4.0 Affected Environment

The Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau in south-eastern Washington State. The Hanford Site occupies an area of approximately 1,517 square kilometers (km^2) (586 square miles [mi^2]) north of the confluence of the Yakima River with the Columbia River. Within the geographic boundary of the Site, there are 36.42 km^2 (14.1 mi^2) of Columbia River surface water, and one section (1 mi^2) of land owned by the State of Washington.

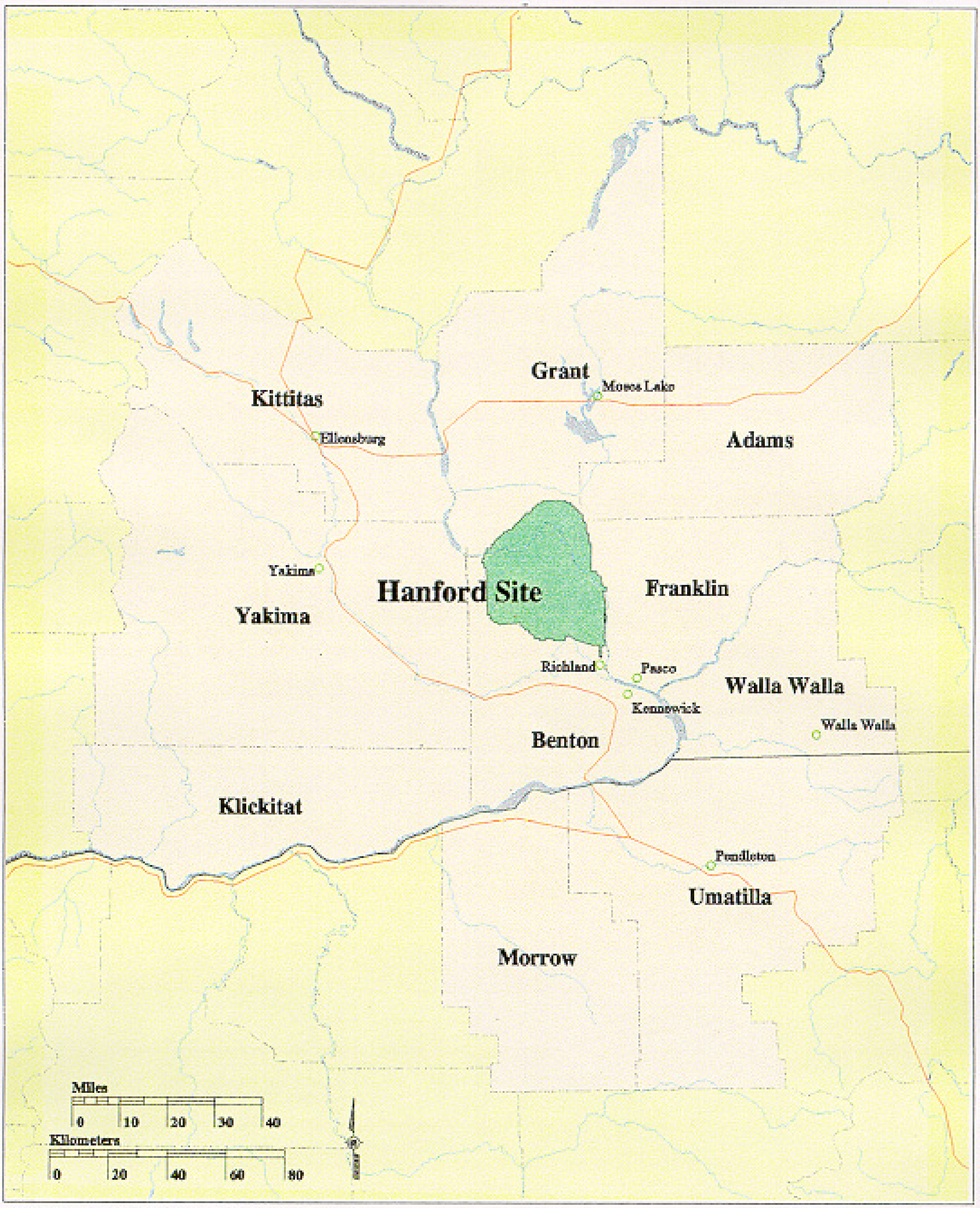
The Hanford Site is about 50 km (30 mi) north to south and 40 km (24 mi) east to west. The Columbia River flows through the northern part of the Hanford Site and, turning south, forms part of the Hanford Site's eastern boundary. The Yakima River runs near the southern boundary and joins the Columbia River below the City of Richland, which bounds the Hanford Site on the southeast. Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge form the southwestern and western boundaries, and the Saddle Mountains form the Hanford Site's northern boundary. Two small east-west ridges, Gable Butte and Gable Mountain, rise above the plateau of the central part of the Hanford Site. Adjoining lands to the west, north, and east are principally agricultural and range land. The cities of Richland, Kennewick, and Pasco (also referred to as the Tri-Cities) constitute the nearest population center and are located immediately southeast of the Hanford Site. Figure 4-1 depicts the Hanford Site and the surrounding area.

The production of defense nuclear materials at the Hanford Site since the 1940s has necessitated the exclusion of public access and most non-government-related development on the Hanford Site. As a result of its defense-related mission, the Hanford Site has also provided *de facto* protection of the natural environment and cultural resources (NPS 1994); however, the defense nuclear production mission has left the Hanford Site with an extensive waste legacy. Nuclear weapons material production and associated activities at the Hanford Site during the past five decades have generated a variety of radioactive, hazardous, and other wastes that have been disposed of or discharged to the air, soil, and water at the Hanford Site.

4.1 Land Uses

For many years, the area along the Columbia River was used extensively by Tribal members for fishing, hunting, and gathering. Pasturing of livestock became important in pre-contact times. The Cayuse, Umatilla, Walla Walla, and Nez Perce people became very skillful at breeding horses (in the 1700s). When Lewis and Clark first came down the Columbia River, there were great herds of horses grazing the rich hills of southeastern Washington and northeastern Oregon. Although the horse meant greater mobility, these people maintained traditional migratory patterns. The Columbia River supplied an endless cycle of vegetable crops. Most bands gathered at winter sites on or near the Columbia River. Culturally, these sites were used by the same people and their ancestors before them for thousands of years. The routes of migration followed ancient patterns with the band stopping at the same spot it camped the year before. In the early spring, family bands would leave the main encampment on the river and travel to the uplands to dig roots. They timed their returns to utilize the main salmon run in the spring and fall. When they had a sufficient stockpile of dried salmon, they would return to the mountains to gather berries and hunt for game until the snows would push them back to the lowlands near or on islands in the Columbia where they would gather together in the large wintering sites and spend the colder months. Mission, Oregon; Walla Walla, Washington; Pasco, Washington; and Umatilla, Oregon, are just a few of the modern-day names of where some of those old winter camping sites were located.

Figure 4-1. Hanford Site and the Vicinity.



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Land uses at the Hanford Site have changed dramatically over the past 100 years. By the turn of the century, settlers had moved into the area, developing irrigated farmland and practicing extensive grazing (see Figure 1-4). In 1943, the Federal government acquired the Hanford Site for production of nuclear materials to be used in the development of the atomic bomb.

4.1.1 Existing Land Uses in the Vicinity of the Hanford Site

Existing land uses within the vicinity of the Hanford Site include urban and industrial development, wildlife protection areas, recreation, irrigated and dryland farming, and grazing. According to the 1992 Census of Agriculture (USDA-NASS 1992), Benton, Franklin, and Grant counties had a total of 958,626 hectares (ha) (2,396,564 acres [ac]) (9,586 square kilometers [km^2]/3,745 square miles [mi^2]) of land in farms, of which 667,027 ha (1,667,568 ac) (6,670 km^2/ 2,606 mi^2) were in crop land. Approximately 46 percent of crop land was irrigated in 1992, and approximately 40 percent of crop land in 1992 was used as pastureland. According to the 1992 census, the total market value of agricultural products in the three counties was $935 million, including $758 million for crops and $177 million for livestock. In 1994, wheat represented the largest single crop (in terms of area) planted in Benton and Franklin counties. The total area planted in the two counties was 97,490 ha (240,900 ac) (975 km^2/376 mi^2] and 12,020 ha (29,700 ac) (120 km^2/46.4 mi^2) for winter and spring wheat, respectively. Other major crops such as alfalfa, apples, asparagus, cherries, corn, grapes, and potatoes are also produced in Benton and Franklin counties (PNNL 1996a). In 1994, the Conservation Reserve Program of the U.S. Department of Agriculture (USDA)[1] included 10,279.8 ha (25,382.3 ac) [102.8 km^2/ 39.7 mi^2] in Benton County, 9,359.3 ha (23,109.3 ac) [93.6 km^2/ 36.1mi^2] in Franklin County, and 10,116.8 ha (24,979.8 ac) (101.1km^2/39.0 mi^2) in Grant County.[2]

In 1992, the Columbia Basin Project, a major irrigation project to the north of the Tri-Cities, produced gross crop returns of $552 million, representing 12.5 percent of all crops grown in Washington State. Also, in that year, the average gross crop value per irrigated acre was $1,042. The largest percentage of irrigated acres produced alfalfa hay (26.1 percent of irrigated acres), wheat (20.2 percent), and feed-grain corn (5.8 percent). Other significant crops are apples, dry beans, potatoes, and sweet corn (PNNL 1996a).

Other land uses in the vicinity of the Hanford Site include a planned, low-level radioactive waste decontamination, super-compaction, plasma gasification and vitrification unit (operated by Allied Technology Group Corporation); and a commercial nuclear fuel fabrication facility (operated by Siemens Power Corporation).

4.1.2 Existing Hanford Site Land Uses

Land-use categories at the Hanford Site include reactor operations, waste operations, administrative support, operations support, sensitive areas, and undeveloped areas. Remedial activities are currently focused within or near the disturbed areas. Much of the Hanford Site is undeveloped, providing a safety and security buffer for the smaller areas used for operations. Public access to most facility areas is restricted.

4.1.2.1 Wahluke Slope. The area north of the Columbia River encompasses approximately 357 km^2 (138 mi^2) of relatively undisturbed or recovering shrub-steppe habitat. The northwest portion of the area is managed by the U.S. Fish and Wildlife Service (USFWS) under a permit issued by DOE in 1971 as the Saddle Mountain National Wildlife Refuge (NWR). The permit conditions

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[1] Agricultural lands at risk for soil erosion set aside to enhance wildlife.

[2] Personal conference with Rod Hamilton, Conservation Program Specialist with the USDA, Farm Service Agency, in Spokane, Washington, October 1997.

require that the refuge remain closed to the public as a protective perimeter surrounding Hanford operations. The closure has benefitted migratory birds, such as curlews, loggerhead shrikes, and waterfowl.

Until recently, in the northeast portion of the Wahluke Slope, the Washington State Department of Fish and Wildlife (WDFW) operated the Wahluke State Wildlife Recreation Area, which was established in 1971. In April 1999, the WDFW and the USFWS notified the DOE of their intent to modify their management responsibilities on the Wahluke Slope under the 1971 agreement leaving only a small portion (about 324 ha (800 ac)) northwest of the Vernita bridge under WDFW permit. The USFWS informed the DOE that it intends to allow essentially the same uses permitted by the State of Washington under the WDFW's management of the Wahluke Slope. Therefore, transfer of management of the Wahluke Slope from the WDFW to the USFWS involves only a change in the agency managing the property and does not involve any change in the management activities for the Wahluke Slope. Management of the entire Wahluke Slope by the USFWS as an overlay wildlife refuge is consistent with the 1996 DOI Hanford Reach EIS ROD. The ROD recommended the Wahluke Slope be designated a wildlife refuge and the Hanford Reach a Wild and Scenic River, and that the wildlife refuge be managed by the USFWS.

The WDFW had leased a total of approximately 43 ha (107 ac) of the Wahluke State Wildlife Recreation Area for sharecropping. The purpose of these agricultural leases is to produce food and cover for wildlife and manage the land for continued multi-purpose recreation. In addition, the WDFW issued a grazing permit for approximately 3,756 ha (9,280 ac), allowing up to 750 animal-unit-months to graze the parcel (WDFW Grazing Permit #W5-01, and WDFW Agricultural Leases #R-01, #WB-01, and #WB-02). This WDFW grazing lease was allowed to expire on December 31, 1998 but, under SEPA regulations for up to 10 years after the expiration of the lease, the WDFW can reinstate the grazing lease without public review.

The Wahluke Wildlife Recreation Area is open to the public for recreational uses during daylight hours. According to data published in the *Hanford Reach of the Columbia River, Comprehensive River Conservation Study and Environmental Impact Statement Final - June 1994* (NPS 1994), the Wahluke State Wildlife Recreation Area has more than 40,000 visits per year by recreationists. Most recreational visits are related to sport fishing in the Columbia River.

The Wahluke Slope once contained small, nonradioactively contaminated sites (i.e., landfills). These sites were subject to an expedited response action and were remediated by DOE in 1997. Although remediation took place, the landfills could still have hazardous materials that would cause injury to trust resources. The DOE is not planning to alter the current land uses of the Wahluke Slope and is specifically prohibited from causing any adverse impacts on the values for which the area is under consideration for Wild and Scenic River or NWR status (DOI 1996).

4.1.2.2 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 by the public and Tribes for boating, water skiing, fishing, and hunting of upland game birds and migratory waterfowl. While 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 100 Areas occupy approximately 68 km^2 (26 mi^2) along the southern shoreline of the Columbia River Corridor. The area contains all of the facilities in the 100 Areas, including nine retired plutonium production reactors, associated facilities, and structures. The primary land uses are reactor decommissioning and undeveloped areas. Future use restrictions have been placed in the vicinity of the 100-H Area, which is associated with the 183-H Solar Evaporation

Basins. Additional deed restrictions or covenants for activities that potentially extend beyond 4.6 meters (m) (15 feet [ft]) below ground surface are expected for other *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remediation areas. Additional information is provided in Section 3.3.1.4.2.

The area known as the Hanford Reach includes an average of a 402-m (1,320-ft) strip of public land on either side of the Columbia River. The Hanford Reach is the last unimpounded, nontidal segment of the Columbia River in the United States. In 1988, Congress passed Public Law 100-605, *Comprehensive River Conservation Study*, which required the Secretary of the Interior to prepare an environmental impact study (in consultation with the Secretary of Energy) to evaluate the outstanding features of the Hanford Reach and its immediate environment.

