4.0 Affected Environment

The purpose of this section is to provide a description of the environment that might be affected by the alternatives discussed in Section 3. Because the Hanford Site is so large, the description includes much of the site itself, as well as the surrounding areas. Information used in this section was taken from the *Hanford Site National Environmental Policy Act (NEPA) Characterization Report* (Neitzel 2002a), unless otherwise noted.

The affected environment section includes the following:

- Land Use
- Meteorology and Air Quality
- Geology, Soils, and Seismology
- Hydrology
- Biology and Ecology
- Cultural Resources
- Socioeconomics
- Noise
- Occupational Safety
- Occupational Radiation Exposure.

4.1 Introduction

The focus of solid waste management activities related to the Hanford Solid (Radioactive and Hazardous) Waste Environmental Impact Statement (HSW EIS) is within the existing boundaries of the Hanford Site 200 Areas or at the Environmental Restoration and Disposal Facility (ERDF). Located on the Central Plateau (i.e., 200 Area Plateau) of the Hanford Site, the 200 East and 200 West Areas are approximately 8 and 11 km (5 and 7 mi), respectively, south and west of the Columbia River. The 200 Areas facilities were built to process irradiated fuel from the production reactors. Subsequent liquid wastes, produced as a result of the fuel processing, were placed in tanks or disposed of in cribs, ponds, or ditches in the 200 Areas. Treatment, storage, and disposal of solid wastes are accomplished in the 200 Areas.

The U.S. Department of Energy (DOE) Hanford Site (Figure 4.1) lies within the semi-arid Pasco Basin of the Columbia Plateau in southeastern Washington State. The site 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 measures approximately 50 km (31 mi) north to south and 40 km (25 mi) east to west. The major portion of this land, with restricted public access, provides a buffer for the smaller areas currently used for nuclear materials storage, waste storage, and waste disposal.

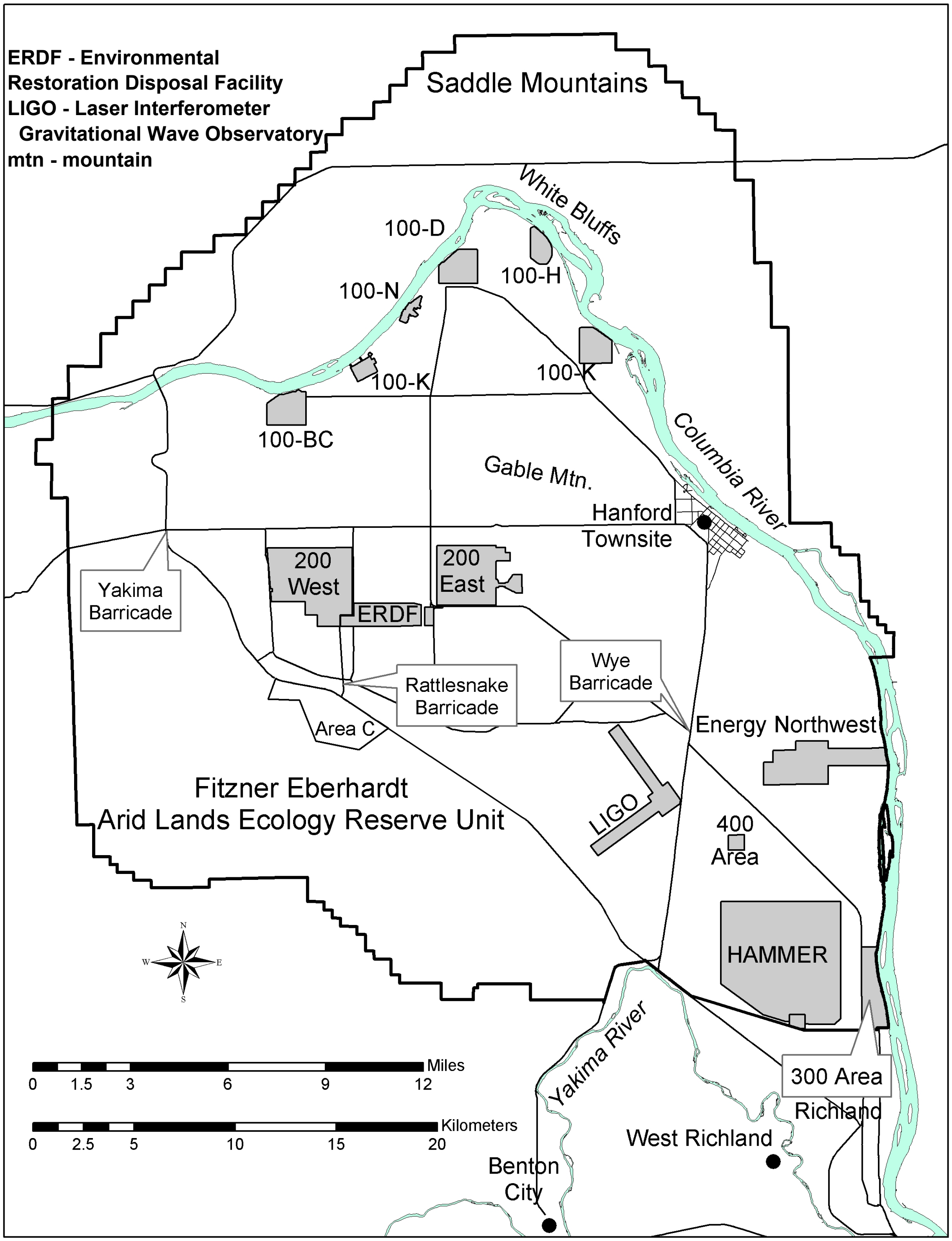


Figure 4.1. Department of Energy – Hanford Site (after Neitzel 2002a)

The Columbia River flows through the northern part of the Hanford Site and, turning south, forms part of the eastern site boundary. The Yakima River runs near the southern boundary of the Hanford Site, joining the Columbia River at the city of Richland that bounds the Hanford Site on the southeast. Rattle-snake Mountain, Yakima Ridge, and Umtanum Ridge form the southwestern and western boundaries. Saddle Mountain constitutes the northern boundary of the Hanford Site. Two small east-west ridges, Gable Butte and Gable Mountain, rise above the plateau in the central part of the Hanford Site. Adjoining lands to the west, north, and east are principally agricultural and rangeland. The cities of Kennewick, Pasco, and Richland (Tri-Cities) and the city of West Richland constitute the nearest population centers and are located south-southeast of the Hanford Site.

4.2 Land Use

DOE completed the Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS; DOE 1999) in September 1999. A Record of Decision (ROD) was issued on November 2, 1999 (64 FR 61615), which adopted the Preferred Alternative as discussed in the EIS. The purpose of this land-use plan and its implementing policies and procedures is to facilitate decision-making about Hanford Site uses and facilities over at least the next 50 years. The Preferred Alternative map from the Final HCP EIS ROD shown in Figure 4.2 represents the DOE future land-management values, goals, and objectives. The land-use plan consists of several key elements that are included in the DOE Preferred Alternative in the Final HCP EIS (DOE 1999). These elements include a land-use map that addresses the Hanford Site as five geographic areas—Wahluke Slope, Columbia River Corridor, Central Plateau, all other areas of the site, and the Fitzner/Eberhardt Arid Lands Ecology Reserve (ALE). The key elements of the Hanford Comprehensive Land-Use Plan include a map that depicts the planned future uses, a set of land-use designations defining the allowable uses for each area of the Hanford Site, and the planning and implementing policies and procedures that will govern the review and approval of future land uses. Together these four elements create the Hanford Comprehensive Land-Use Plan. Much of the land is undeveloped, providing a buffer area for the smaller operations areas. Public access to most facility areas is restricted.

The key features of the Hanford Site that form the basis for the five geographic areas used in the environmental impact analysis and land-use plans are summarized as follows:

Wahluke Slope. The area north of the Columbia River and the Hanford Site proper encompasses approximately 357 km^2 (138 mi^2) of relatively undisturbed or recovering shrub-steppe habitat managed by the U.S. Fish and Wildlife Service (FWS) for DOE. These lands consist of two overlay wildlife management units within the Hanford Reach National Monument/Saddle Mountain National Wildlife Refuge, the 130 km^2 (50 mi^2) Saddle Mountain Unit, and the 225 km^2 (87 mi^2) Wahluke Unit. Portions of the Saddle Mountain Unit, which is closed to public access, still serve as buffer areas for the Hanford Site. The Wahluke Unit is open to public recreational access. A small strip of land approximately 1.62 km^2 (0.63 mi^2) located between State Route (SR) 243 and the Columbia River west of SR 24 is managed by the Washington State Department of Fish and Wildlife.

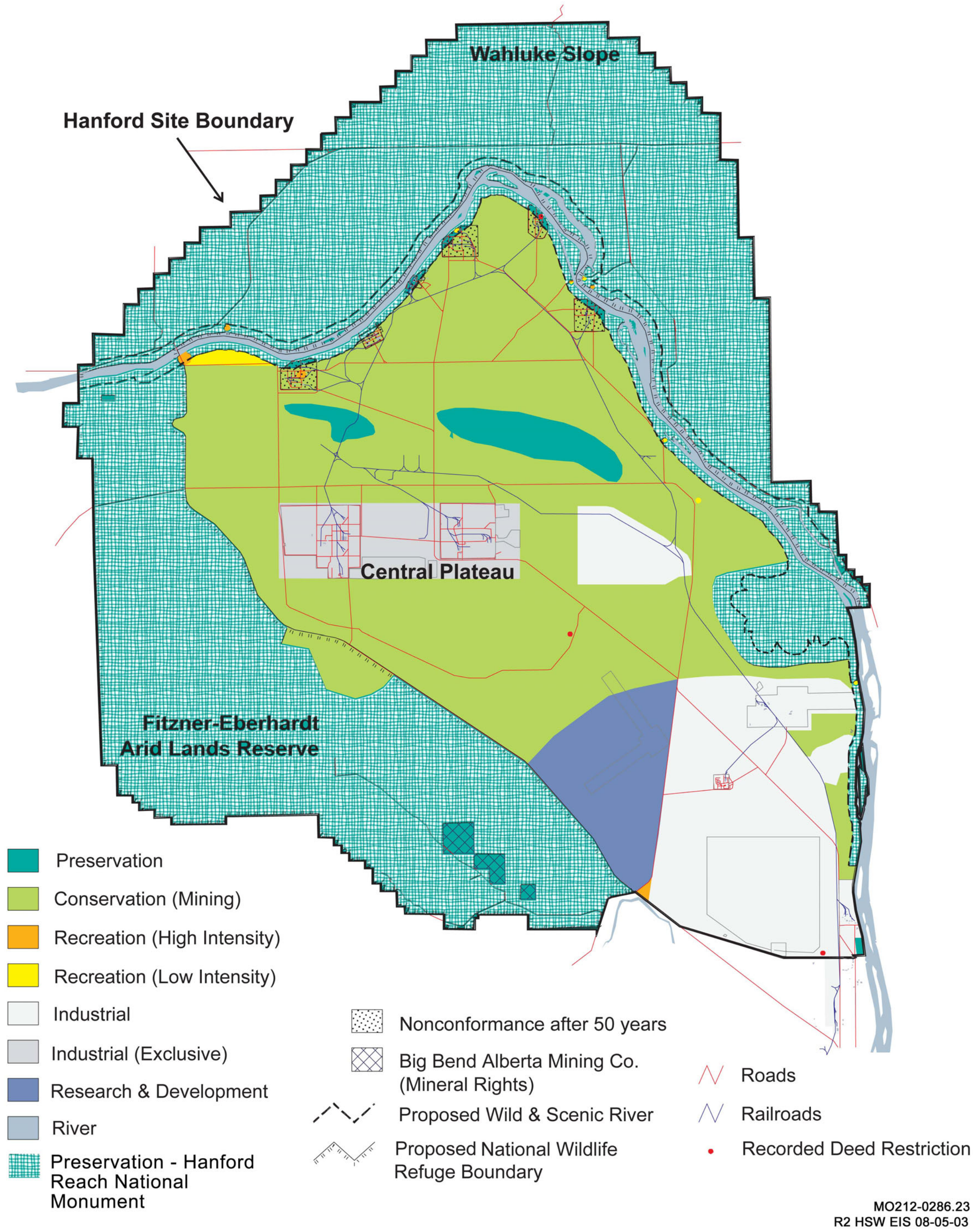


Figure 4.2. DOE Preferred Alternative for Land Use on the Hanford Site from the Final Hanford Comprehensive Land-Use Plan EIS Record of Decision (64 FR 61615)

Columbia River Corridor. The 111.6 km^2 (43.1 mi^2) Columbia River Corridor, which is adjacent to and runs through the Hanford Site, is used for boating, water skiing, fishing, and hunting of upland game birds and migratory waterfowl. Although public access is allowed on certain islands, access to other islands and adjacent areas is restricted because of unique habitats and the presence of cultural resources.

The area within the Columbia River Corridor known as the Hanford Reach includes a quarter mile (402-m) strip of land on either side of the Columbia River, as well as the islands and water surface area. Along the southern shoreline of the Columbia River Corridor, the 100 Areas occupy approximately 68 km^2 (26 mi^2). The facilities in the 100 Areas include nine retired plutonium production reactors, associated facilities, and structures. In the vicinity of the 100-H Area, closure permit restrictions of the Resource Conservation and Recovery Act (RCRA) of 1976 (42 USC 6901 et seq.) that are associated with the 183-H Solar Evaporation Basins have been instituted. Institutional controls are expected for the RCRA post-closure and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (42 USC 9601 et seq.) remediation areas.

Central Plateau. The 200 East and 200 West Areas occupy approximately 51 km^2 (19.5 mi^2) in the Central Plateau (the 200 Area Plateau) of the Hanford Site. Facilities located on the 200 Area Plateau were built to process irradiated fuel from the production reactors. The operation of these facilities resulted in the need for treatment, storage, and disposal facilities for radioactive and hazardous wastes. Unplanned releases of radioactive and non-radioactive waste have contaminated some parts of the 200 Areas. The U.S. Navy also uses Hanford nuclear waste treatment, storage, or disposal facilities. Institutional controls are expected for the Central Plateau.

A commercial LLW disposal facility, operated by US Ecology, Inc., currently occupies 0.4 km^2 (0.16 mi^2) of the 200 Area Plateau. The facility is located on a portion of the 100 ac (originally 1000 ac) leased by the State of Washington from the federal government and subleased to US Ecology, Inc.

All Other Areas. All Other Areas comprise 689 km^2 (266 mi^2) and contain the 300, 400, and 1100 Areas; Energy Northwest facilities; and a section (2.6 km^2 [1 mi^2]) of land currently owned by the State of Washington for the disposal of hazardous substances.

The Hanford 1100 Area and the Hanford railroad southern connection (from Horn Rapids Road to Columbia Center) have been transferred from DOE ownership to Port of Benton ownership to support future economic development. Although the 1100 Area is no longer under DOE control, it was included in the HCP EIS to support the local governments with their State Environmental Policy Act (SEPA) EIS analyses of the Hanford sub-area of Benton County under the State of Washington Growth Management Act (RCW 36.70A).

The 300 Area is located just north of the city of Richland and covers 1.5 km^2 (0.6 mi^2). The 300 Area is the site of former reactor fuel fabrication facilities and is also the principal location of nuclear research and development facilities serving the Hanford Site.

The 400 Area, located southeast of the 200 East Area, is the site of the Fast Flux Test Facility (FFTF). DOE has decided to permanently shut down this facility.

Energy Northwest currently operates Columbia Generating Station on land leased from DOE. The land is approximately 10 km (6 mi) north of the city of Richland. The land was leased for the operation of three nuclear power plants. Construction of two of the plants was halted. Other industrial options for the site are currently being considered. Under the terms of the lease agreements, DOE would need to approve alternative uses of the land.

In 1980, the federal government sold a 2.6 km^2 (1 mi^2) section of land (known as Section 1.0) south of the 200 East Area, near SR 240, to the State of Washington for the purpose of non-radioactive hazardous waste disposal. To date, this parcel has not been used for hazardous waste disposal. The deed requires that if it were used for any purpose other than hazardous waste disposal, ownership would revert to the federal government.

Additional activities in the All Other Areas include:

(1) *A specialized training center*: The Hazardous Materials Management and Emergency Response (HAMMER) Volpentest Training and Education Center is used to train hazardous materials response personnel. It is located north of the former 1100 Area and covers about 32 ha (80 ac).

(2) *A regional law-enforcement training facility*: The Hanford Patrol Training Academy, located adjacent to HAMMER, provides a range of training environments including classrooms, library resources, practice shoot houses, an exercise gym, and an obstacle course.

(3) *A national research facility*: The Laser Interferometer Gravitational Wave Observatory (LIGO), built by the National Science Foundation for scientific research, is designed to detect cosmic gravitational waves. The facility consists of two optical tube arms, each 4 km (2.5 mi) long, arrayed in an L shape, and is extremely sensitive to vibrations.

(4) *Fitzner/Eberhardt Arid Lands Ecology (ALE) Reserve Unit:* The 308.7 km^2 (119.2 mi^2) ALE, a Research Natural Area, is part of the Hanford Reach National Monument and is managed by the U.S. Fish and Wildlife Service (FWS). ALE is located in the southwestern portion of the Hanford Site and is managed as a wildlife reserve and environmental research area. The public is generally restricted from the reserve.

4.2.1 Hanford Reach National Monument

On June 9, 2000, portions of the Hanford Site including ALE, Saddle Mountain Wildlife Refuge, Wahluke Slope, White Bluffs, the sand dune area northwest of the Energy Northwest site, historic structures (including homesteads from small towns established along the riverbanks in the early 20th century), and land 0.4 km (¼ mi) inland on the south and west shores of the 82-km (51-mi) long Hanford Reach, the last free-flowing, non-tidal stretch of the Columbia River, were designated as a National Monument (Figure 4.3) by President Clinton (65 FR 37253). Also included in the 78,900-hectare

(195,000-acre) monument were the McGee Ranch and Riverlands areas and the federally owned islands within that portion of the Columbia River.

On June 14, 2001, U.S. Department of Energy, Richland Operation Office (DOE-RL) and the FWS signed an amended Memorandum of Understanding (MOU) addressing management responsibilities for the Hanford Reach National Monument. As a result of the MOU, the FWS is the lead agency in producing a Comprehensive Conservation Plan (CCP) for management of the Hanford Reach National Monument. Development of the CCP will be a public process, including input from local governments, Native American Tribes, stakeholders, and others, including a Federal Advisory Committee for the Hanford Reach National Monument. The DOE will participate in writing the CCP and, in cooperation with the FWS, approve the plan. Under the MOU, which is intended to remain in effect for 25 years, DOE and the FWS will produce agreements for site access, security, emergency preparedness, mutual assistance, wildland fire response, and cultural and biological resource management.

4.2.2 200 Areas

The focus of the HSW EIS is on waste storage, treatment, and disposal activities. For a description of the facilities, refer to Section 2. The Central Waste Complex (CWC) is located in the 200 West Area (Figure 4.4). Low-level waste (LLW), mixed low-level waste (MLLW), and transuranic (TRU) waste from onsite and offsite generators are stored in CWC pending treatment or disposal.

The Waste Receiving and Processing Facility (WRAP) is located in the 200 West Area. It began operations in 1997 and can process TRU waste, certify TRU waste and LLW for disposal, and provide limited treatment of MLLW. The 4,800 m^2 (52,000 ft^2) facility is located near the CWC, and is designed to process 6,800 drums and 70 boxes of waste annually for 30 years (Poston et al. 2001).

T Plant Complex, located in the northeast corner of the 200 West Area, consists of two major facilities: T Plant canyon and 2706-T Facility. T Plant Complex is used for waste verification, decontamination of equipment, repackaging of radioactive wastes, and storage of pressurized water reactor spent fuel from an offsite reactor. It is also capable of macroencapsulation of debris and contaminated equipment, and neutralization and repackaging of organic and inorganic lab packs. Twenty-seven metric tons (30 tons) of spent nuclear reactor fuel from Shippingport, Pennsylvania, stored at T Plant Complex, are being moved to the Hanford Canister Storage Building. DOE ultimately plans to ship this fuel to Yucca Mountain. K Basins sludge will be moved to T Plant and stored in cells.

The 200 Areas Effluent Treatment Facility (ETF), located in the 200 East Area (Figure 4.5), provides treatment and storage for hazardous and radioactive liquid waste. Liquid effluents are treated to remove metals, radionuclides, and ammonia, as well as to destroy organic compounds. The facility, in operation since 1995, is capable of treating 570 L (150 gal) per minute. Treated effluent is stored in verification tanks, sampled and analyzed, and discharged via pipeline to the State-Approved Land Disposal Site (SALDS), north of the 200 West Area or to the Treated Effluent Disposal Facility (TEDF) east of the 200 East Area (Poston et al. 2002).

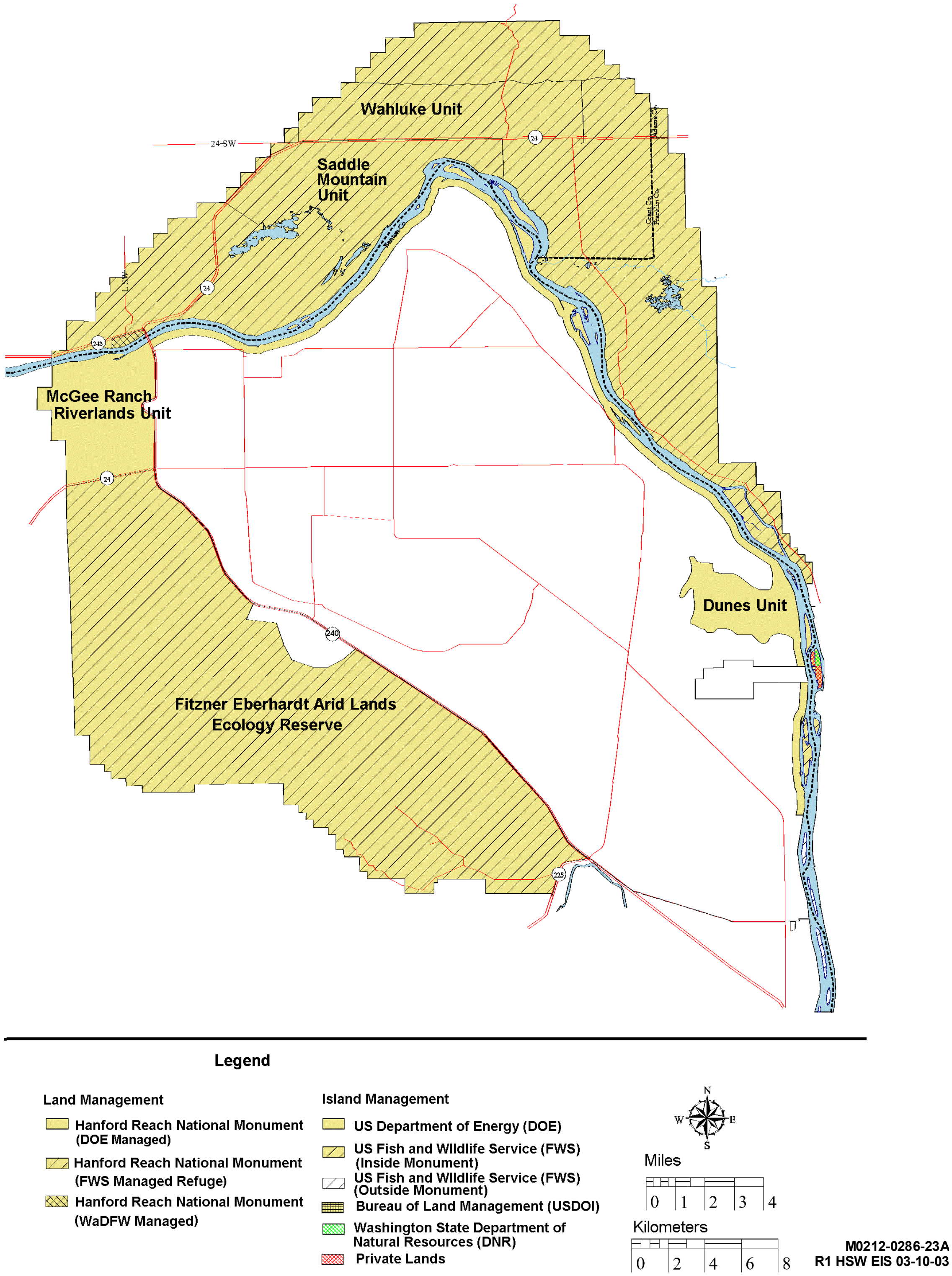


Figure 4.3. Hanford Reach National Monument

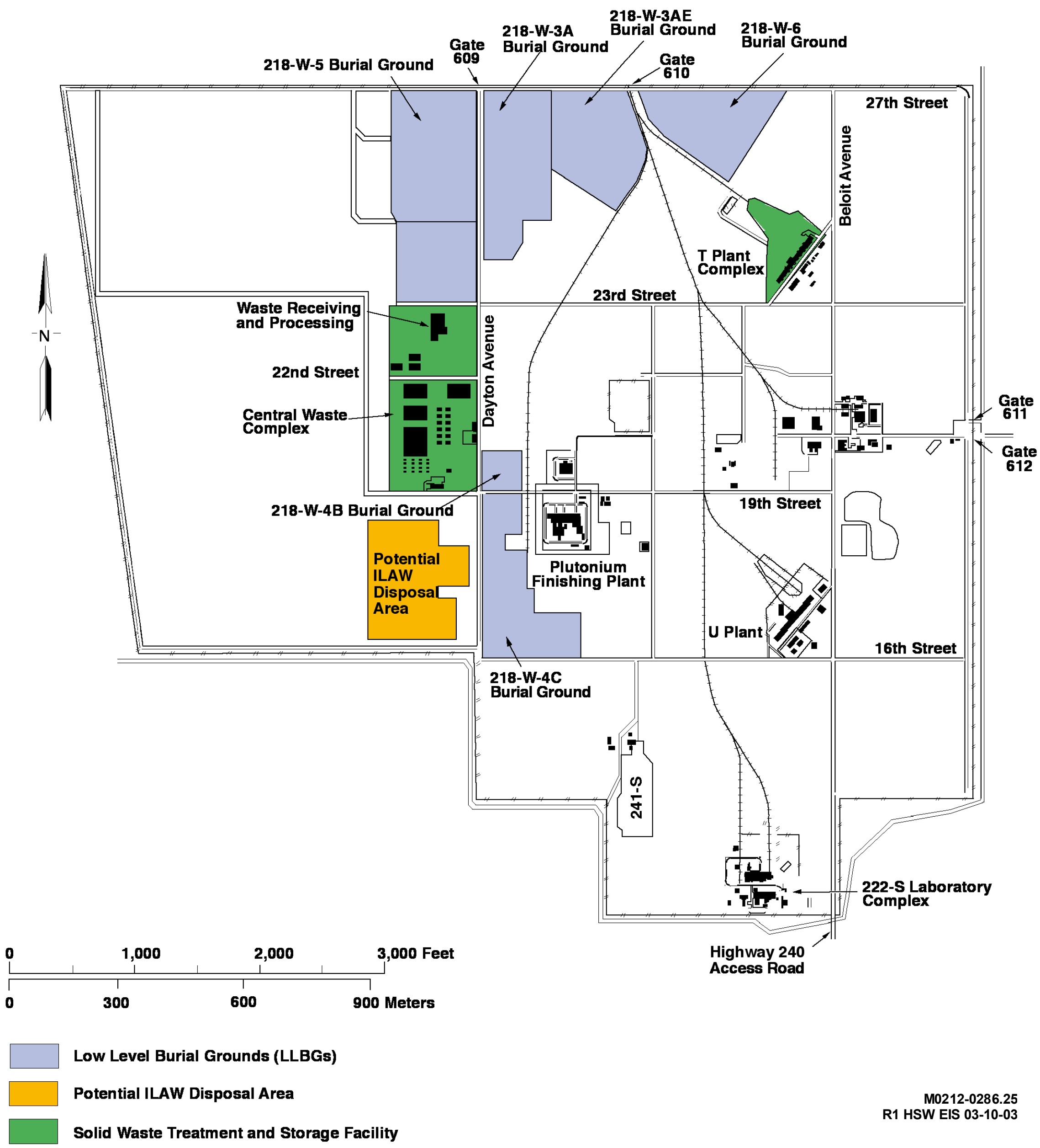


Figure 4.4. 200 West Area

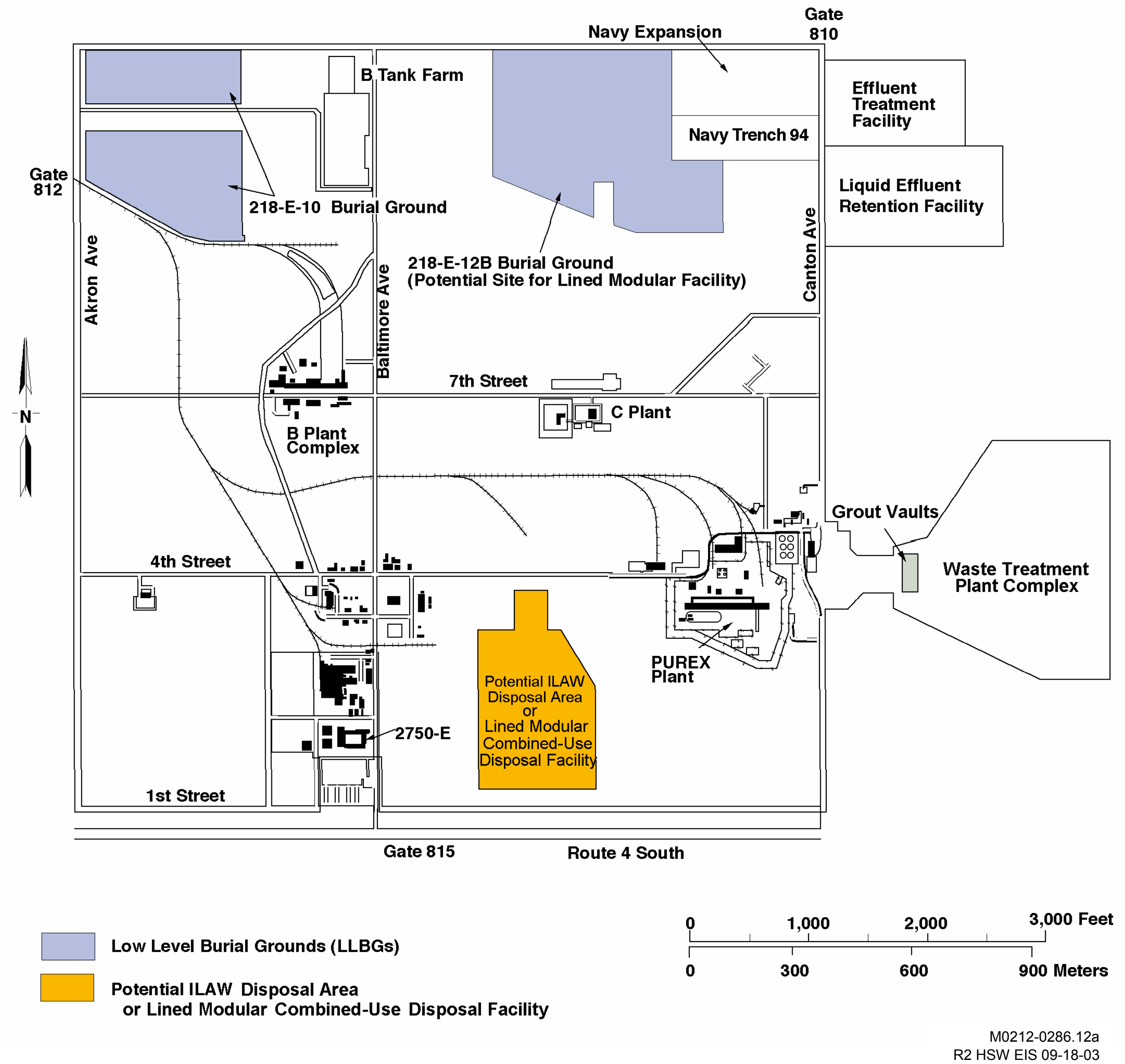


Figure 4.5. 200 East Area

The Liquid Effluent Retention Facility (LERF), located in the 200 East Area, consists of three surface impoundments for the temporary storage of process condensate from the 242-A Evaporator and other aqueous wastes. Each basin has a capacity of 29.5 million L (7.8 million gal) and is constructed of two flexible high-density polyethylene membrane liners. Beneath the secondary liner is a soil/bentonite barrier. Each basin is covered by a mechanically tensioned floating membrane cover, designed to minimize evaporation of the contents and screen unwanted material from entering the basin. The facility began operation in 1994 and receives liquid waste from the RCRA- and CERCLA-regulated cleanup activities.

The 200 Areas Treated Effluent Disposal Facility (TEDF) began operation in 1995 and is a collection and disposal system for permitted waste streams. TEDF has a capacity of 12,900 L/min (3,400 gal/min). Effluent to the ponds must meet drinking water standards before discharge.

The Low Level Burial Grounds (LLBGs) are eight separate waste disposal areas located in the 200 Areas. Information summarizing specifics concerning the LLBGs are found in Appendix D.

The Biological Control Program was established in 1999 to control the growth of deep-rooted vegetation over contaminated and potentially contaminated waste sites. Deep-rooted vegetation growing on or near contaminated waste sites can take up radionuclides and other contaminants into their roots and transport them to the surface. Those contaminants can subsequently spread outside controlled areas as the plants are eaten by animals or are transported by weather. As part of the Biological Control Program, herbicides are applied to kill deep-rooted plants and noxious weeds. The effectiveness of the program is directly related to the timeliness of herbicide application. Spraying herbicides is typically performed in all seasons of the year except deep winter, although the early spring application is most critical, as all later applications depend on it for effectiveness. The elimination of contaminated plant species reduces the number of potential mechanisms for spreading contaminants, as well as reducing biological uptake by insects, small mammals, and birds. Selective herbicides are sometimes applied to minimize deep-rooted vegetation, while allowing shallow-rooted vegetation to remain for erosion control and evapotranspiration (soil water removal). The 200 Areas, including some LLBGs, contain relatively small areas of surface contamination as a result of biotic intrusion by deep-rooted plants or burrowing animals. Surface contamination is present in three of the older LLBGs (218-E-10, 218-E-12B, and 218-W-3AE) and amounts to less than 0.1 ha (0.25 ac) of contaminated surface area compared to a total of about 100 ha (250 ac) in the 200 East and 200 West Areas. As part of the Biological Control Program, areas of underground contamination, such as the LLBGs, cribs, ponds, ditches, and inactive disposal sites, are cleaned up and stabilized as needed to prevent further spread of surface contamination. Areas of surface contamination are posted, monitored, and surveyed at least annually to document their radiological status. Personal protective clothing and special procedures are required for entry into these surface contamination areas. However, surveys of the 200 Area contaminated soil sites during 2001 indicated that radionuclide concentrations were below soil concentration limits established to protect onsite workers (Poston et al. 2002).

The Environmental Restoration Disposal Facility (ERDF) for CERCLA cleanup wastes is located in the 200 Area Plateau between the 200 East and 200 West Areas (Figure 4.1). It is used for the disposal of radioactive, hazardous, dangerous, and mixed wastes generated during waste management and remediation activities at the Hanford Site. ERDF began operation in July 1996 and currently consists of 4 cells, covering an area of approximately 20 ha (50 ac). Two cells received wastes until September 2000 and are no longer active. The third cell began receiving wastes in June 2000, and the fourth cell has not been used to date (Poston et al. 2002). Alternatives proposed in the HSW EIS include the use of a site near ERDF for disposal of operational wastes.

Alternatives for disposal of ILAW include newly constructed trenches on a site just south of the CWC (Figure 4.4), new trenches southwest of the Plutonium-Uranium Extraction (PUREX) Facility in the 200 East Area, or one of several potential combined-use disposal facilities (Figure 4.5).

