate, mg/L	45	**3,230**	**1,740**	**3,150**	**127**	5.75	**133**	**49.6**	**253**[e]
Nitrite, mg/L	3.3	3.02	1.61	**6.24**[c]	1.05		2.89[c]	0.135	
Plutonium-239/240, pCi/L[c]	NA (30)			19.7					
Strontium-90, pCi/L	8 (1,000)	2.8	**26.8**	***3,390***	**20.6**		3.32		
Technetium-99, pCi/L	900 (100,000)	**63,200**	**89,900**	**42,900**	**7,740**		241		
Tetrachloroethene, µg/L	5	**6.4**	2		1.7		0.44	1.1	
Trichloroethene, µg/L	5	**27**	**6.9**		0.81		4.7	**96**	2.3
Tritium, pCi/L	20,000 (2,000,000)	**1,820,000**	**1,020,000**	**95,500**	**571,000**	3,790	**1,470,000**	7,730	258
Uranium, µg/L	30	**129**	**461**	**804**	27.2		**192**	**394**[c]	8.76

Note: Table lists highest concentration for FY 2006 in each groundwater interest area. Concentrations in **bold** exceed drinking water standards. Concentrations in ***bold italic*** exceed DOE derived concentration guides. Blank space indicates the constituent was undetected or not analyzed. (a) DWS = Drinking water standard; DCG = DOE derived concentration guide. See Tables 1.0-4 and 1.0-5 for more information on these standards. (b) Detection limit is higher than DWS. Not a known contaminant of interest on the Hanford Site. (c) Suspected error. (d) There is no drinking water standard for plutonium-239/240. (e) From offsite contaminant sources.

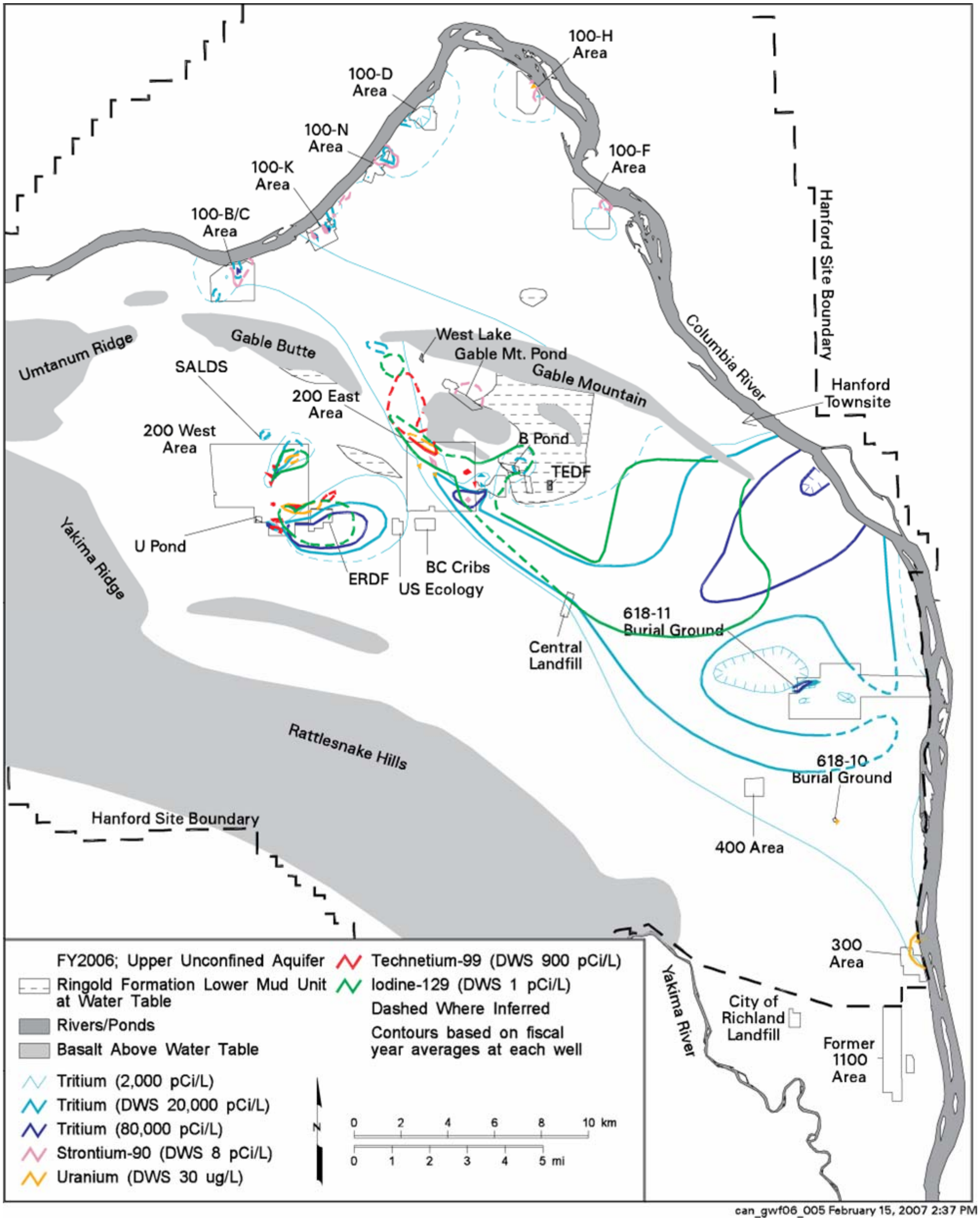

Figure 4.4-12. Distribution of Radionuclides in Groundwater on the Hanford Site, Washington, at Concentrations above the Maximum Contaminant Level or Interim Drinking Water Standard during Fiscal Year 2006 (Hartman et al. 2007) (27 pCi/L = 1 Bq/L)

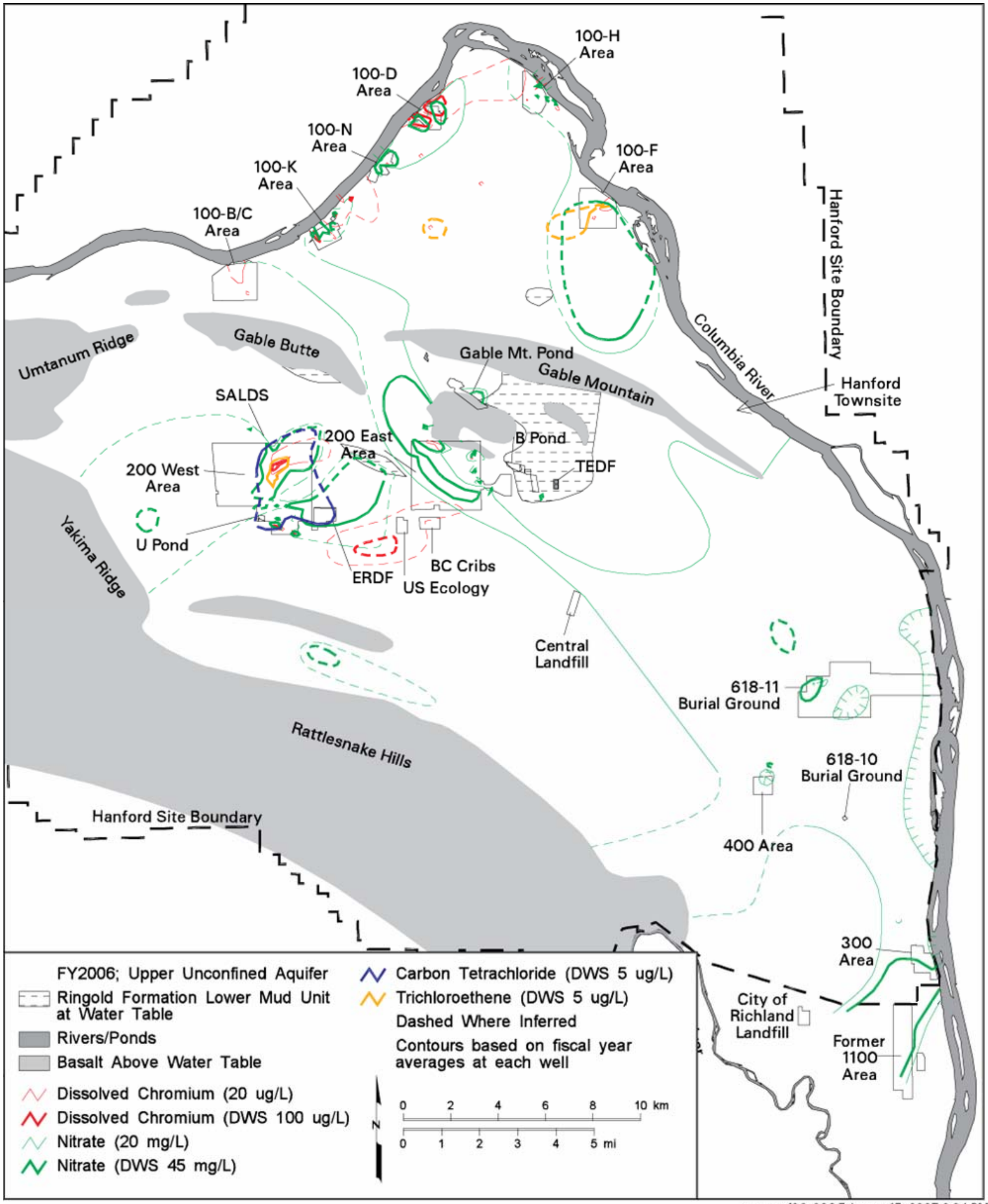

Figure 4.4-13. Distribution of Hazardous Chemicals in Groundwater on the Hanford Site, Washington, at Concentrations above the Maximum Contaminant Level or Interim Drinking Water Standard during Fiscal Year 2006 (Hartman et al. 2007)

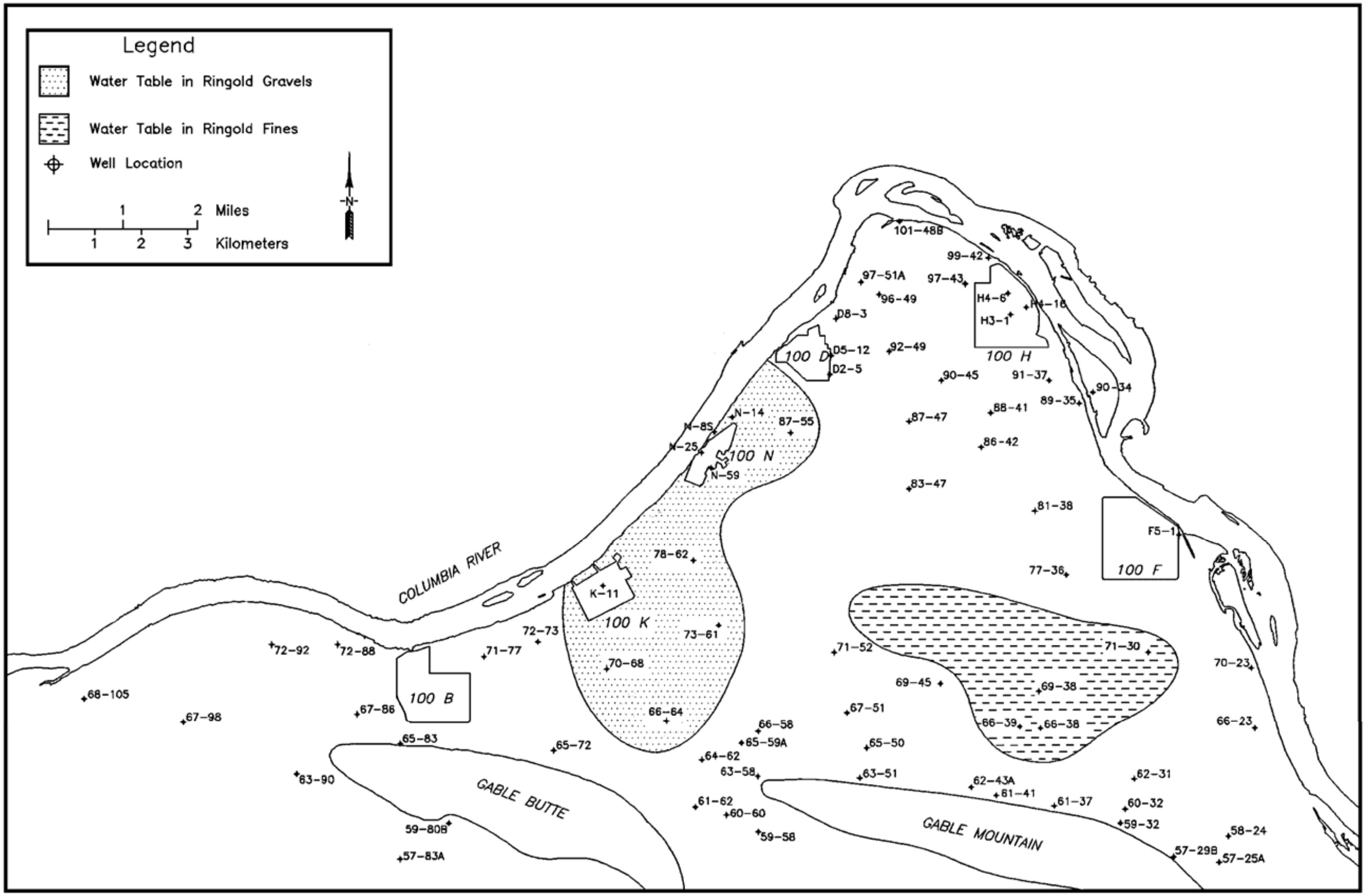

Figure 4.4-14. Geologic Units Intersected by the Water Table in the 100 Areas, Hanford Site, Washington

levels across much of the Hanford Site resulting in a large groundwater mound beneath the former U Pond in the 200 West Area and a smaller mound beneath the former B Pond, east of the 200 East Area (Figure 4.4-11). Water table changes beneath the 200 West Area have been greatest because of the lower transmissivity of the aquifer in this area (Cole et al. 2001). Discharges of water to the ground have been greatly reduced, and corresponding decreases in the elevation of the water table have been observed.

The decline in part of the 200 West Area groundwater mound has been more than 8 m (26 ft) (Hartman et al. 2007). Water levels are expected to continue to decrease as the unconfined groundwater system reaches equilibrium with the new level of artificial recharge (Wurstner and Freshley 1994).

A number of reports dealing with the hydrogeology of the 200 Areas are available including Williams et al. (2000, 2002), Graham et al. (1981), Last et al. (1989), and Connelly et al. (1992a, b).

4.4.7 300 Area Hydrology

The unconfined aquifer water table in the 300 Area (Figure 4.4-11) is found in both the Hanford formation and the Ringold Formation. It is 0 to 19 m (0 to 62 ft) below ground surface depending on location. Elevation of the Columbia River stage strongly affects the groundwater levels and flow near the river in the 300 Area. Water table contours in the vicinity of the 300 Area are somewhat concentric, showing that there is a groundwater discharge area for the unconfined aquifer system in the area of convergence. Groundwater flows from the northwest, west, and even the southwest to discharge into the Columbia River near the 300 Area. Schalla et al. (1988), Swanson (1992), and Hartman et al. (2007) have provided more detailed information on the hydrogeology of the 300 Area.

4.4.8 Offsite Hydrology - North Richland Area

The north Richland area (Figure 4.4-13), referred to as the Richland North Area in preceding documents, is located south of the Hanford Site and includes the former 1100 Area,[a] which was transferred from the DOE to the Port of Benton on October 1, 1998. The groundwater in this area is influenced by artificial recharge associated with the Richland recharge basins and nearby irrigated farming (Liikala 1994). Water is pumped from the Columbia River to the recharge basins and subsequently pumped from nearby wells. This system is used by the city of Richland as a backup filtration system for city water. Because an excess of water is pumped into the recharge basins, a mound has been created in the water table, which helps to reduce the potential for groundwater flow from the Hanford Site into this area (Hartman et al. 2007). The river stage elevation of the Yakima River, which flows just west of the area, is high enough such that the river also acts as a recharge source for the groundwater system. However, a study of water levels in wells adjacent to the river showed that flow between the Yakima River and aquifer may be inhibited in some areas by mud deposited along the riverbed (Thorne et al. 1993).

(a) The 1100 Area was the location of general stores and transportation maintenance facilities at the Hanford Site. The 1100 Area was declared clean by the regulatory agencies during September 1996.

The southern portion of the tritium plume from the 200 East Area extends to the 300 Area. However, tritium concentrations decrease from greater than 10,000 pCi/L (373.4 Bq/L) to less than 100 pCi/L (3.734 Bq/L) across the 300 Area and the distribution across this area has changed little since fiscal year 1999 (Hartman et al. 2007). A few wells south of the 300 Area, in the vicinity of Richland’s recharge ponds, have shown slightly elevated tritium levels compared to expected background levels for the groundwater. However, the observed tritium levels are consistent with tritium concentrations in the Columbia River water that is pumped into the ponds (Hartman et al. 2007). Nitrate contamination is also found in the north Richland area. This is the result of industrial and agricultural sources off the Hanford Site. The nitrate plume is migrating eastward and entering the Columbia River. Concentrations above the 45-mg/L maximum contaminant level are found over most of the north Richland area (Hartman et al. 2007).

4.5 Ecology

T. M. Poston and M. R. Sackschewsky

Ecology is an integrating discipline that defines the relationships between organisms and their environment. Ecological systems can be divided into two broad habitat types for evaluation: terrestrial and aquatic ecosystems. Terrestrial ecosystems include upland and riparian/wetland habitats. Aquatic ecosystems include the Columbia River, intermittent streams, and a few vernal pools. Ecosystems may be examined in terms of food webs, energy flow, trophic levels, or species composition within community levels of organization. This assessment is based primarily on species composition to define the ecosystems and focuses on both plants and animal life. Special habitats and operational areas with relatively unique features are described.

Terrestrial, riparian, and aquatic plant species have been documented on the Hanford Site (Appendix B). The list does not include all species reported on the Site (approximately 750), but has been compiled to broadly represent species most likely to be encountered or that may be of special interest for environmental assessments. In addition to a site map of vegetative communities, a series of vegetation/land cover maps provide information on available habitat in support of a review of ecological data for cleanup activities along the Columbia River shoreline (Appendix C). These maps represent the best available information on vegetation cover types and plant associations located in specific areas at the time the data were collected (from 1997 to 2006). Vegetation communities are subject to change depending on climatic conditions, physical disturbance, progress with waste cleanup, and natural recruitment and succession at the sites. Sackschewsky and Downs (2001) describes upland vegetation; for descriptions of riparian vegetation, see Section 8.0 of the 2003 Hanford Site Annual Environmental Report (Poston et al. 2004).

Hanford Site wildlife characterization includes descriptions of mammals, birds, reptiles, amphibians, fish, invertebrates, and insects. Site terrestrial wildlife communities are generally associated with specific vegetation communities. Approximately 300 species of terrestrial and aquatic vertebrates have been observed on the Hanford Site. To provide an indication of the diversity of biota on the Site, species lists have been compiled for the major classes of vertebrates that have been observed on the Site or within the Hanford Reach of the Columbia River. These lists are relatively complete for all groups with the exception of birds, which includes species that are most common, due to their mobility and migratory behavior. The species list of site inhabitants includes 46 species of mammals (Appendix B, Table B-2), 145 species of birds (Appendix B, Table B-3), 10 species of reptiles, 5 species of amphibians, and 45 species of fish (Appendix B, Table B- 4) (Soll and Soper 1996; Brandt et al. 1993).

From 1991 to 1993, surveys for birds, mammals, insects, and vegetation were conducted at several of the operable units in the 100 Areas and 300 Area (Brandt et al. 1993; Landeen et al. 1993). Soll et al. (1999) summarized their bird and mammal surveys and did not account for all of the species that have been documented historically on the Hanford Site. For example, 221 species of birds were observed in the bird surveys of The Nature Conservancy's biodiversity 4-year effort (Soll et al. 1999). This number falls short of the 238 species identified historically (Landeen et al. 1992). By combining the 1994-1999 list of The Nature Conservancy with the Site list (Landeen et al. 1992), a total of 258 species of birds have been documented on the Hanford Site (Soll et al. 1999). There are 145 bird species considered common to the Hanford Site (Appendix B, Table B 3).

Other descriptions of the ecology of the Hanford Site can be found in Cadwell (1994); Downs et al. (1993); ERDA (1975); Jamison (1982); Landeen (1996); Poston et al. (2007); Rogers and Rickard (1977); Sackschewsky and Downs (2001); Watson et al. (1984); and Weiss and Mitchell (1992). In the 1990s, the Nature Conservancy conducted biodiversity surveys of the Hanford Site (Soll and Soper 1996; Soll et al. 1999). In addition, ecological impact and risk assessments have been conducted on the Hanford Site addressing the risk posed by contaminants to biota that reside onsite (Poston et al. 2005; DOE 2006, 2007b).

This section addresses the habitat, flora, and fauna found in terrestrial (Section 4.5.1) and aquatic ecosystems (Section 4.5.2). A third section addresses species formally listed as threatened, endangered, or special status by federal and state agencies (Section 4.5.3).

4.5.1 Terrestrial Ecology

Terrestrial ecosystems on the Hanford Site include upland and riparian/wetland habitat. Upland habitat at Hanford is influenced by the arid climate and characterized by vegetation and wildlife adapted to hot summers, cold winters, and low precipitation. Riparian habitat occurs along bodies of water and is inhabited by plants with greater requirements for water than upland plants. Wetlands are areas where some open water is present and soils and associated vegetation reflect the presence of water. The distribution of plants within the upland habitat on the Hanford Site is greatly influenced by soil type, altitude, and precipitation. Range fires also have affected ecosystems, as well as the industrial activities of man and his introduction of non-native species.

The upland habitat within the Hanford Site, located within the Columbia Basin (Plateau) Ecoregion, is predominantly shrub-steppe (Stroms et al. 1997). Shrub-steppe ecosystems are typified by a shrub overstory and a grass and forb understory (Daubenmire 1970). Lichens and mosses, often times referred to as “microbiotic or cryptogamic crust,” provide a soil stabilizing growth on undisturbed soils in the shrub-steppe ecosystem. The Columbia Basin Ecoregion historically included over 6 million hectares (14.8 million acres) of steppe and shrub-steppe vegetation across most of central and southeastern Washington, as well as portions of north-central Oregon. Much of this ecoregion has been developed for agriculture, industry, and other development.

In the early 1800s, the dominant vascular plants in the area were big sagebrush underlain by perennial bunchgrasses and forbs. With the advent of Euro-American settlement, livestock grazing and agricultural production contributed to colonization by non-native plant species that currently dominate portions of the landscape. Agriculture and livestock production were the primary subsistence activities at the turn of the 20^{th} century. Although these activities ceased when the Hanford Site was created in January 1943 (DOE 1998c), remnants of past agricultural practices are still evident. Many places on the Hanford Site are relatively free of non-native species and are extensive enough to retain characteristic populations of shrub-steppe plants and animals that are absent or scarce in developed or fire-impacted areas of the ecoregion (Figure 4.5-1). Because of its

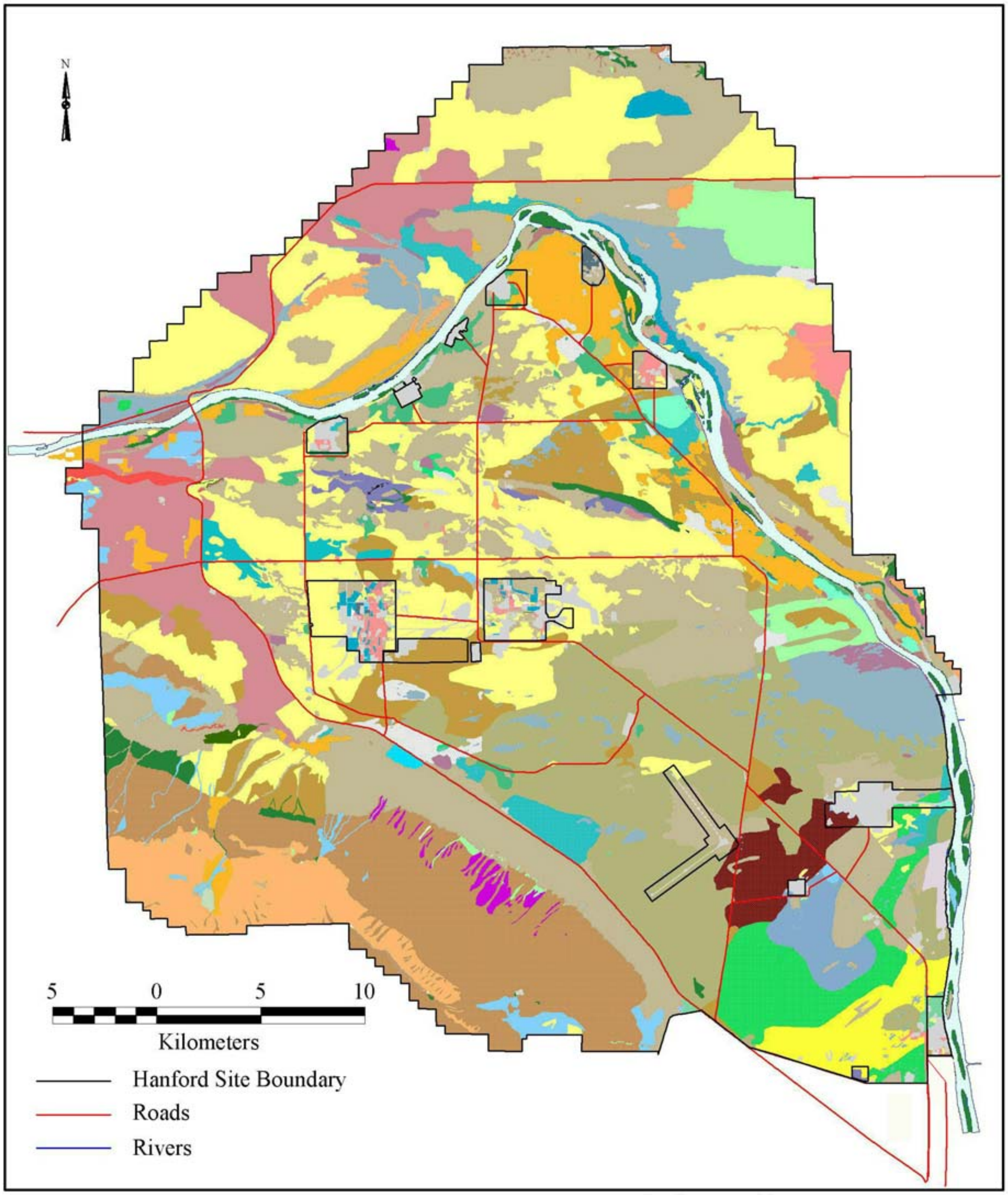

Figure 4.5-1. Distribution of Vegetation Types and Areas on the Hanford Site, Washington, before the Year 2000 Fire

LEGEND

- Abandoned Old Agricultural Fields
- Alkali Saltgrass - Cheatgrass
- Big Sagebrush - Bitterbrush / Bunchgrass
- Big Sagebrush - Bitterbrush / Needle-and-Thread Grass
- Big Sagebrush - Bitterbrush / Sandberg's Bluegrass
- Big Sagebrush - Rigid Sagebrush / Bunchgrass
- Big Sagebrush - Rock Buckwheat / Bunchgrass
- Big Sagebrush - Spiny Hopsage / Bunchgrass
- Big Sagebrush - Spiny Hopsage / Sandberg's Bluegrass - Cheatgrass
- Big Sagebrush / Bluebunch Wheatgrass
- Big Sagebrush / Bunchgrass
- Big Sagebrush / Needle-and-Thread Grass
- Big Sagebrush / Sand Dropseed
- Big Sagebrush / Sandberg's Bluegrass - Cheatgrass
- Bitterbrush / Bunchgrass
- Bitterbrush / Indian Ricegrass
- Bitterbrush / Needle-and-Thread Grass
- Black Greasewood / Alkali Saltgrass
- Bluebunch Wheatgrass - Needle-and-Thread Grass
- Bluebunch Wheatgrass - Sandberg's Bluegrass
- Bunchgrass - Cheatgrass
- Crested Wheatgrass
- Disturbed
- Gray Rabbitbrush - Snow Buckwheat / Bunchgrass
- Gray Rabbitbrush / Bunchgrass
- Gray Rabbitbrush / Cheatgrass
- Gray Rabbitbrush / Needle-and-Thread Grass
- Gray Rabbitbrush / Sand Dropseed
- Gray Rabbitbrush / Sandberg's Bluegrass - Cheatgrass
- Needle-and-Thread Grass - Indian Ricegrass
- Needle-and-Thread Grass -Sandberg's Bluegrass
- Non-Riverine Wetlands and Associated Deepwater Habitats
- Rabbitbrush / Bunchgrass
- Rigid Sagebrush / Sandberg's Bluegrass
- Riparian
- Riverine Wetlands and Associated Deepwater Habitats
- Sand Dropseed - Sandberg's Bluegrass - Cheatgrass
- Sandberg's Bluegrass - Cheatgrass
- Snow Buckwheat - Bitterbrush / Bunchgrass
- Snow Buckwheat / Bunchgrass
- Snow Buckwheat / Sandberg's Bluegrass - Cheatgrass
- Spiny Hopsage / Sandberg's Bluegrass - Cheatgrass
- Talus
- Threetip Sagebrush / Bunchgrass
- Thymeleaf Buckwheat / Sandberg's Bluegrass
- Vernal Pool
- White Bluffs
- Winterfat / Bunchgrass

Figure 4.5-1. (cont'd)

location, the Hanford Site provides important connectivity with adjacent, undeveloped portions of the Columbia Basin Ecoregion.

Large areas of the Hanford Site have experienced range fires that influence the vegetation composition and distribution of wildlife. During 1984, a major fire burned across 800 km^2 (310 mi^2) of the Hanford Site (Price et al. 1986). During 2000, a range fire burned across the Hanford Site consuming most of the shrub-steppe habitat on the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit, a small section of the McGee-Riverlands Unit, and other southwestern portions of the Site (Figure 4.5.2). The fire burned a total of 655 km^2 (250 mi^2) of federal, state, and private lands before it was controlled (BAER 2000).

These fires have altered the composition of the shrub-steppe habitat. Much of the year 2000 burn was considered to be low severity, whereby the soil structure and seed bank remain intact. Much of the burned area is in various stages of recovery. Most perennial plants were unharmed and have returned. Big sagebrush (*Artemesia tridentata*) may take considerably longer to recover than perennial bunchgrass areas depending on the availability of seed in the soil, severity of the burn, and the distance to other seed sources. Reestablishment of mature sagebrush stands is likely to take a minimum of 10 to 20 years and in some areas has been augmented by planting. In addition, some of the burned areas continue to be invaded by non-indigenous plant species such as Russian thistle (*Salsola tragus*, formerly *kali)* and tumble mustard (*Sisymbrium altissimum)*.

4.5.1.1 Upland Habitat

The Hanford Site contains some of the highest quality shrub-steppe habitat in the state of Washington and the larger ecoregions in the northwest. In some areas, unique and rare communities exist in spite of past wildfires and the presence of non-native species introduced by man. Hanford Site plants are adapted to low annual precipitation (17 cm [6.8 in.]), low water-holding capacity of the rooting substrate (sand), dry summers, and cold winters. Because of the diversity of habitats on the Hanford Site, including a relatively large range in elevation of up to 1,000 m (3,300 ft), the riparian corridor, sand dunes, and other special habitats, there is a large number of plant species onsite. A total of 727 species representing 90 families of vascular plants are recorded for the Hanford Site (Sackschewsky and Downs 2001). Of this total, 179 are non-native species. Cheatgrass (*Bromus tectorum*), the dominant non-native species, is an aggressive colonizer and has become well established across the Hanford Site (Rickard and Rogers 1983).

Microbiotic crusts are an important component of the shrub-steppe communities found at Hanford. The microbiotic (or cryptogamic) crusts generally occur in the top 1 to 4 mm (0.04 to 0.16 in.) of soil and are composed primarily of algae, lichens, and mosses. These crusts are formed by organisms and their by-products, creating a consolidated layer of soil particles bound together by organic materials. Microbiotic crusts are common in the semi-arid Columbia Basin, where the dominant organism tends to be green algae (Johansen et al. 1993). The functions of microbiotic crusts include soil stability and protection from erosion; fixation of atmospheric nitrogen; nutrient contribution to plants influencing soil-plant water relations; and increasing water infiltration, seedling germination, and plant growth. The ecological roles of microbiotic crusts depend on the relative cover of various crustal components. Carbon inputs are higher when mosses and lichens are present than

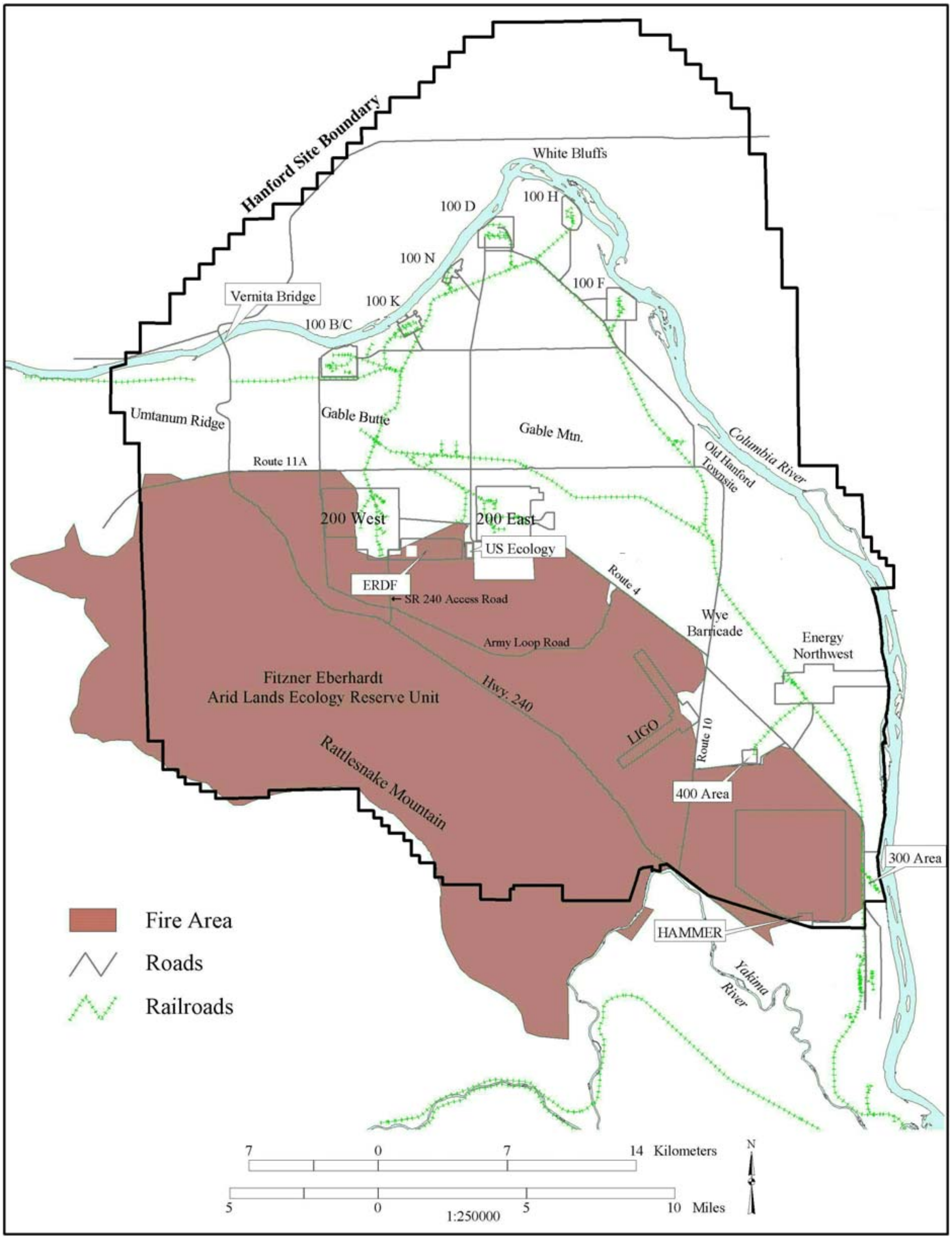

Figure 4.5-2. Area of Hanford Site, Washington, Burned as a Result of the June 27 to July 2, 2000, Wildfire

when the crust is dominated by cyanobacteria. Nitrogen inputs are higher with greater water infiltration. Soil surface stability is related to cyanobacterial biomass as well as total moss and lichen cover (Belnap et al. 2001). The lichen and mosses of the Hanford Site were surveyed and evaluated by Link et al. (2000). Twenty-nine soil lichens in 19 genera and 6 moss species in 4 genera were identified. Twelve (41 percent) lichen species are of the crustose growth form (flat and firmly attached to the substrate), eight (28 percent) are squamulose (having small, flat scales that do not adhere tightly to substrate), seven (24 percent) are foliose (having leaf-like lobes, attached in the center to substrate by clusters of rhizomes), and two (7 percent) are fruticose (plant-like growth attached at one point). More recent surveys have found a total of 120 taxa of lichens and mosses on the Hanford Monument lands surrounding the central portion of the Hanford Site (Evans et al. 2003).

Soll et al. (1999) conducted plant surveys on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit, the Wahluke Slope, central Hanford, and riparian communities along the Columbia River shoreline from 1994 through 1997. These surveys tentatively identified 30 “potential” terrestrial plant communities. Designation as a potential community indicates a type of community that would exist in an area if it were free of disturbance. In addition to characterizing potential plant communities, Soll et al. (1999) found 112 populations/occurrences of 28 rare plant taxa on the Hanford Site. Rare plant taxa are defined by the Washington Natural Heritage Program as plants that are monitored due to of loss of habitat and/or dwindling populations. When combined with observations preceding the 1994-1999 inventory, a total of 127 populations of 30 rare plant taxa have been documented on the Hanford Site. Vegetation cover types found on the Hanford Site include shrubland and grassland species listed below.

Shrublands and Grass Land Vegetation. Shrublands occupy the largest area in terms of acreage and comprise seven of the nine major plant communities on the Hanford Site (Sackschewsky and Downs 2001). Of the shrubland types, sagebrush-dominated communities are predominant, with other shrub communities varying with changes in soil and elevation. About 287 km^2 (111 mi^2) of shrub habitat dominated by big sagebrush was destroyed in the 2000 fire and is in various stages of recovery.

Of the vegetation types found on the Hanford Site (Figure 4.5-1), those with a shrub component (i.e., big sagebrush, threetip sagebrush [*Artemisia tripartita]*, bitterbrush [*Purshia tridentata]*, gray rabbitbrush [*Ericameria nauseousa* previously *Chrysothamnus nauseosus]*, green rabbitbrush [*Chrysothamnus viscidiflorus]*, black greasewood *[Sarcobatus vermiculatus*], winterfat [*Krascheninnikovia (Ceratoides) lanata*], snow buckwheat [*Eriogonum niveum]*, and spiny hopsage [*Grayia (Atriplex) spinosa*]) are considered shrub-steppe. These stands typically have an understory dominated by bunchgrasses such as bluebunch wheatgrass (*Pseudoroegnaria spicata* previously *Agropyron spicatum),* Sandberg’s bluegrass (*Poa sandbergii [secunda])*, needle-and-thread grass (*Hesperostipa comata* previously *Stipa comata),* Indian ricegrass (*Achnatherum hymenoides* previously *Oryzopsis hymenoides)*, bottlebrush squirreltail (*Elymus elymoides* previously *Sitanion hysterix*), and prairie junegrass (*Koeleria cristata*), as well as a number of broad-leaf forbs. Heavily grazed or disturbed areas often have an understory dominated by cheatgrass. Heterogeneity of species composition varies with soil, slope, and elevation. Vegetation types with a significant cheatgrass component are generally of lower habitat quality than those with bunchgrass understories.

A list of common plant species in Hanford areas is presented in Appendix B, Table B-1 and Sackschewsky and Downs (2001).

Most grasses occur as understory in shrub-dominated plant communities. Because shrubs have been removed by fire in many areas, there are large areas of grass-dominated communities on the Hanford Site. Cheatgrass has replaced many native perennial grass species and is well established in many low-elevation (less than 244 m [800 ft]) and/or disturbed areas (Rickard and Rogers 1983; Soll et al. 1999). Of the native grasses that occur on the Hanford Site, bluebunch wheatgrass occurs at higher elevations. Sandberg's bluegrass is widely distributed throughout the Columbia Basin and the intermountain west. Needle-and-thread grass, Indian ricegrass, and thickspike wheatgrass (*Elymus macrourus* previously *Agropyron dasytachyum)* occur in sandy soils and dune habitats. Species preferring more moist locations include streambank or riparian wheatgrass (*Elymus lanceolatus* previously *Agropyron dasystachyum* var. *smithii*), bentgrass (*Agrostis* spp.), bluegrass (*Poa* spp.), meadow foxtail (*Alopecurus aequalis)*, lovegrasses (*Eragrostis* spp.), and reed canarygrass (*Phalaris arundinacea*) (DOE 2001a). A list of common plant species in grassland areas is presented in Appendix B, Table B-1.

Within the past few hundred years, the Hanford Site upland landscape had few trees and the Columbia River shoreline supported a few scattered cottonwood (*Populus* spp.) or willows (*Salix* spp.). Homesteaders and Manhattan Project construction workers planted trees in association with agricultural areas and housing camps. Shade and ornamental trees were planted in the 1950s around former military installations and industrial areas on the Hanford Site. Currently, approximately 23 species of trees occur on the Site. The most commonly occurring species are black locust (*Robinia pseudo-acacia)*, Russian olive (*Eleagnus angustifolia*), cottonwood (*Populus trichocarpa)*, mulberry (*Morus alba)*, sycamore (*Platanus occidentalis)*, and poplar (*Populus* spp.). Many of these non-indigenous species are aggressive colonizers and have become established along the Columbia River (e.g., mulberry, poplar, Russian olive), serving as a functional component of the riparian zone (DOE 2001a). Trees provide nesting habitat and cover for many species of mammals and birds.

Shrub-Steppe and Grassland Wildlife. The shrub and grassland habitat of the Hanford Site supports many groups of terrestrial wildlife. Species include large animals like Rocky Mountain elk (*Cervus elaphus)* and mule deer (*Odocoileus hemionus)*; predators such as coyote (*Canis latrans)*, bobcat (*Lynx rufus)*, and badger (*Taxidea taxus)*; and herbivores including deer mice (*Peromyscus maniculatus)*, harvest mice (*Riethrodontonomys megalotis)*, ground squirrels (*Spermophilus* spp.), voles (*Lagurus* spp., *Microtus* spp.), and black-tailed jackrabbits (*Lepus californicus)*. The most abundant mammal on the Hanford Site is the Great Basin pocket mouse (*Perognathus parvus)*. Many of the rodent species and some predators (badgers) construct burrows on the Site. Other non-burrowing animals including cottontails (*Sylvilagus nutalli)*, jackrabbits, snakes, and burrowing owls (*Athene cunicularia)* may utilize abandoned burrows of other animals.

There was a reported sighting of a cougar (*Felis concolor)* on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit by experienced biologists during the elk relocation effort in March 2000, supplementing anecdotal accounts of other observations of the presence of cougars at the Hanford Site.

Mule deer rely mainly on shoreline vegetation and bitterbrush shrubs for browse (Tiller et al. 1997). Elk, which are more dependent on open grasslands for forage, seek the cover of sagebrush and other shrub species during the summer months. Elk first appeared on the Hanford Site during 1972 (Fitzner and Gray 1991), and have increased from approximately 8 animals observed in 1975 to approximately 900 in 1999. The Rattlesnake Hills herd of elk that inhabits the Hanford Site primarily occupies Fitzner-Eberhardt Arid Lands Ecology Reserve Unit and private lands that adjoin the reserve to the south and west. They are occasionally seen on the 200 Area Plateau and have been sighted at the White Bluffs boat launch on the Hanford Site. The herd tends to congregate on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit in the winter and disperses during the summer months to higher elevations on the reserve, private land to the west, and the Yakima Training Center. Efforts were taken in March 2000 to remove and relocate about 200 elk from the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit and another 31 elk were removed during 2002. Special hunts adjacent to the Hanford Site during 2000 accounted for the removal of 207 additional elk. The fire in June 2000 temporarily destroyed nearly all the elk forage on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit. The herd moved onto unburned private land west of the site, to unburned areas on central Hanford, and along the Columbia River near the 100-B/C and 100-K Areas. Elk have returned to burned areas as the vegetation recovered.

Shrub-steppe and grassland provide nesting and foraging habitat for many passerine (i.e., perching) bird species. Surveys conducted during 1993 (Cadwell 1994) reported the occurrence of western meadowlarks (*Sturnella neglecta)* and horned larks (*Eremophila alpestris)* more frequently in shrub-steppe habitats than in other habitats on the Hanford Site. Soll et al. (1999) reported a total of 41 species that are considered steppe or shrub-steppe habitat dependent. Long-billed curlews (*Numenius americanus*) and vesper sparrows (*Pooecetes gramineus)* were also noted as commonly occurring species in shrub-steppe habitat. Species that are dependent on undisturbed shrub habitat include sage sparrow (*Amphispiza belli)*, sage thrasher (*Oreoscoptes montanus)*, and loggerhead shrike (*Lanius ludovicianus)*. Both the sage sparrow and loggerhead shrike tend to roost and nest in sagebrush or bitterbrush that occurs at lower elevations (DOE 2001a). Ground-nesting species that occur in grass-covered uplands include long-billed curlews, western meadowlark, and burrowing owls. Trees that do not normally occur in arid steppe habitat supply nesting, perching, and roosting sites for many birds. Consequently, herons and raptors, such as ferruginous and Swainson’s hawks, can use trees for breeding in areas that previously did not support breeding populations. Ferruginous hawks also nest on electrical transmission line towers.

Common upland gamebird species that occur in shrub and grassland habitat include chukar (*Alectoris chukar)*, partridge (*Perdix perdix)*, California quail (*Callipepla californica)*, and ring-necked pheasant (*Phasianus colchicus)*. Chukars are most numerous in the Rattlesnake Hills, Yakima Ridge, Umtanum Ridge, Saddle Mountain, and Gable Mountain areas of the Hanford Site. Less common species include greater sage grouse (*Centrocercus urophasianus*) and scaled quail (*Callipepla squamata*). Greater sage grouse were historically abundant on the Hanford Site; however, populations have declined since the early 1800s because of the conversion of sagebrush-steppe habitat to farmland, hunting, and destruction of habitat by range fires. Surveys conducted by the Washington Department of Fish and Wildlife and PNNL during 1993 and biodiversity inventories conducted in 1997 (Soll et al. 1999) did not observe greater sage grouse in the sagebrush-steppe habitat at Fitzner-

Eberhardt Arid Lands Ecology Reserve Unit. Greater sage grouse were observed on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit during 1999 and 2000.[(a)] A greater sage grouse was killed by an automobile near the 100-F area in the spring of 2003; however, this is considered an abnormal occurrence for this part of the Hanford Site. The fire in June 2000 destroyed potential greater sage grouse habitat, and it is unlikely that greater sage grouse will return until the vegetation has recovered to a point where it can support them.

Among the more common raptor species that use shrub and grassland habitat are the ferruginous hawk (*Buteo regalis)*, Swainson's hawk (*B. swainsoni)*, and red-tailed hawk (*B. jamaicensis)*. Northern harriers (*Circus cyaneus)*, sharp-shinned hawks (*Accipiter striatus)*, rough-legged hawks (*B. lagopus)*, and golden eagles (*Aquila chrysaetos)* also occur in this habitat, although infrequently. During 1994, nesting by red-tailed, Swainson's, and ferruginous hawks was known to occur in 41 nests located across the Hanford Site on high voltage transmission towers, trees, cliffs, and basalt outcrops. Since the mid-1990s, the number of breeding ferruginous hawks (a Washington State threatened species) on the Hanford Site has increased, due, in part, to their use of steel powerline towers for nesting in the open grass and shrub-steppe habitats.

The side-blotched lizard (*Uta stansburiana)* is the most abundant reptile species occurring on the Hanford Site. Short-horned (*Phrynosoma douglassii)* and sagebrush (*Sceloporus graciosus*) lizards are also found on the Hanford Site, but occur infrequently. The most common snake species include gopher snake (*Pituophis melanoleucus)*, yellow-bellied racer (*Coluber constrictor)*, and western rattlesnake (*Crotalus viridis)*.

Many species of insects occur throughout all habitats on the Hanford Site. Butterflies, grasshoppers, and darkling beetles are among the most conspicuous of the about 1,500 species of insects that have been identified from specimens collected on the Hanford Site (Soll et al. 1999). The actual number of insect species occurring on the Hanford Site may reach as high as 15,500. A total of 1,509 species-level identifications were completed during 1999 and 500 more are expected. Surveys have included the collection of 40,000 specimens which have resulted in the identification of 43 new taxa and 142 new findings in the state of Washington (Soll et al. 1999). The high diversity of insect species on the Hanford Site reflects the size, complexity, and relatively undisturbed quality of the shrub-steppe habitat.

4.5.1.2 Riparian and Wetland Areas

Riparian areas are vegetated wetlands, especially associated with rivers and streams, and include shoreline areas along sloughs and backwaters. Wetlands also include the shorelines of lakes, ponds, vernal pools temporarily formed by melting snow in basalt outcrops, industrialized ponds, and irrigation wasteways and ponds on the Wahluke Slope.

Riparian habitat that occurs in association with the Columbia River includes riffles, gravel bars, backwater sloughs, and cobble shorelines. These habitats occur infrequently along the Hanford Reach and have acquired greater significance because of the net loss of wetland habitat elsewhere within the region. Other riparian areas include those areas associated with springs on the Fitzner-Eberhardt Arid

(a) Source: Personal communication between T. M. Poston and L.L. Cadwell, PNNL, April 2002.

Lands Ecology Reserve Unit and shoreline areas of irrigation return ditches and ponds located on the Saddle Mountain and Wahluke units of Hanford Reach National Monument.

Riparian Plants. Vegetation that occurs along the Columbia River shoreline includes water smartweed (*Polygonum amphibium*), sedges (*Carex* spp.), reed canary grass (*Phalaris arundinacea)*, bulbous bluegrass (*Poa bulbosa*), common witchgrass (*Panicum capillare)*, and large barnyard grass (*Echinochloa crusgalli)*. Rushes and sedges occur along the shorelines of the Columbia River and at several sloughs along the Hanford Reach. Trees include willow (*Salix* spp.), mulberry (*Morus alba)*, and Siberian elm (*Ulmus pumila).* A list of common Hanford Site riparian plants is provided in Appendix B, Table B-1.

Noxious weeds are also becoming established along the riparian zones of the Hanford Reach. Purple loosestrife (*Lythrum salicaria)*, tamarisk (*Tamarix parviflora*), yellow nutsedge (*Cyperus esculentus*), reed canary grass, knapweed (*Centaurea* spp.), and yellow star thistle (*Centaurea solstitialis)* are some of the more common species found near or on wetlands on the Hanford Site. The DOE and the U.S. Fish and Wildlife Service (USFWS) have an ongoing program to control populations of noxious weeds with aerial applications of herbicides.

Some wetland habitat exists in the riparian zones of some of the larger spring streams on the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit. These are not extensive and usually amount to less than 0.01 km^2 (0.004 mi^2) in size, although the riparian zone along Rattlesnake Springs is about 2 km (1.2 mi) in length and consists of peach leaf willows, cattails, and other non-indigenous plants. Rattlesnake and Snively Springs support highly diverse biological communities (Cushing and Wolf 1984) that include bulrush (*Scirpus* spp.), spike rush (*Eleocharis* spp.), and cattail (*Typha latifolia)*. Watercress (*Rorippa nasturtium-aquaticum)*, which persists at these sites, is also abundant for a large portion of the year. In the past 30 years, introduced trees and shrubs have become established in the riparian zone along these springs. The riparian transects associated with Snively and Rattlesnake Springs were greatly impacted by the year 2000 fire (BAER 2000) (Figure 4.5-2).

Other wetland habitats can be found within the Saddle Mountain National Wildlife Refuge Unit and the Wahluke Unit. These two areas encompass all the lands extending from the north bank of the Columbia River northward to the Hanford Site boundary and east of the Columbia River from Ringold Springs north to Highway 24 in Adams County. Wetland habitat in these areas consists of fairly large pond habitat resulting from irrigation runoff. These ponds have extensive stands of cattails and other emergent aquatic vegetation surrounding the open-water regions (Figure 4.5-1). They are extensively used as nesting sites by waterfowl and support populations of warm water fish that have been introduced by the irrigation network.

Riparian Wildlife. Riparian areas provide nesting and foraging habitat and escape cover for many species of birds and mammals. Shoreline riparian communities are seasonally important for a variety of species. Common bird species that occur in riparian habitats include red-winged blackbird (*Agelaius phoeniceus)*, American robin (*Turdus migratorius)*, black-billed magpie (*Pica pica)*, song sparrow (*Melospiza melodia)*, and dark-eyed junco (*Junco hyemalis)* (Cadwell 1994). Upland gamebirds that use this habitat include ring-necked pheasants and California quail. Predatory birds include common barn owl (*Tyto alba)* and great horned owl (*Bubo virginianus)*. Burrowing owls have been observed on some of the islands in the Columbia River. Species known or expected to nest in riparian habitat are Brewer's blackbird (*Euphagus cyanocephalus)*, mourning dove, black-billed magpie, northern oriole (*Icterus galbula)*, lazuli bunting (*Passerina amoena)*, eastern kingbird (*Tyrannus tyrannus*), western kingbird (*Tyrannus verticalis)*, and western wood peewee (*Contopus sordidulus)*. Bald eagles (*Haliaeetus leucocephalus)* have wintered on the Hanford Site since 1960. Great blue herons (*Ardea herodias*) and black-crowned night herons (*Nycticorax nycticorax)* are associated with trees in riparian habitat along the Columbia River and use groves or individual trees for perching and nesting. On occasion, great blue herons have constructed nests in the large metal powerline towers that are present on the shores of the Columbia River.

The Hanford Site is located in the Pacific Flyway, and the Hanford Reach serves as a resting area for neotropical migrant birds, migratory waterfowl, and shorebirds (Soll et al. 1999). The area between the old Hanford townsite and Vernita Bridge is closed to recreational hunting, and large numbers of migratory waterfowl find refuge in this portion of the river. Other species observed during this period include American white pelicans (*Pelecanus erythrorhynchos)*, egrets (*Casmerodius albus)*, double-crested cormorants (*Phalacrocorax auritus)*, coots (*Fulica americana*), and common loons (*Gavia immer)*.

Willows trap food for waterfowl (e.g., Canada geese [*Branta canadensis*]) and birds that use shoreline habitat (e.g., Forster's tern [*Sterna forsteri]*) as well as providing nesting habitat for passerines (e.g., kingbirds (Tyrannus spp., mourning doves [*Zenaida macroura*]). Sloughs and backwater areas provide shelter for migratory water fowl, cormorants, pelicans, egrets, and herons. Terrestrial and aquatic insects are abundant in emergent grasses and provide food for fish, waterfowl, and shorebirds.

Mammals occurring primarily in riparian areas include rodents, bats, furbearers (e.g., mink [*Mustela vison*] and weasel [*Mustela* spp.]), porcupine (*Erithizon dorsatum)*, raccoon (*Procyon lotor)*, skunk (*Mephitis mephitis)*, and mule deer. Beavers (*Castor canadensis)* rely on shoreline habitat for dens and foraging. River otters (*Lutra canadensis)* have been observed infrequently in the Hanford Reach. During the summer, mule deer rely on riparian vegetation for foraging. Mule deer use Columbia River islands for fawning and nursery areas. Beaver and muskrat (*Ondatra zibethica)* rely on shoreline habitat for dens and foraging. The Columbia River and Rattlesnake Springs provide foraging habitat for bats including Yuma myotis (*Myotis yumanensis*), small-footed myotis (*Myotis subulatus)*, silver-haired bats (*Lasionycteris octivagans)*, and pallid bats (*Antrozous pallidus)*, all of which feed on emergent aquatic insects (Becker 1993).

Along with the reptiles and insects identified in the grasslands discussion, five amphibians have been identified on the Hanford Site.[a] The Great Basin spadefoot toad (*Scaphiopus intermontanus)*, western toad (*Bufo boreas*), Woodhouse's toad (*Bufo woodhousei)*, tiger salamander (*Ambystoma tigrinum)*, and bullfrog (*Rana catesbeiana)* are the only amphibians found in close proximity to water on the Hanford Site (Soll et al. 1999; Brandt et al. 1993).

(a) The Pacific tree frog (*Hila regilla*) has been reported in earlier versions of this report, however, following a comprehensive review, it has not been documented on the Hanford Site, although the riparian zone along the 300 Area is suitable habitat and the species has been reported in Richland.

4.5.1.3 Other Distinctive Terrestrial Habitats

Portions of the Hanford Site exhibit special and/or distinctive terrestrial habitats with unique characteristics associated with natural features. In addition, there are regions associated with past uses to include farming or industrial and facility operations associated with Hanford Site missions. Currently, the major industrialized areas of the Hanford Site are undergoing cleanup and remediation under CERCLA. Ecological risk assessments are being conducted and often include the evaluation of ecological conditions for these areas.

Natural Features. Basalt outcrops, river bluffs, dunes, and Columbia River islands occur on the Hanford Site and their unique qualities create habitat for a distinct assemblage of plant and animal life (DOE 2001a).

<u>Basalt Outcrops</u>. The top of Rattlesnake Mountain, Umtanum Ridge, Gable Butte, and Gable Mountain include rock outcrops and have thin rocky soils. Plant communities dominated by thyme buckwheat (*Eriogonum thymoides*) and Sandberg's bluegrass most often occupy these basalt outcrops. Due to their elevation, these sites often experience higher wind speeds than those observed on lower elevation regions of the upland environs. Because of their geomorphology, basalt outcrops provide unique characteristics as habitat. These outcrops may create talus slopes with fractured ballast that provide dens for rattlesnakes and cover for woodrats and other fossorial wildlife.

<u>White Bluffs</u>. The White Bluffs border the Columbia River along the northern shoreline from river mile (RM) 376 downstream to RM 356 presenting a steep environment with sparse and patchy vegetation. Dense patches of Indian ricegrass occupy the top of the bluff area. Primary shrubs found on the slopes of the bluff are greasewood and spiny hopsage. Bluff areas provide habitat for sensitive plant species, e.g., Hoover's desert parsley (*Lomatium tuberosum*) and the White Bluffs bladderpod (*Lesquerella tuplashensis*), a Washington State endangered plant.

Bluffs provide perching, nesting, and escape habitat for several bird species on the Hanford Site. The White Bluffs and Umtanum Ridge provide nesting habitat for prairie falcons (*Falco mexicanus)*, red-tailed hawks, cliff swallows (*Hirundo pyrrhonota)*, bank swallows (*Riparia riparia)*, and rough-winged swallows (*Stelgidopteryx serripennis*). In the 1970s and 1980s, Canada geese used the lower elevations of the White Bluffs for nesting and brooding. Bald eagles use the White Bluffs for roosting. Bluff areas provide habitat for sensitive species (e.g., peregrine falcon [*Falco peregrinus*]) that otherwise may be subject to impact from frequent or repeated disturbance.

<u>Sand Dunes</u>. Dune habitat is unusual in its association with the surrounding shrub-steppe vegetation type. The individuality of the dunes is noted in its vegetation component as well as its geologic formation. Bitterbrush and Indian ricegrass dominate a large dune area north of the Energy Northwest complex along the Columbia River shoreline (Figure 4.5-1). The terrain of the dune habitat rises and falls between 3 and 5 m (10 and 16 ft) above ground level, creating areas that range from 2.5 to several hundred acres in size (U.S. Department of the Army 1990). Dune vegetation consists of a mosaic of shrubs and grasses, primarily bitterbrush and gray and green rabbitbrush with understory forbs and grasses that include scurfpea (*Psoralea lanceolata)*, needle-and-thread grass, and thickspike wheatgrass. Smaller dunes containing basalt grains that impart a dark color to the sand are found near

the 100-F Area and westward across the Site north of Gable Mountain. As a result of the fire that occurred during 2000, temporary dunes have formed along State Route 240 east to the 200 West Area and Army Loop Road. These burnt areas are in various stages of recovery.

The Hanford dunes, located on the eastern border of the Site, provide habitat for mule deer, burrowing owls, and coyotes as well as many transient species. In contrast, the dunes in west central Hanford, formed as a result of the fire in June 2000, may be temporary and could disappear once vegetation is reestablished. The sparseness of vegetative cover in the dunes puts many small animals at risk of predation.

Columbia River Islands.[(a)] Island habitat accounts for an area of approximately 4.74 km^2 (1.8 mi^2) (Hanson and Browning 1959) and 64.3 km (39.9 mi) of river shoreline within the main channel of the Hanford Reach (Figure 4.5-3). DOE owns and administers the upland portions of Locke Island (RM 371-373.5) and Wooded Island (RM 348-351). The Washington State Department of Natural Resources manages the shorelines of Locke and Wooded islands. Landslides caused by rotational slumping in the White Bluffs area caused accelerated erosion of Locke Island by the Columbia River. Shoreline riparian vegetation on the islands includes willow, poplar, Russian olive, and mulberry. Before regulation of river flows by dams, trees were generally not found along river shoreline habitat, with the exception of small willows and a few juniper trees near the 100-B/C Area and Riverlands. The most common tree to establish itself along the shoreline is mulberry. Species occurring on the island interior include buckwheat, lupine, mugwort, thickspike wheatgrass, giant wildrye, yarrow, and cheatgrass (Warren 1980).