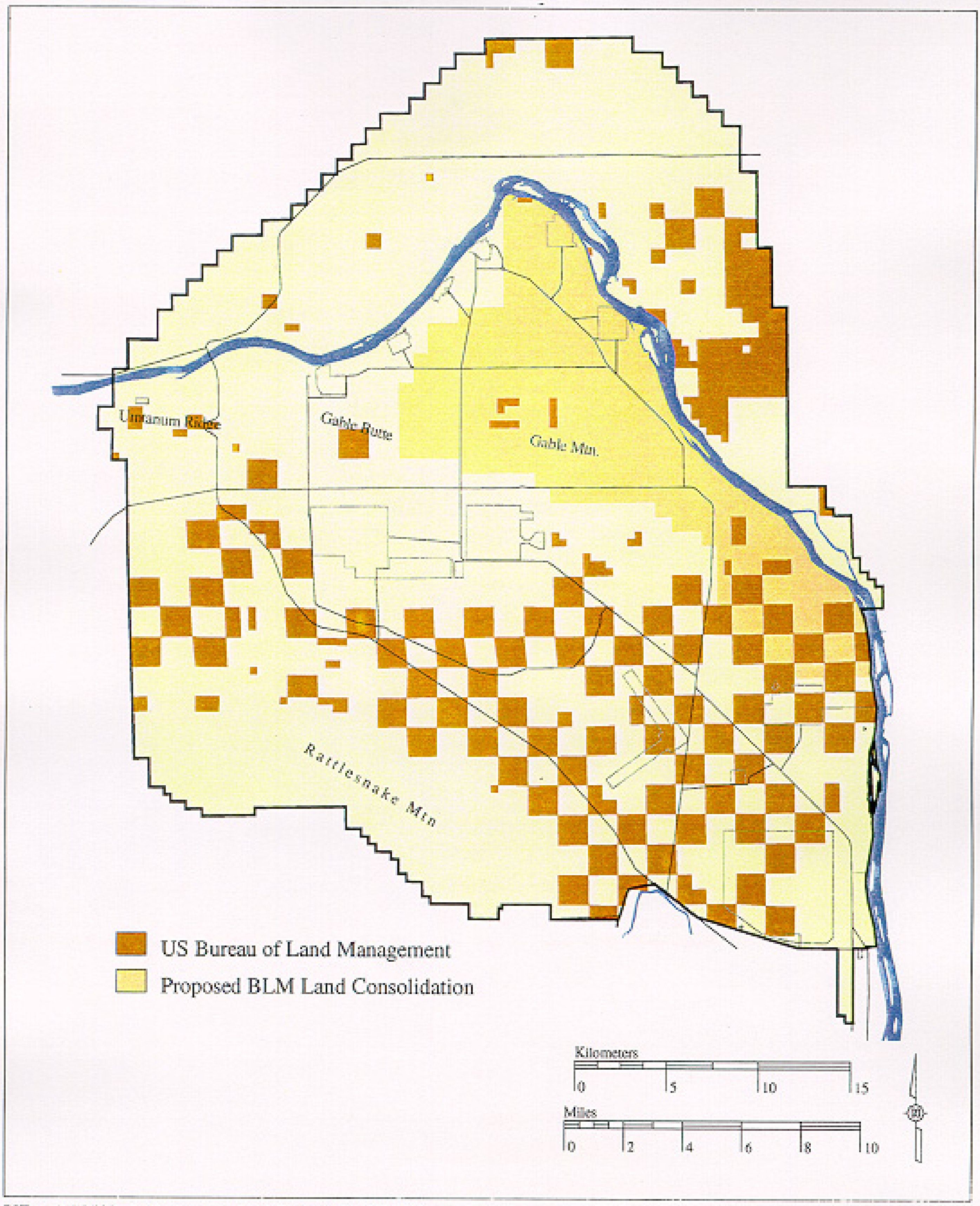
Alternatives for preserving the outstanding features also were examined, including the designation of the Hanford Reach as part of the National Wild and Scenic Rivers system. The results of the study can be found in the *Hanford Reach of the Columbia River, Comprehensive River Conservation Study and Environmental Impact Statement Final - June 1994* (NPS 1994). The Record of Decision (ROD) DOI issued as a result of this EIS in 1996 recommended that the Hanford Reach be designated a “recreational river,” as defined by the *National Wild and Scenic Rivers Act of 1968*. The ROD also recommended that the remainder of the Wahluke Slope be established as a National Fish and Wildlife Refuge. Finally, the ROD recommended that the approximately 728 ha (1,800 ac) of private land located in the Hanford Reach Study Area be included in the recreational river boundary, but not the refuge boundary. The final designation will require Congressional legislation.

There are two proposals currently under consideration in Congress. The primary differences between the proposals include the extent of the geographic scope (whether the Wahluke Slope is addressed in addition to the river corridor) and the designation of the land manager (e.g., local vs. Federal control).

In addition to the control and Wahluke Slope issues, the proposed Wild and Scenic legislation contains a provision for transferring administrative jurisdiction over certain parcels of land in the State of Washington from the Secretary of Energy to the Secretary of the Interior, affecting underlying ownership of about 19,943 ha (49,280 ac, 197 km^2, 75 mi^2) of the Hanford Site. This swap would consolidate the scattered Benton County portion of Hanford’s Bureau of Land Management (BLM) Public Domain lands, into an area beginning near 100-D, running south and east along the Columbia River shore, to just north of Energy Northwest (formerly known as the Washington Public Power Supply System, or WPPSS) and then west to Gable Mountain (see Figure 4-2). As long as these lands are needed (e.g., still withdrawn from BLM by DOE), this legislative action would not affect DOE’s administration of the areas involved. The DOE’s use of withdrawn BLM Public Domain lands is consistent with most land-use designations with the exceptions of Industrial Exclusive, Research and Development, or Industrial designations where BLM’s multiple-use mandate would be limited by an extensive infrastructure.

4.1.2.3 Central Plateau. The 200 East and 200 West Areas occupy approximately 51 km^2 (19.5 mi^2) in the Central Plateau of the Hanford Site. Facilities located in the Central Plateau were built to process irradiated fuel from the production reactors. The operation of these facilities resulted in the storage, disposal, and unplanned release of radioactive and nonradioactive waste. The primary land uses are waste operations and operations support. Deed restrictions or covenants for activities that potentially may extend beyond 4.6 m (15 ft) below ground surface are expected for CERCLA remediation areas in the Central Plateau geographic study area.

Figure 4-2. Proposed BLM Land Swap.



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In 1964, a 410-ha (1,000-ac) tract was leased to the State of Washington to promote nuclear-related development. A commercial low-level radioactive waste disposal facility, run by U.S. Ecology, Inc., currently operates on 41 ha (100 ac) of the leasehold. The rest of the leasehold was not used by the State, and this portion of the leasehold recently reverted to DOE. The DOE constructed the Environmental Restoration Disposal Facility (ERDF) on this tract.

The ERDF is operated on the Central Plateau to provide disposal capacity for environmental remediation waste (e.g., low-level, mixed low-level, and dangerous wastes) generated during remediation of the 100, 200, and 300 Areas of the Hanford Site. The facility is currently about 65 ha (160 ac) and can be expanded up to 414 ha (1.6 mi^2) as additional waste disposal capacity is required.

4.1.2.4 All Other Areas. The All Other Areas geographic area is 689 km^2 (266 mi^2) and contains the 300, 400 and 1100 Areas, Energy Northwest (formerly known as WPPSS) facilities, and a section of land currently owned by the State of Washington.

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 (R&D) facilities serving the Hanford Site. Kaiser Aluminum and Chemical Corporation is leasing the 313 Building in the 300 Area to use an extrusion press that was formerly owned by DOE. The Environmental Molecular Sciences Laboratory (EMSL) and associated research programs provide research capability to advance technologies in support of DOE's mission of environmental remediation and Waste Management.

The 400 Area, located southeast of the 200 East Area, is the site of the Fast Flux Test Facility (FFTF). The FFTF is a 400 megawatt thermal, liquid metal (sodium-cooled) nuclear research test reactor that was constructed in the late 1970s and operated from 1982 to 1992. Although not designed nor operated as a breeder reactor, the FFTF operated during these years as a national research facility for the Liquid Metal Fast Breeder Reactor Program to test advanced nuclear fuels, materials, components, systems, nuclear operating and maintenance procedures, and active and passive safety technologies. The reactor was also used to produce a large number of different isotopes for medical and industrial users, generate tritium for the United States fusion research program, and conduct cooperative, international research.

In December 1993, the FFTF was shutdown due largely at that time from determinations that the facility could not continue to operate economically. In April 1995, defueling was completed and usable fuel is stored on site in fuel storage vessels or in the secure vault at the Plutonium Finishing Plant at the Hanford Site. Unusable spent nuclear fuel (SNF) has been thoroughly washed to remove all sodium residuals, dried, and placed in approved, 50-year Interim Storage Casks on the 400 Area Interim Storage Area pad. In November 1995, the reactor was placed in standby mode with the main cooling system operating at approximately 200°C (400°F) to keep the sodium coolant liquid and circulating to maintain DOE's option to restart and operate the reactor in the future. Essential systems, staffing, and support services are being maintained in a manner that will support either timely restart or deactivation of the FFTF. In January 1997, the Secretary of Energy officially directed that the FFTF be maintained in a standby condition while an evaluation was conducted of any future role the facility might have in the DOE's national tritium production strategy. In December 1998, the Secretary determined that the FFTF would not play a role in the nation's tritium production strategy.

In May 1999, the Secretary announced that DOE would ask the Pacific Northwest National Laboratory (PNNL) to complete a 90-day study that would resolve outstanding informational needs for the FFTF. Results of this study were completed and documented in a program scoping plan presented by PNNL to DOE in early August 1999. As a result of this study, the

Secretary decided, on August 18, 1999, that DOE would conduct a programmatic *National Environmental Policy Act* (NEPA) review, including an Environmental Impact Statement (EIS), evaluating the potential environmental impacts associated with proposed expansion of infrastructure, including the possible role of the FFTF, for civilian nuclear energy research and development activities; production of isotopes for medical, research, and industrial uses; and production of plutonium-238 for use in advanced radioisotope power systems for future National Aeronautic and Space Administration (NASA) space missions. The Notice of Intent for this programmatic EIS is planned for publication in the *Federal Register* on September 15, 1999. The Final EIS (FEIS) is planned for completion in the Fall of 2000; a Record of Decision utilizing the NEPA review (including the FEIS), is planned by December 2000.

The 1100 Area, located just north of Richland, served as the central warehousing, vehicle maintenance, and transportation operations center for the Hanford Site. A deed restriction has been filed with Benton County for the Horn Rapids Asbestos Landfill, which restricts future land uses in the vicinity of the landfill. Also, DOE transferred the 1100 Area to the Port of Benton. The DOE prepared an environmental assessment that resulted in a finding of no significant impact on August 27, 1998, for the transfer of the 1100 Area and the Southern rail connection to the Port of Benton (DOE/RL EA-1260). The Port officially took ownership and control of the 1100 Area (consisting of 318 ha [786 ac], 26 buildings, and 26 km [16 mi] of rail tract) on October 1, 1998. Although the 1100 Area is no longer under DOE control, it is included in this EIS to support the local governments with their SEPA EIS analyses of the Hanford sub-area of Benton County under the State of Washington's Growth Management Act.

Together with the Washington State Department of Transportation and Legislature Transportation Committee, the Port of Benton is currently funding a major study ($600,000) to determine the feasibility of reconnecting the Hanford main rail line to Ellensburg, Washington (as it was in the 1970s), as an alternative route for Yakima Valley rail traffic flowing between the Puget Sound and the Tri-Cities. The current Yakima Valley route passes directly through all the cities in the Valley, including the cities of Yakima and Kennewick which have plans to develop their downtown areas to be more people friendly. Specifically, the Port has expressed a desire to use the Hanford rail system and extend the current system upriver where there is currently only an abandoned railroad grade.

Additional land uses in the All Other Areas geographic area include the following:

- The Hazardous Materials Management and Emergency Response (HAMMER) Volpentest Training and Education Center, which is used to train hazardous materials response personnel. The HAMMER Volpentest Training and Education Center is located north of the 1100 Area and covers about 32 ha (80 ac).

- Land was leased to Energy Northwest (formerly known as WPPSS) to construct three commercial power reactors in the 1970s. One plant, Washington Nuclear Plant Number 2 (WNP-2), was completed and is currently operating. Activities on the other two plants were terminated and the plants will not be completed. The DOE is considering a proposal from Energy Northwest to allow a sublease for siting, construction, and operation of an aluminum smelter (see Section 1.3).

- In 1980, the Federal government sold a 259 ha (640 ac) section of land south of the 200 East Area, near State Route (SR) 240, to the State of Washington for the purpose of nonradioactive hazardous waste disposal. This parcel is uncontaminated (although the underlying groundwater is contaminated) and undeveloped. The deed requires that if it is used for any purpose other than hazardous waste disposal, ownership would revert to the Federal government.

- The Laser Interferometer Gravitational-Wave Observatory (LIGO), built by the National Science Foundation on the Hanford Site, detects cosmic gravitational waves for scientific research. The facility consists of two underground optical tube arms, each 4 km (2.5 mi) long, arrayed in an “L” shape. The facility is sensitive to vibrations in the vicinity, which can be expected to constrain nearby land uses.

4.1.2.5 The Fitzner/Eberhardt Arid Lands Ecology Reserve (ALE Reserve). The Fitzner/Eberhardt Arid Lands Ecology Reserve (also designated as the Rattlesnake Hills Research Natural Area, or the ALE Reserve), encompasses 308.7 km^2 (119.2 mi^2) in the southwestern portion of the Hanford Site and is managed as a habitat and wildlife reserve and environmental research center. A “research natural area” is a classification used by Federal land management agencies to designate lands on which various natural features are preserved in an undisturbed state solely for research and educational purposes. The ALE Reserve remains the largest research natural area in the State of Washington (PNL 1993a).

The mineral rights to a 518 ha (1,280 ac) area on the ALE Reserve are owned by a private company. The company has been free to enter this area and explore for oil or gas since 1977. Additional information is provided in Section 4.2.3. There are also two ongoing R&D projects under way on the ALE Reserve: gravity experiments in underground Nike bunkers located in the southern portion of the Reserve, and on-line science education, teacher training, and astronomy research in the observatory on the top of Rattlesnake Mountain. Both are long-term projects using existing facilities.

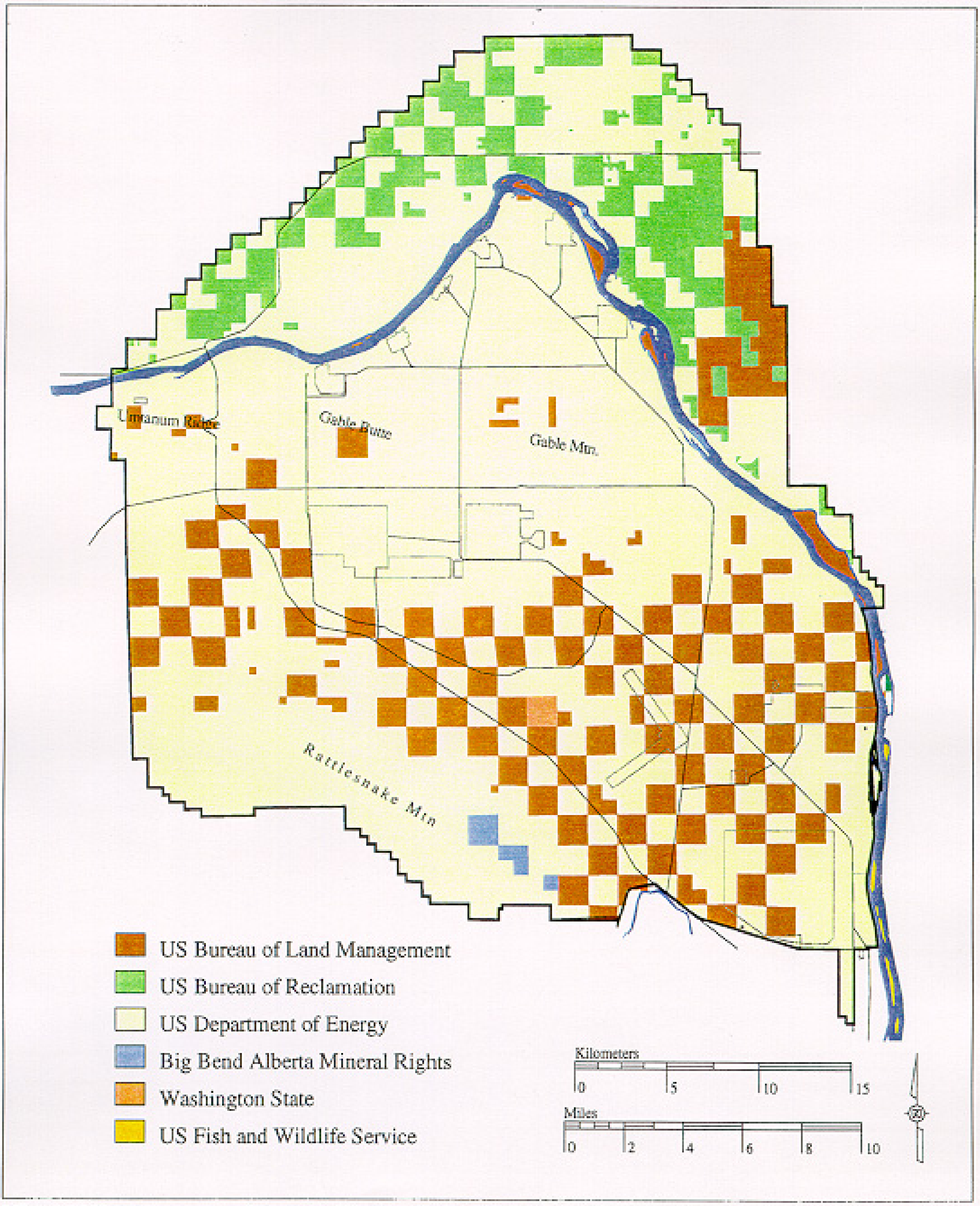
Because public access to the ALE Reserve has been restricted since 1943, the shrub-steppe habitat is virtually undisturbed and is part of a much larger Hanford tract of shrub-steppe vegetation. This geographic area contained a number of small contaminated sites that were remediated in 1994 and 1995 and have been revegetated. There are two landfills on the ALE Reserve, at least one of which was used for disposal of a nonradioactive hazardous waste. Although remediated, one of the landfills may still contain hazardous materials that could cause injury to trust resources.