Area C, a large polygonal area approximately 368 ha (909 ac) located adjacent to the south side of State Route (SR) 240 and centered approximately on the intersection of Beloit Avenue and SR 240, has been identified as a borrow-use area for the fine-grade silt loam and coarse-grade basalt needed to cap the LLBGs (Figure 4.1).

4.3 Meteorology and Air Quality

Air resources addressed in this section include climate and meteorology, atmospheric dispersion, and ambient air quality.

4.3.1 Climate and Meteorology

The Hanford Site is categorized as a mid-latitude semiarid region. Summers are warm and dry, while winters are cool with occasional precipitation. Intense heating during the day and nocturnal cooling produce large diurnal temperature variations. The Cascade Mountain range, beyond Yakima to the west, greatly influences the climate of the Hanford area by means of its rain shadow effect. The Cascade Mountains limit the Pacific Ocean maritime influence by blocking the passage of frontal systems and causing less rain and cloud-cover on the lee (east) side of the mountains. This mountain range also serves as a source of cold air drainage with a considerable effect on the wind regime at the Hanford Site.

Climatological data for the Hanford Site are compiled at the Hanford Meteorology Station (HMS). The HMS is located just outside the northeast corner of 200 West Area and about 4 km (3 mi) west of the 200 East Area. Data from the HMS are representative of the general climatic conditions for the region and describe the specific climate of the 200 Area Plateau. Meteorological measurements have been made at the HMS since late 1944. Prior to the establishment of the HMS, 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. (2002). To accurately characterize meteorological differences across the Hanford Site, the HMS operates a network of automated monitoring stations. These stations, which currently number 30, are located throughout the site and in neighboring areas (Figure 4.6). A 124-m (408-ft) instrumented meteorological tower operates at the HMS, Station 21. 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 utilize short-instrumented towers with heights of about 9 m (30 ft). Instrumentation on each tower is described in Table 4.1. Data are collected and processed at each monitoring site and key information is transmitted to the HMS every 15 minutes. This monitoring network has been in full operation since the early 1980s.

Wind. Wind data at the HMS are collected at 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 at 9.1 m (30 ft) above ground level.

Prevailing wind directions near the surface on the Hanford 200 Area Plateau are from the northwest in all months of the year (Figure 4.7). Winds from the northwest occur most frequently during the winter and summer. Winds from the southwest also have a high frequency of occurrence on the 200 Area Plateau. During the spring and fall, the frequency of winds from the southwest increases and winds from the northwest correspondingly decrease.

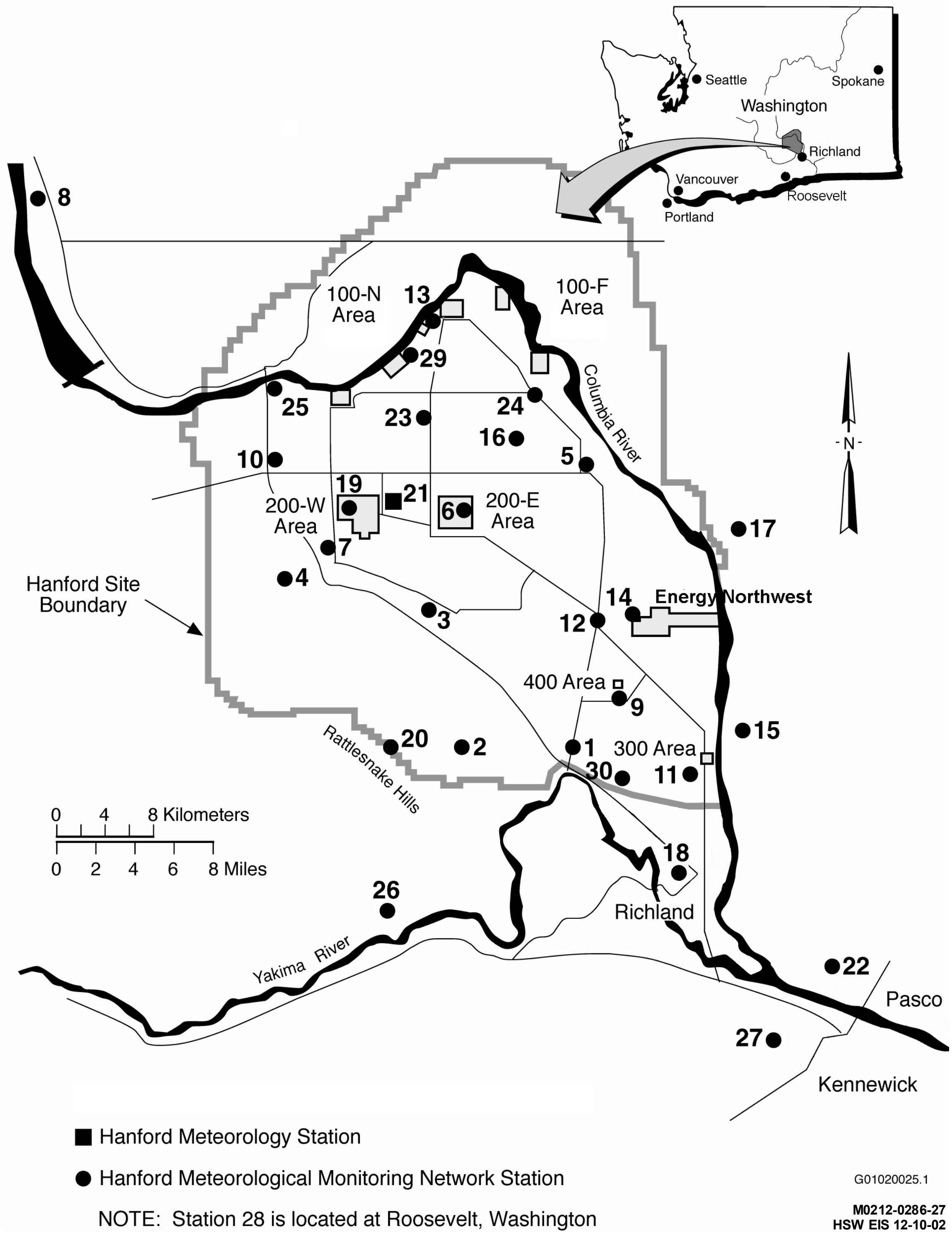


Figure 4.6. Hanford Meteorological Monitoring Network (after Hoitink et al. 2002)

Table 4.1. Station Numbers, Names, and Meteorological Parameters for Each Hanford Meteorological Monitoring Network Site (Hoitink et al. 2002)

Site Number	Site Name	Meteorological Parameter
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	WS, WD, T
6	200 East Area	WS, WD, T, P, AP
7	200 West Area	WS, WD, T, P
8	Beverly	WS, WD, T, P
9	Fast Flux Test Facility (61 m or 200 ft)	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 (Supply System)	WS, WD, T, P
15	Franklin County	WS, WD, T
16	Gable Mountain	WS, WD, T
17	Ringold	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 (125 m or 410 ft)	WS, WD, T, P, 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	WS, WD, T, P
27	Vista	WS, WD, T, P
28	Roosevelt, Washington[a]	WS, WD, T, P, AP
29	100-K Area	WS, WD, T, P, AP
30	HAMMER	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 site.

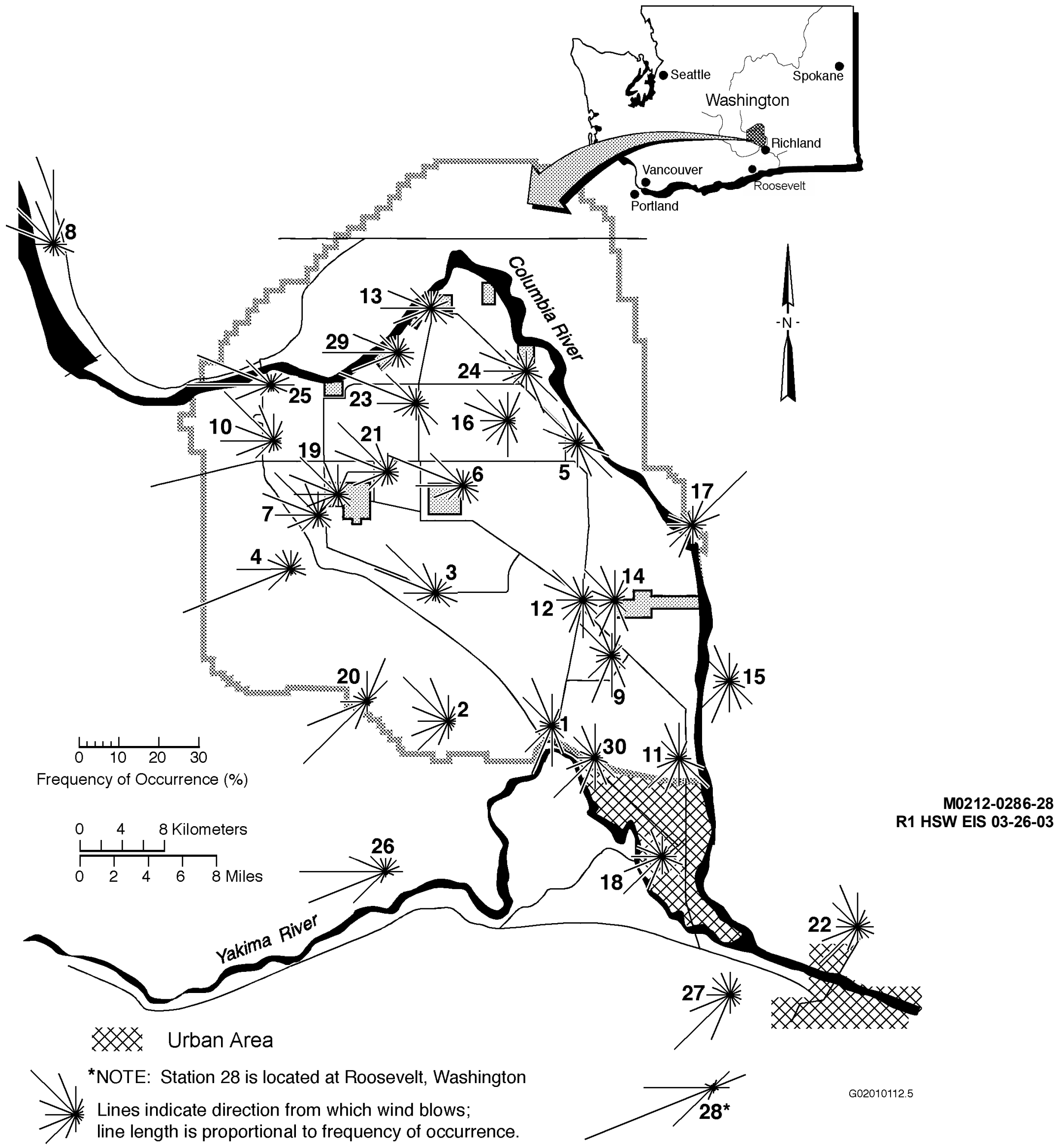


Figure 4.7. Wind Roses at the 9.1-m (30-ft) Level of the Hanford Meteorological Monitoring Network, 1982 to 2001 (after Hoitink et al. 2002)

Monthly and annual joint-frequency distributions of wind direction versus wind speed for the HMS are reported by Hoitink et al. (2002). Monthly average wind speeds at 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 highest during the summer, averaging 3.6 to 4.0 m/s (8 to 9 mph). The highest wind speeds at the HMS are usually associated with flow from the southwest. 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 toward the southeast across the Hanford Site.

Surface features have less influence on winds aloft than winds near the surface. However, substantial spatial variations are found in the wind distributions across Hanford at 61 m (200 ft) above ground level (Figure 4.8). 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.

Table 4.2 presents information on number of days, by month and annually, with wind gusts ≥11 m/s (25 mph) and 16 m/s (35 mph) for the HMS. Table 4.3 presents monthly and annual prevailing wind directions, average wind speeds, and peak wind gusts at the HMS, 1945 through 2001.

Temperature and Humidity. Monthly averages and extremes of temperature, dew point, and humidity are presented by Hoitink et al. (2002). Based on data collected from 1946 through 2001, 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 temperatures were 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 lowest summer monthly average temperature was 17.2°C (63°F) in June 1953. Ranges of daily maximum temperatures vary from an average of 2°C (35°F) in late December and early January to 36°C (96°F) in late July. The record maximum temperature is 45°C (113°F), and the record minimum temperature is -31°C (-23°F).

Relative humidity/dew point temperature measurements are made every 15 minutes at the 200 Area HMS (Station 21). 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).

Precipitation. Precipitation measurement records have been kept at the HMS since 1945. Average annual precipitation at the HMS is 17 cm (6.8 in.). In the wettest year on record, 1995, 31.3 cm (12.3 in.) of precipitation was measured; in the driest year, 1976, only 7.6 cm (3 in.) was measured. Most precipitation occurs during the late autumn and winter, with more than half of the annual amount occurring from November through February. Average snowfall ranges from 0.25 cm (0.1 in.) in October to a maximum of 13.2 cm (5.2 in.) in December and decreases to 0.8 cm (0.3 in.) in March. Snowfall accounts for about 38 percent of all precipitation from December through February.

Fog and Visibility. Fog has been recorded during every month of the year on the 200 Area Plateau; however, 89 percent of the occurrences are from November through February, with less than 3 percent from April through September. Fog is reported any time horizontal visibility is reduced to 9.6 km (6 mi) or less because of the suspension of water droplets in the surface layer of the atmosphere. Dense fog is reported when horizontal visibility is reduced to 0.4 km (0.25 mi) or less.

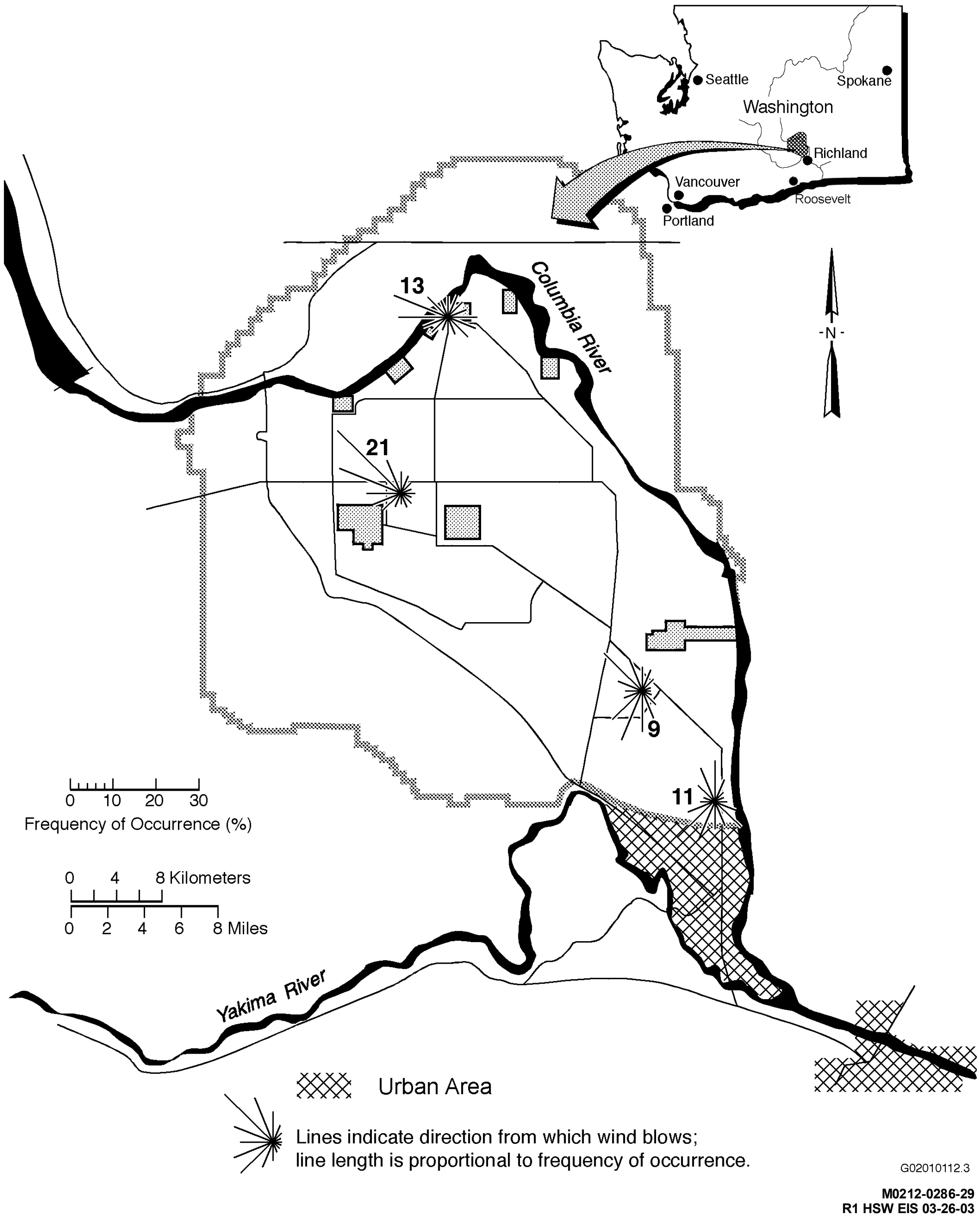


Figure 4.8. Wind Roses at the 60-m (197-ft) Level of the Hanford Meteorological Monitoring Network, 1986 to 2001 (after Hoitink et al. 2002)

Table 4.2. Number of Days with Peak Gusts Above Specific Thresholds at 15-m (50-ft) Level, 1945 through 2001 (Hoitink et al. 2002)

	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	7.6	21	1953	0	1985[a]	4.0	14	1953	0	1985[a]
February	8.6	17	1976[a]	2	1952[a]	3.7	14	1976	0	2001[a]
March	13.0	21	1977	4	1992	5.4	14	1997	0	1992
April	16.9	26	1954	8	1946	6.2	12	1972	1	1967
May	18.7	26	1978	9	1945	6.1	10	2000[a]	0	1957
June	19.6	26	1963	11	1950[a]	6.2	12	1973	1	1982
July	19.5	26	1995	11	1955	5.5	11	1994[a]	1	1982[a]
August	15.8	24	2000	7	1945	4.1	12	1996	0	1978[a]
September	11.1	17	1971	7	1975[a]	3.3	7	2001[a]	0	1975
October	8.9	17	1985[a]	3	1987[a]	3.2	11	1997	0	1993[a]
November	8.3	16	1990	0	1979	3.8	10	1998	0	1997[a]
December	7.6	15	1968	0	1985	4.3	11	1957	0	1985[a]
Annual	155.8	192	1999	123	1952	55.9	83	1999[a]	31	1978
(a) Most recent of multiple occurrences.										

Table 4.3. Monthly and Annual Prevailing Wind Directions, Average Speeds, and Peak Gusts at 15-m (50-ft) Level, 1945 through 2001 (Hoitink et al. 2002)

							Peak Gusts		
Month	**Prevailing Direction**	**Average Speed (mph)**	**Highest Average (mph)**	**Year**	**Lowest Average (mph)**	**Year**	**Speed (mph)**	**Direction**	**Year**
January	NW	6.3	10.3	1972	2.9	1985	80	SW	1972
February	NW	7.1	11.1	1999	4.6	1963	65	SW	1971
March	WNW	8.2	10.7	1977[a]	5.9	1958	70	SW	1956
April	WNW	8.8	11.1	1972[a]	7.4	1989[a]	73	SSW	1972
May	WNW	8.8	10.7	1983	5.8	1957	71	SSW	1948
June	NW	9.1	10.7	1983[a]	7.7	1950[a]	72	SW	1957
July	NW	8.6	10.7	1983	6.8	1955	69	WSW	1979
August	WNW	8.0	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	6.3	10.0	1990	2.9	1956	67	WSW	1993
December	NW	6.0	8.3	1968	3.3	1985	71	SW	1955
Annual	NW	7.6	8.8	1999	6.2	1989	80	SW	Jan-72
(a) Also in earlier years.									

Other phenomena causing restrictions to visibility (visibility less than or equal to 9.6-km [6 mi]) include dust, blowing dust, and smoke from field burning. Few such days occur; an average of 5 d/yr have dust or blowing dust and <1 d/yr has reduced visibility from smoke.

Severe Weather. The average occurrence of thunderstorms on the 200 Area Plateau is 10 per year. Using the National Weather Service (NWS) criteria for classifying a thunderstorm as severe (that is, hail with a diameter ≥19 mm [3/4 in.] or wind gusts of ≥25.9 m/s [58 mph]), only 1.9 percent of all thunderstorm events surveyed at the HMS have been "severe" storms, and they met the NWS 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. Estimates of the extreme winds, based on peak gusts, are given by Hoitink et al. (2002).

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://www.ncdc.noaa.gov/ol/climate/severeweather/extremes.html.) This database reports that in the 10 counties closest to the Hanford Site (Benton, Franklin, Grant, Adams, Yakima, Klickitat, Kittitas, and Walla Walla counties in Washington, Umatilla, and Morrow counties in Oregon), only 18 tornadoes were recorded from 1950 through March 2001. Of these, 12 tornadoes had maximum wind speeds estimated to be in the range of 18 to 32 m/s (40 to 72 mph), 3 had maximum wind speeds in the range of 33 to 50 m/s (73 to 112 mph), and 3 had maximum wind speeds in the range of 51 to 71 m/s (113 to 157 mph). No deaths or substantial property damage were associated with any of these tornadoes.

Ramsdell and Andrews (1986) report that for the area in which the Hanford Site is located (a 5° block centered at 117.5° west longitude and 47.5° north latitude), the expected path length of a tornado is 7.6 km (4.7 mi). The expected width is 95 m (312 ft), and the expected area is about 1.5 km^2 (0.6 mi^2). The estimated probability of a tornado striking any point at Hanford, also from Ramsdell and Andrews (1986), is 9.6 x 10^{-6}/yr. The probabilities of extreme winds associated with tornadoes striking a point can be estimated using the distribution of tornado intensities for the region. These probability estimates are given in Table 4.4.

Table 4.4. Estimate of the Probability of Extreme Winds Associated with Tornadoes Striking a Point at Hanford (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}

4.3.2 Atmospheric Dispersion

Atmospheric dispersion is defined as the transport and diffusion of gases and particles within the atmosphere. It is a function of wind speed, duration and direction of wind, mixing depth, and the intensity of atmospheric turbulence (wind motions at very small time scales that act to disperse gas and particles rather than transporting them downwind). Atmospheric turbulence is not measured directly 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 and wind speeds are low). When the atmosphere is unstable, pollutants can rapidly diffuse through a wide 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 are associated with stable conditions when inversions can trap pollutants near the ground.

Favorable dispersion conditions are most common in the summer when neutral and unstable stratification is present—about 56 percent of the time (Stone et al. 1983). Less favorable dispersion conditions may occur when the wind speed is light and the mixing layer is shallow. These conditions are most common during the winter, when moderately to extremely stable stratification is present, 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, extended periods of poor dispersion conditions are associated with stagnant air in the stationary high-pressure systems that occur primarily 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 hr 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 when the duration of the inversion is more than 12 hr. Table 4.5 summarizes the probabilities associated with extended surface-based inversions.

Many simple dispersion models use the joint frequency distribution of atmospheric stability, wind speed, and wind direction to compute diffusion factors for chronic and acute releases. Joint frequency distributions of atmospheric stability, wind speed, and transport direction for the measurements taken in the 200 Areas at 9.1 m (30 ft) and 60 m (197 ft) are found in Appendix F, Tables F.34 and F.35. The values in the joint frequency distributions represent the percentage of the time that pollutants would initially be transported toward the direction listed[a] (for example, S, SSW, SW).

(a) The transport direction and the wind direction are different methods of reporting the same basic information. Wind direction and transport direction are always out of phase by 180°.

Table 4.5. Percent Probabilities for Extended Periods of Surface-Based Inversions (based on data from Stone et al. 1972)

Months	Inversion Duration		
	12 hr	24 hr	48 hr
	Percent		
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

4.3.3 Air Quality

The U.S. Environmental Protection Agency (EPA) has issued regulations (40 CFR 50) setting national ambient air quality standards. Individual states have the primary responsibility for assuring that air quality within the state meets the national ambient air quality standards through state implementation plans (SIP) that are approved by EPA. Areas that meet ambient air quality standards are said to be in attainment. Areas that do not meet one or more ambient air quality standards are designated as non-attainment areas. The Hanford Site is in attainment or unclassified with respect to national ambient air quality standards (40 CFR 81.348). Table 4.6 summarizes the relevant air quality standards (federal and supplemental Washington State standards). The nearest non-attainment areas to the Hanford Site are the Wallula area, located approximately 30 km (20 mi) southeast of the site, and Yakima, located approximately 70 km (44 mi) east of the site. Wallula and Yakima are non-attainment areas for PM_{10} (40 CFR 81.348).

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 quality standards for sulfur oxides (measured as sulfur dioxide), nitrogen dioxide, carbon monoxide, particulates with an aerodynamic diameter less than or equal to a nominal 10 micrometers (PM_{10}) and 2.5 micrometers ($PM_{2.5}$), lead, and ozone. The standards specify the maximum pollutant concentrations and frequencies of occurrence that are allowed for specific averaging periods. The averaging periods vary from 1 hr to 1 yr, depending on the pollutant.

Table 4.6. Federal and Washington State Ambient Air Quality Standards[a] (after Neitzel 2002a)

Pollutant	National Primary	National 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}			
Annual arithmetic mean	50 μg/m^3	50 μg/m^3	50 μg/m^3
24-hr average	150 μg/m^3	150 μg/m^3	150 μg/m^3
$PM_{2.5}$			
Annual arithmetic mean	15 μ/m^3	15 μg/m^3	NS
24-hr average	65 μg/m^3	65 μg/m^3	
Sulfur Dioxide			
Annual average	0.03 ppm	NS	0.02 ppm
	(≅80 μg/m^3)		(≅50 μg/m^3)
24-hr average	0.14 ppm	NS	0.10 ppm
	(≅365μg/m^3)		(≅260 μg/m^3)
3-hr average	NS	0.50 ppm	NS
		(≅1.3 mg/m^3)	
1-hr average	NS	NS	0.40 ppm
			(≅1.0 mg/m^3)[c]
Carbon Monoxide			
8-hr average	9 ppm	9 ppm	9 ppm
	(≅10 mg/m^3)	(≅10 mg/m^3)	(≅10 mg/m^3)
1-hr average	35 ppm	35 ppm	35 ppm
	(≅40 mg/m^3)	(≅40 mg/m^3)	(≅40 mg/m^3)
Ozone			
8-hr average	0.08 ppm	0.08 ppm	NS
	(~157 μg/m^3)	(~157 μg/m^3)	
1-hr average	0.12 ppm	0.12 ppm	0.12 ppm
	(≅235 μg/m^3)	(≅235 μg/m^3)	(≅235 μg/m^3)
Nitrogen Dioxide			
Annual average	0.053 ppm	0.053 ppm	0.053 ppm
	(≅100 μg/m^3)	(≅100 μg/m^3)	(≅100 μg/m^3)
Lead			
Quarterly average	1.5 μg/m^3	1.5 μg/m^3	1.5 μg/m^3
Radionuclides	[d]	NS	[e]
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 microgram (or milligram) per cubic meter.

(b) NS = no standard.

(c) 0.25 ppm not to be exceeded more than twice in any 7 consecutive days (WAC 246-247; 40 CFR 61).

(d) Emissions of radionuclides to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr (40 CFR 61 Subpart H).

(e) Emissions of radionuclides in the air shall not cause a maximum accumulated dose equivalent of more than 25 mrem/yr to the whole body or 75 mrem/yr to a critical organ of any member of the public (WAC 173-480) or a TEDE of 10 mrem/yr (40 CFR 61 Subpart H; WAC 267-247), whichever is more stringent. Doses due to radon-220, radon-222, and their respective decay products are excluded from these limits.

In 1994, DOE and EPA signed the Federal Facility Compliance Agreement for Radionuclides National Emission Standards for Hazardous Air Pollutants (NESHAPs) (EPA 1994). This agreement provides a compliance plan and schedule designed to bring the Hanford Site into compliance with Clean Air Act requirements under 40 CFR 61, Subpart H, for the continuous measurement of emissions from applicable airborne emissions sources. The Hanford Site air emissions are below the regulatory standard of 10 mrem/yr (Poston et al. 2002). Radioactive air emissions are also regulated by Washington State. Hanford Site radionuclide air emissions are below limits set forth by permits issued by the State of Washington (Table 4.6).

State and local governments have the authority to impose standards for ambient air quality that are stricter than the national standards. Washington State has established more stringent standards for sulfur dioxide (WAC 173-474). In addition, Washington State has established standards for total suspended particulates (Washington State Administrative Code [WAC 173-470]), radionuclides (WAC 246-247), and fluorides (WAC 173-481). The Washington State standards for carbon monoxide, nitrogen dioxide, PM_{10}, and lead are identical to the national standards. The Hanford Site is in compliance with the Washington State ambient air quality standards (see Table 4.6).

4.3.3.1 Emissions of Non-Radiological Pollutants

Non-radiological pollutants are emitted mainly from power-generating and chemical-processing facilities located on the Hanford Site. Table 4.7 summarizes the year 2001 airborne emission rates of non-radiological constituents from these facilities. The 100, 400, and 600 Areas have no non-radioactive emission sources of regulatory concern (Poston et al. 2002).

4.3.3.2 Radiological Air Quality

Air emissions that may contain radioactive constituents are monitored at the Hanford Site. Samples are analyzed for gross alpha and gross beta activity, as well as for selected radionuclides.

Radioactive airborne emissions during 2001 (the most recent year for which data are published) originated in the 100, 200, 300, 400, and 600 Areas. The 100 Area emissions originated from normal evaporation from K Basins (irradiated fuel stored in two water-filled storage basins), the Cold Vacuum Drying Facility in the 100-K Area, and a low-level radiochemistry laboratory. The 200 Area emissions originated from the Plutonium Finishing Plant, T Plant Complex, 222-S Laboratory, tank farms, waste evaporators, and the inactive PUREX Plant. Emissions from the 300 Area originated from the 324 Waste Technology Engineering Laboratory, 325 Applied Chemistry Laboratory, 327 Post-Irradiation Laboratory, and 340 Vault and Tanks. The 400 Area emissions originated from the FFTF, and the Maintenance and Storage Facility. Emissions from the 600 Area originated at the Waste Sampling and Characterization Facility. Releases from this facility are considered as being in the 200 West Area for release and dose-modeling purposes (Poston et al. 2002). A summary of radiological air emissions is provided in Table 4.8.

Table 4.7. Non-Radioactive Constituents Emitted to the Atmosphere for the Year 2001 (Poston et al. 2002)

Constituent	Emission, kg (lb)	
	200 Areas	300 Area
Particulate matter	790 (1,742)	610 (1,345)
Nitrogen oxides	25,000 (55,115)	4500 (9921)
Sulfur oxides	2700 (5952)	35 (77)
Carbon monoxide	17,000 (37,478)	11,000 (24,251)
Lead	0.47 (1.0)	0.0 (0.0)
Volatile organic compounds[a, b]	5800 (12,787)	700 (1543)
Ammonia[c]	12,000 (26,455)	NE[d]
Other toxic air pollutants[c]	2600 (5732)	NE

(a) The estimate of volatile organic compound emissions does not include emissions from certain laboratory operations.
(b) Produced from burning fossil fuels for steam generation and electrical generators, calculated estimates from the 200 East and 200 West Area tank farms, and operation of the 242-A Evaporator and the 200 Areas Effluent Treatment Facility.
(c) Releases are from the 200 East Area tank farms, 200 West Area tank farms, and operation of the 242-A Evaporator, and the 200 Areas Effluent Treatment Facility.
(d) NE = no emissions.

The potential air pathway dose from stack emissions to a maximally exposed individual was calculated to be 0.048 mrem/yr, which represents less than 0.5 percent of the EPA standard (Poston et al. 2002).

4.3.4 Background Radiation

For the year 2001, the average external dose rate near the Hanford Site boundary was measured at 91 ± 4 mrem/yr using thermoluminescent dosimeters (Poston et al. 2002). Similarly for communities nearby the site, such as Richland, Pasco, Kennewick, Mattawa, Othello, Basin City, and Benton City, the average dose rate was measured at 80 ± 3 mrem/yr. The average external dose rate measured for distant communities, such as Toppenish and Yakima, was 72 ± 2 mrem/yr. The national average for external radiation dose from naturally occurring sources is about 55 mrem/yr (NCRP 1987), but it varies substantially with elevation and geological conditions. At a given location, the annual variation in external dose rate is on the order of 5 mrem. External radiation is but one part of total effective dose equivalent received from naturally occurring sources. The information presented here are representative of the external dose rate, excluding radon and presence of radionuclides internal to the body. Naturally occurring sources of ionizing radiation include primordial radionuclides, such as potassium-40 and the uranium series; cosmogenic radionuclides, such as carbon-14 and tritium; and cosmic radiation. The radionuclides are present in varying amounts in nearly all media including soil, air, water, food, biota, and humans.

Table 4.8. Radionuclides Emitted to the Atmosphere at the Hanford Site, 2001 (Poston et al. 2002)

Radionuclide	Half-Life in Years	Emission, Ci [a]				
		100 Areas	200 East Area	200 West Area	300 Area	400 Area
Tritium (as HT)[b]	12.3 yr	NM[c]	NM	NM	8.9E+01	NM
Tritium (as HTO)[b]	12.3 yr	NM	NM	NM	2.4E+02	3.1E-01
Cobalt-60	5.3 yr	3.0E-08	ND[d]	ND	ND	NM
Strontium-90	29.1 yr	9.0E-06	1.2E-04[e]	1.4E-04[e]	2.8E-05[e]	NM
Technetium-99	2.13×10^5 yr	NM	NM	NM	ND	NM
Antimony-125	2.77 yr	ND	ND	ND	ND	NM
Iodine-129	1.6×10^7 yr	NM	8.4E-04	NM	NM	NM
Cesium-137	30 yr	2.1E-05	1.2E-04	5.5E-05	3.7E-06	7.5E-06[f]
Uranium-234	2.4×10^5 yr	NM	NM	NM	1.5E-10	NM
Uranium-238	4.5×10^9 yr	NM	NM	NM	3.3E-11	NM
Plutonium-238	87.7 yr	1.5E-07	4.4E-08	4.5E-06	7.7E-09	NM
Plutonium-239, 240	2.4×10^4 yr	1.2E-06	2.1E-06[g]	2.6E-04[g]	1.9E-07[g]	6.9E-07[g]
Plutonium-241	14.4 yr	1.2E-05	3.1E-06	1.4E-04	NM	NM
Americium-241	432 yr	9.5E-07	2.6E-06	4.2E-05	2.5E-08	NM
Americium-243	7380 yr	NM	NM	NM	ND	NM

(a) 1 Ci = 3.7 E+10 Bq;
(b) HTO = tritiated water vapor; HT = elemental tritium.
(c) NM = not measured;
(d) 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).
(e) This value includes gross beta release data. Gross beta and unspecified beta results assumed to be strontium-90 for dose calculations.
(f) This value includes gross alpha release data. Gross alpha and unspecified alpha results assumed to be plutonium-239/240 for dose calculations.
(g) Analyses were conducted for gross alpha activity, but none was detected. If detected, it would have been assumed to be plutonium-239/240 for dose calculations.

4.4 Geologic Resources

Geologic considerations for the Hanford Site include topography and geomorphology, stratigraphy, soil characteristics, and seismicity. This section, which provides an overview of the Hanford Site subsurface environment, focuses primarily on the 200 Area Plateau, located in the center of the site.