Islands provide resting, nesting, and escape habitat for waterfowl and shorebirds. Use of islands for nesting by Canada geese has been monitored since 1950. The suitability of habitat for nesting Canada geese is attributed to restricted human use of islands during the nesting season, suitable substrate, and adequate forage and cover for broods (Eberhardt et al. 1989). The nesting population fluctuates annually. Since the early 1990s, geese have used the downstream islands in the Hanford Reach for nesting as a result of coyote predation in the upper Reach islands. Islands also accommodate colonial nesting species including California gulls (*Larus californicus),* ring-billed gulls (*Larus delawarensis*), and Forster's terns (*Sterna forsteri)*. Island areas ranging from 0.1 to 0.2 km^2 (0.05 to 0.08 mi^2) accommodate colonial nesting species that may range in population size up to 2,000 individuals. Mule deer have used Columbia River islands for birthing of fawns. Coyotes have been known to swim to the islands to prey on mule deer fawns and nests of Canada geese.

Hanford Operational Facilities and Retired Reactor Areas. Yearly vegetation surveys are conducted around many of the Hanford Site operational facilities and retired reactor areas including facilities in the 100, 200, and 300 Areas (Figure 4.0-1). In addition, there have been several studies examining the vegetation on the 200 Area Plateau and vegetation north of the 300 Area (Sackschewsky et al. 2001; Brandt et al. 1993).

[(a)] Management of these islands is the responsibility of the island owners, which include DOE, USFWS, and the U.S. Bureau of Land Management. Island ownership descriptions pertain to status prior to national monument designation and are subject to change with agreements among the agencies.

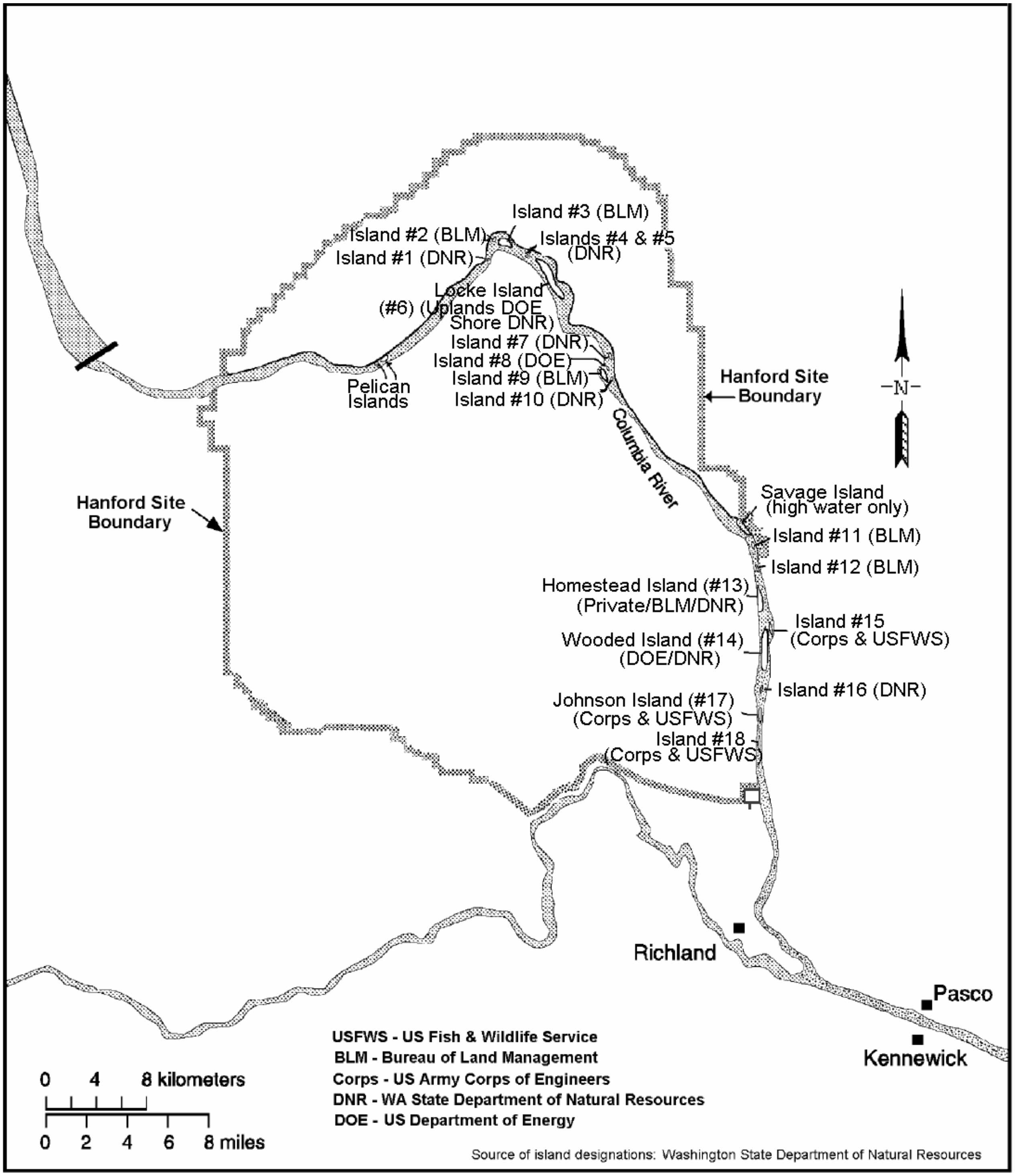

Figure 4.5-3. Columbia River Islands in the Vicinity of the Hanford Site, Washington

100 Areas. The 100 Areas upland region consists of old agricultural fields dominated by cheatgrass and tumble mustard. Scattered big sagebrush and gray rabbitbrush also occur throughout the 100 Areas (Landeen et al. 1993). An area of natural big sagebrush habitat near the 100-D Area experienced a significant and apparently natural decline during the mid-1990s (Cardenas et al. 1997). A total area encompassing 17.8 km^2 (6.9 mi^2) was affected, and a central core area of 2.8 km^2 (1.1 mi^2) experienced more than 80 percent sagebrush mortality.

The reactor areas have undergone extensive remediation as part of the CERCLA cleanup effort. Following remediation, waste sites are backfilled with material from local borrow pits and revegetated with native bunch grass species such as Sandberg's bluegrass (*Poa secunda*), bluebunch wheatgrass (*Pseudoroegneria spicata*), Indian ricegrass (*Achnatherum hymenoides*), thickspike wheatgrass (*Elymus lanceolatus*), prairie junegrass (*Koeleria macrantha*), and bottlebrush squirrel-tail (*Elymus elymoides*). Sagebrush seedlings (*Artemisia tridentata*) are also planted on the remediated waste sites, along with native forbs. Most of the waste sites at the reactor areas have been remediated and revegetated, or are in the final stages of remediation.

200 Areas. The undisturbed portions of the 200 Areas are characterized as sagebrush/cheatgrass or sagebrush/Sandberg’s bluegrass communities. The dominant plants on the 200 Area Plateau are big sagebrush, rabbitbrush, cheatgrass, and Sandberg’s bluegrass (Sackschewsky and Downs 2001; Sackschewsky et al. 2001). Most of the waste disposal and storage sites are planted with crested or Siberian wheatgrass to stabilize surface soil, control soil moisture, or displace more invasive deep-rooted species like Russian thistle.

300 Area. Vegetation surveys were conducted at the 300-FF-5 Operable Unit located north of the 300 Area during 1992. The shrub-steppe vegetation community in the unit is characterized as antelope bitterbrush/Sandberg’s bluegrass with an overstory of bitterbrush and big sagebrush and an understory of cheatgrass and Sandberg’s bluegrass (Brandt et al. 1993). This area is undergoing extensive cleanup and remediation.

Industrialized areas generally are fenced and preclude immigration of the larger wildlife species. In many of the areas, ongoing pest control is needed to address infiltration of rodents, snakes, and, in some cases, rabbits into waste management areas. Bats may utilize abandoned buildings as roosting sites and birds (rock doves, starlings, and other passerines) may nest on and immediately around buildings, equipment, and other facility structures. Insects and swallows may acquire water and mud from these sites and utilize facilities to construct nests.

West Lake. West Lake and its immediate basin represent a habitat that is characterized by highly saline conditions (Poston et al. 1991). These conditions most likely occur from the evaporation of water from the pond and the accumulation of dissolved solids during the early years of Hanford Site operations. West Lake is now classified as a waste site under the Comprehensive Environmental Restoration, Compensation, and Liability Act of 1980 (CERCLA) (42 USC 9601 *et seq*.). Water levels of the pond fluctuate with wastewater discharge levels in the 200 Areas. The water level of West Lake has dropped following the decrease in water discharged to the ground in the 200 Areas during the early 1990s, exposing large sections of saline mud flats and salt deposits along the shoreline. Dominant plants at West Lake include salt grass (*Distichlis stricta*), plantain (*Plantago* species), and salt rattlepod (*Swainsona salsula*). Bulrush (*Scirpus* species) grows along the shoreline; however, the water in the lake is too saline to support rooted aquatic macrophytes.

The high salinity associated with West Lake and associated mud flats has produced a large population of brine flies that in turn provide a food supply for bats and swallows that feed on the emerging adult flies. Migratory shorebirds including avocets also feed on the fly larvae. The lake is not routinely used for drinking water by larger animals due to its salinity content.

4.5.2 Aquatic Ecology

Aquatic resources on the Hanford Site are primarily associated with the Columbia River. The river crosses the Hanford Site entering at the northwest corner, traveling eastward and then turning south, forming the eastern boundary of the Site. The Columbia River and associated riparian zones provide habitat for numerous wildlife and plant species. The area known as the Hanford Reach, the Columbia River from Priest Rapids Dam (RM 397) to McNary Pool (RM 346), is the last non-impounded, non-tidal segment of the Columbia River in the United States. Several small intermittent spring/streams are also found on the Site and, with their unique riparian habitat, provide a break in the vast expanses of shrub-steppe habitat that dominate the Hanford Site.

4.5.2.1 Columbia River (River Habitat)

The Columbia River is the dominant aquatic ecosystem on the Hanford Site and supports a large and diverse population of plankton, benthic and lotic invertebrates, fish, and other communities. Large rivers, like the Columbia River with its series of large reservoirs, contain significant populations of primary energy producers (e.g., algae and plants) that contribute to the biota's basic energy requirements. The discussion of aquatic resources is partitioned into riverine (water column) and benthic habitats.

Riverine Habitat. Plants and animals residing in the water column include planktonic species, macrophytes, aquatic insects, and some species of fish. Phytoplankton and zooplankton populations at the Hanford Site are largely transient, flowing from one reservoir to another. With the relatively rapid flow of the Columbia River, there is generally insufficient time for characteristic endemic groups of phytoplankton and zooplankton to develop in the Hanford Reach and cycles of population are more transient than observed within impoundments and reservoirs.

Riverine Plant Life. Plant life consists of phytoplankton, some forms of attached filamentous algae (e.g., *Cladophora*), and rooted macrophytes (e.g., *Potomogeton* spp.).

Phytoplankton. Phytoplankton (free-floating algae) are abundant in the Columbia River and provide food for herbivores such as immature insects. Plankton populations in the Hanford Reach are influenced by communities that develop in the reservoirs of upstream dams, particularly Priest Rapids Reservoir, and by the manipulation of water levels by dam operations in upstream and downstream reservoirs. Phytoplankton species identified from the Hanford Reach include diatoms, golden or yellow-brown algae, green algae, blue-green algae, red algae, and dinoflagellates. Studies show diatoms are the dominant algae in the Columbia River phytoplankton, usually representing more than 90 percent of the populations. The main genera include *Asterionella, Cyclotella, Fragilaria*, *Melosira*, *Stephanodiscus*, and *Synedra* (Neitzel et al. 1982a). These are typical of those forms found in lakes and ponds and originate in upstream reservoirs. A number of algae found as free-floating species in the Hanford Reach of the Columbia River are actually derived from the periphyton; they were detached and suspended by currents and frequent fluctuations of the water levels.

Cushing (1967a) found peak concentrations of phytoplankton occurred in April and May, with a secondary peak in late summer/early autumn. The spring pulse in phytoplankton density was probably related to increasing light and water temperature rather than to availability of nutrients, as phosphate and nitrate nutrient concentrations are never limiting. Minimum numbers were present in December and January. Green algae (*Chlorophyta*) and blue-green algae (*Cyanophyta*) occur in phytoplankton communities during warmer months but in substantially fewer numbers than diatoms. Diversity indices, carbon uptake, and chlorophyll concentrations for the phytoplankton show similar seasonal trends (Neitzel et al. 1982a; Wolf et al. 1976).

Macrophytes. Macrophytes are sparse in the Columbia River because of strong currents, rocky bottom, and frequently fluctuating water levels. Rushes (*Juncus* spp.) and sedges (*Carex* spp.) occur along shorelines of the slack-water areas such as White Bluffs Slough below the 100-H Area, the slough area downstream of the 100-F Area, and the Hanford Slough. Reed canary grass (*Phalaris arundinacea*) is a common non-native species found along shoreline areas. Macrophytes are also present along gently sloping shorelines that are subject to flooding during the spring freshet and daily fluctuating river levels (downstream of Coyote Rapids and the 100-D Area). Commonly found plants include duckweed (*Lemna* sp.) and the native rooted pond weeds (*Potamogeton* sp. and *Elodea canadensis*). Where they exist, macrophytes have considerable ecological value. They provide food and shelter for juvenile fish and spawning areas for some species of warm-water game fish. Eurasian milfoil (*Myriophyllum spicatum*), an introduced macrophyte, has increased to nuisance levels since the late 1980s and may encourage increased sedimentation of fine particulate matter.

Riverine Animal Life. Animals residing in the water column include zooplankton and fish.

Zooplankton. The zooplankton populations in the Hanford Reach of the Columbia River are generally sparse. Studies by Neitzel et al. (1982b) indicate crustacean zooplankters were dominant in the open-water regions. Dominant genera were *Bosmina, Diaptomus*, and *Cyclops*. Densities were lowest in winter and highest in the summer, with summer peaks dominated by *Bosmina*, ranging up to 160,650 organisms/m^3 (4,500 organisms/ft^3). Winter densities were generally less than 1,785 organisms/m^3 (50 organisms/ft^3). *Diaptomus* and *Cyclops* dominated in winter and spring, respectively (Neitzel et al. 1982b).

Fish. Gray and Dauble (1977) list 43 species of fish in the Hanford Reach of the Columbia River. These include Dolly Varden (*Salvelinus malma*); however, the fish identified as Dolly Varden have been re-designated as bull trout (*Salvelinus confluentus*). The brown bullhead (*Ictalurus nebulosus*), collected since 1977, and the western mosquitofish (*Gambusia affinis)*, bring the total number of fish species identified in the Hanford Reach to 45 (Appendix B, Table B-5). Sixteen of these 45 species are introduced (Wydoski and Whitney 1979). Of these species, Chinook salmon (*Oncorhynchus tshawytscha)*, sockeye salmon (*Oncorhynchus nerka)*, coho salmon (*Oncorhynchus kisutch)*, and steelhead trout (*Oncorhynchus mykiss)* use the river as a migration route to and from upstream spawning areas and are of the greatest economic importance. Additionally, fall Chinook salmon and steelhead trout spawn in the Hanford Reach. The relative contribution of up-river bright stocks to fall Chinook salmon runs in the Columbia River increased from about 24 percent of the total in the early 1980s, to 50 to 60 percent of the total by 1988 (Dauble and Watson 1990). Inundation of other mainstream Columbia River spawning grounds by dams has increased the relative importance of the Hanford Reach to fall Chinook salmon production in the Columbia and Snake rivers (Watson 1970, 1973; Dauble and Watson 1997). Operation of Priest Rapids Dam can result in frequent river level fluctuations exposing shoreline and cobble bars during low-flow periods. In recent years, Priest Rapids Dam has operated with an objective to stabilize fall river levels to prevent salmon from spawning in areas that will be exposed at low river flow during the winter, thus protecting salmon redds from desiccation and temperature extremes. Fall Chinook salmon redd surveys have been conducted in Hanford Reach since 1950. There are presently 10 areas identified in the Hanford Reach (Figure 4.5.4) that support salmon spawning (Dauble and Watson 1997; Poston et al. 2004).

The steelhead fishery in the Hanford Reach (Highway 395 Bridge to Priest Rapids Dam) consists almost exclusively of summer-run fish. The Washington State Department of Fish and Wildlife (WDFW) estimates steelhead sport catch for the 2002 season at 1,100 fish. The majority of these fish were marked hatchery fish. In recent years the return of fall Chinook salmon has been high with 7,550 adults and about 1,000 jacks (precocious males) harvested during 2002 (http://wdfw.wa.gov/fish/harvest/harvest.htm).

American shad (*Alosa sapidissima),* an introduced anadromous species, may also spawn in the Hanford Reach. The upstream range of the shad has been increasing since 1956 when less than 10 adult shad passed McNary Dam. Since then, the number of shad ascending Priest Rapids Dam has risen to many thousands each year and young-of-the-year have been collected in the Hanford Reach. Shad are not dependent on the same conditions that are required by salmonids for spawning and apparently have found favorable conditions for reproduction.

Other fish of importance to sport fishermen are the native mountain whitefish (*Prosopium williamsoni)* and white sturgeon (*Acipenser transmontanus)*. Introduced species like smallmouth bass (*Micropterus dolomieui)*, crappie (*Pomoxis nigromaculatus*), catfish (*Ictalurus punctatus),* walleye (*Stizostedion vitreum),* and yellow perch (*Perca flavescens)* are also popular. Large populations of rough fish are also present, including introduced carp (*Cyprinus carpio)* and native species such as redside shiner (*Richardsonius balteatus),* suckers (*Catostomus macrocheilus),* and northern pikeminnow (*Ptychocheilus oregonensis)*. Because northern pikeminnow feed on juvenile salmon, WDFW has established a bounty program on adult pikeminnow to bolster salmon runs. Northern pikeminnow removed from the Hanford Reach are usually turned in at bounty stations located at Columbia Point in Richland and at the Vernita Bridge rest stop.

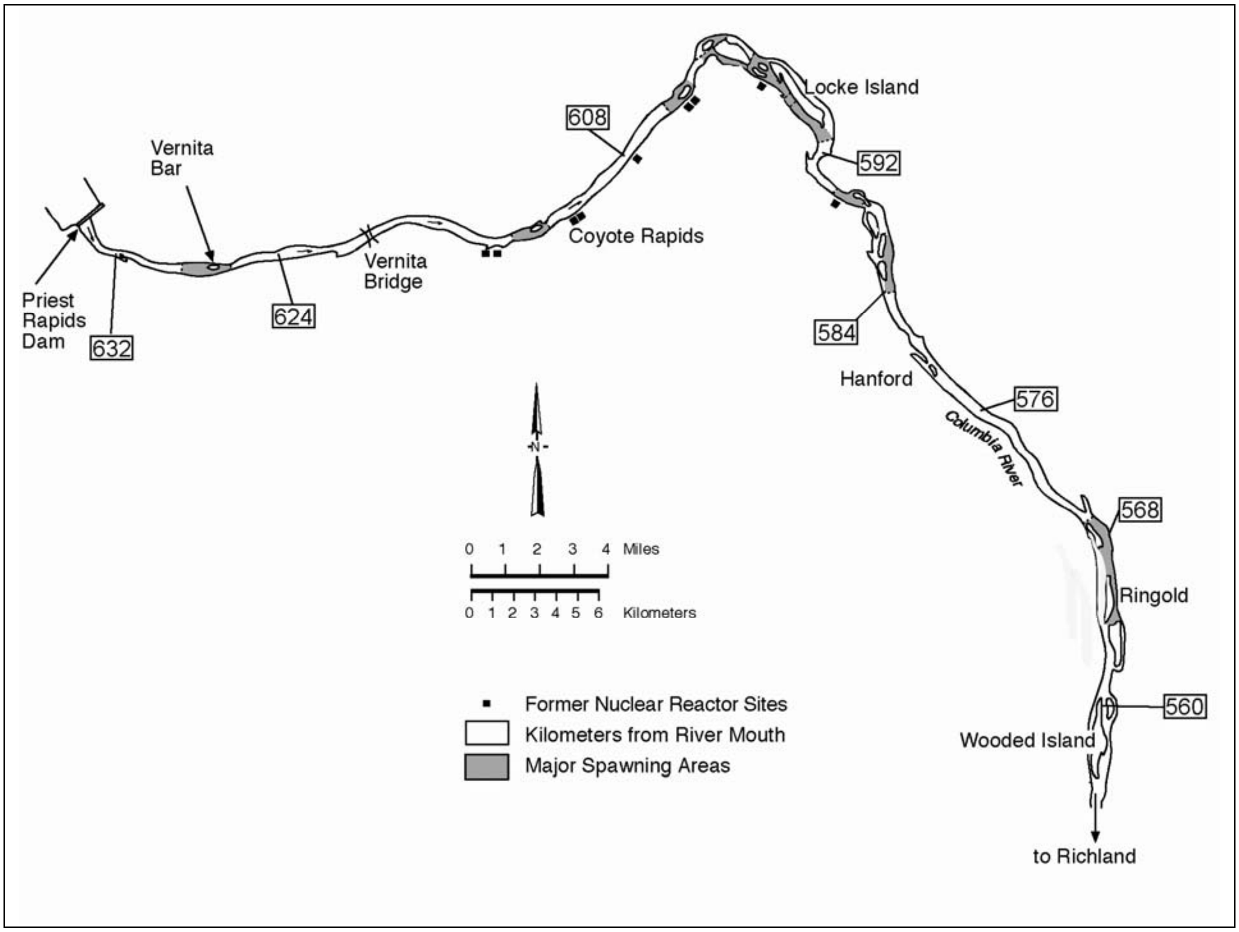

Figure 4.5.4. Fall Chinook Salmon Spawning Areas in the Hanford Reach Area of the Columbia River, Washington

Benthic Habitat. Benthic habitat and its associated biota are defined by the composition of the sediments which range from accumulations of fines (mud in the sloughs, back water areas, and shoreline areas of reduced current flow) to a gradation of gravel and cobbles up to large (>0.5 m diameter) boulders. Classification schemes have been proposed for characterizing benthic habitat based on the distribution of cobble by size and the degree of embeddedness in the fines (Turner 2004).

Periphyton. Communities of periphytic species or "benthic microflora" develop on suitable solid substrate wherever there is sufficient light for photosynthesis and adequate currents to prevent sediment from covering the colonies. Operation of Priest Rapids Dam results in frequent river level fluctuations causing exposed shoreline areas that do not allow for the establishment of viable and persistent periphyton communities in shoreline areas where flows exceed 1,310 m^3/s (46,300 cfs) (Tiller and Downs 2004). Cushing (1967b) observed peaks of production to occur in spring and late summer. Dominant genera are the diatoms *Achnanthes, Asterionella, Cocconeis, Fragilaria, Gomphonema*, *Melosira*, *Nitzchia*, *Stephanodiscus*, and *Synedra* (Beak Consultants Inc. 1980; Neitzel et al. 1982a; Page and Neitzel 1978; Page et al. 1979).

Benthic Invertebrates. Bottom dwelling organisms are found either attached to or closely associated with the substratum. All major freshwater benthic taxa are represented in the Columbia River. Insect larvae such as caddisflies (*Trichoptera*), midge flies (*Chironomidae*), and black flies (*Simuliidae*) are dominant. Dominant caddisfly species include *Hydropsyche cockerelli*, *Cheumatopsyche campyla*, and *C. enonis*. Other benthic organisms include clams (*Corbicula* spp., *Anodontia* spp.), limpets (*Fisherola* spp.), snails (*Physa* spp.), sponges (*Spongilla* spp.), and crayfish (*Astacus trowbridgii*). River fluctuations from the operation of Priest Rapids Dam do not allow for the establishment of persistent benthic communities. Clams and crayfish have difficulty in establishing populations in stranded shoreline areas that are frequently left dewatered by river level fluctuations. Species with rapid life cycles are less likely to be impacted by river fluctuations.

Early Hanford studies found crayfish numbers in shallow water areas ranged from 0.02 to 0.10 individuals/m^2 (0.2 to 1.1 individuals/ft^2) of river bottom, with a diet primarily of vegetation (Coopey 1953). Insect larvae numbers were as high as 185.8/m^2 (2,000/ft^2) (Davis and Cooper 1951). Peak larval insect densities are found in late fall and winter, with major emergence in spring and summer (Wolf 1976). Stomach contents of fish collected in the Hanford Reach from June 1973 through March 1980 revealed that benthic invertebrates were important food items for nearly all juvenile and adult fish. There was a correlation between food organisms in the stomach contents and those in the benthic and invertebrate drift communities. A survey by Soll et al. (1999) identified 21 new taxa of aquatic invertebrates in the Hanford Reach bringing the total number of aquatic invertebrate taxa to 151.

Recent ecological risk evaluations deployed cobble-filled baskets that were placed in-river and allowed to colonize over 6 months before retrieval for benthic community analysis (DOE 2007b). Taxonomic groups were taken to species level when possible and the information was used to calculate diversity indices. Fifty-nine invertebrate and insect taxa were identified. Hilsenhoff indexes, which are indicative of water quality, were calculated for two study sites and reference locations. Values ranged from 6.14 to 7.55 and did not indicate any difference between baskets deployed along the shorelines at the 300 Area, the 100-D Area, and at reference locations upstream of the Hanford Site; however, taxa categorized as most tolerant of “pollution” were found in the highest percentage in the 100-D Area.

4.5.2.2 Spring Streams

Small interrupted streams, such as Rattlesnake, Bobcat, and Snively springs located on the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit, contain diverse biotic communities and are extremely productive (Cushing and Wolf 1984). Dense blooms of watercress arise and are lost when flash floods occur. Aquatic insect production is fairly high as compared with mountain streams (Gaines 1987). The macrobenthic biota varies from site to site and is related to the proximity of colonizing insects and other factors. The fire of 2000 has had little direct impact on the stream ecology, even though the riparian transect along the lower two-thirds of the stream was heavily damaged by the fire (BAER 2000).

Rattlesnake Springs, on the western side of the Hanford Site, forms a small surface stream that flows for about 2.5 km (1.6 mi) before disappearing into the ground as a result of seepage and evapotranspiration. Base flow of this stream is about 0.01 m^3/s (0.4 ft^3/s) (Cushing and Wolf 1982). Water temperature ranges from 2° to 22°C (36° to 72°F), and mean annual total alkalinity (as $CaCO_3$), nitrate nitrogen, phosphate phosphorus, and total dissolved solids are 127, 0.3, 0.18, and 217 mg/L, respectively (Cushing and Wolf 1982; Cushing et al. 1980). The sodium content of the spring water is about 7 ppm (Brown 1970). Rattlesnake Springs is of ecological importance because it provides a source of water to terrestrial animals in an otherwise arid part of the Hanford Site. Snively Springs, located west of and at a higher elevation than Rattlesnake Springs, is another source of drinking water for terrestrial animals. Both springs provide a valuable source of drinking water for the Rattlesnake Hills elk herd. The major rooted aquatic plant, which in places may cover the entire width of the stream, is watercress. Isolated patches of bulrush, spike rush, and cattail occupy less than 5 percent of the streambed.

Primary productivity at Rattlesnake Springs is greatest during the spring and coincident with the maximum periphyton standing crop. Net primary productivity averaged 0.9 g/cm^2/day organic matter during 1969 and 1970; the spring maximum was 2.2 g/cm^2/day. Seasonal productivity and respiration rates are within the ranges reported for arid region streams. Although Rattlesnake Springs is a net exporter of organic matter during much of the growing season, it is subject to flash floods and severe scouring and denuding of the streambed during winter and early spring, making it an importer of organic materials on an annual basis (Cushing and Wolf 1984).

Secondary production is dominated by detritus-feeding, collector-gatherer insects (mostly Chironomidae and Simuliidae) that have multiple cohorts and short generation times (Gaines et al. 1992). Overall production is not high and is likely related to the low diversity found in these systems related to the winter spates that scour the spring streams. Total secondary production in Rattlesnake and Snively springs is 16,356 and 14,154 g dry weight/m^2/yr, respectively. There is an indication that insects in these spring-streams depend on both autochthonous (originating within the stream) and allochthonous (originating outside the stream) primary production as an energy source, despite significant shading by non-native species of trees and shrubs (Mize 1993).

Invertebrate surveys on the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit identified 30 new taxa at Rattlesnake Springs and 12 new taxa at Snively Springs (Soll et al. 1999). These recent findings bring the total number of taxa at each spring to 43 and 24, respectively.

There are other springs occurring on the Rattlesnake Hills (Schwab et al. 1979). Limited physical and chemical data are available for each site.

4.5.2.3 Temporary Water Bodies

West Lake is a small saline pond created by a rise in the water table in the 200 Areas and is not fed by surface flow. Evaporation of groundwater and possible disposal of sewage during the early Hanford years created highly saline and alkaline conditions that greatly restricted the complement of biota in West Lake (Poston et al. 1991).

Several artificial water bodies, both ponds and ditches, were formed as a result of wastewater disposal practices associated with operation of the reactors and separation facilities. Most of these have been taken out of service and have been backfilled with the cessation of Hanford activities.

When present, however, they formed established aquatic ecosystems complete with representative flora and fauna (Emery and McShane 1980). The temporary wastewater ponds and ditches existed for as long as two decades and covered fairly large areas. Rickard et al. (1981) discusses the ecology of Gable Mountain Pond, one of the former major lentic sites at Hanford. Emery and McShane (1980) present ecological characteristics of all the temporary water bodies. The ponds developed luxuriant riparian communities and became quite attractive to autumn and spring migrating birds. Several species have nested near the ponds. Section 4.4.1.8 describes those water bodies still active. These former sites have been decommissioned and are now covered with overburden and planted with grasses for stabilization.

4.5.3 Threatened and Endangered Species

There are a number of species of plants and animals on the Hanford Site that are considered to be rare and of management concern. Species listed as endangered or threatened by either the federal government under the Endangered Species Act (ESA) (50 CFR 17) or by the State of Washington (Washington Natural Heritage Program [WNHP] 2005; WDFW 2005) are listed in Table 4.5.1. There are no federal- or state-listed endangered or threatened mammals, reptiles, amphibians, or invertebrates on the Hanford Site, but there are three species of fish, four species of birds, and 12 species of plants listed as threatened or endangered by either the state or federal governments.

Of the three listed fish species, only the upper Columbia River steelhead trout (*Oncorhynchus mykiss*) spawns in the Hanford Reach, although the extent of spawning is not known. Upper Columbia River spring Chinook salmon (*O. tshawytscha*) do not spawn in the Hanford Reach, but adults pass through the Hanford Reach while migrating to spawning grounds, and the juveniles use the Hanford Reach as a nursery area while they migrate toward the ocean. The bull trout (*Salvelinus confluentus*) primarily inhabits smaller, colder streams, usually at higher elevations. Bull trout have been observed occasionally in the Hanford Reach, in association with the spring freshet. Bull trout are not considered to be residents of the Hanford Site.

Ferruginous hawks (*Buteo regalis*) have successfully nested onsite, especially on several steel transmission line towers. The white pelican (*Pelecanus erythrorhynchos*) is relatively common along the Hanford Reach but does not appear to nest or reproduce on site. The sandhill crane (*Grus canadensis*) migrates over the Site and on rare occasions is observed on the shore or islands of the Hanford Reach. The greater sage grouse (*Centrocercus urophasianus*) was formerly more common on the Hanford Site, especially on the Fitzner-Eberhardt Arid Lands Ecology (ALE) Reserve Unit. It disappeared for a number of years following several large fires in the 1980s. Since the late 1990s, there have been scattered sightings of greater sage grouse on ALE, and during 2003 a dead sage grouse was found near the 100-F Area.

The bald eagle (*Haliaeetus leucocephalus*) was removed from threatened status in the lower 48 contiguous United States on July 9, 2007 (72 FR 37346). The Bald and Golden Eagle Protection Act and Migratory Bird Treaty Act will remain in place for continuance of protective and management actions. The bald eagle is a relatively common winter resident along the Hanford Reach that occasionally attempts to nest on the Hanford Site but has not been successful over the duration of

Table 4.5.1. Federal or Washington State Threatened and Endangered Species on the Hanford Site

Common Name	Scientific Name	Federal[(a)]	State[(a)]
Mammals[(b)]			
Long-legged myotis	*Myotis volans*	Species of Concern	
Small-footed myotis	*Myotis ciliolabrum*	Species of Concern	
Washington ground squirrel	*Spermophilus washingtoni*	Species of Concern	
Birds[(b)]			
American white pelican	*Pelecanus erythrorhynchos*		Endangered
Burrowing owl	*Athene cunicularia*	Species of Concern	
Ferruginous hawk	*Buteo regalis*	Species of Concern	Threatened
Loggerhead shrike	*Lanius ludovicianus*	Species of Concern	
Peregrine falcon	*Falco peregrinus*	Species of Concern	
Northern goshawk	*Accipter gentilis*	Species of Concern	
Sandhill crane	*Grus canadensis*		Endangered
Greater sage grouse	*Centrocercus urophasianus*	Candidate	Threatened
Reptiles[(b)]			
Sagebrush lizard	*Sceloporus graciosus*	Species of Concern	
Fish[(b)]			
Bull trout	*Salvelinus confluentus*	Threatened	Candidate
Pacific lamprey	*Lampetra tridentata*	Species of Concern	Monitored
River lamprey	*Lampetra ayresi*	Species of Concern	Monitored
Spring-run Chinook	*Oncorhynchus tshawytscha*	Endangered	Candidate
Steelhead	*Oncorhynchus mykiss*	Threatened	Candidate
Molluscs[(b)]			
California floater[(a)]	*Anodonta californiensis*	Species of Concern	
Giant Columbia River spire snail[(a)]	*Fluminicola (= Lithoglyphus) columbiana*	Species of Concern	
Plants[(c)]			
Awned halfchaff sedge	*Lipocarpha (= Hemicarpha) aristulata*		Threatened
Desert dodder	*Cuscuta denticulata*		Threatened
Geyer's milkvetch	*Astragalus geyeri*		Threatened
Grand redstem	*Ammannia robusta*		Threatened
Great Basin gilia	*Gilia leptomeria*		Threatened
Loeflingia	*Loeflingia squarrosa var. squarrosa*		Threatened

Common Name	Scientific Name	Federal[a]	State[a]
Lowland toothcup	*Rotala ramosior*		Threatened
Persistentsepal yellowcress	*Rorippa columbiae*	Species of Concern	Endangered
Rosy pussypaws	*Calyptridium roseum*		Threatened
Umtanum desert buckwheat	*Eriogonum codium*	Candidate	Endangered
White Bluffs bladderpod	*Lesquerella tuplashensis*	Candidate	Threatened
White eatonella	*Eatonella nivea*		Threatened

(a) Endangered = species in danger of extinction within all or a significant portion of its range.
Threatened = species likely to become endangered in the foreseeable future.
Candidate = species believed to qualify for threatened or endangered species status, but for which listing proposals have not been prepared.
Species of concern = species not currently listed or candidates under the ESA, but are of conservation concern within specific USFWS regions.
(b) http://www.dnr.wa.gov/nhp/refdesk/lists/animal_ranks.html.
(c) http://www.dnr.wa.gov/nhp/refdesk/lists/plantrnk.html.

Hanford Site operations. Access controls on the Hanford Site will remain in place from November to March for the protection of roosting and nesting sites.

There are no plant species on the Hanford Site that are currently listed as threatened or endangered under the ESA, but two species of plants are candidates for federal protection: Umtanum desert buckwheat (*Eriogonum codium*) which occurs in several small, highly localized populations on Umtanum Ridge, and the White Bluffs bladderpod (*Lesquerella tuplashensis*), which occurs on White Bluffs. Additional plant species are listed as threatened or endangered by Washington State.

Several of these, including the awned halfchaff sedge (*Lipocarpha aristulata*), grand redstem (*Ammannia robusta*), lowland toothcup (*Rotala ramosior*), and persistentsepal yellowcress (*Rorippa columbiae*) are restricted to wetlands in the riparian zone of the Columbia River. Other plant species, such as loeflingia (*Loeflingia squarrosa*) and rosy pussypaws (*Calypdridium roseum*), are small annuals that have been found in relatively undisturbed sagebrush areas in the vicinity of Gable Mountain. The remaining four state threatened or endangered plant species (Geyer’s milkvetch [*Astragalus geyeri*], white eatonella [*Eatonella nivea*], desert dodder [*Cuscuta denticulata*], and the Great Basin gilia [*Gilia leptomeria*]) have been found at various sites on the Wahluke slope.

In addition to the species listed by the state or federal resource agencies as threatened or endangered, there are numerous animal species listed by the State of Washington as candidate, sensitive, monitored, or species with priority habitat (Table 4.5-2). Plant species are also listed as sensitive, review, or watch list (Table 4.5-3). The common loon (*Gavia immer*) and the peregrine falcon (*Falco peregrinus*) are the only animal species on the Hanford Site listed as sensitive by Washington State; there are 17 species of plants listed as state sensitive species.

The Washington ground squirrel (*Spermophilus washingtoni*), listed as a candidate species by both the state and federal governments, is most likely to occur in the Franklin or Grant County portions of the Hanford Site. Townsend’s ground squirrel (*S. townsendii*), a Washington State candidate species, may be found on the Benton County portions of the Hanford Site.

Several state candidate and sensitive species, including the loggerhead shrike (*Lanius ludovicianus*), burrowing owl (*Athene cunicularia*), sagebrush lizard (*Sceloporus graciosus*), peregrine falcon, goshawk (*Accipiter gentilis*), Columbia River spire snail (*Fluminicola columbiana*), and California floater (*Anodonta californiensis*), as well as the state threatened ferruginous hawk, are considered to be animal species of concern by the U.S. Fish and Wildlife Service (USFWS). Three state sensitive plant species, Columbia milkvetch (*Astragalus columbianus*), Hoover’s desert parsley (*Lomatium tuberosum*), and gray cryptantha (*Cryptantha leucophaea*), as well as the state endangered persistentsepal yellowcress, are considered by USFWS to be species of concern in the mid-Columbia Basin. Species of concern are not protected under federal law, but are considered to be vulnerable and of special management concern. More information about the plant species listed in Table 4.5-3 can be found in Sackschewsky and Downs (2001).

Table 4.5-2. Washington State Candidate, Sensitive, Monitored, and Priority Habitat Animal Species on the Hanford Site

Common Name	Scientific Name	Candidate	Sensitive	Monitored	Priority Habitat
Mammals					
Badger	*Taxidea taxus*			X	
Big brown bat	*Eptesicus fuscus*				X
Black-tailed jackrabbit	*Lepus californicus*	X			X
Long-legged myotis[(a)]	*Myotis volans*			X	X
Merriam's shrew	*Sorex merriami*	X			X
Northern grasshopper mouse	*Onychomys leucogaster*			X	
Palid bat	*Antrozous pallidus*			X	X
Sagebrush vole	*Lemmiscus curtatus*			X	
Small-footed myotis[(a)]	*Myotis ciliolabrum*			X	X
Townsend's ground squirrel	*Spermophilus townsendii*	X			X
Washington ground squirrel[(a, b)]	*Spermophilus washingtoni*	X			X
Western pipistrelle	*Pipistrellus hesperus*			X	
White-tailed jackrabbit	*Lepus townsendii*	X			X
Yuma myotis	*Myotis yumanensis*				X
Birds					
Black-crowned night-heron	*Nycticorax nycticorax*			X	X
Burrowing owl[(a)]	*Athene cunicularia*	X			X
Common loon	*Gavia immer*		X		X
Flamulated owl[(b)]	*Otus flammeolus*	X			X
Forster's tern	*Sterna forsteri*			X	X
Golden eagle	*Aquila chrysaetos*	X			X
Grasshopper sparrow	*Ammodramus savannarum*			X	
Great blue heron	*Ardea herodias*			X	X
Great egret	*Ardea alba*			X	
Horned grebe	*Podiceps auritus*			X	X

(a) Federal classification – See Table 4.5-1
(b) Reported, but seldom observed, on the Hanford Site
(c) Probable, but not observed, on the Hanford Site

Common Name	Scientific Name	Candidate	Sensitive	Monitored	Priority Habitat
Lewis's woodpecker[b]	*Melanerpes lewis*	X			X
Loggerhead shrike[a]	*Lanius ludovicianus*	X			X
Long-billed curlew	*Numenius americanus*			X	
Peregrine falcon[a]	*Falco peregrinus*		X		X
Merlin	*Falco columbarius*	X			X
Northern goshawk[a, b]	*Accipter gentilis*	X			X
Osprey	*Pandion haliaetus*			X	
Prairie falcon	*Falco mexicanus*			X	X
Sage sparrow	*Amphispiza belli*	X			X
Sage thrasher	*Oreoscoptes montanus*	X			X
Swainson's hawk	*Buteo swainsoni*			X	
Western grebe	*Aechmorus occidentalis*	X			X
Reptiles/Amphibians					
Night snake	*Hypsiglena torquata*			X	
Sagebrush lizard[a]	*Sceloporus graciosus*	X			X
Short-horned lizard	*Phrynosoma douglassi*			X	
Striped whipsnake	*Masticophis taeniatus*	X			X
Tiger salmander	*Ambystoma tigrinum*			X	
Woodhouse's toad	*Bufo woodhousii*			X	
Fish					
Bull trout[a, b]	*Salvelinus confluentus*	X			X
Leopard dace[b]	*Rhinichthys flacatus*	X			X
Mountain sucker[b]	*Catastomus platyrhynchus*	X			X
Pacific lamprey[a]	*Lampetra tridentata*			X	
Piute sculpin	*Cottus beldingi*			X	
Reticulate sculpin	*Cottus perplexus*			X	
River lamprey[a, b]	*Lampetra ayresi*	X			X
Sand roller	*Percopsis transmontana*			X	

(a) Federal classification – See Table 4.5-1
(b) Reported, but seldom observed, on the Hanford Site
(c) Probable, but not observed, on the Hanford Site

Common Name	Scientific Name	Candidate	Sensitive	Monitored	Priority Habitat
Spring-run Chinook salmon[a]	*Oncorhynchus tshawytscha*	**X**			**X**
Steelhead[a]	*Oncorhynchus mykiss*	**X**			**X**
Molluscs					
California floater[a]	*Anodonta californiensis*	**X**			**X**
Giant Columbia River spire snail[a]	*Fluminicola (= Lithoglyphus) columbiana*	**X**			**X**
Oregon floater	*Anadonta oregonensis*			**X**	
Shortface lanx	*Fisherola* (= *Lanx*) *nuttalli*	**X**			
Western pearlshell	*Margaritifera falcata*			**X**	
Western ridged mussel	*Gonidea angulata*			**X**	
Winged floater	*Anadonta nuttalliana*			**X**	
Insects					
Columbia River tiger beetle[c]	*Cicindela columbica*	**X**			**X**
Bonneville skipper	*Ochlodes sylvanoides bonnevilla*			**X**	
Canyon green hairstreak	*Callophrys sheridanii neoperplexa*			**X**	
Coral hairstreak	*Harkenclenus titus immaculosus*			**X**	
Juba skipper	*Hesperia juba*			**X**	
Monarch	*Danaus plexippus*			**X**	
Nevada skipper	*Hesperia nevada*			**X**	
Northern checkerspot	*Chlosyne palla palla*			**X**	
Persius' duskywing	*Erynnis persius*			**X**	
Purplish copper	*Lycaena helloides*			**X**	
Ruddy copper	*Lycaena rubida perkinsorum*			**X**	

(a) Federal classification – See Table 4.5-1
(b) Reported, but seldom observed, on the Hanford Site
(c) Probable, but not observed, on the Hanford Site

Table 4.5-3. Washington State Plant Species of Concern on the Hanford Site

Common Name	**Scientific Name**	**State Listing**[(a)]
Annual paintbrush	*Castilleja exilis*	Watch List
Annual sandwort	*Minuartia pusilla var. pusilla*	Review Group 1
Basalt milk-vetch	*Astragalus conjunctus var. rickardii*	Watch List
Beaked spike-rush	*Eleocharis rostellata*	Sensitive
Bristly combseed	*Pectocarya setosa*	Watch List
Brittle prickly pear	*Opuntia fragilis*	Review Group 1
Canadian St. John's wort	*Hypericum majus*	Sensitive
Chaffweed	*Centunculus minimus*	Review Group 1
Columbia milkvetch	*Astragalus columbianus*	Sensitive [(b)]
Columbia River mugwort	*Artemisia lindleyana*	Watch List
Coyote tobacco	*Nicotiana attenuata*	Sensitive
Crouching milkvetch	*Astragalus succumbens*	Watch List
Desert evening-primrose	*Oenothera caespitosa*	Sensitive
Dwarf evening primrose	*Camissonia (= Oenothera) pygmaea*	Sensitive
False pimpernel	*Lindernia dubia anagallidea*	Watch List
Fuzzytongue penstemon	*Penstemon eriantherus whitedii*	Sensitive
Giant helleborine	*Epipactis gigantea*	Watch List
Gray cryptantha	*Cryptantha leucophaea*	Sensitive [(b)]
Great Basin gilia	*Gilia leptomeria*	Sensitive
Hedge hog cactus	*Pediocactus simpsonii var. robustior*	Review Group 1
Hoover's desert parsley	*Lomatium tuberosum*	Sensitive [(b)]
Kittitas larkspur	*Delphinium multiplex*	Watch List
Medic milkvetch	*Astragalus speirocarpus*	Watch List
Miner's candle	*Cryptantha scoparia*	Sensitive
Mousetail	*Myosurus clavicaulis*	Sensitive
Piper's daisy	*Erigeron piperianus*	Sensitive
Porcupine sedge	*Carex hystericina*	Watch List
Robinson's onion	*Allium robinsonii*	Watch List
Rosy balsamroot	*Balsamorhiza rosea*	Watch List
Scilla onion	*Allium scilloides*	Watch List
Shining flatsedge	*Cyperus bipartitus (rivularis)*	Sensitive
Small-flowered evening-primrose	*Camissonia (= Oenothera) minor*	Sensitive
Small-flowered nama	*Nama densum var. parviflorum*	Watch List
Smooth cliffbrake	*Pellaea glabella simplex*	Watch List
Snake River cryptantha	*Cryptantha spiculifera (= C. interrupta)*	Sensitive
Southern mudwort	*Limosella acaulis*	Watch List

Common Name	Scientific Name	State Listing[a]
Stalked-pod milkvetch	*Astragalus sclerocarpus*	Watch List
Suksdorf's monkey flower	*Mimulus suksdorfii*	Sensitive
Thompson's sandwort	*Arenaria franklinii thompsonii*	Review Group 2
Winged combseed	*Pectocarya penicillata*	Watch List

(a) Sensitive - Taxa that are vulnerable or declining and could become endangered or threatened without active management or removal of threats.
Review Group 1 - Taxa for which currently there are insufficient data available to support listing as threatened, endangered, or sensitive, and the State is actively searching for additional data or information.
Review Group2 - Taxa with unresolved taxonomic questions that would affect the listing status.
Watch List - Taxa that are more abundant and/or less threatened than previously assumed, but still of interest to the State.
(b) USFWS Columbia Basin federal species of concern.

A species of springsnail was discovered in the lower Hanford Reach during 2004 that, depending on the taxonomic system used, is either the Columbia springsnail (a species of *Pyrgulopsis* that has not been formally described or named) or the Jackson Lake springsnail (*Pyrgulopsis robusta*). Regardless of the name, the USFWS is currently evaluating this species for possible listing as endangered or threatened (70 FR 20512). This species currently has no federal or state status.

The USFWS has indicated that four additional federally listed threatened, endangered, or candidate species may be present in Benton, Franklin, or Grant counties (USFWS 2004). The pygmy rabbit (*Brachylagus idahoensis*) is a federal and state endangered species that is restricted to a few small populations north of the Hanford Site in Grant and Adams counties. Biologists have searched for this species on the Hanford Site, but it has not been conclusively observed. Ute Ladies tresses (*Spiranthes diluvialis*) is a threatened orchid that potentially could be found along the Columbia River but has not been observed near the Site; it is documented in Chelan and Okanogan counties (WNHP 2005). The yellow-billed cuckoo (*Coccyzus americanus*) is a federal candidate species that has been rarely observed in southeast Washington. It normally requires relatively large forested wetland areas for successful breeding. Such habitat is not available on the Hanford Site, and the species has not been observed on the Hanford Site. The northern wormwood (*Artemisia campestris* var *wormskioldii*) is a federal candidate and state endangered species that occurs along the Columbia River near Wanapum Dam. Extensive surveys along the shore of the Hanford Reach have failed to locate this species on the Hanford Site. The USFWS (2004) also lists a number of additional species of concern for Benton, Franklin, and Grant counties, including a number of bat species that may occur on the Hanford Site; most of these have no Washington State-level status designation.

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4.6 Cultural, Archaeological, and Historical Resources

E. P. Kennedy

The following section represents a summary of cultural, archaeological, and historical resources that are known to be located on the Hanford Site. This summary is based on a review of archaeological, historical, and ethnographic data collected from archival records, archaeological surveys, and ethnographic interviews. To date approximately 326 km^2 (126 mi^2) of the Hanford Site and adjacent areas have been surveyed for archaeological resources (Figure 4.6-1).

The Hanford Site is one of the richest cultural resource areas remaining in the western Columbia Plateau. The Hanford Site comprises a series of cultural landscapes that have been documented and evaluated containing the cumulative record of multiple occupations by both Native and non-Native Americans. For management and interpretive purposes, these cultural landscapes have been divided into the Native American landscape, the Early Settlers/Farming landscape, and the Manhattan Project and Cold War landscape. These landscapes contain numerous well-preserved archaeological and above-ground resources representing pre-contact, ethnographic, and historic periods. Period resources include sites with cultural materials that are thousands of years old, traditional cultural places, and buildings and structures from the pre-Hanford, Manhattan Project, and Cold War eras (DOE 1997a). Site-wide management of Hanford’s cultural resources follows the *Hanford Cultural Resources Management Plan* (DOE 2003).

Approximately 1,550 cultural resources sites and isolated finds, and 531 buildings and structures have been documented since 1926 on the Hanford Site. Early archaeological reconnaissance projects dating from 1926 to 1968 (Drucker 1948; Krieger 1928; Rice 1968a, b) and more recent National Historic Preservation Act Section 110 and Section 106 archaeological surveys conducted between 1987 and 2004 have resulted in formal recording of these resources on archaeological site and isolate forms and Washington State Historic Property Inventory forms. The DOE archives these records.

Forty-nine cultural resource sites are listed on the National Register of Historic Places (National Register) (Table 4.6-1). Most of these are associated with the Native American landscape and are part of six archaeological districts situated on the shores and islands of the Columbia River. [(a)] B-Reactor is the exception; it is associated with the Manhattan Project and the Cold War period. Formal National Register-eligibility determinations have been completed for 531 buildings and structures, most as contributing properties to the Manhattan Project/Cold War era Historic District. Eighteen individual archaeological sites, one archaeological district, and three places with traditional cultural value have also been determined eligible for listing in the National Register. These sites are dispersed throughout the Hanford Site and represent the three cultural landscapes. In addition to the National Register sites and districts, 47 of Hanford's cultural resource sites (46 in three districts and one site) are listed in the Washington Heritage Register (Table 4.6-2). These are associated with the Native American cultural landscape and are located predominantly along the Columbia River.

(a) In order to protect resources, the National Historic Preservation Act (16 USC 470) Section 304, and Archaeological Resources Protection Act (16 USC 470aa) Section 9 requires agencies to withhold from public disclosure information on the location and character of cultural resources.

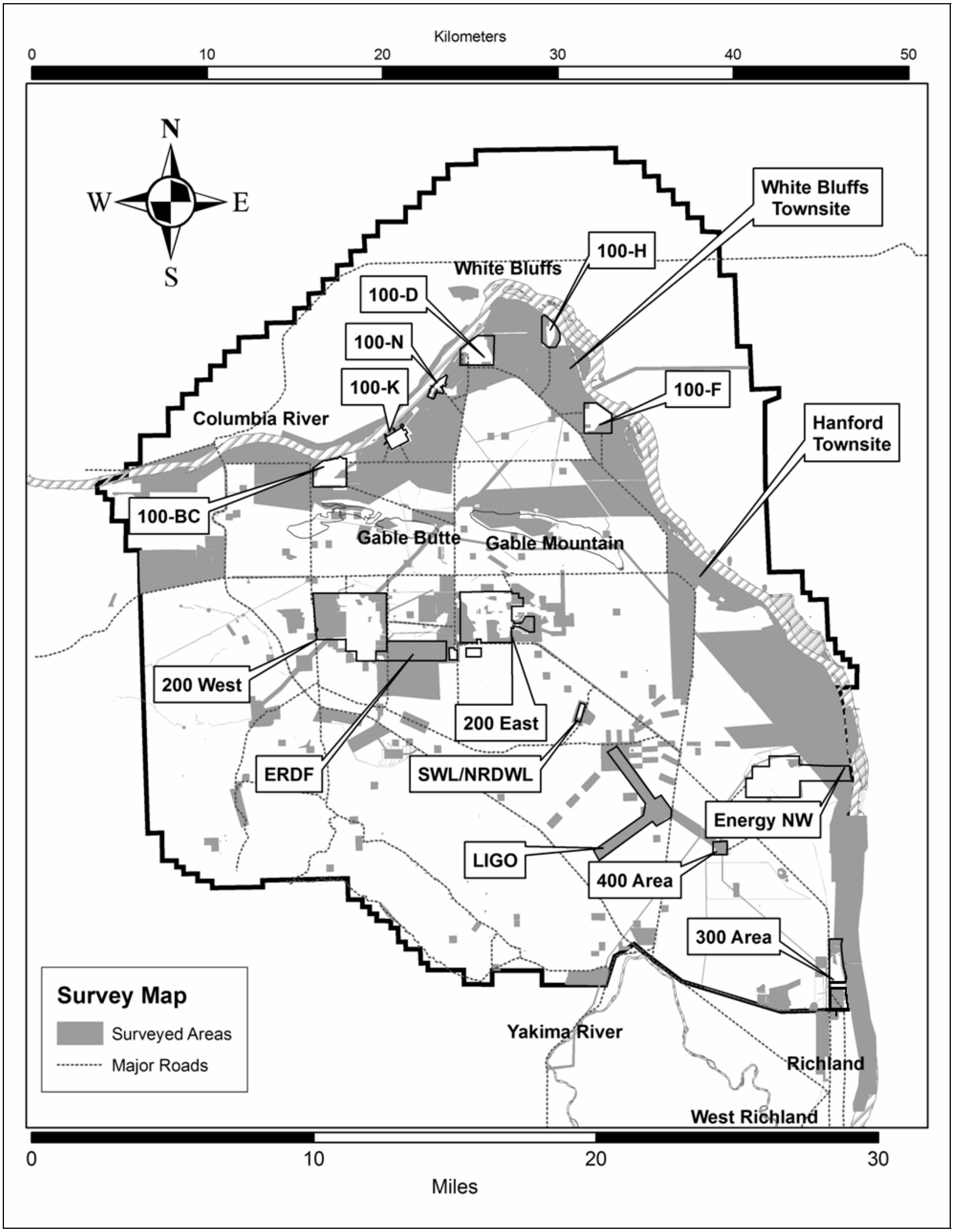

Figure 4.6-1. Areas Surveyed for Cultural Resources on the Hanford Site, Washington, and Local Vicinity

Table 4.6-1. Historic Buildings, Archaeological Sites, and Districts Listed in the National Register of Historic Places on the Hanford Site, Washington

Property Name	General Location	Landscape Association
Districts:		
Hanford North Archaeological District	100-F	Native American
Locke Island Archaeological District	100-H	Native American
Ryegrass Archaeological District	100-K/100-N	Native American
Savage Island Archaeological District	Energy Northwest	Native American
Snively Canyon Archaeological District	Rattlesnake Hills	Native American
Wooded Island Archaeological District	300 Area	Native American
Sites:		
Hanford Island Archaeological site	Hanford Townsite	Native American
Paris Archaeological site	Vernita Bridge	Native American
Rattlesnake Springs sites	Rattlesnake Mountain	Native American
Building:		
105-B Reactor	100-B/C Area	Manhattan Project

Table 4.6-2. Archaeological Sites and Districts Listed in the Washington Heritage Register on the Hanford Site, Washington

Property Name	General Location
Districts:	
Coyote Rapids Archaeological District	100-K Area
Hanford South Archaeological District	300 Area
Wahluke Archaeological District	100-D Area
Site:	
Gable Mountain Archaeological site	600 Area, North of 200 East

DOE identified a National Register-eligible Hanford Site Manhattan Project and Cold War Era Historic District (Historic District) that serves to organize and delineate the evaluation and mitigation of Hanford's plutonium production built environment (Table 4.6-3). Standards for evaluating and mitigating the built environment were established in accordance with National Register criteria, as well as historic contexts and themes associated with nuclear technology for national defense and non-military purposes, energy production, and human health and environmental protection. DOE completed a programmatic agreement that addresses management of the built environment (buildings and structures) constructed during the Manhattan Project and Cold War periods. The Federal Advisory Council on Historic Preservation and the Washington State Historic Preservation Officer concurred with this programmatic agreement in 1996 (DOE 1996a).

Table 4.6-3. Historic Buildings, Archaeological Sites, and Districts Determined Eligible for Listing in the National Register of Historic Places on the Hanford Site, Washington

Property Name	General Location
Native American:	
Wanawish Fishing Village	600 Area
Gable Mountain/Gable Butte	200 East Area/600 Area
Mooli Mooli	100-N Area
45BN423 [(a)]	100-K Area
45BN431/432/433	100-F Area
45BN434	100-F Area
45BN446	100-K Area
45BN606	100-F Area
45BN888	100-D Area
45BN1422	100-B/C Area
45BN135	100-F Area
Early Settlers:	
Midway-Benton Transmission Line	600 Area
McGee Ranch/Cold Creek Valley District	Cold Creek Valley
Fry and Conforth Farm	100-B/C Area
White Bluffs Road	200 West to White Bluffs Townsite
Richland Irrigation Canal	300 Area
First Bank of White Bluffs	White Bluffs Townsite
Bruggemann's Warehouse	100-B/C Area
Hanford Electrical Substation-Switching Station	Hanford Townsite
Hanford High School	Hanford Townsite
Coyote Rapids Hydroelectric Pumping Plant	100-B/C Area
Manhattan Project/Cold War:	
Hanford Site Manhattan Project and Cold War Era Historic District	100, 200, 300, 400, 600, 700, and 1100 Areas
Five Anti-Aircraft Artillery sites	600 Area
Hanford Atmospheric Dispersion Test Facility	200 Area
Hanford Construction Camp Burn Pit (45BN1437)	100 Areas

(a) Smithsonian Trinomial numbers are the standard designation for archaeological sites in the United States. 45 represents the state of Washington. BN, GR and FR represent Benton, Grant and Franklin counties. The number that follows indicates that the site was the n^{th} archaeological site to be recorded.

Establishment of the Historic District resulted in the selection of 190 buildings, structures, and complexes as contributing properties within the historic district recommended for individual documentation. Certain property types, such as mobile trailers, modular buildings, storage tanks, towers, wells, and structures with minimal or no visible surface manifestations, were exempt from the identification and evaluation requirements.

Approximately 900 buildings and structures were identified as either contributing properties with no individual documentation requirement (not selected for mitigation) or as non-contributing/exempt properties (DOE 1998c).

Hanford Site projects that entail transfer or lease of property, disturbing ground, and/or altering or demolishing existing structures result in cultural resource reviews. These reviews ensure that archeological sites, traditional cultural places, and buildings and structures listed in or eligible for the National Register are considered before impacts by proposed projects.

4.6.1 Native American Cultural Landscape

For thousands of years American Indians have utilized the lands both within and around the Hanford Site (Relander 1956; Spier 1936; Walker 1998). Historically, groups such as the Yakama, the Walla Walla, the Wanapum, the Palouse, the Nez Perce, the Columbia, and others had ties to the Hanford area during the ethnohistoric period and before. In 1855, representatives of the U.S. Government signed treaties with representatives from many of the different Indian groups in the southern Plateau. The 14 Bands and Tribes of the Yakama Nation ceded the western portion of present-day Hanford to the U.S. Government retaining the right to fish, hunt, erect fish-curing structures, gather food, and graze stock on open/unclaimed portions of the lands. The Umatilla, Walla Walla, and Cayuse groups ceded the eastern portion of present-day Hanford to the U.S. Government, also retaining rights equivalent the Yakama’s. The Columbia, Palouse, and Wanapum did not sign treaties and either continued living in the area or later moved to reservations where they had relatives.

Today, descendents of those with historical ties to Hanford are generally enrolled members of the following federally recognized groups: the Confederated Tribes and Bands of the Yakama Nation, the Confederated Tribes of the Umatilla Indian Reservation, the Nez Perce Tribe, or the Confederated Tribes of the Colville Reservation. Some Wanapum descendents still live at Priest Rapids, but the group is not a federally recognized Indian Tribe. The record of Native American use and history is reflected in the archaeological sites and traditional cultural places that are located across the Hanford Site.

4.6.1.1 Archaeological Resources

More than 8,000 years of pre-contact human activity in the largely arid environment of the mid-Columbia River region have left extensive archaeological deposits along the river shores (DOE 2003; Greengo 1982; Leonhardy and Rice 1970). Well-watered areas inland from the river also show evidence of concentrated human activity (Chatters 1982; DOE 2003; Daugherty 1952; Greene 1975; Leonhardy and Rice 1970; Rice 1980a) and recent research (Woody 2003) has indicated ephemeral use of arid lowlands for hunting and other resource procurement activities. Throughout most of the region, hydroelectric development, agricultural activities, and domestic and industrial construction have destroyed or covered many of these deposits. Amateur artifact collectors have impacted numerous sites. Because the areas included in the Hanford Site were restricted to public access, archaeological deposits found in the Hanford Reach of the Columbia River and on adjacent plateaus and mountains are more protected than many other areas.