In 1997, DOE granted a permit and entered into an agreement with USFWS to manage the ALE Reserve consistently with the existing ALE Facility Management Plan. Under this framework, USFWS is preparing a Comprehensive Conservation Plan (CCP) pursuant to the *National Wildlife Refuge Improvement Act of 1997* to identify refuge management actions and to bring the ALE Reserve into the NWR System.

4.1.3 Hanford Site Land Ownership

The Hanford Site land holdings consist of three different real property classifications: (1) lands acquired in fee by DOE or its predecessor agencies, (2) BLM Public Domain lands withdrawn from the Public Domain for use as part of the Hanford Site, and (3) lands the Bureau of Reclamation (BoR) has withdrawn from the Public Domain or acquired in fee as part of the Columbia Basin Project (Figure 4-3). All lands in the Hanford area were ceded to the United States by the Treaties of 1855 (see Appendix A), and these treaties contain

Figure 4-3. Hanford Site Land Ownership.



BHI:rpp 01/13/98 draft_2/landown1.aml Database: 03-AUG-1998 reserved rights for perpetuity. All Federal agencies and projects, including the BoR and BLM, have a Federal trust responsibility to protect the rights of the Indian Tribes.

The BoR agreed in a Memorandum of Agreement (MOA) to transfer custody, possession, and use of certain acquired and withdrawn lands situated within the control zone of the Hanford Works to the U.S. Atomic Energy Commission (AEC) on February 27, 1957. These lands consisted of a checkerboard pattern of alternating square-mile sections on the Wahluke Slope. The BoR retained the right to construct, operate, and maintain the Wahluke Canal and related facilities and any necessary wasteways and drainage ways through the Wahluke Slope in connection with irrigation of lands outside of the control zone. These lands were included in the South Columbia Basin Irrigation District and the East Columbia Irrigation District at the time of district formation. In the MOA, the BoR identified a continued interest in development of irrigable lands on the Wahluke Slope as part of the Columbia Basin Project. The AEC acknowledged the interest of the BoR and reaffirmed a policy of keeping DOE land ownership and restrictions of land use on the Wahluke Slope to a minimum.

Withdrawn Public Domain Lands

In addition to the lands acquired by DOE through condemnation during and after World War II (WW II), the Hanford Reservation includes: (1) Bureau of Land Management (BLM) administered lands withdrawn from the Public Domain by DOE during and following WW II, (2) BLM lands withdrawn from the Public Domain by the Bureau of Reclamation (BoR) prior to WW II as part of the Columbia Basin Reclamation Project (CBRP), and (3) lands acquired in fee by the BoR prior to WW II as part of the CBRP. The withdrawn lands and non-withdrawn lands form a checkerboard pattern over large portions of the Hanford Site.

The lands in category (2) (as listed above) were subsequently affected by a second overlapping withdrawal by DOE during and following WW II. When DOE relinquishes its withdrawals on lands that were historically Federal, those lands withdrawn only by DOE would revert to the Public Domain and management by BLM. Those lands withdrawn by the overlapping DOE and BoR withdrawals would remain withdrawn and managed by the BoR.

The BoR's use of the withdrawn Public Domain lands (after the relinquishment of DOE's overlapping withdrawal) must be consistent with the purposes for which they were originally withdrawn from BLM by BoR. If they are not, the BoR could be expected to relinquish or renegotiate its withdrawal notice and the lands could be returned to the Public Domain and management by the BLM, or BoR could negotiate a new withdrawal order with the BLM.

The BoR continues to retain an interest in the ultimate development of the irrigable lands within the Wahluke Slope as part of the Columbia Basin Project. The interest of the BoR pertains not only to irrigation development, but also to other project purposes (e.g., fish and wildlife protection) and to resource management and environmental concerns. The BoR maintains that the agreement with the AEC assures return of the lands when the lands are no longer necessary to support DOE's mission for the Hanford Site. Furthermore, the BoR would not concur with any change in the present use of the lands until technical and environmental studies were completed.

The alternating square-mile sections that would eventually revert to the BLM or BoR are an important consideration that complicates land-use planning. Because the lands are owned by another government agency (i.e., BLM), DOE cannot authorize uses of the property beyond the mission needs of the DOE. Typically, after getting the land back, the BLM evaluates current use(s) of the land, compatibility of uses, and suitability of the land for different uses (i.e., mining, grazing, recreation, and preservation) (see text box, "*Withdrawn Public Domain Lands*.")

4.2 Geological Resources

Geologic considerations for the Hanford Site include physiography, stratigraphy, structural geology, seismic and volcanic hazards, and soil characteristics. The *Hanford Site National Environmental Policy Act (NEPA) Characterization* report (Neitzel 1998) provides the basis for the following discussions.

4.2.1 Landscape

The landscape of the Hanford Site is dominated by the low-relief plains of the Central Plains and the anticlinal ridges of the Yakima Folds physiographic regions. The surface topography has been modified within the past several million years by several geomorphic processes: (1) Pleistocene cataclysmic flooding, (2) Holocene eolian activity, and (3) landsliding. Cataclysmic flooding occurred when ice dams in western Montana and northern Idaho were breached and allowed large volumes of water to spill across eastern and central Washington. This flooding formed the channeled scablands and deposited sediments in the Pasco Basin. The last major flood occurred about 13,000 years ago, during the late Pleistocene Epoch. Braiding flood channels, giant current ripples, and giant flood bars are among the landforms created by the floods. Anastomosing flood channels, giant current ripples, bergmounds, and giant flood bars are among the land forms created by the floods. The 200 Area Waste Management facilities are located on one prominent flood bar, the Cold Creek bar (Figure 4-4).

Since the end of the Pleistocene, winds have locally reworked the flood sediments and have deposited dune sands in the lower elevations and loess (windblown silt) around the margins of the Pasco Basin. Many sand dunes have been stabilized by anchoring vegetation, except where they have been reactivated by human activity disturbing the vegetation.

A series of bluffs occurs for a distance of approximately 56 km (35 mi) along the eastern and northern shores of the Columbia River. In the northern portion of the area, these bluffs are known as the White Bluffs.

Landslides occur along the north limbs of some Yakima Folds and along steep river embankments such as White Bluffs. Landslides on the Yakima Folds occur along contacts between basalt flows or sedimentary units between the basalt, whereas active landslides at White Bluffs occur in sediments above the basalt flows. A study of the Hanford Reach by U. S. Geological Survey geologists (Shuster and Hays 1987) concluded that nearby irrigation has accelerated the rate of landslides occurring in the area. The active landslides at White Bluffs are the result of irrigation activity east of the Columbia River.

4.2.2 Stratigraphy

The stratigraphy of the Hanford Site consists of Miocene-age and younger rocks. Older Cenozoic sedimentary and volcaniclastic rock underlie the Miocene and younger rocks but are not exposed at the surface. The Hanford Site stratigraphy is described in the following subsections and is summarized in Figures 4-5 and 4-6.

4.2.2.1 Columbia River Basalt Group. The Columbia River Basalt Group consists of an assemblage of continental flood basalts of the Miocene age. These basalts cover an area of more than 163,170 km^2 (63,000 mi^2) in Washington, Oregon, and Idaho, and have an estimated volume of about 174,000 km^3 (67,200 mi^3). Isotopic age determinations suggest flows of the Columbia River Basalt Group were erupted during a period from approximately 17 to 6 million years ago, with more than 98 percent by volume being erupted in a 2.5 million-year period (17 to 14.5 million years ago).

Figure 4-4. Topography of the Hanford Site (WHC 1991a).

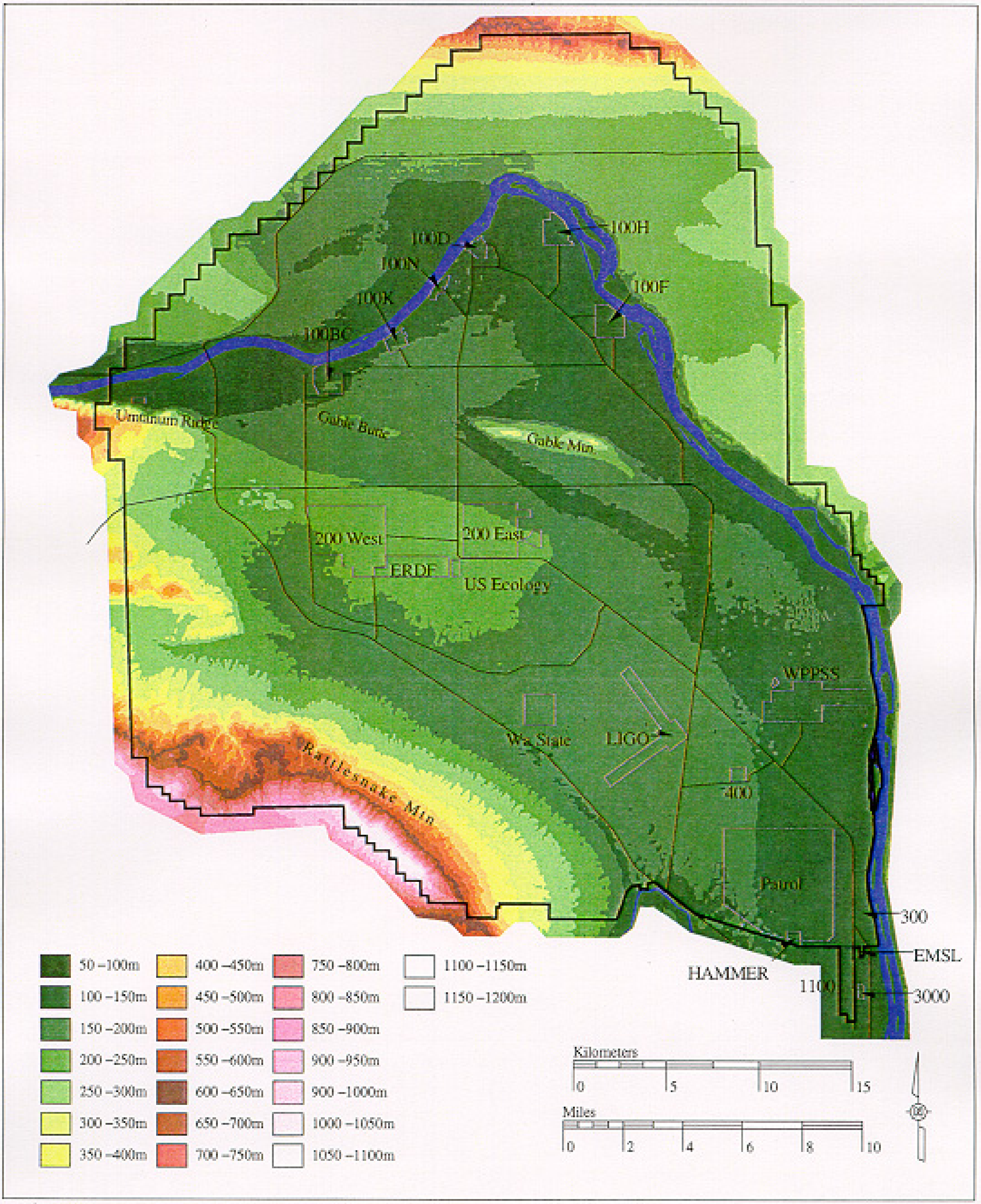


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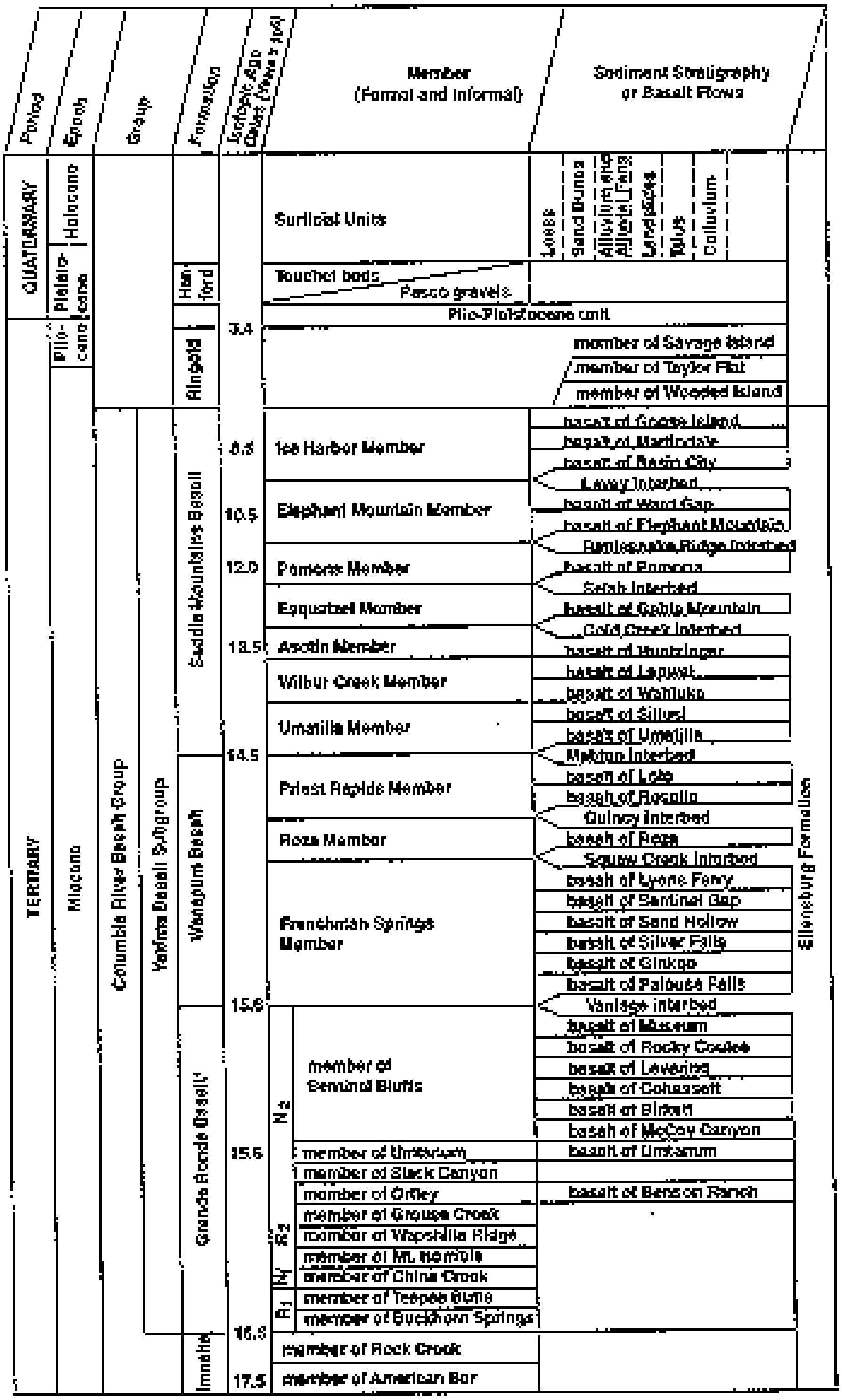
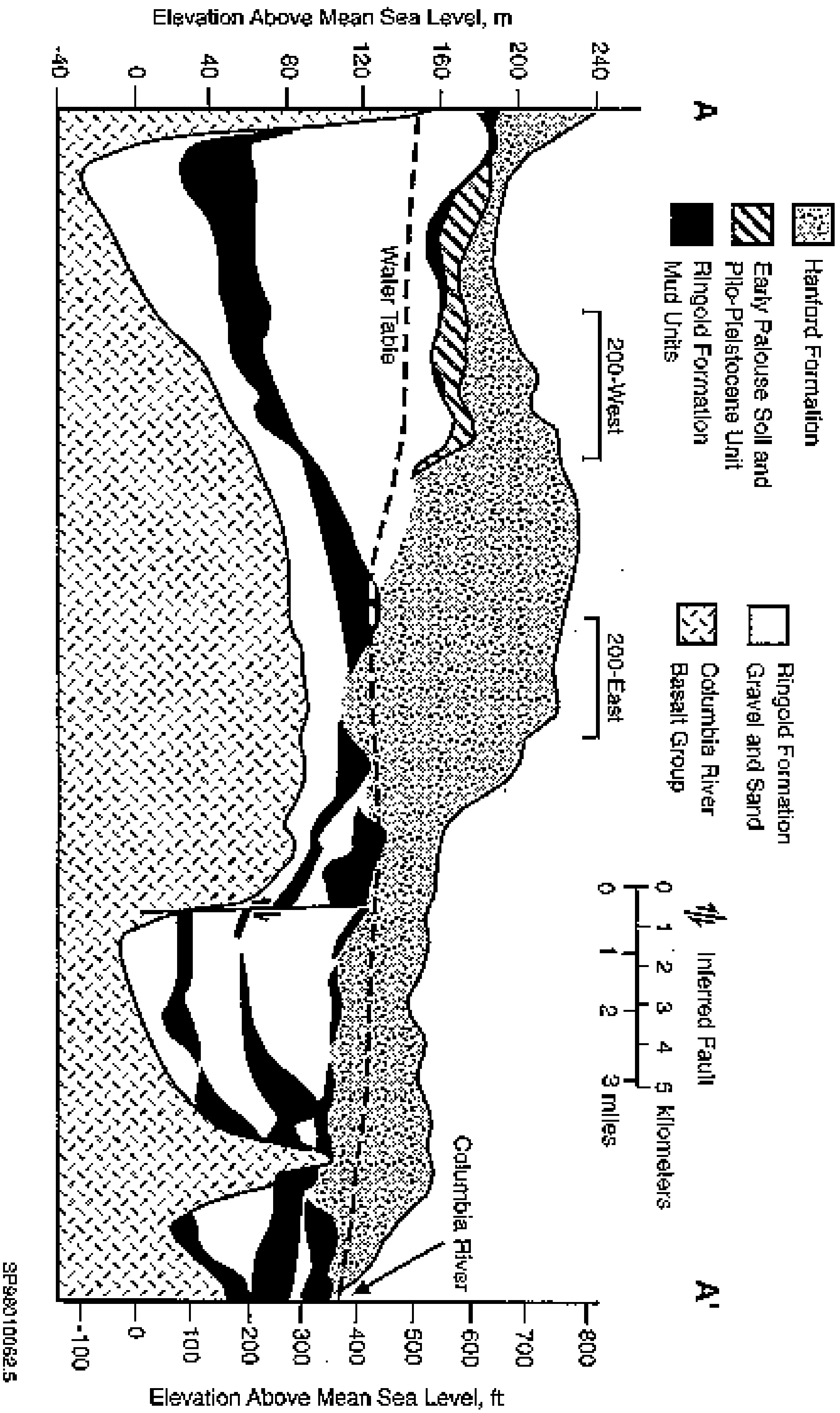
Figure 4-5. A Generalized Stratigraphic Column of the Major Geologic Units of the Hanford Site.