4.4.1 Topography and Geomorphology

The sites associated with the Hanford Solid Waste Program are located on a broad flat area of the Hanford Site commonly referred to as the Central Plateau. The Central Plateau is within the Pasco Basin, a topographic, structural depression in the southwest corner of the Columbia Basin physiographic subprovince. This subprovince is characterized by generally low-relief hills with deeply carved river drainage. The elevation of the Central Plateau is approximately 200 m (650 ft) to 230 m (750 ft) above mean sea level. The Plateau decreases in elevation to the north, northwest, and east toward the Columbia River. Plateau escarpments have elevation changes of 15 m (50 ft) to 30 m (100 ft). The Pasco Basin is an area of generally low relief ranging from 120 m (390 ft) above mean sea level at the Columbia River level, to 230 m (750 ft) above mean sea level in the 200 East Area. The Pasco Basin is bounded on the north by the Saddle Mountains; on the west by Umtanum Ridge, Yakima Ridge, and the Rattlesnake Hills; on the south by Rattlesnake Mountain and the Rattlesnake Hills; and on the east by the Palouse Slope. The Pasco Basin is shown in Figure 4.9.

Surface topography at the Hanford Site is the result of the uplift of anticlinal ridges, Pleistocene cataclysmic flooding, Holocene eolian activity, and landslides (Delaney et al. 1991). Uplift of the ridges began in the Miocene Epoch (24 to 5 million years ago), concurrent with the eruption of the flood basalts. Cataclysmic flooding occurred when glacial ice dams in western Montana and northern Idaho were breached, allowing large volumes of water to spill across eastern and central Washington State.

Much of the landscape in the path of the floodwater was stripped of sediments and basalt bedrock was scoured, forming scabland topography (elevated areas underlain by flat-lying basalt flows that generally exhibit deep, dry channels scoured into the surface). The last major flood occurred approximately 13,000 years ago during the late Pleistocene Epoch. Since then, winds have locally reworked the flood sediments, depositing dune sands in the lower elevations and loess (windblown silt) around the margins of the Pasco Basin. Anchoring vegetation has stabilized many sand dunes. Where human activity or natural events have disturbed this vegetation, dunes have been reactivated. For example, dunes have been reactivated by the removal of vegetation as a consequence of a large wildfire that occurred on the Hanford site in July 2000.

The 200 Areas are situated between the Gable Mountain anticline and the Cold Creek syncline. The Gable Mountain anticline is of particular importance to the groundwater flow. Portions of this anticline have been uplifted to a point where basalt is above the current water table. These basalts have a low hydraulic conductivity and act as a barrier to horizontal groundwater flow in the unconfined aquifer.

4.4.2 Stratigraphy

The stratigraphy of the Hanford Site consists of Miocene-age and younger rocks. Older Cenozoic sedimentary and volcaniclastic rocks underlying the Miocene rocks are not exposed at the surface. Figure 4.10 summarizes the Hanford Site stratigraphy. A generalized west to east cross-section depicting site structure and topography is shown as Figure 4.11.

Over 100 basalt flows of the Columbia River Basalt Group, with a total thickness exceeding 3000 m (10,000 ft), lie beneath the Hanford Site. Interbedded between many of these basalt flows are sedimentary rocks of the Ellensburg Formation, a series of sand, gravel, or silt layers that were deposited by the ancestral Columbia River system. Sediments up to 230 m (750 ft) thick overlie the Columbia River Basalt Group, and include the Ringold and Hanford formations. Thin, laterally discontinuous

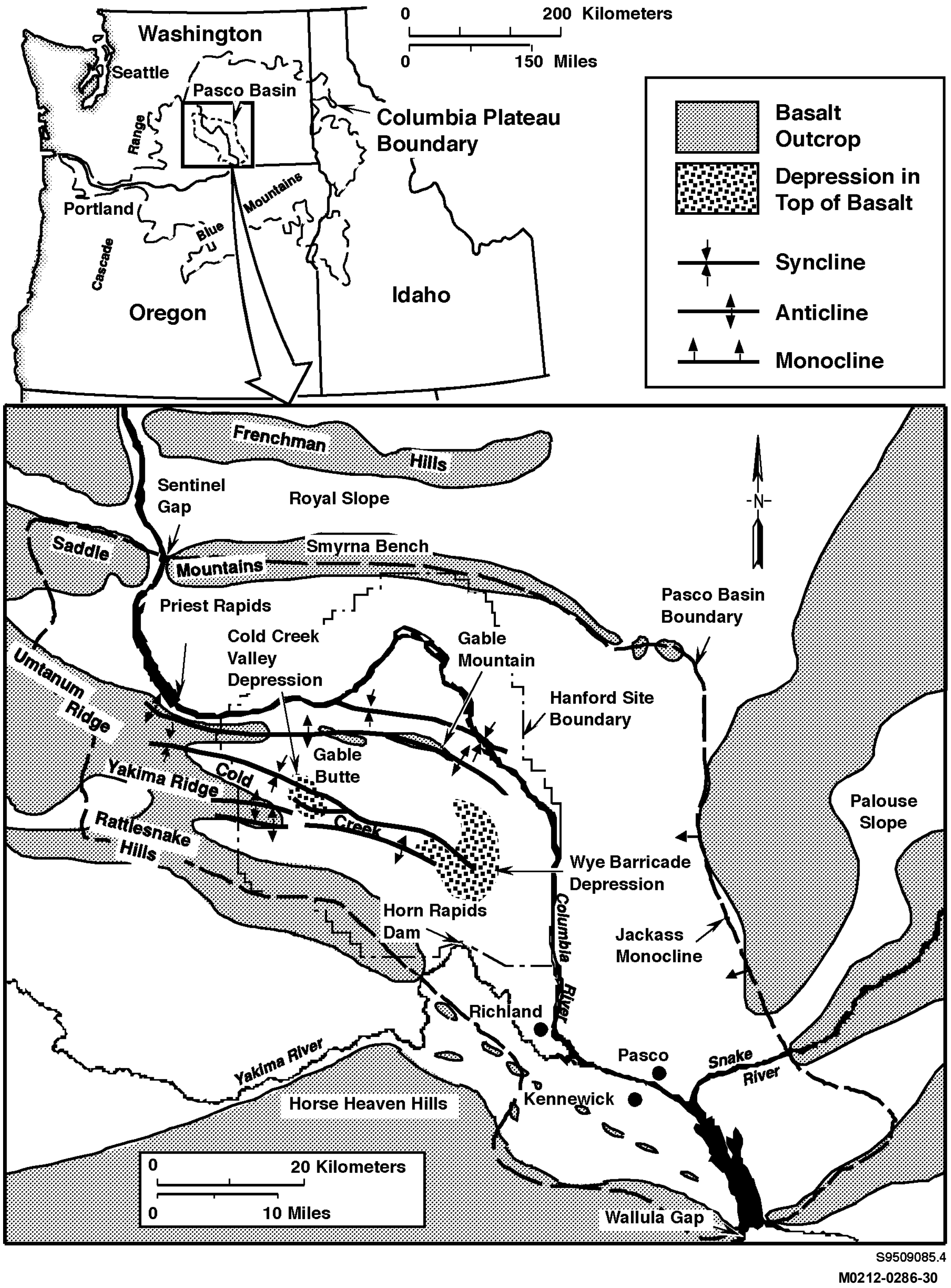


Figure 4.9. Geographic Setting and General Structural Geology of the Pasco Basin and Hanford Site (Bergstrom et al. 1983)

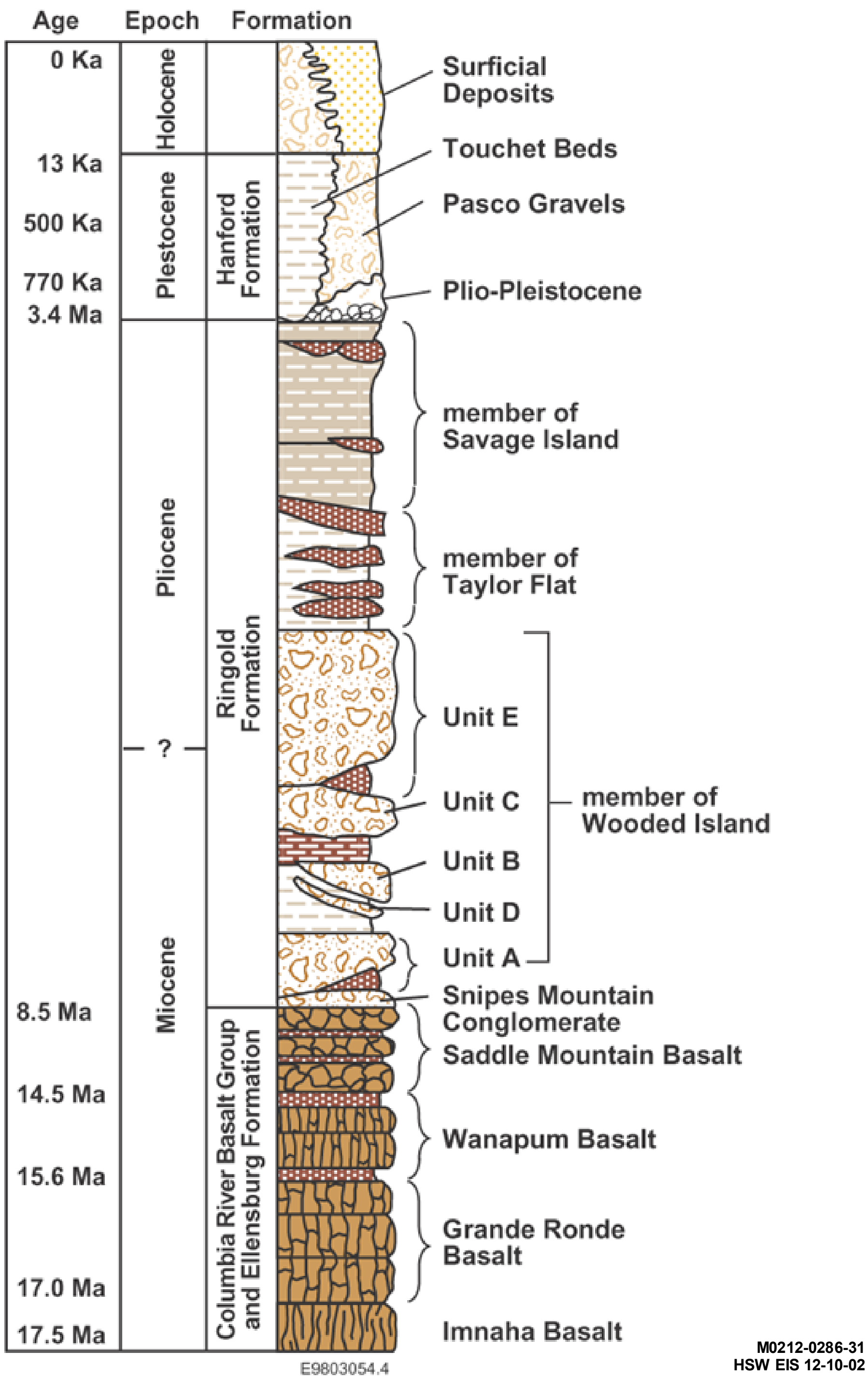


Figure 4.10. Stratigraphic Column for the Hanford Site (Reidel et al. 1992; Ka = thousand years; Ma = million years)

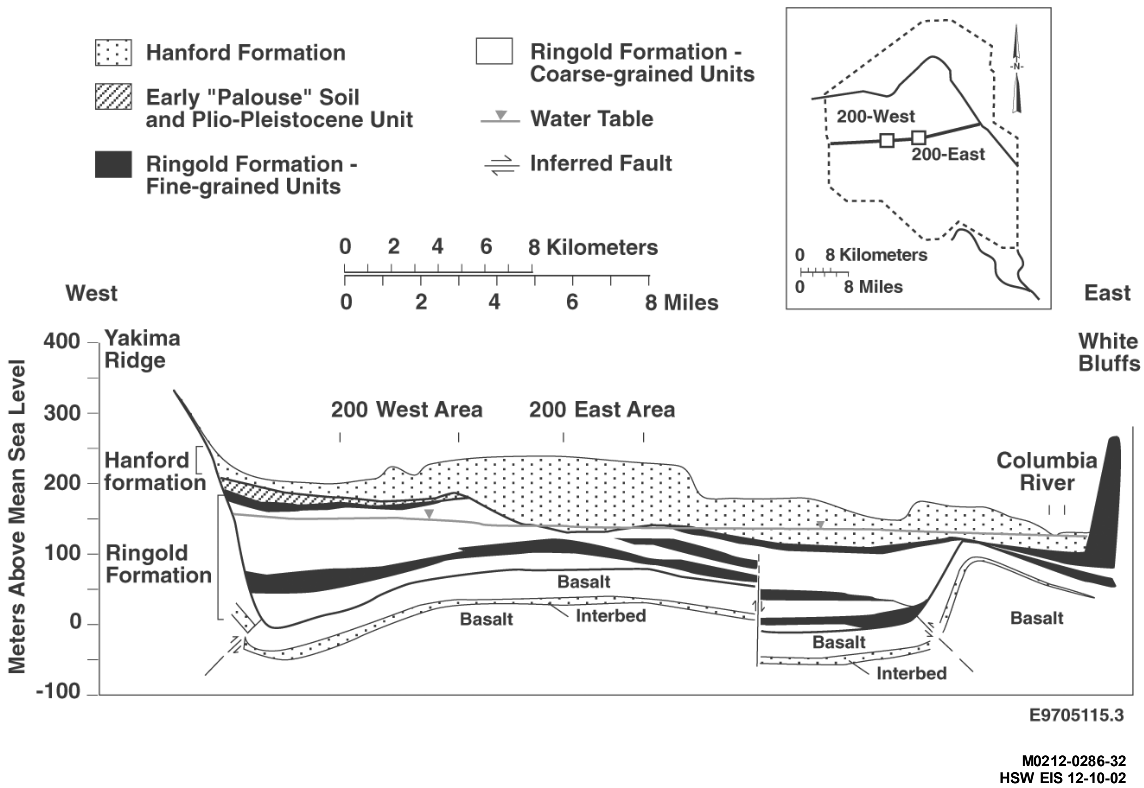


Figure 4.11. Generalized West to East Cross-Section of the Hanford Site Structure and Topography (DOE-RL 1999)

sedimentary deposits, referred to as the Plio-Pleistocene unit, pre-Missoula gravels, and early Palouse soil, locally separate the Ringold Formation from the overlying Hanford formation.

The Ringold Formation consists of siltstones, sandstones, and conglomerates deposited by the ancestral Columbia River system between 8 and 3 million years ago. The Ringold Formation reaches 180 m (600 ft) in thickness in the Cold Creek syncline south of the 200 West Area but thins and pinches out to the north. It is subdivided into five gravel layers referred to as Units A, B, C, D, and E that are separated by finer-grained units, including the lower mud (Figure 4.10).

The Hanford formation was deposited between 2 million years and 10,000 years ago by cataclysmic flooding from glacial Lake Missoula. The Hanford formation consists of pebble to boulder gravel, fine to coarse-grained sand, and silt, and is thickest (up to 65 m [210 ft]) under the 200 Areas. Gravel dominates the Hanford formation in the northern part of the area, while sand-dominated material is found most commonly in the central to southern parts. Holocene surficial deposits consisting of silt, sand, and gravel form a thin (less than 10-m [33-ft]) surface layer across much of the Hanford Site. Eolian (wind) and alluvial processes deposited these surficial materials.

The geology in the 200 West Area is notably different from the 200 East Area, considering a distance of only 6 km (4 mi) separates them. One of the most complete suprabasalt stratigraphic sections on the Hanford Site containing most Ringold units, the Plio-Pleistocene unit, early Palouse soil, and the Hanford formation, is present in the 200 West Area.

In the 200 East Area, most of the Ringold Formation units are present in the southern part but have been eroded in a complex pattern to the north. On the north side of the 200 East Area, the Hanford formation rests directly on the basalt, and no Ringold sediments are present. Erosion by the ancestral Columbia River and catastrophic flooding are believed to have removed the Ringold Formation from this area. A unit of questionable origin locally overlies basalt within the B-BX-BY Waste Management Area (Schalla et al. 2000). This unit, referred to informally as H/PP deposits, may be equivalent or partially equivalent to the Plio-Pleistocene unit or it may represent the earliest ice-age flood deposits overlain by a locally thick sequence of fine-grained non-flood deposits.

4.4.3 Soils

Hajek (1966) describes 15 different soil types on the Hanford Site, varying from sand to silty and sandy loam. These soils are shown in Figure 4.12 and briefly described in Table 4.9.

The majority of the 200 West Area soils are Rupert Sand; the remaining third is Burbank Loamy Sand. The 200 East Area soils are composed of Ephrata Sandy Loam, Rupert Sand, and Burbank Loamy Sand.

4.4.4 Seismicity

The Hanford Site lies in an area of relatively low seismic activity. Figure 4.13 shows the locations of known earthquakes that occurred in the Columbia Plateau between 1850 and 1969 with a Modified Mercalli Intensity (MMI) of V or more and at Richter magnitude 4.0 or more. The largest earthquake that may have occurred in the eastern Washington area shown in Figure 4.13 happened in 1872, with MMI IX and estimated magnitude near 7.0, but its location has been variously estimated from Wenatchee to British Columbia. Figure 4.14 shows the locations of all earthquakes that occurred from 1969 to 2000 at Richter magnitudes of 3.0 or more. The largest known earthquake in the Columbia Plateau occurred in 1936 near Milton-Freewater, Oregon. This earthquake had a Richter magnitude of approximately 6.0 and a maximum MMI of VII, and was followed by a number of aftershocks indicating a northeast-trending fault plane. Other earthquakes with Richter magnitudes ≥ 5 or MMI of VI occurred along the boundaries of the Columbia Plateau in a cluster near Lake Chelan in 1872 extending into the northern Cascade Range, in 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 event in the Milton-Freewater, Oregon, region in 1921; one near Yakima, Washington, in 1892; and one near Umatilla, Oregon, in 1893. In the central portion of the Columbia Plateau, the largest earthquakes near the Hanford Site are two earthquakes that occurred in 1918 and 1973. These two events were magnitude 4.4 and intensity V, and were located north of the Hanford Site near Othello.

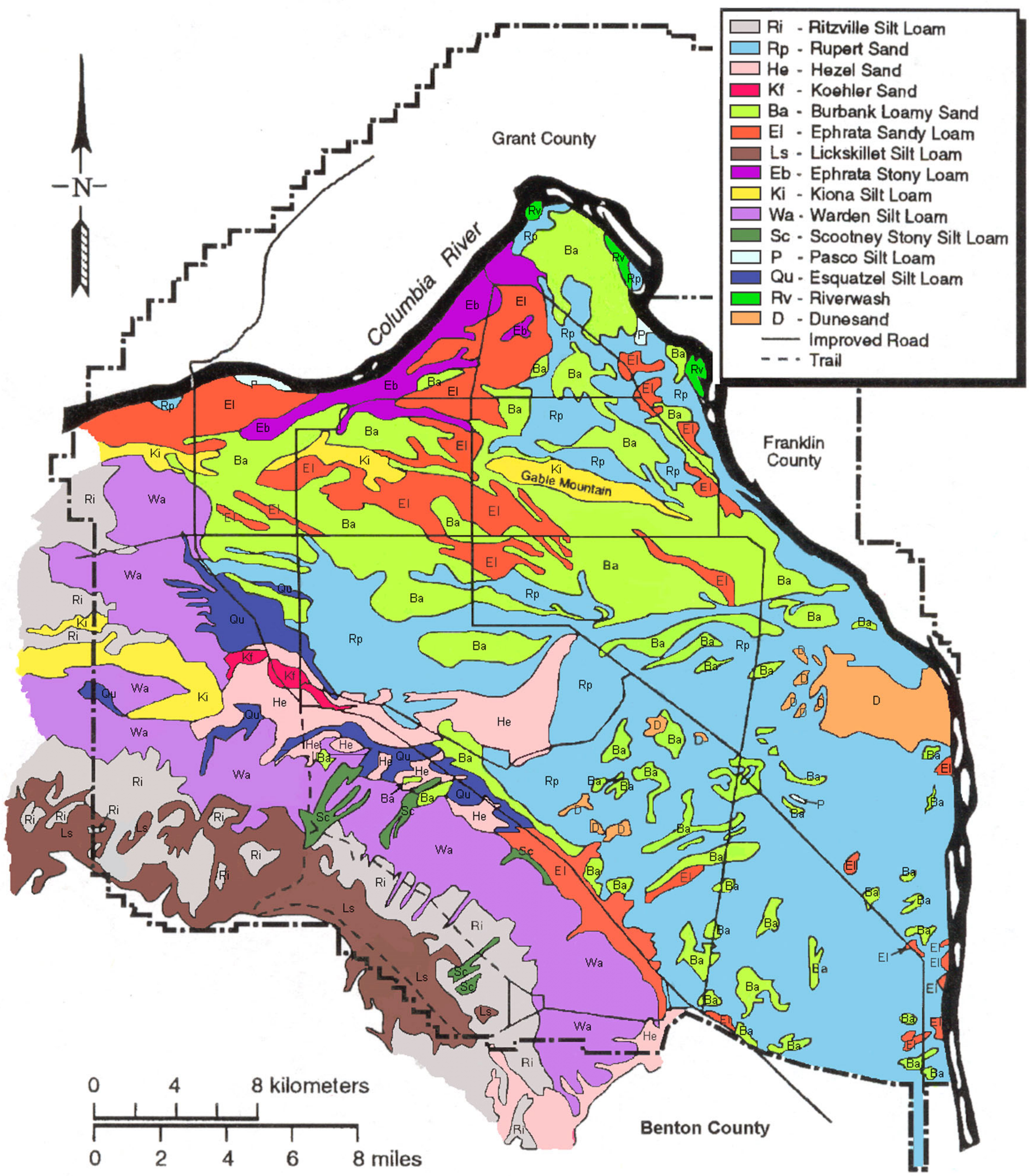


Figure 4.12. Soil Map of the Hanford Site (after Hajak 1966). (See Table 4.9 for description of soil types.)

Table 4.9. Soil Types on the Hanford Site (after Hajek 1966)

Name (symbol)	Description
Ritzville Silt Loam (Ri)	Dark-colored silt loam soils midway up the slopes of the Rattlesnake Hills. Developed under bunch grass from silty wind-laid deposits mixed with small amounts of volcanic ash. Characteristically greater than 150 cm (60 in.) deep, but bedrock may occur between 75 and 150 cm (30 and 60 in.).
Rupert Sand (Rp)	One of the most extensive soils on the Hanford Site. Brown-to grayish-brown coarse sand grading to dark grayish-brown at 90 cm (35 in.). Developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits that were mantled by wind-blown sand. Hummocky terraces and dune-like ridges.
Hezel Sand (He)	Similar to Rupert sands; however, laminated grayish-brown strongly calcareous silt loam subsoil is usually encountered within 100 cm (39 in.) of the surface. Surface soil is very dark brown and was formed in wind-blown sands that mantled lake-laid sediments.
Koehler Sand (Kf)	Similar to other sandy soils on the Hanford Site. Developed in a wind-blown sand mantle. Differs from other sands in the sand mantles a lime-silica cemented Hardpan layer. Very dark grayish-brown surface layer is somewhat darker than Rupert. Calcareous subsoil is usually dark grayish-brown at about 45 cm (18 in.).
Burbank Loamy Sand (Ba)	Dark-colored, coarse-textured soil underlain by gravel. Surface soil is usually about 40 cm (16 in.) thick but can be 75 cm (30 in.) thick. Gravel content of subsoil ranges from 20 percent to 80 percent.
Ephrata Sandy Loam (El)	Surface is dark colored and subsoil is dark grayish-brown medium-textured soil underlain by gravelly material that may continue for many feet. Level topography.
Lickskillet Silt Loam (Ls)	Occupies ridge slopes of Rattlesnake Hills and slopes greater than 765 m (2509 ft) elevation. Similar to Kiona series except the surface soils are darker. Shallow over basalt bedrock, with numerous basalt fragments throughout the profile.
Ephrata Stony Loam (Eb)	Similar to Ephrata sandy loam. Differs in that many large hummocky ridges are made up of debris released from melting glaciers. Areas between hummocks contain many boulders several feet in diameter.
Kiona Silt Loam (Ki)	Occupies steep slopes and ridges. Surface soil is very dark grayish-brown and about 10 cm (4 in.) thick. Dark-brown subsoil contains basalt fragments 30 cm (12 in.) and larger in diameter. Many basalt fragments are found in surface layer. Basalt rock outcrops present. A shallow stony soil normally occurring in association with Ritzville and Warden soils.
Warden Silt Loam (Wa)	Dark grayish-brown soil with a surface layer usually 23 cm (9 in.) thick. Silt loam subsoil becomes strongly calcareous at about 50 cm (20 in.) and becomes lighter colored. Granitic boulders are found in many areas. Usually greater than 150 cm (60 in.) deep.

Table 4.9. (contd)

Name (symbol)	Description
Scootney Stony Silt Loam (Sc)	Developed along the north slope of Rattlesnake Hills; usually confined to floors of narrow draws or small fan-shaped areas where draws open onto plains. Severely eroded with numerous basaltic boulders and fragments exposed. Surface soil is usually dark grayish-brown grading to grayish-brown in the subsoil.
Pasco Silt Loam (P)	Poorly drained very dark grayish-brown soil formed in recent alluvial material. Subsoil is variable, consisting of stratified layers. Only small areas found on the Hanford Site, located in low areas adjacent to the Columbia River.
Esquatzel Silt Loam (Qu)	Deep dark-brown soil formed in recent alluvium derived from loess and lake sediments. Subsoil grades to dark grayish-brown in many areas, but color and texture of the subsoil are variable because of the stratified nature of the alluvial deposits.
Riverwash (Rv)	Wet, periodically flooded areas of sand, gravel, and boulder deposits that make up overflowed islands in the Columbia River and adjacent land.
Dunesand (D)	Miscellaneous land type that consists of hills or ridges of sand-sized particles drifted and piled up by wind. Are either actively shifted or so recently fixed or stabilized that no soil horizons have developed.

In addition, earthquake swarms of small magnitudes that are not associated with mapped faults occur on and around the Hanford Site. 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 generally occur at shallow depths, with 75 percent of the events located at depths <4 km (<2.5 mi). Each earthquake swarm typically lasts several weeks to months, consists of several to 100 or more earthquakes, and the locations are clustered in an area 5 to 10 km (3 to 6.2 mi) in lateral dimension.

Estimates for the 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 (now Energy Northwest) Columbia Generating Station (formerly WNP-2), 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).

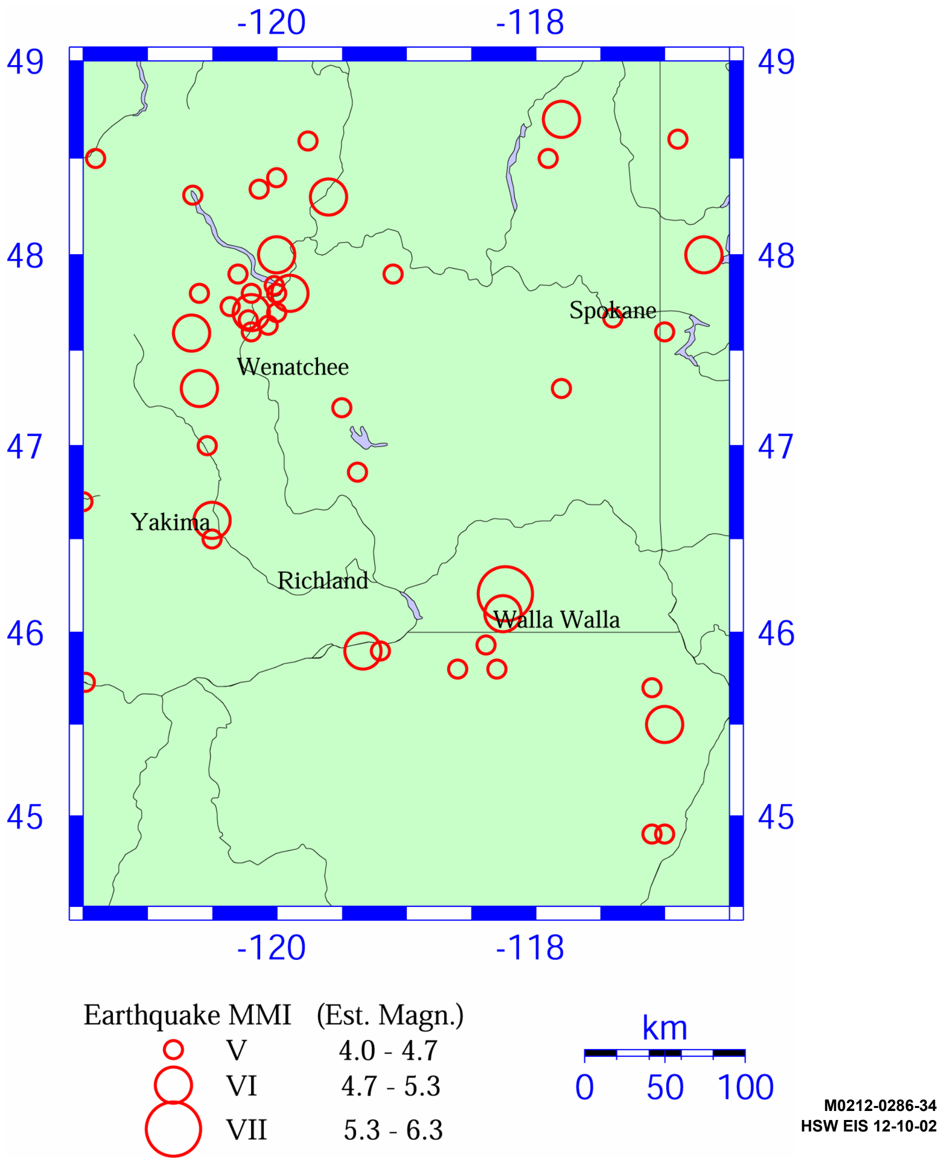


Figure 4.13. Historical Seismicity of the Columbia Plateau and Surrounding Areas. All earthquakes between 1850 and March 20, 1969, with a Modified Mercalli Intensity of V or larger or a Richter magnitude of 4.0 or larger, are shown (Rohay 1989). The magnitude ranges correspond to the original intensity estimated historically. Symbol sizes are only approximately related to those used in Figure 4.14. The uncertain location of the 1872 earthquake is not shown.

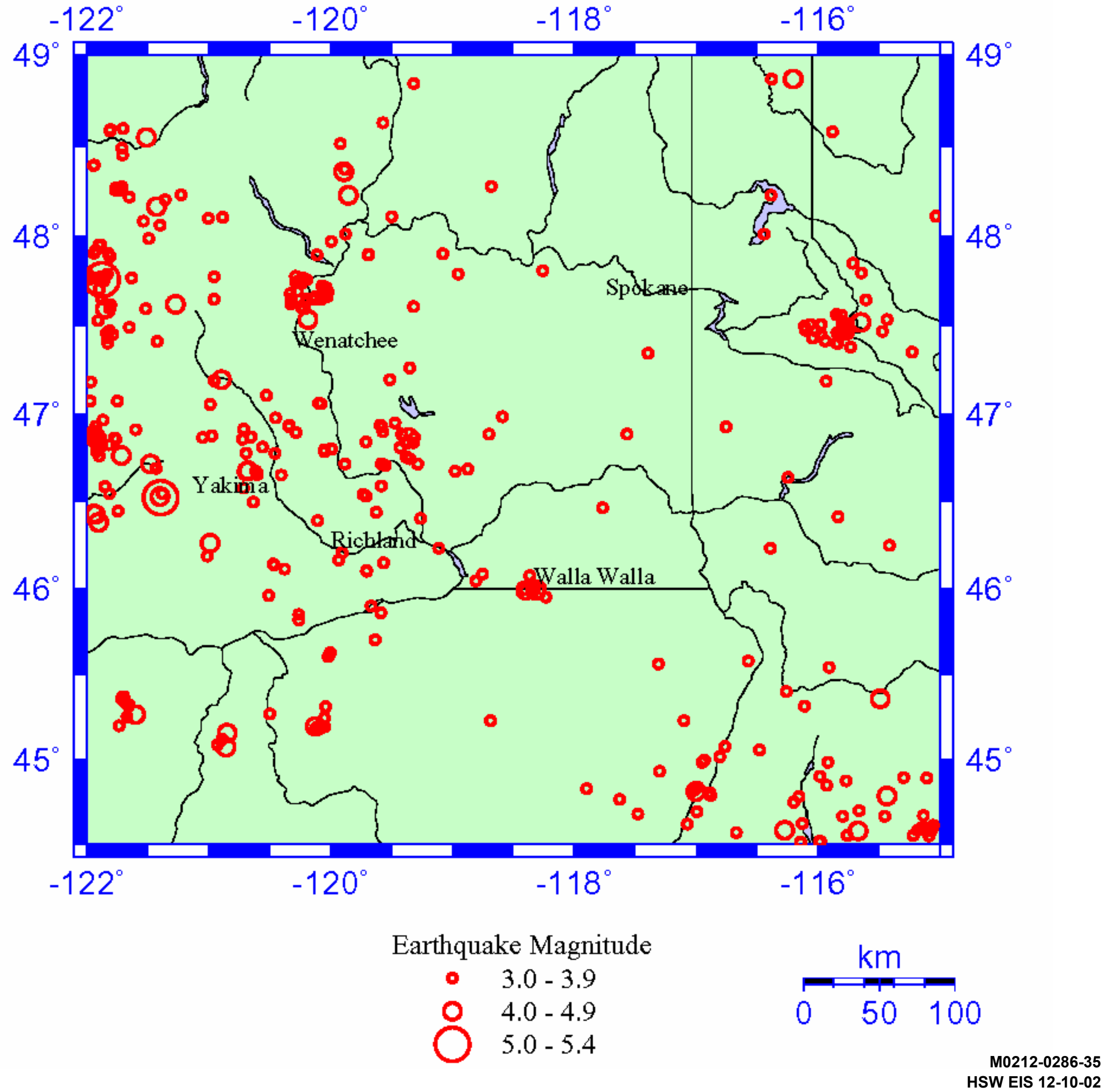


Figure 4.14. Seismicity of the Columbia Plateau and Surrounding Areas as Measured by Seismographs. All earthquakes from 3/20/1969 to 12/31/2000 with Richter magnitude 3 or larger are shown. Data sources: Council of the National Seismic System (CNSS 2001), University of Washington Geophysics Program (UWGP 2001).

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 upon the inferred sense of slip, the fault length, and 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 purpose of Columbia Generating Station seismic design was a Richter magnitude 4.0 event, based on the maximum swarm earthquake in 1973. (The NRC concluded the actual magnitude of this event was smaller than estimated previously.)

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. The most recent Hanford Site-specific hazard analysis (Tallman 1994, 1996) estimated that 0.10 g (1 g is the acceleration of gravity) horizontal acceleration would be experienced on average every 500 yr (or with a 10 percent chance every 50 yr). This study also estimated that 0.2 g would be experienced on average every 2500 yr (or with a 2 percent chance in 50 yr). These estimates are in approximate agreement with the results of national seismic hazard maps produced by the U.S. Geological Survey (Frankel et al. 1996).

The Pacific Northwest National Laboratory (PNNL) and the University of Washington (UW) operate a 40-station seismic monitoring network in eastern Washington, which has been used to determine the locations and magnitudes of earthquakes since 1969. In addition, PNNL operates a network of five strong motion accelerometers near Hanford facilities to measure ground motion levels from larger earthquakes (Hartshorn et al. 2001).

4.5 Hydrology

Hydrology considerations at the Hanford Site include surface water, the vadose zone, and groundwater. The vadose zone is the unsaturated or partially saturated region between 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.