Pre-contact period sites common to the Hanford Site include pit house villages, various types of open campsites; spirit quest monuments (rock cairns); hunting camps, game drive complexes, and quarries in nearby mountains and rocky bluffs (Rice 1968a, b; Rice 1980a); hunting/kill sites in lowland stabilized dunes; and small temporary camps near perennial sources of water located away from the river (Rice 1968b).

A historic context for the pre-contact period of the Hanford Site has been prepared as part of a National Register Multiple Property Documentation form to assist with the evaluation of the National Register eligibility of pre-contact archaeological resources (DOE 1997a).

4.6.1.2 Traditional Cultural Places

During 1990, the National Park Service formalized the concept of traditional cultural property or traditional cultural place (TCP) as a means to identify and protect cultural landscapes, places, and objects that have special cultural significance to American Indians and other ethnic groups (Parker and King 1990). A TCP eligible for the National Register is associated with “cultural practices or beliefs of a living community that are rooted in that community’s history and are important in maintaining the continuing cultural identity of the community” (Parker and King 1990).

The Hanford Reach and the greater Hanford Site, a geographic center for regional American Indian religious activities, is central to the practice of the Indian religion of the region and many believe the Creator made the first people here (DOI 1994). Indian religious leaders such as Smoholla, a prophet of Priest Rapids who brought the Washani religion to the Wanapum and others during the late 19th century, began their teachings here. Native plant and animal foods, some of which can be found on the Hanford Site, are used in the ceremonies performed by tribal members. Based on consultation with affected tribal members and interviews with tribal elders, it is known that prominent landforms such as Rattlesnake Mountain, Gable Mountain, and Gable Butte, as well as various sites along and including the Columbia River, remain sacred to them.

American Indian traditional cultural places within the Hanford Site include, but are not limited to, a wide variety of places and landscapes: archaeological sites, cemeteries, trails and pathways, campsites and villages, fisheries, hunting grounds, plant gathering areas, holy lands, landmarks, important places in Indian history and culture, places of persistence and resistance, and landscapes of the heart (Bard 1997). Because affected tribal members consider these places sacred, many traditional cultural sites remain unidentified. The DOE continues to consult with Hanford Tribes for input on these TCP locations in accordance with Principle IV of the American Indian and Alaska Native Tribal Government Policy (DOE 2000).

A historic context for the Ethnographic/Contact Periods of the Hanford Site has been prepared as part of a National Register Multiple Property Documentation form to assist with the evaluation of the National Register eligibility of American Indian ethnographic resources (DOE 1997a).

4.6.2 Early Settlers/Farming Landscape

The Early Settlers/Farming landscape is comprised of those areas on the Hanford Site where people, mainly of European descent, and some of other ethnicities, settled in the Columbia River Plateau prior to the start of the Manhattan Project during 1943. Non-Native American presence in the mid-Columbia began during 1805 with the arrival of the Lewis and Clark Expedition. It was not until the late 19th and early 20th centuries, however, that non-Native American peoples began intensive settlement on the Hanford Site. A record of their activities and use is present in the archaeological sites, traditional cultural places, and buildings and structures that are located throughout the Hanford Site.

A historic context for the Euro-American resettlement period (pre-Hanford era) has been prepared as part of a National Register Multiple Property Documentation form to assist with the evaluation of the National Register eligibility of historic archaeological resources, traditional cultural places, and historic structures (DOE 1997a).

4.6.2.1 Archaeological Resources

The first Euro-Americans to pass near the Hanford Site were part of the Lewis and Clark expedition, which traveled along the Columbia and Snake rivers during their 1803 to 1806 exploration of the Louisiana Territory. The first European explorer to cross the Hanford Site was David Thompson, who traveled along the Columbia River from Canada during his 1811 exploration of the Columbia River. Other visitors included fur trappers, military units, and miners who traveled through the Hanford Site on their way to lands up and down the Columbia River and across the Columbia Basin. It was not until the 1860s that merchants set up stores, a freight depot, and the White Bluffs Ferry on the Hanford Reach. Chinese miners began to work the gravel bars for gold during the 1860s. Cattle ranches were established in the 1880s and farmers followed during the next two decades. Agricultural development, irrigation districts, and roads were established in the eastern portion of the central Hanford Site. Several small towns, including Hanford, White Bluffs, Richland, and Ringold, grew up along the riverbanks during the early 20th century. In 1913, the communities' accessibility to outside markets expanded with the arrival of the Chicago, Milwaukee, St. Paul and Pacific Railroad branch line (Priest Rapids-Hanford Line) from Beverly, Washington. Ferries were established at Richland, Hanford, Wahluke, and Vernita (Figure 4.6-2). The towns and nearly all other structures were razed in the years after the U.S. Government acquired the land for the Hanford Engineer Works in 1943 (DOE 2003; ERTEC 1981; Rice 1980a).

Archaeological resources from the Early Settlers/Farming period are scattered over the entire Hanford Site and include numerous areas of gold mining features along the riverbanks of the Columbia and remains of homesteads, building foundations, agricultural equipment and fields, ranches, and irrigation features. Archaeological properties from this period include the Hanford Irrigation Canal; Hanford townsite; Wahluke Ferry; White Bluffs townsite; Vernita Ferry; White Bluffs Road; and Chicago, Milwaukee, St. Paul and Pacific Railroad (Priest Rapids-Hanford Line) and associated stops.

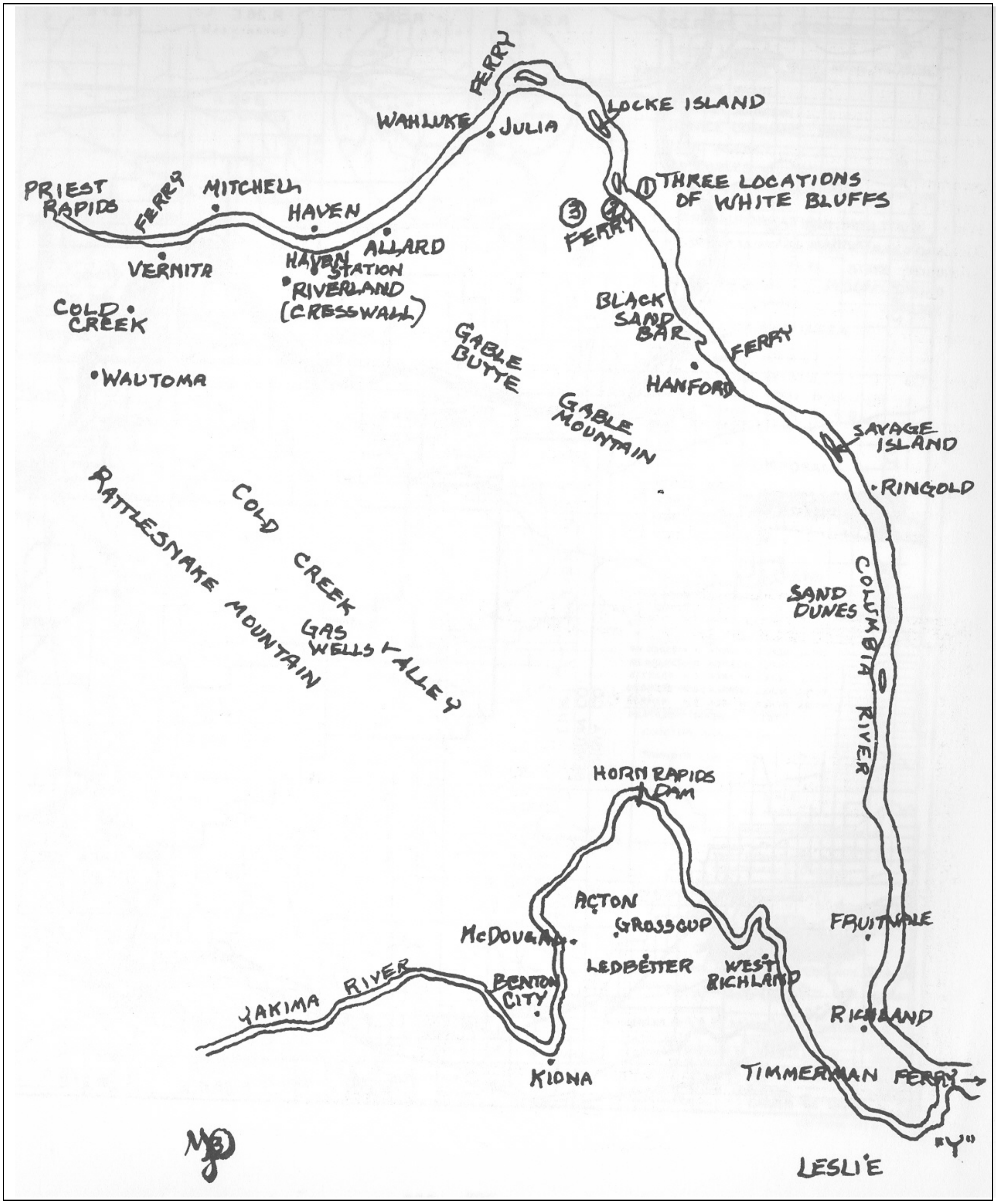

Figure 4.6-2. Map of the Hanford Site, Washington, Showing Towns, Ferries and Prominent Features Associated with the Early Settlers Landscape (Parker 1986)

4.6.2.2 Traditional Cultural Places

Traditional cultural places associated with the Early Settlers/Farming landscape that are located on the Hanford Site include structures and places that are important to descendants of pre-1943 settlers in the region. These places are deeply rooted in the memories of local residents and include, but are not limited to, numerous home sites and townsites, orchards, fields, and places of former community activities (e.g., swimming holes, town square). Previous residents of the region and their descendents visit their homes annually with friends and family.

4.6.2.3 Buildings and Structures

Although most of the Early Settlers/Farming structures were demolished by the U.S. Government to build infrastructure for the Hanford Engineer Works during 1943 (DOE 2003; ERTEC 1981; Rice 1980a), a small number of buildings associated with the Early Settlers/Farming landscape remain standing today. They include the Hanford Irrigation and Power Company’s pumping plant at Coyote Rapids, the high school and the electrical substation at the Hanford townsite, First Bank of White Bluffs, Bruggemann's fruit warehouse, and the blacksmith cabin at the East White Bluffs ferry landing. These structures are located near the Columbia River.

4.6.3 Manhattan Project and Cold War Cultural Landscape

The Manhattan Project and Cold War era landscape is comprised of cultural resources associated with plutonium production, military operations, research and development, waste management, and environmental monitoring activities that took place beginning with the establishment of the Hanford Site (Hanford Engineer Works) during 1943 to the end of the Cold War during 1990.

The Hanford Site built environment is an industrial landscape that consists of buildings and structures constructed during the Manhattan Project and Cold War period. This industrial landscape makes up the Hanford Site Manhattan Project and Cold War Era Historic District. The DOE Richland Operations Office, the State Historic Preservation Officer, and the Federal Advisory Council on Historic Preservation, through a programmatic agreement to manage the Manhattan Project and Cold War built environment, determined that a historic district afforded the best means to inventory, assess, and mitigate the most significant buildings and structures constructed during the Manhattan Project and Cold War era. Industrial, scientific, administrative, environmental monitoring, waste management, infrastructure, and military facilities constructed during the Manhattan Project and Cold War era can be found in all of the Site areas.

While buildings and structures representing this era are located throughout the Site, evidence of military operations consists mostly of archaeological remains. Military operations in various forms took place on the Site from World War II to the early 1960s. Most of the military operations, however, took place beginning with the establishment of Camp Hanford by the U.S. Army during 1950-51 until its closure in 1961. Camp Hanford was a military outpost with the main cantonment located in North Richland and forward positions situated throughout the Site consisting of anti-aircraft artillery sites and Nike missile installations.

Historic contexts were completed for the Manhattan Project and Cold War eras as part of a National Register Multiple Property Documentation Form prepared for the Hanford Site to assist with the evaluation of National Register eligibility of buildings and structures Site wide (DOE 1997a). Additionally, historical narratives and individual building documentations have been completed for the *History of the Plutonium Production Facilities at the Hanford Site Historic District, 1943-1990* (DOE 2002c). Five hundred twenty-eight Manhattan Project and Cold War era buildings/structures and complexes are eligible for the National Register as contributing properties within the Historic District. Of that number, 190 were documented individually as required by the programmatic agreement signed in 1996 (DOE 1996a). U.S. Department of Energy, Richland Operations Office (DOE/RL) is undertaking an assessment of the contents of the contributing buildings and structures to locate and identify any Manhattan Project and Cold War era artifacts that may have interpretive or educational value for museum exhibit purposes (DOE 1998c).

4.6.3.1 Archaeological Resources

Archaeological remains of military sites associated with the Manhattan Project and Cold War landscape are scattered throughout the Hanford Site's 600 Area. These archaeological resources are mainly located within the former Camp Hanford forward positions, the 16 anti-aircraft artillery sites that encircled the 100 and 200 Areas, and the three Nike missile installations on Wahluke Slope. (A fourth Nike position, in relatively intact condition, is located at the base of Rattlesnake Mountain on Fitzner-Eberhardt Arid Lands Ecology Reserve Unit.) The Nike position on the reserve is eligible for inclusion in the National Register as a contributing property within the Hanford Site Manhattan Project and Cold War Era Historic District. Five of the 16 anti-aircraft artillery sites are eligible for the National Register.

The anti-aircraft artillery and Nike sites were strategic components in Camp Hanford's military defense of the Site's plutonium production facilities during the 1950s. Potential archeological resources at these sites include former gun emplacements, launch and radar sites, concrete foundations and pads, pathways/sidewalks, associated dumpsites, small arms firing ranges, and ammunition caches.

The archaeological remains of the Atmospheric Dispersion Test Facility Grid are located in the Hanford Site east of the 200 West Area. The facility was used to conduct air diffusion experiments between 1959 and 1974, as well as the monitoring and study of airborne waste dispersions during the operation of the plutonium production facilities on the Hanford Site.

4.6.3.2 Buildings and Structures

Historic built resources documented from the Manhattan Project and Cold War eras include buildings and structures found in the 100, 200, 300, 400, 600, 700, and the former 1100 Areas. The most significant of these are the plutonium production and test reactors, chemical separation and plutonium finishing buildings, and fuel fabrication/manufacturing facilities. The first reactors, 105-B, 105-D, and 105-F, were constructed during the Manhattan Project. Plutonium for the first atomic explosion and the bomb dropped on Nagasaki, Japan, at the end of World War II were produced at the Hanford Site. Additional reactors and processing facilities were constructed after World War II during the Cold War period. All reactor containment buildings still stand, although many ancillary structures have been removed, and C, D, DR, F, and H Reactors have been considerably modified under the Interim Safe Storage project.

DOE/RL will consider the retention of National Register-eligible buildings and structures that may qualify for adaptive reuse as interpretive centers, museums, industrial, or manufacturing facilities (DOE 1996a).

4.6.4 Site Areas

Archaeological sites, traditional cultural places, buildings, and structures are found in each of several areas on the Hanford Site, including the 100, 200, 300, 400, 600, and 700 Areas. Since it was the Manhattan Project that established these areas as geographical locations on the Hanford Site, many cultural resources located within these areas are associated with that landscape. Many of these areas were developed over the top of existing cultural resources from the Native American and Early Settlers/Farming landscape. Hence, these earlier landscapes were changed; however, many resources remain as they were prior to 1943. A brief synopsis of known resources found in these areas is presented in the following subsections.

4.6.4.1 100 Areas

Field surveys were completed in the 100 Areas from 1991 to 1995 (Andrefsky et al. 1996; Chatters et al. 1992; Wright 1993). Much of the surface area within the 100 Areas operable units has been disturbed by the industrial activities that have taken place during the past 50 years; however, these areas still contain many cultural resources.

Each of the three landscapes is represented in the 100 Areas by the presence of archaeological sites, traditional cultural properties, and reactor facilities. Most of these resources reflect past use of river resources such as open camps, fishing sites, farmsteads, pump houses, gold mining pits, and water intake and outtake structures.

Plutonium production reactors and their ancillary support facilities were located in the 100 Areas. The production reactors functioned to irradiate uranium fuel elements, the essential second step in the plutonium production process. A complete inventory of 100 Areas buildings and structures was completed during FY 1995, and a National Register evaluation for each was finalized during 1996. To date, 146 buildings/structures have been inventoried in the 100 Areas. Of that number, 55 have been individually documented and determined eligible for the National Register as contributing properties within the Historic District recommended for individual documentation (DOE 1998c). As remediation continues in the 100 Areas, the potential exists for inadvertent discoveries of archaeological resources. To understand impacts to cultural resources and to reduce the need to perform extensive reviews on highly disturbed areas, disturbance maps and reports have been completed for 100-B/C, 100-D/DR, and 100-F Areas.

100-B/C Area

Archaeological Resources. There is a high density of archaeological resources associated with the Native American cultural landscape in the 100-B/C Area. Three are located partially within the 100-B/C Area (Rice 1968a; Rice 1980a, b), and 35 have been recorded within the immediate vicinity of the B/C Area during archaeological surveys completed during 1995.

Historic archaeological resources include the remains of Haven Station, a small stop on the former Chicago, Milwaukee, St. Paul and Pacific Railroad, located to the west of the 100-B/C Area.

One archaeological site and the remains of the small community of Haven lie on the opposite bank of the Columbia River.

Three archaeological sites (45BN447, 45BN446, and 45BN1422) located near 100-B/C have been investigated. Test excavations conducted during 1991 at archaeological site 45BN447 revealed large quantities of deer and mountain sheep bone, and projectile points dating from 500 to 1,500 years ago. Archaeological site 45BN446 is considered to be eligible for listing in the National Register, in part, because it may contain new information about the Frenchman Springs and Cayuse Phases of mid-Columbia prehistory. Data recovery efforts conducted during 2006 at archaeological site 45BN1422 documented a discrete activity area (dating between 2,860 and 2,450 years ago) marked by three interrelated features associated with freshwater mussel shell processing.

Traditional Cultural Places. Many sites related to hunting and religious activities are located at the west end of Gable Butte. These sites are associated with the Gable Mountain-Gable Butte Cultural District.

Buildings and Structures. The only structure associated with the Early Settlers/Farming landscape in the 100-B/C Area is the Hanford Irrigation and Power Company pumping plant built at Coyote Rapids during 1908 and located east of the 100-B/C Area.

The 105-B Reactor was the world's first full-scale plutonium production reactor and is designated as a National Historic Mechanical Engineering Landmark. It is also listed in the National Register, is a National Civil Engineering Landmark, and was given the Nuclear Historic Landmark Award. Historic American Engineering Record (HAER) documentation of B Reactor was completed during 1999 (DOE 2001b). A total of 14 buildings and structures within the reactor area have been recorded on historic property inventory forms. Of that number, 10 were selected as representative examples of buildings and structures eligible for the National Register as contributing properties within the Historic District recommended for individual documentation. These include 104-B-1 Tritium Vault, 104-B-2 Tritium Laboratory, 105-B Reactor, 105-B-Rod Tip Cave, 116-B Reactor Exhaust Stack, 117-B Exhaust Air Filter Building, 118-B-1 Solid Waste Burial Trench, 181-B River Pump House, and 182-B Reservoir and Pump House (DOE 1998c).

An assessment of the contents of the 105-B Reactor was conducted to locate and identify Manhattan Project and Cold War era artifacts that may have interpretive or educational value in potential exhibits. Thirty-nine industrial artifacts were identified and tagged, with many on display as interpretive exhibits in the reactor. Tagged artifacts from 105-D and F Reactors were transferred to B Reactor to be displayed as interpretive exhibits.

100-D/DR Area

Archaeological Resources. The Wahluke Archaeological District is located north of the reactor area. Most remaining sites represent early Euro-American settlement activities. The former community of Wahluke, which was at the landing of a ferry of the same name, is situated on the river’s north bank. Remains of historic farmsteads are scattered throughout the nearby area. An archaeological excavation was completed during 2001 at 45BN888, a camp site associated with the Native American cultural landscape adjacent to the reactor area.

Traditional Cultural Places. Twenty-seven individual rock cairns located south of the reactor area are associated with an area known to have traditional cultural importance to affected tribes.

Buildings and Structures. All the buildings and structures in the 100-D/DR Area were built during the Manhattan Project and Cold War eras. Twenty buildings/structures have been inventoried, including the 105-D and 105-DR Reactor buildings. Both reactors are eligible for the National Register as contributing properties within the Historic District. An assessment of the contents of 105-D and 105-DR was conducted to locate and identify Manhattan Project and Cold War era artifacts that may have interpretive or educational value in potential exhibits. Twenty-four industrial artifacts were identified and tagged in 105-D, including control panels, a reactor curtain, lunch tables, benches, tools, and signs. All the tagged artifacts in 105-D were transferred to B Reactor. Ten industrial artifacts were identified and tagged in 105-DR, including a radiological worker procedures poster, an instrument ladder, three metal signs, a lead "pig" sampling chamber, a control panel, vintage ceiling lights, and graphite blocks. The 185/189-D buildings and adjoining facilities, all part of the 190-D complex, were eligible for the National Register and were documented to HAER standards (DOE 1998c); however, the 190-D Complex has been demolished.

100-F Area

Archaeological Resources. The 100-F Area is situated on the shore of the Columbia River and contains many cultural sites associated with the Native American cultural landscape. According to Relander (1956), a nearly continuous string of camps and villages of the Wanapum extended from the Hanford townsite upstream to the White Bluffs townsite. Sites of particular importance include three that are eligible for listing in the National Register – 45BN606, 45BN135, and site complex 45BN431, 432, and 433. Radiocarbon dates obtained from these sites through archaeological investigations provide a range of occupation extending from 8,860 to 270 years ago; however, the majority of dates occur after 3,000 years suggesting an emphasis on relatively recent occupations. Analysis of artifacts and features indicate these were seasonal camps devoted primarily to shellfish, fish, mammal, and plant procurement and processing. A historic Wanapum cemetery also is located near the 100-F Area.

The principal site associated with the Early Settlers/Farming landscape near 100-F is the White Bluffs townsite and ferry landing. This location was the upriver terminus of shipping during the mid-19th century. It was at this point that supplies for trappers, traders, and miners were off-loaded, and commodities from the interior were transferred from pack trains and wagons to riverboats. The first store and ferry of the mid-Columbia region were located at the ferry landing (ERTEC 1981). A log cabin, thought to have been a blacksmith shop built during the late 19th century, still stands. Test excavations conducted at the cabin by the University of Idaho revealed historic and pre-contact cultural materials. The structure was recorded according to standards of the Historic American Buildings Survey (Rice 1976). Stabilization of the structure was carried out by the USFWS during 2001. The only remaining structure associated with the White Bluffs townsite (near the railroad) is the First Bank of White Bluffs.

Traditional Cultural Places. Cemeteries associated with the Native American landscape are known to be in the vicinity of the 100-F Area.

Buildings and Structures. Three Manhattan Project/Cold War era buildings/structures have been inventoried in this area, including the 105-F Reactor building. An assessment of the contents of 105-F was conducted to identify any artifacts that may have value as potential museum exhibits. Eleven industrial artifacts were identified and tagged, including a fuel scale, elevator control panel, two shop signs, four safety signs, a hardhat, graphite blocks, and vintage ceiling lights. All tagged artifacts were transferred to B Reactor or the Columbia River Exhibition of History, Science, and Technology (CREHST) museum in Richland, Washington, for inclusion into the Hanford Collection.

100-H Area

Archaeological Resources. There are two historic Wanapum cemeteries, six camps, and three house pit villages located within the vicinity of the 100-H Area. The largest village contains approximately 100 house pits and numerous storage caches. It appears to have been occupied consistently from 2,500 years ago to 1943 (Rice 1968a). The cemeteries, camps, and villages are included in the Locke Island Archaeological District.

Archaeological sites associated with the Early Settlers/Farming landscape in the 100-H Area include several early 20th century farmsteads and associated domestic debris. None of these sites has yet been evaluated for eligibility for listing in the National Register. Remains of military encampments associated with the Manhattan Project and Cold War landscape are also located near the 100-H Area.

Traditional Cultural Places. Wanapum cemeteries are known to be located in the vicinity of the 100-H Area.

Buildings and Structures. Four Cold War era buildings/structures were inventoried in the 100-H Area. Of that number, only the 105-H Reactor is eligible for the National Register as a contributing property within the Historic District (DOE 1998c). An assessment of the contents of 105-H was conducted to locate and identify Cold War era artifacts that may have interpretive or educational value in potential exhibits. No items were tagged.

100-K Area

Archaeological Resources. Several archaeological sites have been recorded within the vicinity of the 100-K Area. Two of these sites (45BN423 and 45BN434) are believed to date to the Cascade Phase 8,000 to 4,000 years ago and are eligible for listing in the National Register. The Coyote Rapids Archaeological District and the Ryegrass Archaeological District are located near the 100-K Area.

The Hanford Irrigation Canal and the former Chicago, Milwaukee, St. Paul and Pacific Railroad, two important linear features associated with the Early Settlers/Farming landscape, are also present in the 100-K Area. Archaeological remains of the Early Settlers/Farming community at Coyote Rapids and a number of historic farmstead sites are located west of the 100-K Area.

Traditional Cultural Places. Events took place at this locale during the mid-19th century that are important to American Indian people of the interior northwest (Relander 1956). The Washani religion (also known as Seven Drums or Dreamer religion) was first practiced here, eventually spreading to many neighboring tribes. A group of pit houses with an associated long house and sweat lodge have been identified and may have been the site of the Wanapum religious leader Smohalla's first *Washat* dance. An area located a short distance upstream is also recognized as a traditional cultural place because of its association with Wanapum history and traditional cultural beliefs (Relander 1956).

Buildings and Structures. Thirty-eight buildings and structures have been inventoried in the 100-K Area, including the 105-KE and 105-KW Reactor buildings. Of that number, 13 were selected as representative examples of buildings and structures eligible for the National Register as contributing properties within the Historic District recommended for individual documentation. These include the 105-KW Reactor, 107-KW Retention Basin, 181-KW River Pump House, 183-KW Filter Plant, and 190-KW Main Pump House (DOE 1998c).

An assessment of the contents of 105-KE and 105-KW was conducted to identify any artifacts that may have educational or interpretive value as potential museum exhibits. Twenty-two industrial artifacts were identified and tagged in 105-KE Reactor including tools, signage, radiation monitoring equipment, and furniture. Nine artifacts were identified and tagged from 105-KW Reactor including furniture, a measurement scale, tools, and a floodlight. An assessment of the contents of the other historic buildings in the 100-K Area resulted in 23 additional artifacts being identified and tagged. In April 2006, contents of the 116-KW, 117-KW, 118-KW, 119-KW, 181-KW, 1701-K, and 1720-K Buildings were inventoried. No artifacts were identified.

100-N Area

Archaeological Resources. Three significant sites (two house pit villages [45BN149 and 45BN150] and one cemetery [45BN151]) comprise the Ryegrass Archaeological District and are located within close proximity to the 100-N/100-K Area. Another significant pithouse village complex (45BN179 and 45BN180) has been recorded and excavated just upstream from the 100-N area. These sites were later found to be part of 45BN149, which is already listed in the National Register as part of the Ryegrass Archaeological District. Extant knowledge about the archaeology of the 100-N Area is based largely on reconnaissance-level archaeological surveys conducted during the late 1960s to late 1970s (Rice 1968b; Rice 1980a, b), which do not purport to produce complete inventories of the areas covered.

The most common evidence of activities associated with the Early Settlers/Farming landscape found near the 100-N Area consists of the archaeological remains of farmhouses and agricultural fields. The historic Hanford Irrigation Canal is adjacent to and south of the 100-N Area.

Traditional Cultural Places. Three places near the 100-N Area are known to have been of importance to the Wanapum. Cataclysmic flooding at the end of the Pleistocene formed the numerous small rolling hills known as *Mooli Mooli*, which means Little Stacked Hills. Gable Mountain (called *Nookshai* or Otter) and Gable Butte, which lie to the south of the river, are highly significant to the tribes. According to Relander (1956) these are places where Wanapum youths would go on overnight vigils seeking guardian spirits. Rock cairns located in these areas indicate ethnographic use of these areas. Sites of religious importance may also exist near the 100-N Area.

Buildings and Structures. The 100-N Reactor, completed during 1963, was the last of the plutonium production, graphite-moderated reactors. The design of N Reactor differed from the previous eight reactors in several ways, affording greater safety and enabling co-generation of electricity. Sixty-six Cold War era buildings and structures were inventoried in the 100-N Area. Thirty 100-N Area buildings/structures were selected as representative examples of facilities eligible for the National Register as contributing properties within the Historic District recommended for individual documentation (DOE 1998c). These include the 105-N Reactor, 109-N Heat Exchanger Building, 181-N River Water Pump house, 183-N Water Filter Plant, 184-N Plant Service Powerhouse, 185-N Export Powerhouse, and the 1112-N Guard Station (DOE 1997d).

An assessment of the contents of 185-N was conducted to locate and identify Cold War era artifacts that may have interpretive or educational value in potential exhibits. Six artifacts were identified and tagged, including control room panels, phone booths, a "hear-here" phone, a metal cart, and a safety sign. All the artifacts were photographed in place or transferred to CREHST Museum in Richland, Washington, for inclusion to the Hanford Collection. Building 185-N has been demolished. In 2006, the contents of the 105-N, 108-N, 109-N, 116-N, 117-N, 119-N, 119-NA, 163-N, 181-N, 181-NA, 182-N, 183-N, 183-NA, 183-NB, 183-NC, 184-N, 1116-N, 1310-N, 1313-N, 1314-N, 1322-NB, and 1722-N Buildings were inventoried. No artifacts were identified.

4.6.4.2 200 Areas

Much of the 200 Areas have been altered by Hanford operations. The Hanford Cultural Resources Program conducted a comprehensive archaeological resources survey of the fenced portions of the 200 Areas during 1987 and 1988 (Chatters and Cadoret 1990). The results indicate that evidence of cultural resources associated with the Native American cultural landscape and the Early Settlers/Farming landscape is minimal. Archaeological surveys conducted since that time have revealed much the same pattern.

Archaeological Resources. The most significant archaeological resource located in the 200 Areas is an extensive linear feature known as the White Bluffs Road, a portion of which passes diagonally southwest to northeast through the 200 West Area. This road, in its entirety, is eligible for listing in the National Register, except for non-contributing segments of the White Bluffs Road that are located in the 200 West Area. Non-contributing segments of the White Bluffs Road are those sections that have been so considerably altered that they lack historic integrity, but retain evidence of its contiguous bearing. Originally a trail used by area tribes, the White Bluffs Road played a role in Euro-American immigration, development, agriculture, and Hanford Site operations. The survey conducted during 2000 on the White Bluffs Road recorded an additional 54 historic isolated finds and two pre-contact isolated finds, as well as six can dump features.

Traditional Cultural Places. Many sites related to hunting and religious activities are located on Gable Mountain and Gable Butte north of the 200 West and 200 East Areas. These sites are associated with the Gable Mountain/Gable Butte Cultural District.

Buildings and Structures. The 200 Areas contain many significant buildings and structures associated with the Manhattan Project and Cold War landscape. They were formerly used as chemical separations (processing) plants and ancillary and support facilities. The plants functioned to dissolve the irradiated fuel elements to separate out the plutonium, the essential third step in plutonium production. Historic property inventory forms have been completed for 72 buildings/structures in the 200 Areas. Of that number, 58 were selected as representative examples of buildings and structures eligible for the National Register as contributing properties within the Historic District recommended for individual documentation. These include the 202-A Purex Plant, 212-N Lag Storage Facility, 221-T Plant, 222-S Redox Plant, 225-B Encapsulation Building, 231-Z Plutonium Metallurgical Laboratory, 234-5Z Plutonium Finishing Plant, 236-Z Plutonium Reclamation Facility, 242-Z Water Treatment Facility, 282-E Pump house and Reservoir Building, 283-E Water Filtration Plant, and the 284-W Powerhouse and Steam Plant. The 232-Z Waste Incinerator Facility and the 233-S Plutonium Concentration Building are also eligible for the National Register and, along with 221-T Plant, have been documented to HAER standards (DOE 1998c). The 233-S building was recently demolished.

An assessment of the contents of nine facilities in the Plutonium Finishing Plant (PFP) complex was conducted during 1998 and 2002, and a letter report was completed entitled "Interpretive and Curation Plan for the Deactivation and Decommissioning of Historic Buildings at the PFP Complex." These buildings and structures included the 232-Z Waste Recovery Facility, 234-5Z PFP, 236-Z Plutonium Reclamation Facility, 291-Z Exhaust Stack, 2704-Z Safeguards and Security Building, the 2736-Z, ZA, and ZB Plutonium Storage Facilities, and 2736-ZC (non-historic) Cargo Restraint Transport Facility. Because of security/radiological exposure concerns, Buildings 242-Z and 2701-ZA were not accessible for walkthroughs. In 234-5Z, the entire Remote Mechanical A line (glove boxes) and control room, and the Remote Mechanical C line (glove boxes) and control room were identified and tagged. Ten additional Cold War era artifacts were identified and tagged as a result of a walkthrough of the Analytical Laboratories in 234-5Z. The assessment of the 2704-Z Building resulted in two tagged artifacts: a typology of "cans" poster and demonstration training cans. A third artifact, the classified documents vault, was identified but not tagged. The non-historic 2736-ZA building contains historic metal pedestals and a wooden mockup pedestal that were tagged.

Thirty-two industrial artifacts were identified and tagged in chemical separations buildings located outside the PFP complex in the 200 Areas. The following buildings were inspected for artifacts during the walkthroughs: 202-A, 202-S, 221-T, 221-U, 224-U, 224-B, and 271-U. Types of artifacts selected included electrical equipment, control panels, tools, vintage lights, health and safety items, signage, and communications equipment.

4.6.4.3 300 Area

Much of the 300 Area has been used for industrial activities associated with the Manhattan Project and Cold War cultural landscape. Prior to the Manhattan Project, the 300 Area was used by Native Americans as a camp location and by early settlers who developed a farming community known as Fruitvale. Due to its proximity to the Columbia River, many archaeological resources associated with both these landscapes are located along the river shore outside of the 300 Area fence. Subsurface archaeological deposits are likely to be located underneath existing 300 Area facilities within 400 m (1,300 ft) of the Columbia River in pockets of undisturbed ground.

Archaeological Resources. Pre-contact campsites, house pits, and a historic trash scatter, are located at least partially within the 300 Area. Many more may be located in subsurface deposits. Twenty-three archaeological sites and 10 isolated artifacts have been recorded within 1 km (0.6 mi) of the 300 Area fence. Several archaeological sites in this area, including 45BN162, are in the Hanford South Archaeological District, which is listed in the Washington Heritage Register.

Archaeological sites associated with the Early Setters/Farming cultural landscape in the 300 Area are comprised mainly of domestic debris scatters and roadbeds associated with farmsteads.

Traditional Cultural Places. A documented historic Wanapum cemetery is located near the 300 Area.

Buildings and Structures. The 300 Area, the location of the uranium fuel fabrication plants that manufactured fuel rods to be irradiated in the Hanford Site reactors, provided the first essential step in the plutonium production process. The 300 Area was also the location of most of the Hanford Site's research and development laboratories. One hundred fifty-nine buildings/structures in the 300 Area have been documented on historic property inventory forms. Of that number, 47 were selected as representative examples of buildings and structures eligible for the National Register as contributing properties within the Historic District recommended for individual documentation. This total includes the 305 Test Pile, 313 Fuels Fabrication Facility, 314 Metal Press/Extrusion Building, 318 High Temperature Lattice Test Reactor, 321 Separation Building, 325 Radiochemistry Laboratory, 333 Fuel Cladding Facility, 3706 Radiochemistry Laboratory, and the 3760 (former) Hanford Technical Library (DOE 1998c).

Assessments/walkthroughs of the contents of former fuel manufacturing and reactor operations facilities in the 300 Area have been conducted including the 303-A Magazine Product Storage Building, 305 Test Pile, 305-B Engineering Development Laboratory Annex, 306-E Fabrication Test Laboratory, 306-W Materials Development Laboratory, 308 Plutonium Fabrication Pilot Plant, 309 Plutonium Recycle Test Reactor, 313 Fuels Fabrication Facility/Metal Fabrication Building, 314 Press Building, and the 333 Fuel Cladding Facility. The 27 Manhattan Project/Cold War era artifacts that were identified and tagged are mainly industrial in nature associated with the fuel manufacturing processes and reactor operations. A second walkthrough of Building 333 resulted in an additional 12 artifacts being identified including a selection of safety signs/posters, a control panel, a safety shower, protective worker clothes, and a sample uranium fuel element.

Other 300 Area buildings assessed include the 303-K Fresh Metal Storage Building, 304 Uranium Scrap Concentration Storage Facility, 318 High Temperature Lattice Test Reactor Complex, 320 Low Level Radiochemistry Building, 321 Cold Chemical Semi-Works, 324 Chemical Engineering Laboratory, 325 Radiochemistry Laboratory, 326 Physics Laboratory, 327 Post Irradiation Test Laboratory, 328 Engineering Services Building, 329 Biophysics Laboratory, 334 Chemical Handling Facility, 334-A Acid Pump house, 340 Waste Neutralization Complex, 382 Engineering Services Building, 384 Power House, 3614-A River Monitoring Station, 3701-D (former) Hanford Patrol Building, 3706 Radiochemistry Laboratory, 3707-D Patrol Headquarters, 3707-G Change House, 3708 Radiochemical Laboratory, 3713 Storeroom, 3716 Fuels Manufacturing Storage/Automotive Repair Shop, 3720 Environmental Sciences Laboratory, 3722 Area Shop, 3727 Classified Storage Facility, 3745-A Electron Accelerator Building, 3745-B Positive Ion Accelerator Building, 3746 Radiological Physics Building, and the 3762 Technical Safety Building. Approximately 75 to 80 Manhattan Project/Cold War era artifacts were identified and tagged in these buildings.

4.6.4.4 400 Area

Most of the 400 Area has been so altered by construction activities that archaeologists surveying the site during 1978 were able to find only 0.12 km^2 (0.047 mi^2) of land that was undisturbed (Rice et al. 1978). No cultural resources were found in the 400 Area and no archaeological sites are known to be located within 1 km (0.6 mi) of the area.

The 400 Area consists of the Fast Flux Test Facility (FFTF) complex. The FFTF is a 400-megawatt thermal, liquid-metal (sodium) cooled nuclear research and test reactor owned by the DOE. The facility, which operated for about ten years, has been shut down since 1993 and is currently being deactivated. All the buildings and structures in the 400 Area were constructed during the Cold War era. Twenty-one building/structures have been recorded on historic property inventory forms. Of that number, six were selected as representative examples of buildings and structures eligible for the National Register as contributing properties within the Historic District recommended for individual documentation. These include the 405 Reactor Containment Building, 436 Training Facility, 4621-W Auxiliary Equipment Facility, 4703 FFTF Control Building, 4710 Operation Support Building, and the 4790 Patrol Headquarters (DOE 1998c). In response to the production of a Curation Plan for the Deactivation and Decommissioning of Historic Buildings at the FFTF, walkthroughs were conducted of the contributing properties requiring mitigation, with the exception of the 4790 patrol headquarters. In addition, walkthroughs were conducted at 16 contributing properties at FFTF where no individual documentation was required. Operations carried out in these facilities were closely related to the work conducted in the five contributing buildings that required mitigation. Thirty artifacts were identified and tagged in 8 of the 21 historic buildings: 403, 405, 436, 4621-E, 4621-W, 4701-A, 4703, and 4710. Two of the identified artifacts are located in Building 4732-C, a non-historic building. The types of artifacts included industrial equipment and machinery, photographs, publications, control room panels, and models.

An assessment of the contents of Building 427 was also conducted to locate and identify Cold War era artifacts that may have interpretive or educational value in potential exhibits. Four artifacts were identified and tagged, including fuel assembly components.

4.6.4.5 600 Area

The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, and 400 Areas. Project-driven surveys have been conducted throughout the area, but much of the 600 Area has not been surveyed. Based on what is known, the 600 Area contains cultural resources associated with all three cultural landscapes that exist on the Hanford Site. Representing a full range of human activity across the Hanford Site, the activities are best characterized for the Native American cultural landscape by the gathering of inland resources (quarry sites, hunting sites, religious use sites, plant gathering sites) and riverine resources (fishing sites, open camp sites, root gathering). The Early Settlers/Farming landscape is present in the 600 Area, mainly consisting of the archaeological remains of former farmsteads, ranches, and pre-1943 transportation routes. Evidence of cultural resources associated with the Manhattan Project and Cold War Era landscape consists of anti-aircraft artillery sites, meteorological towers, and roads located in the 600 Area.

Archaeological Resources. Numerous National Register Districts associated with the Native American landscape are located within the 600 Area including the Hanford Archaeological Site, Hanford North Archaeological District, the Paris Archaeological Site (45GR317), Rattlesnake Springs sites (45BN170 and 45BN171), Savage Island Archaeological District, Snively Basin Archaeological District, and Wooded Island Archaeological District.

Archaeological properties associated with the Early Settlers/Farming landscape in the 600 Area include the Hanford townsite; the White Bluffs townsite and ferry landing; the Chicago, Milwaukee, St. Paul and Pacific Railroad line and associated whistle stops; early settler's farmsteads; and the Hanford Irrigation Canal and associated irrigation features. The McGee Ranch/District is located in the 600 Area and is eligible for listing in the National Register.

Manhattan Project and Cold War era archaeological resources that are located in the 600 Area include the remains of the Hanford Construction camp and associated features and five National Register-eligible anti-aircraft artillery sites associated with Camp Hanford's defense of the Hanford Site during the 1950s. The Hanford Atmospheric Dispersion Test Facility is a contributing property within the Historic District. Numerous artifacts in the facility were identified as having interpretive or educational value in potential exhibits. A selected representative number of artifacts were removed from the facility and curated into the Hanford Collection.

Traditional Cultural Places. Areas of traditional cultural importance include Rattlesnake Mountain and foothills, the Columbia River, Gable Mountain, Gable Butte, and National Register-eligible *Wanawish.* Cemeteries associated with the Native American cultural landscape are also dispersed throughout the 600 Area.

Buildings and Structures. There are several structures associated with the Early Settlers/Farming landscape that are located in the 600 Area. The Bruggemann Warehouse, located approximately 1.6 km (3 mi) west of 100-B/C, is eligible for listing in the National Register. During 2002, the Hanford Electrical Substation-Switching Station, the Hanford townsite high school, the Coyote Rapids Pumping Plant, and the First Bank of White Bluffs became eligible for listing in the National Register.

The 622 Meteorological Complex, located near 200 West, includes seven inventoried properties. Fifteen Cold War era buildings/structures, including the former underground missile storage facility, have been inventoried at the former 6652 Nike launch and control center in the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit. Both complexes are eligible for the National Register as contributing properties within the Historic District. An assessment of the contents of 622-F and the 6652 Nike site were conducted. No artifacts of interpretive or educational value were identified.

Twenty-five railcars located at the 212-N rail spur were designated Register-eligible as contributing features of the Hanford Site Railroad. Documentation/mitigation of the 25 railcars was completed as an addendum to the Expanded Historic Property Inventory form of the Hanford Site Railroad system. Due to their high contamination levels, most of the railcars have been removed from the Hanford Site. Five other 600 Area properties, the 604 Yakima Patrol Checking Station, 604-A Sentry House, 607 Batch Plant, 618-10 Solid Waste Burial Trench, and Hanford Site Railroad System are eligible for the National Register as contributing properties within the Historic District.

The former Central Shops complex located in the 600 Area north of the 200 Areas is not eligible for the National Register (DOE 1997a).

The 213 Building (Magazine/Waste Storage Vault) and the 623 Building (Gable Mountain Relay Station) are contributing properties within the Historic District.

4.6.4.6 700 Area

The 700 Area was the location of the administrative functions of the early Hanford Site period. Most of the 700 Area was altered by industrial and demolition activities. Of the seven Manhattan Project and Cold War era buildings/structures identified in this area, the 703 Administrative Building, 712 Records/Printing/Mail Office Facility, and the 748 Emergency Decontamination Facility are eligible for listing in the National Register as contributing properties within the Historic District (DOE 1998c).

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4.7 Socioeconomics

R. A. Fowler and M. J. Scott

Activity on the Hanford Site plays a dominant role in the socioeconomics of the Tri-Cities and other parts of Benton and Franklin counties (Figure 4.7-1). The agricultural community also has a significant effect on the local economy. Any major changes in Hanford activities would potentially affect the Tri-Cities and other areas of Benton and Franklin counties. Unless otherwise specifically cited, data in this section are collected from interviews with the referenced organization.

4.7.1 Local Economy

Three major sectors have been the principal driving forces of the economy in the Tri-Cities since the early 1970s: 1) DOE and its contractors operating the Hanford Site; 2) Energy Northwest (formerly the Washington Public Power Supply System) in its construction and operation of nuclear power plants; and 3) the agricultural community, including a substantial food-processing component. Increasingly, a growing cluster of technology-based businesses, many with roots in the Hanford Site and Pacific Northwest National Laboratory, are playing a role in the expansion and diversification of the local private business sector.

In addition to these three major employment sectors, three other components can be readily identified as contributors to the economic base of the Tri-Cities. The first of these, loosely termed "other major employers," includes the five major non-DOE contractor employers in the region (discussed in more detail in Subsection 4.7.1.4). The second component is tourism. The Tri-Cities area has increased its convention business substantially in recent years as well as recreational travel. The third component to the economic base relates to the local purchasing power generated from retired former employees. Government transfer payments, specifically retirement and disability insurance benefit payments constitute a significant proportion of the total spendable income in the local economy.

4.7.1.1 DOE Contractors (Hanford)

DOE and its contractors compose the largest single source of employment in the Tri-Cities. During fiscal year (FY) 2006, an average of 9,759 employees was employed by DOE Office of River Protection (ORP) and its prime contractor CH2M HILL Hanford Group, Inc.; DOE Richland Operations Office (RL) and its prime contractors Fluor Hanford, Inc., Washington Closure Hanford, LLC (WCH), and AdvanceMed Hanford; and the DOE Office of Science Pacific Northwest Site Office (PNSO) and the Pacific Northwest National Laboratory (PNNL), which is operated by Battelle. Fiscal year 2006 year-end employment for all DOE contractors was 9,707, down from 10,135 at the end of FY 2005. In addition to these totals, Bechtel National, Inc. (BNI), which has had the responsibility to design, build, and start up waste treatment facilities for the vitrification of liquid radioactive waste since December 2000, employed 1,647 at the end of FY 2006. BNI employment peaked at 3,867 in July 2004.

Figure 4.7-1. Hanford Site, Washington, and Surrounding Communities

The total annual average number of DOE contractor employees has declined by nearly 7,600 since FY 1994 when employment peaked at 19,200 employees, but DOE contractor employment still represents 11 percent of the total jobs in the economy. Total employment in the Richland, Kennewick, and Pasco metropolitan statistical area averaged 106,100 per month during 2006, down from 107,700 in 2005 (LMEA 2007a).

Based on employee records as of April 2007, over 90 percent of DOE contractor employees live in Benton and Franklin counties. Approximately 73 percent reside in Richland, Pasco, or Kennewick. More than 36 percent are Richland residents, 11 percent are Pasco residents, and 25 percent live in Kennewick. Residents of other areas of Benton and Franklin counties, including West Richland, Benton City, and Prosser, account for about 17 percent of total DOE contractor employment.

4.7.1.2 Energy Northwest

Energy Northwest is a joint operating agency comprising 20 member public utilities from across the state of Washington. Energy Northwest provides electricity, at cost, to public utilities and municipalities in the northwest and operates four electricity generating stations: Columbia Generating Station, Packwood Lake Hydroelectric Project, Nine Canyon Wind Project, and the White Bluffs Solar Station. Although commercial nuclear power plant construction activity ceased with the completion of the 1,157-megawatt (MW) WNP-2 nuclear reactor (now named Columbia Generating Station) during 1983, Energy Northwest continues to be a major employer in the Tri-Cities area. Nuclear power plants WNP-1 and WNP-4 were never completed. The unfinished facilities have been partially remediated with some structures being reused for support and business purposes. As part of an effort to reduce electricity production costs, Energy Northwest headquarters decreased the size of its total workforce from over 1,900 during 1994 to 1,016 at the end of 1999. Total permanent employment at the end of 2006 was 1,079 people. Based on annual payroll and employee counts, Energy Northwest delivers more than $200 million in economic impact to the local economy.

4.7.1.3 Agriculture

During 2005, over 10 percent of workers in Benton and Franklin counties were employed in agriculture. The total agricultural employment was 10,750, a decrease from the 2004 total of 11,200 (LMEA 2007b). Seasonal farm workers are not included in that total but are estimated by the U.S. Department of Labor (DOL) for the agricultural areas in the state of Washington. During 2006, the number of seasonal farm workers averaged 5,313 in Benton, Franklin, and Walla Walla counties, ranging from 826 workers during the winter pruning season to 11,984 workers at the peak of harvest. An estimated average of 2,950 seasonal workers were classified as local (ranging from 519 to 7,366). An average of 15 workers were classified as intrastate, 217 interstate, 585 foreign, and 1,550 as unknown origin. The weighted seasonal wage for 2006 ranged from $7.62/hr to $7.95/hr, with an average wage of $7.75/hr (DOL 2007).

According to the U.S. Department of Commerce’s Regional Economic Information System (REIS), 2,187 people were classified as farm proprietors in Benton and Franklin counties during 2005. Total farm proprietors’ income, according to this same source, was estimated to be $17.3 million (DOC 2007).

The area's farms and ranches generate a sizable number of jobs in supporting activities, such as agricultural services (e.g., application of pesticides and fertilizers and irrigation system development) and wholesale trade (e.g., farm supply and equipment sales and fruit packing). Although formally classified as a manufacturing activity, food processing is a natural extension of the farm sector. As of March 2005, 56 processors in Benton and Franklin counties produce such items as potato products, canned fruits and vegetables, wine, and animal feed. During 2004, food manufacturing jobs accounted for 53 percent of all the manufacturing jobs in the area.

4.7.1.4 Other Major Employers

The five largest non-DOE contractor and non-government employers employed approximately 7,150 people in Benton and Franklin counties as of May 2007. These companies include 1) ConAgra/Lamb Weston, which employed 3,513; 2) Tyson Fresh Meats (formerly Iowa Beef Processing Inc.), which employed 1,250; 3) Wal-Mart (three stores), which employed 1,041; 4) the Tri-Cities Airport, which employed 714; and 5) AREVA, Inc. (formerly Framatome ANP and Siemens Power Corporation) which employed 630. Four of the largest agriculture growers and processors in the area, AgriNorthwest, Broetje Orchards, J.R. Simplot Company, and Twin City Foods, Inc., employed approximately 2,861 people during 2006; however, a large portion of the workers were seasonal.

Other major area employers include school districts: Richland, Kennewick, and Pasco, which employed a total of 4,913; three major health care facilities: Kadlec Medical Center, Kennewick General Hospital, and Lourdes Health Network, which employed a total of 2,900; local government offices: Benton and Franklin county and Richland, Kennewick, and Pasco city offices, which employed 2,112; and Boise Cascade Corporation Paper and Corrugated Container Divisions, which employed 605. Both Boise Cascade and Tyson Fresh Meats are located in western Walla Walla County, but most of their workforce resides in Benton and Franklin counties.

4.7.1.5 Tourism

A significant rise in the number of visitors to the Tri-Cities over the last several years has resulted in tourism playing an increasing role in helping to diversify and stabilize the area's economy. The Tri-Cities Visitors and Convention Bureau reported that in 2006, 188 convention and group activities worth more than $38.7 million in direct spending brought 120,808 people to the Tri-Cities. The number of people attending conventions and group events has nearly doubled in the last 10 years and has more than quadrupled since 1991.

The importance of tourism is evidenced by the amount of money spent on local goods and services. Overall tourism expenditures in the Tri-Cities were over $299 million during 2005, up from $280 million during 2004. Travel-generated employment in Benton and Franklin counties was about 3,980 with an estimated $74.7 million in payroll, up from an estimated 3,960 employed and $72.3 million payroll during 2004. In addition, tourism generated $5.7 million in local taxes and $17.4 million in state taxes during 2004 (OTED 2007).

4.7.1.6 Retirees

In the Tri-Cities, retirees are a major source of consumer spending. Benton and Franklin counties have a relatively young population (approximately 52 percent under the age of 35); however, 22,389 people over the age of 65 resided in Benton and Franklin counties during 2006. Washington State Office of Financial Management (OFM) reports the portion of the total population 65 years and older in Benton and Franklin counties accounts for 10 percent of the total population, which is below the 11.4 percent for the state of Washington (OFM 2007a). This segment of the population supports the local economy through income received from government transfer payments and pensions, private pension benefits, and prior individual savings. Although the retirees are not employed, their income affects the local economy in much the same way as local spending on salaries by the federal government and the area's private sector employers.

Although information on private pensions and savings is not available, data are available regarding the magnitude of government transfer payments. REIS has estimated transfer payments by various programs at the county level. Estimated major government transfer payments received by the residents of Benton and Franklin counties during 2005 total greater than $946 million (Table 4.7-1). Over 41 percent of the payments are for retirement and disability insurance benefit payments, which provide over $391.2 million of spendable income to the local economy.

Table 4.7-1. Federal Government Transfer Payments in Benton County and Franklin County, Washington, 2005 [(a)]

Government Payments to Individuals	Benton County ($Millions)	Franklin County ($Millions)	Total ($Millions)
Retirement and disability insurance payments	312.2	79.0	391.2
Medical payments	267.2	136.6	403.8
Income maintenance benefits	61.2	34.8	96.0
Unemployment insurance benefits	20.1	8.2	28.3
Veterans benefits	15.7	4.0	19.7
Federal education and training assistance	1.6	4.8	6.4
Other payments to individuals	0.7	0.3	0.9
Total	**678.7**	**267.7**	**946.3**

(a) DOC 2007.

4.7.2 Employment and Income

Nonagricultural employment in the Tri-Cities grew steadily from 1988 to 1994. The total annual average employment fell during 1995 and 1996 and then grew every year until 2006 when it dropped slightly. During 2006, nonagricultural employment fell 0.1 percent (Table 4.7-2). There was an average of 86,800 non-agricultural jobs in the Tri-Cities during 2006, a decrease of approximately 100 from the previous year. The decrease in jobs was found in the professional and business services sector, which dropped over 10 percent, but was nearly offset by gains in the trade, transport, warehousing and utility, and the education and health services sectors. Modest gains were seen in manufacturing, natural resources, mining and construction, and the financial sectors (LMEA 2007c).

Three measures of area income are presented in this section: total personal income, per capita income, and median household income. Total personal income comprises all forms of income received by the populace, including wages, dividends, and other revenues. Per capita income is equivalent to total personal income divided by the number of people residing in the area. Median household income is the point at which half of the households have incomes greater than the median and half have less.

During 2005, the total personal income was $4.9 billion for Benton County and $1.3 billion for Franklin County, compared to the State of Washington's total of $223.2 billion. Per capita income during 2005 was $31,433 for Benton County, $20,573 for Franklin County, and $35,479 for Washington State (DOC 2007). The preliminary estimate of median household income during 2005 for Benton County was $54,183; Franklin County was estimated at $38,842. The estimated median income for Franklin County was well below the Washington State estimate of $53,771 (OFM 2007b).

Table 4.7-2. Nonagricultural Wage and Salary Workers in Benton County and Franklin County, Washington, 2005 and 2006 [(a)]

Industry	2005 Annual Average Employment (Revised)	2006 Annual Average Employment (Preliminary)	Change 2005-2006 (Percent)
Manufacturing	5,800	5,900	1.7
Natural Resources, Mining and Construction	5,900	6,000	1.7
Trade, Transportation, Warehousing and Utilities	14,900	15,900	6.7
Financial Activities	3,400	3,500	2.9
Professional and Business Services	20,600	18,500	-10.2
Education and Health Services	8,600	9,200	7.0
Leisure and Hospitality	7,900	7,900	0.0
Government	16,000	16,000	0.0
Other	3,800	3,900	2.5
Total nonagricultural wage and salary workers	**86,900**	**86,800**	**-0.1**

(a) Source: Washington State Employment Security Department (LMEA 2007c).

4.7.3 Demography

An estimated 160,600 people lived in Benton County and 64,200 lived in Franklin County during 2006, totaling 224,800, an increase of over 17 percent from the Census 2000 figure (OFM 2007c). This growth rate is faster than the state of Washington as a whole, which has grown 8.2 percent since the 2000 Census. According to the 2000 Census, population totals for Benton and Franklin counties were 142,475 and 49,347, respectively (Census 2001a). Both Benton and Franklin counties also grew at a faster pace than the state during the 1990s. The population of Benton County increased 26.6 percent, up from 112,560 during 1990, and the population of Franklin County increased 31.7 percent, up from 37,473 during 1990, while the population of the state of Washington rose 21.1 percent. (Census 2001a).

The distribution of the 2006 Tri-Cities population by city is as follows: Richland 44,230; Pasco 47,610; and Kennewick 61,770. The combined populations of Benton City, Prosser, and West Richland totaled 18,405 during 2006. The unincorporated population of Benton County was 36,195. In Franklin County, incorporated areas other than Pasco had a total population of 3,860. The unincorporated population of Franklin County was 12,730 (OFM 2007c).

During 2006, Benton and Franklin counties accounted for 3.5 percent of Washington's population. The population demographics of Benton and Franklin counties are quite similar to those found within Washington. In general, the population of Benton and Franklin counties is somewhat younger than that of Washington as a whole. The 0- to 14-year old age group accounts for 24.1 percent of the total bi-county population compared with 19.9 percent for Washington. The population in Benton and Franklin counties under the age of 35 is 51.5 percent; it is 47.7 percent for the state of Washington (OFM 2007a).

Population estimates and percentages by race and Hispanic origin for Benton, Franklin, Grant, Adams, and Yakima counties and within the 80-km (50-mi) radius of the Hanford Site from the 2000 Census indicate Asians and individuals of Hispanic origin from Benton and Franklin counties represent lower and higher proportions of the population, respectively, than in the state of Washington as a whole (Table 4.7-3). During 2006, county-level estimates of minority populations in Benton, Franklin, Grant, Adams, and Yakima counties demonstrate similar trends (Table 4.7-4).

Additional Hanford area demographic data are available from *Hanford Area 2000 Population* (Elliott et al. 2004). This document includes 2000 Census estimates for the resident population by distance and compass direction within an 80-km (50-mi) radius of the Hanford Site. Population distributions are reported relative to five reference points centered on meteorological stations within major operating areas of the Hanford Site: the 100-F, 100-K, 200, 300, and 400 Areas. Data are presented in both graphical and tabular format and are provided for total populations residing within 80 km (50 mi) of the reference points, as well as for Native American, Hispanic and Latino, total minority, and low-income populations.

4.7.4 Environmental Justice

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" (59 FR 7629), directs federal agencies in the Executive Branch to consider environmental justice so that their programs will not have "disproportionately high and adverse human health or environmental effects" on minority and low-income populations. Executive Order 12898 further directs federal agencies to consider effects to "populations with differential patterns of subsistence consumption of fish and wildlife." The Executive Branch agencies also were directed to develop plans for carrying out the order. The Council on Environmental Quality

Table 4.7-3. Population Estimates and Percentages by Race and Hispanic Origin by County in Washington State and Within the 80-km (50 mi) Radius of Hanford as Determined by the 2000 Census (Census 2003b)

Subject	Washington State	Percent	Benton/Franklin/ Grant/Adams/ Yakima	Percent	Benton County	Franklin County	Grant County	Adams County	Yakima County	80-km (50-mi) Radius of Hanford[(a)]
Total population	5,894,121	100	505,529	100	142,475	49,347	74,698	16,428	222,581	482,280
Single race	5,680,602	96.4	489,206	96.8	138,646	47,302	72,451	15,977	214,830	466,626
White	4,821,823	81.8	367,283	72.7	122,879	30,553	57,174	10,672	146,005	347,047
Black or African American	190,267	3.2	5,494	1.1	1,319	1,230	742	46	2,157	5,507
American Indian/Alaska Native	93,301	1.6	12,468	2.5	1,165	362	863	112	9,966	10,288
Asian	322,335	5.5	6,809	1.3	3,134	800	652	99	2,124	6,681
Native Hawaiian/Pacific Islander	23,953	0.4	482	0.1	163	57	53	6	203	479
Other race	228,923	3.9	96,670	19.1	9,986	14,300	12,967	5,042	54,375	96,625
Two or more races	213,519	3.6	16,323	3.2	3,829	2,045	2,247	451	7,751	15,654
Hispanic origin (of any race)[(b)]	441,509	7.5	150,951	29.9	17,806	23,032	22,476	7,732	79,905	149,588

(a) Includes a portion of Oregon.
(b) Hispanic origin is not a racial category. It may be viewed as the ancestry, nationality group, lineage, or country of birth of the person or person's parents or ancestors before arrival in the United States. Persons of Hispanic origin may be of any race and are counted in the racial categories shown.

Table 4.7-4. Year 2006 Population Estimates and Percentages by Race and Hispanic Origin by County in Washington State (OFM 2007e).

Subject	Washington State	Percent	Benton/ Franklin/ Grant/ Adams/ Yakima	Percent	Benton County	Franklin County	Grant County	Adams County	Yakima County
Total Population	6,375,600	100	554,500	100.0	160,600	64,200	80,600	17,300	231,800
White	5,401,314	84.7	514,376	92.8	150,247	60,090	76,588	16,693	210,758
Black	228,077	3.6	6,909	1.2	1,700	1,435	853	73	2,848
American Indian/Alaska Native	105,650	1.7	13,763	2.5	1,391	532	1,078	162	10,602
Asian/Native Hawaiian/Pacific Islander	445,543	7.0	10,136	1.8	4,275	1,324	926	200	3,411
Two or More Races	195,016	3.1	8,548	1.5	2,220	820	1,155	172	4,181
Hispanic Origin (of any race)[a]	565,377	8.9	193,923	35.0	24,786	36,495	28,219	9,044	95,379

(a) Hispanic origin is not a racial category. It may be viewed as the ancestry, nationality group, lineage, or country of birth of the person or person's parents or ancestors before arrival in the United States. Persons of Hispanic origin may be of any race and are counted in the racial categories shown.