*The Grande Ronde Basalt consists of at least 120 major basalt flows comprising 17 members.
N_2, R_2, N_1, and R_1 are magnetostratigraphic units.

Figure 4-6. Geologic Cross-Section of the Hanford Site (PNNL 1996c).



Columbia River basalt flows were erupted from north-northwest-trending fissures (linear vent systems) in north-central and northeastern Oregon, eastern Washington, and western Idaho. The Columbia River Basalt Group is formally divided into five formations (listed in order from the oldest to the youngest): Imnaha Basalt, Picture Gorge Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. Of these, only the Grande Ronde, Wanapum, and Saddle Mountains Basalts are present in the Pasco Basin. The Saddle Mountains Basalt forms the uppermost basalt unit in the Pasco Basin, with the exception that some of the bounding ridges where the Wanapum and Grande Ronde Basalt flows are exposed.

4.2.2.2 Ellensburg Formation. The Ellensburg Formation includes sedimentary rocks interbedded with the Columbia River Basalt Group in the central and western part of the Columbia Plateau. The age of the Ellensburg Formation is principally Miocene, although locally it may be equivalent to early Pliocene. The thickest accumulations of the Ellensburg Formation lie along the western margin of the Columbia Plateau where Cascade Range volcanic materials interbed with the Columbia River Basalt Group. The lateral extent and thickness of interbedded sediments generally increase upward in the section.

4.2.2.3 Suprabasalt Sediments. The suprabasalt (above the basalt) sediments within and adjacent to the Hanford Site are dominated by the Ringold and Hanford formations, with other minor deposits (PNNL 1996a).

4.2.2.3.1 Ringold Formation. Late Miocene to Pliocene deposits, younger than the Columbia River Basalt Group, are represented by the Ringold Formation within the Pasco Basin. The Ringold Formation was deposited in east-west trending valleys by the ancestral Columbia River and its tributaries in response to development of the Yakima Fold Belt. Exposures of the Ringold Formation are limited to the White Bluffs within the central Pasco Basin and to the Smyrna and Taunton Benches located north of the Pasco Basin. Extensive data on the Ringold Formation are available from boreholes on the Hanford Site.

Flood-related deposits of the Ringold Formation can be broken into different associations based on proximity to the ancestral Columbia and/or Snake River channels. Gravel and associated sand and silt represent a migrating channel deposit of the major river systems and generally are confined to the central portion of the Pasco Basin. Overbank sand, silt, and clay reflect occasional deposition and flooding beyond the influence of the main river channels, and generally are found along the margins of the Pasco Basin. Over time, the main river channels moved back and forth across the basin, causing a shift in location of the various facies. Periodically, the river channels were blocked and caused lakes to develop where mud (with minor amounts of sand) was deposited.

4.2.2.3.2 Plio-Pleistocene Unit. A locally derived unit consisting of an alluvium and/or pedogenic calcrete occurs at the unconformity between the Ringold Formation and the Hanford formation. The sidestream alluvial facies are derived from Cold Creek and its tributaries and are characterized by relatively thick zones of unweathered basalt clasts along with wind-blown materials and soil. The calcrete is relatively thick and impermeable in areas of the western Pasco Basin, often forming an aquitard to downward migration of water in the vadose zone where artificial recharge is occurring.

4.2.2.3.3 Early Palouse Soil. Overlying the Plio-Pleistocene unit in the Cold Creek syncline area is a fine-grained sand to silt. It is believed to consist mainly of eolian (derived from wind deposits) origin, derived from either an older reworked Plio-Pleistocene unit or upper Ringold Formation. The early Palouse soil differs from the overlying slackwater flood deposits by a greater calcium-carbonate content, massive structure in core samples, and a high natural gamma response in geophysical logs.

4.2.2.3.4 Quaternary Deposits. Repositioning of sediments resumed during the Quaternary Period, following the period of late-Pliocene to early-Pleistocene erosion. In the Columbia Plateau, the Quaternary record is dominated by cataclysmic flood deposits with lesser amounts of sediments deposited by water and wind lying below, between, and above flood deposits.

Sand and gravel river sediments, referred to informally as the pre-Missoula gravels, were deposited after incision of the Ringold Formation and before deposition of the cataclysmic flood deposits. The pre-Missoula gravels are similar to the Ringold Formation main-channel gravel facies, consisting of dominantly nonbasaltic clasts. These sediments occur in a swath that runs from the old Hanford townsite on the eastern side of the Hanford Site, across the Site toward Horn Rapids on the Yakima River.

Cataclysmic floods inundated the Pasco Basin a number of times during the Pleistocene, beginning as early as one million years ago. The last major flood sequence is dated at about 13,000 years ago by the presence of erupted material from Mount Mazama interbedded with the flood deposits. The number and timing of cataclysmic floods continues to be debated. As many as 10 flood events have been documented during the last ice age. The largest and most frequent floods came from glacial Lake Missoula in northwestern Montana; however, smaller floods may have escaped down valley from glacial Lakes Clark and Columbia along the northern margin of the Columbia Plateau, or down the Snake River from glacial Lake Bonneville. The flood deposits, informally called the Hanford formation, blanket low-lying areas over most of the central Pasco Basin (Neitzel 1997).

Cataclysmic floodwaters entering the Pasco Basin quickly became impounded behind Wallula Gap (located about 32 km [20 mi] downstream from the Hanford Site), which was too restrictive for the volume of water involved. Floodwaters formed temporary lakes with a shoreline up to 381 m (1,250 ft) in elevation, which lasted only a few weeks or less. Two types of flood deposits predominate: (1) a sand-and-gravel main-channel facies, and (2) a mud-and-sand slackwater facies. Within the Pasco Basin, these deposits are referred to as the Pasco Gravels and slackwater deposits of the Hanford formation. Sediments with intermediate grain sizes (e.g., sand-dominated facies) also are present in areas throughout the Pasco Basin, particularly on the south, protected half of Cold Creek Bar.

Landslide deposits in the Pasco Basin are of variable age and genesis. Most of these deposits occur within the basalt outcrops along the ridges (e.g., on the north side of Rattlesnake Mountain) or steep river embankments (e.g., White Bluffs), where the Upper Unit Ringold Formation crops out in the Pasco Basin.

4.2.3 Structure

The Hanford Site is located near the junction of the Yakima Fold Belt and the Palouse structural subprovinces (DOE 1988a). These structural subprovinces are defined on the basis of their structural fabric, unlike the physiographic provinces that are defined on the basis of landforms. The Palouse subprovince is a regional paleoslope that dips gently toward the Columbia Plateau and exhibits only relatively mild structural deformation. The Palouse Slope is underlain by a wedge of Columbia River basalt that thins gradually toward the east and north, and laps onto the adjacent highlands.

The principal characteristics of the Yakima Fold Belt are a series of segmented, narrow, asymmetric anticlines. These anticlinal ridges are separated by broad synclines or basins that, in many cases, contain thick accumulations of Eocene- to Quaternary-age sediments. The deformation of the Yakima Folds occurred under north-south compression. The fold belt was growing during the eruption of the Columbia River Basalt Group and continued to grow into the

Pleistocene and probably into the present. Thrust or high-angle reverse faults with fault planes that strike parallel or subparallel to the axial trends are found principally along the limbs of the anticlines (Figure 4-7) (PNNL 1996a). The amount of vertical stratigraphic offset associated with these faults varies but commonly exceeds hundreds of meters.

4.2.3.1 Mineral Development. Directly after the discovery of gold in British Columbia and Oregon in the 1850s, gold was discovered in eastern Washington. In 1862, the first very successful strike in Washington was made near the mouth of the Methow River. Strikes were also made on the Clearwater River near present-day Orofino, Idaho, in 1860 and in the Boise Basin ("Treasure Valley") in 1862. These discoveries caused prospectors to explore the mid-Columbia region in the 1860s, upstream from the Dalles to the Canadian border. Between Vantage and Alderdale, Washington, at least seven sites along the Columbia River have had past placer mining activity and gold production. The Chinaman's Bar Placer (located on the south side of the river directly upstream of the Vernita Bridge, partially on the Hanford Site) supported a small operation from 1939 to 1941 with an unknown amount of production (NPS 1994).

In addition to gold mining along the Columbia River, natural gas was discovered on Rattlesnake Mountain in 1913. The small, shallow field was developed in 1929 and produced until it was closed in 1941, yielding a total of approximately 0.07 billion m^3 (2.5 billion ft^3) of gas (NPS 1994). Twenty-four wells were drilled, with the main gas field located on the ALE Reserve. Although intensive exploration occurred, deposits proved to be small.

Oil exploration was also conducted in the Rattlesnake Mountain and Rattlesnake Hills area in the 1920s and 1930s, but useful deposits were not found (Gerber 1997). The mineral rights to a 518 ha (1,280 ac) area are still owned by a private company, the Big Bend Alberta Mining Company. The surface title to this acreage was acquired by the AEC by condemnation in 1952. At that time, the final judgment of the court revested in the owners (at that time, the Big Bend Land Company) the gas and oil rights in the land providing, however, that all rights of ingress and egress over the surface of the land for exploration or exploitation of such rights were prohibited for 25 years from the date of the judgment (January 14, 1952). Presently, the Big Bend Alberta Mining Company is free to enter on the lands at will to explore for oil or gas. The company holds all the oil and mineral rights on one section, the oil and mineral rights on three-quarters of a second section, and the soil and mineral rights on one-quarter of a third section.

4.2.4 Geologic Hazards

The White Bluffs represent a geologic hazard resulting from certain types of land uses, such as irrigated farming and other forms of intensive development (Figure 4-8). The White Bluffs are composed of claystones and siltstones that are relatively strong when dry but lose considerable strength when wet. Visual evidence of recent, suspected human-induced landslide activity has developed over the past two decades. Irrigation water applied to croplands immediately east of the White Bluffs has raised the water table significantly, resulting in local saturation, increased pore pressures, reduced shear strength, and instability of slopes above the river. Leaks in local irrigation canals and irrigation waste water are believed to be contributing groundwater to the slide area, but a regional aquifer may also be responsible (NPS 1994).

Based on studies in the early 1970s, the BoR determined that irrigation would increase the potential for landslide activity along the White Bluffs. Also, a detailed drainage investigation completed in 1967 found a large portion of "red zone" area infeasible to drain based on economic criteria. As part of its effort to restrict irrigation in this area, the BoR rescinded the plats for two irrigation blocks (blocks 36 and 55) and acquired private lands on a "willing seller" basis (NPS 1994).

Figure 4-7. Map of the Hanford Site Region Showing Known Faults.