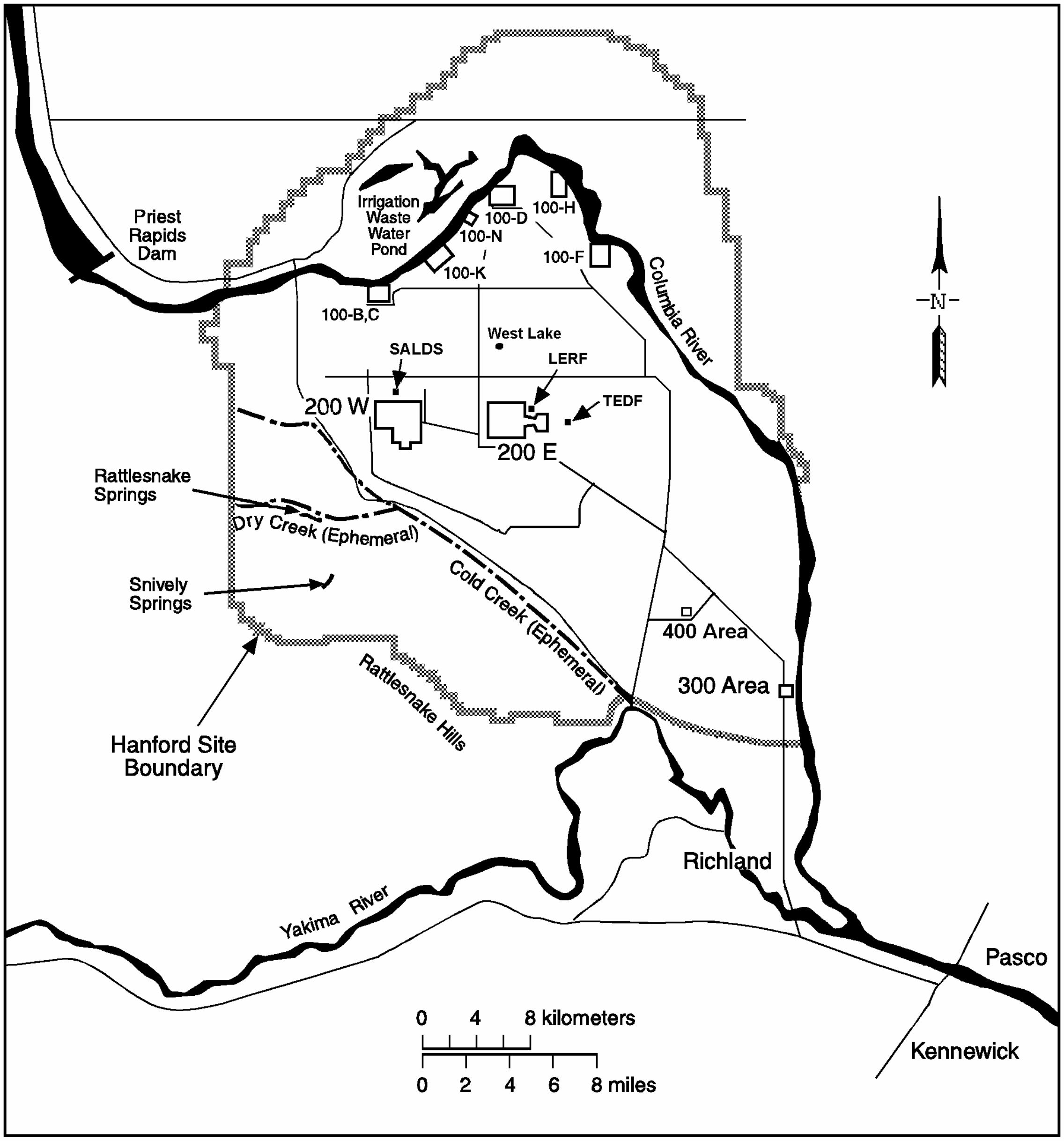
4.5.1 Surface Water

Surface water at Hanford includes the Columbia River, Columbia riverbank seepage, 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 near a short section of the southern boundary of the Hanford Site (Figure 4.15).

4.5.1.1 Columbia River

In terms of total flow, the Columbia River is the second largest river in the contiguous United States 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.

Originating in the mountains of eastern British Columbia, Canada, the Columbia River drains an area of about 680,000 km^2 (260,000 mi^2) en route to the Pacific Ocean. 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. Many communities located on the Columbia River rely on the river as their source of drinking water (see Section 4.8.9). The Columbia River is also used as a source of drinking water and industrial water for several Hanford Site facilities (Dirkes 1993). In addition, the Columbia River is used extensively for recreation that includes fishing, bird hunting, boating, sail boarding, water skiing, diving, and swimming.



LERF – Liquid Effluent Retention Facility
SALDS – State-Approved Land Disposal Structure
TEDF – Treated Effluent Disposal Facility

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Figure 4.15. Surface Water Features Including Rivers, Ponds, Major Springs, Ephemeral Streams, and Artificial Ponds on the Hanford Site (after Neitzel 2002a)

4.5.1.2 Springs and Streams

Rattlesnake Springs and Snively Springs, two small spring-fed streams on the Fitzner/Eberhardt Arid Lands Ecology Reserve (ALE), are the only naturally occurring streams on the Hanford Site. Rattlesnake Springs, located 10 km (6 mi) west of the 200 West Area, forms a small surface stream that flows for approximately 2.5 km (1.6 mi) before it disappears into the ground as a result of seepage. Base flow of this stream is about 0.01 m^3/s (0.4 ft^3/s) (Cushing and Wolf 1982). Snively Springs is located to the west and at a higher elevation than Rattlesnake Springs.

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 it occurs, surface flow infiltrates rapidly and disappears into the surface sediments in the western part of the site.

4.5.1.3 Columbia Riverbank Seepage

The seepage of groundwater into the Columbia River has been known to occur for many years. Riverbank seeps were documented along the Hanford Reach long before Hanford operations began during the Second World War (Jenkins 1922). Seepage occurs below the river surface and also on the exposed riverbank, particularly noticeable at low-river stage. The seeps flow intermittently, apparently influenced primarily by changes in river level. Groundwater contaminants attributed to Hanford operations reach the Columbia River through these seeps.

4.5.1.4 Onsite Ponds and Artificial Water Bodies

West Lake is the only naturally occurring pool on the Hanford Site. West Lake is several hectares in size and is located approximately 8 km (5 mi) northeast of the 200 West Area and about 3 km (2 mi) north of the 200 East Area. It is situated in a topographically low-lying area and is sustained by groundwater inflow resulting from an intersection with the groundwater table. 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. West Lake water quality samplings demonstrate elevated dissolved solids and nitrates. Total dissolved solids are approximately 15,000 mg/L, and pH is over 9. Nitrate concentrations are about 1.8 mg/L and ammonia concentrations are about 2.6 mg/L (Neitzel 2002a). Evaporation has also led to relatively high levels of uranium due to concentration of natural sources (Poston et al. 1991).

The Nature Conservancy (Hall 1998) has documented the existence of several naturally occurring vernal ponds near Gable Mountain and Gable Butte. 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 ranged 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 were found in three clusters. Approximately ten vernal ponds were documented at the eastern end of Umtanum Ridge, six or seven were observed in the central part of Gable Butte, and three were found at the eastern end of Gable Mountain.

The 200 Area Treated Effluent Disposal Facility (TEDF) consists of two man-made disposal ponds. These ponds are each 2 ha (5 ac) in size and receive industrial wastewater permitted in accordance with the State Waste Discharge Permit Program (WAC 173-216). The treated effluent percolates into the ground from the disposal ponds.

The Liquid Effluent Retention Facility (LERF) is a wastewater holding facility consisting of three surface impoundments with a total capacity of 29.5 million L (7.8 million gal) each. The LERF provides storage until the waste is transferred to the ETF for final treatment. These ponds are equipped with double liners, a leak detection system, and floating covers (Poston et al. 2002). The LERF also includes piping and pumping systems, utilities, and a basin operations structure. Aqueous waste from the LERF is transferred to the 200 Area Effluent Treatment Facility (ETF) via pipelines.

The State-Approved Land Disposal Structure (SALDS) is located north of the 200 West Area. The SALDS is a Washington State permitted facility containing drain fields where tritium-bearing wastewater discharge is authorized as per the permit.

4.5.1.5 Floodplains and Runoff

No floodplains are found in the 200 Areas. Although floods in Cold Creek and Dry Creek have occurred historically, no historic flood events have been observed in the 200 Areas. The flooding of Cold Creek and Dry Creek infiltrated into the permeable sediments before reaching the 200 Areas.

Natural runoff generated onsite or from offsite up-gradient sources is not known to occur in the 200 Areas. Measurable runoff occurs during brief periods in two locations, Cold Creek Valley and Dry Creek Valley west and southwest of the 200 West Area (Newcomb et al. 1972). This surface runoff either infiltrates into the valley floor or evaporates. During periods of unusually rapid snowmelt or heavy rain-fall, surface runoff extends beyond Rattlesnake Springs in the upper part of Dry Creek. However, this runoff quickly infiltrates into the alluvial sediments of Cold Creek Valley.

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. This flood would inundate parts of the 100 Areas located adjacent to the Columbia River, but the Central Plateau region of the Hanford Site would remain unaffected (DOE 1986).

In 1980, a flood risk analysis of Cold Creek, an ephemeral stream within the Yakima River drainage system, 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 (Skaggs and Walters 1981). The probable maximum flood discharge rate for the lower Cold Creek Valley was 2265 m^3/s (80,000 ft/s) compared to 564 m^3/s (19,900 ft^3/s) for the 100-year flood. Modeling indicated that State Route (SR) 240 along the Hanford Site's southwestern and western areas would not be usable (Figure 4.16). Water from a probable maximum flood could potentially reach the southwest corner of the 200 West Area, but not the waste management areas.

4.5.2 Hanford Site Vadose Zone

The vadose zone is that part of the subsurface found between the ground surface and the top of the saturated zone. 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 (328 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, however, such as west and south of 200 East 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.

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

Except for SALDS, the 200 Area TEDF ponds, and septic drain fields, artificial recharge (the process by which excess surface water is directed into the ground) to the vadose zone ended in the mid-1990s. Natural infiltration in the vadose zone causes older preexisting water to be displaced downward by newly infiltrated water. The amount of recharge at any particular site is highly dependent on the soil type and the presence of vegetation. Usually, vegetation reduces the amount of infiltration through the biological process of evapotranspiration.

Although most natural recharge is probably uniform flow (Jones et al. 1998), the vadose zone stratigraphy influences the movement of liquid through the soil column. Where conditions are favorable, lateral spreading of liquid effluent or local perched water zones may develop. Perched water zones form where downward moving moisture accumulates on top of low-permeability soil lenses or highly cemented horizons.

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. Preferential flow may also take place via old, abandoned, or poorly sealed vadose zone and groundwater wells.

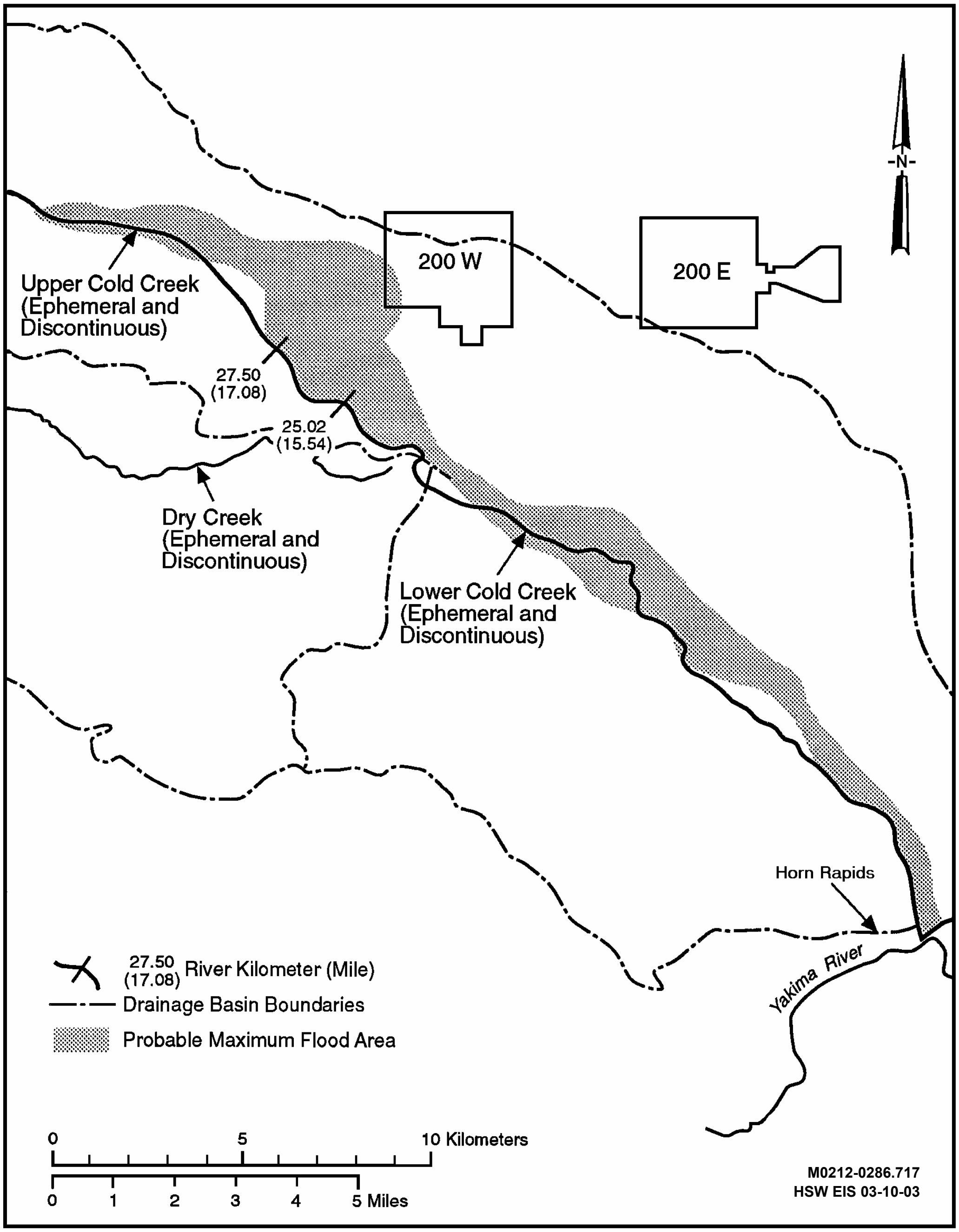


Figure 4.16. Extent of Probable Maximum Flood in Cold Creek Area (Skaggs and Walters 1981)

Subsurface source characterization, sediment sampling and characterization, and vadose zone monitoring are employed to describe the current and future configuration of contamination in the vadose zone.

4.5.2.1 Vadose Zone Contamination

The Hanford Site has more than 800 former (referred to as past-practice) liquid disposal facilities. Radioactive liquid waste was discharged to the vadose zone through reverse (injection) wells, French drains, cribs, ponds, and ditches. Over the last 56 years, 1.5 to 1.7 billion m^3 (396 to 449 billion gal) of effluent were disposed of to the soils (Gephart 1999). Most effluent was released in the 200 Areas. The major groundwater contaminant plumes emanating from the 200 Areas are tritium and nitrate. The major source for both contaminants was liquid discharges resulting from chemical processing activities. These discharges also included technetium-99 and iodine-129 which, like tritium and nitrate, are mobile in groundwater. Carbon tetrachloride was also discharged to cribs near the Plutonium Finishing Plant in the 200 West Area. Vadose zone sources for these contaminants almost certainly remain beneath many past-practice disposal facilities.

Approximately 280 unplanned releases in the 200 Areas also contributed contaminants to the vadose zone (DOE-RL 1997). Many of these were releases 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-RL 1997). 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.

A total of 149 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. Of the single-shell tanks, 67 are assumed to have leaked an estimated total of 2839 to 3975 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).

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-RL (1997) and Kincaid et al. (1998) contain the most recent inventories of contaminants disposed of to past-practice liquid disposal facilities in the 200 Areas. Dorian and Richards (1978) list contaminant inventories disposed of to most 100 Area past-practice facilities. Anderson (1990) lists inventories of effluents sent to single-shell tanks. A series of reports estimate the curies of gamma-emitting radionuclides and the volumes of contaminated soil associated with each single-shell tank farm. (See the series of online reports at the Hanford Tank Farm Vadose Zone Project (http://www.gjo.doe.gov/programs/hanf/HTFVZ.html). Their estimates for all locations for the three most widespread contaminants are 8901 Ci of cesium-137 in 395,550 m^3 of soil, 0.8611 Ci of europium-154 in 30,133 m^3 of soil, and 0.7424 Ci of cobalt-60 in 74,369 m^3 of soil.

4.5.2.2 Vadose Zone Monitoring and Characterization Activities

Although disposal of untreated wastewater to the ground stopped in 1995 (Schmidt et al. 1996), contaminant movement still occurs in the soil column beneath past-practice sites. Vadose zone monitoring/characterization is one approach for evaluating the status of possible leaks or remobilization of contaminants caused by natural or artificial infiltration. The objectives of vadose-zone monitoring/ characterization are to document the location of the contamination, determine the moisture and contaminant movement in the soil column, and assess the effectiveness of remedial actions.

DOE has been conducting an expedited response action to treat carbon tetrachloride contamination since 1992 at the 200-ZP-2 Operable Unit, located in the 200 West Area, with the concurrence of the EPA and the Washington State Department of Ecology (Ecology). Soil-vapor extraction is being used to remove carbon tetrachloride from the vadose zone as part of this expedited response action (Rohay 1999; Hartman et al. 2001). To track the effectiveness of the remediation effort, measurement of soil-vapor concentrations of chlorinated hydrocarbons are made at the inlet to the soil-vapor-extraction system and at individual off-line wells and probes through the soil-vapor extract sites. As of September 2002, 84,700 kg (187,000 lb) of carbon tetrachloride had been removed from the groundwater and vadose zone beneath the 200 West Area. The soil-vapor concentrations monitored deep within the vadose zone during the past few years suggest that soil vapor-extraction remediation has removed a substantial amount of the carbon tetrachloride from the vadose zone (Hartman et al. 2003).

Baseline vadose zone characterization has been conducted at the single-shell tank farms since 1995. Spectral gamma-ray logging detectors were used in approximately 800 boreholes at the 149 single-shell tanks to locate man-made gamma-emitting radionuclides in the soil. During the initial logging of the drywells, several areas were found with levels of contamination high enough to effectively saturate the gamma-ray detectors. Those areas were relogged in 2000 with more robust systems. The maximum radionuclide concentration (cesium-137) detected was about 100 million pCi/g. In addition, during 2000, 88 boreholes that were logged previously were relogged to determine whether contamination continues to move in the vadose zone. Data acquired in 22 of the 88 boreholes showed increases in concentration, suggesting possible continued contaminant movement through the vadose zone (Poston et al. 2001).

During 1999, boreholes around 25 inactive 200 East Area facilities, termed specific retention facilities, were monitored by spectral gamma-ray and neutron moisture methods. Specific retention facilities were designed to use the moisture-retention capability of the soil to retain contaminants. Ideally, liquids disposed of to specific retention facilities would be limited to less than about 10 percent of the soil volume between the facility and the groundwater, resulting in retention of the liquid in the soils (Waite 1991). Significant quantities of radionuclides and chemicals were discharged to specific retention trenches with some trenches receiving up to 1570 Ci of cesium-137, 475 Ci of strontium-90, and 89 Ci of technetium-99. The volume of liquid discharged to each trench is thought to be insufficient to drive contaminants through the vadose zone to groundwater. Therefore, the discharged contaminants remain in the soil column and these sites represent potential sources for future groundwater contamination at the Hanford Site. Of the 29 boreholes logged, 4 had previous spectral gamma logs for comparison. Logs from two of those boreholes showed that changes in subsurface distribution of man-made radionuclides had occurred since 1992 (Horton and Randall 2000), indicating continued movement of contaminants in the vadose zone years after the facilities ceased operations.

4.5.3 Groundwater

Groundwater originates as surface water, either from natural recharge, such as rain, streams, and lakes, or from artificial recharge, such as reservoirs, excess irrigation, canal seepage, deliberate augmentation, industrial processing, and wastewater disposal.

4.5.3.1 Hanford Site Aquifer System

Groundwater beneath the Hanford Site is found in 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. Low-permeability layers of fine-grained sediment locally confine portions of the suprabasalt aquifer system. However, because the entire suprabasalt aquifer system is interconnected on a sitewide scale, it is referred to in this report as the Hanford unconfined aquifer system.

Basalt-Confined Aquifer System. Relatively permeable sedimentary interbeds and the more porous tops and bottoms of basalt flows form 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 communication with the unconfined aquifer system (Hartman et al. 2001; DOE 1988; Spane 1987).

Recharge to the upper basalt-confined aquifer is believed to occur along the margins of the Pasco Basin as a result of precipitation infiltration and surface water where the basalt and interbeds are exposed at ground surface. Recharge may also occur through the Hanford/Ringold aquifer system, where a downward hydraulic gradient exists between the Ringold Formation and the confined and upper basalt-confined aquifers or from deeper basalt aquifers having an upward gradient.

South of the Umtanum Ridge/Gable Mountain area, groundwater in the upper basalt-confined aquifer system generally flows from west to east across the Hanford Site toward the Columbia River. The elevated regions to the west and southwest of the site are believed to be recharge areas for the system, and the Columbia River represents a discharge area.

Unconfined Aquifer System. The unconfined aquifer is generally located in the unconsolidated to semi-consolidated Ringold and Hanford formation sediments that overlie the basalt bedrock. Where it is below the water table, the coarse-grained Hanford formation makes up the most permeable zones of the unconfined aquifer system.

The saturated thickness of the unconfined aquifer on the Hanford Site is greater than 61 m (200 ft) in some areas but pinches out along the flanks of the basalt ridges. Depth to the water table ranges from less than 0.3 m (1 ft) near the Columbia River to more than 106 m (348 ft) near the 200 Areas. Perched water-table conditions have been encountered in sediments above the unconfined aquifer in the 200 West Area (Airhart 1990; Last and Rohay 1993) and in irrigated offsite areas east of the Columbia River (Brown 1979). Because the Ringold sand and gravel sediments are more consolidated and are partially cemented, they are about 10 to 100 times less permeable than the sand and gravel sediments of the overlying Hanford formation. Horizontal hydraulic conductivities of sand and gravel facies within the Ringold Formation generally range from about 0.27 to 2.7 m/d (0.9 to 9 ft/d), compared to 305 to 3050 m/d (1000 to 10,000 ft/d) for the Hanford formation (DOE 1988). Mud-dominated units with the Ringold Formation are relatively impermeable.

Groundwater in the unconfined aquifer at Hanford generally flows from recharge areas in the elevated region near the western boundary of the Hanford Site, and toward the Columbia River on the eastern and northern boundaries. The Columbia River is the primary discharge area for the unconfined aquifer. A map showing water table elevations for the Hanford Site and adjacent areas across the Columbia River is displayed in Figure 4.17. Figure 4.18 details the water table elevations for the 200 Areas. 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). As the river stage rises, a pressure wave is transmitted inland through the groundwater.

Natural area recharge from precipitation across the entire Hanford Site ranges from about 0 to 10 cm/yr (0 to 4 in./yr), but is probably less than 2.5 cm/yr (1 in./yr) over most of the site (Gee and Heller 1985; Bauer and Vaccaro 1990; Fayer and Walters 1995). Between 1944 and the mid-1990s, the volume of artificial recharge from Hanford wastewater disposal was significantly greater than the natural recharge. An estimated 1.7×10^{12} L (4.44×10^{11} gal) of liquid was discharged to disposal ponds and cribs during this period (Hartman et al. 2001). Because of the reduction in discharges, groundwater levels are falling, particularly around the operational areas (Hartman 2000).

After the beginning of Hanford operations, the water table rose about 27 m (89 ft) under the U Pond disposal area in the 200 West Area and about 9 m (30 ft) under disposal ponds near the 200 East Area. 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 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. Water levels have declined over most of the Hanford Site since 1984 because of decreased wastewater discharges (Hartman 2000). 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 (Figures 4.17 and 4.18).

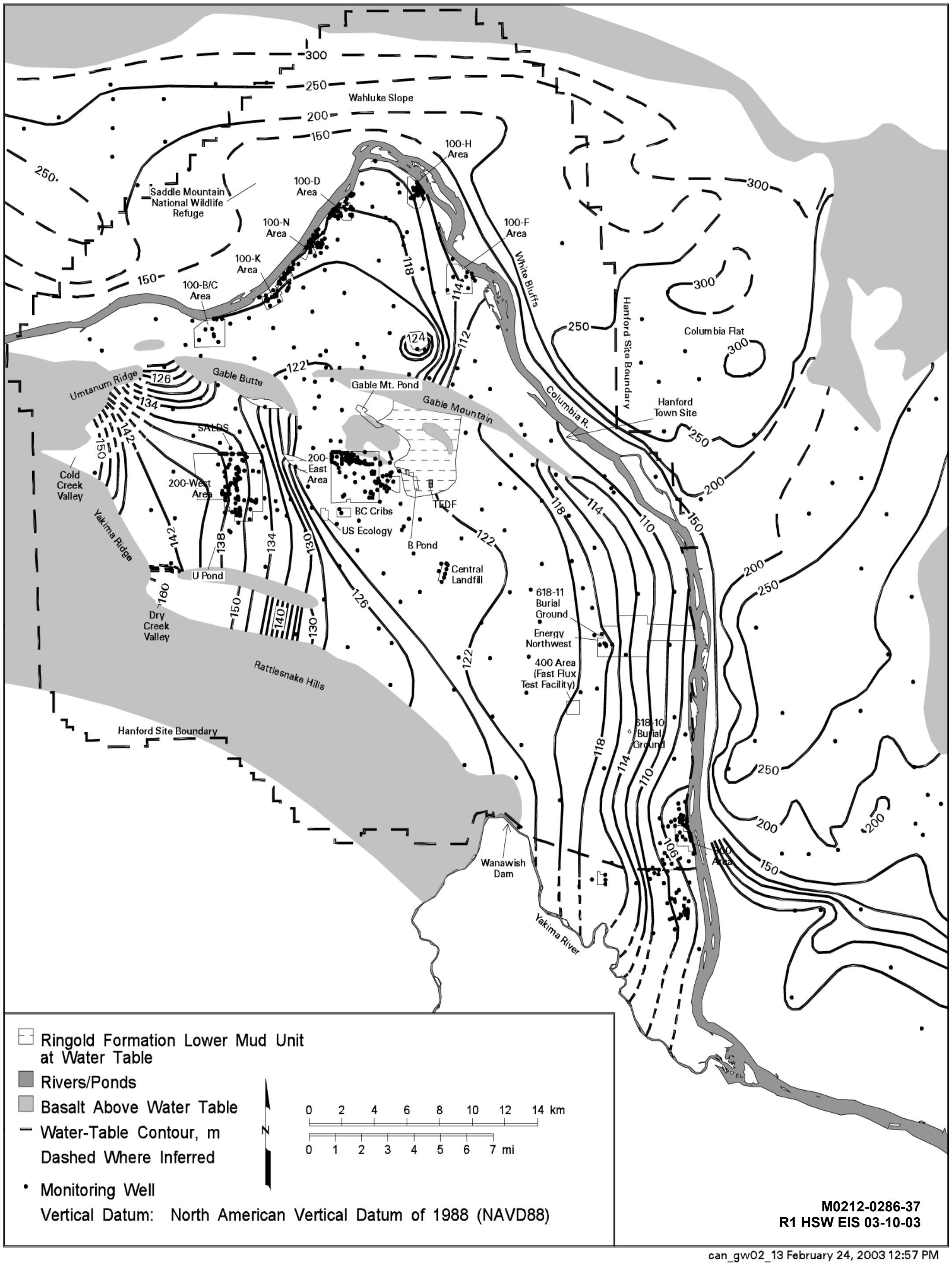


Figure 4.17. Groundwater Elevations for the Unconfined Aquifer at Hanford, March 2001 (after Hartman et al. 2002b)

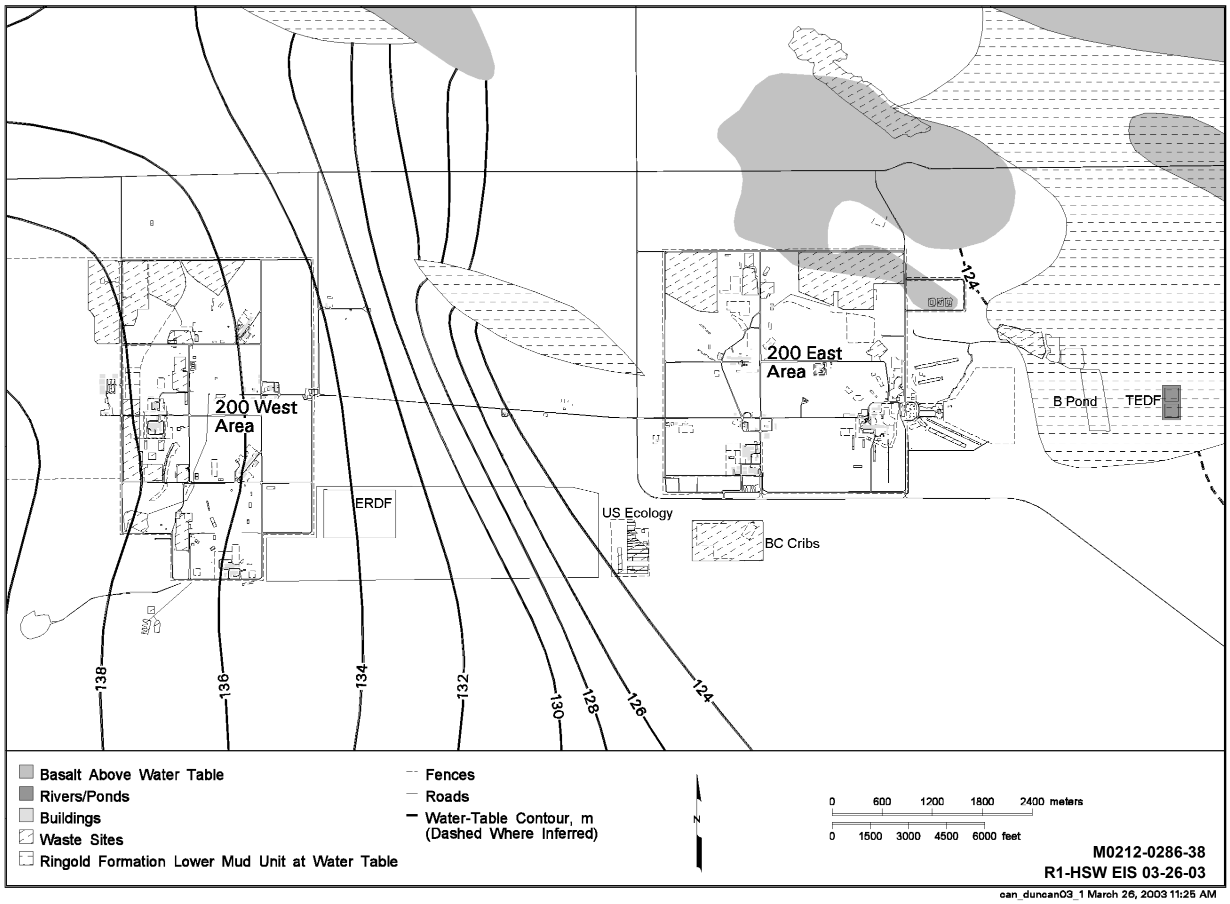


Figure 4.18. Groundwater Elevations for the Unconfined Aquifer at the 200 Areas (after Hartman et al. 2002b)

The saturated thickness and flow conditions in the unconfined aquifer are expected to return to pre-Hanford conditions with the decline and eventual cessation of artificial discharges at Hanford. Water levels have dropped in the vicinity of central areas in the site where the basalt crops out above the water table. Analyses by Cole et al. (1997) suggest the saturated thickness of the unconfined aquifer will decrease and areas of the aquifer may actually dry out. With this thinning and drying of the aquifer, which is predicted to occur in the area between Gable Butte and the outcrop south of Gable Mountain, the potential exists for the northern area of the unconfined aquifer to become hydrologically separated from the area south of Gable Mountain and Gable Butte. Therefore, flow from the 200 West Area and the northern half of the 200 East Area, that currently migrates through the gap between Gable Butte and Gable Mountain, will be effectively cut off in the next 200 to 300 years. In time, the overall water table (including groundwater mounds near the 200 East and West Areas) will decline, and groundwater movement from the 200 Area Plateau will shift to a dominantly west-to-easterly pattern of flow toward points of discharge along the Columbia River between the Old Hanford townsite and the Energy Northwest facility.

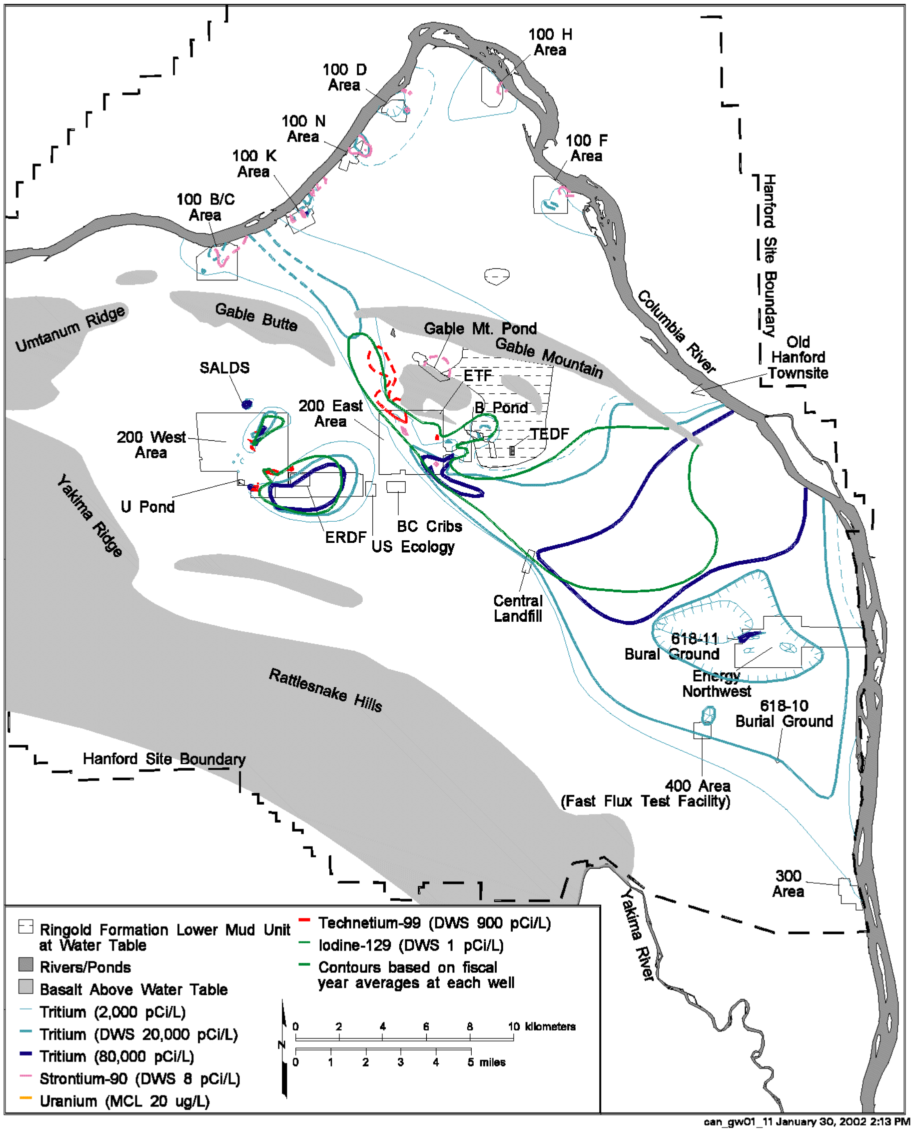
During 2000, the groundwater mounds have become less prominent. Water levels east of the 200 East Area have dropped below the top of a fine-grained confining unit, creating a barrier to movement in the surrounding unconfined aquifer (Hartman et al. 2001). Beneath this confining unit, the uppermost aquifer is a transmissive unit in the Ringold Formation. Groundwater flow in the confined aquifer is still influenced by the recharge mound.