(CEQ) later provided additional guidance for integrating environmental justice (EJ) into the National Environmental Policy Act process in a December 1997 document, *Environmental Justice Guidance under the National Environmental Policy Act* (CEQ 1997).

Minority populations are defined as all nonwhite individuals plus all white individuals of Hispanic origin. The most recent detailed counts are reported in the 2000 Census (Census 2001b), while more recent county-level estimates are reported by the Washington State Office of Financial Management (OFM 2007e). Following federal Office of Management and Budget guidance, the OFM estimates have re-evaluated the “other race” category in the 2000 Census and have reassigned individuals to one of the five Census races, where possible, in addition to accounting for population growth. Low-income persons are defined as living in households that report an annual income less than the United States’ official poverty level, as reported by the Census Bureau. The poverty level varies by size and relationship of the members of the household. The year 2000 poverty level was $17,761 for a family of four (Census 2000, 2001a). Nationally, during 1999, 29.9 percent of all persons were minorities, and 11.8 percent of all persons lived in households that had incomes less than the poverty level (which was $17,029 for a family of four during that year) (Census 2000, 2001a). The 2000 Census reports that 10.6 percent of Washington’s population lived in poverty during 1999, while 10.3 percent of Benton County persons and 19.2 percent of Franklin County persons were below the poverty level (Census 2003a). No post-2000 Census estimates are available for local low-income populations.

Based on the 2000 census (Census 2001b, c), the 80-km (50-mi) radius area surrounding the Hanford Site had a total population of 482,300 and a minority population of 178,500. The ethnic composition of the minority population is primarily white Hispanic (24 percent), self-designated “other and multiple” races (63 percent), and Native American (6 percent). Asians and Pacific Islanders (4 percent) and African Americans (3 percent) make up the remainder. The Hispanic population resides predominantly in Franklin, Yakima, Grant, and Adams counties. Native Americans within the 80-km (50-mi) area reside primarily on the Yakama Reservation and upstream of the Hanford Site near the town of Beverly, Washington.

The low-income population during 2000 was approximately 80,800 individuals, or 17 percent of the total population residing in the 80-km (50-mi) radius of the HMS at the center of the Hanford Site (Census 2002 a, b), approximately the same percentage as the 1990 Census. The majority of these households were located to the southwest and northwest of the Site (Yakima and Grant counties) and in the cities of Pasco and Kennewick.

Figure 4.7-2 shows the location of Census block groups from the 2000 Census that had either a majority of residents who were members of a minority group (racial minority or Hispanic), or a percentage of residents belonging to any minority group that was at least 20 percentage points greater than the corresponding percentage of the state population (Census 2001a, b, c).

Figure 4.7-3 shows the location of Census block groups from the 2000 Census that had either a majority of residents who were low income (members of a household below the national poverty level), or a percentage of low-income residents at least 20 percentage points greater than the corresponding percentage of the state population (Census 2002 a, b).

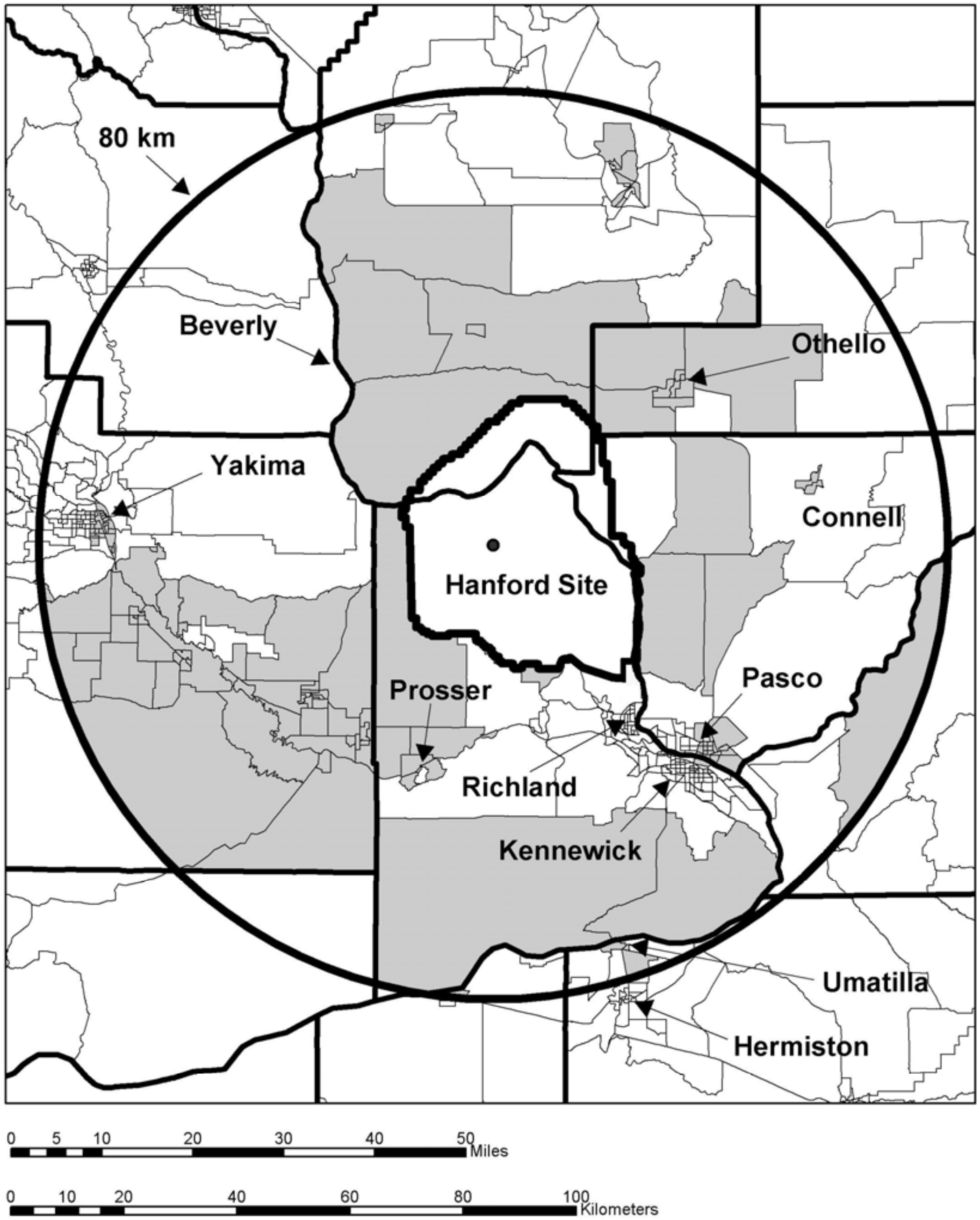

Figure 4.7-2. Location of Minority Populations near the Hanford Site, Washington, Based on 2000 Census. Shaded areas indicate regions that have a majority of residents who are members of a minority group or for which the percentage of minority population is 20 percentage points greater than the statewide average. Minority groups include all nonwhite individuals plus Hispanic whites.

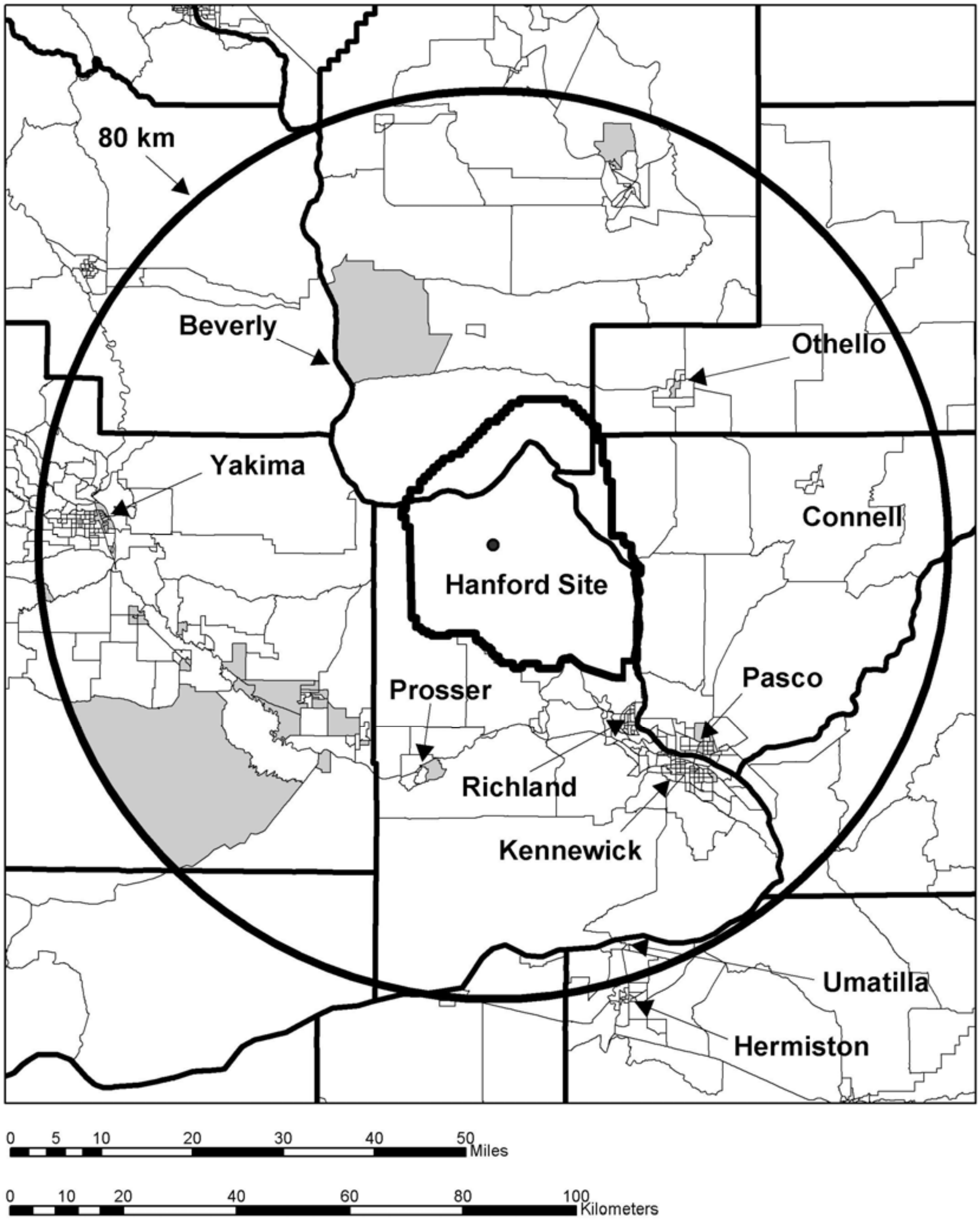

Figure 4.7-3. Location of Low-Income Populations near the Hanford Site, Washington, Based on 2000 Census. Shaded areas indicate regions that have a majority of low-income residents or for which the percentage of low-income population is 20 percentage points greater than the statewide average. Low-income persons live in households with incomes that fall below the official U.S. poverty level ($17,761 for a family of four in the year 2000).

The CEQ guidance for identifying potential disproportionate impacts on minority and low-income populations recognizes that some minority and low-income groups may be more reliant than the majority population on subsistence hunting, fishing, and gathering activities (sometimes for species unlike those consumed by the majority population) or may be dependent on water supplies or other resources that are atypical or used at different rates than other groups. These differential patterns of resource use are to be identified "where practical and appropriate." While no hunting and gathering activities take place on the Hanford Site, some Native Americans of various tribal affiliations who live in the greater Columbia Basin do participate in tribal fishing for salmon and resident fish that use the Hanford Reach for habitat.

Fishing access rights for Native Americans is guaranteed by federal treaty. For example, the Treaty of 1855 with the Confederated Tribes and Bands of the Yakama Nation (Yakama 1855) secured to the Yakamas, "the right of taking fish at all usual and accustomed places, in common with the citizens of the Territory [now the state of Washington] and of erecting temporary buildings for curing them; together with the privilege of hunting, gathering roots and berries, and pasturing their horses and cattle upon open and unclaimed lands" ceded to the government. Some of this ceded territory is located on the Hanford Site. Similar guarantees were extended to the Umatilla, Nez Perce, and Warm Springs groups.

The Wanapum, a non-treaty tribe, historically lived along the Columbia River and continue to live upstream of the Hanford Site. They fish on the Columbia River and gather food resources near the Hanford Site. The Confederated Tribes of the Colville Reservation, established by the Executive Order of April 9, 1872, traditionally fished and gathered food resources in the Hanford area. They also are recognized as having cultural and religious ties to the Hanford Site.

The Walker Research Group discussed the historical location of Native American fishing sites, the level and productivity of the fishing effort, estimates from several studies of fish consumption in traditional Native American diets (Hewes 1947, 1973; Hunn and Bruneau 1989; Walker 1967), and possible exposure levels to radionuclides (Walker and Pritchard 1999). According to the studies, annual rates of fish consumption by Native Americans in the region before European contact ranged from 23 kg (50 lb) to as much as 438 kg (900 lb). The estimate of contemporary fish consumption is as much as 226 kg (500 lbs) indicating a heavy reliance on fish among Native Americans following a traditional diet (CRITFC 1994; Harris and Harper 2004).

4.7.5 Housing

During FY 2006, 3,777 houses were sold in the Tri-Cities at an average price of $180,765, an increase from 3,599 houses sold at an average price of $173,909 in FY 2004 (TCAR 2007). In 2005, 2,164 single-family houses were constructed, a 2.4 percent decrease from the 2,217 that were built during 2004, but well above the 10-year annual average of 1,390 houses (WCRER 2007a).

As of April 1, 2006, there were an estimated 85,501 housing units in Benton and Franklin counties, a 16 percent increase above the 73,982 units reported during 2000 (OFM 2007d). The number of apartments has increased from 10,226 during 2000 to 12,155 during 2006. The apartment vacancy rate in Benton and Franklin counties during 2006 was 9.8 percent, a reduction from the

11.2 percent vacancy rate in 2005. Average monthly rent during 2006 was $578, up from the $551 average rent during 2005 (WCRER 2007b).

4.7.6 Transportation

The Tri-Cities serves as a regional transportation and distribution center with major air, land, and river connections. Regional rail service in Benton and Franklin counties is provided by Burlington Northern Santa Fe (BNSF), Amtrak, Union Pacific, the Tri-City Railroad Company, and the Blue Mountain Railroad. The Columbia Basin Railroad branches off the BNSF at Connell, extending northerly into Adams and Grant Counties. Amtrak passenger service, the "Empire Builder," operates daily on the BNSF trackage from Vancouver through Pasco to Spokane. In 2005, 10,703 passengers embarked on their trips and 11,353 passengers completed their trips at Pasco (BFCOG 2007).

The Hanford Site rail system originally consisted of approximately 210 km (130 mi) of track. It connected to the Union Pacific Railroad commercial track at the Richland Junction (at Columbia Center in Kennewick) and to a now abandoned commercial right-of-way (Chicago, Milwaukee, St. Paul and Pacific Railroad) near Vernita Bridge in the northwest section of the Site. Prior to 1990, annual railcar movements numbered about 1,400 sitewide, transporting materials including coal, fuel, hazardous process chemicals, and radioactive materials and equipment (DOE 1996b). During October 1998, 26 km (16 mi) of track from Columbia Center to Horn Rapids Road were transferred to the Port of Benton and are currently operated by the Tri-City and Olympia Railroad. The Port of Benton has been granted the right to operate portions of the railroad on the Hanford Site.

Regional water transportation is available through the extensive Columbia-Snake river system which allows barge lines serving the region to transport commodities to and from locations throughout the world via the ports of Kalama, Longview, Vancouver, and Portland (the nations largest wheat export portal). The Ports of Benton, Kennewick, Pasco contain some of the 17 barge terminals in the Mid-Columbia and Snake navigation region, each served by truck and/or rail.

The Port of Pasco owns and manages the Big Pasco Industrial Center, which has nearly two miles of waterfront on the north side of the Columbia River upstream from the mouth of the Snake River. The facility has a fully operational container-handling terminal for loading and unloading containerized cargo. The Port of Pasco has the largest bulk cargo tonnage movement of any terminal on the upper river system and provides docking, loading and unloading for grain and petroleum barges.

The Port of Benton has over 1,830 m (6,000 ft) of Columbia River frontage zoned for heavy industrial use at their Richland Technology and Business Campus located on the west bank of the Columbia River in North Richland. Their dock facilities near the north end of the site are used to unload construction materials and heavy equipment, much of which is destined for Hanford and other cargoes bound for North Richland. The Port of Kennewick owns property zoned for heavy industrial use at various locations along a 19 km (12-mi) stretch of the Columbia River in, adjacent to, and southeast of Kennewick (BFCOG 2007).

Daily air passenger and freight services connect the area with most major cities through the Tri-Cities Airport, located in Pasco. This modern commercial airport links the Tri-Cities to major hubs and provides access to destinations anywhere in the world. There are two runways, a main runway and a minor runway for use during crosswinds. The main runway is equipped for precision instrumentation landings and takeoffs. Each runway is 2,347 m (7,700 ft) long and 46 m (150 ft) wide and can accommodate medium-range commercial aircraft.

During 2006, Delta Airlines, Skywest, Horizon Air (partnered with Alaska and Northwest), and Allegiant Air provided daily connections to domestic and international flights through Salt Lake City, Seattle, Denver, Las Vegas, and Portland. There were 225,880 enplanements at the Tri-Cities Airport during 2006, down from 239,320 during 2005, which is the annual record for the airport. The 10-year average number of enplanements is 209,343. Projections indicate that the terminal can serve almost 300,000 passengers annually.

The Tri-Cities region has three general aviation airports that serve private aircraft. The Richland Airport, owned by the Port of Benton, is northwest of the Richland central business district, adjacent to the Richland Bypass highway (SR-240). Vista Field Airport, owned by the Port of Kennewick, is located on West Grandridge Boulevard in central Kennewick, with easy access to SR-240, I-82, and I-182. The Prosser Airport, owned by the Port of Benton, is located 1.61 km (1 mi) northwest of the business district of Prosser and is adjacent to US-12. Airfreight shippers that service the region include DHL from Richland, United Parcel Service from Kennewick, and Federal Express from the Tri-Cities Airport in Pasco.

Mass transit within the Tri-Cities is provided by the Ben Franklin Transit (BFT) system. BFT is a municipal corporation that provides public transportation services in a 1,520 km^2 (588 mi^2) area of Benton and Franklin counties. The area includes the cities of Kennewick, Pasco, Richland, West Richland, Benton City, and Prosser and certain unincorporated areas of Benton and Franklin counties. As of the end of 2006 the Ben Franklin fleet consisted of 65 buses, 58 Dial-a-Ride para-transit vehicles, and 214 VanPool vans. The total number of users in 2006 was 4,728,166, a 14.9 percent increase from 2004. Two local taxi companies provide radio-dispatched taxicab service 24 hours per day: A-1 Tri-Cities Taxi and Tri-City Cab.

The regional transportation network in the Hanford vicinity includes the areas in Benton and Franklin counties from which most of the commuter traffic associated with the Site originates. Interstate highways that serve the area are I-82 and I-182. I-82 is 8 km (5 mi) south-southwest of the Site. I-182, a 24-km (15-mi)-long urban connector route located 8 km (5 mi) south-southeast of the Site, provides an east-west corridor linking I-82 to the Tri-Cities area. I-90, located north of the Site, is the major link to Seattle and Spokane and extends to the east coast. I-82 serves as a primary link between Hanford and both I-90 and I-84. I-84, located south of the Hanford Site in Oregon, is a major corridor leading to Portland, Oregon. SR 224 (Van Giesen Street), also south of the Site, serves as a 16-km (10-mi) link between I-82 and SR 240. SR 24 enters the Site from the west, continues eastward across the northernmost portion of the Site, and intersects SR 17 approximately 24 km (15 mi) east of the Site boundary. SR 17 is a north-south route that links I-90 to the Tri-Cities and joins U.S. Route 395, continuing south through the Tri-Cities. U.S. Route 395 north also provides direct access to I-90. SR 240 and SR 24 traverse the Site and are maintained by Washington State.

A DOE-maintained road network within the Hanford Site consists of 607 km (377 mi) of asphalt-paved road and provides access to the various work centers. Primary access roads to the industrial areas of the Hanford Site are Routes 1, 2, 3, 5, 6, 10, 11, and Beloit Avenue (Figure 4.0-1). Public access to the 200 Areas and interior locations of the Hanford Site is restricted by guarded gates at the Wye Barricade (at the intersection of Routes 10 and 4), the Yakima Barricade (at the intersection of SR 240 and Route 11A), and Rattlesnake Barricade south of the 200 West Area.

The primary commute to the Hanford Site requires most employees to travel through the city of Richland by way of SR 240 (Bypass Highway) or George Washington Way. Single-occupant vehicles accounted for 88 percent of all commute trips, while 12 percent of the vehicles were carpools or vanpools. These two roadways have an average daily traffic (ADT) volume of between 30,000 and 40,000 vehicles. To help accommodate the high volume of traffic, the Washington State Department of Transportation (WSDOT) expanded the Bypass Highway from four to six lanes in 2002. Similarly, the City of Richland made major capacity improvements on Stevens Drive north of SR 240.

The ADT across SR 240 Yakima River Causeway was 55,000 in 2005, up from 47,000 in 1994. In 2007, WSDOT completed the expansion of SR 240 from I-182 south to the Columbia Center Interchange from four to eight lanes, and the expansion of the I-182 overcrossing extending from George Washington Way to southbound SR 240 from one to two lanes. These much needed capacity improvements should substantially alleviate congestion during the daily commute (BFCOG 2007).

4.7.7 Educational Services

Most of the primary and secondary students in the Tri-Cities area are served by the Richland, Pasco, Kennewick, and Kiona-Benton (Benton City) school districts. The total 2006 fall enrollment for all districts in Benton and Franklin counties was 45,257 students, an increase of 4.5 percent from the 2004 total of 43,316 students. The 2006 totals include 10,135 students from the Richland School District, an increase from 9,975 during 2004; 12,654 students from the Pasco School District, an increase from 11,020 during 2004; 14,974 students from the Kennewick School District, an increase from 14,776 during 2004; and 1,601 from the Kiona-Benton School District, a decrease from 1,631 during 2004 (OSPI 2007).

There are fourteen private elementary and secondary schools in the Tri-Cities, including Bethlehem Lutheran (K-8), Calvary Christian (K-5), and St. Joseph’s (K-8) in Kennewick; Christ the King (K-8) and Liberty Christian (K-12) in Richland; and Kingspoint Christian (K-12), Country Haven Academy, St. Patrick’s (K-8), Tri-City Junior Academy (K-10), and Tri-Cities Prep Catholic High School in Pasco. Fall 2006 enrollment at these schools totaled 2,392 students (OSPI 2007).

Post-secondary education in the Tri-Cities area is provided by Columbia Basin College (CBC) and Washington State University, Tri-Cities branch campus (WSU-TC). The 2006 fall/winter enrollment was 6,864 at CBC and 1,096 at WSU-TC. Many of the programs offered by these institutions are geared toward the vocational and technical needs of the area. During 2006-2007, CBC offered 24 Associate in Applied Science (AAS) degree programs, and WSU-TC offered 16 undergraduate and 16 graduate programs, as well as access to graduate programs via satellite.

4.7.8 Health Care and Human Services

The Tri-Cities has three major hospitals and five emergency centers. All three hospitals offer general medical services and include a 24-hr emergency room, surgical services, and intensive and neonatal care.

Kadlec Medical Center in Richland has 172 beds and functioned at 65.1 percent capacity with 10,377 total admissions during 2006, with an average stay of 3.9 days per admission. Non-Medicare/Medicaid patients accounted for 44 percent of Kadlec's admissions.

Kennewick General Hospital maintained a 46.7 percent occupancy rate of its 101 beds with 5,544 total admissions during 2006; average stay was 3.1 days per admission. Non-Medicare/Medicaid patients represented 46.9 percent of its total admissions during 2006.

Lourdes Medical Center operates a 95-bed health center located in Pasco that provides acute, subacute, skilled nursing and rehabilitation, and alcohol and chemical dependency treatment. Lourdes also operates the Lourdes Counseling Center, a 32-bed mental health hospital in Richland, as well as provides a significant amount of outpatient and home health services. For calendar year 2006, Lourdes had a total of 3,178 admissions, 25 percent of which were non-Medicare/Medicaid. During 2006, Lourdes had an average acute care length of stay of 2.8 days, and a 65 percent occupancy rate.

The Tri-Cities offers a broad range of social services. State human service offices in the Tri-Cities include the Job Service Center within the Employment Security Department, food stamp offices, the Developmental Disabilities Division, financial and medical assistance, Child Protective Service, emergency medical service, a senior companion program, and vocational rehabilitation.

The Tri-Cities is also served by a large number of private agencies and voluntary human service organizations. The United Way is an umbrella fund-raising organization that plays a significant role in the Tri-Cities. In 2006, 41 programs were funded through the community funding process; 22 Community Partners received a total of $1,616,747 for 41 programs; and 573 organizations received donor designations from the United Way of Benton and Franklin Counties.

4.7.9 Police and Fire Protection

Benton and Franklin counties' sheriff departments, local municipal police departments, and the Washington State Patrol Division with headquarters in Kennewick, provide police protection in Benton and Franklin counties, with a total of 362 officers (commissioned and reserved) in the Tri-Cities (Table 4.7-5). The Kennewick Municipal Police Department maintains the largest staff of commissioned officers with 92.

Fire protection is provided by the fire departments of the cities of Kennewick, Pasco, and Richland, and by Benton County Rural Fire Departments #1, #2, and #4. A total of 327 fire fighting personnel (194 salaried and 133 volunteer) are on staff in the Tri-Cities (Table 4.7-6).

Table 4.7-5. Police Personnel in the Tri-Cities, Washington, 2006

Area	Commissioned Officers	Reserve Officers	Patrol Cars
Kennewick Municipal	92	6	18
Pasco Municipal	65	12	34
Richland Municipal	52	7	15
West Richland Municipal	14	3	14
Benton County Sheriff	61	10	61
Franklin County Sheriff	26	14	26
Tri-Cities Total	**310**	**52**	**168**

The Hanford Fire Department, a highly trained and professional career industrial fire department with 145 members, provides fire protection on the Hanford Site and nearby areas. There are four fire stations strategically located on the Hanford Site. From these stations, four pumper crews, staffed with at least three firefighters each, provide suppression response. The Hanford Fire Department provides coverage to the entire Hanford Site and to SR 240 and SR 24. Coverage on the highways extends from the Vernita Bridge to the Silver Dollar Cafe on SR 24 and along SR 240 from the Yakima Barricade to the intersection with SR 225. Additionally, the Hanford Fire Department responds to mutual aid requests from 10 surrounding fire districts. Four ambulance crews (one in each fire station), staffed with two firefighters (Emergency Medical Technicians [EMT] or paramedic trained), provide emergency medical services 24 hours per day, seven days a week. A total of 40 emergency response vehicles, representing diverse capabilities, are maintained at the four fire stations. Some emergency equipment is specifically intended to control situations exclusive to the Hanford Site.

Table 4.7-6. Fire Protection Personnel in the Tri-Cities, Washington, 2006

Fire Department	Fire Fighting Personnel	Volunteers	Total	Service Area
Kennewick	70	0	70	City of Kennewick
Richland	55	0	55	City of Richland
Pasco	50	0	50	City of Pasco
BCRFD[(a)] 1	7	80	87	Kennewick Area
BCRFD 2	6	28	34	Benton City
BCRFD 4	6	25	31	West Richland
Tri-Cities Total	**194**	**133**	**327**	
Hanford	145	0	145	Hanford Site

(a) BCRFD = Benton County Rural Fire Department.

4.7.10 Parks and Recreation

The convergence of the Columbia, Snake, and Yakima rivers offers residents of the Tri-Cities a variety of recreational opportunities. The Lower Snake River Project includes Ice Harbor, Lower Monumental, Little Goose, and Lower Granite locks and dams, and a levee system and parkway at Clarkston and Lewiston (Figure 4.4-6). Although navigation capabilities and the electrical output are the major benefits of these projects, recreational benefits have also resulted. The Lower Snake River Project provides boating, camping, and picnicking facilities in nearly a dozen areas along the Snake River. During FY 2006, 2.3 million people visited the area and participated in activities along the Snake River.

Similarly, the Columbia River provides ample water recreational opportunities on the lakes formed by the dams. Lake Wallula, formed by McNary Dam, offers a large variety of parks and activities that attracted more than 3.9 million visitors during FY 2006. The Columbia River Basin is also a popular area for migratory waterfowl and upland game bird hunting.

Other opportunities for recreational activities in the Tri-Cities are accommodated by indoor and outdoor facilities, including numerous tennis courts, ball fields, and golf courses which offer outdoor recreation to residents and tourists (Table 4.7-7). Several privately owned health clubs in the area offer indoor tennis and racquetball courts, pools, and exercise programs. Bowling lanes and skating rinks also serve the Tri-Cities.

4.7.11 Utilities

The principal source of water in the Tri-Cities and the Hanford Site is the Columbia River. The water systems of Richland, Pasco, and Kennewick drew a large portion of the 48.8-billion L (12.9 billion gal) used during 2006 from the Columbia River. Each city operates its own supply and treatment system. The Richland water supply system derives about 82 percent of its water directly from the Columbia River, while the remainder is split between a well field in North Richland (that is recharged from the river) and groundwater wells. The city of Richland’s total water usage during 2006 was 20.1 billion L (5.3 billion gal). The Kennewick system uses two wells and the Columbia River for its water supplies. These wells serve as the sole source of water between November and March and can provide approximately 40 percent of the total maximum supply of 94.6 billion liters per day (25 million gal). Total 2006 usage in Kennewick was 13.4 billion L (3.5 billion gal). A significant number of Kennewick’s residents (about 22,000 residential customers) draw irrigation water from the Kennewick Irrigation District, which has the Yakima River as its source. The city of Pasco system also draws from the Columbia River for its water needs. During 2006, Pasco consumed 15.3 billion L (4.1 billion gal).

The major incorporated areas of Benton and Franklin counties are served by municipal wastewater treatment systems, whereas the unincorporated areas are served by onsite septic systems. Richland’s wastewater treatment system processed an average flow of 20.8 million L/day (5.5 million gal/day) during 2006 and is designed to treat 43.1 million L/day (11.4 million gal/day). Kennewick’s waste treatment system processed an average 22.5 million L/day (5.9 million gal/day) during 2004.

Table 4.7-7. Examples of Physical Recreational Facilities Available in the Tri-Cities, Washington

Activity	**Facilities**
Team sports	Baseball fields and basketball courts are located throughout the Tri-Cities. Soccer and football fields are also located in various areas. Spectator sports include minor league baseball and junior professional hockey.
Bowling	Lanes are found in each city, including Fiesta Bowling Center, Celebrity Bowl, and Go-Bowl.
Camping	Several hundred campsites can be found within driving distance from the Tri-Cities area, including Fishhook Park and Sun Lakes.
Fishing	Steelhead, sturgeon, trout, walleye, bass, and crappie fishing is excellent in the lakes and rivers near the Tri-Cities.
Golf	Several public courses include Sun Willows, Columbia Park, Canyon Lakes, Columbia Point, Buckskin, and West Richland Municipal, two semi-private courses, two private courses, and a number of driving ranges and pro shops.
Hunting	Duck, geese, pheasant, and quail hunting is available. Deer and elk hunting is available in the Blue Mountains and the Cascade Range.
Skating	There are roller-skating arenas in Richland and Prosser and recreational ice skating in Kennewick; a junior professional ice hockey arena is available to the public in Kennewick.
Water sports	There are public swimming pools in Pasco, Kennewick, and Richland, plus numerous private club pools. Boating, sailing, windsurfing, diving, water-skiing, swimming, etc., are available on the Columbia River, with 31 boat ramps in the Tri-Cities.
Tennis	Several outdoor city courts are available in each city, with additional outdoor courts located at area schools. Two private health clubs have indoor courts available.
Walking/bicycling	There are over 30 miles of paved bike/hike paths and 5,600 acres of parks in the Tri-Cities.

Their system is capable of treating about 46.1 million L/day (12.2 million gal/day). Pasco's waste treatment system processed an average 12.2 million L/day (3.2 million gal/day) and is capable of treating 16.1 million L/day (4.25 million gal/day).

The Benton County Public Utility District, Franklin County Public Utility District, and City of Richland Energy Services Department provide electricity to the Tri-Cities and surrounding areas. Nearly all the power these utilities provide in the local area is purchased from the Bonneville Power Administration (BPA), a federal power-marketing agency. These three utilities served over 89,400 customers and had 3.17 billion kilowatt-hour (kWh) total sales during 2006. The average rate for residential customers was approximately $0.0693/kWh during 2006, up slightly from $0.0669 during

2004. The Benton Rural Electrical Association serves portions of the rural areas of Benton and adjacent counties.

Electrical power for the Hanford Site is purchased wholesale from BPA, which provided 90 percent of the electricity consumed on the Hanford Site during 2006. Energy requirements for the Hanford Site during FY 2006 were 220 million kWh for a total cost of $7.3 million. Additionally, the Site spends about $0.024/kWh for electrical transportation and distribution within the Hanford Site.

Natural gas, provided by the Cascade Natural Gas Corporation (CNG), serves a small but growing portion of local residents, with 19,500 residential customers served in 2006. During 2000, CNG had 7,300 residential customers. The average annual gas bill for residential customers is approximately $1,100. CNG also serves the Hanford Site 300 Area.

Wind energy is a new but growing component of Pacific Northwest generating resources and is quite visible in the Tri-Cities area. Phase I of FPL Energy's Stateline wind generation project entered service during December 2001 near Walla Walla and has a current peak output of 300 MW. Energy Northwest's Nine Canyon Wind Farm entered service during October 2002 near Kennewick and has a current peak output of 63 MW (BPA 2007). At prices of 4.0 to 6.0 cents per kWh, wind energy is becoming more competitive with other sources, despite relatively high costs per installed kWh and capacity factors of around 35 percent (NPCC 2007). A capacity factor is the net electricity generated, for the period of time considered, to the energy that could have been generated at continuous full-power operation during the same period. For comparison, the average capacity factor for nuclear plants in the United States during 2005 was 89.4 percent (EIA 2007).

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4.8 Visual Resources

With the exception of Rattlesnake Mountain, the land near the Hanford Site is generally flat with little relief. Rattlesnake Mountain, rising to 1,060 m (3,477 ft) above mean sea level forms the western boundary of the Hanford Site, and Gable Mountain and Gable Butte are the highest landforms within the Site (Figure 4.8-1). The view toward Rattlesnake Mountain is visually pleasing, especially during the springtime when wildflowers are in bloom. Large rolling hills are located to the west and far north. The Columbia River, flowing across the northern part of the Hanford Site and forming the eastern boundary, is generally considered scenic, with its contrasting blue against a background of brown basaltic rocks and sagebrush (DOE 1999b). The White Bluffs, steep whitish-brown bluffs adjacent to the Columbia River and above the northern boundary of the river in this region, are a major feature of the landscape.

Traditional Native American religion is manifest in the earth, water, sky, and all animate or inanimate beings that inhabit a given location. The National Historic Preservation Act (16 USC 470 *et seq.*), the Native American Graves Protection and Repatriation Act (25 USC 3001 *et seq.*), the Archaeological Resources Protection Act (16 USC 470aa *et seq.*), and DOE's American Indian Policy (DOE 1992b), among other legislation and guidelines, all require the identification and protection of areas and resources of concern to Native Americans. The acquisition of spiritual guidance and assistance through personal vision quests is a religious practice of the Native Americans that lived near the Hanford Site. High locations were selected as sacred sites in part because they afforded extensive views of the landscape and seclusion for meditation. The Gable Butte Block Survey conducted during 2001 determined that Gable Butte and Gable Mountain were likely used for vision quests (Hale and Harvey 2002). Many Hanford facilities that clearly are not part of the “natural” landscape are easily seen from these sites.

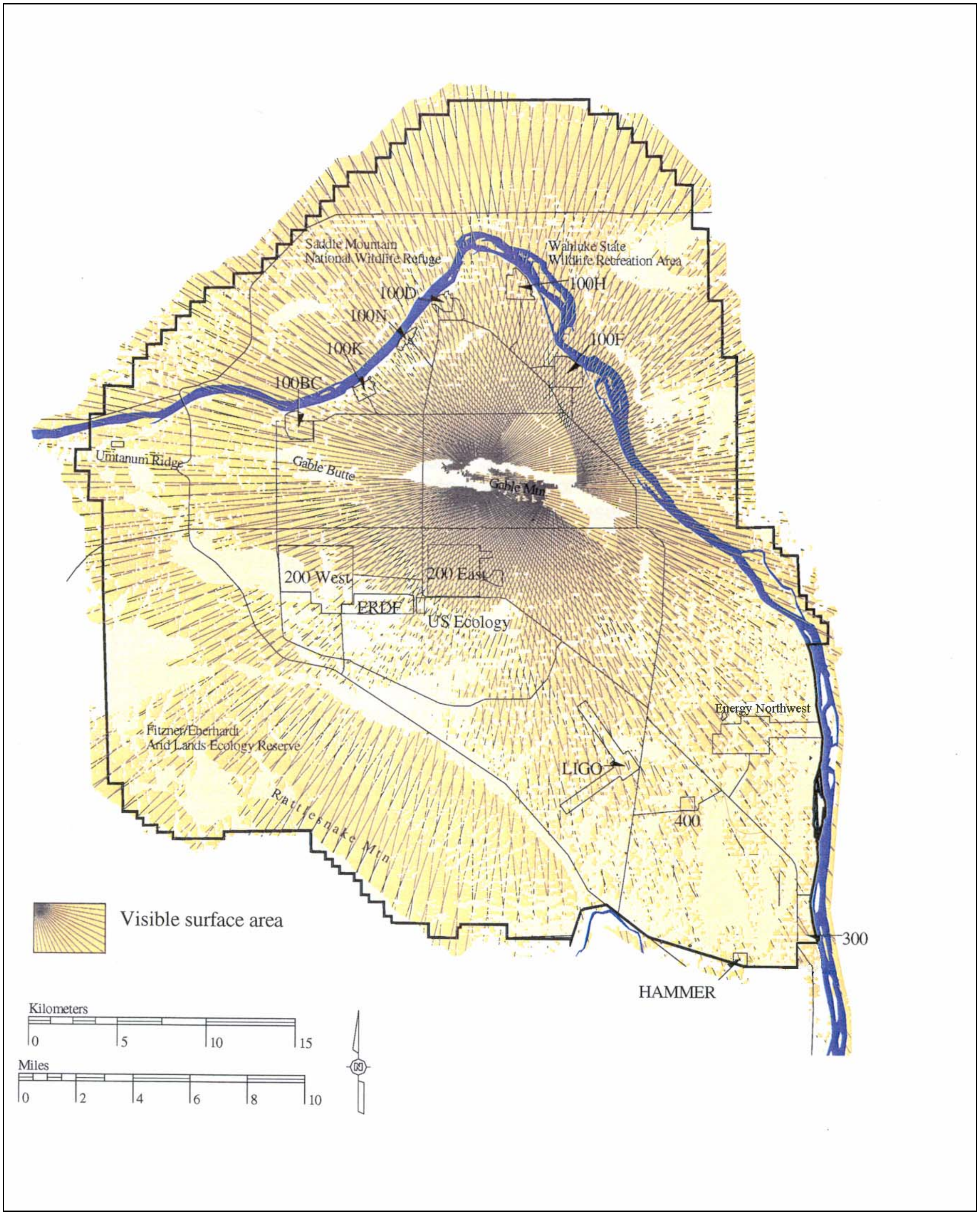

Figure 4.8-1. Viewshed from Gable Mountain on the Hanford Site, Washington (modified from DOE 1999b)

4.9 Noise

B. G. Fritz

Noise is technically defined as the intensity, duration, and character of sounds from any and all sources (RCW 70.107). Sound waves are characterized by frequency, measured in Hertz (Hz), and sound pressure expressed as decibels (dB). Humans have a perceptible hearing range of 31 to 20,000 Hz. The decibel is a value equal to 10 times the logarithm of the ratio of a sound pressure squared to a standard reference sound-pressure level (20 micropascals) squared (Harris 1991). The threshold of audibility ranges from about 60 dB at a frequency of 31 Hz to less than about 1 dB between 900 and 8,000 Hz. (For regulatory purposes, noise levels for perceptible frequencies are weighted to provide an A-weighted sound level [dBA] that correlates highly with individual community response to noise.) Sound levels outside the range of human hearing are not considered noise in a regulatory sense, even though wildlife may hear at these frequencies.

Noise levels are often reported as the equivalent sound level (L_{eq}). The L_{eq} is expressed in dBA over a specified period of time, usually 1 hour or 24 hours. The L_{eq} is the equivalent steady sound level that, if continuous during a specified time period, would contain the same total energy as the actual time-varying sound over the monitored or modeled time period (Harris 1991).

4.9.1 Background Information

Studies of the propagation of noise at Hanford have been concerned primarily with occupational noise at work sites. Environmental noise levels have not been extensively evaluated because of the remoteness of most Hanford activities and isolation from receptors that are covered by federal or state statutes. This discussion focuses on what few environmental noise data are available. The majority of available information consists of model predictions, which in many cases have not been verified because the predictions indicate that the potential to violate federal or state standards is remote or unrealistic.

4.9.2 Environmental Noise Regulations

The Noise Control Act of 1972 (42 USC 4901) and its subsequent amendments (Quiet Communities Act of 1978 and 40 CFR 201-211) direct the regulation of environmental noise to individual states. The State of Washington has adopted Revised Code of Washington (RCW) 70.107, which authorizes Ecology to implement rules consistent with federal noise control legislation. RCW 70.107 and the implementing regulations embodied in WAC 173-60 through 173-70 define the management of environmental noise levels. Maximum noise levels are defined for the zoning of the area in accord with the environmental designation for noise abatement (EDNA). The Hanford Site is classified as a Class C EDNA on the basis of industrial activities. Unoccupied areas are also classified as Class C areas by default because they are neither Class A (residential) nor Class B (commercial). Maximum noise levels are established based on the EDNA classification of the receiving area and the source area (Table 4.9-1).

Table 4.9-1. Applicable State Noise Limitations for the Hanford Site, Washington, Based on Source and Receptor EDNA Designation

Source Hanford Site	Receptor		
	Class A Residential (dBA)	**Class B Commercial (dBA)**	**Class C Industrial (dBA)**
Class C - Day	60	65	70
Night	50	--	--

4.9.3 Hanford Site Sound Levels

Most industrial facilities on the Hanford Site are located far enough away from the Site boundary that noise levels at the boundary are not measurable or are barely distinguishable from background noise levels. Modeling of environmental noises has been performed for commercial reactors and SR 240 through the Hanford Site. These data are not concerned with background levels of noise and are not reviewed here. There have been two studies measuring environmental noise at Hanford: during a 1981 site characterization for the Skagit/Hanford Nuclear Power Plant Site (NRC 1982) and when the Hanford Site was considered for a geologic waste repository (Basalt Waste Isolation Project) for spent commercial nuclear fuel and other high-level nuclear waste. Hanford Site characterization studies performed during 1987 included measurement of background environmental noise levels at five locations (Figure 4.9-1). Additionally, certain activities such as well drilling and sampling have the potential for producing noise in the field apart from major permanent facilities.

4.9.3.1 Skagit/Hanford Data

Measurements of environmental noise were collected during June 1981 on the Hanford Site during site characterization prior to the construction of the Skagit/Hanford Nuclear Power Plant (NRC 1982). Fifteen sites were monitored and noise levels ranged from 30 to 61 dBA (L_{eq}). The values for isolated areas ranged from 30 to 39 dBA. Measurements taken around the sites where Energy Northwest was constructing nuclear power plants (WNP-1, WNP-2 (now the Columbia Generating Station), and WNP-4) ranged from 51 to 64 dBA. Measurements taken along the Columbia River near the intake structures for the Columbia Generating Station were 48 and 52 dBA compared with more remote river noise levels of 46 dBA (measured about 4.8 km [3 mi] upstream of the intake structures). Community noise levels in North Richland (Horn Rapids Road and SR 240) were 61 dBA.

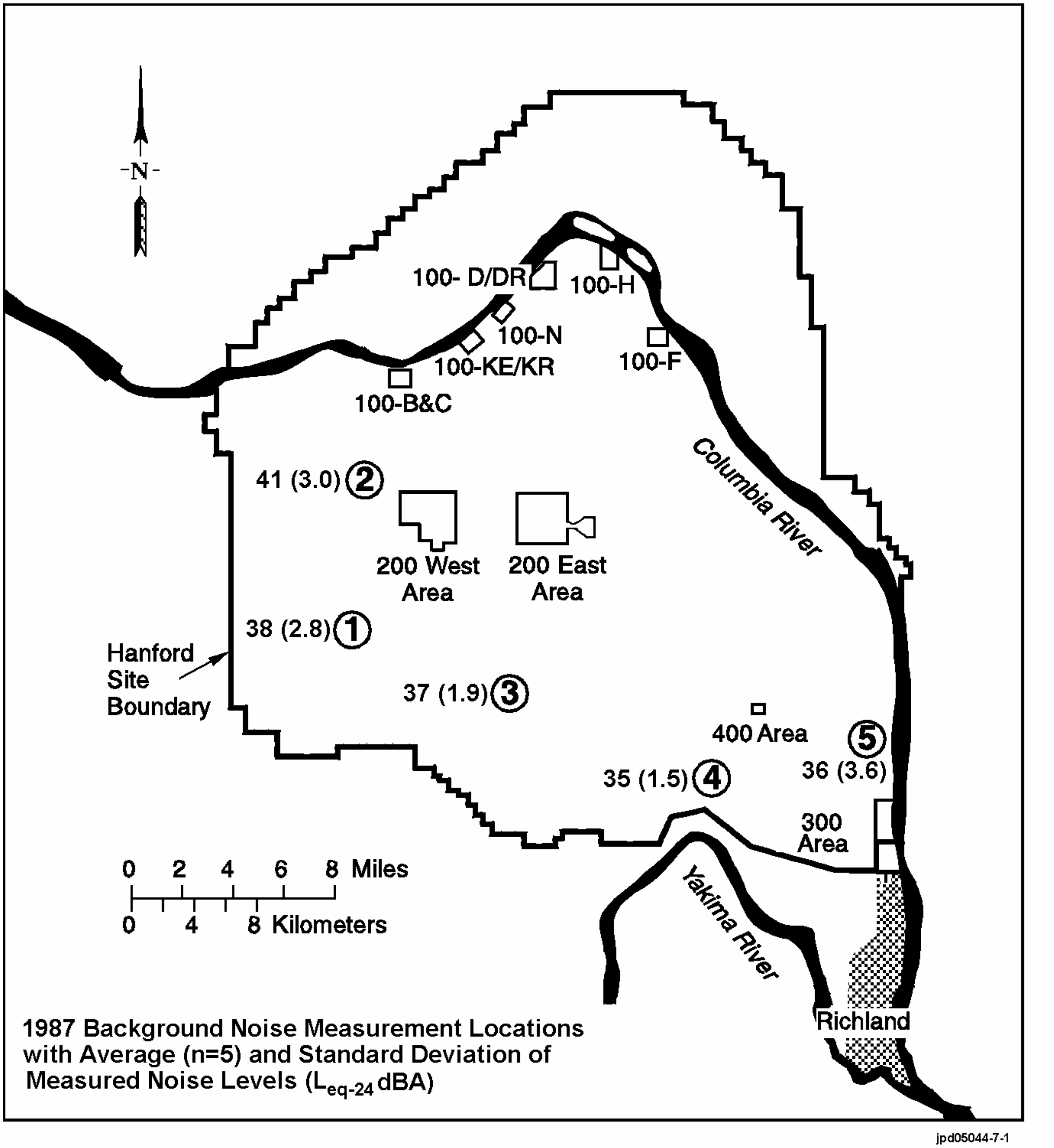

Figure 4.9-1. Location of Background Noise Measurements Collected for the Basalt Waste Isolation Project, Hanford Site, Washington (modified from Coleman 1988)

4.9.3.2 Basalt Waste Isolation Project (BWIP) Data

Background noise levels were measured at five locations within the Hanford Site boundary (Figure 4.9-1). Noise levels are expressed as L_{eq} for 24 hours (L_{eq}-24). Wind was identified as the primary contributor to background noise levels, with winds exceeding 19 km/hr (12 mph) having a significant effect on noise levels. Background noise levels (L_{eq}-24) in undeveloped areas around the Hanford Site were observed to range between 24 and 36 dBA (Coleman 1988). Periods of high wind, which normally occur in the spring, would elevate background noise levels (Harris 1991).

4.9.3.3 New Production Reactor (NPR) EIS

Baseline noise estimates were determined for two locations: SR 24, leading from the Hanford Site west to Yakima, and SR 240, south of the Hanford Site and west of Richland where it handles maximum traffic volume (DOE 1991). Traffic volumes were predicted based on an operational work force and a construction work force. Both peak (rush hour) and off-peak hours were estimated. Noise levels were expressed in L_{eq} for 1-hr periods in dBA at a receptor located 15 m (49 ft) from the road edge (Table 4.9-2). Adverse responses would not be expected at increases of 5 dBA over background noise levels.

4.9.3.4 Noise Levels of Hanford Field Activities

Numerous field activities performed routinely by Hanford Site workers have the potential to generate noise at levels above typical background noise levels. These activities could possibly disturb wildlife when performed in remote areas. Typical field activities include well drilling, operation of pile drivers, driving heavy trucks on rough roads, and operation of heavy construction equipment such as dumptrucks and bulldozers. Typical noise levels achieved from Hanford Site activities range from 85 to 100 dBA at 15 m (49 ft). Attenuation of noise levels to 80 dBA and 60 dBA range from 30 to 150 m (98 to 492) and 250 to 1,300 m (820 to 4,270 ft), respectively (Harris 1991).

Table 4.9-2. Estimated Noise Resulting from Automobile Traffic at Hanford, Washington, with the New Production Reactor Environmental Impact Statement (DOE 1991)[a]

Location[b]	Scenario	Traffic flow (Vehicles/hr)		Noise levels (L_{eq}-1 hr in dBA)		Maximum Increase (dBA)
		Baseline	Maximum[c]	Baseline Noise Levels	Estimated Noise Levels[c]	
Construction phase						
SR 24	Off-Peak	91	91	62.0	62.0	0.0
	Peak	91	343	62.0		
SR 240	Off-Peak	571	579	70.2	70.6	0.4
	Peak	571	2,839	70.2	73.5	3.3
Operation phase						
SR 24	Off-Peak	91	91	62.0	62.0	0.0
	Peak	300	386	65.7	66.2	1.5
SR 240	Off-Peak	571	582	70.2	70.5	0.3
	Peak	2,239	3,009	74.1	74.7	0.6

(a) Measured 15 m (49 ft) from the road edge.
(b) SR 24 leads to Yakima; SR 240 leads to the Tri-Cities area.
(c) Traffic flow and noise estimates varied with NPR technology; the maximum impacts from three NPR techniques are shown here.

Table 4.9-3. Noise Levels Propagated from Construction Activities (Harris 1991)

Activity	Noise Level (dBA) at 15 m (49 ft)	Distance to Attenuate to 80 dBA	Distance to Attenuate to 60 dBA
Truck	85	30 m (98 ft)	250 m (820 ft)
Pile driver	100	150 m (492 ft)	1,300 m (4,270 ft)
Bulldozer	95	80 m (262 ft)	800 m (2,620 ft)

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4.10 Occupational Health and Safety

S. F. Snyder

This section describes worker health and safety experience at the Hanford Site for use in comparing and estimating projected effects of proposed activities evaluated in NEPA documents. Information is presented on industrial accident and illness experience as well as worker exposure to radiation.

4.10.1 Industrial Illness and Injury Experience at the Hanford Site

Total occupational work hours at the Hanford Site for the five-year period 2001-2005 were 145,258,223 hours, or an annual average of 14,530 worker-years.[(a)] For record-keeping, the Hanford Site is comprised of the DOE Office of River Protection and DOE Richland Operations. The DOE records occupational injuries and illnesses in categories pertinent to NEPA analysis. Total recordable cases (TRC) are the total number of work-related injuries or illnesses that resulted in death, days away from work, job transfer or restriction, or “other recordable case" as identified in columns G, H, and J of the Occupational Safety and Health Administration (OSHA) Form 300, *Log of Work-Related Injury and Illness* (OSHA 2007). Lost workday cases (LWC) represent the number of cases recorded resulting in days away from work or days of restricted work activity, or both. Fatalities are the number of occupationally related deaths (DOE 2007c).

TRC, LWC, and fatality rates are summarized in Table 4.10-1 for the Bureau of Labor Statistics (BLS), the Office of River Protection, and Richland Operations Office. In addition, total DOE rates are shown for comparison. Occupational injury and illness TRC incidence rates for the Hanford Site Office of River Protection were 1.7, 1.9, and 1.5 cases per 200,000 worker hours during 2001, 2002, and 2003, respectively (Figure 4.10-1). Rates increased to 2.6 and 2.4 cases per 200,000 worker hours during 2004 and 2005. Due to changes in record-keeping requirements, the 2001 data are not directly comparable to the 2002 and later rates (DOE 2007c). Occupational injury and illness incidence rates for Richland Operations have decreased annually from 2001 through 2005, from 2.2 to 1.1 cases per 200,000 worker hours (DOE 2007c). The TRC trend with Richland Operations is consistent with that found over all DOE sites. Occupational injury and illness incidence rates for all DOE sites demonstrate annual decreases, ranging from 2.4 cases per 200,000 worker hours in 2001 to 1.6 cases in 2005 (DOE 2007c).

Over the 5-yr period from 2001 to 2005, the Office of River Protection and Richland Operations TRC rates averaged 2.0 and 1.6 cases per 200,000 worker hours, respectively, whereas the incidence rate for all DOE sites fell within these two values, at 1.9 cases per 200,000 worker hours (DOE 2007c). Both Hanford Site rates and the DOE-wide average TRC rates were well below the BLS average rate for U.S. private industry of 5.1 cases per 200,000 worker hours during the same period (BLS 2007).

(a) Based on a 40-hour week for 50 weeks per year.

During the 5-yr period from 2001-2005, Richland Operations TRC and LWC rates were somewhat lower than those for all DOE sites, whereas the private sector was consistently higher (Table 4.10-1). There were no fatalities at the Hanford Site during the 2001 to 2005 period (DOE 2007c).

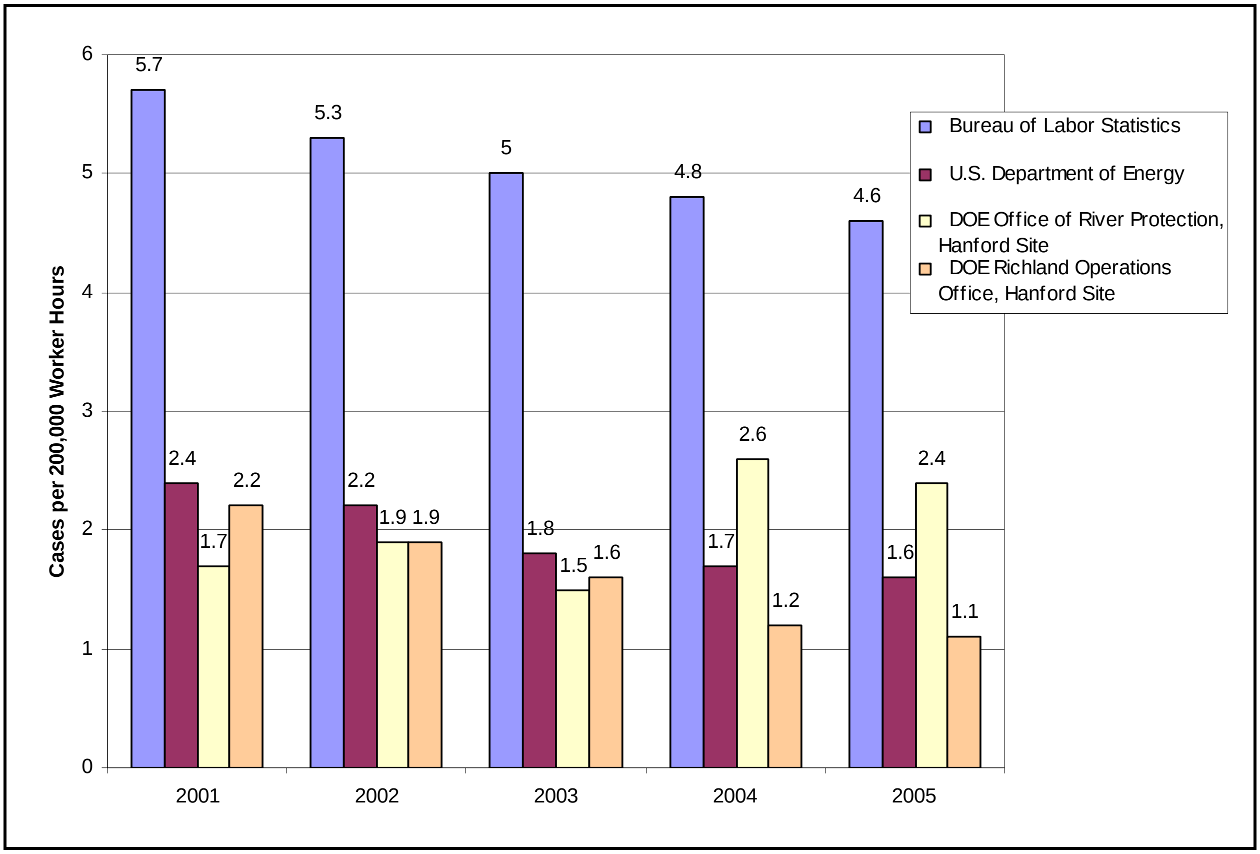

Figure 4.10-1. Occupational Injury and Illness Total Recordable Case Rates at the Hanford Site, Washington, Compared with Department of Energy and Private Industry. (Note: Due to changes in the record-keeping requirement, 2001 values are not comparable to 2002 and later rates) (DOE 2007c).

Table 4.10-1. Occupational Injury and Illness Incidence Rates, and Fatality Counts for U.S. Department of Energy Facilities and Private Industry. (Note: Due to record-keeping requirement changes, 2001 data are not comparable to later years) (DOE 2007c; BLS 2007).

	Total Recordable Cases [a]					Lost Work Cases [a]					Fatalities [b]				
	2001	**2002**	**2003**	**2004**	**2005**	**2001**	**2002**	**2003**	**2004**	**2005**	**2001**	**2002**	**2003**	**2004**	**2005**
Bureau of Labor Statistics	5.7	5.3	5	4.8	4.6	2.8	2.8	2.6	2.5	2.4	4.3	4	4	4.1	4
BLS 2001-2005 Average			5.1					2.6					4.1		
U.S. Department of Energy	2.4	2.2	1.8	1.7	1.6	1	1	0.8	0.7	0.7	0	0.7	0	0	0
DOE 2001-2005 Average			1.9					0.8					0.1		
DOE Office of River Protection, Hanford Site	1.7	1.9	1.5	2.6	2.4	0.5	0.9	0.9	1.6	1.5	0	0	0	0	0
ORP 2001-2005 Average			2.0					1.1					0		
DOE Richland Operations Office, Hanford Site	2.2	1.9	1.6	1.2	1.1	0.8	1	0.9	0.5	0.4	0	0	0	0	0
RL 2001-2005 Average			1.6					0.7					0		

(a) Per 200,000 worker hours.
(b) Per 100,000 workers.

4.10.2 Occupational Radiation Exposure at the Hanford Site

DOE has established dose limits to control radiation exposures. Doses are expressed as Total Effective Dose Equivalent (TEDE), which is defined as the sum of the dose from radiation sources internal and external to the body, reported in units of rem or mrem. The regulatory limit for an individual worker is 5,000 mrem (50 mSv) per year TEDE (10 CFR 835). A DOE Administrative Control Level (ACL) of 2,000 mrem (20 mSv) per year TEDE has been established for all DOE workers to maintain doses well below the regulatory limit (DOE 1999c).

DOE's Office of Safety and Health reports occupational radiation exposure data for all monitored DOE employees, contractors, subcontractors, and members of the public associated with DOE facilities. The number of workers monitored during the 5-yr period, 2001-2005, at the Hanford Site (excluding Office of River Protection [ORP]) ranged from 8,730 to 9,289, for a total of 45,177 worker-years of monitored exposure. Employees at the ORP represented approximately 16 percent of the Site's monitored workers, a total of 7,606 worker-years of exposure (DOE 2007d). There were no individual worker doses in excess of the 2,000 mrem (20 mSv) per year TEDE ACL or the 5,000 mrem (50 mSv) per year TEDE regulatory limit at the Hanford Site during the period 2001-2005 (DOE 2007d).

Measurable dose is used to report the dose for individuals whose TEDE is statistically greater than background measurements. Twenty-four percent of the total monitored Hanford Site non-ORP employees and 22 percent of the ORP employees had measurable doses during the 2001-2005 period. The average measurable dose for all monitored ORP employees increased from 59 to 84 mrem/yr (0.059 to 0.084 mSv/yr) TEDE during the period from 2001 to 2003 before decreasing to 49 mrem/yr (0.049 mSv/yr) TEDE in 2004 and 2005. The average dose for all non-ORP monitored Hanford workers experienced a net decrease from 103 mrem/yr (1.03 mSv/yr) TEDE during 2001 to 95 mrem/yr (0.95 mSv/yr) TEDE during 2005, a net decrease of 8 percent (Figure 4.10-2) (DOE 2007d).