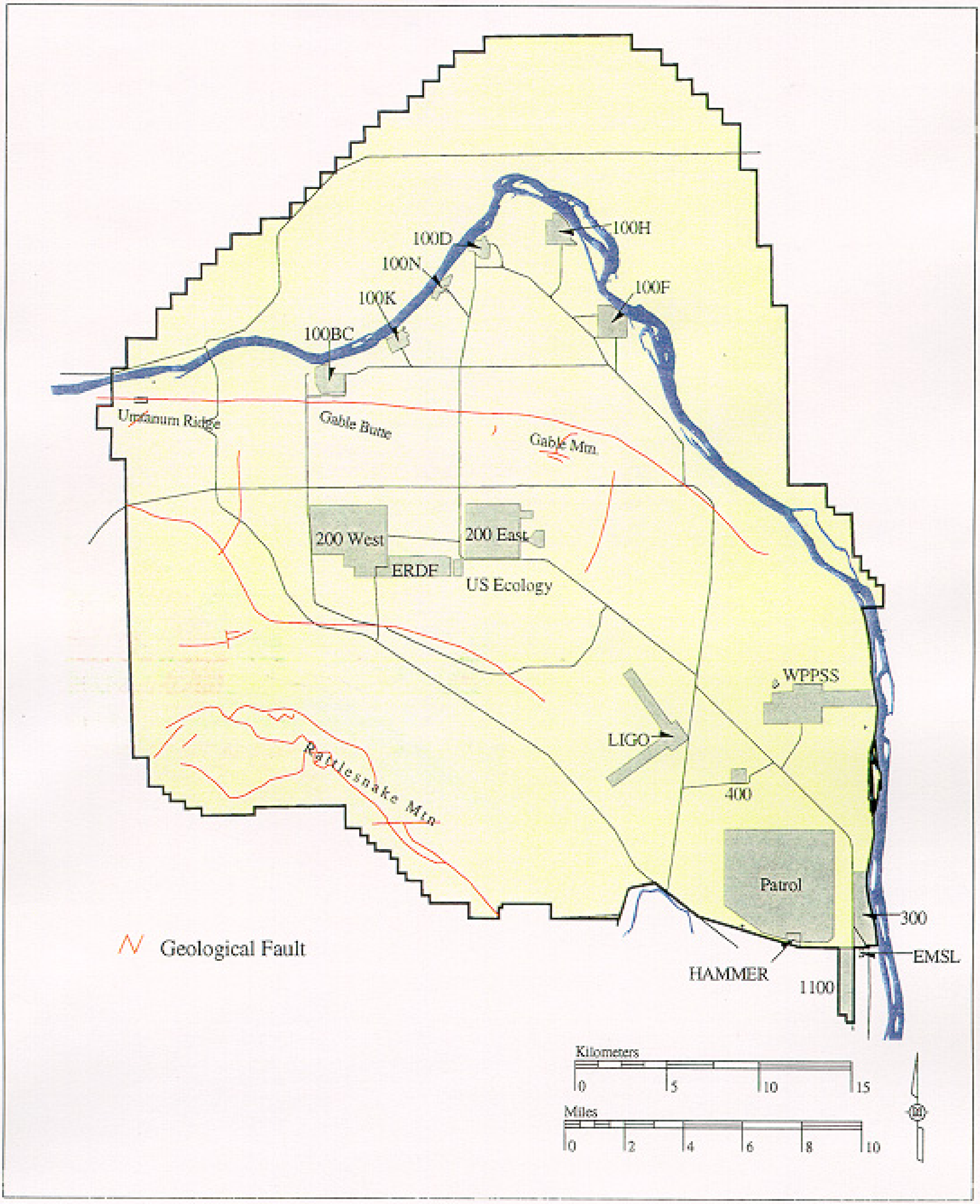


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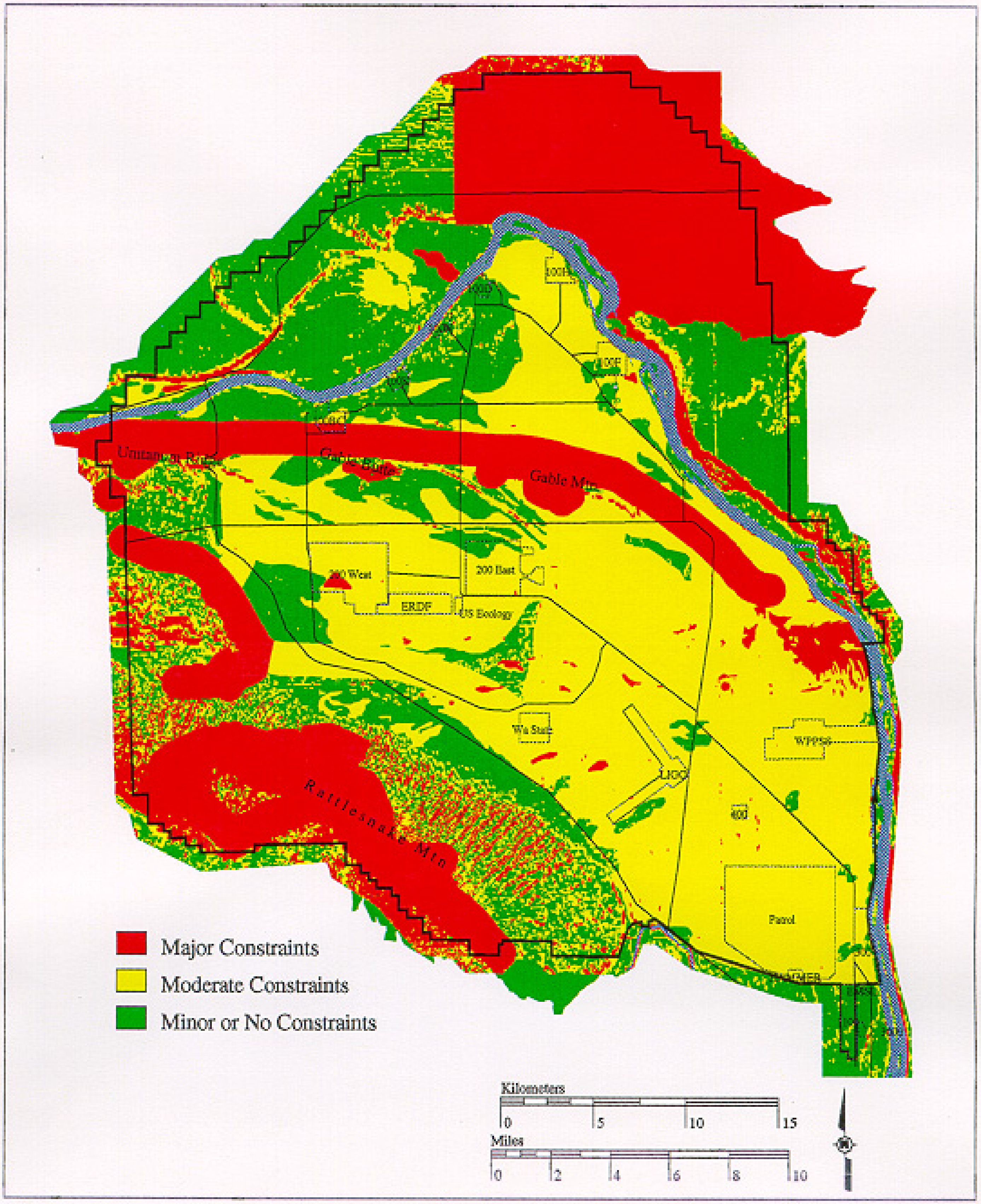
Figure 4-8. Geologic Hazards Related to Economic Land Uses.



Ringold Formation sediments that make up a large portion of the White Bluffs are largely unconsolidated and uncemented (BHI 1995a). These sediments were deposited between 6 and 3.5 million years ago. During and following deposition of Ringold sediment, the floor of the Pasco Basin was subsiding while the surrounding highlands were rising. Consequently, the Ringold sediment layers dip toward the center of the Pasco Basin, which lies in the east-central part of the Hanford Site. The angle of dip of these layers is less than 2 degrees. Ringold sediment layers dip down from the northern and eastern edges of the basin toward the Columbia River. Ringold sediments found in the bluffs consist predominantly of layers of river-deposited sand, ancient soils (paleosols), and sand, silt, and clay deposited in lakes (BHI 1995a).

Throughout the Hanford Site, a series of catastrophic flood deposits, informally known as the Hanford formation, lies atop the Ringold Formation sediments. The Hanford formation consists of fine-grained sediments know as Touchet beds and gravel beds known as the Pasco ravels. The sediments of the Hanford formation are unconsolidated, uncemented, and highly transmissive for the flow of water.

Shuster and Hays (1987) concluded that the entire area of the bluffs along the northern and eastern shores of the Columbia River is susceptible to landslides. Recent landslides have occurred in four areas along the bluffs; these areas are the Locke Island, Savage Island, Homestead Island, and Johnson Island slide areas. The length of the slide areas parallel to the river shoreline ranges from more than a mile at Locke Island to about 0.4 km (0.25 mi) of a mile near Homestead Island.

The Hanford powerline area shows evidence of Late Pleistocene landslides, and the area coincides with lack of irrigation adjacent to the bluffs (Shuster and Hays 1987). The landslides, both active and inactive, total about 11.2 km^2 (4.3 mi^2) in area, and the total landslide susceptible area is about 15.1 km^2 (5.8 mi^2) (Shuster and Hays 1987). These slide areas are characterized by major cracks about two-thirds of the way up the bluff face, surface areas on the slopes below the cracks with an irregular ground surface, and mud flows at the base of the slope. The irregular surface forms as the bluff face slides away and begins to break up. The mud flows occur as a result of a process known as liquefaction, which is water-saturated soil that flows similar to a liquid. Some of the slide areas, such as Savage Island and Locke Island slides, are rimmed by a scarp or cliff. Surface cracks located upland of the bluff face can be found, which indicate the slopes behind the bluffs are very unstable and prone to future landslides.

Examination of slide areas reveals the universal presence of water seeping from the bluffs in springs and marshes. Observation of these springs, saturated cliff faces, and mud flows indicates that water plays a role in producing landslides along the bluffs. The water found in the bluffs reduces the strength, decreases frictional resistance, and adds weight to the unconsolidated Ringold Formation. Because the transmissivity of the Ringold layers varies, water accumulates in certain sediment layers within the bluffs. This wet layer is the plane on which the slide begins. The bluff above a wet layer will slide when the water-laden and lubricated layer fails under the weight of the overburden.

Sources of water on the bluffs are natural precipitation, irrigated farmlands, irrigation and wastewater canals, and irrigation wastewater ponds located up-slope and east of the bluffs and on the Wahluke Slope. Water from these activities percolates through the soil to the Ringold Formation. Some of the layers within the formation resist the downward flow of water, forcing the water to flow laterally. Ringold Formation layers dip toward the Columbia River and the water that collects above less transmissive Ringold Formation layers moves downslope toward the bluffs. Eventually, this water reaches the bluffs and increases the potential for a landslide.

Shuster and Hays (1987) concluded, “In the present climate, most of these bluffs are very stable under natural conditions, but irrigation of the upland surface to the east, which began in the

1950s and has been greatly expanded, led to increased and more widespread seepage in the bluffs and to a spectacular increase in slope failures since 1970. With continuing irrigation, areas of the bluff wetted by seepage will be subject to landslides wherever slopes exceed about 15 degrees and, on lesser slopes, wherever the surficial material is old landslide debris."

The hazards posed by landslides in bluffs range from minor to catastrophic. Economic loss from landslides in the bluffs has not been large because the area is relatively undeveloped. Road closures have occurred. A concrete flume, part of the Ringold wasteway, was destroyed by the Homestead Island slide in the late 1960s (Shuster and Hays 1987). Encroachment up-slope by the Savage Island slide destroyed the riverward margins of irrigated fields along the top of the bluffs (Shuster and Hays 1987).

Perhaps the most unlikely occurrence would be an earthquake-triggered, massive slope failure caused by liquefaction of the White Bluffs, which would temporally block the Columbia River. Hanford facilities on the west side of the river could be endangered, as well as citizens and property located downstream of this temporary dam. Also, contaminants left at depth in the soil column would be further mobilized by the subsequent rise in groundwater levels on the Hanford facilities side of the river.

The Locke Island slide caused the loss of cultural artifacts on the island by changing the channel of the river and causing erosion to occur on Locke Island. Since its beginning in the mid-1970s, the Locke Island slide has extended 150 m (492 ft) into the channel of the Columbia River (Neitzel 1997). Since November 1995, Locke Island has an actively eroding cut bank that is 400 m (1,312 ft) in length, with a horizontal loss of 16 m (53 ft) (Neitzel 1997). These slides can disturb and destroy salmon spawning beds by siltation, and the increase in sediment load in the Hanford Reach could potentially adversely affect the Energy Northwest (formerly known as WPPSS) reactor cooling-water intake systems (Shuster and Hays 1987).

The Hanford Dune Field, located north of the Energy Northwest (formerly known as WPPSS) reactor, also represents a hazard to certain types of land uses. The Hanford Dune Field is one of three great dune fields in the Columbia River Basin. It is an active area of migrating barchan dunes and partially stabilized transverse dunes derived from alluvium, with bare rock-rubbled areas between dunes. In the late 1970s, a study performed by the Heritage Conservation and Recreation Service determined this dune field to be of national significance and proposed a 2,560 ha (6,320 ac) protected area for inclusion in the National Natural Landmark system. For security purposes and other reasons, DOE requested that the site not be designated as such, and the request was honored (NPS 1994).

There is also an extensive dune system that is stabilized with vegetation, located south of the 200 Areas, trending to the northeast toward the Columbia River. This stabilized dune system, which forms hummocky terraces and dune-like ridges, also represents a potential geologic hazard to development. Should the vegetation on the dune system be altered, cleared, or otherwise disturbed, the dunes might remobilize, resulting in dune sand movement and blowing sand during windy weather.

4.2.4.1 Seismic and Volcanic Hazards. The historic record of earthquakes in the Pacific Northwest dates from about 1840. The early part of this record is based on newspaper reports of structural damage and human perception of the shaking and structural damage as classified by the Modified Mercalli Intensity (MMI) scale and is probably incomplete because the region was sparsely populated. Seismograph networks did not start providing earthquake locations and magnitudes in the Pacific Northwest until about 1960. A comprehensive network of seismic stations, which provide accurate locating information for most earthquakes greater than a magnitude of 2.5 on the Richter scale, was installed in eastern Washington in 1969.

Seismicity of the Columbia Plateau, as determined by the rate of earthquakes per area and the historical magnitude of these events, is relatively low when compared to other regions of the Pacific Northwest, the Puget Sound area, and western Montana/eastern Idaho. The largest known earthquake in the Columbia Plateau occurred in 1936 near Milton-Freewater, Oregon. This earthquake had a Richter scale magnitude of 5.75 and a maximum MMI of VII and was followed by a number of aftershocks that, when analyzed, indicated a northeast-trending fault plane. Other earthquakes with Richter scale magnitudes greater than 5.0 and/or MMIs of VI have occurred along the boundaries of the Columbia Plateau in a cluster near Lake Chelan extending into the northern Cascade Range, in northern Idaho and Washington, and along the boundary between the western Columbia Plateau and the Casade Range.. Three MMI VI earthquakes have occurred within the Columbia Plateau, including one in the Milton-Freewater 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 that occurred in 1918 and 1973. These two events were at Richter scale magnitude of 4.4 and MM of V, and were located north of the Hanford Site, near Othello, Washington.

Earthquakes often occur in spatial and temporal clusters in the Columbia Plateau and are termed “earthquake swarms.” The region north and east of the Hanford Site is concentrated with earthquake swarm activity; however, earthquake swarms also have occurred in several locations within the Hanford Site. Earthquakes in a swarm tend to gradually increase and decay in frequency of events, and usually no outstanding large event is present within the sequence. These earthquake swarms occur at shallow depths, with 75 percent of the events located at depths less than 4 km (2.5 mi). Each earthquake swarm typically lasts several weeks to months, may consist of anywhere from several to more than 100 earthquakes, and is clustered in an area 5 to 10 km (3 to 6 mi) in lateral dimension. Often, the longest dimension of the swarm area is elongated in an east-west direction.

Earthquakes in the Columbia Plateau also occur to depths of approximately 30 km (18 mi). These deeper earthquakes are less clustered and occur more often as single, isolated events. Based on epicenter studies and refraction surveys in the region, the shallow earthquake swarms occur in the Columbia River Basalts and the deeper earthquakes occur in crustal layers below the basalts.

Several major volcanoes are located in the Cascade Range west of the Hanford Site. The nearest volcano, Mount Adams, is about 165 km (102 mi) from the Hanford Site. The most active volcano, Mount St. Helens, is located approximately 220 km (136 mi) west-southwest of the Hanford Site.

Because of their close proximity, the volcanic mountains of the Cascades are the principal volcanic hazard at the Hanford Site. The major concern is that ash fall could affect Hanford Site communications equipment and electronic devices, as well as the movement of truck and automobile traffic in and out of the area.

4.2.5 Soils

The *Soil Survey Hanford Project in Benton County Washington*, BNWL-243 (PNL 1966), describes 15 different soil types on the Hanford Site, varying from sand to silty and sandy loam. The soil classifications given in BNWL-243 have not been updated to reflect current reinterpretations of soil classifications (see text box, *“Hanford Site Quick Facts: Soils”*). Until soils on the Hanford Site are

Hanford Site Quick Facts: Soils

- Fifteen types of soils identified
- Textures range from sand to silty and sandy loam
- Most common soil type: Quincy Sand

resurveyed, the descriptions presented in BNWL-243 will continue to be used (see Table 4-1 and Figure 4-9). No soils on the Hanford Site are currently classified as prime farmlands because (1) there are no current soil surveys, and (2) the only prime farmland soils in the region are irrigated (August 1996 Draft HRA-EIS).

The parent material for predominant soil types at the Hanford Site consists of the Hanford formation and Holocene surficial deposits (Cushing 1992). Soils with well-developed profiles occur only where fine and poorly-drained sediments have been deposited and typically are low in organic matter (PNL 1991a).

Wind and water erosion have been key factors in modifying developed soil profiles on the Hanford Site, and have resulted in the loss of soil down to parent material in some areas and the creation of large active sand dunes in other areas. Currently stabilized dune complexes can potentially be reactivated as a result of surface disturbances.

4.3 Water Resources

This section provides an overview of the Hanford Site hydrologic setting, which includes surface water and groundwater resources, and a discussion of existing water rights.

In 1980, Congress enacted the *Northwest Power Act* (NPA) (16 U.S.C. 839-839h), which "marked an important shift in Federal policy." Continually declining fish runs had revealed the failures of previous legislative efforts requiring that "equal consideration" be given to fish and wildlife affected by resource exploitation. The NPA created "a pluralistic intergovernmental and public review process." At the hub of this process, Congress established the Pacific Northwest Electric Power and Conservation Planning Council (Council), directing it to create "a program to protect, mitigate, and enhance" the Columbia River Basin's fish and wildlife "to the extent affected by the development and operation of the Basin's hydropower system." The Council's authority with respect to fish and wildlife measures is contained; the Council "can guide, but not command, Federal river management."

In addition, Canada and the United States signed the Pacific Salmon Treaty in 1985. The Pacific Salmon Treaty has provided for improved conservation and management of the resource. The Treaty covers five species of Pacific salmon and steelhead (two of which -- the Upper Columbia steelhead and the Redfish Lake sockeye salmon -- are now also covered by the *Endangered Species Act of 1973)*, and applies to fisheries in Southeast Alaska, British Columbia, Washington, and Oregon.