4.5.3.2 Groundwater Quality

Groundwater beneath large areas of the Hanford Site has been impacted by radiological and chemical contaminants resulting from past Hanford Site operations. These contaminants were primarily introduced through wastewater discharged to cribs, ditches, injection wells, and ponds (Kincaid et al. 1998). Additional contaminants from spills, leaking waste tanks, and 618-10 and 618-11 Burial Grounds have also impacted groundwater in some areas. Contaminant concentrations in the existing groundwater plumes are expected to decline through radioactive decay, chemical degradation, and dispersion. However, contaminants also exist within the vadose zone beneath waste sites (see Section 4.5.2), as well as in waste storage and disposal facilities. These contaminants have a potential to continue to move downward into the aquifer. Some contaminants, such as tritium, move with the groundwater while 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. Groundwater contamination is monitored and is being actively remediated in several areas through pump-and-treat operations.

Contaminant concentrations in groundwater were compared with established drinking water standards as a benchmark for quality of the groundwater resource. These benchmark standards include the maximum contaminant level (MCL) and drinking water standard (DWS) for specific chemicals and radionuclides, which are legally enforceable limits for public drinking water supplies set by EPA or the Washington State Department of Health (WDOH). DOE Order 5400.5 establishes a limit for dose from radionuclides in public drinking water supplies operated by DOE or its contractors (DOE 1993). The dose limit is 4 mrem/yr (as total effective dose equivalent) from consumption of water at 2 L/day, which is intended to provide protection equivalent to that of the EPA and state standards. The published DOE derived concentration guide (DCG) for a specific radionuclide in drinking water may also be used as a benchmark for groundwater quality in the same manner as the EPA and state standards. The DCG represents the concentration of each radionuclide in drinking water that would result in a dose of 100 mrem/yr at a consumption rate of 2 L/day. Therefore, the DOE standard for a given radionuclide in drinking water corresponds to 4 percent of the DCG for that radionuclide.

Radiological constituents, including carbon-14, cesium-137, iodine-129, strontium-90, technetium-99, total alpha, total beta, tritium, uranium, and plutonium-239/240, were detected at concentrations greater than the MCL in one or more onsite wells within the unconfined aquifer. Concentrations of strontium-90, tritium, uranium, and plutonium were detected at levels greater than their respective DOE DCGs. Certain non-radioactive chemicals regulated by the EPA or the State of Washington (carbon tetrachloride, chloroform, chromium, cyanide, cis-1, 2 dichloroethene, fluoride, nitrate, sulfate, and trichloroethene) were also present in Hanford Site groundwater. Figure 4.19 shows the distribution of some radiological contamination in Hanford Site groundwater and Figure 4.20 shows the distribution of some hazardous chemical



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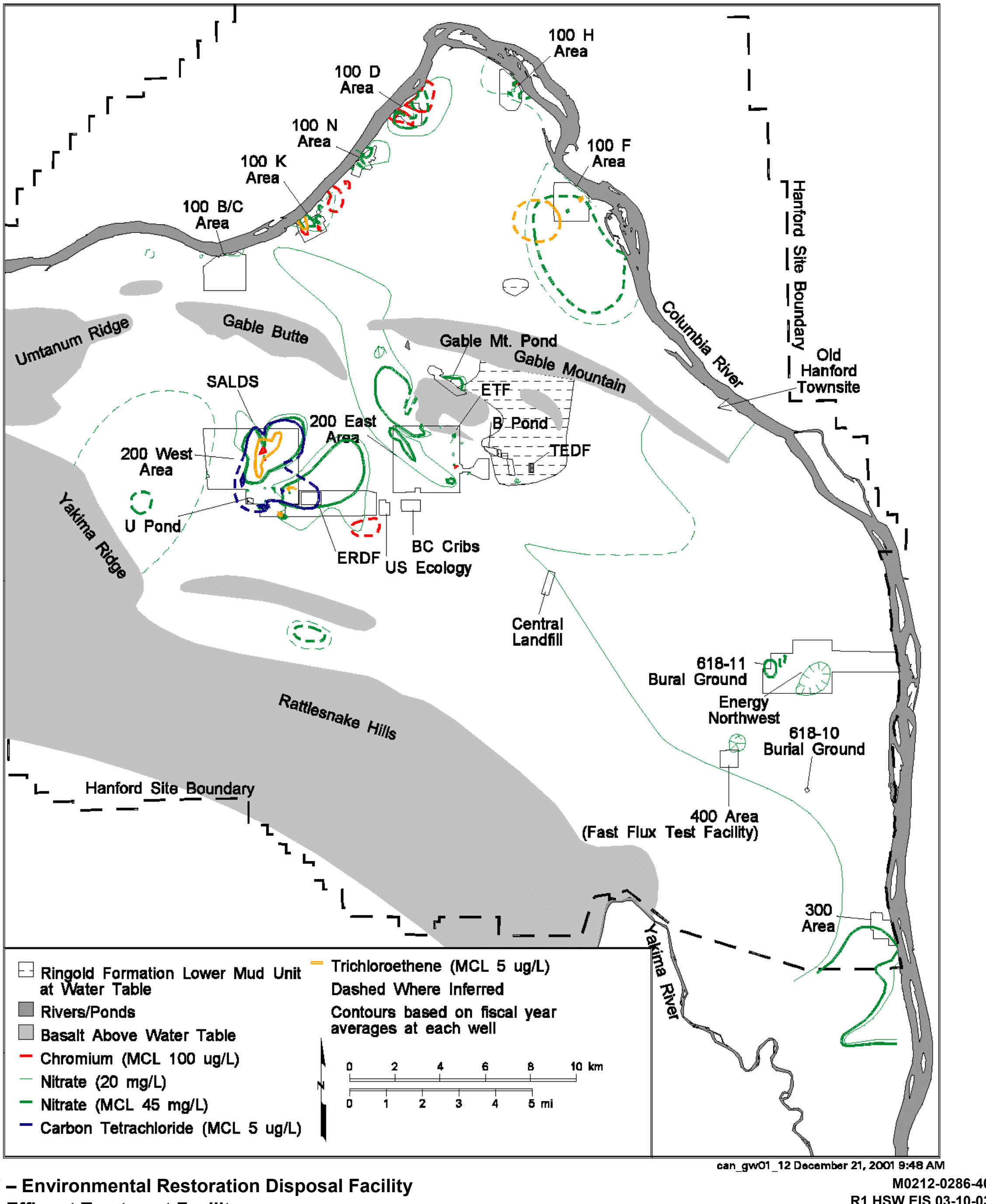
ERDF – Environmental Restoration Disposal Facility
ETF – Effluent Treatment Facility
SALDS – State-Approved Land Disposal Structure
TEDF – Treated Effluent Disposal Facility

Figure 4.19. Distribution of Major Radionuclides in Groundwater at Concentrations Above the Drinking Water Standards During FY 2001 (after Hartman et al. 2002b). Maximum concentrations are listed in Table 4.10.



ERDF – Environmental Restoration Disposal Facility
ETF – Effluent Treatment Facility
SALDS – State-Approved Land Disposal Structure
TEDF – Treated Effluent Disposal Facility

Figure 4.20. Distribution of Major Hazardous Chemicals in Groundwater at Concentrations Above the Drinking Water Standards During FY 2001 (after Hartman et al. 2002b). Maximum concentrations are listed in Table 4.10.

Table 4.10. Maximum Concentrations of Groundwater Contaminants at Hanford in FY 2001 (Hartman et al. 2002b)

Contaminant (alphabetical order)	**DWS or MCL** [DCG][(a)]	**Units**	**100-B/C**		**100-K**		**100-N**		**100-D**		**100-H**		**100-F**		**200 West**
			Wells	**Shore**[(b)]	**Wells**	**Shore**[(b)]	**Wells**	**Shore**[(b)]	**Wells**	**Shore**[(b)]	**Wells**	**Shore**[(b)]	**Wells**	**Shore**	**Wells**
Carbon tetrachloride	5	µg/L													**7400**
Carbon-14	2000 [70,000]	pCi/L			**16,300**	ND									
Cesium-137	200 [3000]	pCi/L													
Chloroform	100	µg/L													160
Chromium (dissolved)	100	µg/L	86	48	**1332**	**110**	**173**	12	**4750**	**521**	**160**	88	79	19	**248**
Cobalt-60	100 [5000]	pCi/L													
Cyanide	200	µg/L													
cis-1,2 Dichloroethene	70	µg/L													
Fluoride	4	mg/L									0.32				**4.9**
Gross alpha	15	pCi/L									**33**				**18**
Gross beta	50	pCi/L	**270**	50	**8670**	**82**	**3440**	5.9	**75**	14	**278**	27	**80**	10	**28,700**
Iodine-129	1 [500]	pCi/L													**64**
Nitrate (as NO_3^-)	45	mg/L	34	**67**	**160**	**74**	**125**	22	**86**	**88**	**150**	17	**158**	(c)	**1300**
Nitrite (as NO_2)	3.3	mg/L							**8.3**						**27**
Plutonium 239/240	NA [30]	pCi/L													undetected
Strontium-90	8 [1000]	pCi/L	**135**	**15.8**	***5210***	ND	***9690***	***9690***	**12**	1.4	**38**	**14**	**38**	1.7	**69**
Technetium-99	900 [100,000]	pCi/L									471				**81,500**
Trichloroethene	5	µg/L			**19**								**16**		**21**
Tritium	20,000 [2,000,000]	pCi/L	**40,700**	**31,300**	**1,750,000**	6140	**36,900**	**29,700**	18,600	**22,100**	7740	5460	**38,600**	1380	**1,540,000**
Uranium	30 [790]	µg/L									**49**		23		***2140***

Note: Table lists highest concentration for fiscal year 2001 in each geographic region. Concentrations in **bold** exceed drinking water standards. Concentrations in ***bold italic*** exceed DOE derived concentration guides. Blank spaces indicate the constituent is not of concern in the given area. ND = not detected.

(a) DWS = drinking water standard; MCL = maximum contaminant level; DCG = derived concentration guide (based on 100 mrem/yr). See PNNL-13080 (Hartman 2000) for more information on these standards.

(b) Shoreline sampling includes aquifer sampling tubes, seeps, and shoreline wells from fall 2000. 200 East Area plumes monitored at Old Hanford Townsite.

(c) Fiscal year 2001 results appear erroneous. Past year's results up to 55 mg/L.

Table 4.10. (contd)

Contaminant (alphabetical order)	DWS or MCL [DCG][a]	Units	200 East Wells	200 East Shore[b]	400 Wells	600 Wells	300 Wells	300 Shore[b]	618-11 Wells	Richland North Wells	Basalt-Confined Wells
Carbon tetrachloride	5	μg/L				ND					
Carbon-14	2000 [70,000]	pCi/L									
Cesium-137	200 [3000]	pCi/L	**1910**								
Chloroform	100	μg/L				0.43					
Chromium (filtered)	100	μg/L	**1640**			17					
Cobalt-60	100 [5000]	pCi/L78	78								ND
Cyanide	200	μg/L	**423**								29
cis-1,2 Dichloroethene	70	μg/L					**190**				
Fluoride	4	mg/L								**15**	**8.5**
Gross alpha	15	pCi/L	**357**				**43**	**88**	8.0	10	3.5
Gross beta	50	pCi/L	**25,700**	36			**282**	33	**84**	24	**330**
Iodine-129	1 [500]	pCi/L	**10**	0.27							ND
Nitrate (as NO_3^-)	45	mg/L	**748**	**100**	**87**	22	**89**	**104**	**93**	**162**	38
Nitrite (as NO_2)	3.3	mg/L			0.36						
Plutonium 239/240	NA [30]	pCi/L	**63**								
Strontium-90	8 [1000]	pCi/L	***12,000***								ND
Technetium-99	900 [100,000]	pCi/L	**13,000**	112							**1120**
Trichloroethene	5	μg/L					**5.3**			**5.1**	
Tritium	20,000 [2,000,000]	pCi/L	***4,300,000***	**107,000**	**57,600**	**49,800**	**57,700**	11,700	***8,370,000***	551	5770
Uranium	30 [790]	μg/L	**678**				**205**	**210**	11	23	

Note: Table lists highest concentration for fiscal year 2001 in each geographic region. Concentrations in **bold** exceed drinking water standards. Concentrations in ***bold italic*** exceed DOE derived concentration guides. Blank spaces indicate the constituent is not of concern in the given area. ND = not detected.

(a) DWS = drinking water standard; MCL = maximum contaminant level; DCG = derived concentration guide (based on 100 mrem/yr). See PNNL-13080 (Hartman 2000) for more information on these standards.

(b) Shoreline sampling includes aquifer sampling tubes, seeps, and shoreline wells from fall 2000. 200 East Area plumes monitored at Old Hanford Townsite.

(c) Fiscal year 2001 results appear erroneous. Past year's results up to 55 mg/L.

constituents above the applicable DWSs. The area of contaminant plumes on the Hanford Site with concentrations exceeding drinking water standards was estimated to be 208 km^2 (80.3 mi^2) in fiscal year (FY) 2001. This estimate is 1 percent smaller than that for FY 2000. The decrease is primarily due to shrinkage of the tritium plume from 200 East Area, which was caused primarily by radioactive decay. Table 4.10 shows the maximum concentrations of groundwater contaminants observed on the Hanford Site during FY 2001, along with DWS and DCG values (Hartman et al. 2002b).

The upper basalt-confined aquifer is monitored by about 40 wells that are sampled annually to triennially. Most of these wells are located near the 200 Areas. During the year 2001, seventeen upper basalt-confined aquifer wells were sampled. Tritium, iodine-129, and nitrate were sampled in most of the wells, as they are most mobile in groundwater, the most widespread in the overlying unconfined aquifer, and provide an early warning of potential contamination in the upper basalt-confined aquifer. Results for each of these constituents were less than their respective drinking water standards for 2001. Monitoring results for the groundwater in the upper basalt-confined aquifer in 2000 indicate a tritium concentration of 5770 pCi/L beneath B Pond. Levels of tritium in this location are believed to be a result of downward migration from the overlying unconfined aquifer and have declined since 1996. The highest nitrate concentration, 38 mg/L, was found in the northern section of the 200 East Area in well 299-E33-12. Iodine-129 was not detected in 2001 (Hartman et al. 2002b).

4.5.3.3 200 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. 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 Missoula floods that subsequently deposited Hanford gravels and sands on the remains of the Ringold Formation. Because the Hanford formation 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, evidence appears of erosional channels that may allow communication between the unconfined and uppermost basalt-confined aquifer (Graham et al. 1984; Jensen 1987).

Groundwater occurs in the 200 West Area within the Ringold Formation primarily under unconfined conditions, approximately 61 to 87 m (200 to 285 ft) beneath the surface. The saturated section is 110 m (360 ft) thick. Hydraulic conductivities measured in the 200 West Area in the Ringold Unit E aquifer range from approximately 0.02 to 60 m/day (0.06 to 200 ft/day). Hydraulic conductivities range from 0.5 to 1.2 m/day (1.6 to 4 ft/day) in the semi-confined to confined Ringold Unit A gravels. Groundwater in the 200 West Area generally flows east toward the 200 East Area. In the northwest corner of the 200 East Area, groundwater has flowed northward through the gap between Gable Butte and Gable Mountain. This northward flow appears to be diminishing (Hartman et al. 2002b).

Natural recharge from precipitation falling on the Hanford Site is highly variable spatially and temporally, ranging from near zero to more than 100 mm/yr, depending on climate, vegetation, and soil texture (Gee et al. 1992; Fayer and Walters 1995). Areas with shrubs and fine-textured soils like silt loams tend to have low recharge rates, while areas with little vegetation and coarse-textured soils, such as dune sands, tend to have high recharge rates. Recharge is also generally higher near the basalt ridges because of greater precipitation and runoff. Past estimates of recharge have been summarized in earlier status reports (Thorne and Chamness 1992; Thorne et al. 1993). Fayer and Walters (1995) developed a natural recharge map for 1979 conditions to support the Hanford Site three-dimensional groundwater and transport model. The distributions of soil and vegetation types were mapped first. A recharge rate was then assigned to each combination on the basis of data from lysimeters, tracer studies, neutron probe measurements, and computer modeling. Estimated recharge rates for 1992 were found to range from 2.6 to 127 mm/yr, and the total volume of natural recharge from precipitation over the Hanford Site was estimated at 8.47 x 10^6 m^3/yr. This value is of the same order of magnitude as the artificial recharge to the 200 Area waste disposal facilities during 1992 and is about half the volume of discharge to these facilities during 1979 (Fayer and Walters 1995).

The other source of recharge to the unconfined aquifer is artificial recharge from wastewater disposal. Over the past 50 years, the large volume of wastewater discharged to disposal facilities at the Hanford Site has significantly affected groundwater flow and contaminant transport in the unconfined aquifer. The volume of artificial recharge has decreased significantly during the past 10 years and continues to decrease. Wurstner et al. (1995) summarized the major discharge facilities incorporated in the three-dimensional model. Cole et al. (1997) summarized the major wastewater discharges from past and future sources.

Depth to groundwater in the 200 East Area ranges from 97 m (320 ft) in the southeast to 37 m (120 ft) in the vicinity of the 216-B-3C pond (B Pond mound). A downward gradient has formed in the B Pond vicinity due to groundwater mounding from discharges. Based on data collected in March 2002 for well pair 699-43-42J (water table) and 699-42-42B (7.37 m deeper), the downward gradient was 0.038. This is greater than the horizontal gradient, 0.002. Groundwater flow in the 200 East Area is to the southeast. Interconnection between the unconfined and lower confined aquifer is possible across the Central Plateau. However, except for the area near the erosional windows that occur in the basalt several kilometers north of the 200 East Area and B Pond vicinity in the 200 East Area, no indication is shown of aquifer interconnection. Several kilometers north of the 200 East Area, an absence of confining layer(s) is associated with an erosional window that has resulted in enhanced interconnection of the aquifers in this area. Hydraulic conductivities of the unconfined aquifer in the 200 East Area range from 150 to 300 m/day (500 to 1000 ft/day). Flow may split east of Gable Butte, one path heading north toward the gap between Gable Butte and Gable Mountain, and the other path east to the Columbia River.

Groundwater is monitored in the vicinity of the LLBGs as a result of interim status requirements of WAC 173-303. The LLBGs are divided into five low-level waste management areas (LLWMAs). Since 1996, groundwater has not been monitored within LLWMA-5, the location of the 218-W-6 Burial Ground, as the site has never received waste.

LLWMA-1 consists of the 218-E-10 Burial Ground. Well 299-E33-34, a downgradient monitoring well, exceeded the critical mean for specific conductance in 2000, but this was related to the nitrate plume with an upgradient source in the northern portion of this LLWMA (Poston et al. 2001).

LLWMA-2 is located in the 200 East Area and includes all of the 218-E-12B Burial Ground. Upgradient well 299-E34-7 exceeded the critical mean value for specific conductance in 2000. Sulfate and calcium are the major contributors to the increase and their source is not known. However, only 0.6 m (2 ft) of water remains in this well, which is at the top of the basalt, and the increases may be due to basalt chemistry. Well 299-E34-7 also exceeded the comparison value for total organic carbon in 2000. Results for volatile and semi-volatile organics were less than detection limits, with the exception of bis (2-ethylhexyl) phthalate at 1.7 μg/L.

LLWMA-3 includes the 218-W-3A, 218-W-3AE, and 218-W-5 Burial Grounds in the 200 West Area. Indicator parameter data from upgradient wells were statistically evaluated and values from downgradient wells were compared with established values from upgradient wells in 2000. The critical mean value for specific conductance was exceeded in an upgradient well, but is due to increases in sulfate and nitrate from upgradient sources. None of the other wells in LLWMA-3 exceeded contamination parameters during 2000. Several of the wells in LLWMA-3 have gone dry, as the water table continues to decline.

LLWMA-4 is located in the 200 West Area and includes 218-W-4B and 218-W 4C Burial Grounds. Indicator parameter data from upgradient wells were statistically evaluated and values from downgradient wells were compared with established values from upgradient wells in 2000. The critical mean value for total organic halides was exceeded in one downgradient well in 2000, caused by carbon tetrachloride from an upgradient source. Groundwater in LLWMA-4 is being actively remediated using pump-and-treat methods.

DOE has an Integrated Monitoring Plan for the Hanford Groundwater Monitoring Project (Hartman et al. 2002a) that integrates all of the separate monitoring plans that are prepared for RCRA, CERCLA, and DOE Orders. Groundwater is a dynamic system, and the monitoring network is annually reviewed and modified to accommodate changes. Any additional wells for the LLBGs will be defined through the RCRA permit process and will be drilled under the TPA M-24 Milestone. DOE-RL has worked with EPA and Ecology to revise the M-24 Milestone as needed, and tentative agreement has been reached on a four-year schedule for drilling additional wells, including 17 proposed new wells for the LLBG waste management areas. The M-24 TPA Change Package for the new wells was issued for public comment in September 2003. A total of 1,278 wells are scheduled to be sampled in fiscal years 2003, 2004, or 2005 for all programs combined.

4.6 Biological and Ecological Resources

The Hanford Site is characterized as a shrub-steppe ecosystem (Daubenmire 1970). Such ecosystems are typically dominated by a shrub overstory with a grass understory. In the early 1800s, the dominant plant in the area was big sagebrush underlain by perennial Sandberg's bluegrass and bluebunch wheatgrass. With the advent of settlement, livestock grazing and agricultural production contributed to colonization by nonnative vegetation species that currently dominate the landscape. Although agriculture and production of livestock were the primary activities at the beginning of the twentieth century, these activities ceased when the site was established in 1943. Remnants of past agricultural practices are still evident.

The Columbia River borders the DOE-managed portion of the Hanford Site to the east. Operation of Priest Rapids Dam upstream of the site accommodates maintenance of intakes at the Hanford Site and helps to manage anadromous fish populations. The Columbia River and associated riparian zones provide habitat for numerous wildlife and vegetation species.

Large areas of the Hanford Site have experienced range fires that have greatly influenced the vegetation canopy and distribution of wildlife. In 1984, a major fire burned across 800 km^2 (310 mi^2) of the Hanford Site (Price et al. 1986). From June 27 through July 2, 2000, the *24 Command Fire* burned across the Hanford Site consuming most of the shrub-steppe habitat on the ALE Unit, a small section of the McGee-Riverlands Unit, and other southwestern portions of the site. The fire consumed a total of 655 km^2 (250 mi^2) of federal, state, and private lands before it was controlled (BAER 2000). Range fires are a component of natural plant succession.

The Hanford Site Fire Department provides the planning to guide the management of wildland and prescribed fires on the site. This planning is designed to ensure safety, protect facilities and resources, and restore and perpetuate natural processes.

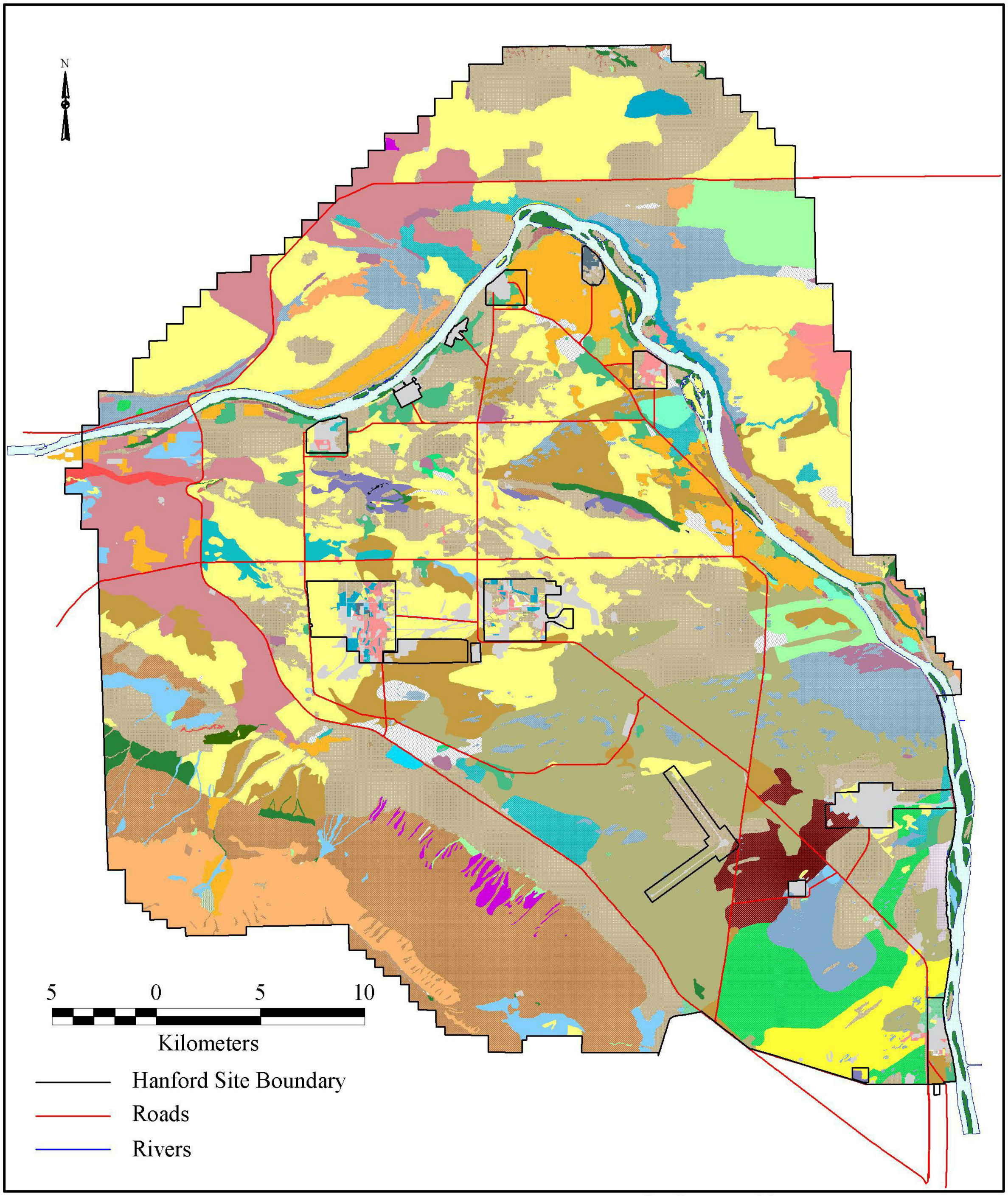
DOE manages the Hanford Site through the Hanford Site Biological Resources Management Plan (BRMaP; DOE-RL 2001) and the Hanford Site Biological Resources Mitigation Strategy (BRMiS; DOE-RL 2003b) that were adopted after preparation of the HCP EIS (DOE 1999), which included an ecosystem analysis.

4.6.1 Vegetation

Plants at the Hanford Site are adapted to low annual precipitation, low water-holding capacity of the rooting substrate (sand), dry summers, and cold winters. Range fires that burn through the area during dry summers have reduced species that are less resistant to fire (for example, big sagebrush) and have allowed more opportunistic and fire-resistant species a chance to become established. Perennial shrubs and bunchgrasses generally dominate native plant communities on the site. However, Euro-American settlement and development have resulted in the proliferation of non-native species. Of the 590 species of vascular plants recorded on the Hanford Site, approximately 20 percent of the species are considered nonnative (Sackschewsky et al. 1992). Cheatgrass is the dominant non-native species. It is an aggressive colonizer and has become well established across the site (Rickard and Rogers 1983). The biodiversity inventories conducted by The Nature Conservancy of Washington (TNC 1999) have identified 85 additional taxa, establishing the actual number of plant taxa on the Hanford Site at 675.

The Nature Conservancy of Washington also conducted rare plant surveys. The Conservancy found 112 populations/occurrences of 28 rare plant taxa on the Hanford Site. When combined with observations preceding the 1994-1999 inventories, a total of 127 populations of 30 rare plant taxa have been documented on the Hanford Site (TNC 1999).

Figure 4.21 shows existing vegetation and land use areas on the Hanford Site, prior to the *24 Command Fire* that occurred in late June 2000. Table 4.11 presents a list of common plant species in shrub-steppe and riparian areas.



Data Collected: 1994, 1997/The Nature Conservancy
1991, 1999 Pacific Northwest National Laboratory
Map Created: September 1999/Pacific Northwest National Laboratory

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Figure 4.21. Distribution of Vegetation Types and Land Use Areas on the Hanford Site Prior to the *24 Command Fire* of 2000 (Neitzel 2002a). Legend on following page.

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

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Figure 4.21. (contd) Legend for Figure 4.21

Table 4.11. Common Vascular Plants on the Hanford Site (Taxonomy follows Hitchcock and Cronquist 1973)

A. Shrub-Steppe Species	Scientific Name
Shrub	
big sagebrush	*Artemisia tridentata*
bitterbrush	*Purshia tridentata*
gray rabbitbrush	*Chrysothamnus nauseosus*
green rabbitbrush	*Chrysothamnus viscidiflorus*
snow buckwheat	*Eriogonum niveum*
spiny hopsage	*Grayia (Atriplex) spinosa*
threetip sagebrush	*Artemisia tripartita*
Perennial Grasses	
bluebunch wheatgrass	*Agropyron spicatum*
bottlebrush squirreltail	*Sitanion hystrix*
crested wheatgrass	*Agropyron desertorum (cristatum)*[a]
indian ricegrass	*Oryzopsis hymenoides*
needle-and-thread grass	*Stipa comata*
prairie junegrass	*Koeleria cristata*
sand dropseed	*Sporobolus cryptandrus*
Sandberg's bluegrass	*Poa sandbergii (secunda)*
thickspike wheatgrass	*Agropyron dasytachyum*
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*
Franklin's sandwort	*Arenaria franklinii*
Gray's desertparsley	*Lomatium grayi*
hoary aster	*Machaeranthera canescens*
hoary falseyarrow	*Chaenactis douglasii*
longleaf phlox	*Phlox longifolia*

Table 4.11. (contd)

A. Shrub-Steppe Species	Scientific Name
Perennial Forbs (cont)	
Munro's globemallow	*Sphaeralcea munroana*
pale evening primrose	*Oenothera pallida*
sand beardtongue	*Penstemon acuminatus*
stalked-pod milkvetch	*Astragalus sclerocarpus*
threadleaf fleabane	*Erigeron filifolius*
turpentine spring parsley	*Cymopteris terebinthinus*
winged dock	*Rumex venosus*
yarrow	*Achillea millefolium*
yellow bell	*Fritillaria pudica*
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)]
rough wallflower	*Erysimum asperum*
Russian thistle (tumbleweed)	*Salsola kali*[(a)]
slender hawksbeard	*Crepis atrabarba*
spring whitlowgrass	*Draba verna*[(a)]
storksbill	*Erodium cicutarium*[(a)]
tall willowherb	*Epilobium paniculatum*
tarweed fiddleneck	*Amsinckia lycopsoides*
threadleaf scorpion weed	*Phacelia linearis*

Table 4.11. (contd)

A. Shrub-Steppe Species	Scientific Name
Annual Forbs (contd)	
western tansymustard	*Descurainia pinnata*
white cupseed	*Plectritis macrocera*
whitestem stickleaf	*Mentzelia albicaulis*
winged cryptantha	*Cryptantha pterocarya*
yellow salsify	*Tragopogon dubius*[(a)]
Annual Grasses	
cheatgrass	*Bromus tectorum*[(a)]
slender sixweeks	*Festuca octoflora*
small sixweeks	*Festuca microstachys*
Trees and Shrubs	
black cottonwood	*Populus trichocarpa*
black locust	*Robinia pseudo-acacia*
coyote willow	*Salix exigua*
dogbane	*Apocynum cannabinum*
peach, apricot, cherry	*Prunus* spp.
peachleaf willow	*Salix amygdaloides*
willow	*Salix* spp.
white mulberry	*Morus alba*[(a)]
B. Riparian Species	**Scientific Name**
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*
hairy golden aster	*Heterotheca villosa*
heartweed	*Polygonum persicaria*
horsetails	*Equisetum* spp.

Table 4.11. (contd)

B. Riparian Species	Scientific Name
Perennial Grasses and Forbs (contd)	
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[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]
Aquatic Vascular	
Canadian waterweed	Elodea Canadensis
Columbia yellowcress	Rorippa columbiae
duckweed	Lemna minor
pondweed	Potamogeton spp.
spiked water milfoil	Myriophyllum spicatum
watercress	Rorippa nasturtium-aquaticum

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

200 Areas Flora. Waste management areas and crib sites are generally either barren or vegetated by invasive species, including Russian thistle (tumbleweed), tumble mustard, and cheatgrass. Russian thistle and gray rabbitbrush occurring in these areas are deep rooted and have the potential to accumulate radionuclides and other buried contaminants, functioning as a pathway to other parts of the ecosystem (Landeen et al. 1993). Russian thistle, an annual weed, accumulates nitrates and soluble oxalates, and has significant seed dispersion. Vegetation samples are collected annually from the 200/600 Areas and analyzed for uranium, cobalt-60, strontium-90, cesium-137, and plutonium-239/240. The Hanford Integrated Biological Control (IBC) program was established to control the growth of deep-rooted vegetation over contaminated and potentially contaminated waste sites. The program also established vegetation control through herbicide spraying and cleanup activities. The effectiveness of the program is directly related to the timeliness of herbicide application and removal of tumbleweeds, rabbitbrush, and sagebrush.

The portions of the 200 Areas undisturbed by DOE and its predecessor agencies, but previously disturbed by farmers and ranchers, are characterized as sagebrush/cheatgrass or Sandberg's bluegrass communities of the 200 Area Plateau. Cheatgrass provides half of the total plant cover. Most of the waste disposal and storage sites are covered by nonnative vegetation or are kept in a vegetation-free condition with the use of herbicides, because the plants could potentially accumulate waste constituents. Figures 4.22 and 4.23 illustrate existing vegetation and land use areas mapped prior to the *24 Command Fire* for the 200 West Area and 200 East Area, respectively. Early observations suggest the soil structure and seed bank may have been damaged to the point where vegetative recovery will be slower than in other areas, and the resulting community may not resemble the sagebrush-steppe that existed before the fire.

West Lake and its immediate basin represent a unique habitat that is characterized by highly saline conditions (Poston et al. 1991). Water levels of the pond fluctuate with groundwater levels. Predominant plants include salt grass, plantain, and rattlebox. Three-spine bulrush grows along the shoreline.

4.6.2 Wildlife

Three hundred species of terrestrial vertebrates have been observed on the Hanford Site. The species list includes approximately 42 species of mammals, 246 species of birds, 5 species of amphibians, and 12 species of reptiles (Soll and Soper 1996; Brandt et al. 1993).

The shrub and grassland habitat of the Hanford Site supports many groups of terrestrial wildlife. Species include large game animals like Rocky Mountain elk and mule deer; predators such as coyote, bobcat, and badger; and herbivores like deer mice, harvest mice, ground squirrels, voles, and black-tailed jackrabbits. The most abundant mammal on the Hanford Site is the Great Basin pocket mouse.

Mule deer rely 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 in 1972 (Fitzner and Gray 1991), and have increased from approximately eight animals in 1975 to 900 in 1999. The Rattlesnake Hills elk herd that inhabits the Hanford Site primarily occupies ALE and private lands that adjoin the reserve to the north and west. Elk 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 ALE in the winter and disperses during the summer months to higher elevations on ALE, private land to the west of ALE, and the U.S. Army Yakima Training Center. Approximately 300 elk have been relocated or removed by special hunts during 1999-2000. Elk relocation continued in 2002. The *24 Command Fire* in June 2000 destroyed nearly all the elk forage on ALE. 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. Post-fire surveys suggest very low mortality of adult elk as a result of the wildfire.