Collective dose, an indicator of the overall workforce radiation exposure, is the sum of the dose received by all individual workers with measurable dose and is expressed in units of person-rem. (For example, a dose of 1 rem to each of 10 workers would result in a collective dose of 10 person-rem.) The annual collective dose for Hanford Site ORP employees ranged from 13 to 37 person-rem during the 5-year period from 2001 to 2005. The corresponding collective dose to all Hanford non-ORP workers ranged from 191 to 249 person-rem per year during this same period (Figure 4.10-3).

Radiation exposure data for the period 2001 to 2005 indicate the total number of individuals monitored on the Hanford Site has varied, while the number of individuals with measurable dose had an upward trend through 2004 and decreased in 2005 (Table 4.10-2) (DOE 2007d). The 5-yr average occupational dose for workers with measurable dose was 103 mrem/yr (10.3 mSv/yr) for Hanford non-ORP workers and 62 mrem/yr (0.62 mSv/yr) for ORP workers, well below the established ACL of 2,000 mrem/yr (20 mSv/yr).

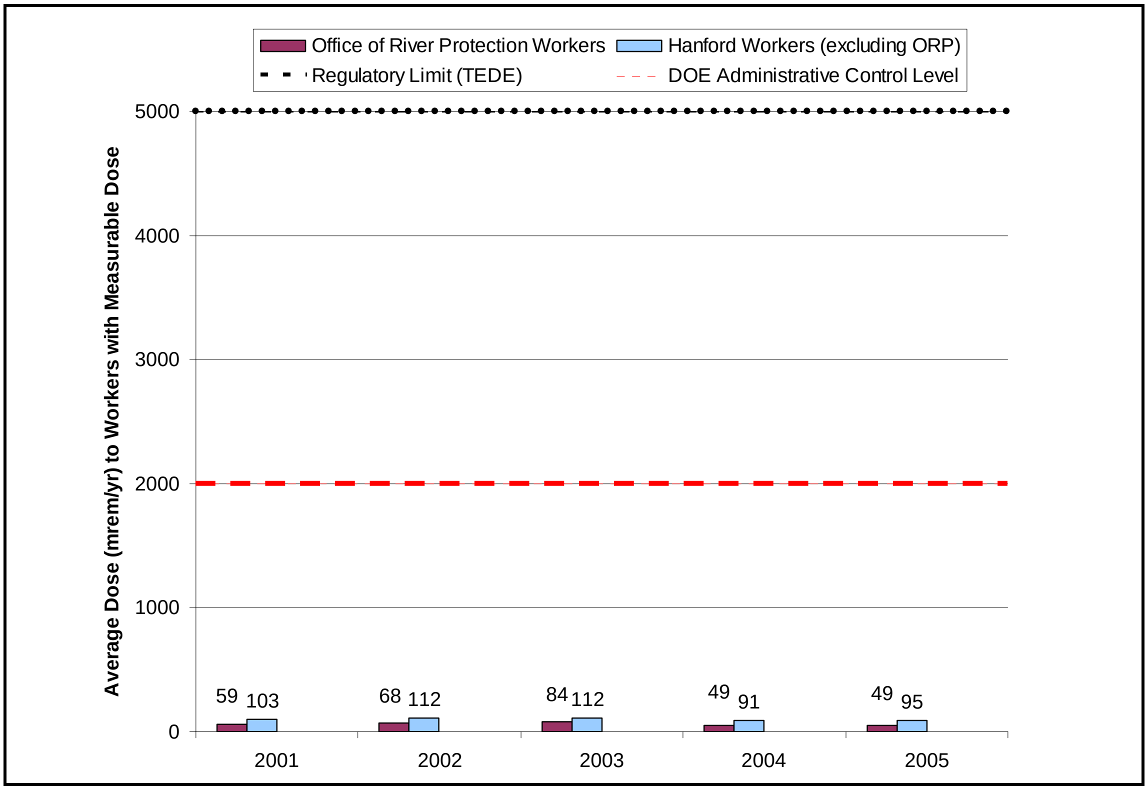

Figure 4.10-2. Average Measurable Dose (mrem/yr) to Hanford Site, Washington, 2001-2005 (DOE 2007d) (1 mrem = 0.01 mSv)

Figure 4.10-3. Collective Operational Dose (person-mrem/yr) at the Hanford Site, Washington, 2001-2005 (DOE 2007d) (1 rem = 0.01 Sv)

Table 4.10-2. Radiation Exposure Data for the Hanford Site, Washington, 2001-2005 (DOE 2007d) (1 mrem = 0.01 mSv)

Year	Total Number Monitored	Number with Measurable Dose	Percent with Dose >0	Total Collective Dose (TEDE) to Workers with Measurable Dose (person-mrem/yr)	Average Dose to Workers with Measurable Dose (mrem) (Dose >0)
Hanford Site excluding Office of River Protection					
2005	9,042	2,022	22%	191,000	95
2004	8,730	2,278	26%	205,000	91
2003	8,876	2,177	25%	243,500	112
2002	9,289	2,242	24%	249,000	112
2001	9,240	1,924	21%	196,000	103
Cumulative Totals					
2001-2005	45,177	10,643	24%	1,084,500	103
Office of River Protection					
2005	1,676	272	16%	13,000	49
2004	1,603	288	18%	14,000	49
2003	1,688	449	27%	37,000	84
2002	1,380	369	27%	25,000	68
2001	1,259	295	23%	17,000	59
Cumulative Totals					
2001-2005	7,606	1,673	22%	106,000	62

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Appendix A

Atmospheric Dispersion Tables

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Appendix A
Atmospheric Dispersion Tables

Definitions:

X = Air Concentration in Curies per Cubic Meter (Ci/m^3)

Q = Emission Rate in Curies per Second (Ci/s)

E = Short term 95 Percent Centerline Concentration (Ci/m^3)

Atmospheric Stability Class:

A – Extremely unstable

B – Moderately unstable

C – Slightly unstable

D – Neutral

E – Slightly stable

F – Moderately stable

G – Very stable

Conversion Factors:

1 Ci = 37,000 mBq

1 pCi = 0.037 Bq

1 Ci = 10^{12} pCi

1 m^3 = 35.3 ft^3

1.61 km = 1 mi

Examples for the use of Chronic (X/Q') and Acute (E/Q') Release Tables:

Chronic Release (Long Term):

Assume wind is from 100-N Area toward the south. To find the estimated air concentration 1 km downwind from a constant source (i.e., stack) with a release rate of 0.0028 Ci/s, multiply the X/Q' value from the table (3.1×10^{-6} s/m^3) by the release rate (0.0028 Ci/s):

$$\mathbf{X} = (3.1 \times 10^{-6}\ s/m^3)\ (0.0028\ Ci/s) = 10^{-8}\ Ci/m^3 = 10{,}000\ pCi/m^3$$

Acute Release (Short Term):

Assume wind is from 100-N Area towards the south. To find the estimated maximum centerline concentration (95 percent in this direction from a ground level accidental release (10 Ci in 1 hr = 0.0028 Ci/s) at a location 1 km downwind, multiply the E/Q' value from the table (9.8×10^{-4} s/m^3) by the release rate (0.0028 Ci/s):

$$\mathbf{E} = (9.8 \times 10^{-4}\ s/m^3)\ (0.0028\ Ci/s) = 2.7 \times 10^{-6}\ Ci/m^3 = 2.7 \times 10^{6}\ pCi/m^3$$

Maximum Emission Rate:

Another use of the X/Q' value is to estimate a maximum allowable release rate. Assume that the maximum allowable air concentration of a radionuclide 4 km north of 100-N Area is 100 pCi/m^3. The maximum allowable release rate can be estimated by dividing the X/Q' value from the table ($2.5 \times 10^{-7}\ s/m^3$) by the maximum allowable concentration:

$$\mathbf{Q} = 2.5 \times 10^{-7}\ s/m^3 / 100\ pCi/m^3 = 2.5 \times 10^{-9}\ pCi/s$$

Table A1. Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 100 Areas at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. Based on 1983-2006 data from the 100-N Area instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows in the 100-N Area toward the Direction Indicated															
	9.1 m	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s	A	0.29	0.23	0.19	0.17	0.23	0.20	0.16	0.12	0.12	0.11	0.15	0.20	0.28	0.34	0.40	0.34
(2 mph)	B	0.11	0.09	0.09	0.08	0.11	0.14	0.10	0.07	0.06	0.06	0.08	0.09	0.13	0.13	0.17	0.14
	C	0.11	0.08	0.08	0.08	0.10	0.11	0.10	0.07	0.07	0.06	0.07	0.08	0.10	0.12	0.13	0.12
	D	0.49	0.40	0.44	0.54	0.79	0.94	0.80	0.59	0.53	0.48	0.53	0.60	0.72	0.68	0.66	0.54
	E	0.49	0.47	0.55	0.65	0.87	0.86	0.73	0.55	0.49	0.46	0.54	0.64	0.75	0.78	0.69	0.53
	F	0.50	0.47	0.61	0.68	0.82	0.69	0.50	0.34	0.29	0.32	0.46	0.63	0.81	0.85	0.76	0.60
	G	0.21	0.20	0.23	0.30	0.32	0.23	0.17	0.12	0.11	0.13	0.20	0.32	0.47	0.44	0.38	0.27
2.65 m/s	A	0.49	0.52	0.38	0.17	0.26	0.34	0.28	0.17	0.13	0.14	0.31	0.48	0.57	0.52	0.53	0.50
(6 mph)	B	0.14	0.15	0.11	0.06	0.10	0.14	0.13	0.08	0.05	0.04	0.11	0.17	0.20	0.15	0.16	0.12
	C	0.10	0.11	0.10	0.05	0.08	0.11	0.11	0.07	0.04	0.03	0.09	0.13	0.16	0.12	0.10	0.10
	D	0.39	0.45	0.37	0.35	0.53	0.69	0.69	0.40	0.28	0.29	0.49	0.91	0.98	0.70	0.52	0.39
	E	0.23	0.23	0.33	0.56	0.74	0.73	0.65	0.36	0.26	0.27	0.62	1.34	1.55	0.93	0.49	0.26
	F	0.14	0.14	0.25	0.62	0.80	0.54	0.32	0.16	0.10	0.14	0.33	0.78	0.93	0.57	0.30	0.15
	G	0.03	0.04	0.08	0.26	0.30	0.16	0.08	0.04	0.03	0.04	0.13	0.33	0.44	0.23	0.08	0.04
4.7 m/s	A	0.09	0.28	0.21	0.04	0.05	0.09	0.12	0.06	0.05	0.08	0.26	0.30	0.36	0.40	0.17	0.08
(10.5 mph)	B	0.02	0.07	0.05	0.01	0.02	0.02	0.04	0.02	0.02	0.02	0.07	0.08	0.11	0.10	0.04	0.02
	C	0.02	0.05	0.04	0.01	0.01	0.02	0.04	0.02	0.01	0.02	0.05	0.05	0.08	0.07	0.03	0.02
	D	0.15	0.21	0.14	0.06	0.06	0.13	0.29	0.15	0.10	0.16	0.33	0.50	0.88	0.68	0.20	0.13
	E	0.09	0.13	0.09	0.05	0.05	0.07	0.26	0.15	0.12	0.15	0.31	0.79	1.48	0.92	0.20	0.07
	F	0.06	0.07	0.04	0.05	0.03	0.03	0.08	0.04	0.02	0.02	0.07	0.26	0.24	0.12	0.04	0.04
	G	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.04	0.03	0.01	0.01	0.01
7.2 m/s	A	0.04	0.11	0.08	0.01	0.00	0.01	0.03	0.02	0.01	0.03	0.19	0.14	0.23	0.41	0.20	0.02
(16 mph)	B	0.02	0.03	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.07	0.03	0.06	0.09	0.05	0.01
	C	0.01	0.02	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.05	0.03	0.05	0.07	0.04	0.01
	D	0.06	0.11	0.06	0.02	0.00	0.01	0.05	0.06	0.06	0.11	0.29	0.18	0.37	0.72	0.26	0.05
	E	0.04	0.09	0.06	0.02	0.00	0.01	0.03	0.04	0.04	0.08	0.15	0.17	0.46	0.70	0.15	0.03
	F	0.02	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.03	0.01	0.01
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
9.8 m/s	A	0.00	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.05	0.07	0.20	0.14	0.00
(22 mph)	B	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.02	0.05	0.04	0.00
	C	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.04	0.03	0.00
	D	0.02	0.03	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.07	0.13	0.07	0.08	0.26	0.16	0.01
	E	0.02	0.03	0.03	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.06	0.03	0.04	0.16	0.07	0.01
	F	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.7 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.02	0.06	0.04	0.00
(29 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00
	D	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.02	0.02	0.06	0.03	0.01
	E	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.02	0.02	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.6 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(35 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(43 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A2. Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 100 Areas at 60 m (197 ft) above Ground Level, Hanford Site, Washington. Based on 1986-2006 data from the 100-N Area instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows in the 100-N Area toward the Direction Indicated															
	60 m	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s	A	0.27	0.25	0.19	0.18	0.23	0.23	0.18	0.15	0.12	0.11	0.14	0.18	0.23	0.29	0.31	0.33
(2 mph)	B	0.13	0.10	0.10	0.09	0.11	0.14	0.10	0.07	0.07	0.06	0.07	0.09	0.11	0.11	0.12	0.12
	C	0.11	0.09	0.07	0.08	0.10	0.11	0.12	0.08	0.06	0.06	0.05	0.07	0.10	0.10	0.10	0.11
	D	0.44	0.38	0.39	0.47	0.72	0.81	0.73	0.54	0.44	0.39	0.39	0.47	0.56	0.55	0.51	0.43
	E	0.39	0.36	0.42	0.55	0.75	0.72	0.61	0.45	0.38	0.33	0.36	0.40	0.51	0.48	0.42	0.37
	F	0.33	0.33	0.48	0.68	0.97	0.82	0.59	0.39	0.28	0.25	0.24	0.29	0.35	0.38	0.37	0.33
	G	0.15	0.16	0.23	0.35	0.52	0.40	0.22	0.15	0.11	0.09	0.10	0.11	0.15	0.18	0.19	0.16
2.65 m/s	A	0.44	0.53	0.37	0.19	0.25	0.35	0.28	0.19	0.13	0.13	0.27	0.43	0.46	0.32	0.30	0.30
(6 mph)	B	0.13	0.16	0.10	0.06	0.10	0.14	0.16	0.09	0.05	0.04	0.10	0.14	0.16	0.13	0.10	0.09
	C	0.10	0.13	0.09	0.05	0.08	0.12	0.11	0.08	0.04	0.04	0.07	0.11	0.14	0.10	0.07	0.07
	D	0.42	0.45	0.37	0.32	0.51	0.65	0.71	0.43	0.28	0.22	0.34	0.52	0.75	0.65	0.43	0.34
	E	0.26	0.28	0.27	0.44	0.71	0.72	0.67	0.39	0.25	0.20	0.28	0.44	0.81	0.96	0.59	0.29
	F	0.21	0.19	0.22	0.49	0.99	0.86	0.53	0.24	0.13	0.09	0.13	0.22	0.50	0.71	0.48	0.23
	G	0.09	0.07	0.11	0.24	0.49	0.38	0.19	0.07	0.04	0.03	0.04	0.06	0.16	0.26	0.22	0.11
4.7 m/s	A	0.09	0.27	0.23	0.05	0.05	0.11	0.13	0.07	0.06	0.08	0.24	0.27	0.33	0.27	0.12	0.09
(10.5 mph)	B	0.04	0.09	0.06	0.01	0.01	0.03	0.05	0.04	0.03	0.03	0.08	0.07	0.11	0.09	0.03	0.02
	C	0.03	0.07	0.05	0.02	0.01	0.03	0.05	0.03	0.02	0.02	0.05	0.06	0.08	0.06	0.02	0.02
	D	0.20	0.25	0.16	0.09	0.09	0.16	0.33	0.16	0.14	0.15	0.24	0.30	0.51	0.43	0.18	0.15
	E	0.16	0.18	0.14	0.12	0.14	0.19	0.36	0.21	0.17	0.16	0.26	0.43	1.04	1.12	0.33	0.15
	F	0.10	0.10	0.06	0.09	0.12	0.14	0.22	0.11	0.04	0.04	0.05	0.15	0.42	0.55	0.18	0.08
	G	0.03	0.04	0.02	0.03	0.04	0.05	0.06	0.02	0.01	0.01	0.01	0.03	0.06	0.13	0.07	0.03
7.2 m/s	A	0.06	0.18	0.10	0.02	0.01	0.02	0.05	0.03	0.03	0.05	0.19	0.16	0.26	0.35	0.12	0.03
(16 mph)	B	0.03	0.05	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.05	0.04	0.07	0.08	0.04	0.01
	C	0.02	0.02	0.01	0.01	0.00	0.01	0.02	0.02	0.01	0.01	0.04	0.03	0.05	0.07	0.02	0.01
	D	0.11	0.14	0.08	0.03	0.04	0.04	0.13	0.12	0.10	0.14	0.25	0.24	0.57	0.74	0.22	0.06
	E	0.08	0.12	0.09	0.05	0.04	0.05	0.18	0.17	0.11	0.12	0.23	0.30	1.12	1.53	0.23	0.05
	F	0.06	0.08	0.05	0.03	0.02	0.02	0.07	0.05	0.02	0.01	0.02	0.06	0.29	0.26	0.04	0.03
	G	0.01	0.02	0.00	0.01	0.02	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.03	0.03	0.01	0.01
9.8 m/s	A	0.04	0.06	0.04	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.10	0.09	0.14	0.28	0.13	0.01
(22 mph)	B	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.02	0.03	0.06	0.04	0.00
	C	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.03	0.02	0.05	0.03	0.00
	D	0.06	0.08	0.06	0.02	0.01	0.02	0.03	0.05	0.05	0.09	0.18	0.14	0.26	0.58	0.22	0.02
	E	0.05	0.07	0.06	0.02	0.02	0.02	0.03	0.04	0.05	0.07	0.12	0.12	0.37	0.83	0.15	0.03
	F	0.04	0.04	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.07	0.07	0.01	0.01
	G	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
12.7 m/s	A	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.04	0.05	0.12	0.09	0.00
(29 mph)	B	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.02	0.03	0.02	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.02	0.00
	D	0.02	0.03	0.03	0.01	0.00	0.01	0.01	0.02	0.02	0.08	0.11	0.08	0.10	0.24	0.10	0.01
	E	0.03	0.05	0.05	0.01	0.00	0.00	0.01	0.02	0.02	0.05	0.06	0.04	0.09	0.21	0.08	0.01
	F	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.6 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.01	0.00
(35 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
	D	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.03	0.02	0.05	0.02	0.00
	E	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.03	0.02	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
(43 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.01	0.01	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A3. Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 200 Areas at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. Based on 1983-2006 data from the Hanford Meteorology Station instrumented tower.

Average Wind Speed	**Atmospheric Stability Class**	**Percentage of Time Wind Blows in the 200 Areas toward the Direction Indicated**															
	9.1 m	**S**	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**	**N**	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**
0.89 m/s	A	0.28	0.32	0.34	0.26	0.26	0.24	0.19	0.14	0.12	0.11	0.10	0.08	0.10	0.12	0.17	0.21
(2 mph)	B	0.14	0.13	0.14	0.10	0.10	0.09	0.08	0.05	0.05	0.05	0.05	0.04	0.05	0.06	0.09	0.12
	C	0.13	0.13	0.13	0.08	0.08	0.09	0.08	0.06	0.04	0.03	0.04	0.04	0.05	0.06	0.08	0.11
	D	0.78	0.67	0.65	0.50	0.51	0.54	0.54	0.41	0.33	0.28	0.31	0.35	0.43	0.52	0.68	0.75
	E	0.38	0.29	0.27	0.25	0.28	0.34	0.46	0.40	0.36	0.35	0.46	0.51	0.55	0.60	0.62	0.52
	F	0.24	0.16	0.16	0.15	0.16	0.19	0.26	0.24	0.29	0.31	0.37	0.37	0.42	0.43	0.40	0.32
	G	0.10	0.08	0.10	0.08	0.08	0.08	0.10	0.10	0.10	0.10	0.12	0.11	0.13	0.15	0.16	0.13
2.65 m/s	A	0.67	0.48	0.38	0.33	0.40	0.41	0.39	0.25	0.20	0.22	0.29	0.22	0.19	0.27	0.63	0.74
(6 mph)	B	0.23	0.16	0.11	0.10	0.10	0.12	0.11	0.07	0.07	0.07	0.09	0.07	0.07	0.14	0.28	0.30
	C	0.20	0.12	0.10	0.08	0.08	0.09	0.10	0.06	0.05	0.05	0.06	0.06	0.06	0.09	0.23	0.26
	D	0.63	0.42	0.30	0.27	0.34	0.38	0.45	0.31	0.23	0.23	0.30	0.39	0.54	1.02	1.65	1.10
	E	0.27	0.16	0.12	0.12	0.22	0.29	0.36	0.39	0.32	0.31	0.57	1.04	1.83	2.16	1.70	0.69
	F	0.13	0.07	0.05	0.06	0.09	0.13	0.30	0.38	0.35	0.43	0.75	1.46	1.92	1.98	1.56	0.53
	G	0.04	0.03	0.02	0.03	0.04	0.03	0.11	0.19	0.19	0.21	0.34	0.69	0.66	0.74	0.65	0.16
4.7 m/s	A	0.20	0.22	0.13	0.05	0.06	0.04	0.03	0.04	0.05	0.13	0.30	0.38	0.21	0.28	0.68	0.29
(10.5 mph)	B	0.05	0.05	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.08	0.12	0.08	0.10	0.22	0.08
	C	0.03	0.03	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.03	0.06	0.08	0.06	0.09	0.19	0.07
	D	0.13	0.12	0.07	0.04	0.05	0.03	0.05	0.09	0.11	0.20	0.35	0.52	0.57	1.14	1.41	0.29
	E	0.06	0.05	0.04	0.02	0.02	0.02	0.05	0.10	0.13	0.17	0.41	0.77	1.15	2.09	1.69	0.20
	F	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.08	0.04	0.03	0.10	0.34	0.32	0.53	0.63	0.08
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.01	0.04	0.19	0.08	0.17	0.27	0.02
7.2 m/s	A	0.02	0.06	0.05	0.01	0.00	0.00	0.00	0.01	0.01	0.05	0.24	0.35	0.13	0.18	0.47	0.09
(16 mph)	B	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.08	0.03	0.05	0.12	0.02
	C	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.07	0.03	0.03	0.09	0.01
	D	0.02	0.04	0.03	0.01	0.00	0.00	0.01	0.03	0.08	0.18	0.40	0.37	0.22	0.64	0.88	0.07
	E	0.01	0.04	0.02	0.01	0.00	0.00	0.00	0.03	0.09	0.15	0.31	0.25	0.16	0.51	0.86	0.04
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.8 m/s	A	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.12	0.04	0.03	0.16	0.01
(22 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.01	0.01	0.04	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.03	0.00
	D	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.09	0.18	0.11	0.03	0.10	0.24	0.01
	E	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.07	0.04	0.01	0.06	0.15	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.7 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.01	0.00
(29 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.03	0.01	0.01	0.01	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.01	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.6 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(35 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(43 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A4. Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 200 Areas at 60 m (197 ft) above Ground Level, Hanford Site, Washington. Based on 1983-2006 data from the Hanford Meteorology Station instrumented tower.

Average Wind Speed	**Atmospheric Stability Class**	**Percentage of Time Wind Blows in the 200 Areas toward the Direction Indicated**															
	60 m	**S**	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**	**N**	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**
0.89 m/s	A	0.11	0.13	0.15	0.11	0.12	0.11	0.08	0.06	0.05	0.03	0.04	0.03	0.04	0.04	0.06	0.08
(2 mph)	B	0.07	0.08	0.08	0.07	0.06	0.05	0.05	0.04	0.02	0.03	0.02	0.02	0.03	0.03	0.05	0.07
	C	0.07	0.07	0.09	0.07	0.06	0.06	0.06	0.04	0.02	0.03	0.02	0.02	0.03	0.03	0.04	0.07
	D	0.50	0.47	0.46	0.38	0.40	0.38	0.46	0.33	0.22	0.20	0.20	0.19	0.24	0.30	0.39	0.48
	E	0.26	0.20	0.19	0.18	0.21	0.25	0.33	0.24	0.18	0.16	0.16	0.16	0.21	0.24	0.27	0.29
	F	0.19	0.14	0.12	0.12	0.13	0.14	0.19	0.16	0.12	0.13	0.14	0.13	0.18	0.18	0.21	0.20
	G	0.06	0.05	0.05	0.05	0.06	0.06	0.09	0.07	0.07	0.07	0.07	0.08	0.09	0.11	0.11	0.09
2.65 m/s	A	0.60	0.56	0.48	0.44	0.51	0.41	0.46	0.37	0.23	0.21	0.21	0.16	0.14	0.20	0.46	0.66
(6 mph)	B	0.22	0.19	0.15	0.12	0.14	0.12	0.13	0.10	0.07	0.07	0.08	0.06	0.06	0.10	0.22	0.27
	C	0.20	0.14	0.12	0.09	0.09	0.09	0.12	0.07	0.05	0.05	0.06	0.04	0.04	0.08	0.18	0.24
	D	0.73	0.52	0.40	0.34	0.41	0.37	0.49	0.36	0.23	0.21	0.24	0.26	0.35	0.60	1.20	1.05
	E	0.35	0.24	0.18	0.18	0.23	0.24	0.36	0.33	0.19	0.17	0.26	0.34	0.53	0.80	0.94	0.62
	F	0.28	0.14	0.12	0.09	0.12	0.13	0.26	0.26	0.20	0.18	0.24	0.34	0.58	0.80	0.83	0.59
	G	0.08	0.05	0.04	0.04	0.05	0.04	0.07	0.12	0.09	0.10	0.15	0.20	0.33	0.38	0.31	0.20
4.7 m/s	A	0.31	0.29	0.19	0.09	0.11	0.07	0.08	0.08	0.09	0.16	0.28	0.28	0.14	0.22	0.68	0.42
(10.5 mph)	B	0.08	0.08	0.03	0.02	0.03	0.02	0.02	0.03	0.03	0.04	0.08	0.09	0.06	0.10	0.27	0.13
	C	0.06	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.05	0.06	0.04	0.08	0.21	0.11
	D	0.19	0.15	0.09	0.06	0.10	0.08	0.11	0.13	0.11	0.16	0.27	0.31	0.33	0.83	1.47	0.43
	E	0.18	0.10	0.10	0.07	0.12	0.10	0.12	0.20	0.12	0.15	0.29	0.53	0.99	1.77	1.51	0.41
	F	0.12	0.06	0.04	0.02	0.04	0.04	0.08	0.20	0.09	0.07	0.16	0.40	0.88	1.46	1.41	0.45
	G	0.03	0.01	0.00	0.00	0.00	0.00	0.02	0.05	0.03	0.03	0.06	0.15	0.35	0.47	0.57	0.22
7.2 m/s	A	0.06	0.12	0.08	0.02	0.01	0.01	0.01	0.02	0.02	0.09	0.28	0.36	0.13	0.19	0.50	0.11
(16 mph)	B	0.02	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.06	0.09	0.04	0.08	0.13	0.02
	C	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.05	0.07	0.03	0.05	0.11	0.01
	D	0.06	0.08	0.04	0.02	0.01	0.01	0.03	0.07	0.09	0.16	0.33	0.43	0.37	0.91	1.08	0.11
	E	0.06	0.06	0.04	0.02	0.02	0.01	0.04	0.10	0.10	0.15	0.35	0.69	0.94	2.31	1.65	0.13
	F	0.03	0.03	0.02	0.01	0.01	0.00	0.02	0.07	0.03	0.02	0.06	0.25	0.40	1.01	1.25	0.13
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.01	0.00	0.01	0.05	0.08	0.19	0.62	0.08
9.8 m/s	A	0.01	0.02	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.16	0.20	0.05	0.11	0.33	0.03
(22 mph)	B	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.05	0.01	0.03	0.07	0.01
	C	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.01	0.03	0.06	0.00
	D	0.01	0.03	0.02	0.01	0.00	0.00	0.00	0.02	0.04	0.13	0.30	0.27	0.14	0.57	0.67	0.03
	E	0.01	0.04	0.03	0.01	0.00	0.00	0.00	0.03	0.08	0.12	0.29	0.31	0.20	0.87	0.98	0.03
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.02	0.04	0.04	0.10	0.18	0.01
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.00
12.7 m/s	A	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.10	0.10	0.02	0.03	0.17	0.01
(29 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.02	0.01	0.01	0.05	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.00	0.01	0.04	0.00
	D	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.03	0.12	0.25	0.13	0.04	0.26	0.47	0.00
	E	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.09	0.15	0.09	0.04	0.24	0.33	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.6 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.02	0.00	0.00	0.02	0.00
(35 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.09	0.03	0.01	0.03	0.05	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.02	0.01	0.03	0.05	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
(43 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.01	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A5. Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 300 Area at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. Based on 1983-2006 data from the 300 Area instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows in the 300 Area toward the Direction Indicated															
	9.1 m	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s	A	0.07	0.07	0.09	0.11	0.11	0.11	0.12	0.10	0.07	0.05	0.05	0.04	0.04	0.04	0.06	0.07
(2 mph)	B	0.05	0.04	0.04	0.04	0.05	0.05	0.06	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.05
	C	0.04	0.03	0.04	0.04	0.04	0.05	0.06	0.05	0.04	0.04	0.02	0.02	0.03	0.02	0.03	0.05
	D	0.33	0.20	0.17	0.18	0.21	0.34	0.38	0.37	0.34	0.32	0.29	0.26	0.28	0.28	0.40	0.45
	E	0.35	0.20	0.14	0.13	0.20	0.35	0.50	0.54	0.55	0.46	0.43	0.39	0.42	0.46	0.54	0.49
	F	0.28	0.17	0.12	0.09	0.16	0.28	0.49	0.53	0.49	0.37	0.35	0.30	0.31	0.38	0.50	0.46
	G	0.16	0.08	0.05	0.05	0.07	0.11	0.19	0.21	0.20	0.14	0.15	0.12	0.13	0.17	0.24	0.22
2.65 m/s	A	0.24	0.32	0.41	0.50	0.67	0.67	0.62	0.30	0.27	0.34	0.29	0.15	0.08	0.05	0.08	0.17
(6 mph)	B	0.13	0.14	0.12	0.14	0.19	0.21	0.27	0.15	0.11	0.13	0.12	0.06	0.03	0.02	0.04	0.12
	C	0.12	0.11	0.10	0.11	0.14	0.18	0.21	0.11	0.10	0.11	0.09	0.04	0.02	0.02	0.06	0.11
	D	0.96	0.49	0.31	0.31	0.51	0.96	1.31	0.69	0.63	0.64	0.51	0.33	0.22	0.23	0.57	1.10
	E	1.09	0.34	0.08	0.09	0.23	1.13	1.81	1.07	1.01	0.75	0.59	0.42	0.35	0.39	0.69	1.23
	F	0.66	0.16	0.03	0.02	0.09	1.01	1.98	1.02	0.69	0.43	0.24	0.13	0.13	0.17	0.43	0.82
	G	0.27	0.06	0.01	0.01	0.03	0.33	0.79	0.38	0.21	0.11	0.06	0.03	0.03	0.05	0.19	0.36
4.7 m/s	A	0.28	0.57	0.42	0.11	0.15	0.30	0.34	0.15	0.25	0.62	0.66	0.29	0.08	0.06	0.09	0.15
(10.5 mph)	B	0.12	0.16	0.08	0.03	0.03	0.08	0.10	0.05	0.09	0.21	0.22	0.11	0.04	0.02	0.04	0.09
	C	0.11	0.11	0.06	0.03	0.02	0.05	0.08	0.04	0.07	0.16	0.18	0.08	0.02	0.01	0.04	0.08
	D	0.74	0.41	0.20	0.07	0.09	0.22	0.39	0.24	0.42	0.88	0.88	0.48	0.18	0.14	0.44	0.87
	E	1.07	0.34	0.05	0.03	0.04	0.25	0.34	0.24	0.51	0.85	0.91	0.48	0.21	0.17	0.38	0.79
	F	0.74	0.22	0.02	0.02	0.02	0.26	0.30	0.11	0.25	0.38	0.34	0.14	0.03	0.02	0.07	0.40
	G	0.36	0.10	0.00	0.00	0.01	0.14	0.18	0.04	0.07	0.10	0.08	0.03	0.01	0.00	0.02	0.16
7.2 m/s	A	0.12	0.19	0.05	0.00	0.00	0.00	0.02	0.01	0.06	0.34	0.56	0.41	0.11	0.05	0.10	0.08
(16 mph)	B	0.04	0.04	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.11	0.16	0.10	0.03	0.01	0.03	0.05
	C	0.03	0.02	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.09	0.14	0.08	0.02	0.01	0.03	0.04
	D	0.16	0.10	0.03	0.01	0.00	0.01	0.04	0.04	0.14	0.49	0.69	0.38	0.15	0.08	0.39	0.42
	E	0.13	0.07	0.03	0.02	0.01	0.01	0.04	0.04	0.10	0.36	0.64	0.26	0.09	0.05	0.29	0.29
	F	0.06	0.03	0.02	0.02	0.00	0.00	0.00	0.01	0.02	0.08	0.17	0.05	0.01	0.00	0.01	0.05
	G	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.05	0.01	0.00	0.00	0.00	0.01
9.8 m/s	A	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.09	0.16	0.17	0.07	0.02	0.04	0.02
(22 mph)	B	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.04	0.02	0.00	0.01	0.01
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.04	0.01	0.00	0.02	0.01
	D	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.15	0.29	0.14	0.07	0.02	0.16	0.08
	E	0.01	0.04	0.02	0.01	0.00	0.00	0.00	0.01	0.02	0.11	0.28	0.06	0.02	0.01	0.08	0.04
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00
12.7 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.04	0.02	0.00	0.01	0.00
(29 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00
	D	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.17	0.04	0.02	0.01	0.03	0.01
	E	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.11	0.01	0.01	0.00	0.02	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
15.6 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
(35 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.01	0.01	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(43 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A6. Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 300 Area at 60 m (197 ft) above Ground Level, Hanford Site, Washington. Based on 1986-2006 data from the 300 Area instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows in the 300 Area toward the Direction Indicated															
	60 m	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s	A	0.08	0.07	0.08	0.11	0.12	0.12	0.14	0.10	0.08	0.05	0.05	0.04	0.04	0.04	0.06	0.07
(2 mph)	B	0.05	0.04	0.03	0.04	0.04	0.07	0.07	0.05	0.04	0.03	0.02	0.02	0.03	0.02	0.03	0.04
	C	0.04	0.04	0.04	0.03	0.05	0.05	0.06	0.06	0.04	0.03	0.02	0.02	0.02	0.03	0.03	0.04
	D	0.28	0.22	0.19	0.18	0.23	0.33	0.33	0.34	0.31	0.22	0.21	0.20	0.20	0.22	0.29	0.34
	E	0.30	0.21	0.18	0.17	0.21	0.27	0.33	0.35	0.35	0.29	0.25	0.23	0.23	0.25	0.30	0.32
	F	0.25	0.19	0.18	0.15	0.17	0.26	0.33	0.31	0.31	0.26	0.23	0.17	0.17	0.20	0.23	0.25
	G	0.10	0.08	0.06	0.04	0.07	0.11	0.15	0.13	0.14	0.10	0.10	0.08	0.09	0.11	0.12	0.13
2.65 m/s	A	0.22	0.26	0.39	0.48	0.62	0.66	0.57	0.30	0.24	0.30	0.25	0.12	0.06	0.04	0.07	0.13
(6 mph)	B	0.13	0.11	0.11	0.13	0.17	0.20	0.25	0.14	0.12	0.13	0.10	0.06	0.03	0.02	0.04	0.09
	C	0.10	0.09	0.09	0.10	0.14	0.18	0.18	0.11	0.09	0.10	0.08	0.05	0.02	0.02	0.04	0.09
	D	0.75	0.49	0.34	0.31	0.43	0.69	1.01	0.67	0.55	0.55	0.45	0.27	0.19	0.19	0.40	0.72
	E	0.73	0.39	0.15	0.10	0.20	0.45	0.87	0.81	0.84	0.73	0.63	0.42	0.35	0.36	0.46	0.67
	F	0.54	0.28	0.07	0.04	0.12	0.50	0.97	0.84	0.80	0.56	0.38	0.24	0.18	0.13	0.27	0.45
	G	0.23	0.09	0.02	0.01	0.03	0.22	0.45	0.33	0.27	0.17	0.10	0.07	0.06	0.05	0.11	0.21
4.7 m/s	A	0.25	0.53	0.44	0.13	0.13	0.27	0.40	0.17	0.26	0.62	0.62	0.22	0.07	0.04	0.08	0.14
(10.5 mph)	B	0.12	0.17	0.09	0.04	0.03	0.07	0.12	0.07	0.08	0.22	0.21	0.10	0.03	0.02	0.03	0.08
	C	0.10	0.12	0.08	0.03	0.03	0.05	0.08	0.05	0.07	0.17	0.17	0.07	0.02	0.01	0.03	0.06
	D	0.70	0.46	0.22	0.10	0.11	0.23	0.50	0.29	0.38	0.81	0.78	0.42	0.19	0.17	0.39	0.75
	E	0.90	0.35	0.07	0.05	0.07	0.24	0.61	0.42	0.58	0.93	0.90	0.56	0.33	0.27	0.49	0.94
	F	0.70	0.27	0.02	0.02	0.03	0.25	0.70	0.36	0.42	0.61	0.50	0.23	0.08	0.04	0.10	0.46
	G	0.36	0.12	0.01	0.00	0.01	0.10	0.32	0.14	0.14	0.16	0.12	0.04	0.01	0.01	0.03	0.19
7.2 m/s	A	0.14	0.27	0.07	0.01	0.00	0.01	0.03	0.02	0.06	0.38	0.59	0.41	0.10	0.06	0.08	0.08
(16 mph)	B	0.06	0.06	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.12	0.18	0.10	0.03	0.02	0.03	0.05
	C	0.04	0.04	0.01	0.00	0.00	0.00	0.01	0.00	0.02	0.10	0.15	0.08	0.02	0.01	0.03	0.04
	D	0.29	0.16	0.04	0.01	0.01	0.02	0.08	0.08	0.16	0.59	0.78	0.46	0.16	0.15	0.43	0.50
	E	0.50	0.16	0.03	0.02	0.02	0.06	0.16	0.11	0.18	0.56	1.03	0.56	0.21	0.17	0.45	0.68
	F	0.38	0.12	0.03	0.02	0.01	0.04	0.10	0.03	0.05	0.21	0.45	0.20	0.03	0.01	0.08	0.37
	G	0.22	0.05	0.00	0.00	0.00	0.02	0.04	0.01	0.02	0.06	0.11	0.04	0.01	0.00	0.02	0.15
9.8 m/s	A	0.03	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.11	0.21	0.23	0.08	0.02	0.05	0.02
(22 mph)	B	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.05	0.02	0.01	0.02	0.02
	C	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.05	0.05	0.01	0.01	0.02	0.01
	D	0.05	0.04	0.02	0.01	0.00	0.00	0.01	0.01	0.04	0.22	0.38	0.24	0.10	0.07	0.32	0.16
	E	0.06	0.05	0.03	0.01	0.00	0.01	0.02	0.02	0.04	0.18	0.56	0.24	0.08	0.05	0.30	0.16
	F	0.03	0.01	0.01	0.02	0.00	0.00	0.01	0.00	0.01	0.04	0.15	0.06	0.01	0.00	0.02	0.04
	G	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.02	0.00	0.00	0.00	0.01
12.7 m/s	A	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08	0.08	0.05	0.01	0.01	0.01
(29 mph)	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.02	0.01	0.00	0.01	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.00	0.01	0.00
	D	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.10	0.23	0.11	0.05	0.01	0.11	0.03
	E	0.01	0.03	0.03	0.01	0.00	0.00	0.01	0.00	0.01	0.08	0.29	0.06	0.02	0.02	0.09	0.02
	F	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
15.6 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.00
(35 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.13	0.02	0.01	0.01	0.01	0.00
	E	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.11	0.01	0.00	0.00	0.01	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
19 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(43 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.01	0.01	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.01	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A7. Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 400 Area at 9.1 m (30 ft) above Ground Level, Hanford Site, Washington. Based on 1983-2006 data from the Fast Flux Test Facility (FFTF) instrumented tower.

Average Wind Speed	**Atmospheric Stability Class**	**Percentage of Time Wind Blows at FFTF toward the Direction Indicated**															
	9.1 m	**S**	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**	**N**	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**
0.89 m/s	A	0.11	0.13	0.11	0.12	0.12	0.16	0.12	0.10	0.11	0.09	0.08	0.06	0.06	0.06	0.07	0.10
(2 mph)	B	0.04	0.05	0.07	0.05	0.05	0.06	0.07	0.05	0.05	0.04	0.04	0.02	0.03	0.03	0.04	0.05
	C	0.04	0.05	0.05	0.05	0.05	0.05	0.06	0.04	0.04	0.04	0.03	0.02	0.03	0.03	0.04	0.05
	D	0.32	0.31	0.28	0.24	0.25	0.30	0.33	0.31	0.30	0.29	0.27	0.22	0.22	0.28	0.37	0.34
	E	0.28	0.24	0.21	0.19	0.21	0.22	0.26	0.29	0.36	0.37	0.37	0.32	0.34	0.35	0.40	0.35
	F	0.29	0.23	0.18	0.14	0.15	0.15	0.19	0.21	0.30	0.29	0.29	0.25	0.26	0.27	0.29	0.27
	G	0.12	0.10	0.07	0.06	0.06	0.06	0.08	0.09	0.11	0.12	0.10	0.09	0.11	0.11	0.12	0.12
2.65 m/s	A	0.38	0.44	0.41	0.32	0.34	0.43	0.51	0.48	0.56	0.41	0.21	0.13	0.15	0.15	0.19	0.25
(6 mph)	B	0.17	0.15	0.13	0.08	0.10	0.11	0.17	0.17	0.18	0.15	0.08	0.05	0.04	0.05	0.09	0.14
	C	0.14	0.13	0.10	0.07	0.08	0.09	0.15	0.14	0.16	0.11	0.05	0.03	0.03	0.05	0.09	0.12
	D	0.67	0.62	0.50	0.32	0.30	0.35	0.72	0.91	0.88	0.69	0.39	0.24	0.29	0.47	0.88	0.89
	E	0.62	0.52	0.37	0.20	0.18	0.26	0.63	1.02	1.14	1.14	0.66	0.46	0.51	0.69	1.09	0.88
	F	0.57	0.55	0.31	0.13	0.10	0.15	0.44	0.81	0.98	0.85	0.48	0.26	0.22	0.33	0.72	0.67
	G	0.29	0.27	0.14	0.05	0.03	0.05	0.14	0.31	0.33	0.26	0.16	0.08	0.07	0.14	0.32	0.31
4.7 m/s	A	0.37	0.42	0.22	0.07	0.08	0.09	0.16	0.21	0.66	0.71	0.29	0.17	0.17	0.15	0.22	0.25
(10.5 mph)	B	0.13	0.11	0.05	0.02	0.02	0.02	0.06	0.08	0.21	0.28	0.10	0.06	0.04	0.04	0.09	0.11
	C	0.08	0.09	0.05	0.01	0.01	0.02	0.04	0.06	0.16	0.21	0.07	0.04	0.04	0.04	0.07	0.09
	D	0.37	0.29	0.17	0.07	0.05	0.08	0.29	0.55	0.87	1.08	0.42	0.22	0.22	0.49	1.04	0.75
	E	0.22	0.19	0.10	0.03	0.02	0.03	0.32	0.93	0.98	1.16	0.55	0.26	0.29	0.70	1.49	0.80
	F	0.17	0.16	0.07	0.01	0.00	0.01	0.24	1.00	0.80	0.69	0.23	0.06	0.05	0.13	0.68	0.59
	G	0.08	0.07	0.02	0.00	0.00	0.01	0.11	0.45	0.28	0.19	0.05	0.01	0.01	0.03	0.29	0.25
7.2 m/s	A	0.09	0.13	0.07	0.01	0.00	0.01	0.02	0.02	0.17	0.62	0.41	0.20	0.14	0.12	0.19	0.10
(16 mph)	B	0.02	0.03	0.01	0.00	0.00	0.00	0.01	0.01	0.04	0.20	0.11	0.06	0.03	0.03	0.06	0.04
	C	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.04	0.17	0.09	0.05	0.03	0.03	0.05	0.03
	D	0.08	0.08	0.03	0.01	0.00	0.01	0.04	0.06	0.27	0.87	0.50	0.22	0.16	0.31	0.71	0.19
	E	0.04	0.05	0.03	0.00	0.00	0.00	0.03	0.09	0.25	0.71	0.50	0.17	0.10	0.30	0.63	0.12
	F	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.07	0.12	0.27	0.10	0.02	0.01	0.01	0.05	0.03
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.05	0.10	0.04	0.01	0.00	0.00	0.02	0.01
9.8 m/s	A	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.11	0.17	0.13	0.07	0.03	0.08	0.01
(22 mph)	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.05	0.03	0.02	0.01	0.03	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.02	0.01	0.00	0.03	0.00
	D	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.03	0.21	0.27	0.12	0.06	0.09	0.25	0.02
	E	0.00	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.17	0.23	0.06	0.03	0.05	0.11	0.01
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
12.7 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.04	0.02	0.01	0.01	0.00
(29 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.00	0.00	0.01	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.01	0.00
	D	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.16	0.04	0.01	0.01	0.04	0.00
	E	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.08	0.02	0.00	0.01	0.02	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15.6 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
(35 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.01	0.01	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(43 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A8. Joint Frequency Distributions of Atmospheric Stability, Wind Speed, and Transport Direction for the 400 Area at 60 m (197 ft) above Ground Level, Hanford Site, Washington. Based on 1986-2006 data from the Fast Flux Test Facility (FFTF) instrumented tower.

Average Wind Speed	Atmospheric Stability Class	Percentage of Time Wind Blows at FFTF toward the Direction Indicated															
	60 m	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.89 m/s	A	0.11	0.12	0.12	0.10	0.13	0.14	0.13	0.10	0.09	0.09	0.07	0.05	0.05	0.05	0.08	0.08
(2 mph)	B	0.05	0.05	0.06	0.05	0.06	0.06	0.05	0.05	0.05	0.03	0.04	0.03	0.03	0.03	0.04	0.04
	C	0.05	0.04	0.05	0.04	0.05	0.06	0.05	0.04	0.04	0.03	0.03	0.02	0.03	0.03	0.04	0.04
	D	0.27	0.25	0.22	0.22	0.25	0.24	0.31	0.30	0.26	0.21	0.22	0.18	0.19	0.20	0.25	0.26
	E	0.22	0.19	0.16	0.15	0.17	0.19	0.24	0.26	0.28	0.23	0.24	0.22	0.23	0.18	0.21	0.23
	F	0.17	0.16	0.14	0.13	0.14	0.15	0.21	0.22	0.24	0.21	0.20	0.18	0.16	0.15	0.15	0.17
	G	0.07	0.05	0.05	0.06	0.06	0.05	0.08	0.10	0.10	0.06	0.06	0.06	0.06	0.05	0.05	0.06
2.65 m/s	A	0.32	0.38	0.35	0.26	0.31	0.38	0.42	0.41	0.44	0.32	0.18	0.13	0.12	0.13	0.15	0.23
(6 mph)	B	0.15	0.13	0.11	0.07	0.09	0.10	0.16	0.15	0.17	0.14	0.07	0.04	0.04	0.06	0.09	0.12
	C	0.12	0.11	0.10	0.06	0.07	0.08	0.13	0.12	0.14	0.10	0.04	0.04	0.04	0.05	0.08	0.09
	D	0.52	0.50	0.43	0.28	0.27	0.33	0.54	0.66	0.68	0.52	0.30	0.22	0.23	0.33	0.62	0.62
	E	0.43	0.35	0.26	0.18	0.18	0.20	0.36	0.56	0.65	0.55	0.48	0.38	0.42	0.47	0.61	0.55
	F	0.42	0.38	0.23	0.12	0.10	0.15	0.31	0.61	0.66	0.50	0.38	0.26	0.27	0.26	0.38	0.45
	G	0.19	0.16	0.09	0.05	0.03	0.04	0.12	0.27	0.27	0.18	0.13	0.08	0.09	0.09	0.14	0.17
4.7 m/s	A	0.39	0.42	0.25	0.09	0.08	0.09	0.19	0.24	0.63	0.65	0.24	0.14	0.13	0.14	0.19	0.24
(10.5 mph)	B	0.14	0.12	0.06	0.02	0.02	0.02	0.07	0.09	0.21	0.24	0.10	0.05	0.04	0.04	0.08	0.11
	C	0.09	0.09	0.06	0.02	0.02	0.03	0.06	0.08	0.16	0.18	0.06	0.03	0.03	0.04	0.07	0.10
	D	0.44	0.36	0.25	0.11	0.08	0.10	0.33	0.47	0.76	0.86	0.40	0.18	0.20	0.34	0.79	0.66
	E	0.36	0.27	0.19	0.08	0.05	0.07	0.35	0.60	0.80	0.83	0.66	0.32	0.34	0.59	1.02	0.66
	F	0.32	0.23	0.12	0.04	0.02	0.03	0.25	0.61	0.69	0.64	0.46	0.14	0.12	0.18	0.51	0.59
	G	0.17	0.13	0.05	0.01	0.00	0.01	0.10	0.28	0.29	0.23	0.12	0.03	0.02	0.05	0.22	0.32
7.2 m/s	A	0.16	0.18	0.08	0.01	0.00	0.01	0.03	0.03	0.19	0.65	0.37	0.17	0.13	0.12	0.18	0.12
(16 mph)	B	0.04	0.03	0.01	0.00	0.00	0.00	0.01	0.01	0.06	0.20	0.11	0.06	0.03	0.04	0.07	0.06
	C	0.03	0.03	0.01	0.00	0.00	0.00	0.01	0.01	0.05	0.18	0.09	0.04	0.03	0.03	0.05	0.04
	D	0.15	0.11	0.05	0.02	0.00	0.01	0.10	0.16	0.37	0.91	0.50	0.22	0.16	0.38	0.88	0.37
	E	0.15	0.10	0.07	0.01	0.01	0.01	0.16	0.27	0.44	0.99	0.79	0.24	0.19	0.70	1.51	0.50
	F	0.13	0.08	0.05	0.02	0.01	0.00	0.11	0.20	0.33	0.58	0.38	0.05	0.03	0.13	0.65	0.43
	G	0.04	0.02	0.01	0.00	0.00	0.00	0.03	0.09	0.16	0.20	0.10	0.01	0.01	0.05	0.25	0.21
9.8 m/s	A	0.02	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.03	0.18	0.23	0.15	0.09	0.06	0.11	0.03
(22 mph)	B	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.05	0.07	0.04	0.02	0.01	0.04	0.01
	C	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.05	0.03	0.01	0.02	0.04	0.01
	D	0.02	0.04	0.02	0.01	0.01	0.00	0.02	0.03	0.09	0.35	0.35	0.16	0.10	0.24	0.66	0.08
	E	0.03	0.04	0.04	0.01	0.01	0.01	0.03	0.04	0.11	0.45	0.48	0.14	0.09	0.47	0.98	0.10
	F	0.02	0.02	0.02	0.01	0.00	0.00	0.01	0.02	0.04	0.19	0.14	0.02	0.01	0.06	0.24	0.06
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.08	0.05	0.00	0.00	0.02	0.08	0.02
12.7 m/s	A	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.09	0.05	0.01	0.05	0.00
(29 mph)	B	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.02	0.01	0.01	0.02	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.00	0.02	0.00
	D	0.01	0.02	0.02	0.00	0.00	0.00	0.01	0.00	0.02	0.14	0.21	0.10	0.04	0.09	0.27	0.03
	E	0.01	0.04	0.02	0.00	0.00	0.00	0.01	0.01	0.02	0.15	0.27	0.08	0.03	0.09	0.23	0.02
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.01	0.00	0.00	0.01	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
15.6 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.00	0.01	0.00
(35 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.13	0.03	0.01	0.01	0.04	0.00
	E	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.09	0.03	0.01	0.01	0.03	0.01
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19 m/s	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(43 mph)	B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.01	0.01	0.00	0.00	0.00
	E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.01	0.00	0.00	0.00	0.00
	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	G	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A9. X/Q’ Values (s m^{-3}) for Chronic Ground-Level Releases from 100-N Area Based on 1983 through 2006 Meteorological Information, Hanford Site, Washington

Distance km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
	Sector (Wind from 100-N toward Direction Indicated)															
0.1 (0.06)	1.8E-04	1.7E-04	2.0E-04	2.6E-04	3.2E-04	2.8E-04	2.3E-04	1.6E-04	1.3E-04	1.4E-04	2.1E-04	3.2E-04	4.1E-04	3.6E-04	2.8E-04	2.1E-04
0.2 (0.12)	5.0E-05	4.8E-05	5.6E-05	7.1E-05	8.8E-05	7.8E-05	6.3E-05	4.3E-05	3.6E-05	3.8E-05	5.7E-05	8.8E-05	1.1E-04	1.0E-04	7.8E-05	5.8E-05
0.3 (0.19)	2.4E-05	2.3E-05	2.7E-05	3.4E-05	4.2E-05	3.7E-05	3.0E-05	2.0E-05	1.7E-05	1.8E-05	2.7E-05	4.2E-05	5.5E-05	4.8E-05	3.7E-05	2.7E-05
0.4 (0.25)	1.4E-05	1.4E-05	1.6E-05	2.0E-05	2.5E-05	2.2E-05	1.8E-05	1.2E-05	1.0E-05	1.1E-05	1.6E-05	2.5E-05	3.3E-05	2.9E-05	2.2E-05	1.6E-05
0.5 (0.31)	9.4E-06	9.0E-06	1.1E-05	1.4E-05	1.7E-05	1.5E-05	1.2E-05	8.1E-06	6.9E-06	7.3E-06	1.1E-05	1.7E-05	2.2E-05	1.9E-05	1.5E-05	1.1E-05
0.6 (0.37)	6.8E-06	6.5E-06	7.7E-06	9.8E-06	1.2E-05	1.1E-05	8.7E-06	5.9E-06	5.0E-06	5.3E-06	7.9E-06	1.2E-05	1.6E-05	1.4E-05	1.1E-05	7.8E-06
0.7 (0.43)	5.2E-06	5.0E-06	5.9E-06	7.5E-06	9.3E-06	8.2E-06	6.6E-06	4.5E-06	3.8E-06	4.0E-06	6.0E-06	9.3E-06	1.2E-05	1.1E-05	8.1E-06	6.0E-06
0.8 (0.50)	4.1E-06	3.9E-06	4.6E-06	5.9E-06	7.3E-06	6.5E-06	5.2E-06	3.5E-06	3.0E-06	3.2E-06	4.7E-06	7.3E-06	9.5E-06	8.3E-06	6.4E-06	4.7E-06
0.9 (0.56)	3.3E-06	3.2E-06	3.8E-06	4.8E-06	6.0E-06	5.3E-06	4.2E-06	2.9E-06	2.5E-06	2.6E-06	3.8E-06	5.9E-06	7.7E-06	6.7E-06	5.2E-06	3.8E-06
1 (0.62)	2.7E-06	2.6E-06	3.1E-06	4.0E-06	5.0E-06	4.4E-06	3.5E-06	2.4E-06	2.0E-06	2.1E-06	3.2E-06	4.9E-06	6.4E-06	5.6E-06	4.3E-06	3.2E-06
2.4 (1.5)	6.3E-07	6.1E-07	7.2E-07	9.3E-07	1.2E-06	1.0E-06	8.1E-07	5.5E-07	4.7E-07	4.9E-07	7.4E-07	1.1E-06	1.5E-06	1.3E-06	1.0E-06	7.3E-07
4 (2.5)	2.9E-07	2.8E-07	3.3E-07	4.3E-07	5.3E-07	4.6E-07	3.7E-07	2.5E-07	2.1E-07	2.3E-07	3.4E-07	5.2E-07	6.8E-07	6.0E-07	4.6E-07	3.4E-07
5.6 (3.5)	1.8E-07	1.7E-07	2.0E-07	2.6E-07	3.2E-07	2.8E-07	2.2E-07	1.5E-07	1.3E-07	1.4E-07	2.0E-07	3.2E-07	4.1E-07	3.6E-07	2.8E-07	2.0E-07
7.2 (4.5)	1.2E-07	1.2E-07	1.4E-07	1.8E-07	2.2E-07	2.0E-07	1.6E-07	1.1E-07	9.0E-08	9.5E-08	1.4E-07	2.2E-07	2.9E-07	2.5E-07	1.9E-07	1.4E-07
12 (7.5)	5.9E-08	5.7E-08	6.8E-08	8.8E-08	1.1E-07	9.4E-08	7.5E-08	5.1E-08	4.3E-08	4.6E-08	6.9E-08	1.1E-07	1.4E-07	1.2E-07	9.5E-08	6.9E-08
24 (15)	2.3E-08	2.2E-08	2.6E-08	3.4E-08	4.2E-08	3.6E-08	2.8E-08	1.9E-08	1.6E-08	1.7E-08	2.6E-08	4.1E-08	5.4E-08	4.7E-08	3.7E-08	2.7E-08
40 (25)	1.2E-08	1.1E-08	1.3E-08	1.7E-08	2.1E-08	1.8E-08	1.4E-08	9.6E-09	8.1E-09	8.7E-09	1.3E-08	2.1E-08	2.7E-08	2.4E-08	1.8E-08	1.4E-08
56 (35)	7.4E-09	7.1E-09	8.5E-09	1.1E-08	1.4E-08	1.2E-08	9.0E-09	6.1E-09	5.2E-09	5.5E-09	8.4E-09	1.3E-08	1.7E-08	1.5E-08	1.2E-08	8.6E-09
72 (45)	5.3E-09	5.1E-09	6.1E-09	7.9E-09	9.7E-09	8.2E-09	6.4E-09	4.3E-09	3.7E-09	4.0E-09	6.0E-09	9.6E-09	1.2E-08	1.1E-08	8.5E-09	6.2E-09

Table A10. X/Q’ Values (s m^{-3}) for Chronic 60-m Stack Releases from 100-N Area Based on 1986 through 2006 Meteorological Information, Hanford Site, Washington

Distance km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
	Sector (Wind from 100-N toward Direction Indicated)															
0.1 (0.06)	1.1E-09	1.2E-09	9.0E-10	6.2E-10	7.8E-10	8.9E-10	7.3E-10	5.6E-10	4.3E-10	4.3E-10	7.5E-10	9.8E-10	1.2E-09	1.3E-09	1.1E-09	1.1E-09
0.2 (0.12)	2.1E-07	2.4E-07	1.8E-07	1.2E-07	1.5E-07	1.8E-07	1.5E-07	1.1E-07	8.6E-08	8.4E-08	1.5E-07	1.9E-07	2.3E-07	2.5E-07	2.2E-07	2.1E-07
0.3 (0.19)	4.1E-07	4.5E-07	3.4E-07	2.4E-07	3.0E-07	3.5E-07	3.0E-07	2.2E-07	1.7E-07	1.7E-07	2.8E-07	3.7E-07	4.5E-07	4.7E-07	4.2E-07	4.0E-07
0.4 (0.25)	3.5E-07	3.8E-07	2.9E-07	2.1E-07	2.6E-07	3.2E-07	2.7E-07	1.9E-07	1.5E-07	1.5E-07	2.4E-07	3.1E-07	3.9E-07	4.0E-07	3.5E-07	3.4E-07
0.5 (0.31)	2.8E-07	2.9E-07	2.3E-07	1.7E-07	2.2E-07	2.6E-07	2.3E-07	1.6E-07	1.3E-07	1.2E-07	1.9E-07	2.5E-07	3.1E-07	3.1E-07	2.7E-07	2.6E-07
0.6 (0.37)	2.3E-07	2.4E-07	1.9E-07	1.5E-07	1.9E-07	2.3E-07	2.1E-07	1.5E-07	1.2E-07	1.1E-07	1.6E-07	2.1E-07	2.6E-07	2.6E-07	2.3E-07	2.1E-07
0.7 (0.43)	2.0E-07	2.1E-07	1.7E-07	1.4E-07	1.9E-07	2.2E-07	2.1E-07	1.5E-07	1.1E-07	1.1E-07	1.5E-07	1.9E-07	2.4E-07	2.4E-07	2.0E-07	1.9E-07
0.8 (0.50)	1.9E-07	1.9E-07	1.6E-07	1.4E-07	1.9E-07	2.3E-07	2.1E-07	1.5E-07	1.2E-07	1.1E-07	1.4E-07	1.8E-07	2.4E-07	2.4E-07	1.9E-07	1.7E-07
0.9 (0.56)	1.8E-07	1.8E-07	1.5E-07	1.4E-07	2.0E-07	2.3E-07	2.2E-07	1.5E-07	1.2E-07	1.1E-07	1.4E-07	1.8E-07	2.4E-07	2.4E-07	1.9E-07	1.7E-07
1 (0.62)	1.8E-07	1.8E-07	1.5E-07	1.4E-07	2.0E-07	2.4E-07	2.3E-07	1.6E-07	1.2E-07	1.1E-07	1.4E-07	1.8E-07	2.5E-07	2.5E-07	1.9E-07	1.6E-07
2.4 (1.5)	1.3E-07	1.3E-07	1.2E-07	1.4E-07	2.1E-07	2.2E-07	2.0E-07	1.4E-07	1.1E-07	9.9E-08	1.2E-07	1.5E-07	2.2E-07	2.3E-07	1.6E-07	1.2E-07
4 (2.5)	8.6E-08	8.4E-08	8.6E-08	1.1E-07	1.6E-07	1.6E-07	1.4E-07	9.7E-08	7.5E-08	6.7E-08	7.8E-08	9.9E-08	1.5E-07	1.6E-07	1.1E-07	8.1E-08
5.6 (3.5)	6.3E-08	6.1E-08	6.5E-08	8.1E-08	1.2E-07	1.2E-07	1.1E-07	7.1E-08	5.4E-08	4.8E-08	5.6E-08	7.1E-08	1.1E-07	1.2E-07	7.9E-08	6.0E-08
7.2 (4.5)	4.9E-08	4.8E-08	5.1E-08	6.6E-08	9.7E-08	9.5E-08	8.2E-08	5.5E-08	4.2E-08	3.7E-08	4.3E-08	5.5E-08	8.4E-08	9.2E-08	6.2E-08	4.6E-08
12 (7.5)	2.8E-08	2.8E-08	3.1E-08	4.0E-08	6.0E-08	5.7E-08	4.8E-08	3.2E-08	2.4E-08	2.1E-08	2.4E-08	3.1E-08	4.8E-08	5.3E-08	3.6E-08	2.7E-08
24 (15)	1.3E-08	1.3E-08	1.5E-08	2.0E-08	3.0E-08	2.7E-08	2.2E-08	1.4E-08	1.1E-08	9.4E-09	1.1E-08	1.4E-08	2.1E-08	2.4E-08	1.7E-08	1.3E-08
40 (25)	7.1E-09	7.1E-09	8.2E-09	1.1E-08	1.7E-08	1.5E-08	1.2E-08	7.9E-09	5.8E-09	5.1E-09	5.9E-09	7.4E-09	1.2E-08	1.3E-08	9.3E-09	7.0E-09
56 (35)	4.8E-09	4.8E-09	5.6E-09	7.7E-09	1.2E-08	1.1E-08	8.1E-09	5.3E-09	3.9E-09	3.4E-09	3.9E-09	4.9E-09	7.7E-09	8.8E-09	6.3E-09	4.7E-09
72 (45)	3.6E-09	3.5E-09	4.2E-09	5.8E-09	8.7E-09	7.8E-09	6.0E-09	3.9E-09	2.8E-09	2.5E-09	2.9E-09	3.6E-09	5.7E-09	6.5E-09	4.7E-09	3.5E-09