There is no single "law of the river" on the Columbia River. Instead, there is a maze of overlapping treaties, laws, and regulations, which together attempt to balance the varied interests on the river. (See text box, "*Columbia River Flow – Who Controls It?*")

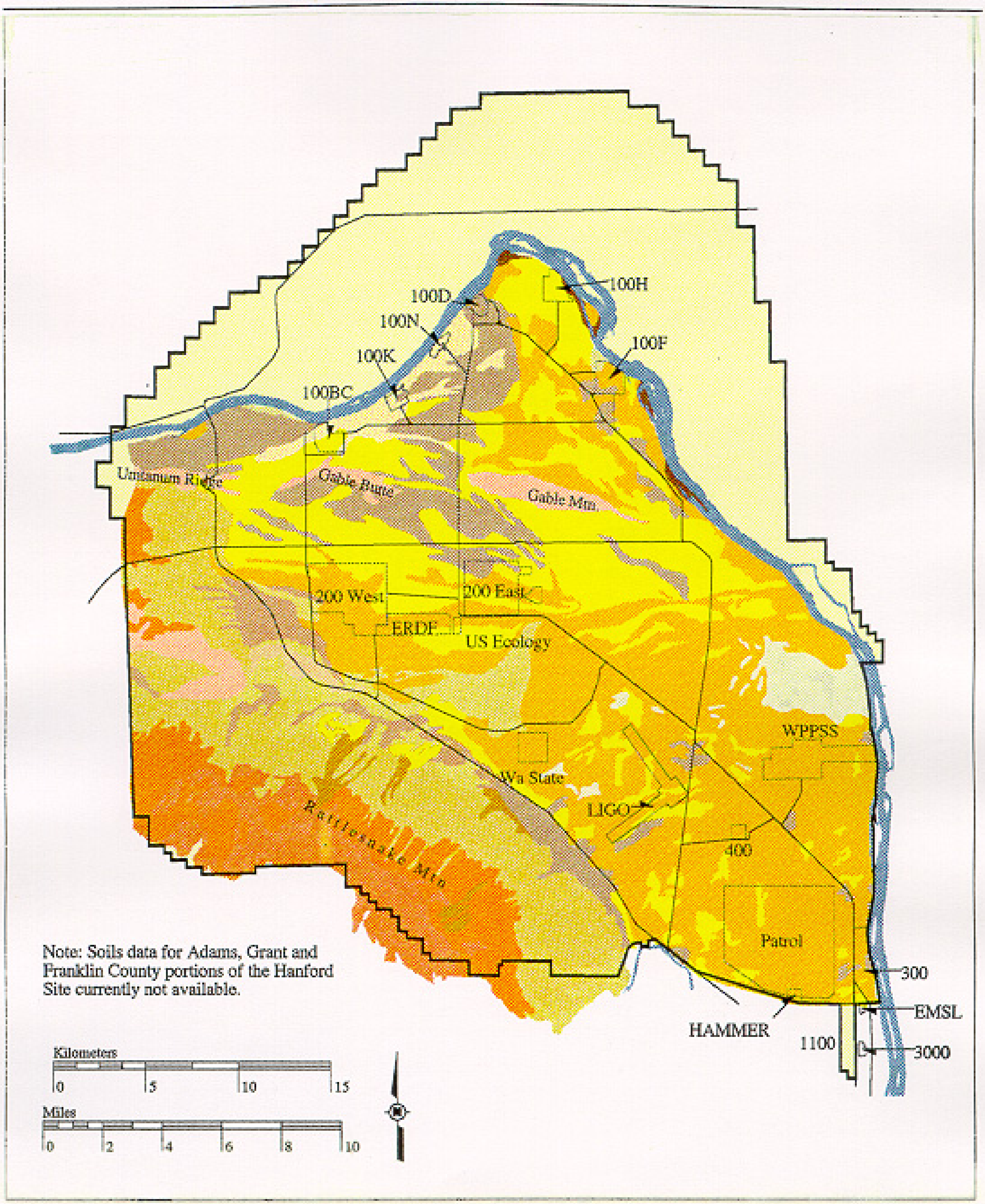
4.3.1 Surface Water

The Pasco Basin occupies about 4,900 km^2 (1,900 mi^2) and is located centrally within the Columbia Basin. Elevations within the Pasco Basin generally are lower than other parts of the Columbia Plateau, and surface drainage enters the Pasco Basin from other basins. Within the Pasco Basin, the Columbia River is joined by three major tributaries: the Yakima River, the Snake River, and the Walla Walla River.

Table 4-1. Soil Types on the Hanford Site (adapted from PNNL 1996a).

Name (Symbol)	Description
Ritzville silt loam (Ri)	Dark-colored silt loam soils midway up the slopes of the Rattlesnake Hills. Developed under bunchgrass from silty wind-laid deposits mixed with small amounts of volcanic ash. Characteristically greater than 150-cm (59-in.) deep; bedrock may occur at less than 150 cm (59 in.) but greater than 75 cm (30 in.).
Quincy (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 approximately 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, a laminated grayish-brown strongly calcareous silt loam subsoil usually is 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 because the sand mantles a lime-silica-cemented layer “hardpan.” Very dark grayish-brown surface layer is somewhat darker than Rupert Sand. Calcareous subsoil usually is dark grayish-brown at approximately 45 cm (18 in.).
Burbank loamy sand (Ba)	Dark, coarse-textured soil underlain by gravel. Surface soil usually is 40-cm (16-in.) thick, but can be 75-cm (30-in.) thick. Gravel content of subsoil ranges from 20 to 80 percent.
Kiona silt loam (Ki)	Located on steep slopes and ridges. Surface soil is very dark grayish-brown and approximately 10-cm (4-in.) thick. Dark brown subsoil contains basalt fragments 30 cm (12 in.) and larger in diameter. Many basalt fragments 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 approximately 50 cm (20 in.) and becomes lighter in color. Granitic boulders are found in many areas. Usually greater than 150-cm (59-in.) deep.
Ephrata sandy loam (El)	Surface is dark colored, and subsoil is dark grayish-brown medium-textured soil underlain by gravelly material, which may continue for many meters (feet). Level topography.
Ephrata stony loam (Eb)	Similar to Ephrata sandy loam. Differs in that many large hummocky ridges presently are made up of debris released from melting glaciers. Areas between hummocks contain many boulders several meters (feet) in diameter.
Scooteney 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 usually is 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 vary 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.
Dune sand (D)	Miscellaneous land type that consists of hills or ridges of sand-sized particles drifted and piled up by wind, and are either actively shifted or so recently fixed or stabilized that no soil horizons have developed.
Lickskillet silt loam (Ls)	Located on ridge slopes of Rattlesnake Hills and slopes greater than 765 m (2,509 ft) in elevation. Similar to Kiona series except surface soils are darker. Shallow over basalt bedrock, with numerous basalt fragments throughout the profile.

Figure 4-9. Soil Map of the Hanford Site (adapted from PNNL 1996a).



The Hanford Site occupies approximately one-third of the land area within the Pasco Basin. Primary surface-water features associated with the Hanford Site are the Columbia and Yakima rivers (see text box, *"Hanford Site Quick Facts: Surface Water"*). Several surface ponds and ditches in the 200 Areas, which were generally associated with fuel- and waste-processing activities, are shown in their historical locations (Figure 4-10). In the 100 Area and 300 Area, historical Hanford irrigation canals are shown. Other active irrigation wasteways (i.e., canals or ditches that carry excess irrigation water back to the Columbia River) that belong to the BoR are shown on the Wahluke Slope. In addition, several small spring-fed streams occur on the ALE Reserve in the southwestern portion of the Hanford Site.

A network of dams and multi-purpose water resource projects is located along the course of the Columbia River. Water storage behind Grand Coulee Dam, combined with storage upstream in Canada, totals 3.1 x 10^{10} m^3 (1.1 x 10^{12} ft^3) of usable storage to regulate the Columbia River for power, flood control, and irrigation.

The flow of the Columbia River has been inventoried and described in detail by the U.S. Army Corps of Engineers (USACE) (DOE, DOA, and DOI 1995). Flows through the Hanford Reach fluctuate significantly and are controlled primarily by releases from the Priest Rapids Dam. Recorded flow rates in the Hanford Reach have ranged from 4,500 to 18,000 m^3/s (approximately 158,900 to 635,600 ft^3/s) during the runoff in spring and early summer, and from 1,000 to 4,500 m^3/s (35,300 to 158,900 ft^3/s) during the low-flow period of late summer and winter.

Annual flows near Priest Rapids during the 68 years prior to 1985 averaged nearly 3,360 m^3/s (120,000 ft^3/s) (McGavock et al. 1987). Daily average flows during this period ranged from 1,000 to 7,000 m^3/s (36,000 to 250,000 ft^3/s). During the last 10 years, the average daily flow was also about 3,360 m^3/s (120,000 ft^3/s). However, larger than normal snowpacks resulted in exceptionally high spring runoff during 1996 and 1997. The peak flow rate during 1997 was nearly 11,750 m^3/s (415,000 ft^3/s) (DART 1998). Normal river elevations range from 120 m (394 ft) above mean sea level where the river enters the Hanford Site near Vernita, to 104 m (341 ft) where the river

Columbia River Flow — Who Controls It?

On the Columbia River above the Hanford Site, there are dams such as the Grant County Public Utility District (PUD) Rock Island Dam and Rocky Reach Dam; the Douglas County PUD Wells Dam; the U.S. Army Corps of Engineers Chief Joseph Dam; the BoR Grand Coulee Dam; and the British Columbia Hydro Keenleyside Dam, Revelstoke Dam, and Mica Dam.

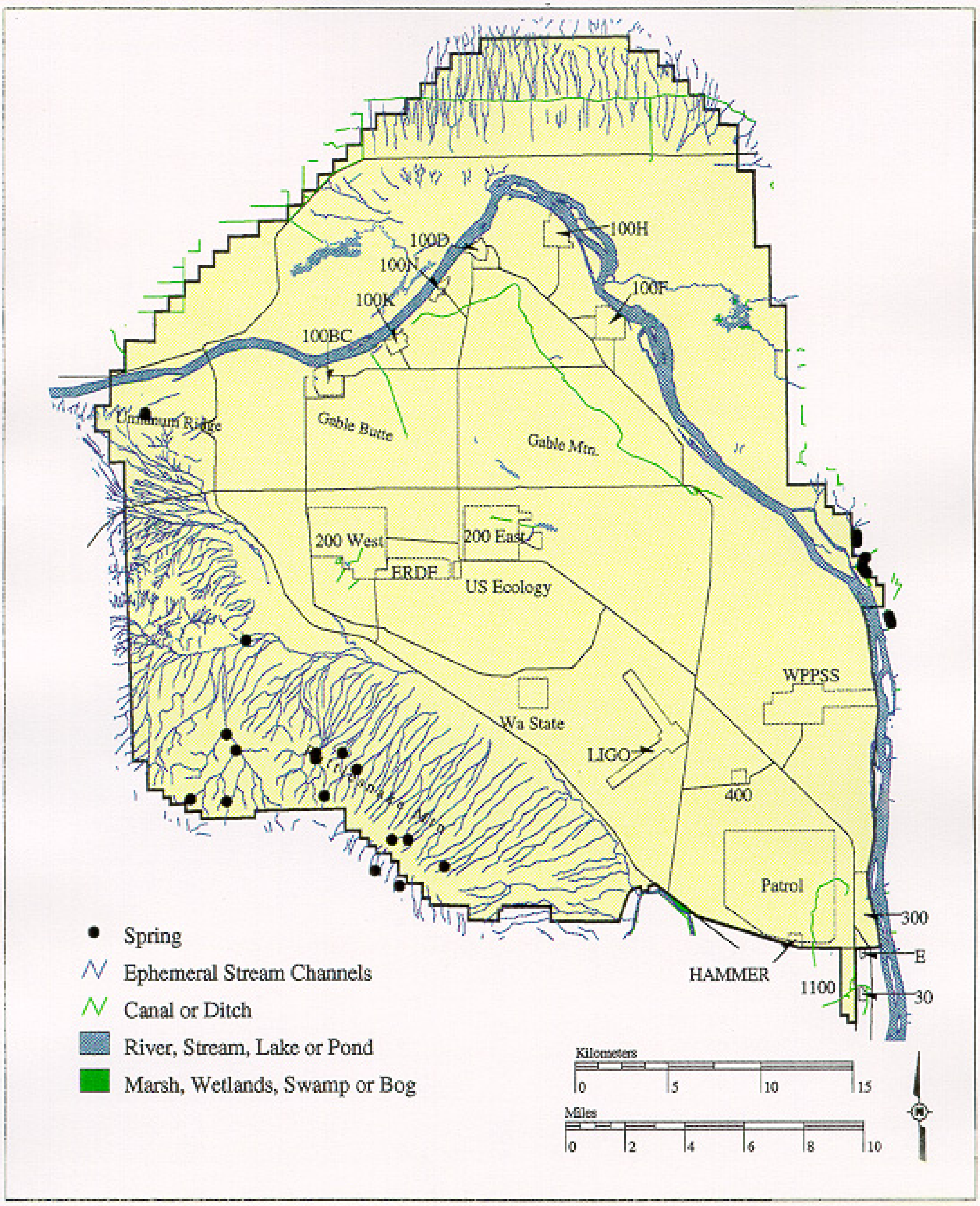
The 1964 Columbia River Treaty between the United States and Canada provided for building four storage reservoirs: three in Canada (Mica, Kennleyside, and Duncan) and one in the United States (Libby). The reservoirs that were built and operated under the Treaty represent almost half the water storage on the Columbia River System. The Treaty required over 15.5 million acre-feet of Canadian storage, but reservoirs actually built contained storage capacity of 20.5 million acre-feet. The excess storage capacity, most of which is behind Mica Dam, is referred to as non-Treaty storage. The Non-Treaty Storage Agreements made by DOE's BPA were necessary to govern the rights to this additional storage capacity. Nothing in the Treaty prevented Canada from using all of the non-Treaty storage unilaterally, although the United States argued it had the right to compensation if use of the non-Treaty storage resulted in reduced Columbia River flows into the United States.

The three dams in British Columbia were developed to provide water storage for power generation in the United States. Mica Dam has the highest "head" at 200 m (656.2 ft) and is the only installation of the three to have a powerhouse. In return for building the three dams (Mica, Keenleyside, and Duncan), B.C. Hydro was entitled to half the additional power generated in the United States that resulted from storage operations in Canada. These "downstream benefits" were sold to a group of American utilities for 30 years. This share, known as the "Canadian Entitlement," is owned by B.C. Hydro. In September 1994, British Columbia and the United States signed a Memorandum of Agreement which outlines new arrangements for the return of the Canadian Entitlement, beginning in 1998.

The Vernita Bar Agreement (signed June 16, 1988, by the U.S. Department of Energy, Federal and state agencies, Tribal governments, and public utility districts in Grant, Chelan, and Douglas counties) was entered into by the dam owners to prevent salmon eggs from being left high and dry when river flows fluctuate to meet peak power demands.

The overall water flow in the Columbia River is precisely controlled with cooperation from all dam owners from the U.S. Army Corps of Engineers Operations Center in Portland, Oregon.

Figure 4-10. Surface Water on the Hanford Site.



leaves the Hanford Site near the 300 Area. Vertical fluctuations of approximately 1.5 m (greater than 5 vertical ft) are not uncommon along the Hanford Reach (Dirkes 1993). The width of the river varies from approximately 300 m (1,000 ft) to 1,000 m (3,300 ft) within the Hanford Site.

Hanford Site Quick Facts: Surface Water

- Columbia River average annual flow: 3,400 m^3 (120,100 ft^3) per second
- Yakima River average annual flow: 104 m^3 (3,673 ft^3) per second

Several drains and intakes are present along the Hanford Reach. These include irrigation outfalls from the Columbia Basin Irrigation Project, Hanford Site intakes for the onsite water export system, and Energy Northwest (formerly known as WPPSS) water intakes.

The primary uses of the Columbia River include the production of hydroelectric power, irrigation of cropland in the Columbia Basin, and transportation of materials by barge. The Hanford Reach is the upstream limit of barge traffic on the main stem of the Columbia River. Barges are used to transport reactor vessels from decommissioned nuclear submarines to Hanford for disposal. Several communities located on the Columbia River rely on the river as their source of drinking water. The Columbia River is also used as a source of both drinking water and industrial water for several Hanford Site facilities (Dirkes 1993). In addition, the Columbia River is used extensively for recreation, which includes fishing, hunting, boating, sailboarding, waterskiing, diving, and swimming.

The Yakima River, bordering the southern portion of the Hanford Site, has a low annual flow compared to the Columbia River. The average flow, based on nearly 60 years of records, is about 104 m^3/s (3,712 ft^3/s), with an average monthly maximum of 490 m^3/s (17,500 ft^3/s) and minimum of 4.6 m^3/s (165 ft^3/s). Exceptionally high flows were observed during 1996 and 1997. The peak average daily flow rate during 1997 was nearly 1,300 m^3/s (45,900 ft^3/s). Approximately one-third of the Hanford Site is drained by the Yakima River system.