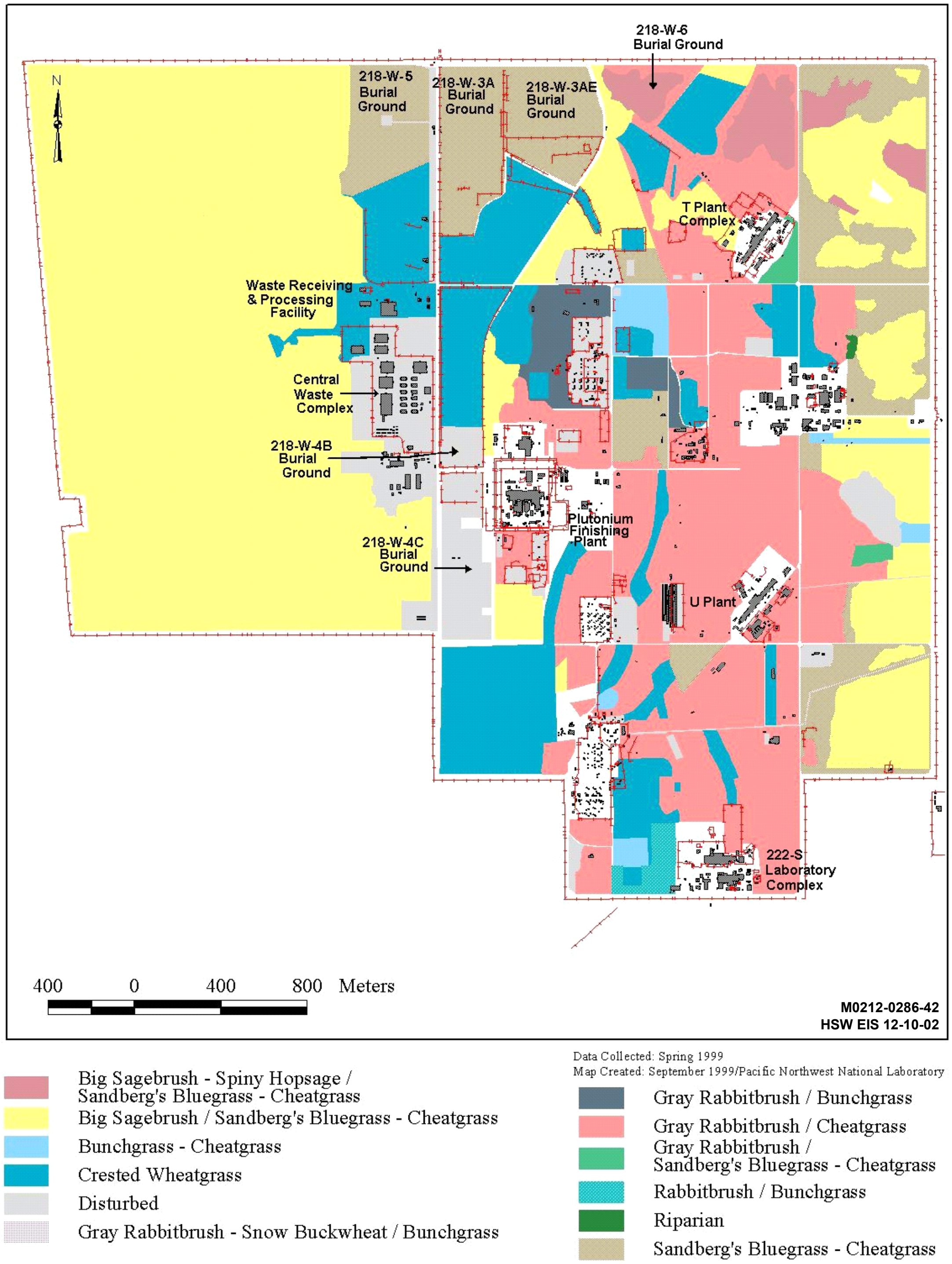


Figure 4.22. Distribution of Vegetation Types and Land Use Areas in the 200 West Area Prior to the *24 Command Fire* (DOE-RL 2001)

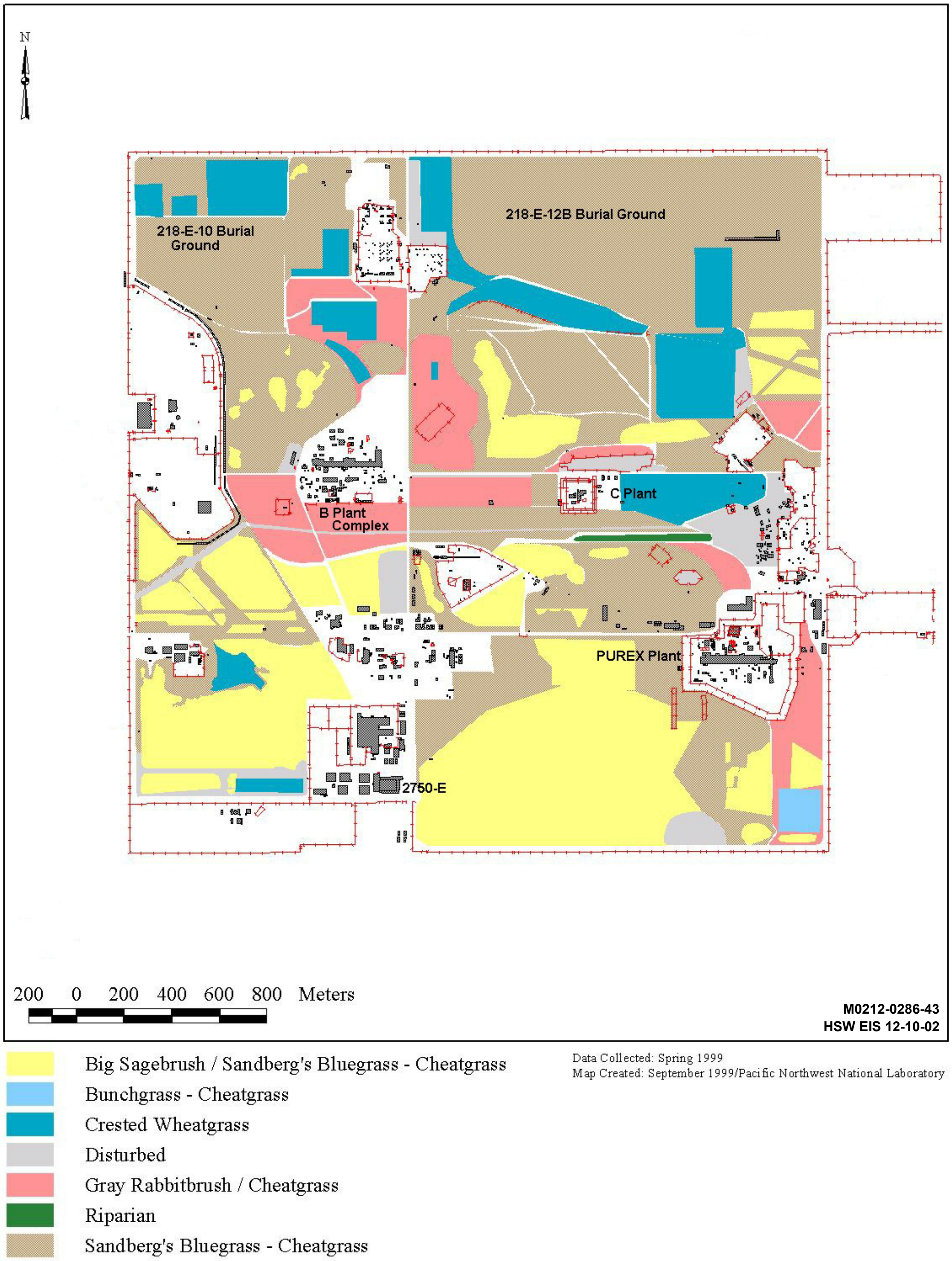


Figure 4.23. Distribution of Vegetation Types and Land Use Areas in the 200 East Area Prior to the *24 Command Fire* (DOE-RL 2001)

However, the wildfire occurred in the middle of calving season, which may have an impact on the number of calves and their survival to adulthood. A cougar sighting on ALE was reported during the elk relocation effort in March 2000.

Shrubland and grassland provide nesting and foraging habitat for many passerine bird species. Surveys conducted during 1993 (Cadwell 1994) reported the occurrence of western meadowlarks and horned larks more frequently in shrubland habitats than in other habitats on the site. TNC (1999) reported a total of 41 species that are considered dependent on steppe or shrub-steppe habitat. Long-billed curlews and vesper sparrows were also noted as commonly occurring species in shrubland habitat. Species that are dependent on undisturbed shrub habitat include sage sparrow, sage thrasher, and loggerhead shrike. The sage sparrow and loggerhead shrike tend to roost and nest in sagebrush or bitterbrush that occurs at lower elevations (DOE-RL 2001). Ground-nesting species that occur in grass-covered uplands include long-billed curlews, western meadowlark, and burrowing owls.

Common upland game bird species that occur in shrub and grassland habitat include chukar partridge, California quail, and Chinese ring-necked pheasant. Chukars are most numerous in the Rattlesnake Hills, Yakima Ridge, Umtanum Ridge, Saddle Mountains, and Gable Mountain areas of the Hanford Site. Less common species include western sage grouse, Hungarian partridge, and scaled quail. Western 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. Surveys conducted by the Washington State Department of Fish and Wildlife (WDFW) and PNNL during late winter and early spring 1993, and biodiversity inventories conducted by The Nature Conservancy in 1997, did not observe western sage grouse in sagebrush-steppe habitat at ALE. However, sage grouse have been observed on ALE in 1999 and 2000 (Tiller 2000).

Among the raptor species that use shrubland and grassland habitats are American kestrel, red-tailed hawk, Swainson's hawk, and ferruginous hawks. Northern harriers, sharp-shinned hawks, rough-legged hawks, and golden eagles also occur in these habitats but are not sighted as frequently. In 1994, nesting by red-tailed, Swainson's, and ferruginous hawks included 41 nests located across the Hanford Site on high voltage transmission towers, trees, cliffs, and basalt outcrops. In recent years, the number of nesting ferruginous hawks on the Hanford Site has increased, in part as a result of their acceptance of steel power line towers in the open grass and shrubland habitats.

Many species of insects occur throughout all habitats on the Hanford Site. Butterflies, grasshoppers, and darkling beetles are among the most conspicuous of the approximately 1500 species of insects that have been identified from specimens collected on the Hanford Site (TNC 1999). The actual number of insect species occurring on the Hanford Site may reach as high as 15,500. A total of 1509 species-level identifications were completed in 1999 and 500 more are expected. Recent surveys performed by The Nature Conservancy included the collection of 40,000 specimens and have resulted in the identification of 43 new taxa and 142 new findings in the state of Washington (TMC 1999). The high diversity of insect species on the Hanford Site is believed to reflect the size, complexity, and quality of the shrub-steppe habitat.

The side-blotched lizard is the most abundant reptile species that occurs on the Hanford Site. Sagebrush lizards and short-horned lizards are reportedly found on the site, but occur infrequently. The most common snake species include gopher snake, yellow-bellied racer, and Pacific rattlesnake. The Great Basin spadefoot toad, Woodhouse's toad, Pacific tree frog, tiger salamander, and bullfrog are the only amphibians found on the site (TNC 1999; Brandt et al. 1993).

With the cessation of production activities at Hanford, the amount of water discharged to the ground in the 200 Area Plateau has substantially decreased. West Lake has shrunk and is presently a group of small isolated pools and mud flats. Avocets and sandpipers still use the site, but it does not support coots or other nesting waterfowl.

4.6.3 Aquatic Ecology

Two types of natural aquatic habitats are found on the Hanford Site: the Columbia River that flows along the northern and eastern edges of the site, and the small spring-streams and seeps located mainly on ALE in the Rattlesnake Hills.

The Columbia River is the dominant aquatic ecosystem on the Hanford Site and supports a large and diverse community of plankton, benthic invertebrates, fish, and other communities. It has a drainage area of about 680,000 km^2 (260,000 mi^2), an estimated average annual discharge of 6600 m^3/s (71,000 ft^3/s), and a total length of about 2000 km (1240 mi) from its origin in British Columbia to its mouth at the Pacific Ocean. The Columbia has been dammed upstream and downstream of the Hanford Site, and the Hanford Reach flowing through the site is the last free-flowing, but regulated, section of the Columbia River in the United States above Bonneville Dam. Plankton populations in the Hanford Reach are influenced by communities that develop in the reservoirs of upstream dams, particularly Priest Rapids Reservoir, and by manipulation of water levels below by dam operations in upstream and downstream reservoirs. Phytoplankton and zooplankton populations provide food for herbivores such as immature insects that are then consumed by predaceous species. These phytoplankton and zooplankton are largely transient, flowing from one reservoir to another. There is generally insufficient time for characteristic endemic groups of phytoplankton and zooplankton to develop in the Hanford Reach. No tributaries enter the Columbia River during its passage through the Hanford Site; however, there are several irrigation water return canals that discharge into the river along the Franklin County shoreline.

Gray and Dauble (1977) listed 43 species of fish in the Hanford Reach of the Columbia River. The brown bullhead, collected since 1977, brings the total number of fish species identified in the Hanford Reach to 44. Of these species, Chinook salmon, sockeye salmon, coho salmon, and steelhead trout 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.

Small interrupted streams, such as Rattlesnake and Snively springs, contain diverse biotic communities and are extremely productive (Cushing and Wolf 1984). Dense blooms of watercress occur and aquatic insect production is high compared with mountain streams (Gaines 1987). The macrobenthic biota varies from stream to stream and is related to the proximity of colonizing insects and other factors. Rattlesnake Springs is of ecological importance because it provides a source of water to terrestrial animals in an otherwise arid part of the site. Snively Springs, located farther west and at a higher elevation than Rattlesnake Springs, is a source of drinking water for terrestrial animals. The major rooted aquatic plant, which in places may cover the entire width of the stream, is watercress (*Rorippa nasturtium-aquaticum*). Isolated patches of bulrush (*Scirpus* sp.), spike rush (*Eleocharis* sp.), and cattail (*Typha latifolia*) occupy less than 5 percent of the streambed.

4.6.4 Threatened and Endangered Species

The federal Endangered Species Act (16 USC 1531-1544) defines endangered species as plants and animals in danger of extinction within the foreseeable future throughout all or a significant portion of its range. Threatened species are those likely to become endangered within the foreseeable future throughout all or a significant portion of its range. Candidate species are plants and animals with a status of concern, but more information is needed before they can be proposed for listing.

No plants or mammals on the federal list of threatened and endangered wildlife and plants (50 CFR 17) are known to occur on the Hanford Site. However, the bald eagle and two species of fish (steelhead and spring-run Chinook salmon), currently found on the federal list of threatened and endangered species, are present on the Hanford Site on a regular basis. Surveys of the 200 Areas (Sackschewsky 2002, 2003) and Area C (Sackschewsky 2003) revealed no federal or state threatened or endangered species (see Appendix I).

Federally listed threatened, endangered, candidate species (50 CFR 17), and species of concern (http://www.wa.gov/wdfw/wlm/diversty/soc/adv_search.htm) and threatened and endangered species listed by Washington State (Washington Natural Heritage Program 2002) identified on the Hanford Site are shown in Table 4.12. Several candidate species of plants and animals are under consideration for formal listing by the federal government and Washington State. The FWS annually reviews the status of candidate species for listing under the Endangered Species Act. The results of these reviews are posted on the FWS homepage http://www.fws.gov. Several federal plant and animal species of concern require further information before the FWS can decide whether the species should be considered for formal listing (http://www.wa.gov/wdfw/wlm/diversty/soc/adv_search.htm). Anadromous fish are reviewed and listed by the National Marine Fisheries Service (NMFS) (http://www.nwr.noaa.gov).

Washington State defines endangered species as wildlife species native to the state of Washington that are seriously threatened with extinction throughout all or a significant portion of their ranges within the state. Threatened species include wildlife species native to the state that are likely to become an endangered species within the foreseeable future throughout a significant portion of their ranges within the state (WAC 232-12-297). A State of Washington sensitive species is a wildlife species native to the state that is vulnerable or declining and is likely to become endangered or threatened throughout a significant portion of its range within the state without cooperative management or removal of threats. The common loon (*Gavia immer*) is the only Washington State sensitive animal species found on the Hanford Site. Table 4.13 lists the Washington State-designated candidate animal species that potentially are found on the Hanford Site and are under consideration for possible addition to the threatened or endangered list. A state candidate species is one that is being reviewed for possible listing as a state endangered, threatened, or sensitive species as specified in Washington Department of Fish and Wildlife Policy M-6001 (WDFW 1998).

Table 4.12. Federally Listed Threatened, Endangered, Candidate Species, and Species of Concern and Washington State-Listed Threatened and Endangered Species Occurring or Potentially Occurring on the Hanford Site (Fitzner and Gray 1991, Landeen et al. 1992, FWS 2003, and Neitzel 2002a)

Common Name	Scientific Name	Federal	State[a]
Plants			
Columbia milkvetch	*Astragalus columbianus*	SC[b]	T[c]
dwarf evening primrose	Camissonia (= Oenothera) pygmaea		T
Hoover's desert parsley	Lomatium tuberosum	SC	T
Loeflingia	Loeflingia squarrosa var. squarrosa		T
persistent sepal yellowcress	Rorippa columbiae	SC	T
Umtanum desert (wild) buckwheat	Eriogonum codium	C[d]	E[e]
White Bluffs bladderpod	Lesquerella tuplashensis	C	E
white eatonella	Eatonella nivea		T
Ute ladies'-tresses[g]	*Spiranthes diluvialis*	T	
Fish			
bull trout [g]	*Salvelinus confluentus*	T	
spring-run Chinook	Oncorhynchus tshawytscha	E	C
Upper Columbia steelhead	Oncorhynchus mykiss	E	C
Middle Columbia steelhead	*Oncorhynchus mykiss*	T	C
Birds			
American white pelican	Pelecanus erythrorhychos		E
bald eagle[f]	Haliaeetus leucocephalus	T	T
ferruginous hawk	Buteo regalis	SC	T
greater sage grouse	*Centrocercus urophasianus phaios*	C	T
olive-sided flycatcher	*Contopus cooperi*	SC	
sandhill crane	Grus canadensis		E
willow flycatcher	*Empidonax trailii*	SC	
yellow-billed cuckoo[g]	*Coccyzus americanus*	C	
Reptiles			
Northern sagebrush lizard	*Sceloporous graciosus*	SC	

(a) http://www.wa.gov/wdfw/ select Habitat, Priority Habitats and Species List, Species of Concern List, Endangered Species (WAC 232-12-297)
(b) SC = Federal species of concern, 50 CFR 17 http://www.fws.gov.
(c) T = Federal threatened species, 50 CFR 17 http://www.fws.gov.
(d) C = Federal candidate species, 50 CFR 17 http://www.fws.gov.
(e) E = Federal endangered species, 50 CFR 17 http://www.fws.gov.
(f) Currently under review for change in status.
(g) Not believed present on the Hanford Site, but identified by FWS 2003.

Table 4.13. Washington State Candidate Animal Species Found on the Hanford Site (Fitzner and Gray 1991; Landeen et al. 1992; and Neitzel 2002a)

Common Name	Scientific Name
Molluscs	
giant Columbia River spire snail[a,b] giant Columbia River limpet	*Fluminicola (= Lithoglyphus) columbiana* *Fisherola* (= *Lanx*) *nuttalli*
Fish	
spring-run Chinook[c] steelhead[b]	*Oncorhynchus tshawytscha* *Oncorhynchus mykiss*
Insects	
Columbia River tiger beetle[d]	*Cicindela columbica*
Birds	
burrowing owl[a,b]	*Athene cunicularia*
golden eagle	*Aquila chrysaetos*
Lewis' woodpecker	*Melanerpes lewis*
loggerhead shrike[a,b]	*Lanius ludovicianus*
merlin	*Falco columbarius*
northern goshawk[a,b,e]	*Accipter gentilis*
sage sparrow	*Amphispiza belli*
sage thrasher	*Preoscoptes montanus*
Vaux's swift	*Chaetura vauxi*
Reptiles	
striped whipsnake	*Masticophis taeniatus*
Mammals	
black-tailed jackrabbit	*Lepus californicus*
Merriam's shrew	*Sorex merriami*
Washington ground squirrel[f]	*Spermophilus washingtoni*
white-tailed jackrabbit	*Lepus townsendi*

(a) Information from Washington Department of Fish and Wildlife http://www.wa.gov/wdfw/ select Habitat, Priority Habitats and Species List, Species of Concern List) (WDFW Policy M-6001 1988).
(b) Federal endangered.
(c) Probable, but not observed on the Hanford Site.
(d) Reported, but seldom observed on the Hanford Site.
(e) Federal candidate.

Washington State considers shrub-steppe habitat as a priority habitat because of its relative scarcity in the state and because of its requirement as nesting/breeding habitat by several state and federal species of concern (see Figure 4.21 for vegetation habitat coverage). Designation and characterization of priority habitat serves to provide a basis for sound and defensible land management planning and assists the DOE in implementing sound stewardship activities into site management to protect regulated species.

Table 4.14 lists Washington State plant species of concern that are currently listed as sensitive or are in one of three monitored groups (Washington Natural Heritage Program 2002; TNC 1999). The

Washington Natural Heritage Program established the ratings reported in Table 4.14 as Sensitive (vulnerable or declining and could become endangered or threatened), Review 1 (more field work needed), and Review 2 (unresolved taxonomic problems).

Figure 4.24 shows the general locations of species of concern on the Hanford Site prior to the wildfire, and the *24 Command Fire* coverage. In some areas the wildfire burn intensity was generally low, allowing belowground portions of some perennial plants and seeds to survive. However, there were some areas of high burn where the soil and seed bank may have been damaged. Most of the rare plants are expected to recover within 1 to 3 years, although their populations may be reduced.

200 Areas. The annual review of the LLBGs was conducted in April of 2001 (Sackschewsky 2002). Due to access restrictions, visual observations from the burial ground perimeters were performed. The LLBGs include 218-E-10 and 218-E-12B in the 200 East Area, and 218-W-3A, 218-W-3AE, 218-W-4B, 218-W-4C, 218-W-5, and 218-W-6 in the 200 West Area. The western half of 218-W-6, the undeveloped portion of 218-W-4C (along 16th Street), and the undeveloped portion of the 218-E-10 Burial Ground (north of the existing powerline) were not reviewed during recent evaluations.

Crouching milkvetch (*Astragalus succumbens*) and stalked-pod milkvetch (*Astragalus sclerocarpus*), State of Washington watch list species, were observed within the 218-W-4C Burial Ground and the extreme western edge of the 218-W-5 Burial Ground. Crouching milkvetch was also observed in the south end of the 218-W-6 Burial Ground. Piper's daisy (*Erigeron piperianus*), a State of Washington sensitive species was noted in the 218-E-12B and 218-E-10 Burial Grounds in previous years.

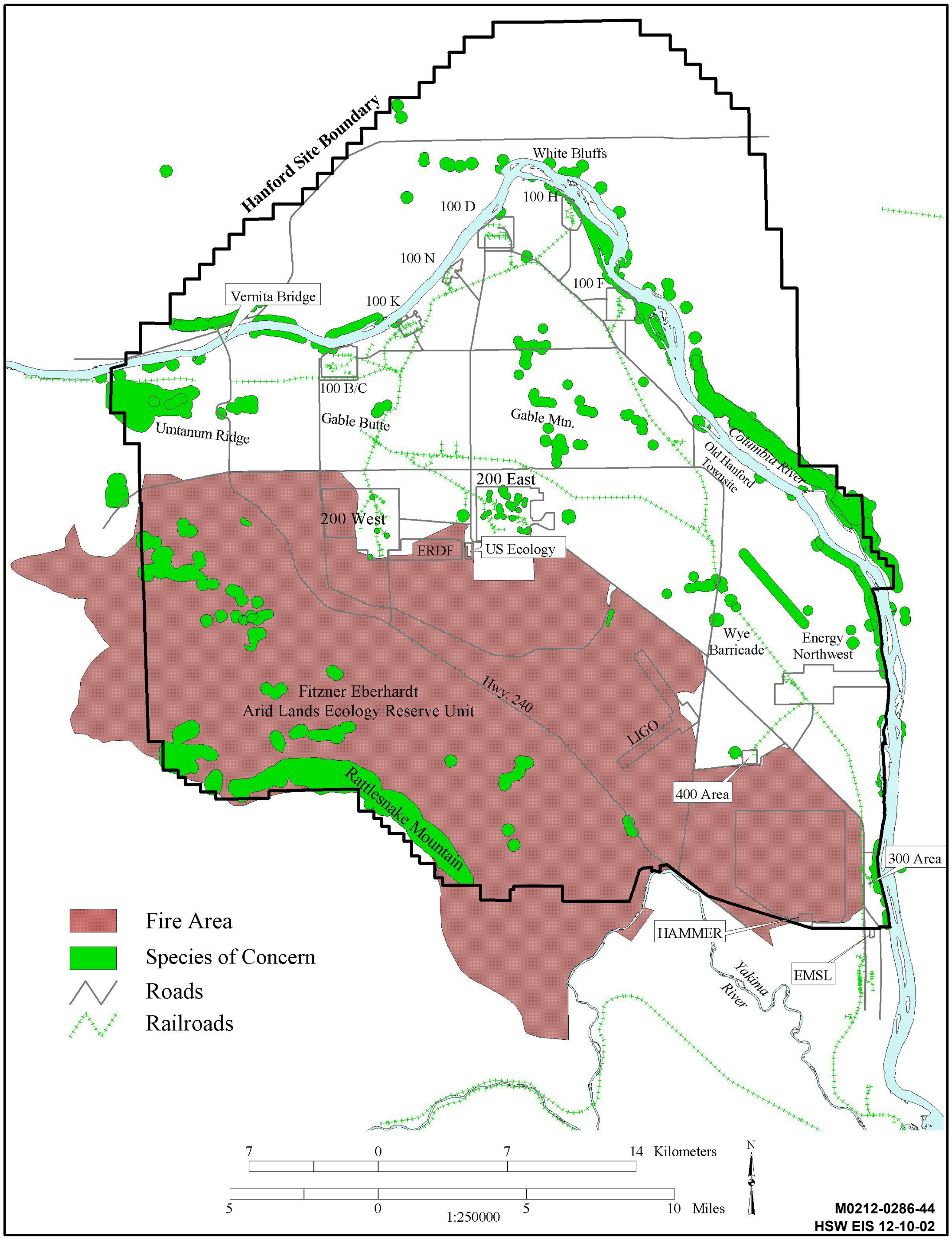
Birds observed within the 200 East Area LLBGs include long-billed curlews (*Numenius americanus*), killdeer (*Charadrius viociferus*), horned larks (*Eremophila alpestris*), Say's phoebe (*Sayornis saya*), American robin (*Turdus migratorius*), American kestrel (*Falco sparverius*), western meadowlark (*Sturnella neglecta*), and common raven (*Corvus corax*). Two bird species, loggerhead shrike (*Lanius ludovicianus*) and sage sparrow (*Amphispiza belli*), Washington State candidate species, have been sighted in the vicinity of the 218-W-4C Burial Ground. Burrowing owls (*Athene cunicularia*), Washington State candidate species, have been observed in the vicinity of the 218-W-6 Burial Ground.

A 1998 amendment to the Fish and Conservation Act directs the FWS to identify species, subspecies, and populations of all migratory non-game birds that, without additional conservation actions, are likely to become candidates for listing under the Endangered Species Act (FWS 2002). These birds, designated as Birds of Conservation Concern, also include recently delisted species. Table 4.15 lists Birds of Conservation Concern, as recognized by the FWS, which have been observed on the Hanford Site.

Table 4.14. Washington State Plant Species of Concern Occurring on the Hanford Site, as Determined by the Washington Natural Heritage Program 2002 (Neitzel 2002a)

Common Name	Scientific Name	State Listing
annual paintbrush	*Castilleja exilis*	R1
awned halfchaff sedge	*Lipocarpha (= Hemicarpha) aristulata*	R1
basalt milk-vetch	*Astragalus conjunctus var. rickardii*	R1
bristly combseed	*Pectocarya setosa*	W
brittle prickly pear	*Opuntia fragilis*	R1
Canadian St. John's wort	*Hypericum majus*	S
chaffweed	*Centunculus minimus*	R1
Columbia River mugwort	*Artemesia lindleyana*	W
coyote tobacco	*Nicotiana attenuata*	S
crouching milkvetch	*Astragalus succumbens*	W
desert dodder	*Cuscuta denticulata*	S
desert evening-primrose	*Oenothera caespitosa*	S
false pimpernel	*Lindernia dubia anagallidea*	R2
fuzzytongue penstemon	*Penstemon eriantherus whitedii*	R1
Geyer's milkvetch	*Astragalus geyeri*	S
grand redstem	*Ammannia robusta*	R1
gray cryptantha	*Cryptantha leucophaea*	S
Great Basin gilia	*Gilia leptomeria*	R1
hedge hog cactus	*Pediocactus simpsonii var. robustior*	R1
Kittitas larkspur	*Delphinium multiplex*	W
lowland toothcup	*Rotala ramosior*	R1
miner's candle	*Cryptantha scoparia*	R1
Piper's daisy	*Erigeron piperianus*	S
Robinson's onion	*Allium robinsonii*	W
rosy balsamroot	*Balsamorhiza rosea*	W
rosy pussypaws	*Calyptridium roseum*	S
scilla onion	*Allium scilloides*	W
shining flatsedge	*Cyperus bipartitus (rivularis)*	S
small-flowered evening-primrose	*Camissonia (= Oenothera) minor*	R1
small-flowered nama	*Nama densum var. parviflorum*	R1
smooth cliffbrake	*Pellaea glabella simplex*	W
Snake River cryptantha	*Cryptantha spiculifera (= C. interrupta)*	S
southern mudwort	*Limosella acaulis*	W
stalked-pod milkvetch	*Astragalus sclerocarpus*	W
Suksdorf's monkey flower	*Mimulus suksdorfii*	S
winged combseed	*Pectocarya linearis*	R1
The following species have been reported as occurring on the Hanford Site, but the known collections are questionable in terms of location or identification, and have not been collected recently on the site.		
Beaked spike-rush	*Eleocharis rostellata*	S
dense sedge	*Carex densa*	S
few-flowered collinsia	*Collinsia sparsiflora var. bruciae*	S
giant helleborine	*Epipactis gigantea*	S
medic milkvetch	*Astragalus speirocarpus*	W
orange balsam	*Impatiens aurella*	R2
Palouse milkvetch	*Astragalus arrectus*	S
Palouse thistle	*Cirsium brevifolium*	W
porcupine sedge	*Carex hystericina*	S
Thompson's sandwort	*Arenaria franklinii thompsonii*	R2

S = Sensitive (i.e., taxa vulnerable or declining) and could become endangered or threatened without active management or removal of threats.
R1 = Taxa for which there are insufficient data to support listing as threatened, endangered, or sensitive (formerly monitor group 1).
R2 = Taxa with unresolved taxanomic questions (formerly monitor group 2).
W = Taxa that are more abundant or less threatened than previously assumed (formerly monitor group 3).



EMSL – Environmental and Molecular Sciences Laboratory
ERDF – Environmental Restoration Disposal Facility
HAMMER – Hazardous Materials Management and Emergency Response
mtn. - mountain

Figure 4.24. Species of Concern on the Hanford Site and the *24 Command Fire* Area (after DOE-RL 2001 and BAER 2000)

Table 4.15. Birds of Conservation Concern Observed on the Hanford Site (FWS 2002).

Common Name	Scientific Name
Swainson's hawk	*Buteo swainsoni*
ferruginous hawk	*Buteo regalis*
golden eagle	*Aquila chrysaetos*
peregrine falcon	*Falco peregrinus*
prairie falcon	*Falco mexicanus*
grasshopper sparrow	*Ammodramus savannarum*
greater sage grouse (a)	*Centrocercus urophasianus phaios*
American avocet	*Recurvirostra americana*
solitary sandpiper	*Tringa solitaria*
long-billed curlew	*Numenius americanus*
marbled godwit	*Limosa fedoa*
sanderling	*Calidris alba*
Wilson's phalarope	*Phalaropus tricolor*
flammulated owl	*Otus flammeolus*
burrowing owl	*Athene cunicularia*
Lewis' woodpecker	*Melanerpes lewis*
loggerhead shrike	*Lanius ludovicianus*
Brewer's sparrow	*Spizella breweri*
sage sparrow	*Amphispiza belli*
sage thrasher	*Oreoscopets montanus*

(a) Endangered Species Act candidate.

4.6.5 Microbiotic Crusts

Microbiotic crusts generally occur in the top 1 to 4 mm (0.04 to 0.16 in.) of soil and are formed by living organisms and their by-products, creating a crust of soil particles bound together by organic materials. Microbiotic crusts are common in the semiarid Columbia Basin, where the dominant form 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, 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 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). They found 29 soil lichens in 19 genera and 6 moss species in 4 genera. 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).

4.6.6 Biodiversity

The Hanford Site is located within the Columbia Basin Ecoregion, an area that historically included over 6 million ha (14.8 million ac) of steppe and shrub-steppe vegetation across most of central and southeastern Washington state, as well as portions of north-central Oregon. The pre-settlement vegetation consisted primarily of shrubs, perennial bunchgrasses, and a variety of forbs. An estimated 60 percent of shrub-steppe in Washington has been converted to agriculture or other uses. Much of what remains is in small parcels, in shallow rocky soils, or has been degraded by historic land uses (mostly livestock grazing) (TNC 1999).

The Hanford Site retains some of the largest remaining blocks of relatively undisturbed shrub-steppe in the Columbia Basin Ecoregion. Hanford's importance as a refuge for the shrub-steppe ecosystem is not solely size-related, however. The presence of a high diversity of physical features and examples of rare, undeveloped deep and sandy soil has led to a corresponding diversity of plant and animal communities. 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 other areas. Because of its location, the site provides important connectivity with other undeveloped portions of the ecoregion.

4.7 Cultural, Archaeological, and Historical Resources

The Hanford vicinity is one of the most culturally rich resource areas in the western Columbia Plateau. The site consists of a series of cultural landscapes containing the cumulative record of multiple occupations by Native and non-Native Americans. These landscapes contain numerous well-preserved archaeological sites representing prehistoric, 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. The National Historic Preservation Act (16 USC 470), the Native American Graves Protection and Repatriation Act (25 USC 3001 et seq.), the Archaeological Resources Protection Act (16 USC 469 et seq.), and the DOE American Indian Policy (DOE 2000), among other legislation and guidelines, require the identification and protection of areas and resources of concern to the Native American community (see Sections 6.13 and 6.14).

4.7.1 Native American Cultural Resources and Archaeological Resources

Traditional Native American religion is manifest in the earth, the water, the sky, and all animate or inanimate beings that inhabit a given location. In prehistoric and early historic times, Native Americans of various tribal affiliations populated the Hanford Reach of the Columbia River. The Wanapum and the Chamnapum dwelt along the Columbia River from south of Richland upstream to Vantage (Relander 1956; Spier 1936). Some of their descendants (Wanapum) still live nearby at Priest Rapids;

others live on the Yakama and Umatilla Reservations. Palus people, who lived on the lower Snake River, joined the Wanapum and Chamnapum to fish the Hanford Reach of the Columbia River and some inhabited the east bank of the river (Relander 1956; Trafzer and Scheuerman 1986). Many descendants of the Palus now live on the Colville Reservation. The Nez Perce, Yakama, Walla Walla, and Umatilla, and other Native American peoples also periodically visited to fish in the area. Traditional uses of the Hanford Site included fishing, hunting, and gathering roots and medicinal plants. The area was also used as a wintering ground. Descendants of these people retain traditional secular and religious ties to the region and many have knowledge of the ceremonies and life ways of their ancestral culture.