Table A11. X/Q' Values (s m^{-3}) for Chronic Ground-Level Releases from 200 Areas Based on 1983 through 2006 Meteorological Information, Hanford Site, Washington

Distance	Sector (Wind from 200 Areas toward Direction Indicated)															
km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	1.5E-04	1.2E-04	1.1E-04	9.4E-05	1.0E-04	1.1E-04	1.5E-04	1.4E-04	1.3E-04	1.4E-04	1.9E-04	2.7E-04	3.1E-04	3.8E-04	3.9E-04	2.2E-04
0.2 (0.12)	4.1E-05	3.2E-05	3.1E-05	2.6E-05	2.8E-05	3.1E-05	4.0E-05	3.8E-05	3.6E-05	3.8E-05	5.3E-05	7.4E-05	8.7E-05	1.1E-04	1.1E-04	5.9E-05
0.3 (0.19)	1.9E-05	1.5E-05	1.4E-05	1.2E-05	1.3E-05	1.5E-05	1.9E-05	1.8E-05	1.7E-05	1.8E-05	2.6E-05	3.5E-05	4.2E-05	5.0E-05	5.1E-05	2.8E-05
0.4 (0.25)	1.1E-05	8.8E-06	8.4E-06	7.1E-06	7.8E-06	8.7E-06	1.1E-05	1.1E-05	1.0E-05	1.1E-05	1.5E-05	2.1E-05	2.5E-05	3.0E-05	3.0E-05	1.7E-05
0.5 (0.31)	7.6E-06	5.8E-06	5.6E-06	4.7E-06	5.2E-06	5.8E-06	7.5E-06	7.3E-06	6.9E-06	7.2E-06	1.0E-05	1.4E-05	1.7E-05	2.0E-05	2.0E-05	1.1E-05
0.6 (0.37)	5.4E-06	4.2E-06	4.0E-06	3.4E-06	3.7E-06	4.2E-06	5.4E-06	5.2E-06	5.0E-06	5.2E-06	7.4E-06	1.0E-05	1.2E-05	1.5E-05	1.5E-05	8.0E-06
0.7 (0.43)	4.1E-06	3.2E-06	3.0E-06	2.6E-06	2.8E-06	3.2E-06	4.1E-06	4.0E-06	3.8E-06	4.0E-06	5.6E-06	7.8E-06	9.2E-06	1.1E-05	1.1E-05	6.0E-06
0.8 (0.50)	3.2E-06	2.5E-06	2.4E-06	2.0E-06	2.2E-06	2.5E-06	3.3E-06	3.2E-06	3.0E-06	3.1E-06	4.4E-06	6.2E-06	7.3E-06	8.8E-06	8.8E-06	4.8E-06
0.9 (0.56)	2.6E-06	2.0E-06	1.9E-06	1.6E-06	1.8E-06	2.0E-06	2.6E-06	2.6E-06	2.5E-06	2.6E-06	3.6E-06	5.0E-06	5.9E-06	7.2E-06	7.2E-06	3.9E-06
1 (0.62)	2.2E-06	1.7E-06	1.6E-06	1.4E-06	1.5E-06	1.7E-06	2.2E-06	2.1E-06	2.0E-06	2.1E-06	3.0E-06	4.2E-06	4.9E-06	6.0E-06	6.0E-06	3.2E-06
2.4 (1.5)	5.0E-07	3.8E-07	3.7E-07	3.1E-07	3.4E-07	3.8E-07	5.1E-07	4.9E-07	4.7E-07	4.9E-07	6.9E-07	9.7E-07	1.2E-06	1.4E-06	1.4E-06	7.4E-07
4 (2.5)	2.3E-07	1.7E-07	1.7E-07	1.4E-07	1.6E-07	1.7E-07	2.3E-07	2.3E-07	2.2E-07	2.3E-07	3.2E-07	4.5E-07	5.3E-07	6.3E-07	6.3E-07	3.3E-07
5.6 (3.5)	1.4E-07	1.0E-07	1.0E-07	8.5E-08	9.4E-08	1.1E-07	1.4E-07	1.4E-07	1.3E-07	1.4E-07	1.9E-07	2.7E-07	3.2E-07	3.9E-07	3.8E-07	2.0E-07
7.2 (4.5)	9.3E-08	7.1E-08	6.9E-08	5.9E-08	6.5E-08	7.3E-08	9.7E-08	9.5E-08	9.1E-08	9.6E-08	1.4E-07	1.9E-07	2.2E-07	2.7E-07	2.6E-07	1.4E-07
12 (7.5)	4.5E-08	3.4E-08	3.3E-08	2.8E-08	3.1E-08	3.5E-08	4.7E-08	4.6E-08	4.4E-08	4.6E-08	6.6E-08	9.2E-08	1.1E-07	1.3E-07	1.3E-07	6.7E-08
24 (15)	1.7E-08	1.3E-08	1.3E-08	1.1E-08	1.2E-08	1.3E-08	1.8E-08	1.8E-08	1.7E-08	1.8E-08	2.5E-08	3.6E-08	4.2E-08	5.0E-08	4.9E-08	2.6E-08
40 (25)	8.4E-09	6.4E-09	6.2E-09	5.4E-09	5.9E-09	6.6E-09	8.9E-09	8.8E-09	8.6E-09	9.0E-09	1.3E-08	1.8E-08	2.1E-08	2.5E-08	2.4E-08	1.3E-08
56 (35)	5.4E-09	4.1E-09	4.0E-09	3.4E-09	3.8E-09	4.2E-09	5.7E-09	5.6E-09	5.5E-09	5.8E-09	8.2E-09	1.2E-08	1.4E-08	1.6E-08	1.6E-08	8.1E-09
72 (45)	3.8E-09	2.9E-09	2.8E-09	2.5E-09	2.7E-09	3.0E-09	4.1E-09	4.0E-09	3.9E-09	4.2E-09	5.9E-09	8.3E-09	9.7E-09	1.1E-08	1.1E-08	5.8E-09

Table A12. X/Q' Values (s m^{-3}) for Chronic 60-m Stack Releases from 200 Areas Based on 1983 through 2006 Meteorological Information, Hanford Site, Washington

Distance	Sector (Wind from 200 Areas toward Direction Indicated)															
km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	9.1E-10	9.4E-10	8.7E-10	6.7E-10	7.5E-10	6.3E-10	6.0E-10	4.8E-10	3.5E-10	3.5E-10	5.3E-10	5.0E-10	3.3E-10	4.4E-10	1.1E-09	9.6E-10
0.2 (0.12)	1.8E-07	1.8E-07	1.7E-07	1.3E-07	1.5E-07	1.2E-07	1.2E-07	9.5E-08	6.9E-08	6.9E-08	1.0E-07	9.7E-08	6.4E-08	8.8E-08	2.1E-07	1.9E-07
0.3 (0.19)	3.5E-07	3.6E-07	3.3E-07	2.5E-07	2.8E-07	2.3E-07	2.3E-07	1.8E-07	1.3E-07	1.4E-07	2.0E-07	1.9E-07	1.3E-07	1.8E-07	4.2E-07	3.7E-07
0.4 (0.25)	3.0E-07	3.1E-07	2.8E-07	2.2E-07	2.4E-07	2.0E-07	2.0E-07	1.6E-07	1.1E-07	1.2E-07	1.7E-07	1.6E-07	1.1E-07	1.6E-07	3.6E-07	3.3E-07
0.5 (0.31)	2.5E-07	2.4E-07	2.2E-07	1.8E-07	1.8E-07	1.6E-07	1.6E-07	1.3E-07	8.6E-08	9.7E-08	1.3E-07	1.2E-07	9.5E-08	1.4E-07	3.0E-07	2.7E-07
0.6 (0.37)	2.1E-07	2.0E-07	1.9E-07	1.5E-07	1.6E-07	1.4E-07	1.4E-07	1.1E-07	7.4E-08	8.5E-08	1.1E-07	1.0E-07	8.7E-08	1.3E-07	2.6E-07	2.4E-07
0.7 (0.43)	2.0E-07	1.8E-07	1.7E-07	1.4E-07	1.4E-07	1.3E-07	1.4E-07	1.0E-07	6.9E-08	8.0E-08	9.9E-08	9.6E-08	8.7E-08	1.3E-07	2.5E-07	2.2E-07
0.8 (0.50)	1.9E-07	1.7E-07	1.6E-07	1.3E-07	1.3E-07	1.2E-07	1.4E-07	1.0E-07	6.9E-08	7.8E-08	9.6E-08	9.5E-08	9.2E-08	1.5E-07	2.6E-07	2.2E-07
0.9 (0.56)	1.9E-07	1.7E-07	1.6E-07	1.3E-07	1.3E-07	1.2E-07	1.4E-07	1.1E-07	7.0E-08	7.9E-08	9.7E-08	9.6E-08	9.8E-08	1.6E-07	2.7E-07	2.2E-07
1 (0.62)	1.9E-07	1.7E-07	1.5E-07	1.2E-07	1.3E-07	1.2E-07	1.4E-07	1.1E-07	7.2E-08	8.0E-08	9.8E-08	9.9E-08	1.1E-07	1.7E-07	2.8E-07	2.2E-07
2.4 (1.5)	1.3E-07	1.1E-07	1.0E-07	8.4E-08	9.3E-08	9.1E-08	1.2E-07	9.1E-08	6.3E-08	6.5E-08	8.3E-08	9.3E-08	1.2E-07	2.0E-07	2.5E-07	1.6E-07
4 (2.5)	8.4E-08	6.8E-08	6.2E-08	5.3E-08	5.9E-08	5.9E-08	7.6E-08	6.2E-08	4.3E-08	4.4E-08	5.7E-08	6.5E-08	8.7E-08	1.5E-07	1.8E-07	1.1E-07
5.6 (3.5)	5.9E-08	4.8E-08	4.3E-08	3.7E-08	4.1E-08	4.2E-08	5.5E-08	4.5E-08	3.2E-08	3.2E-08	4.1E-08	4.9E-08	6.7E-08	1.1E-07	1.3E-07	7.8E-08
7.2 (4.5)	4.5E-08	3.6E-08	3.2E-08	2.8E-08	3.1E-08	3.2E-08	4.2E-08	3.5E-08	2.5E-08	2.5E-08	3.2E-08	3.8E-08	5.3E-08	8.6E-08	1.0E-07	6.0E-08
12 (7.5)	2.5E-08	2.0E-08	1.7E-08	1.5E-08	1.7E-08	1.8E-08	2.4E-08	2.0E-08	1.4E-08	1.4E-08	1.9E-08	2.3E-08	3.2E-08	5.1E-08	5.9E-08	3.4E-08
24 (15)	1.1E-08	8.4E-09	7.5E-09	6.5E-09	7.5E-09	7.6E-09	1.0E-08	9.1E-09	6.5E-09	6.6E-09	8.4E-09	1.1E-08	1.5E-08	2.4E-08	2.7E-08	1.5E-08
40 (25)	5.8E-09	4.5E-09	4.0E-09	3.5E-09	4.0E-09	4.1E-09	5.6E-09	5.0E-09	3.6E-09	3.6E-09	4.7E-09	5.8E-09	8.5E-09	1.3E-08	1.5E-08	8.4E-09
56 (35)	3.8E-09	2.9E-09	2.6E-09	2.3E-09	2.7E-09	2.7E-09	3.7E-09	3.3E-09	2.4E-09	2.4E-09	3.1E-09	3.9E-09	5.8E-09	8.8E-09	9.9E-09	5.6E-09
72 (45)	2.8E-09	2.2E-09	1.9E-09	1.7E-09	1.9E-09	2.0E-09	2.7E-09	2.5E-09	1.8E-09	1.8E-09	2.3E-09	2.9E-09	4.3E-09	6.5E-09	7.4E-09	4.2E-09

Table A13. X/Q' Values (s m^{-3}) for Chronic Ground-Level Releases from 300 Area Based on 1983 through 2006 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 300 Area toward Direction Indicated) S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	2.3E-04	1.1E-04	6.0E-05	5.5E-05	8.3E-05	2.1E-04	3.4E-04	2.5E-04	2.3E-04	2.1E-04	2.0E-04	1.4E-04	1.2E-04	1.4E-04	2.2E-04	2.8E-04
0.2 (0.12)	6.4E-05	2.9E-05	1.6E-05	1.5E-05	2.3E-05	5.7E-05	9.5E-05	7.0E-05	6.4E-05	5.7E-05	5.4E-05	3.8E-05	3.4E-05	3.9E-05	6.1E-05	7.7E-05
0.3 (0.19)	3.1E-05	1.4E-05	7.7E-06	7.0E-06	1.1E-05	2.7E-05	4.5E-05	3.4E-05	3.1E-05	2.7E-05	2.6E-05	1.8E-05	1.6E-05	1.9E-05	2.9E-05	3.7E-05
0.4 (0.25)	1.8E-05	8.2E-06	4.5E-06	4.1E-06	6.3E-06	1.6E-05	2.7E-05	2.0E-05	1.8E-05	1.6E-05	1.5E-05	1.1E-05	9.8E-06	1.1E-05	1.7E-05	2.2E-05
0.5 (0.31)	1.2E-05	5.5E-06	3.0E-06	2.7E-06	4.2E-06	1.1E-05	1.8E-05	1.3E-05	1.2E-05	1.1E-05	1.0E-05	7.2E-06	6.6E-06	7.5E-06	1.2E-05	1.5E-05
0.6 (0.37)	8.9E-06	4.0E-06	2.2E-06	1.9E-06	3.0E-06	7.9E-06	1.3E-05	9.7E-06	8.9E-06	7.8E-06	7.4E-06	5.2E-06	4.8E-06	5.4E-06	8.4E-06	1.1E-05
0.7 (0.43)	6.7E-06	3.0E-06	1.6E-06	1.5E-06	2.3E-06	6.0E-06	1.0E-05	7.4E-06	6.8E-06	5.9E-06	5.6E-06	4.0E-06	3.6E-06	4.1E-06	6.4E-06	8.1E-06
0.8 (0.50)	5.3E-06	2.4E-06	1.3E-06	1.2E-06	1.8E-06	4.7E-06	7.9E-06	5.9E-06	5.4E-06	4.7E-06	4.4E-06	3.1E-06	2.9E-06	3.3E-06	5.1E-06	6.4E-06
0.9 (0.56)	4.3E-06	1.9E-06	1.0E-06	9.4E-07	1.5E-06	3.9E-06	6.4E-06	4.8E-06	4.4E-06	3.8E-06	3.6E-06	2.6E-06	2.3E-06	2.7E-06	4.1E-06	5.2E-06
1 (0.62)	3.6E-06	1.6E-06	8.6E-07	7.8E-07	1.2E-06	3.2E-06	5.3E-06	4.0E-06	3.6E-06	3.2E-06	3.0E-06	2.1E-06	1.9E-06	2.2E-06	3.4E-06	4.3E-06
2.4 (1.5)	8.3E-07	3.7E-07	2.0E-07	1.8E-07	2.8E-07	7.4E-07	1.2E-06	9.2E-07	8.4E-07	7.3E-07	6.9E-07	4.9E-07	4.5E-07	5.1E-07	8.0E-07	1.0E-06
4 (2.5)	3.8E-07	1.7E-07	8.9E-08	8.0E-08	1.3E-07	3.4E-07	5.7E-07	4.2E-07	3.9E-07	3.4E-07	3.2E-07	2.2E-07	2.1E-07	2.4E-07	3.7E-07	4.6E-07
5.6 (3.5)	2.3E-07	1.0E-07	5.4E-08	4.9E-08	7.7E-08	2.1E-07	3.5E-07	2.6E-07	2.4E-07	2.0E-07	1.9E-07	1.4E-07	1.3E-07	1.4E-07	2.2E-07	2.8E-07
7.2 (4.5)	1.6E-07	7.0E-08	3.7E-08	3.4E-08	5.3E-08	1.4E-07	2.4E-07	1.8E-07	1.6E-07	1.4E-07	1.3E-07	9.4E-08	8.7E-08	1.0E-07	1.6E-07	1.9E-07
12 (7.5)	7.8E-08	3.4E-08	1.8E-08	1.6E-08	2.6E-08	7.0E-08	1.2E-07	8.7E-08	8.0E-08	6.8E-08	6.4E-08	4.6E-08	4.2E-08	4.8E-08	7.5E-08	9.4E-08
24 (15)	3.0E-08	1.3E-08	6.9E-09	6.2E-09	9.8E-09	2.7E-08	4.5E-08	3.4E-08	3.1E-08	2.6E-08	2.5E-08	1.8E-08	1.6E-08	1.9E-08	2.9E-08	3.6E-08
40 (25)	1.5E-08	6.6E-09	3.5E-09	3.1E-09	5.0E-09	1.4E-08	2.3E-08	1.7E-08	1.5E-08	1.3E-08	1.2E-08	8.7E-09	8.1E-09	9.4E-09	1.4E-08	1.8E-08
56 (35)	9.6E-09	4.2E-09	2.2E-09	2.0E-09	3.2E-09	8.6E-09	1.5E-08	1.1E-08	9.9E-09	8.3E-09	7.8E-09	5.6E-09	5.1E-09	6.0E-09	9.2E-09	1.2E-08
72 (45)	6.9E-09	3.0E-09	1.6E-09	1.4E-09	2.3E-09	6.2E-09	1.1E-08	7.8E-09	7.1E-09	6.0E-09	5.6E-09	4.0E-09	3.7E-09	4.3E-09	6.6E-09	8.3E-09

Table A14. X/Q' Values (s m^{-3}) for Chronic 60-m Stack Releases from 300 Area Based on 1986 through 2006 Meteorological Information, Hanford Site, Washington

Distance km (mi)	Sector (Wind from 300 Area toward Direction Indicated) S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	5.3E-10	7.1E-10	7.3E-10	7.1E-10	8.5E-10	9.5E-10	9.9E-10	5.7E-10	5.3E-10	7.8E-10	8.4E-10	4.8E-10	2.3E-10	1.7E-10	2.7E-10	3.7E-10
0.2 (0.12)	1.1E-07	1.4E-07	1.4E-07	1.4E-07	1.6E-07	1.8E-07	1.9E-07	1.1E-07	1.0E-07	1.5E-07	1.6E-07	9.4E-08	4.6E-08	3.4E-08	5.4E-08	7.4E-08
0.3 (0.19)	2.1E-07	2.7E-07	2.6E-07	2.6E-07	3.1E-07	3.5E-07	3.8E-07	2.2E-07	2.0E-07	3.0E-07	3.1E-07	1.8E-07	9.3E-08	6.7E-08	1.1E-07	1.5E-07
0.4 (0.25)	1.9E-07	2.3E-07	2.2E-07	2.1E-07	2.5E-07	3.0E-07	3.3E-07	2.0E-07	1.8E-07	2.6E-07	2.6E-07	1.5E-07	8.2E-08	6.1E-08	9.7E-08	1.4E-07
0.5 (0.31)	1.6E-07	1.8E-07	1.7E-07	1.6E-07	1.9E-07	2.4E-07	2.6E-07	1.6E-07	1.5E-07	2.0E-07	2.1E-07	1.2E-07	6.8E-08	5.3E-08	8.4E-08	1.2E-07
0.6 (0.37)	1.5E-07	1.5E-07	1.3E-07	1.3E-07	1.6E-07	2.0E-07	2.2E-07	1.4E-07	1.3E-07	1.7E-07	1.8E-07	1.1E-07	6.2E-08	5.1E-08	8.1E-08	1.2E-07
0.7 (0.43)	1.4E-07	1.4E-07	1.2E-07	1.1E-07	1.4E-07	1.8E-07	2.0E-07	1.4E-07	1.2E-07	1.6E-07	1.6E-07	1.0E-07	6.1E-08	5.4E-08	8.6E-08	1.3E-07
0.8 (0.50)	1.5E-07	1.3E-07	1.1E-07	9.8E-08	1.2E-07	1.7E-07	1.9E-07	1.4E-07	1.3E-07	1.6E-07	1.6E-07	1.0E-07	6.4E-08	5.9E-08	9.5E-08	1.4E-07
0.9 (0.56)	1.5E-07	1.3E-07	1.0E-07	9.2E-08	1.2E-07	1.6E-07	1.9E-07	1.4E-07	1.3E-07	1.6E-07	1.6E-07	1.0E-07	6.7E-08	6.4E-08	1.0E-07	1.5E-07
1 (0.62)	1.6E-07	1.3E-07	9.8E-08	8.8E-08	1.1E-07	1.6E-07	1.9E-07	1.5E-07	1.4E-07	1.6E-07	1.6E-07	1.1E-07	7.1E-08	6.9E-08	1.1E-07	1.6E-07
2.4 (1.5)	1.5E-07	1.0E-07	6.8E-08	5.9E-08	7.8E-08	1.2E-07	1.7E-07	1.4E-07	1.4E-07	1.5E-07	1.5E-07	1.0E-07	7.4E-08	7.5E-08	1.2E-07	1.6E-07
4 (2.5)	1.1E-07	6.8E-08	4.5E-08	3.9E-08	5.1E-08	8.2E-08	1.2E-07	1.0E-07	1.0E-07	1.1E-07	1.1E-07	7.1E-08	5.3E-08	5.3E-08	8.1E-08	1.1E-07
5.6 (3.5)	7.9E-08	5.0E-08	3.2E-08	2.8E-08	3.6E-08	6.0E-08	8.8E-08	7.5E-08	7.6E-08	7.8E-08	7.8E-08	5.2E-08	3.9E-08	3.9E-08	5.9E-08	8.1E-08
7.2 (4.5)	6.2E-08	3.8E-08	2.5E-08	2.1E-08	2.8E-08	4.7E-08	7.0E-08	6.0E-08	6.0E-08	6.1E-08	6.1E-08	4.0E-08	3.0E-08	3.1E-08	4.6E-08	6.3E-08
12 (7.5)	3.7E-08	2.2E-08	1.4E-08	1.2E-08	1.6E-08	2.8E-08	4.2E-08	3.5E-08	3.6E-08	3.6E-08	3.5E-08	2.3E-08	1.8E-08	1.8E-08	2.6E-08	3.7E-08
24 (15)	1.7E-08	1.0E-08	6.4E-09	5.4E-09	7.1E-09	1.3E-08	2.0E-08	1.7E-08	1.7E-08	1.6E-08	1.6E-08	1.1E-08	8.1E-09	8.2E-09	1.2E-08	1.7E-08
40 (25)	9.4E-09	5.6E-09	3.5E-09	2.9E-09	3.9E-09	7.1E-09	1.1E-08	9.3E-09	9.3E-09	9.0E-09	8.7E-09	5.7E-09	4.4E-09	4.5E-09	6.5E-09	9.2E-09
56 (35)	6.4E-09	3.8E-09	2.3E-09	1.9E-09	2.6E-09	4.8E-09	7.6E-09	6.3E-09	6.3E-09	6.0E-09	5.8E-09	3.8E-09	3.0E-09	3.0E-09	4.3E-09	6.1E-09
72 (45)	4.7E-09	2.8E-09	1.7E-09	1.4E-09	1.9E-09	3.6E-09	5.7E-09	4.7E-09	4.7E-09	4.5E-09	4.3E-09	2.8E-09	2.2E-09	2.2E-09	3.2E-09	4.5E-09

Table A15. X/Q' Values (s m^{-3}) for Chronic Ground-Level Releases from 400 Area Based on 1983 through 2006 Meteorological Information, Hanford Site, Washington

Distance	Sector (Wind from 400 Area toward Direction Indicated)															
km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	1.7E-04	1.5E-04	1.1E-04	7.5E-05	7.5E-05	8.6E-05	1.4E-04	2.2E-04	2.5E-04	2.5E-04	1.7E-04	1.2E-04	1.2E-04	1.5E-04	2.5E-04	2.1E-04
0.2 (0.12)	4.6E-05	4.2E-05	3.0E-05	2.1E-05	2.0E-05	2.3E-05	3.9E-05	6.0E-05	6.8E-05	6.8E-05	4.7E-05	3.2E-05	3.3E-05	4.2E-05	6.8E-05	5.8E-05
0.3 (0.19)	2.2E-05	2.0E-05	1.4E-05	9.7E-06	9.7E-06	1.1E-05	1.9E-05	2.9E-05	3.2E-05	3.3E-05	2.2E-05	1.5E-05	1.6E-05	2.0E-05	3.3E-05	2.8E-05
0.4 (0.25)	1.3E-05	1.2E-05	8.4E-06	5.7E-06	5.7E-06	6.5E-06	1.1E-05	1.7E-05	1.9E-05	1.9E-05	1.3E-05	9.2E-06	9.5E-06	1.2E-05	1.9E-05	1.7E-05
0.5 (0.31)	8.8E-06	7.9E-06	5.6E-06	3.8E-06	3.8E-06	4.4E-06	7.4E-06	1.2E-05	1.3E-05	1.3E-05	8.9E-06	6.1E-06	6.4E-06	8.1E-06	1.3E-05	1.1E-05
0.6 (0.37)	6.4E-06	5.7E-06	4.0E-06	2.8E-06	2.7E-06	3.1E-06	5.3E-06	8.3E-06	9.3E-06	9.4E-06	6.5E-06	4.4E-06	4.6E-06	5.8E-06	9.5E-06	8.1E-06
0.7 (0.43)	4.8E-06	4.3E-06	3.1E-06	2.1E-06	2.1E-06	2.4E-06	4.1E-06	6.3E-06	7.1E-06	7.1E-06	4.9E-06	3.4E-06	3.5E-06	4.4E-06	7.2E-06	6.1E-06
0.8 (0.50)	3.8E-06	3.4E-06	2.4E-06	1.7E-06	1.6E-06	1.9E-06	3.2E-06	5.0E-06	5.6E-06	5.6E-06	3.9E-06	2.7E-06	2.8E-06	3.5E-06	5.7E-06	4.8E-06
0.9 (0.56)	3.1E-06	2.8E-06	2.0E-06	1.3E-06	1.3E-06	1.5E-06	2.6E-06	4.1E-06	4.5E-06	4.6E-06	3.2E-06	2.2E-06	2.3E-06	2.9E-06	4.6E-06	3.9E-06
1 (0.62)	2.6E-06	2.3E-06	1.6E-06	1.1E-06	1.1E-06	1.3E-06	2.2E-06	3.4E-06	3.8E-06	3.8E-06	2.6E-06	1.8E-06	1.9E-06	2.4E-06	3.9E-06	3.3E-06
2.4 (1.5)	6.0E-07	5.3E-07	3.7E-07	2.6E-07	2.5E-07	2.9E-07	5.0E-07	7.8E-07	8.7E-07	8.8E-07	6.1E-07	4.2E-07	4.3E-07	5.5E-07	8.9E-07	7.6E-07
4 (2.5)	2.7E-07	2.4E-07	1.7E-07	1.2E-07	1.2E-07	1.3E-07	2.3E-07	3.6E-07	4.0E-07	4.0E-07	2.8E-07	1.9E-07	2.0E-07	2.5E-07	4.1E-07	3.5E-07
5.6 (3.5)	1.7E-07	1.5E-07	1.0E-07	7.1E-08	7.0E-08	8.0E-08	1.4E-07	2.2E-07	2.4E-07	2.4E-07	1.7E-07	1.2E-07	1.2E-07	1.5E-07	2.5E-07	2.1E-07
7.2 (4.5)	1.2E-07	1.0E-07	7.2E-08	4.9E-08	4.8E-08	5.5E-08	9.5E-08	1.5E-07	1.7E-07	1.7E-07	1.2E-07	8.1E-08	8.4E-08	1.1E-07	1.7E-07	1.5E-07
12 (7.5)	5.6E-08	5.0E-08	3.5E-08	2.4E-08	2.3E-08	2.7E-08	4.6E-08	7.4E-08	8.2E-08	8.2E-08	5.7E-08	3.9E-08	4.1E-08	5.1E-08	8.3E-08	7.1E-08
24 (15)	2.2E-08	1.9E-08	1.3E-08	9.0E-09	8.9E-09	1.0E-08	1.8E-08	2.8E-08	3.2E-08	3.2E-08	2.2E-08	1.5E-08	1.6E-08	2.0E-08	3.2E-08	2.7E-08
40 (25)	1.1E-08	9.6E-09	6.7E-09	4.5E-09	4.5E-09	5.1E-09	8.8E-09	1.4E-08	1.6E-08	1.6E-08	1.1E-08	7.5E-09	7.8E-09	9.7E-09	1.6E-08	1.4E-08
56 (35)	7.0E-09	6.2E-09	4.3E-09	2.9E-09	2.9E-09	3.3E-09	5.6E-09	9.1E-09	1.0E-08	1.0E-08	7.0E-09	4.8E-09	5.0E-09	6.2E-09	1.0E-08	8.7E-09
72 (45)	5.0E-09	4.4E-09	3.1E-09	2.1E-09	2.1E-09	2.3E-09	4.0E-09	6.5E-09	7.3E-09	7.3E-09	5.0E-09	3.5E-09	3.6E-09	4.4E-09	7.2E-09	6.2E-09

Table A16. X/Q' Values (s m^{-3}) for Chronic 60-m Stack Releases from 400 Area Based on 1986 through 2006 Meteorological Information, Hanford Site, Washington

Distance	Sector (Wind from 400 Area toward Direction Indicated)															
km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	7.5E-10	8.5E-10	7.2E-10	4.9E-10	6.0E-10	6.9E-10	7.5E-10	6.9E-10	9.2E-10	1.0E-09	6.0E-10	3.9E-10	3.4E-10	3.4E-10	4.9E-10	5.3E-10
0.2 (0.12)	1.5E-07	1.6E-07	1.4E-07	9.6E-08	1.2E-07	1.3E-07	1.5E-07	1.4E-07	1.8E-07	2.0E-07	1.2E-07	7.6E-08	6.7E-08	6.7E-08	9.6E-08	1.1E-07
0.3 (0.19)	2.9E-07	3.1E-07	2.7E-07	1.8E-07	2.2E-07	2.5E-07	2.8E-07	2.6E-07	3.5E-07	3.8E-07	2.3E-07	1.5E-07	1.3E-07	1.3E-07	1.9E-07	2.1E-07
0.4 (0.25)	2.5E-07	2.6E-07	2.3E-07	1.6E-07	1.9E-07	2.1E-07	2.4E-07	2.3E-07	3.0E-07	3.2E-07	2.0E-07	1.3E-07	1.1E-07	1.2E-07	1.7E-07	1.9E-07
0.5 (0.31)	2.0E-07	2.0E-07	1.8E-07	1.2E-07	1.5E-07	1.7E-07	1.9E-07	1.8E-07	2.4E-07	2.5E-07	1.5E-07	1.0E-07	9.1E-08	9.6E-08	1.5E-07	1.5E-07
0.6 (0.37)	1.7E-07	1.7E-07	1.5E-07	1.0E-07	1.2E-07	1.4E-07	1.6E-07	1.6E-07	2.0E-07	2.1E-07	1.3E-07	8.5E-08	7.9E-08	8.7E-08	1.3E-07	1.4E-07
0.7 (0.43)	1.5E-07	1.5E-07	1.3E-07	9.2E-08	1.1E-07	1.2E-07	1.5E-07	1.5E-07	1.8E-07	1.9E-07	1.2E-07	7.9E-08	7.5E-08	8.6E-08	1.4E-07	1.3E-07
0.8 (0.50)	1.5E-07	1.4E-07	1.2E-07	8.7E-08	1.0E-07	1.1E-07	1.4E-07	1.4E-07	1.7E-07	1.8E-07	1.2E-07	7.8E-08	7.5E-08	8.9E-08	1.4E-07	1.4E-07
0.9 (0.56)	1.4E-07	1.3E-07	1.2E-07	8.5E-08	9.7E-08	1.1E-07	1.4E-07	1.4E-07	1.7E-07	1.8E-07	1.2E-07	7.9E-08	7.8E-08	9.4E-08	1.5E-07	1.4E-07
1 (0.62)	1.4E-07	1.3E-07	1.1E-07	8.4E-08	9.5E-08	1.0E-07	1.4E-07	1.5E-07	1.7E-07	1.8E-07	1.2E-07	8.1E-08	8.0E-08	9.9E-08	1.6E-07	1.4E-07
2.4 (1.5)	1.1E-07	9.7E-08	8.0E-08	6.1E-08	6.6E-08	7.2E-08	1.1E-07	1.3E-07	1.5E-07	1.5E-07	1.2E-07	7.9E-08	7.9E-08	9.9E-08	1.6E-07	1.3E-07
4 (2.5)	7.4E-08	6.5E-08	5.3E-08	4.1E-08	4.3E-08	4.7E-08	7.4E-08	9.1E-08	1.0E-07	1.1E-07	8.6E-08	5.6E-08	5.6E-08	6.9E-08	1.1E-07	9.0E-08
5.6 (3.5)	5.4E-08	4.8E-08	3.8E-08	2.9E-08	3.1E-08	3.4E-08	5.4E-08	6.8E-08	7.8E-08	7.8E-08	6.4E-08	4.2E-08	4.1E-08	5.1E-08	8.2E-08	6.6E-08
7.2 (4.5)	4.2E-08	3.7E-08	2.9E-08	2.2E-08	2.4E-08	2.6E-08	4.2E-08	5.3E-08	6.1E-08	6.1E-08	5.0E-08	3.3E-08	3.2E-08	3.9E-08	6.4E-08	5.2E-08
12 (7.5)	2.4E-08	2.1E-08	1.7E-08	1.3E-08	1.3E-08	1.5E-08	2.4E-08	3.2E-08	3.6E-08	3.6E-08	2.9E-08	1.9E-08	1.9E-08	2.2E-08	3.6E-08	3.0E-08
24 (15)	1.1E-08	9.8E-09	7.6E-09	5.8E-09	6.0E-09	6.5E-09	1.1E-08	1.5E-08	1.7E-08	1.6E-08	1.3E-08	8.7E-09	8.5E-09	1.0E-08	1.6E-08	1.4E-08
40 (25)	6.2E-09	5.4E-09	4.1E-09	3.2E-09	3.3E-09	3.6E-09	6.0E-09	8.3E-09	9.4E-09	9.0E-09	7.3E-09	4.7E-09	4.6E-09	5.4E-09	8.8E-09	7.6E-09
56 (35)	4.2E-09	3.6E-09	2.8E-09	2.1E-09	2.2E-09	2.4E-09	4.0E-09	5.6E-09	6.3E-09	6.0E-09	4.9E-09	3.2E-09	3.1E-09	3.6E-09	5.8E-09	5.1E-09
72 (45)	3.1E-09	2.7E-09	2.1E-09	1.6E-09	1.6E-09	1.8E-09	3.0E-09	4.2E-09	4.7E-09	4.5E-09	3.6E-09	2.3E-09	2.3E-09	2.6E-09	4.3E-09	3.8E-09

Table A17. 95th Percentile E/Q Values (s m^{-3}) for Acute Ground Level Releases from 100-N Area Based on 1983 through 2006 Meteorological Information, Hanford Site, Washington

Distance		Sector (Wind from 100-N toward Direction Indicated)															
km	(mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1	(0.06)	6.9E-02	6.3E-02	7.1E-02	7.6E-02	7.2E-02	6.3E-02	5.4E-02	5.7E-02	6.1E-02	6.1E-02	5.2E-02	5.1E-02	5.3E-02	5.6E-02	7.0E-02	7.4E-02
0.2	(0.12)	2.1E-02	1.9E-02	2.1E-02	2.3E-02	2.2E-02	1.9E-02	1.6E-02	1.7E-02	1.8E-02	1.8E-02	1.6E-02	1.6E-02	1.6E-02	1.7E-02	2.1E-02	2.2E-02
0.3	(0.19)	1.0E-02	9.6E-03	1.1E-02	1.1E-02	1.1E-02	9.6E-03	8.2E-03	8.7E-03	9.2E-03	9.3E-03	7.8E-03	7.8E-03	8.1E-03	8.5E-03	1.1E-02	1.1E-02
0.4	(0.25)	6.4E-03	5.9E-03	6.6E-03	7.1E-03	6.7E-03	5.9E-03	5.1E-03	5.3E-03	5.7E-03	5.7E-03	4.8E-03	4.8E-03	5.0E-03	5.3E-03	6.5E-03	6.9E-03
0.5	(0.31)	4.4E-03	4.1E-03	4.5E-03	4.9E-03	4.6E-03	4.1E-03	3.5E-03	3.7E-03	3.9E-03	3.9E-03	3.3E-03	3.3E-03	3.4E-03	3.6E-03	4.5E-03	4.8E-03
0.6	(0.37)	3.3E-03	3.0E-03	3.3E-03	3.6E-03	3.4E-03	3.0E-03	2.6E-03	2.7E-03	2.9E-03	2.9E-03	2.4E-03	2.4E-03	2.5E-03	2.7E-03	3.3E-03	3.5E-03
0.7	(0.43)	2.5E-03	2.3E-03	2.6E-03	2.8E-03	2.6E-03	2.3E-03	2.0E-03	2.1E-03	2.2E-03	2.2E-03	1.9E-03	1.9E-03	2.0E-03	2.1E-03	2.5E-03	2.7E-03
0.8	(0.50)	2.0E-03	1.8E-03	2.1E-03	2.2E-03	2.1E-03	1.9E-03	1.6E-03	1.7E-03	1.8E-03	1.8E-03	1.5E-03	1.5E-03	1.6E-03	1.6E-03	2.0E-03	2.2E-03
0.9	(0.56)	1.7E-03	1.5E-03	1.7E-03	1.8E-03	1.7E-03	1.5E-03	1.3E-03	1.4E-03	1.5E-03	1.5E-03	1.2E-03	1.2E-03	1.3E-03	1.4E-03	1.7E-03	1.8E-03
1	(0.62)	1.4E-03	1.3E-03	1.4E-03	1.5E-03	1.4E-03	1.3E-03	1.1E-03	1.2E-03	1.2E-03	1.2E-03	1.0E-03	1.0E-03	1.1E-03	1.1E-03	1.4E-03	1.5E-03
2.4	(1.5)	3.6E-04	3.3E-04	3.6E-04	3.9E-04	3.7E-04	3.3E-04	2.8E-04	3.0E-04	3.1E-04	3.2E-04	2.7E-04	2.7E-04	2.8E-04	2.9E-04	3.6E-04	3.8E-04
4	(2.5)	1.7E-04	1.6E-04	1.8E-04	1.9E-04	1.8E-04	1.6E-04	1.4E-04	1.4E-04	1.5E-04	1.5E-04	1.3E-04	1.3E-04	1.3E-04	1.4E-04	1.8E-04	1.9E-04
5.6	(3.5)	1.1E-04	1.0E-04	1.1E-04	1.2E-04	1.2E-04	1.0E-04	8.7E-05	9.2E-05	9.8E-05	9.9E-05	8.3E-05	8.3E-05	8.6E-05	9.1E-05	1.1E-04	1.2E-04
7.2	(4.5)	8.0E-05	7.3E-05	8.2E-05	8.8E-05	8.3E-05	7.4E-05	6.3E-05	6.6E-05	7.1E-05	7.1E-05	6.0E-05	6.0E-05	6.2E-05	6.5E-05	8.1E-05	8.6E-05
12	(7.5)	4.2E-05	3.8E-05	4.3E-05	4.6E-05	4.3E-05	3.8E-05	3.3E-05	3.5E-05	3.7E-05	3.7E-05	3.1E-05	3.1E-05	3.2E-05	3.4E-05	4.2E-05	4.5E-05
24	(15)	1.8E-05	1.6E-05	1.8E-05	1.9E-05	1.8E-05	1.6E-05	1.4E-05	1.5E-05	1.6E-05	1.6E-05	1.3E-05	1.3E-05	1.4E-05	1.4E-05	1.8E-05	1.9E-05
40	(25)	9.5E-06	8.7E-06	9.7E-06	1.0E-05	9.9E-06	8.7E-06	7.5E-06	7.9E-06	8.4E-06	8.4E-06	7.1E-06	7.1E-06	7.3E-06	7.7E-06	9.6E-06	1.0E-05
56	(35)	6.3E-06	5.8E-06	6.5E-06	7.0E-06	6.6E-06	5.8E-06	5.0E-06	5.3E-06	5.6E-06	5.6E-06	4.7E-06	4.7E-06	4.9E-06	5.2E-06	6.4E-06	6.8E-06
72	(45)	4.7E-06	4.3E-06	4.8E-06	5.2E-06	4.9E-06	4.3E-06	3.7E-06	3.9E-06	4.1E-06	4.2E-06	3.5E-06	3.5E-06	3.6E-06	3.8E-06	4.8E-06	5.1E-06

Table A18. 95th Percentile E/Q Values (s m^{-3}) for Acute 60-m Stack Releases from 100-N Area Based on 1986 through 2006 Meteorological Information, Hanford Site, Washington

Distance		Sector (Wind from 100-N toward Direction Indicated)															
km	(mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1	(0.06)	1.3E-07	1.2E-07	1.1E-07	7.3E-08	5.3E-08	6.7E-08	5.0E-08	6.6E-08	7.1E-08	6.2E-08	6.4E-08	8.1E-08	4.8E-08	3.6E-08	9.6E-08	1.5E-07
0.2	(0.12)	2.5E-05	2.4E-05	2.1E-05	1.4E-05	1.0E-05	1.3E-05	9.9E-06	1.3E-05	1.4E-05	1.2E-05	1.3E-05	1.6E-05	9.1E-06	6.3E-06	1.9E-05	2.9E-05
0.3	(0.19)	4.5E-05	3.7E-05	3.4E-05	3.2E-05	2.8E-05	3.0E-05	2.5E-05	2.9E-05	3.3E-05	3.0E-05	2.7E-05	2.9E-05	1.9E-05	1.5E-05	3.7E-05	5.2E-05
0.4	(0.25)	4.1E-05	3.5E-05	3.4E-05	3.2E-05	2.6E-05	2.8E-05	2.2E-05	2.8E-05	3.3E-05	3.0E-05	2.1E-05	2.2E-05	1.6E-05	1.5E-05	3.5E-05	4.3E-05
0.5	(0.31)	3.2E-05	2.8E-05	2.7E-05	2.7E-05	2.4E-05	2.5E-05	2.3E-05	2.6E-05	2.8E-05	2.7E-05	2.0E-05	2.2E-05	1.5E-05	1.2E-05	2.7E-05	3.4E-05
0.6	(0.37)	3.3E-05	2.2E-05	2.1E-05	2.0E-05	1.6E-05	1.6E-05	1.6E-05	1.7E-05	2.3E-05	1.9E-05	1.5E-05	1.5E-05	1.4E-05	1.3E-05	2.1E-05	3.7E-05
0.7	(0.43)	2.3E-05	1.4E-05	1.4E-05	1.4E-05	1.3E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.3E-05	1.3E-05	1.2E-05	1.2E-05	1.3E-05	2.7E-05
0.8	(0.50)	2.6E-05	2.2E-05	2.3E-05	2.4E-05	2.3E-05	2.4E-05	2.3E-05	2.4E-05	2.5E-05	2.4E-05	2.0E-05	2.0E-05	1.6E-05	1.5E-05	2.2E-05	2.7E-05
0.9	(0.56)	2.3E-05	2.2E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.2E-05	2.2E-05	2.0E-05	1.6E-05	2.2E-05	2.3E-05
1	(0.62)	2.8E-05	2.5E-05	2.6E-05	2.7E-05	2.7E-05	2.8E-05	2.8E-05	2.8E-05	2.9E-05	2.8E-05	2.4E-05	2.4E-05	2.2E-05	2.0E-05	2.5E-05	2.9E-05
2.4	(1.5)	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.2E-05	2.2E-05	2.3E-05	2.3E-05
4	(2.5)	1.8E-05	1.7E-05	1.8E-05	1.9E-05	1.9E-05	1.9E-05	1.8E-05	1.9E-05	1.9E-05	1.9E-05	1.8E-05	1.7E-05	1.6E-05	1.5E-05	1.7E-05	1.8E-05
5.6	(3.5)	1.5E-05	1.4E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.5E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.5E-05
7.2	(4.5)	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.2E-05	1.2E-05	1.1E-05	1.1E-05	1.3E-05	1.3E-05
12	(7.5)	8.9E-06	8.4E-06	9.9E-06	9.9E-06	9.9E-06	9.9E-06	9.4E-06	9.5E-06	9.5E-06	9.1E-06	7.3E-06	7.1E-06	6.6E-06	6.5E-06	8.1E-06	9.3E-06
24	(15)	5.7E-06	5.6E-06	5.9E-06	6.0E-06	6.0E-06	5.9E-06	5.7E-06	5.7E-06	5.7E-06	5.7E-06	5.2E-06	5.0E-06	4.1E-06	3.6E-06	5.6E-06	5.8E-06
40	(25)	3.8E-06	3.6E-06	4.2E-06	4.5E-06	4.4E-06	4.3E-06	3.9E-06	3.9E-06	3.9E-06	3.7E-06	3.2E-06	3.0E-06	2.4E-06	2.1E-06	3.5E-06	4.0E-06
56	(35)	2.8E-06	2.6E-06	3.2E-06	3.5E-06	3.5E-06	3.3E-06	2.9E-06	2.9E-06	2.9E-06	2.8E-06	2.1E-06	2.0E-06	1.3E-06	1.3E-06	2.6E-06	3.0E-06
72	(45)	2.2E-06	2.1E-06	2.6E-06	2.8E-06	2.8E-06	2.7E-06	2.3E-06	2.3E-06	2.3E-06	2.2E-06	1.6E-06	1.5E-06	1.1E-06	1.0E-06	2.0E-06	2.4E-06

Table A19. 95th Percentile E/Q Values (s m^{-3}) for Acute Ground-Level Releases from 200 Areas Based on 1983 through 2006 Meteorological Information, Hanford Site, Washington

Distance						Sector (Wind from 200 Areas toward Direction Indicated)										
km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	3.4E-02	3.2E-02	4.0E-02	4.6E-02	4.1E-02	4.2E-02	4.7E-02	4.8E-02	5.5E-02	4.8E-02	3.4E-02	3.3E-02	3.3E-02	3.1E-02	2.9E-02	3.3E-02
0.2 (0.12)	1.0E-02	9.7E-03	1.2E-02	1.4E-02	1.2E-02	1.3E-02	1.4E-02	1.4E-02	1.7E-02	1.5E-02	1.0E-02	9.8E-03	9.8E-03	9.3E-03	8.8E-03	9.9E-03
0.3 (0.19)	5.1E-03	4.9E-03	6.1E-03	7.0E-03	6.2E-03	6.3E-03	7.1E-03	7.3E-03	8.4E-03	7.3E-03	5.1E-03	4.9E-03	4.9E-03	4.7E-03	4.4E-03	5.0E-03
0.4 (0.25)	3.1E-03	3.0E-03	3.7E-03	4.3E-03	3.8E-03	3.9E-03	4.4E-03	4.5E-03	5.1E-03	4.5E-03	3.2E-03	3.0E-03	3.0E-03	2.9E-03	2.7E-03	3.1E-03
0.5 (0.31)	2.2E-03	2.1E-03	2.6E-03	2.9E-03	2.6E-03	2.7E-03	3.0E-03	3.1E-03	3.5E-03	3.1E-03	2.2E-03	2.1E-03	2.1E-03	2.0E-03	1.9E-03	2.1E-03
0.6 (0.37)	1.6E-03	1.5E-03	1.9E-03	2.2E-03	1.9E-03	2.0E-03	2.2E-03	2.3E-03	2.6E-03	2.3E-03	1.6E-03	1.5E-03	1.5E-03	1.5E-03	1.4E-03	1.5E-03
0.7 (0.43)	1.2E-03	1.2E-03	1.5E-03	1.7E-03	1.5E-03	1.5E-03	1.7E-03	1.8E-03	2.0E-03	1.8E-03	1.2E-03	1.2E-03	1.2E-03	1.1E-03	1.1E-03	1.2E-03
0.8 (0.50)	9.9E-04	9.5E-04	1.2E-03	1.3E-03	1.2E-03	1.2E-03	1.4E-03	1.4E-03	1.6E-03	1.4E-03	9.9E-04	9.5E-04	9.6E-04	9.1E-04	8.5E-04	9.6E-04
0.9 (0.56)	8.1E-04	7.8E-04	9.6E-04	1.1E-03	9.8E-04	1.0E-03	1.1E-03	1.2E-03	1.3E-03	1.2E-03	8.2E-04	7.8E-04	7.9E-04	7.4E-04	7.0E-04	7.9E-04
1 (0.62)	6.8E-04	6.5E-04	8.1E-04	9.3E-04	8.2E-04	8.4E-04	9.5E-04	9.7E-04	1.1E-03	9.8E-04	6.8E-04	6.6E-04	6.6E-04	6.2E-04	5.9E-04	6.6E-04
2.4 (1.5)	1.7E-04	1.7E-04	2.1E-04	2.4E-04	2.1E-04	2.1E-04	2.4E-04	2.5E-04	2.8E-04	2.5E-04	1.7E-04	1.7E-04	1.7E-04	1.6E-04	1.5E-04	1.7E-04
4 (2.5)	8.5E-05	8.2E-05	1.0E-04	1.2E-04	1.0E-04	1.0E-04	1.2E-04	1.2E-04	1.4E-04	1.2E-04	8.5E-05	8.2E-05	8.2E-05	7.8E-05	7.4E-05	8.2E-05
5.6 (3.5)	5.4E-05	5.2E-05	6.4E-05	7.4E-05	6.6E-05	6.7E-05	7.5E-05	7.7E-05	8.9E-05	7.8E-05	5.4E-05	5.2E-05	5.2E-05	5.0E-05	4.7E-05	5.3E-05
7.2 (4.5)	3.9E-05	3.7E-05	4.6E-05	5.3E-05	4.7E-05	4.8E-05	5.4E-05	5.6E-05	6.4E-05	5.6E-05	3.9E-05	3.8E-05	3.8E-05	3.6E-05	3.4E-05	3.8E-05
12 (7.5)	2.0E-05	1.9E-05	2.4E-05	2.8E-05	2.5E-05	2.5E-05	2.8E-05	2.9E-05	3.3E-05	2.9E-05	2.0E-05	2.0E-05	2.0E-05	1.9E-05	1.8E-05	2.0E-05
24 (15)	8.6E-06	8.2E-06	1.0E-05	1.2E-05	1.0E-05	1.1E-05	1.2E-05	1.2E-05	1.4E-05	1.2E-05	8.6E-06	8.3E-06	8.3E-06	7.9E-06	7.4E-06	8.3E-06
40 (25)	4.6E-06	4.4E-06	5.5E-06	6.3E-06	5.6E-06	5.7E-06	6.4E-06	6.6E-06	7.6E-06	6.7E-06	4.6E-06	4.5E-06	4.5E-06	4.3E-06	4.0E-06	4.5E-06
56 (35)	3.1E-06	3.0E-06	3.7E-06	4.2E-06	3.7E-06	3.8E-06	4.3E-06	4.4E-06	5.1E-06	4.4E-06	3.1E-06	3.0E-06	3.0E-06	2.8E-06	2.7E-06	3.0E-06
72 (45)	2.3E-06	2.2E-06	2.7E-06	3.1E-06	2.8E-06	2.8E-06	3.2E-06	3.3E-06	3.8E-06	3.3E-06	2.3E-06	2.2E-06	2.2E-06	2.1E-06	2.0E-06	2.2E-06

Table A20. 95th Percentile E/Q Values (s m^{-3}) for Acute 60-m Stack Releases from 200 Areas Based on 1983 through 2006 Meteorological Information, Hanford Site, Washington

Distance						Sector (Wind from 200 Areas toward Direction Indicated)										
km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	1.0E-07	1.2E-07	1.3E-07	1.3E-07	1.3E-07	1.3E-07	1.0E-07	8.5E-08	7.7E-08	4.9E-08	4.0E-08	2.9E-08	1.8E-08	3.9E-09	2.8E-08	6.0E-08
0.2 (0.12)	2.0E-05	2.3E-05	2.5E-05	2.6E-05	2.5E-05	2.5E-05	2.0E-05	1.7E-05	1.5E-05	9.3E-06	6.3E-06	5.9E-06	4.0E-06	2.3E-06	5.6E-06	1.2E-05
0.3 (0.19)	3.0E-05	3.2E-05	3.8E-05	3.7E-05	3.4E-05	3.4E-05	2.9E-05	2.7E-05	2.5E-05	1.8E-05	1.2E-05	1.1E-05	8.7E-06	6.6E-06	1.1E-05	2.3E-05
0.4 (0.25)	2.1E-05	2.9E-05	3.8E-05	3.9E-05	3.4E-05	3.3E-05	2.1E-05	1.7E-05	1.6E-05	1.5E-05	1.3E-05	8.9E-06	7.9E-06	6.8E-06	8.9E-06	1.6E-05
0.5 (0.31)	2.2E-05	2.6E-05	3.1E-05	3.2E-05	2.8E-05	2.8E-05	2.2E-05	1.7E-05	1.5E-05	1.3E-05	8.8E-06	8.3E-06	6.8E-06	5.2E-06	8.6E-06	1.5E-05
0.6 (0.37)	1.6E-05	1.8E-05	3.2E-05	3.3E-05	2.4E-05	2.4E-05	1.6E-05	1.4E-05	1.4E-05	1.4E-05	7.7E-06	7.0E-06	6.6E-06	5.8E-06	7.3E-06	1.4E-05
0.7 (0.43)	1.4E-05	1.6E-05	2.6E-05	2.7E-05	1.7E-05	1.8E-05	1.4E-05	1.3E-05	1.3E-05	1.2E-05	1.2E-05	1.0E-05	1.1E-05	5.0E-06	8.6E-06	1.3E-05
0.8 (0.50)	2.3E-05	2.4E-05	2.7E-05	2.7E-05	2.5E-05	2.5E-05	2.4E-05	2.1E-05	1.8E-05	1.7E-05	1.2E-05	7.7E-06	8.1E-06	6.6E-06	7.6E-06	1.7E-05
0.9 (0.56)	2.2E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.2E-05	2.2E-05	2.0E-05	1.1E-05	7.7E-06	7.8E-06	7.3E-06	7.7E-06	2.1E-05
1 (0.62)	2.7E-05	2.8E-05	3.0E-05	3.0E-05	2.9E-05	2.9E-05	2.8E-05	2.6E-05	2.4E-05	2.3E-05	1.1E-05	9.1E-06	9.9E-06	8.0E-06	9.4E-06	2.3E-05
2.4 (1.5)	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.3E-05	2.2E-05	1.8E-05	1.0E-05	1.5E-05	8.9E-06	8.8E-06	2.2E-05
4 (2.5)	1.6E-05	1.6E-05	1.7E-05	1.7E-05	1.7E-05	1.8E-05	1.8E-05	1.7E-05	1.7E-05	1.6E-05	1.4E-05	1.3E-05	1.4E-05	1.0E-05	9.5E-06	1.5E-05
5.6 (3.5)	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.2E-05	9.4E-06	1.1E-05	7.1E-06	6.5E-06	1.4E-05
7.2 (4.5)	1.2E-05	1.2E-05	1.2E-05	1.2E-05	1.2E-05	1.3E-05	1.3E-05	1.2E-05	1.2E-05	1.2E-05	9.1E-06	6.9E-06	8.4E-06	4.9E-06	4.8E-06	1.1E-05
12 (7.5)	6.6E-06	6.6E-06	6.6E-06	7.1E-06	6.9E-06	7.6E-06	7.8E-06	7.0E-06	7.3E-06	6.6E-06	6.4E-06	5.6E-06	6.2E-06	4.1E-06	3.3E-06	6.5E-06
24 (15)	4.4E-06	4.2E-06	4.5E-06	5.1E-06	5.1E-06	5.4E-06	5.5E-06	5.1E-06	5.4E-06	4.8E-06	2.9E-06	2.6E-06	2.8E-06	2.0E-06	1.9E-06	3.4E-06
40 (25)	2.6E-06	2.4E-06	2.6E-06	3.1E-06	3.1E-06	3.3E-06	3.4E-06	3.1E-06	3.3E-06	2.9E-06	1.6E-06	1.6E-06	1.6E-06	1.5E-06	1.4E-06	1.9E-06
56 (35)	1.6E-06	1.3E-06	1.5E-06	2.0E-06	2.0E-06	2.3E-06	2.4E-06	2.1E-06	2.3E-06	2.0E-06	1.2E-06	1.2E-06	1.3E-06	1.0E-06	9.4E-07	1.2E-06
72 (45)	1.3E-06	1.1E-06	1.2E-06	1.6E-06	1.6E-06	1.7E-06	1.8E-06	1.6E-06	1.8E-06	1.6E-06	9.9E-07	9.4E-07	1.1E-06	7.7E-07	7.0E-07	1.0E-06

Table A21. 95th Percentile E/Q Values (s m^{-3}) for Acute Ground-Level Releases from 300 Area Based on 1983 through 2006 Meteorological Information, Hanford Site, Washington

Distance						Sector (Wind from 300 Area toward Direction Indicated)										
km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	3.2E-02	3.0E-02	3.2E-02	3.3E-02	3.4E-02	3.2E-02	3.4E-02	5.5E-02	5.0E-02	3.1E-02	2.9E-02	3.4E-02	6.2E-02	7.4E-02	5.9E-02	3.4E-02
0.2 (0.12)	9.5E-03	9.2E-03	9.7E-03	9.9E-03	1.0E-02	9.8E-03	1.0E-02	1.6E-02	1.5E-02	9.4E-03	8.8E-03	1.0E-02	1.9E-02	2.2E-02	1.8E-02	1.0E-02
0.3 (0.19)	4.8E-03	4.6E-03	4.9E-03	5.0E-03	5.2E-03	4.9E-03	5.1E-03	8.3E-03	7.5E-03	4.7E-03	4.4E-03	5.1E-03	9.4E-03	1.1E-02	9.0E-03	5.2E-03
0.4 (0.25)	2.9E-03	2.8E-03	3.0E-03	3.1E-03	3.2E-03	3.0E-03	3.1E-03	5.1E-03	4.6E-03	2.9E-03	2.7E-03	3.1E-03	5.8E-03	6.8E-03	5.5E-03	3.2E-03
0.5 (0.31)	2.0E-03	2.0E-03	2.1E-03	2.1E-03	2.2E-03	2.1E-03	2.2E-03	3.5E-03	3.2E-03	2.0E-03	1.9E-03	2.2E-03	4.0E-03	4.7E-03	3.8E-03	2.2E-03
0.6 (0.37)	1.5E-03	1.4E-03	1.5E-03	1.6E-03	1.6E-03	1.5E-03	1.6E-03	2.6E-03	2.3E-03	1.5E-03	1.4E-03	1.6E-03	2.9E-03	3.5E-03	2.8E-03	1.6E-03
0.7 (0.43)	1.2E-03	1.1E-03	1.2E-03	1.2E-03	1.3E-03	1.2E-03	1.2E-03	2.0E-03	1.8E-03	1.1E-03	1.1E-03	1.2E-03	2.3E-03	2.7E-03	2.2E-03	1.2E-03
0.8 (0.50)	9.2E-04	8.9E-04	9.4E-04	9.6E-04	1.0E-03	9.5E-04	9.8E-04	1.6E-03	1.5E-03	9.1E-04	8.5E-04	9.9E-04	1.8E-03	2.1E-03	1.7E-03	1.0E-03
0.9 (0.56)	7.6E-04	7.3E-04	7.7E-04	7.9E-04	8.2E-04	7.8E-04	8.1E-04	1.3E-03	1.2E-03	7.5E-04	7.0E-04	8.1E-04	1.5E-03	1.8E-03	1.4E-03	8.2E-04
1 (0.62)	6.4E-04	6.1E-04	6.5E-04	6.6E-04	6.9E-04	6.6E-04	6.8E-04	1.1E-03	1.0E-03	6.3E-04	5.9E-04	6.8E-04	1.2E-03	1.5E-03	1.2E-03	6.9E-04
2.4 (1.5)	1.6E-04	1.6E-04	1.7E-04	1.7E-04	1.8E-04	1.7E-04	1.7E-04	2.8E-04	2.6E-04	1.6E-04	1.5E-04	1.7E-04	3.2E-04	3.8E-04	3.1E-04	1.8E-04
4 (2.5)	8.0E-05	7.7E-05	8.1E-05	8.3E-05	8.6E-05	8.2E-05	8.4E-05	1.4E-04	1.3E-04	7.9E-05	7.4E-05	8.5E-05	1.6E-04	1.9E-04	1.5E-04	8.6E-05
5.6 (3.5)	5.1E-05	4.9E-05	5.2E-05	5.3E-05	5.5E-05	5.2E-05	5.4E-05	8.8E-05	8.0E-05	5.0E-05	4.7E-05	5.4E-05	1.0E-04	1.2E-04	9.6E-05	5.5E-05
7.2 (4.5)	3.6E-05	3.5E-05	3.7E-05	3.8E-05	3.9E-05	3.8E-05	3.9E-05	6.3E-05	5.8E-05	3.6E-05	3.4E-05	3.9E-05	7.2E-05	8.5E-05	6.9E-05	3.9E-05
12 (7.5)	1.9E-05	1.8E-05	1.9E-05	2.0E-05	2.1E-05	2.0E-05	2.0E-05	3.3E-05	3.0E-05	1.9E-05	1.8E-05	2.0E-05	3.7E-05	4.4E-05	3.6E-05	2.1E-05
24 (15)	8.0E-06	7.8E-06	8.2E-06	8.4E-06	8.7E-06	8.3E-06	8.5E-06	1.4E-05	1.3E-05	8.0E-06	7.5E-06	8.6E-06	1.6E-05	1.9E-05	1.5E-05	8.7E-06
40 (25)	4.3E-06	4.2E-06	4.4E-06	4.5E-06	4.7E-06	4.4E-06	4.6E-06	7.5E-06	6.8E-06	4.3E-06	4.0E-06	4.6E-06	8.5E-06	1.0E-05	8.2E-06	4.7E-06
56 (35)	2.9E-06	2.8E-06	2.9E-06	3.0E-06	3.1E-06	3.0E-06	3.1E-06	5.0E-06	4.6E-06	2.9E-06	2.7E-06	3.1E-06	5.7E-06	6.8E-06	5.5E-06	3.1E-06
72 (45)	2.1E-06	2.1E-06	2.2E-06	2.2E-06	2.3E-06	2.2E-06	2.3E-06	3.7E-06	3.4E-06	2.1E-06	2.0E-06	2.3E-06	4.2E-06	5.0E-06	4.1E-06	2.3E-06