An alkaline spring at the east end of Umtanum Ridge was documented by The Nature Conservancy in *Biodiversity Inventory and Analysis of the Hanford Site* (TNC 1998). Several springs are also found on the slopes of the Rattlesnake Hills, along the western edge of the Hanford Site. Cold Creek and its tributary, Dry Creek, are ephemeral streams within the Yakima River drainage system that roughly parallel SR 240 through the Hanford Site. Both streams drain areas to the west of Hanford Site. Surface flow, when it occurs, infiltrates and disappears into the surface sediments in the western portion of the Hanford Site. Rattlesnake Springs, located on the western portion of the Hanford Site, forms a small surface stream that flows for approximately 3 km (1.9 mi) before disappearing into the ground.

There are no currently active ditches on the Hanford Site. The only active pond in Benton County's portion of the Hanford Site is West Lake. West Lake is located north of the 200 East Area and is a natural feature recharged from groundwater (PNNL 1996a). West Lake has not received direct effluent discharges from Hanford Site facilities; rather, its existence is caused by the intersection of the elevated water table with the land surface in the topographically low area south of Gable Mountain (and north of the 200 East Area). The artificially elevated water table occurs under much of the Hanford Site and reflects the artificial recharge from past Hanford Site operations. This elevated water table is dropping and so is the size of West Lake.

The seepage of groundwater into the Columbia River has been known to occur for many years. The riverbank seep discharges were documented along the Hanford Reach long before Hanford Site operations began during World War II (PNNL 1996a). These relatively small seeps flow intermittently, apparently influenced primarily by changes in river level. Hanford-origin contaminants have been documented in these groundwater discharges along the Hanford Reach (PNNL 1996a).

In the 200 West Area, the West Powerhouse Pond, 216-T-1 Ditch, 216-T-4-2 Ditch, and 216-Z-21 Basin are active. In the 200 East Area, only the East Powerhouse Ditch and the 216-B-3C Pond are active. The 216-B-3C Pond originally was excavated in the mid-1950s for disposal of process cooling water and other liquid wastes occasionally containing low levels of Radionuclides. The FFTF pond is located near the 400 Area and was excavated in 1978 for the disposal of cooling and sanitary water from various facilities in the 400 Area (PNNL 1996a). The ponds are not accessible to the public and do not constitute a direct offsite environmental impact (PNNL 1996a). However, the ponds are accessible to migratory waterfowl, creating a potential pathway for the dispersion of contaminants. Periodic sampling provides an independent check on effluent control and monitoring systems (PNNL 1996a).

Among the most interesting discoveries of the 1997 field season were three previously undocumented clusters of approximately 20 vernal pools. Vernal pools are associated more typically with arid areas in California and Oregon. Vernal pools in Washington are little known or studied; therefore, their occurrence on the Hanford Site is significant (TNC 1998). The Hanford Site pools were located on the eastern end of Umtanum Ridge, in the central part of Gable Butte, and at the eastern end of Gable Mountain. Each cluster of pools was situated on top of an impermeable basalt layer that enabled water to pond in shallow depressions during wetter winter seasons. The pools often were characterized by a distinct zonation of species from the bottom of the pool, which might be barren throughout the growing season, to the upper pool edge, which was occupied by various annual plant species. The vernal pools also showed wide variation in their degree of development (i.e., some appeared to be pools that filled intermittently and were invaded by sagebrush during extended dry periods). Most pools apparently filled with water most years.

Vernal pools on the Hanford Site showed wide variation in regard to a number of traits, including pool size, species composition, dominant species, degree of invasion by weedy (mostly non-native) species, and presence of rare plant species. Pools averaged about 60 by 60 ft (18 by 18 m) in size, but ranged from 20 by 20 ft (6 by 6 m) to 150 by 100 ft (46 by 30 m). Dominant species were typically annuals. Some vernal pools had a high cover of moss and lichen species. In addition to their botanical resources, there was ample evidence of avian and other wildlife use of these vernal pools as they often provided water during dry times of the year (TNC 1998).

The cluster of 10 to 11 vernal pools on the eastern end of Umtanum Ridge were of relatively high quality and appeared to be the most undisturbed (pristine) pools on the Site. Large and vigorous subpopulations of *Mimulus suksdorfii* (Suksdorf's Monkey-flower) were found in almost all of these pools. *Myosurus* x *clavicaulis* (Tiny mousetail) was located in one of the vernal pools. The pools were spread out over an area of about 1,000 by 3,000 ft (305 by 915 m). The lower, middle portion of Gable Butte supported a cluster of six or seven vernal pools. These pools supported healthy populations of several thousand *Mimulus suksdorfii* (Suksdorf's Monkey-flower) and *Loeflingia squarrosa* var. *squarrosa* (Sagebrush loeflingia) plants. The area was far from current development; however, an old road did cross through the largest vernal pool. The cluster of three pools on the eastern end of Gable Mountain was the least pristine of the three sets of vernal pools. These weedy, intermittently filled pools supported a population of several hundred *Mimulus suksdorfii* (Suksdorf's Monkey-flower) plants. The aggressive weed *Centaurea solstitialis* (Yellow Starthistle) posed a serious threat to the native plants at these pools (TNC 1998). Because these vernal pools are systems of significant quality, good management practices would include careful monitoring for invasive species. Immediate management action would be needed to stop invasive plants, if detected.

An alkaline spring and marshy area was found in a large shallow basin at the east end of Umtanum Ridge. This previously unknown spring did not appear to have been significantly damaged by past grazing. It is perhaps the only spring of its kind on the Hanford Site. This spring supports a population of *Castilleja exilis* (Foothill Indian Paintbrush) and other alkalitolerant plant species. There also were a number of weedy species present that could threaten the persistence of native plant species at the spring. The alkaline spring, as well as the vernal pool clusters, are considered to be special habitat areas (TNC 1998).

West Lake and its adjacent wetlands also were surveyed during the 1997 field season. A highly alkaline lake, West Lake results from an artificially elevated rise in the water table due to historic waste management practices on Hanford's central plateau (Cushing 1994). There also was evidence of significant groundwater changes in the area, probably due to recent changes in waste management activities that have reduced groundwater discharges on the central plateau. Native plant communities at West Lake appeared to be substantially degraded (TNC 1998). A historic siting of *Castilleja exilis* and many other species for the Hanford Site that had been documented at West Lake in the past (Sackschewsky et al. 1992) were not located during the 1997 survey. Much of the lake basin was invested with weedy species, primarily Bassia hyssopifolia (smotherweed).

Other than rivers and springs, there are no naturally occurring bodies of surface water adjacent to the Hanford Site. However, there are artificial wetlands (caused by irrigation) exist on the east and west sides of the Wahluke Slope portion of the Hanford Site, which lies north of the Columbia River. Hatcheries and canals associated with the Columbia Basin Irrigation Project constitute the only other artificial surface water expressions in the area. The Ringold Hatchery, located just south of the Hanford Site boundary on the east side of the Columbia River (northeast of the 300 Area), is the only local fish hatchery. In addition to the public hatchery, the Yakama Nation raised several species of fish in settling pools in the 100-K Area as part of an experimental program.

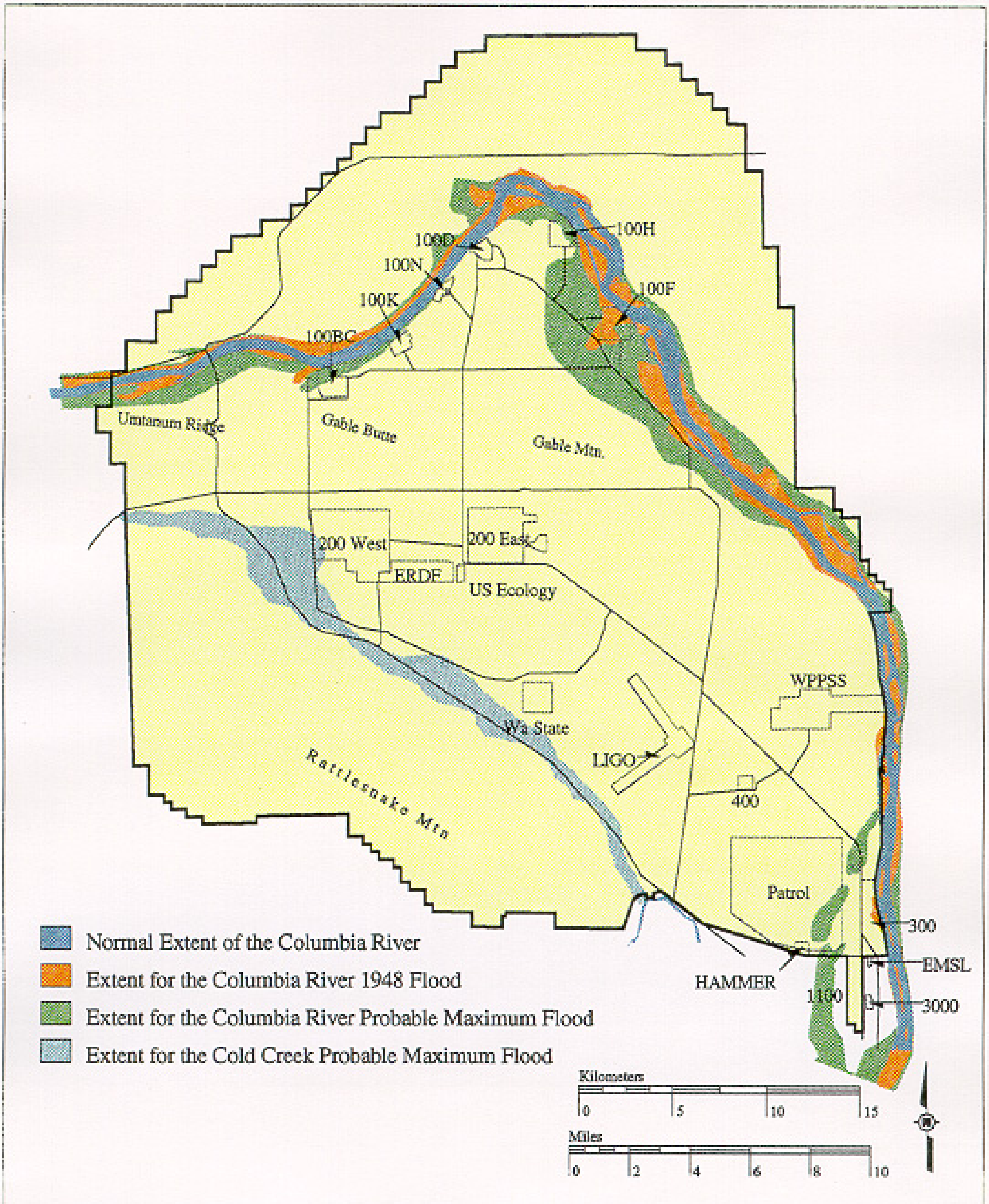
Total estimated precipitation over the Pasco Basin is about 9×10^{8} m^3 (3.2×10^{10} ft^3) annually, averaging less than 20 cm/yr (approximately 8 in./yr). Mean annual runoff from the Pasco Basin is estimated at less than 3.1×10^{7} m^3/yr (1.1 x 10 ft^3/yr), or approximately 3 percent of the total precipitation. The basin-wide runoff coefficient is zero for all practical purposes. The remaining precipitation is assumed to be lost through evapotranspiration, with less than 1 percent recharging the groundwater system. Precipitation contributes recharge to the groundwater in areas where soils are coarse-textured and bare of vegetation (PNNL 1996a).

4.3.1.1 Flooding. Large Columbia River floods have occurred in the past, but the likelihood of recurrence of large-scale flooding has been reduced by the construction of several flood control and water storage dams upstream of the Hanford Site. Major floods on the Columbia River typically result from rapid melting of the winter snowpack over a wide area, augmented by above-normal precipitation. The maximum historical flood on record occurred June 7, 1894, with a peak discharge at the Hanford Site of 21,000 m^3/s (742,000 ft^3/s). The largest recent flood took place in 1948, with an observed peak discharge of 20,000 m^3/s (706,280 ft^3/s) at the Hanford Site (PNNL 1996a). The exceptionally high runoff during the spring of 1996 resulted in a maximum discharge of nearly 11,750 m^3/s (415,000 ft^3/s) (DART 1998). The floodplain associated with the 1948 flood is shown in Figure 4-11 (see text box, *"Hanford Site Quick Facts: Columbia River Floods"*).

Hanford Site Quick Facts: Columbia River Floods

- Largest flood on record: 1894 at 21,000 m^3/s
- Largest recent flood: 1948 at 20,000 m^3/s
- Probable maximum flood: 40,000 m^3/s

Figure 4-11. Probable Maximum Flood of the Columbia River and Cold Creek, and the Actual 1948 Flood of the Columbia River (adapted from PNNL 1996a).



The Federal Emergency Management Agency has not prepared floodplain maps for the Hanford Reach because they only prepare maps for areas that are being developed (a criterion that specifically excludes the Hanford Reach).

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 (e.g., antecedent moisture conditions, snowmelt, and tributary conditions) that could result in maximum runoff. The probable maximum flood for the Columbia River below the Priest Rapids Dam has been calculated at 40,000 m^3/s (1.4 million ft^3/s) (see Figure 4-11) and is greater than the 500-year flood. This flood would inundate some portions of the 100 Area that are located adjacent to the Columbia River; but the central portion of the Hanford Site would remain unaffected (PNNL 1996a). Floodplain issues are further discussed in Appendix C.

The USACE has derived the Standard Project Flood with both dam-regulated and unregulated peak discharges given for the Columbia River below Priest Rapids Dam (PNNL 1996a). The regulated Standard Project Flood for this portion of the river is given as 15,200 m^3/s (540,000 ft^3/s), and the 100-year regulated flood as 12,400 m^3/s (440,000 ft^3/s).

Potential dam failures on the Columbia River have been evaluated (PNNL 1996a). Upstream failures could arise from a number of causes, with the magnitude of the resulting flood depending on the degree of breaching at the dam. The USACE evaluated a number of scenarios for failure of the Grand Coulee Dam, assuming flow conditions of 11,000 m^3/s (400,000 ft^3/s). For purposes of emergency planning, they hypothesized that 25 and 50 percent breaches (the instantaneous disappearance of 25 or 50 percent of the center section of the dam) would result from the detonation of nuclear explosives in sabotage or war. The discharge or floodwave from such an instantaneous 50 percent breach at the outfall of the Grand Coulee Dam was determined to be 600,000 m^3/s (21 million ft^3/s). In addition to the areas inundated by the probable maximum flood, the remainder of the 100 Areas, the 300 Area, and nearly all of Richland, Washington, would be flooded (PNNL 1996).

Determinations were not made for (1) failures of dams upstream, (2) associated failures downstream of Grand Coulee, or (3) breaches greater than 50 percent of Grand Coulee, because the 50 percent scenario was believed to represent the largest realistically conceivable flow that could result from a natural or human-induced breach; that is, it was not considered credible that a structure as large as the Grand Coulee Dam would be 100 percent destroyed instantaneously. The analysis also assumed that the 50 percent breach would occur only as the result of direct explosive detonation, not because of a natural event (i.e., an earthquake), and that even a 50 percent breach under these conditions would indicate an emergency situation in which other overriding major concerns might be present.

The possibility of a landslide resulting in river blockage and flooding along the Columbia River also has been examined for an area bordering the east side of the river upstream from the City of Richland (PNNL 1996a). The possible landslide area considered was the 75-m (250-ft)-high bluff (generally known as White Bluffs). Calculations were made for an 8×10^5 m^3 (1×10^6 yd^3) landslide volume with a concurrent flood flow of 17,000 m^3/s (600,000 ft^3/s) (a 200-year flood) that results in a flood wave crest elevation of 122 m (400 ft) above mean sea level. Areas inundated upstream from such a landslide event would be similar to a 50 percent breach of the Grand Coulee Dam. A flood-risk analysis of Cold Creek was conducted in 1980 as part of the characterization of a geologic repository for high-level radioactive waste. This design work evaluated the probable maximum flood rather than the worst-case and/or 100-year flood scenarios. Therefore, in lieu of 100- and 500-year floodplain studies, a probable maximum flood evaluation was made for a reference repository located directly west of the 200 East Area that encompasses the 200 West Area (PNNL 1996a). Figure 4-11 identifies the extent of this probable maximum flood.

4.3.1.2 Surface Water Quality. The Washington State Department of Ecology (Ecology) classifies the Columbia River, from Grand Coulee to the Washington-Oregon border, which includes the Hanford Reach, as Class A (excellent) (PNNL 1996a). Class A waters are suitable for essentially all uses, including raw drinking water, recreation, and wildlife habitat. Federal and state drinking water standards, as well as DOE Order 5400.5 (DOE 1993a), apply to the Columbia River and are currently being met.