The Hanford Reach and the greater Hanford Site, geographic centers for regional Native American religious belief, are central to the practice of Indian religion of the region, and many believe the creator made the first people here (DOI 1994). Indian religious leaders began their teachings here, including Smoholla, a prophet of Priest Rapids who brought the Washani religion to the Wanapum and others during the late nineteenth century. Native plant and animal foods, some of which can be found on the Hanford Site, are used in the ceremonies performed by tribal members. Certain landforms, especially Rattlesnake Mountain, Gable Mountain, Gable Butte, and various sites along and including the Columbia River, remain sacred to them. Aesthetic and scenic resources are discussed in Section 4.8.10. The Gable Mountain Block Survey conducted by tribal members in 2000, recorded important attributes that contribute to the significance of Gable Mountain to Native Americans (Poston et al. 2001). Native American 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). Traditional cultural places of importance to Native Americans are determined through methods that are mutually agreed upon by DOE and the Native American community.

Native Americans have lived in and around the present-day Hanford Site for thousands of years (Relander 1956; Spier 1936; Sturtevant and Walker 1998). When Euro-Americans arrived in the 1800s, peoples presently referred to as the Wanapum inhabited villages and fishing camps. Neighboring groups known today as the Yakama, Umatilla, Cayuse, Walla Walla, Palus, Nez Perce, and Middle Columbia Salish frequented the area to trade, gather resources, and conduct other activities. Many descendants of these tribes are affiliated with the Wanapum, Yakama Nation, Confederated Tribes of the Umatilla Indian Reservation, Nez Perce Tribe, or the Confederated Tribes of the Colville Reservation, and they retain traditional, cultural, and religious ties to Hanford's places and resources. (See Section 6.14 for further information on the treaties associated with the Hanford Site). This record of Native American use and history is reflected in the archaeological sites and traditional cultural places that are located across the Hanford Site.

People have inhabited the Middle Columbia River region since the end of the glacial period. More than 8000 years of prehistoric human activity in this largely arid environment have left extensive archaeological deposits along the river shores (DOE-RL 2003a; Leonhardy and Rice 1970). Well-watered areas inland from the river also show evidence of concentrated human activity (Chatters 1982; DOE-RL 2003a; Daugherty 1952; Leonhardy and Rice 1970; Neitzel 2002a), and recent surveys have indicated extensive, although dispersed, use of arid lowlands for hunting. Throughout most of the region, hydroelectric development, agricultural activities, and domestic and industrial construction have destroyed or covered the majority of these deposits. Amateur artifact collectors have had an immeasurable impact on what remains at numerous sites. However, by virtue of their inclusion in the Hanford Site from which the public is restricted, archaeological deposits found in the Hanford Reach of the Columbia River and on adjacent plateaus and mountains largely have not been destroyed.

Archaeological sites and isolated finds totaling 439 associated with the prehistoric period have been recorded on the site; of these, approximately 68 contain historic components as well. Prehistoric period sites common to the Hanford Site include remains of numerous 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; Neitzel 2002a); hunting/kill sites in lowland stabilized dunes; and small temporary camps near perennial sources of water located away from the river (Rice 1968b).

Many recorded sites were found during four archaeological reconnaissance projects conducted between 1926 and 1968 (Krieger 1928; Rice 1968a,b). Much of this early archaeological survey and reconnaissance activity concentrated on islands and on a strip of land about 400 m (1300 ft) wide on either side of the river (Neitzel 2001). Reconnaissance of selected locations conducted through the mid-1980s, as well as systematic archaeological surveys conducted from the middle 1980s through 1996, added to the recorded site inventories, (DOE-RL 2003a; Chatters and Cadoret 1990; Chatters and Gard 1992; Chatters et al. 1990, 1991, 1992; Last et al. 1994; Andrefsky et al.1996).

During his reconnaissance of the Hanford Site in 1968, Rice (1968b) inspected portions of Gable Mountain, Gable Butte, Snively Canyon, Rattlesnake Mountain, and Rattlesnake Springs. Rice also inspected additional portions of Gable Mountain and part of Gable Butte in the late 1980s (Neitzel 2001). Some reconnaissance of the Basalt Waste Isolation Project (BWIP) Reference Repository Location (Neitzel 2001), a proposed land exchange in T. 22 N., R. 27 E., Section 33 (Neitzel 2001), and three narrow transportation and utility corridors (Morgan 1981; Smith et al. 1977) was also conducted. Other large-scale project areas completed in recent years include the 100 Areas from 1991 through 1993 and 1995 (Chatters et al. 1992; Wright 1993); McGee Ranch (Gard and Poet 1992); the Laser Interferometer Gravitational Wave Observatory Project; the Environmental Restoration Disposal Facility; and the Washington State University 600 Area Block Survey (Andrefsky et al. 1996). To date, approximately 12 percent of the Hanford Site has been surveyed for archaeological resources.

4.7.2 Historic Archaeological Resources

Two of the early Euro-Americans who passed near the Hanford Site were Lewis and Clark, who 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 soon began to work the gravel bars for gold. Cattle ranches were established in the 1880s, and farmers soon followed. Agricultural development, irrigation districts, and roads soon dotted the landscape, particularly in the eastern portion of the central Hanford Site. Several small thriving towns, including Hanford, White Bluffs, Richland, and Ringold, grew up along the riverbanks in the early twentieth century. Community accessibility to outside markets grew with the 1913 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, White Bluffs, and Richmond. 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-RL 2003a; Neitzel 2002a).

Since 1987, the Hanford Cultural Resources Laboratory (HCRL) has recorded 655 historic archaeological sites associated with the pre-Hanford (Euro-American) era, the Manhattan Project, and Cold War Era, including an assortment of farmsteads, corrals, dumps, and military sites. Of these, 56 sites contain prehistoric components as well. Archaeological resources from the pre-Hanford 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. Properties from this period include the Hanford Irrigation Ditch; former Hanford Townsite; Wahluke ferry landing; White Bluffs Townsite; Richmond ferry landing; Arrowsmith Townsite; White Bluffs road; and the Chicago, Milwaukee, St. Paul, and Pacific Railroad.

Areas of traditional cultural importance to pre-Hanford residents are also found on the Hanford Site. These areas include places and structures that are important to descendents of pre-1943 settlers in the former White Bluffs, Hanford, Allard, and Cold Creek areas.

4.7.3 Historic Built Environment

A number of buildings associated with the pre-Hanford Site era have been documented. They include the Hanford Irrigation and Power Company 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.

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 former 1100 and 3000 Areas. The most important of these are the plutonium production and test reactors, chemical separation and plutonium finishing buildings, and fuel fabrication/manufacturing facilities. The first reactors, 100-B, 100-D, and 100-F, were constructed during the Manhattan Project. Plutonium for the first atomic explosion and the bomb that destroyed Nagasaki was 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 the C, D, DR, F, and H reactors have been considerably modified.

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 of Historic Places (National Register) eligibility of buildings and structures sitewide (Bard 1997). Additionally, historical narratives and individual building documentations have been compiled in the *History of the Plutonium Production Facilities at the Hanford Site Historic District, 1943-1990*, published in 2002 (DOE-RL 2002). At the site, 528 Manhattan Project and Cold War Era buildings/structures and complexes have been determined to be eligible for the National Register as contributing properties within the designated Hanford Site Manhattan Project and Cold War Era Historic District. Of that number, 190 were recommended for individual documentation (DOE-RL 1998).

4.7.4 200 Areas

Much of the 200 East and West Areas has been disturbed by construction of facilities associated with the chemical separations process as part of the Manhattan Project and Cold War Era. Other facilities have been constructed as part of ongoing cleanup efforts for the Hanford Site. Comprehensive efforts were made in 1986 and 1989 to inventory the undisturbed portions of the 200 East and West Areas for cultural resources. The 1989 survey was "an intensive pedestrian survey of all undisturbed portions of the 200 East Area and a stratified random survey [of the undisturbed portions] of the 200 West Area" (Chatters and Cadoret 1990). No cultural resources are known to exist within currently active borrow areas (DOE 2001a).

The 1989 survey located two historic-archaeological sites (can and glass scatters), four isolated historic artifacts, one isolated cryptocrystalline flake, and an extensive linear feature (that is, the White Bluffs Road). These were the only materials older than 50 years discovered during the field survey. A prominent archaeological resource located in the 200 Areas is the 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, was determined eligible for listing in the National Register. Within the 200 West Area, two intact segments of the road are considered contributing elements: 1) the southwest segment from the perimeter fence to approximately 19th Street at Dayton Avenue, and 2) the extreme northeast segment above T Plant Complex to the perimeter fence. A 100-m (328-ft) easement has been created to protect these segments of the road from uncontrolled disturbance. The remaining portions of the road within the 200 West Area have been determined to be non-contributing. Such non-contributing segments of the White Bluffs Road are those that do not add to the historic significance of the road, but retain evidence of its contiguous bearing. Originally used as a Native American trail, it played a role in Euro-American immigration, development, agriculture, and Hanford Site operations. In 1996, an inventory was completed of the remainder of the undisturbed ground; an area totaling 2.2 km^2 (0.85 mi^2). Although six isolated finds and two historic debris scatters were located, none were considered to be eligible for the National Register. A survey of the White Bluffs Road in 2000 recorded an additional 54 historic isolated finds and 2 prehistoric isolated finds, as well as six can dump features (Neitzel 2002a).

Although other areas of undisturbed land in the 200 East and 200 West Areas have been surveyed as part of cultural resource reviews of proposed projects, no new significant cultural resources have been located. Reviews include the 1989 permit application for the LLBGs (218-E-10, 218-E-12B, 218-W-3A, 218-W-3AE, 218-W-4B, 218-W-4C, 218-W-5, 218-W-6) (Hanford Cultural Resources Case [HCRC] # 89-200-008; see Table K.1). Previous borrowing and burying activities at the grounds had extensively disturbed the majority of the LLBGs. However, portions of 218-E-12B, 218-W-5 and 218-W-6 were undisturbed. These areas were surveyed and reviewed by the HCRL in the summer of 1988 as part of HCRC# 88-200-038 (see Table K.1) and clearance for the project was granted. The ETF location was reviewed for the presence or absence of cultural resources in 1990 (HCRC# 89-200-023; see Table K.1). The WRAP Facility location was reviewed in 1993 (HCRC# 93-200-074; see Table K.2) and the CWC was reviewed in 1995 (HCRC# 95-200-104; see Table K.1). No significant resources were identified. Over the past 15 years, 50 cultural resource reviews were conducted on the LLBGs for grouting, geologic testing, subsidence repair and maintenance, removal of contaminated soils, retrieval of vented drums, culvert installation, drilling to install high-integrity containers, and trench construction.

Chemical separations facilities (processing plants and their ancillary and support services) were located in the 200 Areas. Irradiated fuel elements were dissolved and desired materials such as plutonium were separated out. Historic property inventory forms have been completed for 72 buildings and structures in the 200 Area. Of that number, 58 have been determined to be eligible for the National Register as contributing properties within the Historic District recommended for mitigation. Included are the 234-5Z Plutonium Finishing Plant, 236-Z Plutonium Reclamation Facility, 242-Z Water Treatment Facility, 231-Z Plutonium Metallurgical Laboratory, 225-B Encapsulation Building, 221-T Canyon (T Plant) Building, 202-A Purex Building, 222-S Redox Plant, 212-N Lag Storage Facility, 282-E Pumphouse and Reservoir Building, 283-E Water Filtration Plant, and 284-W Power House and Steam Plant. The 232-Z Waste Incinerator Facility and the 233-S Plutonium Concentration Building, determined eligible for the National Register, have been documented to Historic American Engineering Record (HAER) standards (DOE-RL 1998).

Completed in December 1944, T Plant (221-T) was the world's first large-scale plutonium (chemical) separation facility. T Plant, like the other chemical separation buildings at Hanford, is a massive, concrete, canyon-like structure measuring 800 feet long, 65 feet wide, and 80 feet high. Because of its role as the primary chemical separations plant at the Hanford Site from 1944 until the opening of the REDOX Plant in 1952, T Plant was found to be eligible for inclusion in the National Register as a contributing property within the Historic District and recommended for individual documentation (mitigation). Mitigation of T Plant has been completed and consisted of a HAER documentation of the facility and a walkthrough/assessment of the building contents. Industrial artifacts at T Plant and other historic facilities in the 200 Area were identified and tagged for future exhibit purposes.

DOE entered into the Programmatic Agreement for the Maintenance, Deactivation, Alteration, and Demolition of the Built Environment on the Hanford Site (DOE-RL 1996) with the Advisory Council on Historic Preservation and the Washington State Historic Preservation Office. One stipulation of the agreement requires DOE to undertake an assessment of the contents of the historic buildings and structures prior to any deactivation, decommissioning, or decontamination activities. The purpose of these assessments is to locate any artifacts that may have interpretive and or educational value as exhibits within local, state, or national museums.

4.8 Socioeconomic Activity

Activity on the Hanford Site plays a dominant role in the socioeconomic activity of the Tri-Cities and other parts of Benton and Franklin counties. The agricultural community also has a significant effect on the local economy. Any major changes in the Hanford mission could potentially affect the Tri-Cities and other areas of Benton and Franklin counties.

4.8.1 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. With the exception of a minor amount of agricultural commodities sold to local-area consumers, the goods and services produced by these sectors are exported outside the Tri-Cities. In addition to the direct employment and payrolls, these major sectors also support a sizable number of jobs in the local economy through their procurement of equipment, supplies, and business services.

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: payrolls from the five major non-Hanford employers in the region, tourism, and pension benefits from former employees.

4.8.1.1 Employment and Income

DOE Hanford Site Employment. During FY 2001, the DOE Office of River Protection (ORP) and its prime contractors CH2M Hill Hanford Group, Inc. and Bechtel National, Inc.; DOE-RL and its prime contractors Fluor Hanford, Inc. (and its principal subcontractors); PNNL; Bechtel Hanford, Inc.; and the Hanford Environmental Health Foundation employed an average of 10,700 employees. Fiscal year 2001 year-end employment at Hanford was 10,670, down slightly from 10,870 in FY 2000. In FY 1999, average employment was 10,290, compared with an average employment of 11,940 in 1996. The drop between FY 1996 and FY 1999 reflects employment declines and reorganization of the DOE contractors under the Project Hanford Management Contract (PHMC), which was created in 1996. Under the PHMC, almost 2200 employees of the former management and operations contractor were moved into six "enterprise companies" and were no longer counted as official Hanford employees. The number of employees at Hanford is down considerably from a peak of 19,200 in FY 1994, but still represents 12 percent of the 89,100 total jobs in the economy.

Based on employee residence records as of April 2002, 92 percent of the direct employees of Hanford live in Benton and Franklin counties. Approximately 73 percent of Hanford employees reside in Richland, Pasco, or Kennewick. More than 36 percent are Richland residents, 9 percent are Pasco residents, and 28 percent live in Kennewick. Residents of other areas of Benton and Franklin counties, including West Richland, Benton City, and Prosser, account for about 18 percent of total Hanford Site employment (Neitzel 2002a).

Energy Northwest. Although activity related to commercial nuclear power plant construction ceased with the completion of the WNP-2 reactor in 1983 (now named Columbia Generating Station), Energy Northwest continues to be a major employer in the Tri-Cities area. Headquarters personnel based in Richland oversee the operation of the Columbia Generating Station. Decommissioning of mothballed nuclear power plants (WNP-1 and WNP-4), which never were completed, began in 1995. In FY 1999, Energy Northwest employed around 29 people at the two plants (one-third of the 90 people who were employed in 1994 as a result of decommissioning activities). As part of an effort to reduce electricity production costs, Energy Northwest headquarters decreased the size of its workforce from over 1900 in 1994 to 1016 at the end of 1999. As part of a refueling and maintenance project, as of April 2002 employment was 1208 personnel.

Agriculture. In 2000, agricultural production and services in the bi-county area generated about 10,260 wage and salary jobs, or about 12 percent of the area's total employment, as represented by the employees covered by unemployment insurance (LMEA 2001a). 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. In 2001, there was an average of 5148 seasonal farm workers per month in Benton, Franklin, and Walla Walla counties, ranging from 1153 workers during the winter pruning season to 11,329 workers at the peak of harvest. An estimated average of 4391 seasonal workers were classified as local (ranging from 1131 to 10,054); an average of 15 were classified as intrastate (ranging from 0 to 146), and an average of 748 were classified as interstate (ranging from 0 to 1612). The weighted seasonal wage for 2001 ranged from $6.20/hr to $7.58/hr, with an average wage of $6.88/hr (DOL 2001).

According to the U.S. Department of Commerce's Regional Economic Information System (REIS), about 2640 people were classified as farm proprietors in 2000. Farm proprietors' income, according to this same source, was estimated to be $53.2 million (DOC 2001).

The area farms and ranches generate a sizable number of jobs in supporting activities, such as agricultural services (for example, application of pesticides and fertilizers and irrigation system development) and wholesale trade (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. More than 20 food processors in Benton and Franklin counties produce such items as potato products, canned fruits and vegetables, wine, and animal feed.

Other Major Employers. In 2001, the five largest non-Hanford Site and non-government employers employed approximately 5035 people in Benton and Franklin counties. These companies include (1) Lamb Weston, which employed 1800; (2) Iowa Beef Processing Inc., which employed 1450; (3) Framatome ANP, Richland Inc. (formerly Siemens Power Corporation), which employed 750; (4) Boise Cascade Corporation Paper and Corrugated Container Divisions, which employed 685, and (5) Burlington Northern and Santa Fe Railway, which employed 350. Boise Cascade and Iowa Beef are located in western Walla Walla County, but most of their workforce resides in Benton and Franklin counties. Four of the largest agriculture growers and processors in the area: Broetje Orchards, J.R. Simplot Company, Twin City Foods, Inc., and AgriNorthwest, employed approximately 2000 people in 2001; however, a large portion of the workers were seasonal (TRIDEC 2002).

Employment and Income Figures. In 2001, nonagricultural employment rose 4 percent. There was an average of 78,500 nonagricultural jobs in the Tri-Cities in 2001, up approximately 3000 from year 2000. Gains in employment ranged from 100 workers in the manufacturing sector to, 700 in services, as every sector added workers except finance, insurance, and real estate, which stayed the same (LMEA 2001b).

In 2000, the total personal income for Benton County was $3.7 billion and for Franklin County was $932 million, compared with the Washington state total of $184.5 billion. Per capita income in 2000 was $25,624 for Benton County, $18,813 for Franklin County, and $31,230 for Washington State (DOC 2001). The preliminary estimate of median household income in 2001 for Benton County is $48,893; Franklin County is estimated at $40,976, and for Washington is estimated at $48,835 (OFM 2001).

4.8.1.2 Tourism

A significant rise in the number of visitors to the Tri-Cites over the last several years has resulted in tourism playing an increasing role in helping to diversify and stabilize the area economy. The Tri-Cities Visitors and Convention Bureau reported that 97,770 people attended conventions and sporting events, spending an estimated $32.3 million in the Mid-Columbia in 2001. The number of people attending convention and group events has more than doubled since 1995 and more than tripled 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 roughly $220 million in 2000, up from $204.7 million in 1999. Travel-generated employment in Benton and Franklin counties was about 4120 with an estimated $56.4 million in payroll, up from an estimated 4090 employed and a $44.7 million payroll in 1999. In addition, tourism generated $3.4 million in local taxes and $15.1 million in state taxes in 2000 (OTED 2002).

4.8.1.3 Retirees

Although Benton and Franklin counties have a relatively young population (approximately 53 percent under the age of 35), 19,523 people over the age of 65 resided in Benton and Franklin counties in 2002. The portion of the total population 65 years and older in Benton and Franklin counties accounts for 9.8 percent of the total population, which is below the 11.2 percent for the state of Washington (OFM 2003). This segment of the population supports the local economy on the basis of income received from government transfer payments and pensions, private pension benefits, and prior individual savings.

4.8.2 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 directed 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 complying with the Order. The Council on Environmental Quality (CEQ) provided additional guidance later for integrating environmental justice into the NEPA process in a December 1997 document, *Environmental Justice Guidance under the NEPA* (CEQ 1997).

Minority populations are defined as all nonwhite individuals, plus all individuals of Hispanic origin, as reported in the 2000 Census (Census 2001a). 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 2001a). Nationally, in 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 in that year) (Census 2000a, b). The year 2000 Census state and county area poverty estimates report that Washington had 11.6 percent of its population living in poverty in 1997, while Benton County and Franklin County had 10.3 percent and 19.2 percent, respectively (Census 2002).

The year 2000 Census data indicate that a total population of approximately 482,300 people resided within an 80-km (50-mi) radius of the Hanford Site. Based on the 2000 Census, the 80-km (50-mi) area surrounding the Hanford Site had a total minority population of about 178,500, about 37 percent of the total. The ethnic composition of the minority population is primarily White Hispanic (24 percent), self-designated "other" and multiple races (63 percent), and American Native (6 percent). Asians and Pacific Islanders (4 percent) and African American (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, west of the Hanford Site, and upstream of the site near the town of Beverly, Washington.

Figure 4.25 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 whose percentage of residents belonging to any minority group was at least 20 percentage points greater than the corresponding percentage of the state population (Census 2001b, c). Table 4.16 presents population estimates and percentages by race and Hispanic origin for Benton, Franklin, Grant, Adams, and Yakima counties, and the 80-km (50-mi) radius of the Hanford Site.

The 2000 low-income population was approximately 80,700 or 17 percent of the total population residing in the 80-km (50-mi) radius of the Hanford Site. The majority of these households were located to the southwest and north of the site (Yakima and Grant counties), and in the cities of Pasco and Kennewick.

Table 4.17 shows the estimated numbers and percentages of people living below the poverty level in the counties touched by the 80-km (50-mi) circle in Figure 4.26 for the year 2000. The low-income population of this larger area is dispersed throughout this region with the highest concentrations occurring in Franklin, Yakima, and Kittitas counties and the largest numbers in Benton, Yakima, and Grant counties

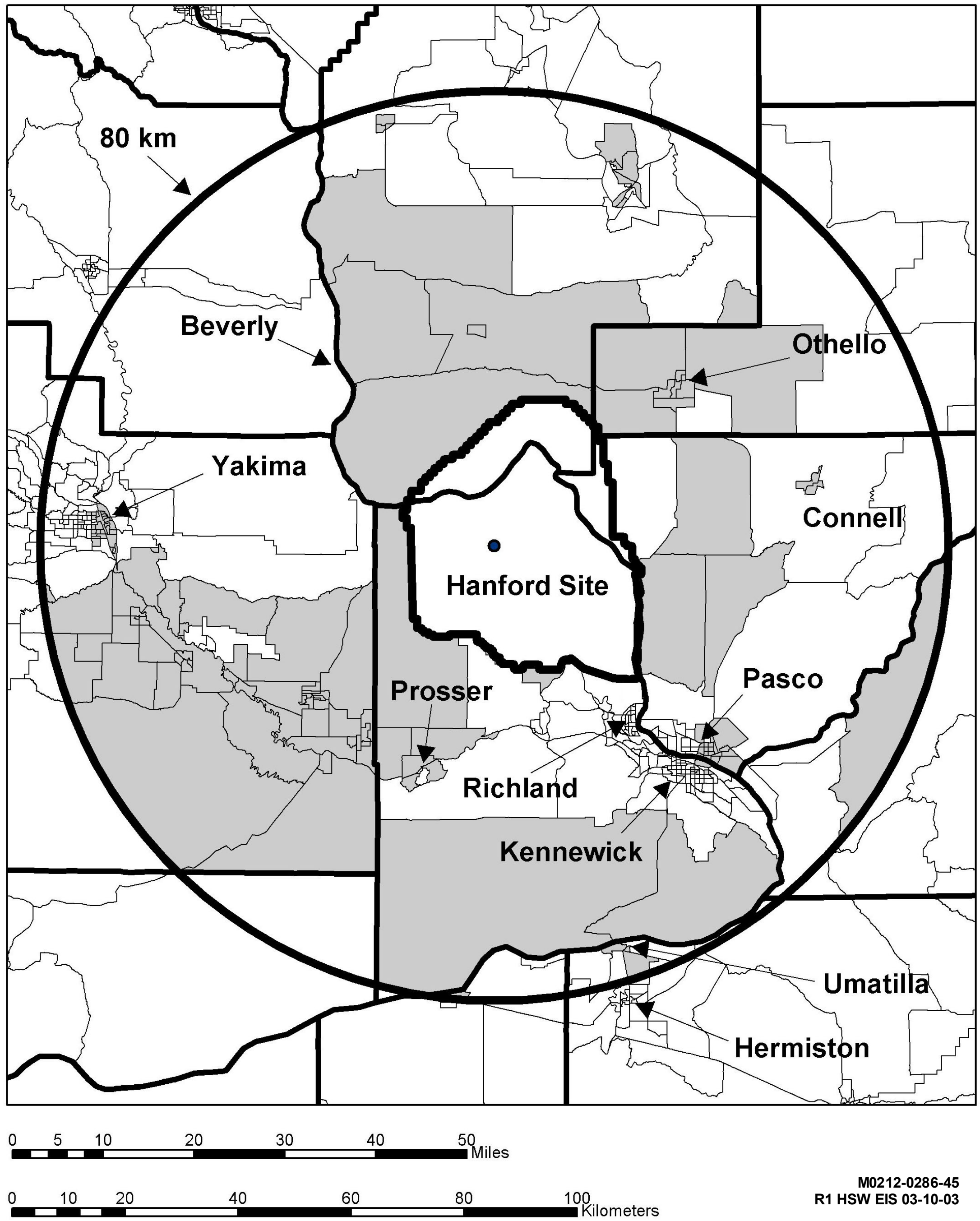


Figure 4.25. Location of Asian, Black, Hispanic, Native American, Pacific Islander, and Overall Minority Populations Near the Hanford Site. (Shading denotes block groups with potential environmental justice concerns).

Table 4.16. Population Estimates and Percentages by Race and Hispanic Origin within Selected Counties in Washington State and the 80-km (50 mi) Radius of Hanford as Determined by the 2000 Census (Census 2003)

Subject	WA 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	482,300
Single Race	5,680,602	96.4	489,206	96.8	138,646	47,302	72,451	15,977	214,830	482,280
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	1319	1230	742	46	2,157	5507
American Indian/Alaska Native	93,301	1.6	12,468	2.5	1165	362	863	112	9966	10,288
Asian	322,335	5.5	6809	1.3	3134	800	652	99	2124	6681
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	9986	14,300	12,967	5042	54,375	112,278
Two or More Races	213,519	3.6	16,323	3.2	3829	2045	2247	451	7751	20
Hispanic Origin (of any race)[(b)]	441,509	7.5	150,951	29.9	17,806	23,032	22,476	7732	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 4.17. Number and Percentages of Persons Defined as Low-Income Living in Counties Near the Hanford Site, in 1999, as Determined by the 2000 Census (Census 2002)

	Number[a]		Percent Below Poverty Level
	All Income Levels	Below Poverty Level	
Washington:			
Adams County	16,217	2951	18.2
Benton County	141,232	14,517	10.3
Chelan County	65,564	8147	12.4
Columbia	4008	507	12.6
Franklin	48,307	9280	19.2
Grant County	73,591	12,809	17.4
Kittitas County	31,177	6,122	19.6
Klickitat County	18,983	3236	17.0
Walla Walla County	50,245	7567	15.1
Yakima County	218,966	43,070	19.7
Oregon:			
Morrow County	10,919	1617	14.8
Umatilla County	67,329	8524	12.7
Union County	23,795	3281	13.8
Total	770,333	121,628	15.8
(a) All individuals for whom poverty status is determined.			

The CEQ guidance recognizes that many minority and low-income populations derive part of their sustenance from subsistence hunting, fishing, and gathering activities (sometimes for species unlike those consumed by the majority population) or are 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. There are Native Americans of various tribal affiliations that live in the greater Columbia Basin who rely on natural resources for subsistence.

There is some dependence on natural resources for dietary subsistence for the Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation, and the Yakama Nation (Harris and Harper 1997). The treaties of 1855 maintain the rights of these tribes to fish and erect fish-curing structures in their usual and accustomed places, and to hunt, gather food, and graze stock on open and unclaimed portions of the lands ceded to the government. The Wanapum, a non-treaty tribe, historically lived on what is now the Hanford Site and continue to live adjacent to the Site. They fish on the Columbia River and gather food resources near the Hanford Site. The Confederated Tribes of the Colville Reservation, established by an Executive Order in 1872, traditionally fished and gathered food resources in the Hanford area. They are also recognized as having cultural and religious ties to the Hanford Site.

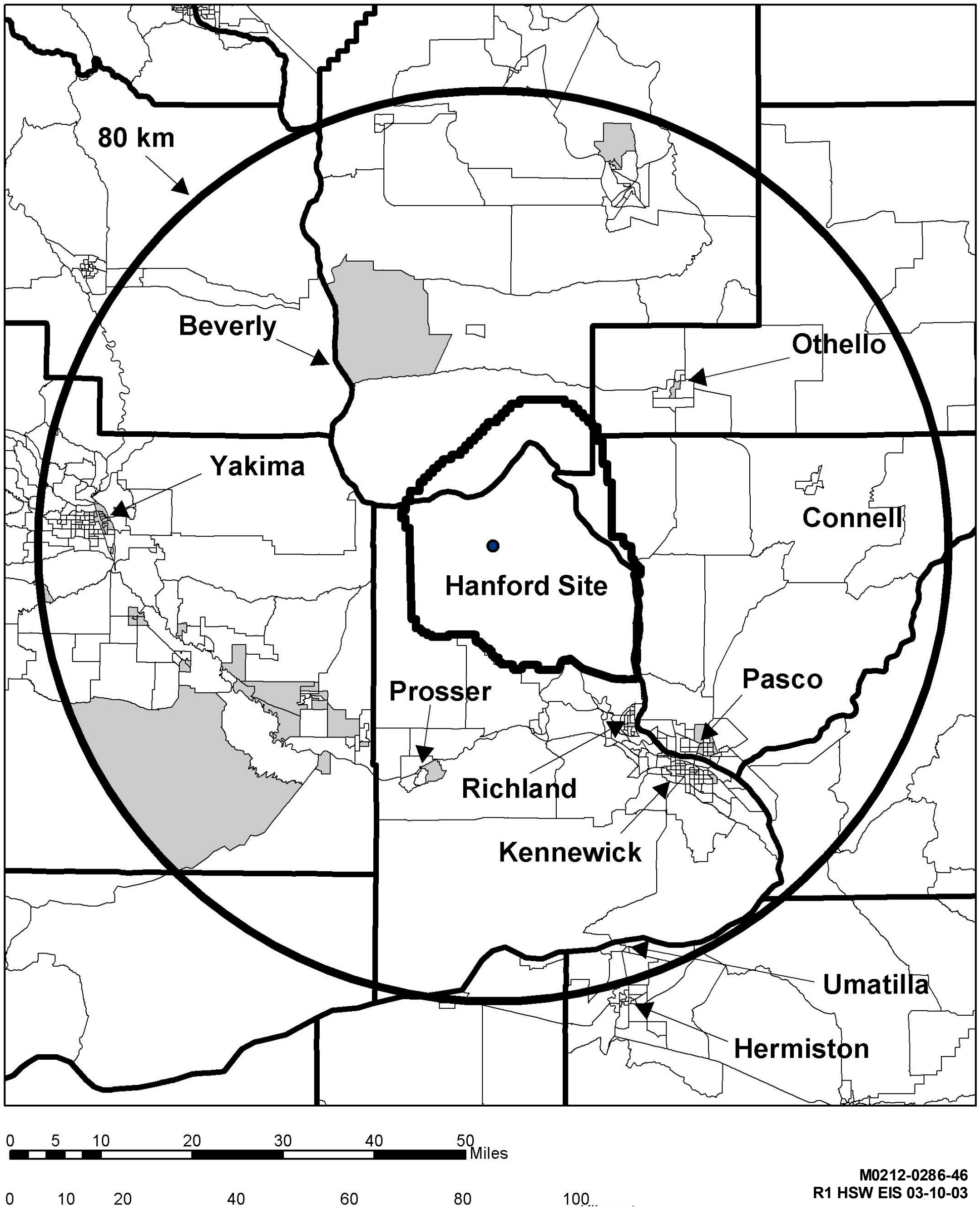


Figure 4.26. Location of Low-Income Populations Near the Hanford Site. (Shading denotes block groups with potential environmental justice concerns).

4.8.3 Demography

Census 2000 report population totals for Benton and Franklin counties were 142,475 and 49,347, respectively (Census 2001b). Washington State did as a whole. The population of Benton County grew 26.6 percent up from 112,560 in 1990. The population of Franklin County grew 31.7 percent, up from 37,473 in 1990 (Census 2001b).

Within each county, census figures indicate the distribution of the Tri-Cities population by city as follows: Richland 38,708; Pasco 32,066; and Kennewick 54,693. The combined populations of Benton City, Prosser, and West Richland totaled 15,847 in 2000. The unincorporated population of Benton County was 33,227. In Franklin County, incorporated areas other than Pasco had a total population of 3595. The unincorporated population of Franklin County was 13,886 (Census 2001b).

The 2000 population figures for Benton and Franklin counties indicate that Asians represent a lower proportion, and individuals of Hispanic origin represent a higher proportion of the racial distribution than those in the state of Washington. Countywide, Benton and Franklin counties exhibit varying racial distributions.

In 2000, Benton and Franklin counties accounted for 3.3 percent of Washington's population. The population demographics of Benton and Franklin counties are quite similar to those found within Washington. The population in Benton and Franklin counties under the age of 35 is 53.1 percent, compared with 49.4 percent for Washington State. In general, the population of Benton and Franklin counties is somewhat younger than that of Washington. The 0- to 14-year-old age group accounts for 25.6 percent of the total bi-county population as compared with 21.3 percent for Washington. In 2000, the 65-year-old and older age group constituted 9.8 percent of the population of Benton and Franklin counties, compared with 11.2 percent for Washington (Census 2001b).

4.8.4 Housing

In FY 2001, 2519 houses were sold in the Tri-Cities at an average price of $134,570, compared with 2195 houses sold at an average price of $128,928 in 2000 (TCAR 2001). In FY 2001, 869 single-family houses were built, up 14 percent from the 760 that were built in 2000, but down from a peak of 1117 in 1994 (WCRER 2001a).

As of April 1, 2001, there were estimated to be 73,410 housing units in Benton and Franklin counties, which is 26.4 percent more than the 58,541 in 1990 (OFM 2001). The number of apartments has increased from 8225 in 1990 to 10,238 in 2001. The vacancy rate of apartments in Benton and Franklin counties in September 2001 was 2.0 percent, and the average rent was $576. These figures are down from the 4.3 percent vacancy rate and up from the $530 average rent in 2000 (WCRER 2001b).

4.8.5 Traffic and Transportation

The Tri-Cities serves as a regional transportation and distribution center with major air, land, and river connections. The Burlington Northern and Santa Fe Railway and the Union Pacific Railroad companies provide direct rail service. Union Pacific operates the largest fleet of refrigerated rail cars in the United States and is essential to food processors that ship frozen food from this area. Amtrak provides passenger rail service with a station in Pasco.

Docking facilities at the Ports of Benton, Kennewick, and Pasco are important aspects of the regional infrastructure. These facilities are located on the 525-km (326-mi) long commercial waterway that includes the Snake and Columbia Rivers and extends from the ports of Lewiston-Clarkston in Idaho to the deep-water ports of Portland, Oregon, and Vancouver, Washington. The average shipping time from the Tri-Cities to these deep-water ports by barge is 36 hours.