Table A22. 95th Percentile E/Q Values (s m^{-3}) for Acute 60-m Stack Releases from 300 Area Based on 1986 through 2006 Meteorological Information, Hanford Site, Washington

Distance						Sector (Wind from 300 Area toward Direction Indicated)										
km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	3.0E-08	4.9E-08	1.1E-07	1.4E-07	1.3E-07	1.0E-07	5.3E-08	4.7E-08	4.1E-08	3.9E-08	3.1E-08	2.8E-08	2.6E-08	2.1E-08	1.7E-08	1.5E-08
0.2 (0.12)	6.1E-06	8.2E-06	2.1E-05	2.7E-05	2.6E-05	2.0E-05	1.0E-05	9.0E-06	6.4E-06	6.2E-06	6.0E-06	5.7E-06	5.8E-06	5.0E-06	3.8E-06	3.8E-06
0.3 (0.19)	1.1E-05	1.7E-05	3.0E-05	3.8E-05	3.4E-05	2.9E-05	2.1E-05	1.8E-05	1.5E-05	1.1E-05	1.1E-05	1.1E-05	1.1E-05	1.0E-05	8.5E-06	9.7E-06
0.4 (0.25)	1.3E-05	1.5E-05	2.0E-05	3.4E-05	2.9E-05	1.9E-05	1.6E-05	1.6E-05	1.4E-05	1.2E-05	8.9E-06	8.9E-06	1.1E-05	1.2E-05	8.0E-06	8.9E-06
0.5 (0.31)	9.4E-06	1.3E-05	2.1E-05	2.6E-05	2.6E-05	2.0E-05	1.5E-05	1.5E-05	1.1E-05	8.8E-06	8.6E-06	8.7E-06	8.8E-06	8.8E-06	7.8E-06	8.7E-06
0.6 (0.37)	8.3E-06	1.4E-05	1.5E-05	1.8E-05	1.6E-05	1.5E-05	1.4E-05	1.4E-05	1.2E-05	7.7E-06	7.4E-06	7.5E-06	7.7E-06	7.7E-06	7.4E-06	7.7E-06
0.7 (0.43)	1.2E-05	1.2E-05	1.3E-05	1.4E-05	1.6E-05	1.3E-05	1.2E-05	1.3E-05	1.2E-05	1.1E-05	7.6E-06	1.1E-05	1.2E-05	1.2E-05	1.2E-05	1.2E-05
0.8 (0.50)	1.3E-05	1.5E-05	1.8E-05	2.1E-05	2.1E-05	1.8E-05	1.5E-05	1.6E-05	1.5E-05	8.5E-06	7.3E-06	8.9E-06	1.6E-05	1.9E-05	1.5E-05	1.4E-05
0.9 (0.56)	1.2E-05	1.6E-05	2.1E-05	2.2E-05	2.2E-05	2.1E-05	1.6E-05	2.0E-05	1.7E-05	7.8E-06	7.3E-06	7.9E-06	2.0E-05	2.2E-05	1.7E-05	1.4E-05
1 (0.62)	1.1E-05	1.9E-05	2.4E-05	2.5E-05	2.5E-05	2.3E-05	1.8E-05	2.3E-05	2.1E-05	9.7E-06	8.0E-06	1.0E-05	2.2E-05	2.4E-05	2.1E-05	1.6E-05
2.4 (1.5)	2.2E-05	2.2E-05	2.3E-05	2.3E-05	2.3E-05	2.2E-05	2.2E-05	2.3E-05	2.2E-05	1.2E-05	9.3E-06	2.1E-05	2.3E-05	2.3E-05	2.2E-05	2.2E-05
4 (2.5)	1.5E-05	1.5E-05	1.7E-05	1.8E-05	1.8E-05	1.6E-05	1.5E-05	1.7E-05	1.7E-05	1.4E-05	1.3E-05	1.4E-05	1.7E-05	1.8E-05	1.7E-05	1.5E-05
5.6 (3.5)	1.3E-05	1.4E-05	1.4E-05	1.5E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.2E-05	8.3E-06	1.3E-05	1.4E-05	1.5E-05	1.4E-05	1.4E-05
7.2 (4.5)	1.0E-05	1.1E-05	1.3E-05	1.3E-05	1.3E-05	1.2E-05	1.1E-05	1.2E-05	1.2E-05	9.3E-06	6.0E-06	1.0E-05	1.2E-05	1.3E-05	1.2E-05	1.1E-05
12 (7.5)	6.5E-06	6.6E-06	8.0E-06	8.4E-06	8.0E-06	7.3E-06	6.6E-06	7.5E-06	7.2E-06	6.5E-06	5.0E-06	6.5E-06	7.7E-06	9.0E-06	6.7E-06	6.6E-06
24 (15)	3.5E-06	4.1E-06	5.4E-06	5.4E-06	5.5E-06	5.2E-06	4.5E-06	5.3E-06	5.2E-06	3.0E-06	2.2E-06	3.3E-06	5.5E-06	5.7E-06	5.0E-06	3.9E-06
40 (25)	2.0E-06	2.4E-06	3.3E-06	3.3E-06	3.4E-06	3.1E-06	2.7E-06	3.2E-06	3.1E-06	1.6E-06	1.6E-06	1.8E-06	3.4E-06	3.9E-06	3.0E-06	2.3E-06
56 (35)	1.4E-06	1.5E-06	2.3E-06	2.3E-06	2.4E-06	2.2E-06	2.0E-06	2.3E-06	2.2E-06	1.2E-06	1.0E-06	1.2E-06	2.4E-06	2.9E-06	2.0E-06	1.5E-06
72 (45)	1.1E-06	1.2E-06	1.8E-06	1.8E-06	1.9E-06	1.7E-06	1.6E-06	1.8E-06	1.7E-06	9.5E-07	7.5E-07	9.3E-07	1.9E-06	2.3E-06	1.6E-06	1.2E-06

Table A23. 95th Percentile E/Q Values (s m^{-3}) for Acute Ground-Level Releases from 400 Area Based on 1983 through 2006 Meteorological Information, Hanford Site, Washington

Distance								Sector (Wind from 400 Area toward Direction Indicated)								
km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	3.4E-02	3.3E-02	3.3E-02	4.3E-02	4.7E-02	3.4E-02	3.1E-02	2.9E-02	3.0E-02	2.3E-02	3.1E-02	3.5E-02	4.7E-02	3.3E-02	2.9E-02	3.2E-02
0.2 (0.12)	1.0E-02	1.0E-02	1.0E-02	1.3E-02	1.4E-02	1.0E-02	9.5E-03	8.8E-03	8.9E-03	6.9E-03	9.2E-03	1.1E-02	1.4E-02	1.0E-02	8.8E-03	9.5E-03
0.3 (0.19)	5.1E-03	5.0E-03	5.0E-03	6.5E-03	7.1E-03	5.2E-03	4.8E-03	4.4E-03	4.5E-03	3.5E-03	4.6E-03	5.3E-03	7.1E-03	5.1E-03	4.4E-03	4.8E-03
0.4 (0.25)	3.2E-03	3.1E-03	3.1E-03	4.0E-03	4.3E-03	3.2E-03	2.9E-03	2.7E-03	2.8E-03	2.1E-03	2.9E-03	3.3E-03	4.4E-03	3.1E-03	2.7E-03	2.9E-03
0.5 (0.31)	2.2E-03	2.1E-03	2.1E-03	2.7E-03	3.0E-03	2.2E-03	2.0E-03	1.9E-03	1.9E-03	1.5E-03	2.0E-03	2.2E-03	3.0E-03	2.1E-03	1.9E-03	2.0E-03
0.6 (0.37)	1.6E-03	1.6E-03	1.6E-03	2.0E-03	2.2E-03	1.6E-03	1.5E-03	1.4E-03	1.4E-03	1.1E-03	1.4E-03	1.6E-03	2.2E-03	1.6E-03	1.4E-03	1.5E-03
0.7 (0.43)	1.2E-03	1.2E-03	1.2E-03	1.6E-03	1.7E-03	1.3E-03	1.1E-03	1.1E-03	1.1E-03	8.4E-04	1.1E-03	1.3E-03	1.7E-03	1.2E-03	1.1E-03	1.2E-03
0.8 (0.50)	9.9E-04	9.7E-04	9.7E-04	1.3E-03	1.4E-03	1.0E-03	9.2E-04	8.6E-04	8.7E-04	6.7E-04	9.0E-04	1.0E-03	1.4E-03	9.8E-04	8.5E-04	9.3E-04
0.9 (0.56)	8.2E-04	7.9E-04	8.0E-04	1.0E-03	1.1E-03	8.3E-04	7.6E-04	7.0E-04	7.1E-04	5.5E-04	7.4E-04	8.4E-04	1.1E-03	8.0E-04	7.0E-04	7.6E-04
1 (0.62)	6.9E-04	6.7E-04	6.7E-04	8.6E-04	9.4E-04	6.9E-04	6.3E-04	5.9E-04	6.0E-04	4.6E-04	6.2E-04	7.0E-04	9.5E-04	6.8E-04	5.9E-04	6.4E-04
2.4 (1.5)	1.7E-04	1.7E-04	1.7E-04	2.2E-04	2.4E-04	1.8E-04	1.6E-04	1.5E-04	1.5E-04	1.2E-04	1.6E-04	1.8E-04	2.4E-04	1.7E-04	1.5E-04	1.6E-04
4 (2.5)	8.5E-05	8.3E-05	8.4E-05	1.1E-04	1.2E-04	8.6E-05	7.9E-05	7.4E-05	7.5E-05	5.8E-05	7.7E-05	8.8E-05	1.2E-04	8.4E-05	7.4E-05	8.0E-05
5.6 (3.5)	5.4E-05	5.3E-05	5.3E-05	6.9E-05	7.5E-05	5.5E-05	5.1E-05	4.7E-05	4.8E-05	3.7E-05	4.9E-05	5.6E-05	7.6E-05	5.4E-05	4.7E-05	5.1E-05
7.2 (4.5)	3.9E-05	3.8E-05	3.8E-05	5.0E-05	5.4E-05	4.0E-05	3.6E-05	3.4E-05	3.4E-05	2.7E-05	3.5E-05	4.0E-05	5.5E-05	3.9E-05	3.4E-05	3.7E-05
12 (7.5)	2.0E-05	2.0E-05	2.0E-05	2.6E-05	2.8E-05	2.1E-05	1.9E-05	1.8E-05	1.8E-05	1.4E-05	1.8E-05	2.1E-05	2.8E-05	2.0E-05	1.8E-05	1.9E-05
24 (15)	8.6E-06	8.4E-06	8.5E-06	1.1E-05	1.2E-05	8.7E-06	8.0E-06	7.5E-06	7.6E-06	5.9E-06	7.8E-06	8.9E-06	1.2E-05	8.5E-06	7.5E-06	8.1E-06
40 (25)	4.6E-06	4.5E-06	4.6E-06	5.9E-06	6.4E-06	4.7E-06	4.3E-06	4.0E-06	4.1E-06	3.2E-06	4.2E-06	4.8E-06	6.5E-06	4.6E-06	4.0E-06	4.3E-06
56 (35)	3.1E-06	3.0E-06	3.0E-06	3.9E-06	4.3E-06	3.1E-06	2.9E-06	2.7E-06	2.7E-06	2.1E-06	2.8E-06	3.2E-06	4.3E-06	3.1E-06	2.7E-06	2.9E-06
72 (45)	2.3E-06	2.2E-06	2.3E-06	2.9E-06	3.2E-06	2.3E-06	2.1E-06	2.0E-06	2.0E-06	1.6E-06	2.1E-06	2.4E-06	3.2E-06	2.3E-06	2.0E-06	2.2E-06

Table A24. 95th Percentile E/Q Values (s m^{-3}) for Acute 60-m Stack Releases from 400 Area Based on 1986 through 2006 Meteorological Information, Hanford Site, Washington

Distance								Sector (Wind from 400 Area toward Direction Indicated)								
km (mi)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE
0.1 (0.06)	5.2E-08	7.3E-08	1.0E-07	1.2E-07	1.4E-07	1.4E-07	8.9E-08	5.0E-08	4.6E-08	3.6E-08	2.7E-08	3.4E-08	3.8E-08	2.6E-08	1.6E-08	3.4E-08
0.2 (0.12)	1.0E-05	1.4E-05	2.0E-05	2.4E-05	2.7E-05	2.7E-05	1.7E-05	9.7E-06	7.7E-06	6.1E-06	5.6E-06	6.2E-06	6.3E-06	5.7E-06	3.5E-06	6.2E-06
0.3 (0.19)	2.1E-05	2.6E-05	3.1E-05	3.8E-05	4.5E-05	4.3E-05	2.8E-05	1.9E-05	1.6E-05	1.1E-05	1.1E-05	1.2E-05	1.4E-05	1.1E-05	7.5E-06	1.2E-05
0.4 (0.25)	1.6E-05	1.7E-05	2.5E-05	3.7E-05	4.2E-05	4.1E-05	2.0E-05	1.5E-05	1.4E-05	1.1E-05	8.9E-06	1.2E-05	1.4E-05	1.0E-05	7.6E-06	1.4E-05
0.5 (0.31)	1.6E-05	1.7E-05	2.4E-05	2.9E-05	3.2E-05	3.1E-05	2.0E-05	1.3E-05	1.1E-05	8.8E-06	8.2E-06	8.8E-06	9.9E-06	8.7E-06	6.5E-06	9.7E-06
0.6 (0.37)	1.4E-05	1.4E-05	1.6E-05	2.6E-05	3.3E-05	3.1E-05	1.5E-05	1.4E-05	1.1E-05	7.7E-06	7.0E-06	7.7E-06	9.2E-06	7.5E-06	6.5E-06	9.1E-06
0.7 (0.43)	1.3E-05	1.3E-05	1.4E-05	1.7E-05	2.4E-05	2.3E-05	1.3E-05	1.2E-05	1.2E-05	9.5E-06	9.7E-06	1.2E-05	1.2E-05	1.2E-05	8.1E-06	1.2E-05
0.8 (0.50)	1.6E-05	1.6E-05	1.9E-05	2.4E-05	2.6E-05	2.5E-05	1.7E-05	1.5E-05	1.2E-05	7.7E-06	7.7E-06	1.4E-05	1.6E-05	1.2E-05	7.5E-06	1.3E-05
0.9 (0.56)	1.9E-05	1.9E-05	2.2E-05	2.3E-05	2.3E-05	2.3E-05	2.1E-05	1.6E-05	1.1E-05	7.5E-06	7.5E-06	1.4E-05	1.8E-05	1.1E-05	7.6E-06	1.2E-05
1 (0.62)	2.1E-05	2.1E-05	2.4E-05	2.7E-05	2.9E-05	2.8E-05	2.3E-05	2.0E-05	1.1E-05	8.4E-06	8.6E-06	1.7E-05	2.2E-05	1.1E-05	9.2E-06	1.1E-05
2.4 (1.5)	2.2E-05	2.2E-05	2.2E-05	2.3E-05	2.3E-05	2.3E-05	2.2E-05	2.2E-05	1.6E-05	9.1E-06	1.1E-05	2.2E-05	2.3E-05	2.0E-05	9.2E-06	1.9E-05
4 (2.5)	1.5E-05	1.5E-05	1.6E-05	1.8E-05	1.8E-05	1.8E-05	1.6E-05	1.5E-05	1.4E-05	1.2E-05	1.4E-05	1.6E-05	1.7E-05	1.4E-05	1.1E-05	1.4E-05
5.6 (3.5)	1.4E-05	1.4E-05	1.4E-05	1.4E-05	1.5E-05	1.4E-05	1.4E-05	1.4E-05	1.2E-05	7.8E-06	1.1E-05	1.4E-05	1.4E-05	1.2E-05	7.1E-06	1.2E-05
7.2 (4.5)	1.1E-05	1.1E-05	1.2E-05	1.3E-05	1.3E-05	1.3E-05	1.2E-05	1.1E-05	9.3E-06	5.5E-06	8.1E-06	1.2E-05	1.2E-05	9.6E-06	5.1E-06	8.9E-06
12 (7.5)	6.5E-06	6.5E-06	6.6E-06	8.3E-06	8.5E-06	8.2E-06	6.6E-06	6.6E-06	6.5E-06	4.4E-06	5.6E-06	6.6E-06	6.6E-06	6.3E-06	3.3E-06	6.0E-06
24 (15)	3.7E-06	3.5E-06	4.3E-06	5.6E-06	5.6E-06	5.5E-06	4.8E-06	3.9E-06	2.9E-06	2.0E-06	2.5E-06	4.5E-06	4.8E-06	2.8E-06	1.9E-06	2.7E-06
40 (25)	2.1E-06	2.0E-06	2.5E-06	3.5E-06	3.6E-06	3.3E-06	2.8E-06	2.3E-06	1.6E-06	1.5E-06	1.6E-06	2.7E-06	2.8E-06	1.6E-06	1.3E-06	1.6E-06
56 (35)	1.5E-06	1.4E-06	1.7E-06	2.6E-06	2.6E-06	2.3E-06	1.9E-06	1.7E-06	1.2E-06	1.0E-06	1.1E-06	1.7E-06	1.9E-06	1.2E-06	9.1E-07	1.2E-06
72 (45)	1.2E-06	1.1E-06	1.3E-06	2.0E-06	2.1E-06	1.8E-06	1.5E-06	1.3E-06	1.0E-06	7.5E-07	8.3E-07	1.3E-06	1.5E-06	9.1E-07	6.8E-07	9.1E-07

Appendix B

Hanford Site Species Lists

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Appendix B

Hanford Site Species Lists

This appendix contains five tables that list species of vascular plants, mammals, birds, reptiles and amphibians, and fish that have been sighted on the Hanford Site. The lists are for those species likely to be encountered on the Site and are not intended to represent a complete listing of all species. When appropriate, more comprehensive listings have been identified.

Table B1. Common Vascular Plants on the Hanford Site, Washington (Taxonomy follows Hitchcock and Cronquist 1973). See Sackschewsky and Downs (2001) for a complete listing of Hanford Site vascular plants.

A. Shrub-Steppe Species	**Scientific Name**
Shrub	
big sagebrush	*Artemisia tridentata*
bitterbrush	*Purshia tridentata*
gray rabbitbrush	*Ericameria nauseousa*
green rabbitbrush	*Chrysothamnus viscidiflorus*
snow buckwheat	*Eriogonum niveum*
spiny hopsage	*Grayia (Atriplex) spinosa*
threetip sagebrush	*Artemisia tripartita*
Perennial Grasses	
bluebunch wheatgrass	*Pseudoroegnaria spicata*
bottlebrush squirreltail	*Elymus elymoides*
crested wheatgrass	*Agropyron desertorum (cristatum)*[(a)]
Indian ricegrass	*Achnatherum hymenoides*
needle-and-thread grass	*Stipa comata*
prairie junegrass	*Koeleria cristata*
sand dropseed	*Sporobolus cryptandrus*
Sandberg’s bluegrass	*Poa sandbergii (secunda)*
thickspike wheatgrass	*Elymus macrourus*
Biennial/Perennial Forbs	
bastard toad flax	*Comandra umbellata*
buckwheat milkvetch	*Astragalus caricinus*
Carey’s balsamroot	*Balsamorhiza careyana*
Cusick’s sunflower	*Helianthus cusickii*
cutleaf ladysfoot mustard	*Thelypodium laciniatum*
Douglas’ clusterlily	*Brodiaea douglasii*
dune scurfpea	*Psoralea lanceolata*

A. Shrub-Steppe Species (cont'd)	**Scientific Name**
Franklin's sandwort	*Arenaria franklinii*
Gray's desertparsley	*Lomatium grayi*
hoary aster	*Machaeranthera canescens*
hoary falseyarrow	*Chaenactis douglasii*
sand beardtongue	*Penstemon acuminatus*
yarrow	*Achillea millefolium*
yellow bell	*Fritillaria pudica*
yellow salsify	*Tragopogon dubius*[a]
Annual Forbs	
annual Jacob's ladder	*Polemonium micranthum*
blue mustard	*Chorispora tenella*[a]
bur ragweed	*Ambrosia acanthicarpa*
clasping pepperweed	*Lepidium perfoliatum*
Indian wheat	*Plantago patagonica*
jagged chickweed	*Holosteum umbellatum*[a]
Jim Hill's tumblemustard	*Sisymbrium altissimum*[a]
matted cryptantha	*Cryptantha circumscissa*
pink microsteris	*Microsteris gracilis*
prickly lettuce	*Lactuca serriola*[a]
Russian thistle (tumbleweed)	*Salsola kali*[a]
spring whitlowgrass	*Draba verna*[a]
storksbill	*Erodium cicutarium*[a]
tall willowherb	*Epilobium paniculatum*
tarweed fiddleneck	*Amsinckia lycopsoides*
threadleaf scorpion weed	*Phacelia linearis*
western tansymustard	*Descurainia pinnata*
white cupseed	*Plectritis macrocera*
whitestem stickleaf	*Mentzelia albicaulis*
winged cryptantha	*Cryptantha pterocarya*
Annual Grasses	
cheatgrass	*Bromus tectorum*[a]
slender sixweeks	*Festuca octoflora*
small sixweeks	*Festuca microstachys*
B. Riparian Species	
Trees and Shrubs	
black cottonwood	*Populus trichocarpa*
black locust	*Robinia pseudo-acacia*
coyote willow	*Salix exigua*
peach, apricot, cherry	*Prunus* spp.
peachleaf willow	*Salix amygdaloides*[a]

Trees and Shrubs (cont'd)	**Scientific Name**
willow	*Salix* spp.
white mulberry	*Morus alba*[(a)]
Perennial Grasses and Forbs	
bentgrass	*Agrostis* spp. [(b)]
blanket flower	*Gaillardia aristata*
bulrushes	*Scirpus* spp.[(b)]
cattail	*Typha latifolia*[(b)]
Columbia River gumweed	*Grindelia columbiana*
dogbane	*Apocynum cannabinum*
hairy golden aster	*Heterotheca villosa*
heartweed	*Polygonum persicaria*
horsetails	*Equisetum* spp.
horseweed tickseed	*Coreopsis atkinsoniana*
lovegrass	*Eragrostis* spp. [(b)]
lupine	*Lupinus* spp.
meadow foxtail	*Alopecurus aequalis* [(b)]
Pacific sage	*Artemisia campestris*
prairie sagebrush	*Artemisia ludoviciana*
reed canary grass	*Phalaris arundinacea*[(a,b)]
rushes	*Juncus* spp.
Russian knapweed	*Centaurea repens*[(a)]
sedge	*Carex* spp.[(b)]
water speedwell	*Veronica anagallis-aquatica*
western goldenrod	*Solidago occidentalis*
wild onion	*Allium* spp.
wiregrass spikerush	*Eleocharis* spp.[(b)]
C. Aquatic Vascular Species	
Canadian waterweed	*Elodea canadensis*
duckweed	*Lemna minor*
pondweed	*Potamogeton* spp.
spiked water milfoil	*Myriophyllum spicatum*
watercress	*Rorippa nasturtium-aquaticum*

(a) Introduced
(b) Perennial grasses and graminoids.

Table B2. Mammals that Have Been Observed on the Hanford Site, Washington (Becker 1993; Fitzner and Gray 1991; Soll et al. 1999)

Common Name	**Scientific Name**
Shrews (family Soricidae)	
Merriam's shrew	*Sorex merriami*
vagrant shrew	*Sorex vagrans*
Evening bats (family Vespertilionidae)	
pallid bat	*Antrozous pallidus*
big brown bat	*Eptesicus fuscus*
silver-haired bat	*Lasionycteris noctivagans*
hoary bat	*Lasiurus cinereus*
California myotis	*Myotis californicus*
small-footed myotis	*Myotis leibii*
little brown myotis	*Myotis lucifugus*
long-legged myotis	*Myotis volans*
Yuma myotis	*Myotis yumanensis*
western pipistrelle	*Pipistrellus hesperus*
Hares, rabbits (family Leporidae)	
black-tailed jackrabbit	*Lepus californicus*
white-tailed jackrabbit	*Lepus townsendii*
Nuttall's (or mountain) cottontail	*Sylvilagus nuttallii*
Chipmunks, marmots, Squirrels (family Sciuridae)	
yellow-bellied marmot	*Marmota flaviventris*
Townsend's ground squirrel	*Spermophilus townsendii*
Washington ground squirrel	*Spermophilus washingtoni*
least chipmunk	*Tamias minimus*
Pocket gophers (family Geomyidae)	
northern pocket gopher	*Thomomys talpoides*
Heteromyid rodents, pocket mice (family Heteromyidae)	
Great Basin pocket mouse	*Perognathus parvus*
Beavers (family Castoridae)	
beaver	*Castor canadensis*
Campagnols, mice, rats, souris, voles (family Muridae)	
sagebrush vole	*Lemmiscus curtatus*
montane vole	*Microtus montanus*

Table B2 (cont'd)

Common Name	Scientific Name
<u>Campagnols, mice, rats, souris, voles (family Muridae)</u> (cont'd)	
house mouse	*Mus musculus*
bushy-tailed woodrat	*Neotoma cinerea*
muskrat	*Ondatra zibethicus*
northern grasshopper mouse	*Onychomys leucogaster*
deer mouse	*Peromyscus maniculatus*
Norway rat	*Rattus norvegicus*
western harvest mouse	*Reithrodontomys megalotis*
<u>New World porcupines (family Erethizontidae)</u>	
porcupine	*Erethizon dorsatum*
<u>Coyotes, dogs, foxes, jackals, wolves (family Canidae)</u>	
coyote	*Canis latrans*
<u>Raccoons (family Procyonidae)</u>	
raccoon	*Procyon lotor*
<u>Martins, weasels, wolverines, otters, badgers (family Mustelidae)</u>	
river otter	*Lontra canadensis*
short-tail weasel	*Mustela erminea*
long-tailed weasel	*Mustela frenata*
mink	*Mustela vison*
badger	*Taxidea taxus*
<u>Skunks (family Mephitidae)</u>	
striped skunk	*Mephitis mephitis*
<u>Cats (family Felidae)</u>	
bobcat	*Lynx rufus*
mountain lion	*Puma concolor concolor*
<u>Caribou, cervids, deer, moose, Wapiti (family Cervidae)</u>	
Rocky Mountain elk	*Cervus elaphus*
moose	*Alces alces*
mule deer	*Odocoileus hemionus*
white-tailed deer	*Odocoileus virginianus*

Table B3. Common Bird Species Known to Occur on the Hanford Site, Washington (Fitzner and Gray 1991; Landeen et al. 1992; Duberstein 1997).
Season Code: Yr = all year, W = winter, B = Breeding, M = Migration

Common Name	Scientific Name	Season of Highest Abundance
Gaviiformes - Loons or divers		
common loon	*Gavia immer*	Yr
Podicipediformes - Grebes		
eared grebe	*Podiceps nigricollis*	W
horned grebe	*Podiceps auritus*	W
pied-billed grebe	*Podilymbus podiceps*	Yr
western grebe	*Aechmophorus occidentalis*	W
Pelecaniformes - Pelicans and allies		
American white pelican	*Pelecanus erythrorhynchos*	Yr
double-crested cormorant	*Phalacrocorax auritus*	Yr
Anseriformes - Waterfowl		
American green-winged teal	*Anas crecca*	Yr
American wigeon	*Anas americana*	W
Barrow's goldeneye	*Bucephala islandica*	W
blue-winged teal	*Anas discors*	B
bufflehead	*Bucephala albeola*	W
cinnamon teal	*Anas cyanoptera*	B
Canada goose	*Branta canadensis*	Yr
common goldeneye	*Bucephala clangula*	W
common merganser	*Mergus merganser*	Yr
gadwall	*Anas strepera*	Yr
hooded merganser	*Lophodytes cucullatus*	W
mallard	*Anas platyrhynchos*	Yr
northern pintail	*Anas acuta*	Yr
northern shoveler	*Anas clypeata*	Yr
redhead	*Aythya americana*	W
ruddy duck	*Oxyura jamaicensis*	Yr
Gruiformes - Cranes, rails, and allies		
American coot	*Fulica americana*	Yr
sora	*Porzana carolina*	B
Virginia rail	*Rallus limicola*	B
Charadriiformes - Shorebirds and allies		
California gull	*Larus californicus*	Yr
Forster's tern	*Sterna forsteri*	B

Table B3 (cont'd)

Common Name	Scientific Name	Season of Highest Abundance
Charadriiformes - Shorebirds and allies (cont'd)		
American avocet	*Recurvirostra americana*	B
black-crowned night-heron	*Nycticorax nycticorax*	B
Caspian tern	*Sterna caspia*	B
common snipe	*Gallinago gallinago*	B
dunlin	*Calidris alpinis*	M
glaucous-winged gull	*Leucosticte tephrocotis*	Yr
great blue heron	*Ardea herodias*	Yr
great egret	*Casmerodius albus*	B
greater yellowlegs	*Tringa melanoleuca*	M
herring gull	*Larus argentatus*	W
killdeer	*Charadrius vociferus*	B
lesser yellowlegs	*Tringa flavipes*	M
long-billed curlew	*Numenius americanus*	B
long-billed dowitcher	*Limnodromus scolopaceus*	M
red-necked phalarope	*Larus glaucescens*	M
ring-billed gull	*Larus delawarensis*	Yr
sandhill crane	*Grus canadensis*	M
spotted sandpiper	*Actitis macularia*	B
solitary sandpiper	*Tringa solitaria*	M
western sandpiper	*Calidris mauri*	M
Galliformes - Chicken-like birds		
California quail	*Callipepla californica*	Yr
chukar	*Alectoris chukar*	Yr
grey partridge	*Perdix perdix*	Yr
ring-necked pheasant	*Phasianus colchicus*	Yr
Falconiformes - Diurnal birds of prey		
American kestrel	*Falco sparverius*	Yr
bald eagle	*Haliaeetus leucocephalus*	W
Cooper's hawk	*Accipiter cooperii*	W
ferruginous hawk	*Buteo regalis*	B
golden eagle	*Aquila chrysaetos*	Yr
merlin	*Falco columbarius*	M
northern harrier	*Circus cyaneus*	Yr
northern rough-legged hawk	*Buteo lagopus*	W
osprey	*Pandion haliaetus*	B
prairie falcon	*Falco mexicanus*	Yr
red-tailed hawk	*Buteo jamaicensis*	Yr
sharp-shinned hawk	*Accipiter striatus*	W
Swainson's hawk	*Buteo swainsoni*	B

Table B3 (cont'd)

Common Name	Scientific Name	Season of Highest Abundance
Strigiformes - Owls		
burrowing owl	*Athene cunicularia*	B
common barn-owl	*Tyto alba*	Yr
great horned owl	*Bubo virginianus*	Yr
long-eared owl	*Asio otus*	Yr
short-eared owl	*Asio flammeus*	Yr
Coraciiformes - Rollers and allies		
belted kingfisher	*Ceryle alcyon*	Yr
Columbiformes - Pigeons		
mourning dove	*Zenaida macroura*	Yr
rock dove	*Columba livia*	Yr
Caprimulgiformes - Nightjars and allies		
common nighthawk	*Chordeiles minor*	B
common poorwill	*Phalaenoptilus nuttallii*	B
Apodiformes - Hummingbirds, swifts		
rufous hummingbird	*Selasphorus rufus*	M
Piciformes - Woodpeckers and allies		
northern flicker	*Colaptes auratus*	Yr
Passeriformes - Perching birds		
American crow	*Corvus brachyrhynchos*	Yr
American goldfinch	*Carduelis tristis*	Yr
American robin	*Turdus migratorius*	Yr
bank swallow	*Riparia riparia*	B
barn swallow	*Hirundo rustica*	B
Bewick's wren	*Thryomanes bewickii*	B
black-billed magpie	*Pica pica*	Yr
black-headed grosbeak	*Pheucticus melanocephalus*	B
blue-headed vireo	*Vireo solitarius*	M
Brewer's blackbird	*Euphagus cyanocephalus*	B
Brewer's sparrow	*Spizella breweri*	B
brown-headed cowbird	*Molothrus ater*	B
Bullock's oriole	*Icterus galbula*	B
canyon wren	*Catherpes mexicanus*	B
cedar waxwing	*Bombycilla cedrorum*	M
chipping sparrow	*Spizella passerina*	M
cliff swallow	*Hirundo pyrrhonota*	B
common raven	*Corvus corax*	Yr
dark-eyed junco	*Junco hyemalis*	Yr
eastern kingbird	*Tyrannus tyrannus*	B

Table B3 (cont'd)

Common Name	Scientific Name	Season of Highest Abundance
<u>Passeriformes - Perching birds (cont'd)</u>		
European starling	*Sturnus vulgaris*	Yr
golden-crowned kinglet	*Regulus satrapa*	M
golden-crowned sparrow	*Zonotrichia atricapilla*	M
grasshopper sparrow	*Ammodramus savannarum*	B
gray-crowned rosy finch	*Phalaropus lobatus*	M
Hammond's flycatcher	*Empidonax hammondii*	M
horned lark	*Eremophila alpestris*	Yr
house finch	*Carpodacus mexicanus*	Yr
house sparrow	*Passer domesticus*	Yr
house wren	*Troglodytes aedon*	B
lark sparrow	*Chondestes grammacus*	B
lazuli bunting	*Passerina amoena*	B
Lincoln's sparrow	*Melospiza lincolnii*	M
loggerhead shrike	*Lanius ludovicianus*	Yr
MacGillivray's warbler	*Oporornis tolmiei*	B
marsh wren	*Cistothorus palustris*	B
Nashville warbler	*Vermivora ruficapilla*	M
northern rough-winged swallow	*Stelgidopteryx serripennis*	B
orange-crowned warbler	*Vermivora celata*	M
Pacific-slope flycatcher	*Empidonax difficilis*	M
red-breasted nuthatch	*Sitta canadensis*	W
red-winged blackbird	*Agelaius phoeniceus*	B
rock wren	*Salpinctes obsoletus*	B
ruby-crowned kinglet	*Regulus calendula*	M
rufous-sided towhee	*Pipilo erythrophthalmus*	B
sage sparrow	*Amphispiza belli*	B
sage thrasher	*Oreoscoptes montanus*	B
savannah sparrow	*Passerculus sandwichensis*	B
Say's phoebe	*Sayornis saya*	B
song sparrow	*Melospiza melodia*	Yr
Townsend's solitaire	*Myadestes townsendi*	M
Townsend's warbler	*Dendroica townsendi*	M
tree swallow	*Tachycineta bicolor*	M
varied thrush	*Ixoreus naevius*	W
vesper sparrow	*Pooecetes gramineus*	B
violet-green swallow	*Tachycineta thalassina*	M
warbling vireo	*Vireo gilvus*	M
western kingbird	*Tyrannus verticalis*	B
western meadowlark	*Sturnella neglecta*	Yr
white-crowned sparrow	*Zonotrichia leucophrys*	W

Table B3 (cont'd)

Common Name	Scientific Name	Season of Highest Abundance
Passeriformes - Perching birds (cont'd)		
western tanager	*Piranga ludoviciana*	M
western wood-pewee	*Contopus sordidulus*	M
Wilson's warbler	*Wilsonia pusilla*	M
winter wren	*Troglodytes troglodytes*	W
yellow-breasted chat	*Icteria virens*	B
yellow-rumped warbler	*Dendroica coronata*	M
yellow warbler	*Dendroica petechia*	M
yellow-headed blackbird	*Xanthocephalus xanthocephalus*	B

Table B4. Reptiles and Amphibians Found on the Hanford Site, Washington

Common Name	Scientific Name
<u>Reptiles</u>	
common garter snake	*Thamnophis sirtalis*
Great Basin gopher snake	*Pituiphis melanoleucus*
night snake	*Hypsiglena torquata*
northern sagebrush lizard	*Sceloporus graciosus*
painted turtle	*Chrysemys picta*
short-horned lizard	*Phrynosoma douglassii*
side-blotched lizard	*Uta stansburiana*
striped whipsnake	*Masticophis taeniatus*
western rattlesnake	*Crotalus viridis*
western yellow-bellied racer	*Coluber constrictor*
<u>Amphibians</u>	
bullfrog	*Rana catesbeiana*
Great Basin spadefoot	*Scaphiopus intermontanus*
tiger salamander	*Ambystoma tigrinum*
western toad	*Bufo boreas*
Woodhouse's toad	*Bufo woodhousii*

Table B5. Fish Species in the Hanford Reach, Washington, Region of the Columbia River (Gray and Dauble 1977)

Common Name	Scientific Name
Paddlefishes, spoonfishes, sturgeons (family Acipenseridae)	
white sturgeon	*Acipenser transmontanus*
Anchovies, herrings (family Clupeidae)	
American shad	*Alosa sapidissima*
Cyprins, minnows, suckers (family Catostomidae)	
chiselmouth	*Acrocheilus alutaceus*
bridgelip sucker	*Catostomus columbianus*
largescale sucker	*Catostomus macrocheilus*
mountain sucker	*Catostomus platyrhynchus*
common carp	*Cyprinus carpio*
peamouth	*Mylocheilus caurinus*
northern pikeminnow	*Ptychocheilus oregonensis*
longnose dace	*Rhinichthys cataractae*
leopard dace	*Rhinichthys falcatus*
speckled dace	*Rhinichthys osculus*
redside shiner	*Richardsonius balteatus*
tench	*Tinca tinca*
Livebearers (family Poeciliidae)	
western mosquitofish	*Gambusia affinis*
Cods (family Gadidae)	
burbot	*Lota lota*
Pipefishes, sticklebacks (family Gasterosteidae)	
threespine stickleback	*Gasterosteus aculeatus*
Perch-like fishes (family Centrarchidae)	
pumpkinseed	*Lepomis gibbosus*
bluegill	*Lepomis macrochirus*
smallmouth bass	*Micropterus dolomieui*
largemouth bass	*Micropterus salmoides*
yellow perch	*Perca flavenscens*
white crappie	*Pomoxis annularis*
black crappie	*Pomoxis nigromaculatus*
walleye	*Sander vitreus*
Trout perches (family Perocpsidae)	
sand roller	*Percopsis transmontana*

Common Name	Scientific Name
<u>Lampreys (family Petromyzontidae)</u>	
river lamprey	*Lampetra ayresii*
Pacific lamprey	*Lampetra tridentata*
<u>Salmonids, salmons, trouts (family Salmonidae)</u>	
lake whitefish	*Coregonus clupeaformis*
bull trout	*Salvelinus confluentus*
cutthroat trout	*Oncorhynchus clarkii*
coho salmon	*Oncorhynchus kisutch*
rainbow trout (steelhead)	*Oncorhynchus mykiss*
sockeye salmon	*Oncorhynchus nerka*
Chinook salmon	*Oncorhynchus tshawytscha*
mountain whitefish	*Prosopium williamsoni*
<u>Chabots, sculpins (family Cottidae)</u>	
prickley sculpin	*Cottus asper*
mottled sculpin	*Cottus bairdii*
piute sculpin	*Cottus beldingii*
reticulate sculpin	*Cottus perplexus*
torrent sculpin	*Cottus rhotheus*
<u>Bullhead catfishes, North American freshwater catfishes (family Ictaluridae)</u>	
yellow bullhead	*Ameiurus natalis*
brown bullhead	*Ameiurus nebulosus*
black bullhead	*Ameiurus melas*
channel catfish	*Ictalurus punctatus*

Appendix B References

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Appendix C

Vegetation Maps

Appendix C

Vegetation Maps

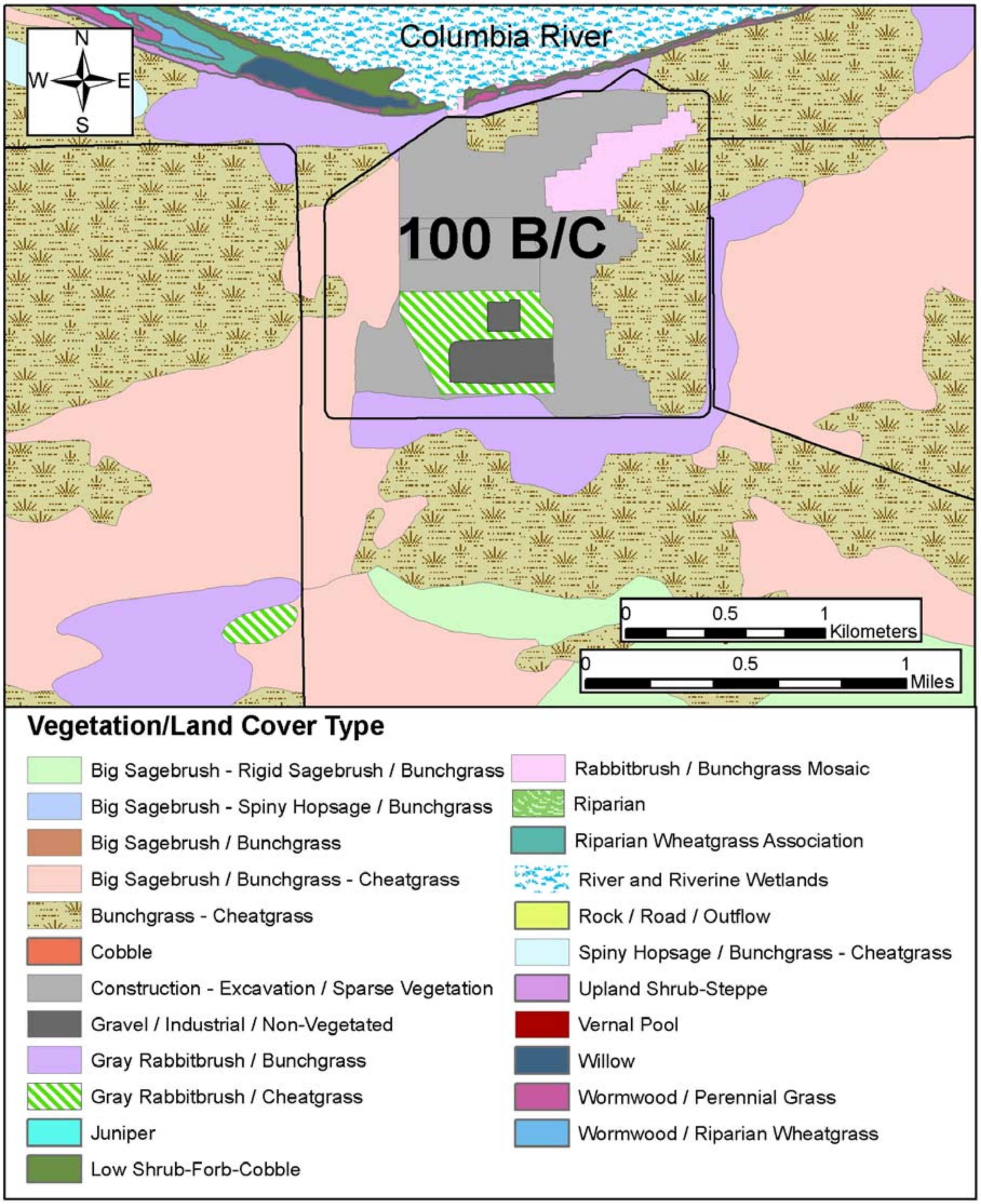

Figure C1. Vegetation/Land Coverage Map for the 100-B/C Area, Hanford Site, Washington, during 2006

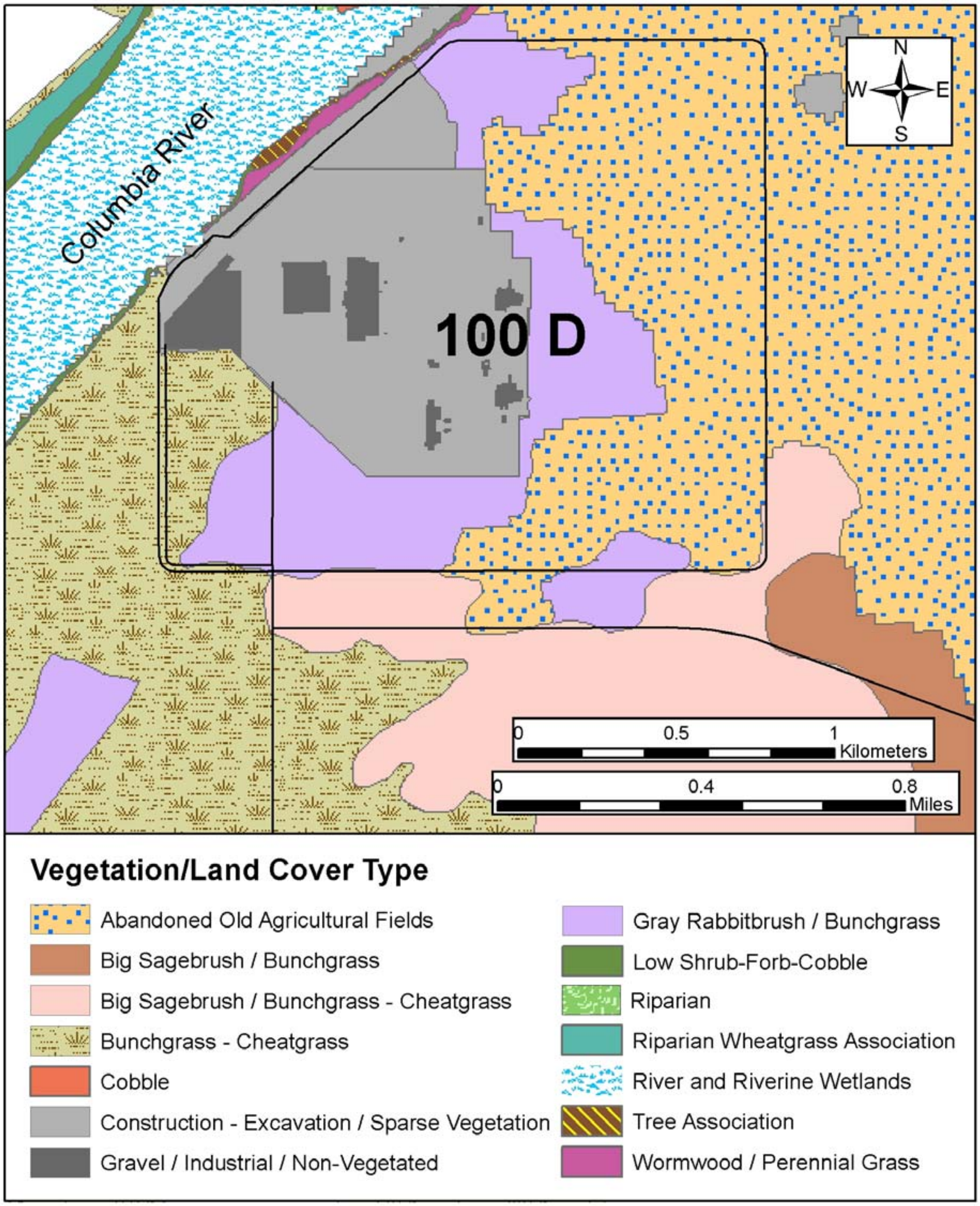

Figure C2. Vegetation/Land Coverage Map for the 100-D Area, Hanford Site, Washington, during 2006

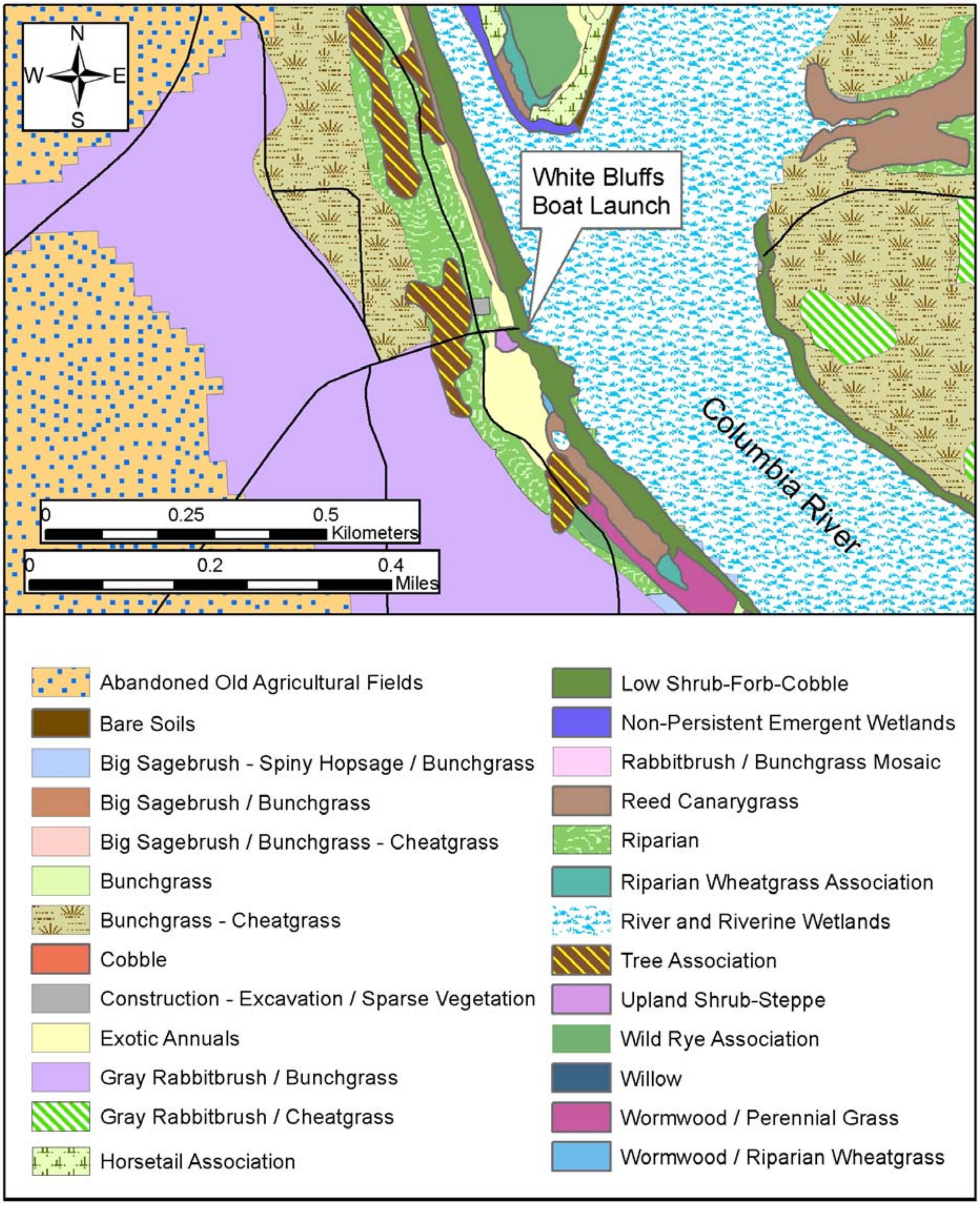

Figure C3. Vegetation/Land Coverage Map for the White Bluffs Boat Launch Vicinity, Hanford Site, Washington, during 2006

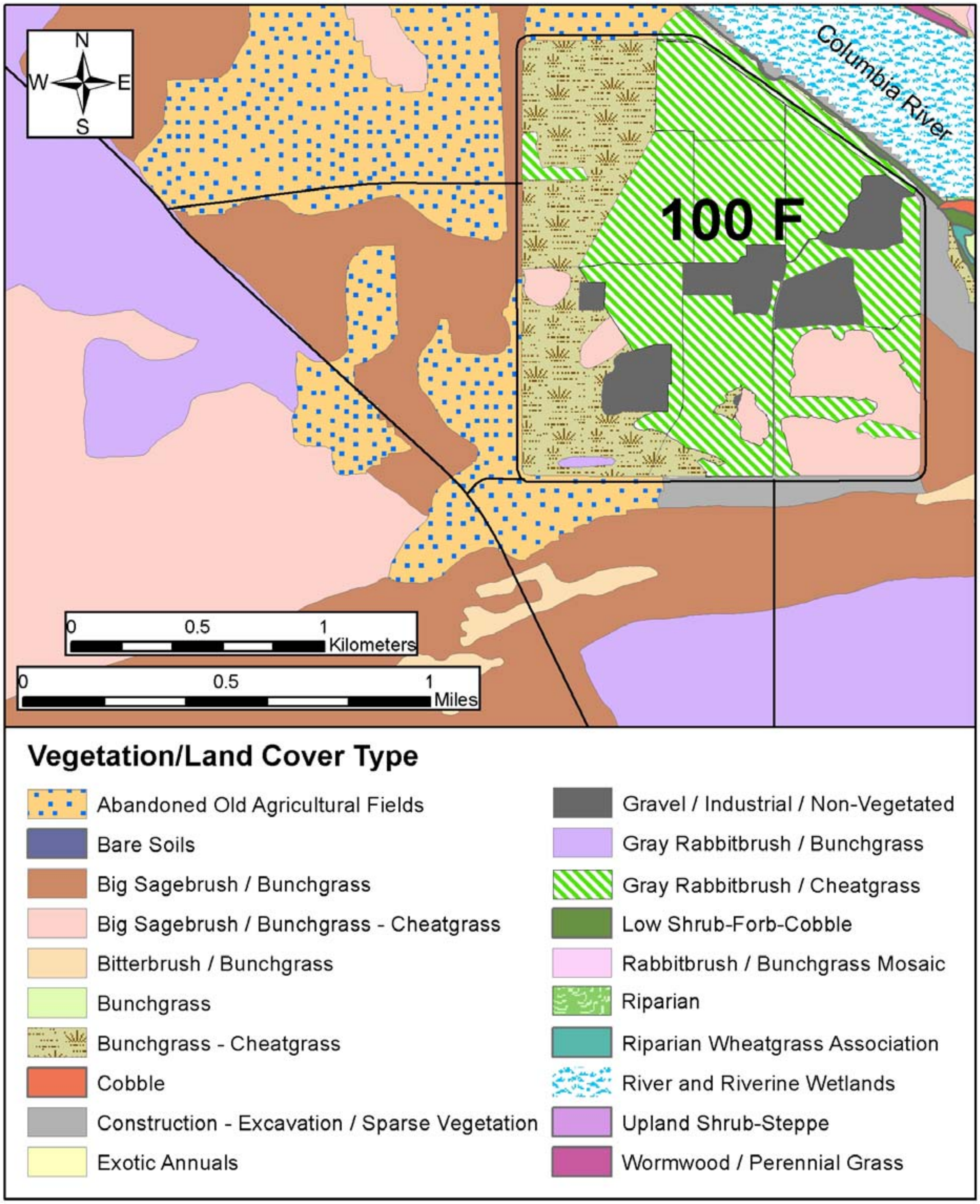

Figure C4. Vegetation/Land Coverage Map for the 100-F Area, Hanford Site, Washington, during 2006

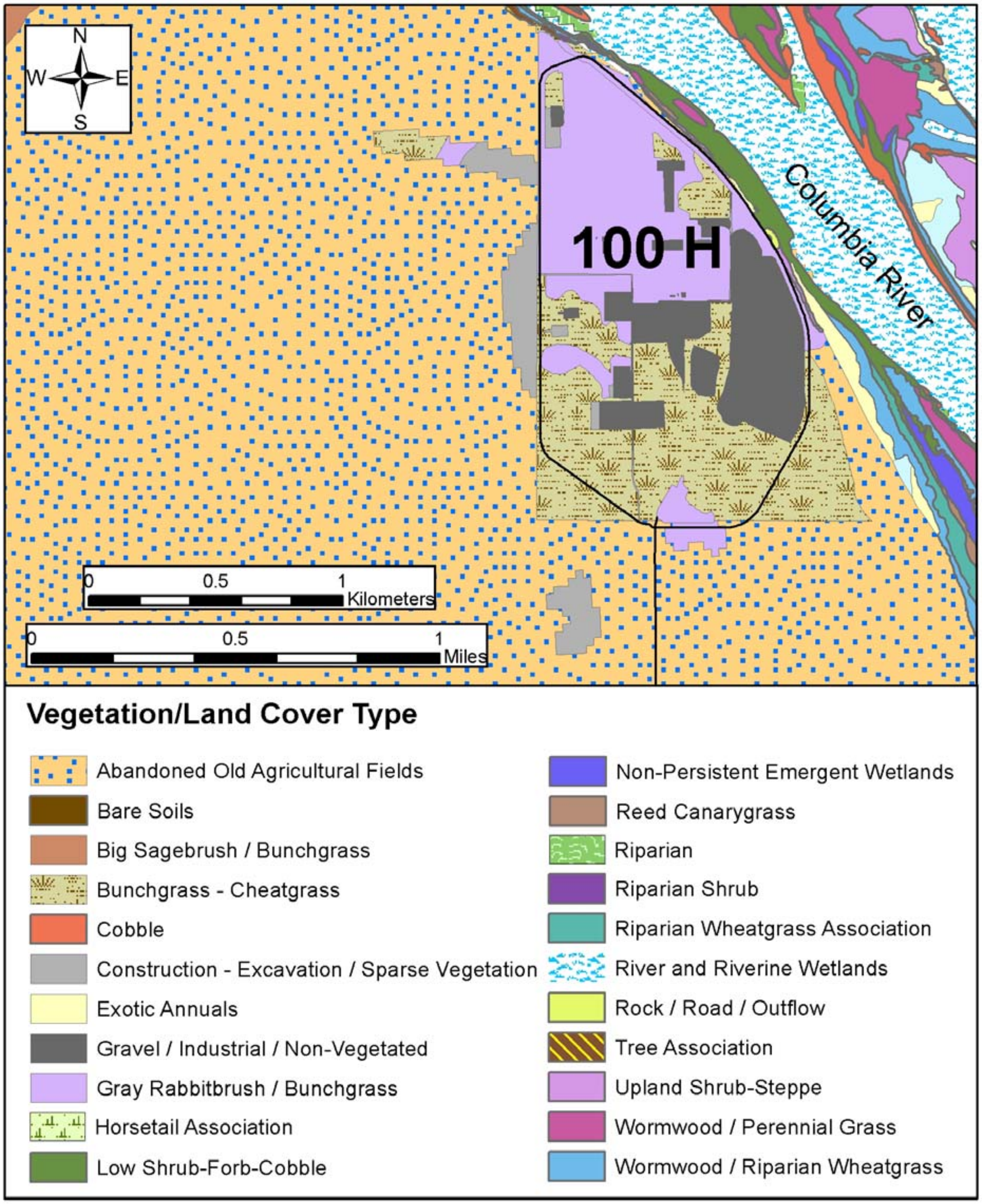

Figure C5. Vegetation/Land Coverage Map for the 100-H Area, Hanford Site, Washington, during 2006