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. Delta Airlines, United Express, and Horizon Air offer 33 flights into and out of the Tri-Cities daily connecting to domestic and international flights through Salt Lake City, Seattle, Denver, Spokane, and Portland. A total of 206,188 passengers, used the Tri-Cities Airport in 2001, which was down slightly from 2000 when the airport set a record of 209,434 passengers and was the sixth year in a row of passenger increases. Projections indicate the terminal can serve almost 300,000 passengers annually. The Tri-Cities region has three general aviation airports that serve private aircraft. Air freight shippers that service the region include Airborne from the Richland airport, United Parcel Service from the Kennewick airport, and Federal Express from the Tri-Cities Airport in Pasco.

Mass transit in the area is provided by the Ben Franklin Transit system. The system covers more than 286 km^2 (110 mi^2) and provides frequent service to most local communities. The Ben Franklin transit system consists of 54 buses, 31 Dial-a-Ride para-transit vehicles, and 75 Van Pool vans. Two local taxi companies provide radio-dispatched taxicab service 24 hours a day: A-1 Tri-Cities Cab and AMR Transportation. Intercity bus transportation is available.

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 (I) highways that serve the area are I-82 and I-182. I-82 is 8 km (5 mi) south-southwest of the Hanford Site. I182, 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 I-90, as well as I-84. I-84, located south of the Hanford Site in Oregon, is a major corridor leading to Portland, Oregon. SR 224, 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 24 traverse the Hanford Site and are maintained by Washington State.

Waste may be shipped from sites throughout the United States. Potential transportation routes include Interstates I-70, I-90, I-80, I-15, I-5, I-84, I-82, I-182, I-64, I-81, I-76, and I-78, as well as numerous state and local roads (Figure 4.27). Potential offsite generators are listed in Appendix C and transportation distances for these generators are listed in Appendix H.

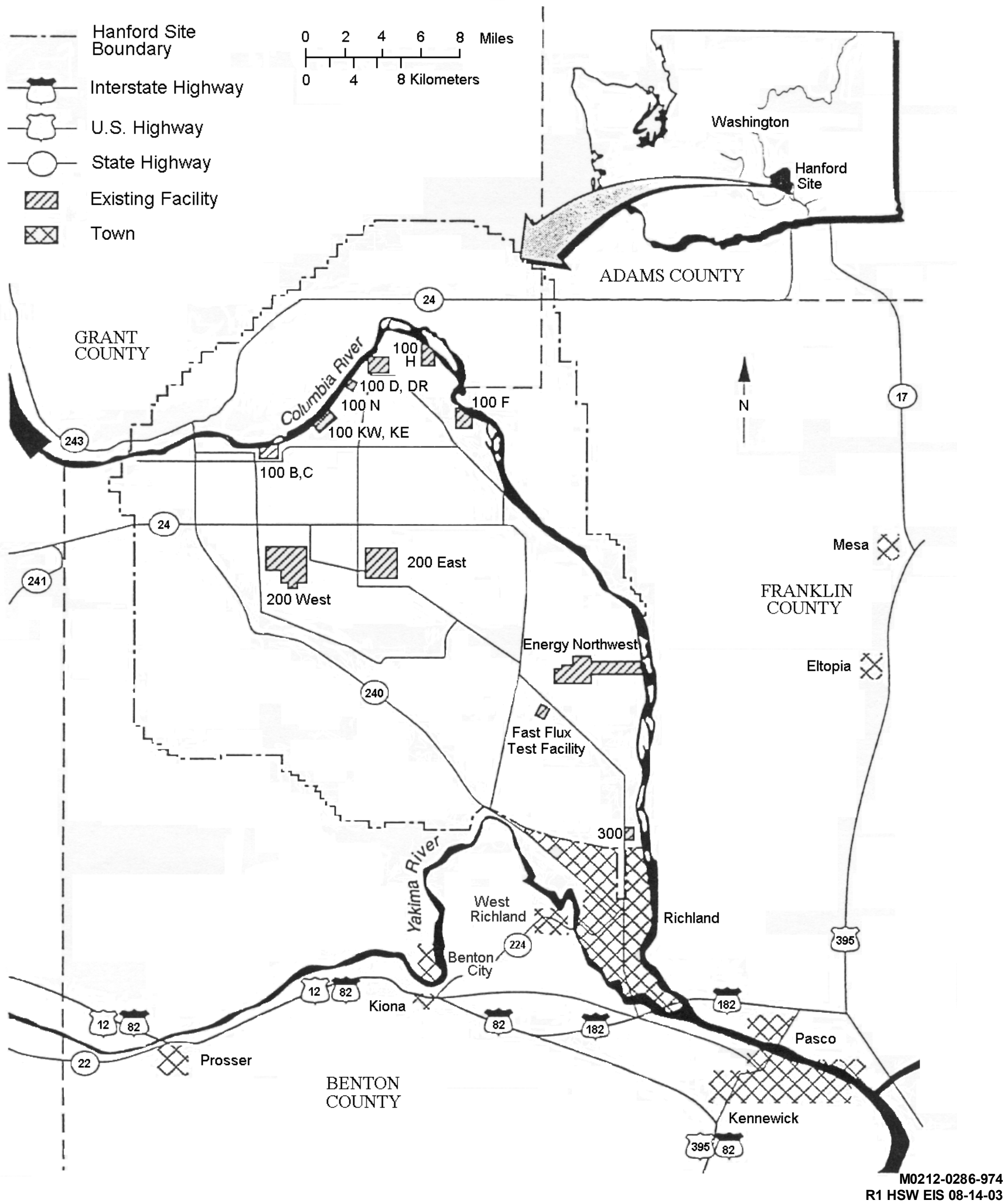


Figure 4.27. Transportation Routes in the Vicinity of the Hanford Site

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 (Figure 4.28). Primary access roads on the Hanford Site are Routes 1, 2, 3, 4, 6, 10, and 11A. The 200 East Area is accessed primarily by Route 4 South from the east and from Route 4 North off Route 11A from the north and from Route 11A for vehicles entering the site at the Yakima Barricade. A new access road was opened in late 1994 to provide access directly to the 200 Areas from SR 240. Public access to the 200 Areas and interior locations of the Hanford Site has been 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. None of the previously listed roadways have experienced any substantial congestion except Route 4 (DOE 2001b). Onsite road usage is being assessed to determine whether roads could be closed to reduce the cost of infrastructure and maintenance.

Access to the Hanford Site is via three main routes, Hanford Route 4S from Stevens Drive or George Washington Way in the City of Richland, Route 10 from SR 240 near its intersection with SR 225, or via Route 11A from SR 240. Another route, through the Rattlesnake Barricade, is located 35 km (22 mi) northwest of Stevens Drive and is for passenger vehicle access only. The estimated total number of commuters to this area is 3100. Approximately 87 percent of the workers commuting to the 200 Areas are from the Tri-Cities, West Richland, Benton City, and Prosser (Perteet et al. 2001).

The portion of SR 240 most affected by 200 Area commuters is between U.S. 395 and Stevens Drive. Portions of this roadway currently operate below the minimum level of service established by the Regional Transportation Planning Organization. Peak annual average daily traffic (AADT) on the section from Columbia Center Boulevard to I-182 is 54,000 (Perteet et al. 2001).

I-182 has peak traffic counts of 35,000 AADT in the vicinity of SR 240. I-182 also has current deficiencies at the interchanges with Queensgate Drive and 20th Avenue. Van Giesen transports most of the commuters from West Richland and Benton City to SR 240. The intersection of SR 224 and SR 240 is the only section of SR 224 with current level of service (LOS) deficiencies. LOS is a qualitative measure of the roadway ability to accommodate vehicular traffic, ranging from free-flow conditions (LOS A) to extreme congestion (LOS F). LOS D is considered the lower end of acceptable LOS (Perteet et al. 2001).

Stevens Drive has peak traffic counts of 8300 AADT at Horn Rapids Road and 22,000 AADT just north of its intersection with SR 240. Currently this roadway experiences LOS deficiencies. George Washington Way is the principal north-south arterial through Richland. AADT at the entrance of the Hanford Site on George Washington Way is 1800. Counts north of McMurray are 18,000 AADT and on George Washington Way just north of I-182 are 43,000 AADT. George Washington Way has LOS deficiencies between I-182 and Swift Boulevard (Perteet et al. 2001).

Private vehicles account for 91 percent of the person trips to the Hanford Site. The remaining person trips are by forms of high-occupancy vehicles (mostly Ben-Franklin Vanpools). Of the 91 percent of private vehicles only 3 percent are by carpool with the remaining 88 percent being single occupancy vehicles. The Draft Regional Transportation Plan identifies 11,468 employees working at Hanford. Based on 88 percent of the trips carrying a single person to Hanford, 10,092 single occupancy trips are made daily or an AADT of 10,184 (Perteet et al. 2001).

Figure 4.28. Transportation Routes on the Hanford Site

The Hanford Site rail system originally consisted of approximately 210 km (130 mi) of track. It connected to the Union Pacific 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 1400 sitewide, transporting materials including coal, fuel, hazardous process chemicals, and radioactive materials and equipment (DOE and Ecology 1996). In 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 & Olympia Railroad. The Port of Benton has been granted the right to operate portions of the railroad on the Hanford Site.

4.8.6 Educational Services

The majority of primary and secondary education in the Tri-Cities area is served by the Richland, Pasco, Kennewick, and Benton City School Districts. The total 2001 fall enrollment for all districts in Benton and Franklin counties was 40,590 students, an increase of 2.2 percent from the 2000 total of 39,702 students. The 2000 totals include 9622 from the Richland School District, up from 9464 in 2000; 9227 students from the Pasco School District, up from 8850 in 2000; 13,993 students from the Kennewick School District, up from 13,629 in 2000; and 1664 from the Kiona-Benton School District, down from 1673 in 2000 (OSPI 2002).

Several private elementary and secondary schools are located in the Tri-Cities, including Bethlehem Lutheran (K-8) and St. Josephs (K-8) in Kennewick, Christ the King (K-8) and Liberty Christian (K-12) in Richland, Faith Christian (K-12), Country Haven Academy (9-12), St. Patrick's (K-8), Tri-City Junior Academy (K-10), and Tri-Cities Prep Catholic High School in Pasco (9-12). Fall 2001 enrollment at these schools totaled 2350 students, an increase of 1.6 percent from the 2000 total of 2312 (OSPI 2002). Home schooling is prevalent in the Tri-Cities, with students totaling 544. Richland School District reports 205 students are home schooled within their jurisdiction, Pasco School District reports 113, and Kennewick School District has 226 students home schooled (Neitzel 2002b).

Post-secondary education in the Tri-Cities area is provided by Columbia Basin College (CBC), City University, and Washington State University, Tri-Cities branch campus (WSU-TC). The 2001 fall/winter enrollment was approximately 7750 at CBC, 100 at City University, and 1083 at WSU-TC. Many of the programs offered by these three institutions are geared toward the vocational and technical needs of the area. In the 2000-01 academic year, CBC offered 25 Associate in Applied Science (AAS) degree programs. City University offers two associate degree programs, four undergraduate, and three graduate programs, plus access to several more programs through Distance Learning. WSU-TC offers 14 undergraduate and 16 graduate programs, as well as access to graduate programs via satellite (Neitzel 2002a).

4.8.7 Health Care and Human Services

The Tri-Cities area has three major hospitals and five minor emergency centers, as well as a cancer treatment center. All three hospitals offer general medical services and each includes a 24-hour emergency room, basic surgical services, intensive care, and neonatal care.

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; the 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. United Way incorporates 21 participating agencies offering 38 programs (Batchelor 2001 [see Volume II of this EIS, Appendix O]). These member agencies had a cumulative budget total of $27 million in 2000. In addition, 572 organizations received funds as part of the United Way Benton-Franklin County donor designation program.

4.8.8 Police and Fire Protection

The Benton and Franklin County sheriff departments, local municipal police departments (Pasco, Kennewick, Richland, West Richland), and the Washington State Patrol Division in Kennewick provide local police protection.

Fire protection in the Tri-Cities area is provided by fire departments in Kennewick, Richland, and Pasco, a volunteer fire department in West Richland, and three rural fire departments in Benton County.

The Hanford Site Fire Department has fire stations onsite, and the Benton County Sheriff Department provides onsite law enforcement. Site security is provided onsite by the Hanford Patrol.

4.8.9 Utilities

The principal sources of water in the Tri-Cities and the Hanford Site are the Columbia River and groundwater. The water systems of Richland, Pasco, and Kennewick drew a large portion of the 51.5 billion L (13.6 billion gal) used in 2000 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 usage in 2001 was 25.2 billion L (6.7 billion gal). The Pasco system also draws from the Columbia River for its water needs. In 2001, Pasco consumed 11.8 billion L (3.1 billion gal). The Kennewick system uses two wells and the Columbia River for its supply. 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 30 billion L (8 billion gal). Total 2001 usage in Kennewick was 13.2 billion L (3.5 billion gal) (Neitzel 2002a).

The Benton County Public Utility District, Benton Rural Electric Association, Franklin County Public Utility District, and City of Richland Energy Services Department provide the Tri-Cities with electricity. Almost all of the power these utilities provide in the local area is purchased from the Bonneville Power Administration (BPA) that also provides power to the Hanford Site. Natural gas, provided by the Cascade Natural Gas Corporation, serves approximately 11,000 customers in the Tri-Cities, as well as the 300 Area of the Hanford Site.

4.8.10 Aesthetic and Scenic Resources

Broad basins and plateaus interspersed with ridges characterize the Hanford Site landscape. The wide vistas composing much of the area are interrupted by numerous large industrial facilities (for example, reactors and processing facilities). However, DOE and its predecessors have disturbed only about 6 percent of the site. The remainder lies undeveloped and includes natural areas and abandoned agricultural lands that remain undisturbed because of restricted public access. The Hanford Reach National Monument was established in part because of these aesthetic and scenic resources.

The Columbia River flows through the northern portion of the Hanford Site before turning south and forming the eastern site boundary. The White Bluffs, steep whitish-brown cliffs adjacent to the Columbia River, comprise a striking natural feature of the landscape. Rattlesnake Mountain, rising to 1092 m (3581 ft) above mean sea level forms the southeastern boundary of the Hanford Site. Gable Mountain and Gable Butte are the highest landforms within the Hanford Site. Large rolling hills are located to the west and north.

SR 240 provides public access through the southwestern portion of the Hanford Site. Views along this highway include the open lands of the Fitzner/Eberhardt Arid Lands Ecology Reserve (ALE) in the foreground to the west, with the prominent peak of Rattlesnake Mountain and the extended ridgelines of the Rattlesnake Hills in the background. To the east, the views include relatively flat terrain with the structures of the 200 East and 200 West Areas visible in the central area with Gable Butte and Gable Mountain in the background. From the highway, the Saddle Mountains can be seen in the distance to the north and steam plumes from the Energy Northwest reactor cooling towers are often visible in the distance to the east. The views along SR 240 are expansive due to the flat terrain and the predominantly short, treeless, vegetation cover.

Hanford Site facilities can also be seen from elevated locations, such as Gable Mountain, Gable Butte, Rattlesnake Mountain, and other parts of the Rattlesnake Hills along the western perimeter. Facilities are visible from the Columbia River as well. Because of the vast expanse, terrain, and distances involved, only portions of the site are visible from any one point.

The acquisition of spiritual guidance and assistance through personal vision quests is deeply rooted in the religious practices of the indigenous people of the Columbia Basin. High spots were selected because they afforded extensive views of the natural landscape and seclusion for quiet meditation. These practices, and the areas where they took place, are critical in maintaining the continuing cultural identity of the Native American community, and, as such, are eligible for inclusion in the National Register. The high points of the Hanford Site, including Gable Mountain, Rattlesnake Mountain, and Wahluke Slope, are representative of locations where vision quests were conducted. The physical landscape visible from each location is a means to determine areas and resources of concern.

4.9 Noise

Noise is technically defined as sound waves that are unwanted and perceived as a nuisance by humans. Sound waves are characterized by frequency, measured in Hertz (Hz), and sound pressure expressed as decibels (dB). Most humans have a perceptible hearing range of 31 to 20,000 Hz. A decibel is a standard unit of sound pressure. The threshold of audibility for most humans ranges from about 60 dB at a frequency of 31 Hz to less than about 1 dB between 900 and 8000 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 pressure levels outside the range of human hearing are not considered noise in a regulatory sense, even though wildlife may be able to 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 or 24 hour(s). 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.

Environmental noise measurements were made on the Hanford Site in 1981 during site characterization for the Skagit/Hanford Nuclear Power Plant Site (NRC 1982). Measurements were also made at five locations during 1987 when the Hanford Site was considered for a geologic waste repository (BWIP) for spent commercial nuclear fuel and other high-level nuclear waste. Additionally, noise levels as a result of field activities, such as well drilling and sampling, were measured. Baseline offsite noise measurements attributable to automobile traffic were also determined.

During site characterization for the Skagit/Hanford Nuclear Power Plant (NRC 1982), 15 sites were monitored and noise levels were found to range from 30 to 60.5 dBA (L_{eq}). The values for isolated areas ranged from 30 to 38.8 dBA. Measurements taken around the sites where Energy Northwest was constructing nuclear power plants (WNP-1, WNP-2, and WNP-4) ranged from 50.6 to 64 dBA. Measurements taken along the Columbia River near the intake structures for WNP-2 were 47.7 and 52.1 dBA, compared with more remote river noise levels of 45.9 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 60.5 dBA.

Background noise levels were determined at five locations within the Hanford Site for studies supporting the BWIP. Noise levels are expressed as L_{eqs} for 24 hr ($L_{eq\text{-}24}$). On the dates tested, the average noise level for the five sites was 38.9 dBA. Wind was identified as the primary contributor to background noise levels, with winds exceeding 19 km/hr (12 mi/hr) significantly affecting noise levels. Background noise levels in undeveloped areas at Hanford can best be described as a mean $L_{eq\text{-}24}$ of 24 to 36 dBA. Periods of high wind that normally occur in the spring would elevate background noise levels.

Baseline noise levels as a result of automobile traffic were determined for two locations: SR 24, leading from the Hanford Site west to Yakima, and SR 240, south of the site and west of Richland where the route handles maximum traffic volume (DOE 1991). Traffic volumes were predicted based on an operational workforce and a construction workforce. Peak (rush hour) and off-peak hours were modeled. 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. Baseline noise levels during the construction phase were 62 dBA for SR 24 and 70.2 dBA for SR 240. Levels based on the operational phase ranged from 62 to 65.7 dBA for SR 24 and 70.2 to 74.1 dBA for SR 240. Adverse community responses would not be expected at increases of 5 dBA over background noise levels.

In the interest of protecting Hanford workers and complying with Occupational Safety and Health Administration (OSHA) standards for noise in the workplace, that Hanford Environmental Health Foundation (HEHF) has monitored noise levels resulting from several routine operations performed at Hanford. Occupational sources of noise propagated in the field include well sampling, well drilling, water wagon operation, trucks, compressors, and generators. Noise levels from these activities ranged from 74.8 to 125 dBA (Neitzel 2002a) and have the potential for disturbing sensitive wildlife.

4.10 Occupational Safety

Total occupational work hours at the Hanford Site for the 5-year period, 1997-2001, were 106,836,082 hours, or about 56,230 worker-years (DOE 2002). The DOE records occupational injuries and illnesses in four categories pertinent to NEPA analysis. Total recordable cases (TRCs) are work-related deaths, illnesses, or injuries resulting in loss of consciousness, restriction of work or motion, transfer to another job, or required medical treatment beyond first aid. Lost workday cases (LWCs) represent the number of cases recorded resulting in days away from work or days of restricted work activity, or both, for affected employees. Lost workdays (LWDs) are the total number of workdays (consecutive or not), after the day of injury or onset of illness, during which employees were away from work or limited to restricted work activity because of an occupational injury or illness. Fatalities are the number of occupationally related deaths. Information on occupational safety used in this section is updated quarterly and is available at URL: http://tis.eh.doe.gov/cairs.

Occupational injury and illness incidence rates for the Hanford Site Office of River Protection showed a steady decrease from 1997 through 2000 (Figure 4.29). Rates ranged from 3.0 cases per 200,000 worker hours (100 worker years) in 1997 to 1.7 cases in 2001. Occupational injury and illness incidence rates for Richland Operations declined from 1997 to 2000, increasing slightly during 2001. In 1997 there were 3.1 cases per 200,000 worker hours. Rates decreased to 2.0 cases in 2000 and increased slightly in 2001 to 2.1 cases per 200,000 worker hours. Occupational injury and illness incidence rates for the DOE complex also demonstrate annual decreases, ranging from 3.5 cases per 200,000 worker hours during 1997 to 2.3 cases in 2001 (DOE 2002).

Over the 5-year period from 1997 to 2001, rates on the Hanford Site averaged 2.4 cases per 200,000 worker hours, whereas the incidence rate for the entire DOE complex averaged slightly higher, at 2.8 cases per 200,000 worker hours (DOE 2002). The Hanford Site and DOE-wide average TRC rates were well below the Bureau of Labor Statistics (BLS) rates for U.S. private industry of 6.7 cases per 200,000 worker hours during the same period (BLS 2002).

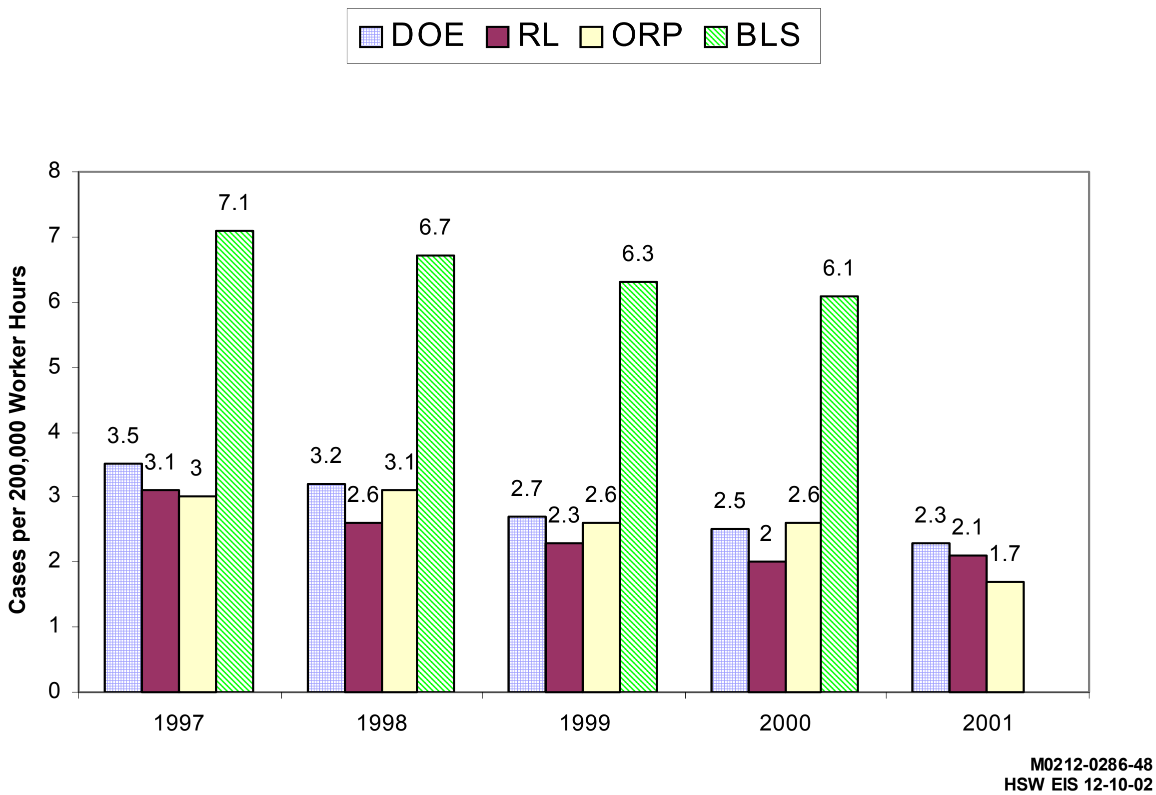


Figure 4.29. Occupational Injury and Illness Total Recordable Case Rates at the Hanford Site Compared with the DOE Complex and Private Industry (DOE 2002)

Table 4.18 shows occupational injury, illness, and fatality incidence rates reported for the private sector by the BLS (Department of Labor), and throughout the DOE complex, including DOE's Richland Operations and Office of River Protection. During the 5-year period from 1997 to 2001, Hanford Site TRC and LWC rates were somewhat lower than those for DOE, whereas the private sector was consistently higher. Average LWD rates for Richland Operations for the 1997 to 2001 period were higher than Hanford's Office of River Protection and the entire DOE complex. There were no fatalities at the Hanford Site during the 1997 to 2001 period (DOE 2002).

4.11 Occupational Radiation Exposure at the Hanford Site

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 total number monitored for the 5-yr period, 1997-2001, at the Hanford Site was 53,888 individuals. Waste processing and management facility employees monitored for the same period was 7404, or approximately 14 percent of the site workforce (DOE 2003).

Table 4.18. Occupational Injury, Illness, and Fatality Incidence Rates for U.S. Department of Energy Facilities and Private Industry (DOE 2002)[a]

	Total Recordable Cases					Lost Work Cases					Lost Work Days					Fatalities
	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001	Average
Bureau of Labor Statistics	7.1	6.7	6.1	6.3	NA	3.3	3.1	3.0	3.0	NA	NA	NA	NA	NA	NA	
1997-2000 Average	6.6					3.1										0.0046
U.S. Department of Energy	3.5	3.2	2.7	2.5	2.3	1.7	1.5	1.2	1.1	1.0	52.3	42.6	44.9	33.8	23.0	
1997-2001 Average	2.8					1.3					39.3					0.0012
DOE Office of River Protection, Hanford Site	3.0	3.1	2.6	2.6	1.7	1.0	1.4	1.1	1.1	0.4	34.0	32.8	66.9	51.5	9.5	
1997-2001 Average	2.6					1.0					38.9					0
DOE Richland Operations Office, Hanford Site	3.1	2.6	2.3	2.0	2.1	1.3	1.1	1.0	0.8	0.7	47.9	56.8	50.4	27.8	26.0	
1997-2001 Average	2.4					1.0					41.8					0
(a) Per 200,000 worker hours (100 worker-years).																

DOE has established dose limits in order to control radiation exposures. The primary DOE dose limit is 5000 mrem/yr (50 mSv/yr) to the whole body, expressed as the total effective dose equivalent (TEDE), which is the sum of dose due to radiation sources internal and external to the body (10 CFR 835).

A maximum DOE Administrative Control Level (ACL) of 2000 mrem/yr (20 mSv/yr) per person is recommended for all DOE activities. DOE organizations are encouraged to establish site and facility-specific ACLs below this 2000-mrem/yr (20-mSv/yr) value. An ACL of 500 mrem/yr (5 mSv/yr) has been established for the vast majority of Hanford workers. Higher ACLs than 500 mrem/yr (5 mSv/yr) have been necessary for only a very small number of Hanford workers. There were no individual worker doses in excess of the 2000-mrem/yr (20-mSv/yr) ACL or the 5000-mrem/yr (50-mSv/yr) TEDE regulatory limit doses at the Hanford Site during the period 1997-2001 (DOE 2003).

Nineteen percent of the total monitored Hanford Site employees and 27 percent of the waste processing and management facility employees had measurable dose during the 1997-2001 period. Figure 4.30 illustrates the average Hanford Site occupational dose (mrem/yr). The average occupational dose for all monitored waste processing and management facility employees decreased from 40 to 14 mrem/yr (400 to 140 µSv/yr) for the period 1999 to 2001, a decline of 65 percent. The average dose for all monitored Hanford workers for the same time period generally increased (from 16 mrem/yr [160 µSv/yr] in 1999 to 20 mrem/yr [200 µSv/yr] in 2001) (DOE 2003).

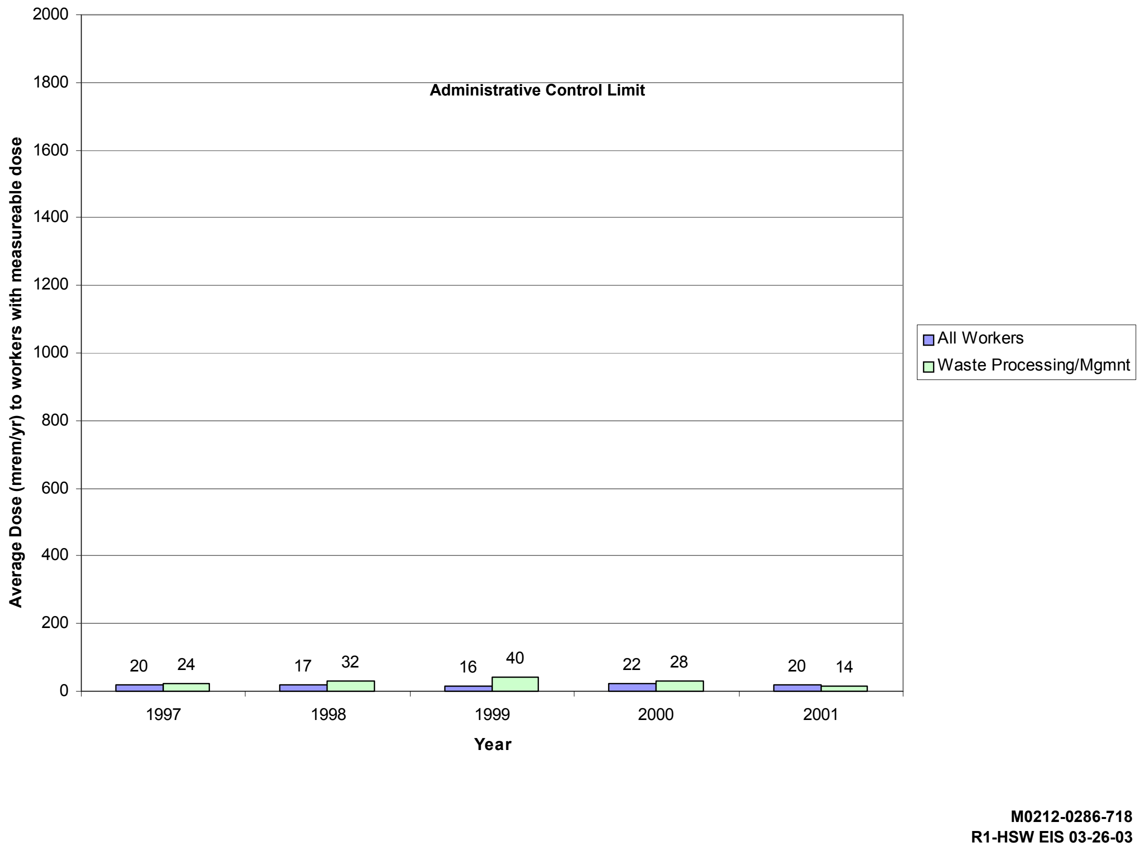


Figure 4.30. Average Occupational Dose (mrem/yr) to Hanford Site Individuals with Measurable Dose, 1997-2001 (DOE 2003)

Collective dose is the sum of the dose received by all individuals with measurable dose and is measured in units of person-rem. (For example, a dose of 1 rem to 10 people would result in a collective dose of 10 person-rem.) Figure 4.31 shows the collective operational dose (person-rem/yr) at Hanford for the years 1997-2001.

The collective dose at the Hanford Site has decreased for the waste processing and management facility employees from 64 to 17 person-rem/yr for the period 1999 to 2001, a 73 percent decline. The collective dose for all workers for the same time period increased.

Table 4.19 shows the radiation exposure data for the Hanford Site (DOE 2003). For the period 1997-2001, the total number of individuals monitored has generally decreased, while the number of individuals with measurable dose has increased. The 5-year average occupational dose for workers with measurable dose was similar for all Hanford workers (103 mrem/yr [1 mSv/yr]) and waste management facility workers (107 mrem/yr [1.1 mSv/yr]), well below the typical Hanford ACL of 500 mrem/yr (5 mSv/yr).

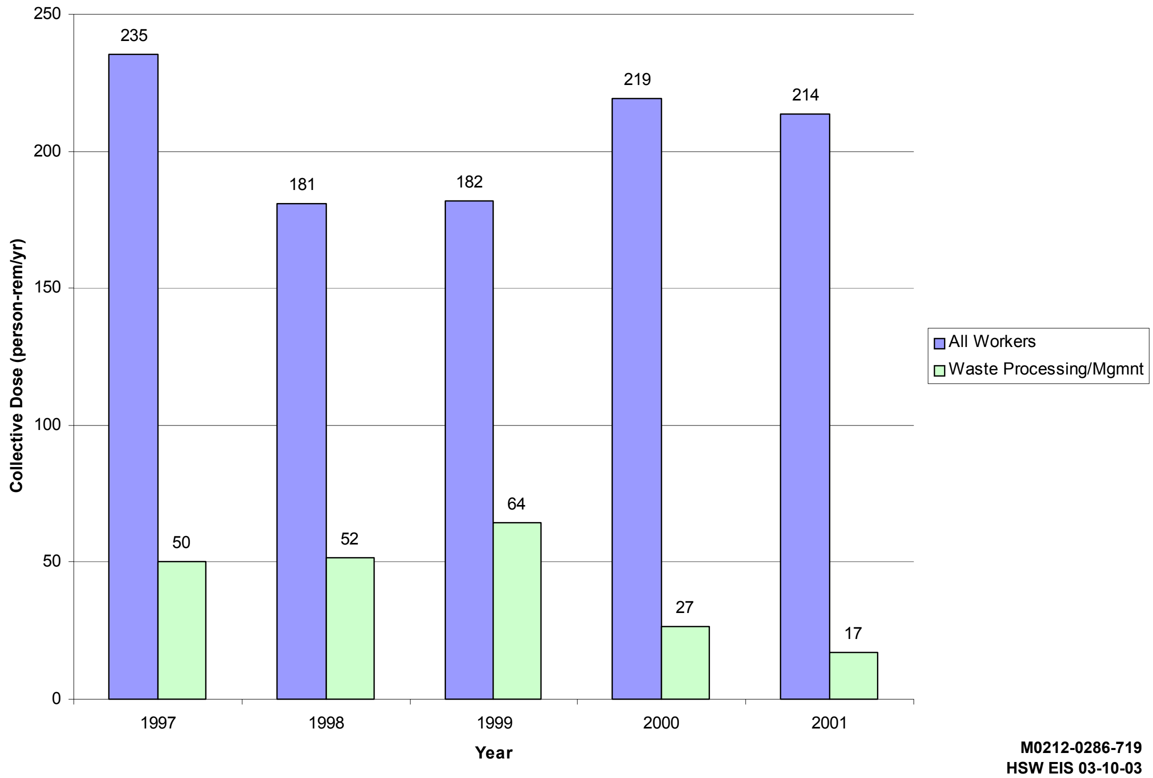


Figure 4.31. Collective Operational Dose (person-rem/yr) at the Hanford Site, 1997-2001 (DOE 2003)

Table 4.19. Radiation Exposure Data for the Hanford Site, 1997-2001 (DOE 2003)

Year	Total Number Monitored	Number with Meas. Dose	Percent with Dose >0	Total Collective Dose (TEDE)		Average Dose to Workers (mrem)	
				(Person-rem/yr)	(Person-mrem/yr)	All Monitored	All with Dose >0
Hanford Site							
2001	10,485	2218	21%	214	213,628	20	96
2000	10,048	1923	19%	219	219,032	22	114
1999	11,310	2013	18%	182	182,000	16	90
1998	10,441	1772	17%	181	180,927	17	102
1997	11,604	2058	18%	235	235,355	20	114
Cumulative Totals							
1997-2001	53,888	9984	19%	1031	1,030,942	19	103
Waste Processing/Management Facility							
2001	1216	294	24%	17	17,277	14	59
2000	938	234	25%	27	26,722	28	114
1999	1598	479	30%	64	64,258	40	134
1998	1609	419	26%	52	51,728	32	123
1997	2043	538	26%	50	50,033	24	93
Cumulative Totals							
1997-2001	7404	1964	27%	210	210,018	28	107

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