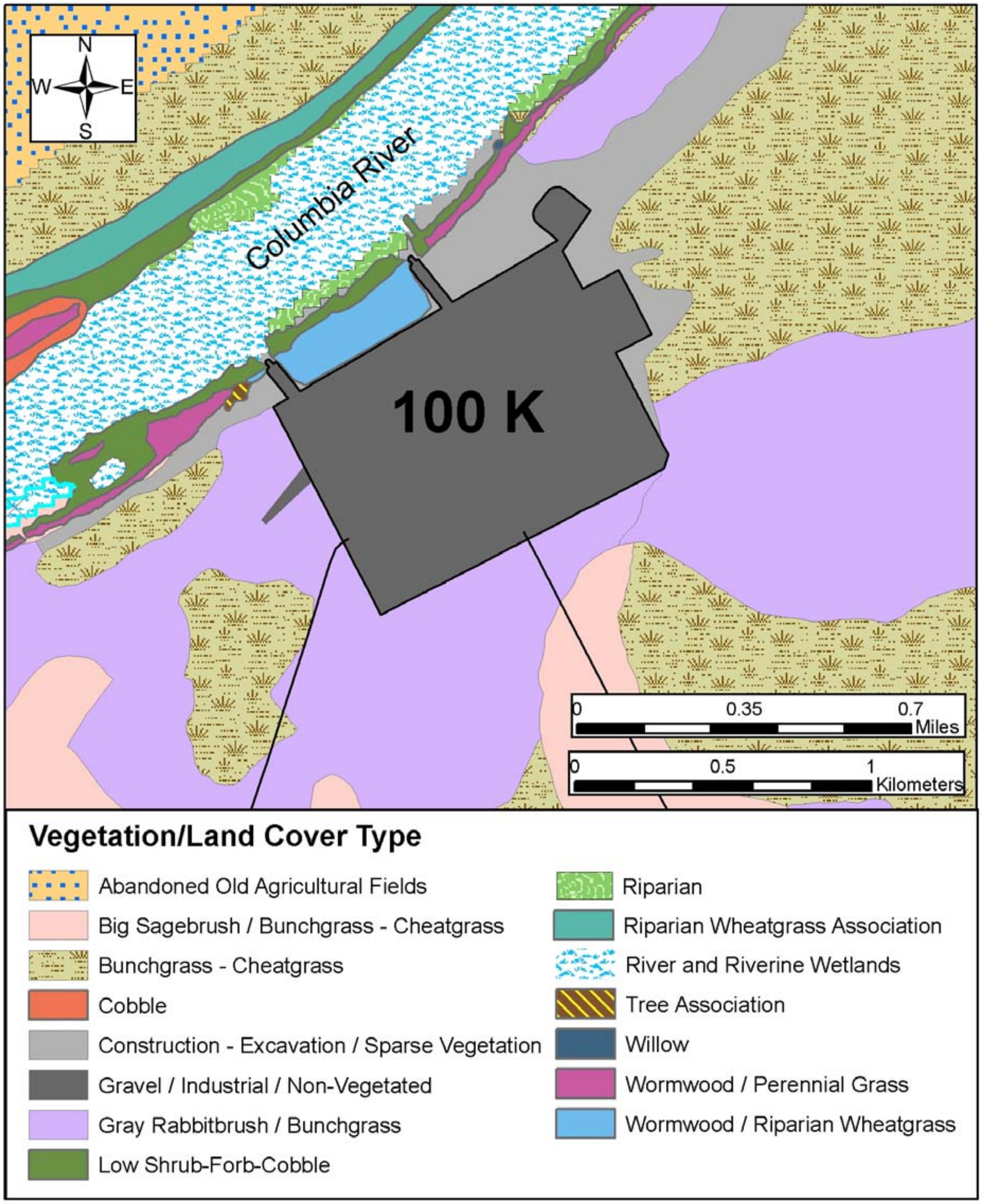

Figure C6. Vegetation/Land Coverage Map for the 100-K Area, Hanford Site, Washington, during 2006

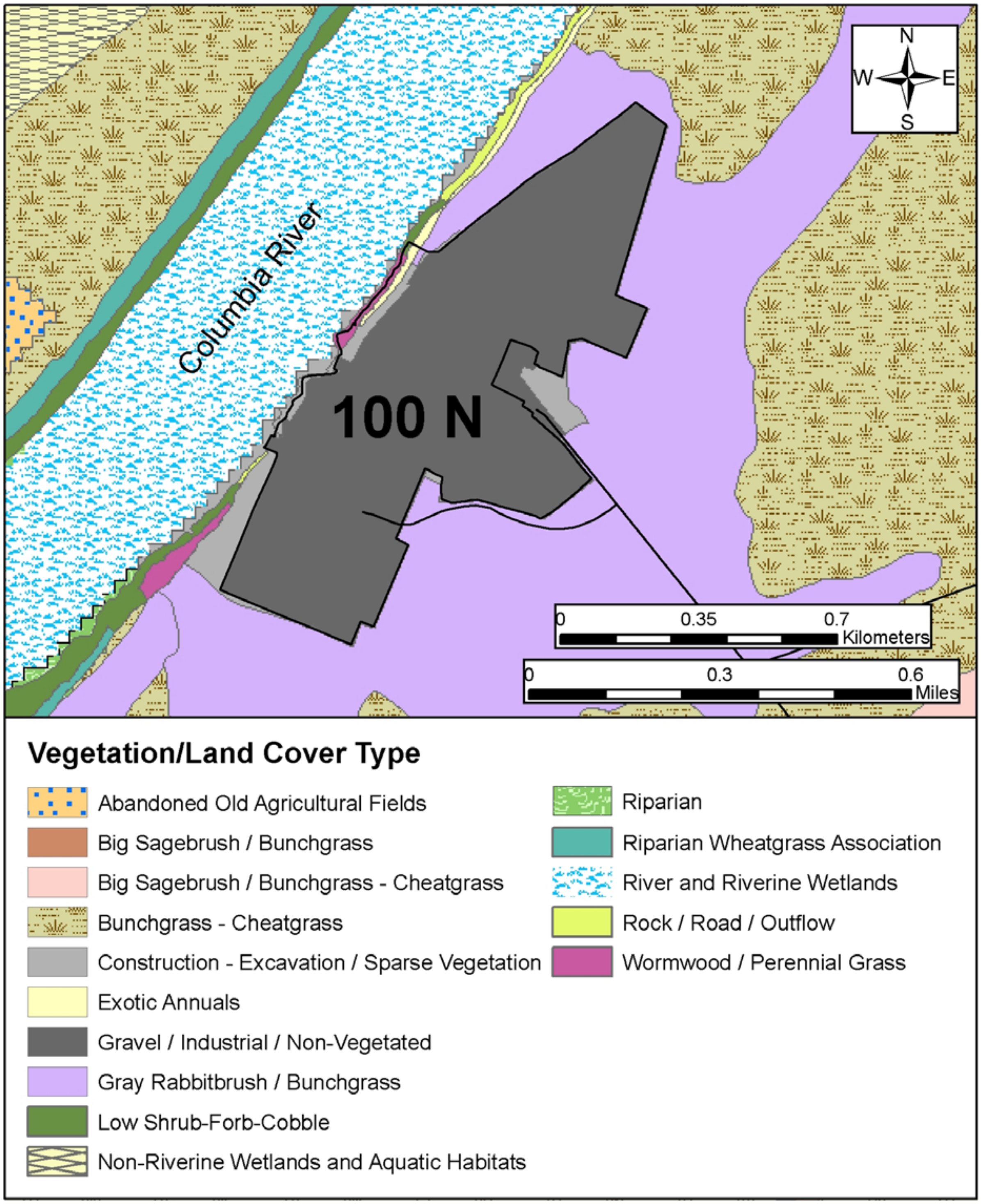

Figure C7. Vegetation/Land Coverage Map for the 100-N Area, Hanford Site, Washington, during 2006

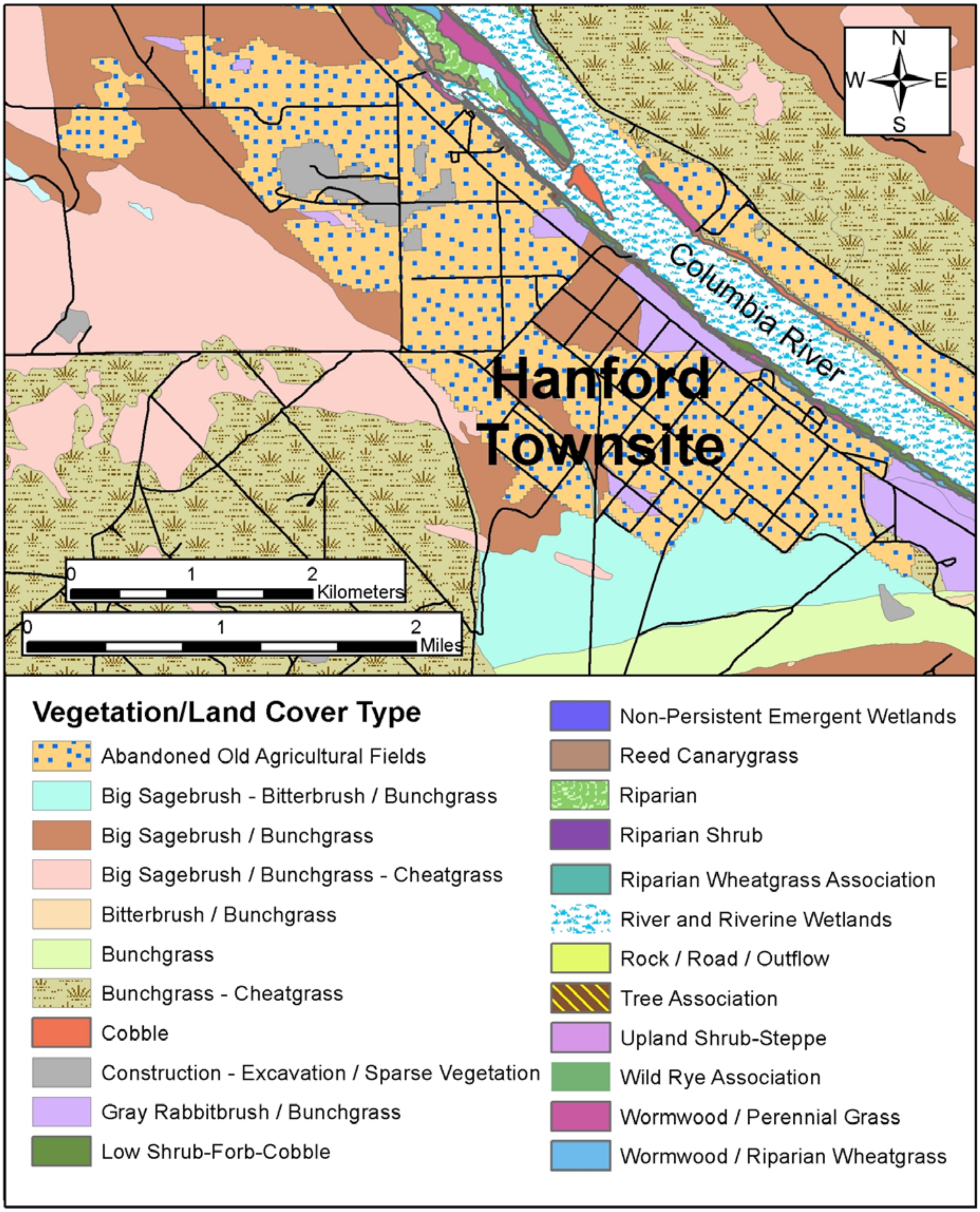

Figure C8. Vegetation/Land Coverage Map for the Hanford Townsite Vicinity, Hanford Site, Washington, during 2006

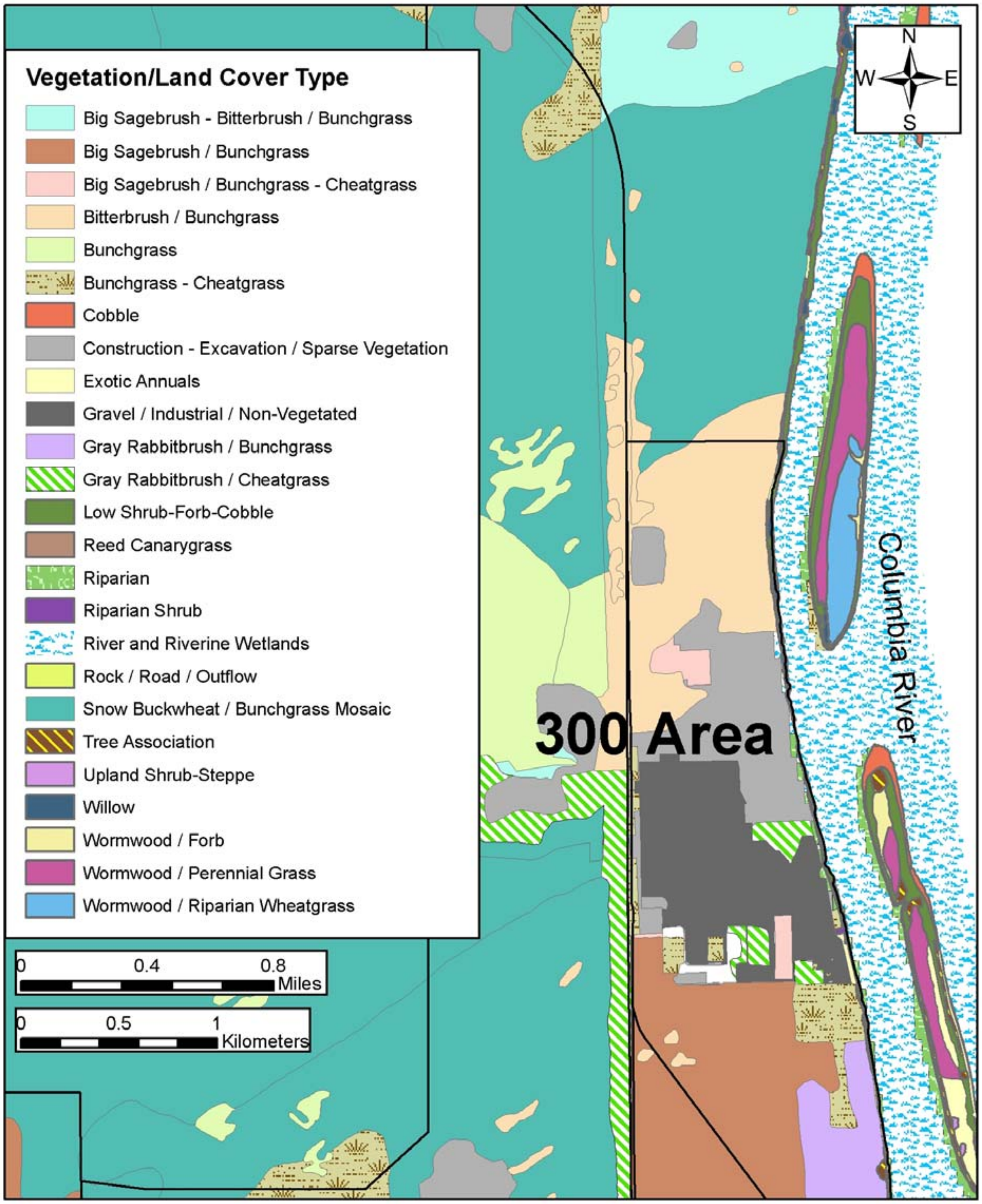

Figure C9. Vegetation/Land Coverage Map for the 300 Area, Hanford Site, Washington, during 2006

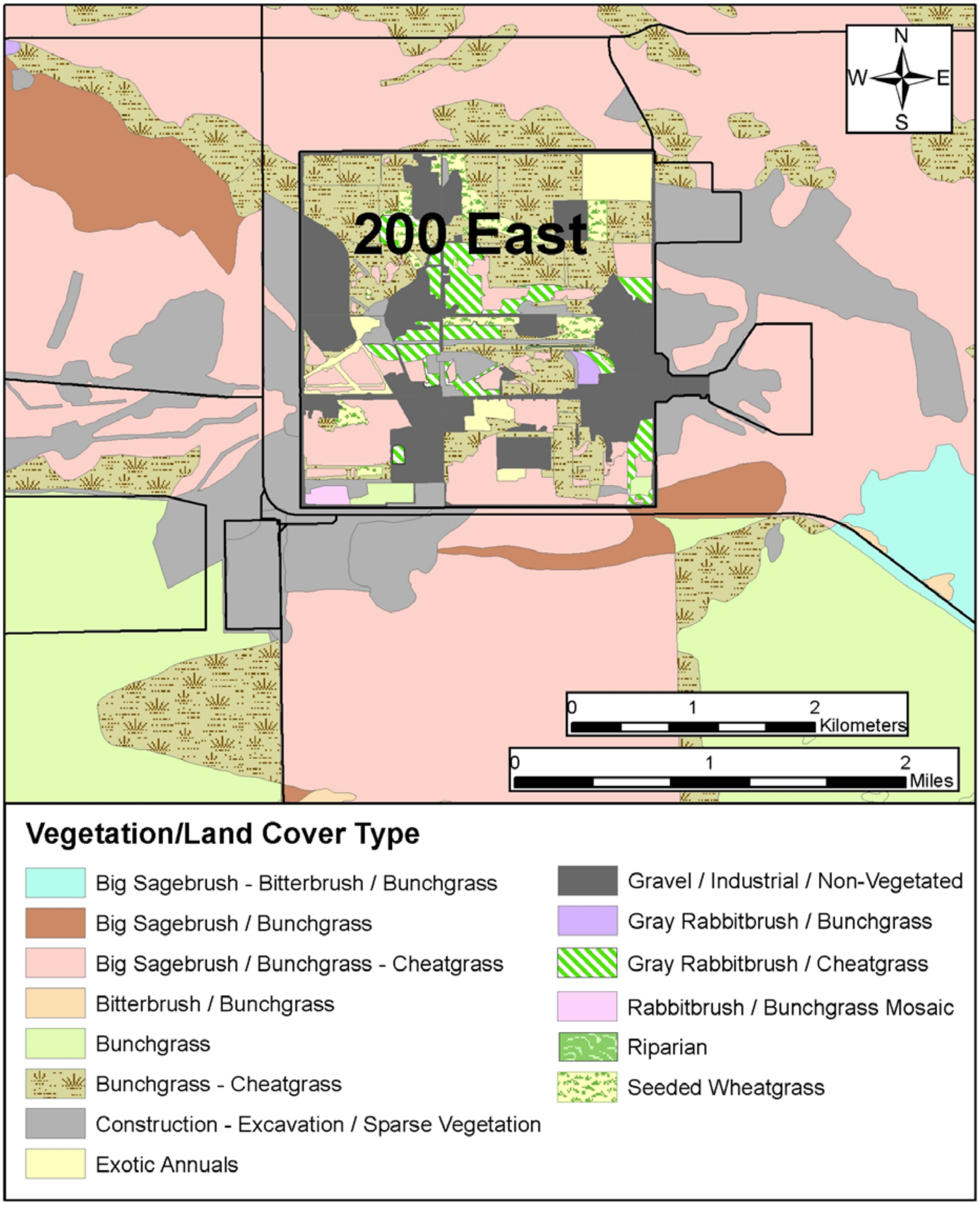

Figure C10. Vegetation/Land Coverage Map for the 200 East Area, Hanford Site, Washington, during 2006

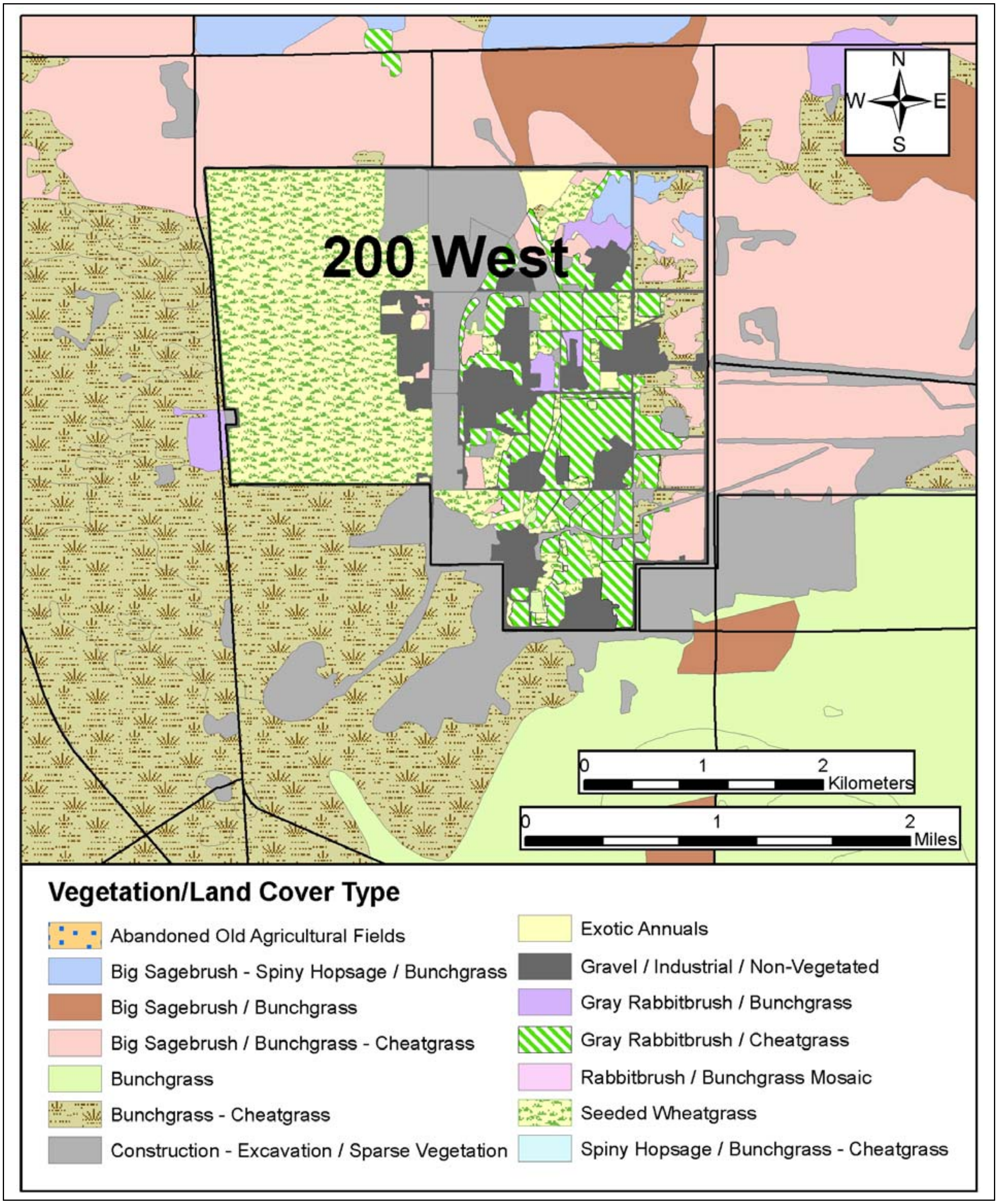

Figure C11. Vegetation/Land Coverage Map for the 200 West Area, Hanford Site, Washington, during 2006

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6.0 Statutory and Regulatory Requirements

P. L. Hendrickson

The Hanford Site is owned by the U.S. Government and is managed by the U.S. Department of Energy (DOE). It is the policy of the DOE to carry out its operations in compliance with all applicable federal, state, and local laws and regulations, presidential executive orders, DOE directives, and treaty rights. Environmental regulatory authority over the Hanford Site is vested both in federal agencies, primarily the U.S. Environmental Protection Agency (EPA), and in Washington State agencies, primarily the Washington State Department of Ecology (Ecology) and the Washington State Department of Health (DOH). In addition, the Benton Clean Air Authority (BCAA) has certain regulatory authority over Hanford activities, including open burning, asbestos removal, and fugitive dust control. Significant environmental laws, regulations, and other requirements are discussed in this chapter in the following order:

- Major federal environmental laws
- Significant applicable federal and state regulations
- Presidential executive orders
- DOE directives
- Treaties, statutes, and policies relating to Indian Tribes of the Hanford region
- Existing environmental permits covering activities at the Hanford Site.

There are a number of sources of information available concerning statutory and regulatory requirements as they relate to the National Environmental Policy Act (NEPA) process. Sources available over the Internet include the following:

- Links to Hanford NEPA documents at: http://www.hanford.gov/rl/?page=113&parent=0
- DOE's NEPA web site at: http://www.eh.doe.gov/nepa/
- Council on Environmental Quality's (CEQ's) web site at: http://www.whitehouse.gov/ceq/
- EPA's NEPA web site at: http://epa.gov/compliance/nepa/index.html
- Ecology's *Permit Handbook* at: http://apps.ecy.wa.gov/permithandbook/.

The DOE Office of Environment, Safety, and Health has issued a variety of guidance documents to aid the preparation of DOE NEPA documents. The guidance documents are posted at http://www.eh.doe.gov/nepa/guidance.html.

(The following introduction [boxed text] is intended to be explanatory for persons writing the chapter of a Hanford Site environmental impact statement [EIS] or environmental assessment [EA] covering regulatory requirements, but is not intended to be included in the EIS or EA.) The material following the boxed text can be adapted, as appropriate, for use in an EIS or EA at the discretion of the authors. Additional specificity should be added to the material to reflect the particular circumstances and facts that are the subject of the EIS or EA. An EIS will normally contain more detail than an EA.

Introduction

The CEQ regulations in the Code of Federal Regulations (CFR) at 40 CFR 1500-1508 implement NEPA and set forth requirements for the preparation of environmental documentation by federal agencies that satisfy NEPA. DOE has adopted the CEQ regulations as part of its NEPA implementing procedures (10 CFR 1021.103). The CEQ regulations identify the types of actions proposed by a federal agency that require preparation of an EIS, prescribe the content of an EIS, and identify actions and other environmental reviews that must or should be undertaken by the federal agency in preparing and circulating an EIS. In general, an EIS must be prepared by a federal agency for any major federal action significantly affecting the quality of the human environment (40 CFR 1502.3). The regulations also state reasons why an agency may want to prepare an EA instead of an EIS (40 CFR 1508.9).

A specific requirement in the CEQ regulations (40 CFR 1502.25) is that the draft EIS must list "all federal permits, licenses, and other entitlements which must be obtained in implementing the proposal." If it is uncertain whether a federal permit or license is needed, the draft EIS is to so indicate. There is, however, no requirement in the CEQ regulations or in the DOE NEPA implementing procedures at 10 CFR Part 1021 that the EIS must list or discuss applicable environmental laws and regulations. Nevertheless, applicable environmental laws and regulations (federal, state, and local) have been discussed in recent Hanford Site EISs and EAs in a chapter usually captioned "Statutory and Regulatory Requirements." The discussion below assumes this chapter is chapter 6 of the EIS or EA, but another chapter number is possible.

Chapter 6 of Hanford Site EISs and EAs should include the list called for by 40 CFR 1502.25(b). The list should also include significant permits that will be needed from federal, state, and local government agencies. Chapter 6 should not normally include information on environmental impacts associated with any of the requirements. For example, Executive Order (E.O.) 12962 requires federal agencies to evaluate the effects of their actions on aquatic systems and recreational fisheries. Although E.O. 12962 should be mentioned in Chapter 6 in appropriate cases, the actual impacts of the alternatives on aquatic systems and recreational fisheries should be discussed in the Environmental Consequences chapter (normally Chapter 5) of the EIS or EA and any recreational fisheries aspects of the affected environment should be discussed in the Affected Environment chapter (normally Chapter 4) of the EIS or EA. Chapter 6 can refer the reader to the portion of the EIS or EA where the environmental impacts associated with a particular environmental requirement are discussed.

A summary of prior EAs and EISs prepared for activities at the Hanford Site is in *National Environmental Policy Act Source Guide for the Hanford Site* (Fluor Hanford 2002).

The purpose, then, of Chapter 6 in this document is to present a "reference" that can be used as the basis for the preparation of future Hanford Site EISs and EAs. The intent is to present a reasonably complete discussion of federal, state, and local environmental laws, regulations, and permit requirements that are applicable to activities at the Hanford Site. The information in this chapter can then be adapted to any future Hanford Site EIS/EA by deleting irrelevant parts and by adding some specificity with respect to the proposed action and the alternatives being considered.

It should be noted that environmental standards and permit requirements usually appear in regulations and not in the laws themselves. Thus, more emphasis is placed on regulations and less on laws in this chapter.

Federal and State Environmental Laws

Federal law governs environmental regulation of federal facilities. Most major federal environmental laws now include provisions for regulation of federal activities that impact the environment. The activity to be regulated is usually an activity being carried out by an agency of the executive branch. The federal environmental law will also typically designate a specific agency, such as EPA or the U.S. Nuclear Regulatory Commission (NRC), as the regulator. In addition, federal laws may provide for the delegation of the environmental regulation of federal facilities to the states or may directly authorize the environmental regulation of federal facilities by the states through waivers of sovereign immunity. At Hanford, all these situations apply in varying degrees. EPA has regulatory authority over Hanford facilities and has delegated regulatory authority to, shares regulatory authority with, or is in the process of delegating regulatory authority to the State of Washington. The State of Washington also asserts its own independent regulatory authority over Hanford facilities under federal waivers of sovereign immunity and state legislation. The Washington State Department of Ecology has also delegated various air compliance responsibilities to the BCAA.

As a legal matter at Hanford, applicable federal and state environmental standards must be met. As a practical matter, differences in language between federal and state laws and regulations may result in some differences in applicability and interpretation. Guidance on specific applicability should be obtained from the Office of Chief Counsel of the DOE Richland Operations Office (DOE/RL) or the Office of River Protection (DOE-ORP).

Citation of Laws and Regulations

Laws and regulations may be cited both by their common name and by their location in the appropriate document. Federal laws are most often cited by their common name (e.g., Clean Water Act [CWA]), by their public law (Pub. L. or PL) number, or by their location in the United States Code (USC). Section numbers differ between laws as enacted and as codified in the USC, so it must be understood which is being cited. Federal regulations appear in the CFR. Washington State laws are most often cited by their location in the Revised Code of Washington (RCW). Washington State regulations are cited by their location in the Washington Administrative Code (WAC). Links to the RCW and WAC are available at http://www1.leg.wa.gov/CodeReviser/. Announcements of proposed and final federal regulations appear in the Federal Register (FR). Announcements of proposed and final Washington State regulations appear in the Washington State Register.

Specific Federal Laws Cited in the CEQ Regulations

Four federal laws are specifically cited in the CEQ regulations [40 CFR 1502.25(a) and 1504.1(b)]:

- Section 309 of the Clean Air Act (CAA) (42 USC 7609)
- Fish and Wildlife Coordination Act (16 USC 661 *et seq.*)
- National Historic Preservation Act (NHPA) (16 USC 470 *et seq.*)
- Endangered Species Act (ESA) (16 USC 1531 *et seq.*).

Section 309 of the CAA directs EPA to review and comment in writing on the environmental impacts of any matter relating to EPA's authority contained in proposed legislation, federal construction projects, other federal actions requiring EISs, and new regulations. In addition to commenting on EISs, EPA rates every draft EIS prepared by a federal agency under its Section 309 authority. Ratings are made for the environmental impact of the proposed action and the adequacy of the impact statement. Rating categories for environmental impact are: LO - lack of objections, EC - environmental concerns, EO - environmental objections, and EU - environmentally unsatisfactory. Rating categories for adequacy are: Category 1 - adequate, Category 2 - insufficient information, and Category 3 - inadequate. A summary of EPA rating definitions is available at: http://www.epa.gov/compliance/nepa/comments/ratings.html. Responses to EPA's comments on a draft EIS are included in the final EIS.

The CEQ regulations (40 CFR 1502.25[a]) direct federal agencies to prepare draft EISs concurrently with and integrated with environmental impact analyses and related surveys required by the Fish and Wildlife Coordination Act, the NHPA, the ESA, and other environmental review laws and executive orders. The three preceding statutes should be cited in Chapter 6 of a draft EIS. Environmental impacts associated with the laws should be discussed in Chapter 5.

6.1 Federal Environmental Laws

Significant federal environmental laws potentially applicable to the Hanford Site include the following:

- Antiquities Act (16 USC 431 *et seq.*)
- American Indian Religious Freedom Act (42 USC 1996)
- Archaeological and Historic Preservation Act (16 USC 469 *et seq.*)
- Archaeological Resources Protection Act (ARPA) (16 USC 470aa *et seq.*)
- Bald and Golden Eagle Protection Act (16 USC 668 *et seq.*)
- Clean Air Act (CAA) (42 USC 7401 *et seq.*)
- Clean Water Act (CWA) (33 USC 1251 *et seq.*) (The CWA is also known as the Federal Water Pollution Control Act.)
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) (42 USC 9601 *et seq.*)
- Emergency Planning and Community Right-to-Know Act (EPCRA) (42 USC 11001 *et seq.*)
- Endangered Species Act (16 USC 1531 *et seq.*)
- Farmland Protection Policy Act of 1981 (7 USC 4201 *et seq.*)
- Fish and Wildlife Coordination Act (16 USC 661 *et seq.*)
- Hanford Reach Study Act (PL 100-605), as amended by PL 104-333
- Hazardous Materials Transportation Act (49 USC 5101 *et seq.*)
- Migratory Bird Treaty Act (16 USC 703 *et seq.*)
- National Historic Preservation Act (NHPA) (16 USC 470 *et seq.*)
- Native American Graves Protection and Repatriation Act (25 USC 3001 *et seq.*)
- National Environmental Policy Act (NEPA) (42 USC 4321 *et seq.*)
- Noise Control Act (42 USC 4901 *et seq.*)

- Pollution Prevention Act (42 USC 13101 *et seq.*)
- Resource Conservation and Recovery Act (RCRA) of 1976 as amended by the Hazardous and Solid Waste Amendments (42 USC 6901 *et seq.*) of 1984
- Rivers and Harbors Appropriation Act of 1899 (33 USC 401 *et seq.*)
- Safe Drinking Water Act (SDWA) (42 USC 300f *et seq.*)
- Toxic Substances Control Act (TSCA) (15 USC 2601 *et seq.*).

In addition, the Atomic Energy Act (AEA) (42 USC 2011 *et seq.*), the Low-Level Radioactive Waste Policy Act (LLWPA) (42 USC 2021b *et seq.*), and the Nuclear Waste Policy Act (NWPA) (42 USC 10101 *et seq.*), while not environmental laws per se, contain provisions under which environmental regulations applicable to the Hanford Site may be or have been promulgated. A brief description of many of the preceding statutes is available at the following DOE web site: http://www.hss.energy.gov/NuclearSafety/NSEA/oepa/laws/.

6.2 Federal and State Environmental Regulations

Under the Supremacy Clause of the U.S. Constitution (Article VI, Clause 2), activities of the federal government are ordinarily not subject to regulation by the states unless Congress creates specific exceptions. Congress has created exceptions with respect to environmental regulation and provisions in several federal laws giving specific authority to the states to regulate federal activities affecting the environment. These waivers (or partial waivers) of sovereign immunity appear in Section 118 of the CAA, Section 313 of the CWA, Section 4 of the Noise Control Act, Section 1447 of the SDWA, Section 6001 of RCRA, and Section 120 of CERCLA/SARA. The Federal Facilities Compliance Act is an amendment to RCRA that makes the RCRA waiver of sovereign immunity more explicit. Many Washington State programs, with respect to the environmental regulation of Hanford Site facilities under the preceding statutes, are coordinated with the U.S. Environmental Protection Agency (EPA) Region 10 office.

Federal and state environmental regulations that may apply to operations at the Hanford Site have been promulgated under the CAA, CWA, SDWA, RCRA, CERCLA, SARA, AEA, LLWPA, NWPA, under other federal statutes, and under relevant state statutes.

Several of the more important existing federal and state environmental regulations are discussed briefly below. These regulations are grouped according to environmental media.

6.2.1 Air Quality

The federal Clean Air Act and the Washington Clean Air Act (Revised Code of Washington [RCW] 70.94) provide the statutory basis for air quality regulation of Hanford Site activities. The federal CAA establishes a floor or minimum level of requirements. State requirements can exceed, i.e., be more stringent than, federal requirements.

- 40 Code of Federal Regulations (CFR) 50, "National Primary and Secondary Ambient Air Quality Standards." EPA regulations in 40 CFR 50 set national ambient air quality standards for sulfur oxides, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. The standards are not directly enforceable, but other enforceable regulations are based on the standards. Washington's ambient air standards are at Washington Administrative Code (WAC) 173-470 through 173-481 and include standards for radionuclides and fluorides. The Hanford Site is within an area that is in attainment with or is unclassifiable for all national ambient air quality standards (40 CFR 81.348).

- 40 CFR 51-52, State Implementation Plans (SIPs). EPA regulations in 40 CFR 51-52 establish the requirements for SIPs and record the approved plans. The SIPs are directed at the control of emissions for which federal ambient air standards exist. Information on the Washington SIP is available at: http://yosemite.epa.gov/r10/airpage.nsf/webpage/SIP+-+WA+Table+of+Contents?OpenDocument.

- 40 CFR 60, "Standards of Performance for New Stationary Sources." EPA regulations in 40 CFR 60 provide standards for the control of the emission of pollutants to the atmosphere. Construction or modification of an emissions source in an attainment area such as Hanford can require a prevention of significant deterioration (PSD) of air quality permit under 40 CFR 52.21 and WAC 173-400-700 through 750.

- 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants" (NESHAP); 40 CFR 63, "National Emission Standards for Hazardous Air Pollutants for Source Categories." EPA hazardous emission standards in 40 CFR 61 provide for the control of the emission of hazardous pollutants to the atmosphere. Standards in 40 CFR 61 Subpart H apply specifically to the emission of radionuclides from DOE facilities. Emissions of radionuclides (other than radon-220 and radon-222) to the ambient air from DOE facilities are not to exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr (0.1 mSv/yr) (40 CFR 61.92). Standards in 40 CFR 61 Subpart Q apply to the emission of radon from DOE facilities. No source at a DOE facility is to emit more than 20 picocuries per square meter per second (pCi/(m^2-s)) (1.9 pCi/(ft^2-s)) of radon-222 as an average for the entire source into the air (40 CFR 61.192). Approval to construct a new facility or to modify an existing one may be required under 40 CFR 61.07. Emission standards for sources of hazardous air pollutants designated in the 1990 CAA amendments appear at 40 CFR 63.

- 40 CFR 70, "State Operating Permit Programs." These regulations provide for the establishment of comprehensive state air quality permitting programs. All major sources of air pollutants including hazardous air pollutants are covered. Washington's operating permit regulations appear at WAC 173-401.

- 40 CFR 93 Subpart B, "Determining Conformity of General Federal Actions to State or Federal Implementation Plans." The general conformity requirements require that actions of federal agencies are to comply with state implementation plans designed to achieve national ambient air quality standards.

- WAC 173-400 through 173-495, Washington State Air Pollution Control Regulations. Ecology air pollution control regulations, promulgated under the Washington CAA, appear in WAC 173-400 through 173-495. These regulations include emission standards, ambient air quality standards, and the standards in WAC 173-460, "Controls for New Sources of Toxic Air Pollutants." The State of Washington has delegated much of its authority under the Washington CAA to the BCAA. However, except for certain air pollution sources (e.g., asbestos removal, fugitive dust, and open burning) administered by the BCAA, Ecology continues to administer air pollution control requirements for the Hanford Site.

- WAC 246-247, "Radiation Protection--Air Emissions." Washington Department of Health (DOH) regulations in WAC 246-247 contain standards and permit requirements for the emission of radionuclides to the atmosphere.

- Regulation 1 of the Benton Clean Air Authority can be accessed at: http://www.bcaa.net/RegPol.htm.

6.2.2 Water Quality

The CWA and the Washington Water Pollution Control Act provide the statutory basis for the regulation of water quality in Washington State. The CWA established the National Pollutant Discharge Elimination System (NPDES) to limit the amount of pollutants that could be discharged.

- 40 CFR 121, "State Certification of Activities Requiring a Federal License or Permit." These regulations provide for state certification that any activity requiring a federal water permit, i.e., a NPDES permit or a discharge of dredged or fill material permit, will not violate state water quality standards.

- 40 CFR 122, "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System." EPA regulations in 40 CFR 122 (and also in 40 CFR 125 and 129) apply to the discharge of pollutants from any point source into waters of the United States. These regulations also apply to the discharge of storm waters (40 CFR 122.26) and the discharge of runoff waters from construction areas over 0.02 km^2 (0.008 mi^2) in size into waters of the United States. NPDES permits may be required by 40 CFR 122. EPA has not delegated to the State of Washington the authority to issue NPDES permits at the Hanford Site.

- 40 CFR 141, "National Primary Drinking Water Regulations." EPA drinking water standards in 40 CFR 141 apply to Columbia River water at community water supply intakes downstream of the Hanford Site. The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water is not to produce an annual dose equivalent to the body or any internal organ of greater than 4 mrem (0.04 mSv) in a year. Maximum contaminant levels in community water systems of 5 pCi/L (0.18 Bq/L) of combined radium-226 and radium-228; 15 pCi/L (0.56 Bq/L) of gross alpha particle activity, including radium-226 but excluding radon and uranium; and 30 µg/L for uranium are specified in 40 CFR 141.66. The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water must not produce an annual dose equivalent to the total body or any internal organ greater than 4 mrem/yr (0.04 mSv/yr) [40 CFR 141.66(d)].

- 40 CFR 144-147, Underground Injection Control Program. EPA regulations in 40 CFR 144-147 apply to the underground injection of liquids and wastes and may require a permit for any underground injection. In Washington State, EPA has approved Ecology regulations in WAC 173-218, "Underground Injection Control Program," to operate in lieu of the EPA program. The Ecology regulations provide standards and permit requirements for the disposal of fluids by well injection.

- 10 CFR 1022, “Compliance with Floodplain/Wetlands Environmental Review Requirements.” DOE regulations in 10 CFR 1022 implement Executive Orders 11988 and 11990 and apply to DOE activities that are proposed to take place either in wetlands or in floodplains.
- 33 CFR 322-323, 40 CFR 230-233. Construction or placement of structures in the Columbia River and work in the Columbia River, as well as the discharge of dredged or fill material into the Columbia River, require permits under these U.S. Army Corps of Engineers and EPA regulations.
- WAC 173-160. Under WAC 173-160, DOE provides notification to Ecology for water-well drilling on the Hanford Site.
- WAC 173-216, “State Waste Discharge Permit Program.” Ecology regulations in WAC 173-216 establish a state permit program for the discharge of waste materials from industrial, commercial, and municipal operations into ground and surface waters of the state. Discharges covered by NPDES or WAC 173-218 permits are excluded from the WAC 173-216 program. DOE has agreed to meet the requirements of this program at the Hanford Site for discharges of liquids to the ground.
- WAC 332-30, “Aquatic Land Management.” Where applicable, DOE will obtain an aquatic land use lease or permit from the Washington Department of Natural Resources for the placement of structures in the Columbia River on lands owned by the State of Washington. The U.S. Government owns most of the riverbed along the Hanford Site to the line of navigation.
- WAC 246-272A and 246-272B. These regulations, administered by the Washington DOH, contain permit requirements for onsite sewage systems.
- WAC 246-290. These regulations, administered by the Washington DOH, contain requirements applicable to water systems providing piped water for human consumption.

6.2.3 Hazardous Waste Management

Regulation of hazardous wastes at Hanford is conducted under RCRA, CERCLA, the Tri-Party Agreement (Ecology et al. 1989), and the Washington State Hazardous Waste Management Act.

- 40 CFR 300, “National Oil and Hazardous Substances Pollution Contingency Plan.” EPA CERCLA regulations in 40 CFR 300 apply to the cleanup of inactive hazardous waste disposal sites, the cleanup of hazardous substances released into the environment, the reporting of hazardous substances released into the environment, and natural resource damage assessments. Four regions of the Hanford Site (the 100, 200, 300, and 1100 Areas) were listed on the EPA’s National Priorities List (NPL) in November 1989. The 1100 Area was subsequently delisted. Placement on the list requires DOE, in consultation with EPA and Washington State, to conduct remedial investigations and feasibility studies leading to a Record of Decision (ROD) on the cleanup of inactive waste disposal sites at Hanford.

Standards for cleanup under CERCLA are “applicable or relevant and appropriate requirements” (ARARs), which may include both federal and state laws and regulations. In anticipation of Hanford’s being placed on the NPL, DOE, EPA, and Ecology signed the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) on May 15, 1989. This agreement describes the cleanup responsibilities and authorities of the three parties under CERCLA (and RCRA) and also provides for permitting of the treatment, storage, and disposal of hazardous wastes under RCRA. The Tri-Party Agreement has been amended a number of times (http://www.hanford.gov/tpa/tpahome.htm).

- 40 CFR 260-268 and 270-272, Hazardous Waste Management. EPA RCRA regulations in 40 CFR 260-268 and 270-272 apply to the generation, transport, treatment, storage, and disposal of hazardous wastes (but not to source, by-product, or special nuclear material [i.e., not in general to radioactive wastes]) and apply to the hazardous component of hazardous radioactive mixed wastes (but not to the radioactive component) managed by DOE. RCRA regulations (40 CFR 268) require treatment of many hazardous wastes before they can be disposed of in landfills (land disposal restrictions). RCRA permits are required for the treatment, storage, or disposal of hazardous wastes. The regulations also require cleanup (corrective action) of any RCRA facility from which there is an unauthorized release before a RCRA permit is granted. Ecology has been authorized by EPA to administer the RCRA program within Washington. Ecology has oversight authority for RCRA corrective actions at Hanford under the Tri-Party Agreement.

- 40 CFR 280-281, Underground Storage Tanks. EPA has regulations in 40 CFR 280-281 issued under RCRA Subtitle IX that apply to new and existing underground storage tanks containing petroleum or substances regulated under CERCLA (except for hazardous wastes regulated under RCRA). New tanks must meet strict design and operating standards. Owners of new tanks must notify the applicable regulatory agency and certify compliance with the regulations. The regulations require the reporting, investigation, and cleanup of releases from underground tanks. EPA has authorized Washington State to administer the underground storage tank program. Washington’s requirements are in RCW 90.76 and WAC 173-360.

- WAC 173-303, “Dangerous Waste Regulations.” EPA has authorized the State of Washington through Ecology to conduct its own dangerous waste regulation program in lieu of major portions of the RCRA interim and final permit program for the treatment, storage, and disposal of hazardous wastes. Ecology is also authorized to conduct its own program for the hazardous portion of radioactive mixed wastes. The state regulations include both standards and permit requirements, as well as a larger universe of covered materials than the federal hazardous waste program.

6.2.4 Species Protection

- 50 CFR 10-24, 222-224, 402, and 450-453, Species Protection Regulations. Regulations under the Endangered Species Act, the Bald and Golden Eagle Protection Act, and the Migratory Bird Treaty Act in 50 CFR 10-24 apply to the protection of plant and animal species on the Hanford Site. Regulations in 50 CFR 17, 81, 222-224, 402, and 450-453 apply to endangered or threatened species. Section 7 of the Endangered Species Act (16 USC 1536) requires that federal agencies 1) utilize their authority in furtherance of the purposes of the Act by carrying out programs for the conservation of listed endangered and threatened species, and 2) consult with appropriate federal agencies to ensure that any action carried out is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat for such species. The Fish and Wildlife Coordination Act [16 USC 662(a, h)] requires that a federal agency consult with the U.S. Fish and Wildlife Service and the state agency exercising administration over wildlife if any body of water over 0.04 km^2 (0.016 mi^2) in size is to be modified by a federal agency, or a licensee or permitee of the agency, for any purpose. The purpose of this consultation is to prevent loss and damage to wildlife resources.

6.2.5 Historic and Cultural Resource Preservation

The DOE policy on management of cultural resources (DOE 2001) provides that:

> DOE will uphold [the NHPA, the Archaeological Resources Protection Act, and the Native American Graves Protection and Repatriation Act] by preserving, protecting, and perpetuating cultural resources for future generations in a spirit of stewardship to the extent feasible given the agency's mission and mandates. To do this, DOE will implement management accountability for compliance with federal statutes, executive orders, treaties, DOE orders, and implementation guidance. The Department also ensures that DOE contractors are obligated to implement DOE programs and projects in a manner that is consistent with this Policy and that reflects this commitment in site management contracts.

The background statement in "Management of Cultural Resources at Department of Energy Facilities" (DOE 2006) further states that:

> DOE recognizes the cultural and scientific value of the resources that may exist on the properties under its management or over which it has direct or indirect control. Therefore, DOE has implemented a program to protect these resources and ensure that all DOE facilities and programs comply with all existing cultural resource executive orders, laws, and regulations.

The DOE management document (DOE 2006) defines cultural resources to include "historic properties" as defined in the NHPA, "archaeological resources" as defined in the Archaeological Resources Protection Act of 1979 (16 USC 470aa), and "cultural items" as defined in the Native American Graves Protection and Repatriation Act.

The NHPA authorizes the Secretary of the Interior to maintain a National Register of Historic Places (16 USC 470a[a][1]). Federal agencies are to consider the effect of their actions on properties included in or eligible for inclusion in the Register and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment on such actions (16 USC 470f).

The Archaeological Resources Protection Act of 1979 prohibits the excavation of material remains of past human life that have archaeological interest and are at least 100 years old without a permit from the appropriate federal land manager or an exemption (16 USC 470bb, 470ee).

The Native American Graves Protection and Repatriation Act prohibits the intentional excavation or removal of human remains or cultural items without a written permit and prescribes protective measures and repatriative actions to be taken in the event that human remains or cultural items are discovered inadvertently (25 USC 3001 *et seq.*).

Additional information is available by contacting the DOE/RL Hanford Cultural and Historic Resources Program or by accessing the Hanford website at http://www.hanford.gov/doe/history/.

6.2.6 Land Use

In September 1999, DOE issued the Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement (DOE 1999). The ROD issued by DOE in November 1999 (64 FR 61615) states that the purpose of the land-use plan and its implementing policies is to facilitate decision making about the Hanford Site's uses and facilities over at least the next 50 years. The ROD adopts the Preferred Alternative land use maps, designations, policies, and implementing procedures as described in the 1999 EIS and designates the Central Plateau (200 Areas) for Industrial-Exclusive use. In November 1999, USFWS signed a Record of Decision documenting USFWS's adoption of the DOE's Final Comprehensive Land-Use Plan (64 FR 66928).

The Hanford Reach National Monument was created on June 9, 2000, by a proclamation (65 FR 37253) signed by President William J. Clinton under the authority of the Antiquities Act. The Monument includes 792.6 km^2 (306 mi^2) of federally owned land making up a portion of the Hanford Site. The principal components of the Monument are

- the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit,
- the McGee Ranch and Riverlands Unit,
- the Saddle Mountain National Wildlife Refuge Unit,
- the quarter-mile study strip along the south and west sides of the Columbia River corridor as designated by the Hanford Reach Study Act (Hanford Reach Study Act [1988] as amended by Public Law 104-333),
- the federally owned islands within the portion of the Columbia River included in the Monument,
- and the Hanford Sand Dune Field Unit.

The U.S. Fish and Wildlife Service (USFWS) manages approximately 67,000 ha (166,000 ac) of Monument lands that are within the Fitzner-Eberhardt Arid Lands Ecology Reserve Unit and the Wahluke Slope (Wahluke Unit and Saddle Mountain Unit) under permit from DOE. DOE manages the remainder of the Monument. The June 9, 2000, proclamation does not affect the responsibilities and authority of DOE on Hanford Site lands nor does it affect DOE activities on lands not included within the Monument boundaries. In a separate memorandum to the Secretary of Energy, DOE was directed by President Clinton to protect the natural values of the Hanford Site land not included within the Monument (Clinton 2000). DOE and USFWS signed a Memorandum of Understanding on June 14, 2001, covering management responsibilities for the Monument. USFWS issued the *Draft Hanford Reach National Monument Comprehensive Conservation Plan and Environmental Impact Statement* in 2006 (71 FR 74929).

Most of the Hanford Site managed by DOE is under the management of the DOE Office of Environmental Management (EM). In August 2004, management of approximately 130 acres in the southern most portion of the Hanford Site was re-assigned from EM to the DOE Office of Science (SC) (Rispoli 2007). In May 2007, DOE proposed to re-assign an additional 220 acres in the southern most portion of the Hanford Site from EM management to SC management (Rispoli 2007). The objective of the two land transfers was to facilitate the acquisition of replacement laboratories at the Pacific Northwest National Laboratory.

6.2.7 Other

- 40 CFR 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes." EPA regulations in 40 CFR 191 provide environmental standards for the management, storage, and disposal of spent nuclear fuel, high-level radioactive wastes, and transuranic radioactive wastes at high-level or transuranic waste disposal sites.

- 40 CFR 355, 370, and 372. These regulations implement the federal Emergency Planning and Community Right-to-Know Act (EPCRA). EPCRA was signed into law in October 1986 as part of the Superfund Amendments and Reauthorization Act. DOE policy is to comply with the Act (DOE 2003).

- 40 CFR 700-799, TSCA Regulations. EPA's regulations in 40 CFR 700-799 implement TSCA and, in particular, regulate polychlorinated biphenyls (PCBs) and dioxins and partially regulate asbestos.

- 40 CFR 1500-1508, Council on Environmental Quality. The CEQ regulations in 40 CFR 1500 to 1508 implement NEPA.

- 10 CFR 830, "Nuclear Safety Management." Part 830 contains nuclear safety management requirements applicable to DOE contractors.

- 10 CFR 835, "Occupational Radiation Protection." These DOE regulations establish radiation protection standards, limits, and program requirements for protecting individuals from ionizing radiation resulting from DOE activities.

- 10 CFR 1021, "National Environmental Policy Act Implementing Procedures." DOE regulations in 10 CFR 1021 set out procedures that DOE uses to comply with section 102(2) of NEPA and the CEQ regulations for implementing the procedural provisions of NEPA (40

CFR parts 1500-1508). The DOE regulations supplement, and are to be used in conjunction with, the CEQ regulations.

- 49 CFR 171-179, Hazardous Materials Regulations. These Department of Transportation regulations apply to the handling, packaging, labeling, and shipment of hazardous materials offsite, including radioactive materials and wastes.
- WAC 173-60, "Maximum Environmental Noise Levels." These regulations contain maximum permissible environmental noise levels in Washington. Additionally, the Occupational Safety and Health Administration (OSHA) has regulations covering noise exposure of occupational workers at 29 CFR 1910.95.

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6.3 Executive Orders

DOE is subject to a number of presidential executive orders (E.O.s) concerning environmental matters. Some of these orders may be appropriately considered in a Hanford EIS or EA. Potentially relevant E.O.s include:

E.O. 11514	Protection and Enhancement of Environmental Quality
E.O. 11593	Protection and Enhancement of the Cultural Environment
E.O. 11738	Providing for Administration of the Clean Air Act and the Federal Water Pollution Control Act with Respect to Federal Contracts, Grants, or Loans
E.O. 11988	Floodplain Management
E.O. 11990	Protection of Wetlands
E.O. 12088	Federal Compliance with Pollution Control Standards
E.O. 12114	Environmental Effects Abroad of Major Federal Actions
E.O. 12196	Occupational Safety and Health Programs for Federal Employees
E.O. 12580	Superfund Implementation
E.O. 12898	Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations
E.O. 12962	Recreational Fisheries
E.O. 13007	Indian Sacred Sites
E.O. 13045	Protection of Children from Environmental Health Risks and Safety Risks (as amended by E.O. 13296)
E.O. 13112	Invasive Species
E.O. 13150	Federal Workforce Transportation
E.O. 13175	Consultation and Coordination with Indian Tribal Governments
E.O. 13186	Responsibilities of Federal Agencies to Protect Migratory Birds
E.O. 13195	Trails for America in the 21st Century
E.O. 13287	Preserve America
E.O. 13423	Strengthening Federal Environmental, Energy, and Transportation Management

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6.4 DOE Directives

Categories of DOE directives include orders, policy statements, standards, notices, manuals, and contractor requirements documents.

DOE directives can be accessed at: http://www.directives.doe.gov/.

Directives with particular application to DOE's environmental activities are found in the 400 series of the new series directives and the 5000 series (particularly the 5400 and 5800 series) under the old series directives.

Topics covered in DOE directives include environmental protection, safety, and health protection standards; hazardous and radioactive-mixed waste management; cleanup of retired facilities; safety requirements for the packaging and transportation of hazardous materials; safety of nuclear facilities; radiation protection; and other standards for the safety and protection of workers and the public. Regulations and standards of other federal agencies and standard setting entities are incorporated by reference into some DOE directives.

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6.5 Treaties, Statutes, and Policies Relating to Indian Tribes of the Hanford Region

DOE's relationship with American Indians is based on treaties, statutes, executive orders, and DOE policy statements. Representatives of the United States negotiated treaties with leaders of various Columbia Plateau American Tribes and Bands in June 1855 at Camp Stevens in the Walla Walla Valley. The negotiations resulted in three treaties, one with the 14 tribes and bands of the group that would become the Confederated Tribes and Bands of the Yakama Nation, one with the three tribes that would become the Confederated Tribes of the Umatilla Indian Reservation, and one with the Nez Perce Tribe of Idaho. The U.S. Senate ratified the treaties in 1859. The three treaties are included in Appendix A of the *Final Hanford Comprehensive Land-Use Plan EIS* (DOE 1999). The negotiated treaties are as follows:

1. Treaty with the Walla Walla, Cayuse, etc. (June 9, 1855; 12 Stats. 945)
2. Treaty with the Yakama (June 9, 1855; 12 Stats. 951)
3. Treaty with the Nez Perce (June 11, 1855; 12 Stats. 957).

The Confederated Tribes and Bands of the Yakama Nation, Washington; the Confederated Tribes of the Umatilla Indian Reservation, Oregon; and the Nez Perce Tribe of Idaho are federally recognized tribes that are eligible for funding and services from the U.S. Bureau of Indian Affairs by virtue of their status as Indian tribes (72 FR 13648, March 22, 2007).

The terms of the three preceding treaties are similar. Each of the three tribal organizations agreed to cede large blocks of land to the United States. The Hanford Site is within the ceded lands of the Confederated Tribes and Bands of the Yakama Nation and the Confederated Tribes of the Umatilla Indian Reservation. The treaties reserved to the Tribes certain lands for their exclusive use (the three reservations). The treaties also secured to the Tribes certain rights and privileges to continue traditional activities outside the reservations. These included 1) the right to fish at usual and accustomed places in common with citizens of the United States, and 2) the privileges of hunting, gathering roots and berries, and pasturing horses and cattle on open and unclaimed lands.

The *U.S. Department of Energy American Indian and Alaska Native Tribal Government Policy* (DOE 2000) states, in part, that DOE

- Recognizes the federal trust relationship with American Indians and Alaska Native Nations and will fulfill its trust responsibilities to them
- Recognizes and commits to a government-to-government relationship and will institute appropriate protocols and procedures for program and policy implementation
- Complies with applicable federal cultural resource protection and other laws and executive orders and will assist in preservation and protection of historic and cultural sites and traditional religious practices.

DOE also has an Information Brief covering consultation with Native Americans (DOE 2004b).

The American Indian Religious Freedom Act (42 USC 1996) establishes that U.S. policy is to protect and preserve for American Indians their inherent rights of freedom to believe, express, and exercise their traditional religions, including access to sites, use and possession of sacred objects, and the freedom to worship through ceremonies and traditional rites.

The Native American Graves Protection and Repatriation Act establishes the right of lineal descendants, Indian Tribes, and Native Hawaiian organizations to certain Native American human remains, funerary objects, sacred objects, or objects of cultural patrimony discovered on federal lands after November 16, 1990 (25 USC 3002). When discovered during an activity on federal lands, the activity is to cease and appropriate tribal governments are to be notified. Work on the activity may resume, if the activity is otherwise lawful, 30 days after the receipt of certification that tribal governments have received the notice.

Executive Order 13007 "Indian Sacred Sites," (61 FR 26771, May 29, 1996) directs federal agencies, to the extent practicable, permitted by law, and not clearly inconsistent with essential agency functions, to 1) accommodate access to and ceremonial use of American Indian sacred sites by their religious practitioners, and 2) avoid adversely affecting the physical integrity of such sacred sites. Where appropriate, agencies are to maintain the confidentiality of sacred sites.

DOE/RL interacts and consults regularly and directly with the three federally recognized tribes affected by Hanford operations; that is, the Nez Perce Tribe of Idaho; the Confederated Tribes of the Umatilla Indian Reservation, Oregon; and the Confederated Tribes and Bands of the Yakama Nation, Washington. In addition, the Wanapum, who still live adjacent to the Hanford Site, are a non-federally recognized tribe that has strong cultural ties to the Site. The Hanford area was also used by groups whose descendants are now enrolled members of the Confederated Tribes of the Colville Reservation. The Wanapum and the Confederated Tribes of the Colville Reservation are also consulted on cultural resource issues in accordance with DOE policy and relevant legislation.

6.6 Permits

Information on the status of environmental permits at Hanford is included in the *Annual Hanford Site Environmental Permitting Status Report* (DOE 2004a). The report includes information on environmental permitting under RCRA; TSCA; CAA; CWA; the State Waste Discharge, Hydraulic Permit, and Underground Injection Control Programs; the Onsite Sewage System Program; and the Petroleum Underground Storage Tank Program.

The Hanford Site RCRA permit is in two portions, one portion issued by EPA Region 10 and the other portion issued by Ecology. The EPA portion of the RCRA permit covers the Hazardous and Solid Waste Amendments portion of the RCRA permit (EPA 1994). The Ecology portion of the Hanford Site RCRA permit covers compliance with Ecology's dangerous waste regulations (Ecology 2006a). The Ecology portion of the permit includes standard conditions, general facility conditions, and specific conditions for individual operating Treatment, Storage, and/or Disposal (TSD) units, TSD units undergoing corrective action, and TSD units undergoing closure.

Clean Air Act compliance requires both facility and sitewide compliance. The *Annual Hanford Site Environmental Permitting Status Report* (DOE 2004a) identifies existing facility-specific and sitewide CAA compliance activities. The air operating permit for the Hanford Site issued by Ecology became effective in July 2001 (Ecology 2001) and was renewed in December 2006 (Ecology 2006b).

The Hanford Site National Pollutant Discharge Elimination System Permit (WA-002591-7) governs liquid process effluent discharges to the Columbia River (DOE 2004a).

DOE has asserted a federally reserved water withdrawal right with respect to its Hanford operations. Current Hanford activities use water withdrawn under the DOE's federally reserved water rights.

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References

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