Pacific Northwest National Laboratory (PNNL) conducts routine monitoring (for both radiological and nonradiological water quality parameters) of the Columbia River. A yearly summary of these monitoring results has been published since 1973 (PNNL 1996b). Numerous water quality studies have been conducted on the Columbia River during the past 37 years. Three outfalls, located in the 100-K, 100-N, and 300 Areas of the Hanford Site, are covered by a National Pollutant Discharge Elimination System Permit (Permit No. WA-000374-3). These discharge locations are monitored for various measures of water quality, including nonradioactive and radioactive pollutants. The estimated dose from radionuclide releases is presented in environmental reports such as the *Hanford Site Environmental Report for Calendar Year 1996* (PNNL 1997a). In 1994, monitored liquid discharges resulted in a dose of 0.016 mrem to the downstream maximally exposed individual (PNL 1995).

Radiological monitoring of the Columbia River continues to show low levels of radionuclides. Although radionuclides associated with Hanford Site operations continued to be identified in Columbia River water in 1994, concentrations remained well below applicable standards at all monitored locations (PNL 1995). In 1995, tritium, iodine-129, and uranium concentrations downstream of the Hanford Site were found to be slightly higher than upstream concentrations, but these concentrations were well below guidelines established by DOE through DOE Order 5400.5 (DOE 1993a) and the U.S. Environmental Protection Agency (EPA) drinking water standards (Table 4-2). In 1995, the average annual strontium-90 and technetium-99 concentrations were essentially the same at Priest Rapids Dam (upstream of the Hanford Site) and at the Richland pump house (PNNL 1996b).

Total alpha and beta measurements are useful indicators of the general radiological quality of the river that provide an early indication of changes in radioactive contamination levels because results are obtained quickly. Total alpha and beta measurements for 1996 were similar to the previous year, and were approximately 5 percent or less of the applicable drinking water standards of 15 and 50 pCi/L, respectively. Tritium measured at the Richland pump house was significantly higher than at Vernita Bridge, but continued to be well beyond the state and Federal drinking water standards (Dirkes 1997). The presence of a ^{3}H concentration gradient at the Richland pump house supports previous conclusions made by Backman (1962) and Dirkes (1993) that contaminants in the 200 Area groundwater plume entering the Columbia River at and upstream of the 300 Area are not completely mixed by the time the river reaches the Richland pump house.

Table 4-2. Annual (1995) Average Concentrations of Radionuclides in the Columbia River (adapted from PNNL 1996b).

Radionuclides	Water Concentrations (pCi/L)			Downstream Concentration as Percentage of Drinking Water Standard
	Upstream Concentration (Priest Rapids Dam)	Downstream Concentration (Richland Pump House)	EPA Drinking Water Standard	
H-3	34	79	20,000	0.40
Sr-90	0.08	0.09	8.0	1.1
U	0.40	0.50	20.0 (ug/L)[a]	2.5
Tc-99	ND	0.06	900	--
I-129	3.6×10^{-6}	5.7×10^{-5}	0.48	0.01

[a] Proposed
ND = Not *Detected*.

For nonradiological water quality parameters measured in Columbia River water during 1995, concentrations of metals and anions were similar upstream and downstream and were found to be in compliance with applicable primary drinking water standards. Concentrations of volatile organic compounds (VOCs) also were below regulatory standards (PNNL 1996b).

4.3.2 Groundwater

The following sections describe the groundwater resources at the Hanford Site. Groundwater under the Hanford Site occurs under unconfined and confined conditions. The uppermost aquifer beneath most of the Hanford Site is unconfined and is composed of unconsolidated to semi-consolidated sediments deposited on the basalt bedrock. In some areas, deeper parts of the aquifer are locally confined by layers of silt and clay. Groundwater in the unconfined aquifer systems generally moves from recharge areas along the western boundary of the Hanford Site to the east and north toward the Columbia River, which is the major discharge area. This natural flow pattern was altered by the formation of groundwater mounds created by the discharge of large volumes of wastewater at disposal facilities. These mounds are declining, however, and groundwater flow is gradually returning to earlier patterns.

The confined aquifers consist of sedimentary interbeds and/or interflow zones that occur between dense basalt flows in the Columbia River Basalt group. The main water-bearing portions of the interflow zones occur within a network of interconnecting vesicles and fractures of the basalt flow tops or flow bottoms. Figure 4-6 presents a generalized subsurface cross-section of the Hanford Site.

4.3.2.1 Groundwater Hydrology. The multi-aquifer system within the Pasco Basin has been conceptualized as consisting of four geohydrologic units: (1) Grande Ronde Basalt, (2) Wanapum Basalt, (3) Saddle Mountain Basalt, and (4) Hanford and Ringold formation sediments lying above the basalt units (see Figure 4-5). Geohydrologic units older than the Grande Ronde Basalt probably are of minor importance to the regional hydrologic dynamics and system. Together, the Grande Ronde, Wanapum, Saddle Mountains, and Imnaha Basalts compose the Columbia River Basalt group.

The Grande Ronde Basalt is the most voluminous and widely spread formation within the Columbia River Basalt group and has a thickness of at least 2,745 m (9,000 ft). The Grande Ronde Basalt is composed of the basalt flows and minor intercalated sediments that are equivalent to or part of the Ellensburg Formation (DOE 1988a). More than 50 flows of Grande Ronde Basalt underlie the Pasco Basin, but little is known of the lower 2,200 to 2,500 m (7,216 to 8,200 ft). Groundwater in these basalts is confined to semi-confined and is recharged along the margins of the Columbia Plateau where the basalt is at, or close to, the land surface and by surface-water and groundwater inflow from lands adjoining the plateau. Vertical movement into and out of this system is known to occur. Groundwater within the Grande Ronde Basalt in the eastern Pasco Basin is believed to originate from groundwater inflow from the east and the northeast.

The Wanapum Basalt consists of basalt flows intercalated with minor and discontinuous sedimentary interbeds of the Ellensburg Formation or equivalent sediments. In the Pasco Basin, the Wanapum Basalt consists of three members, each consisting of multiple flows. The Wanapum Basalt underlies the entire Pasco Basin and has a maximum thickness of 370 m (1,215 ft). Groundwater within the Wanapum Basalt is confined to semi-confined.

The Saddle Mountain Basalt is composed of the youngest formation of the Columbia River Basalt group and several thick sedimentary beds of the Ellensburg Formation or equivalent sediments, which comprise up to 25 percent of the unit. Within the Pasco Basin, the Saddle Mountain Basalt contains seven members, each with one or more flows. This Saddle Mountain Basalt underlies most of the Pasco Basin, attaining a thickness of about 290 m (950 ft), but is absent along the northwest part of the basin and along some anticlinal ridges. Groundwater in the Saddle Mountain Basalt is confined to semi-confined, with recharge and discharge believed to be local (PNL 1991a).

The rock materials that overlie the basalts in the structural and topographic basins within the Columbia Plateau generally consist of Miocene-Pliocene sediments, volcanics, Pleistocene sediments (including those from catastrophic flooding), and Holocene sediments consisting mainly of alluvium and eolian deposits. The suprabasalt sediment (referred to as the Hanford/Ringold unit) consists principally of the Miocene-Pliocene Ringold Formation stream, lake, and alluvial materials, and the Pleistocene catastrophic flood deposits informally called the Hanford formation. Groundwater within the suprabasalt sediment is unconfined, with recharge and discharge usually coincident with topographic highs and lows (PNL 1991a). The Hanford/Ringold unit is restricted to the Pasco Basin; principal recharge occurs (along the periphery of the basin) from precipitation and ephemeral streams.

4.3.2.2 Groundwater Recharge. Little, if any, natural recharge occurs within the Hanford Site, but artificial recharge occurs from liquid waste disposal activities (PNNL 1996b) (Figure 4-12). Recharge from irrigation occurs east and north of the Columbia River and in the synclinal valleys west of the Hanford Site. Within the Pasco Basin, recharge occurs along the anticlinal ridges to the north and west and from groundwater inflow from the east and northeast. Sources of natural recharge to the unconfined aquifer are rainfall and runoff from the higher bordering elevations, water infiltrating from small ephemeral streams, and river water along influent reaches of the Yakima and Columbia rivers. To define the movement of water in the unsaturated (vadose) zone, the movement of precipitation through the vadose zone has been studied at several locations on the Hanford Site. Conclusions from these studies vary depending on the location studied.

From the recharge areas to the west, groundwater flows downgradient to the discharge areas, primarily along the Columbia River (Figure 4-13a and 4-13b). This general west-to-east flow pattern is interrupted locally by the groundwater mounds in the 200 East and 200 West Areas. From the 200 East and 200 West Areas, a component of groundwater also flows to the north, between Gable Mountain and Gable Butte. These flow directions represent current conditions; the aquifer is dynamic, and responds to changes in natural and artificial recharge (see Figures 4-14 and 4-15, respectively).

Figure 4-12. Estimated Recharge from Infiltration of Precipitation and Irrigation on the Hanford Site.

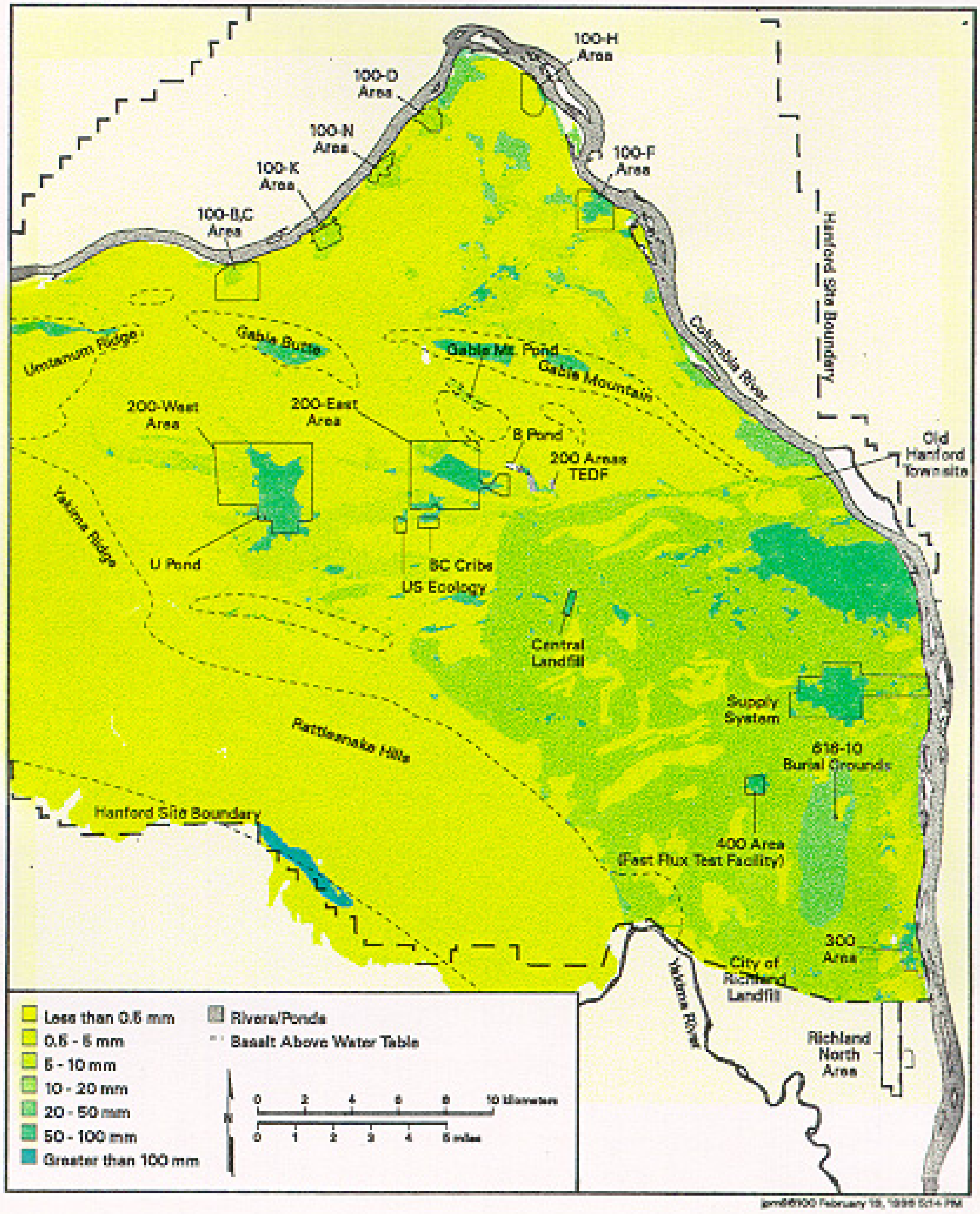


Figure 4-13a. Hanford Site and Outlying Areas Water Table Map -- June 1998 (PNNL 1998).

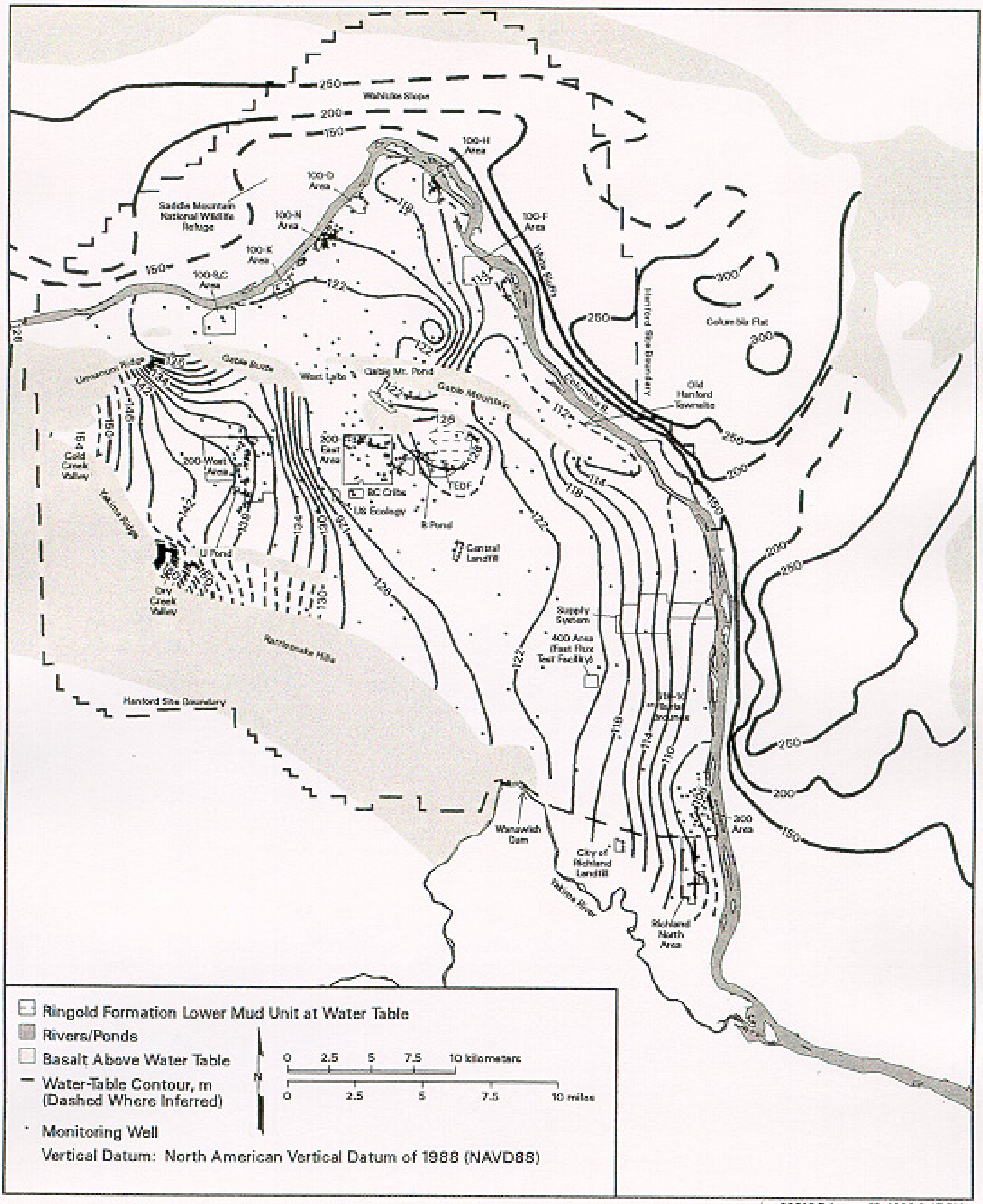


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Figure 4-13b. Potentiometric Map of Upper Basalt-Confined Aquifer System -- June 1998 (PNNL 1998).

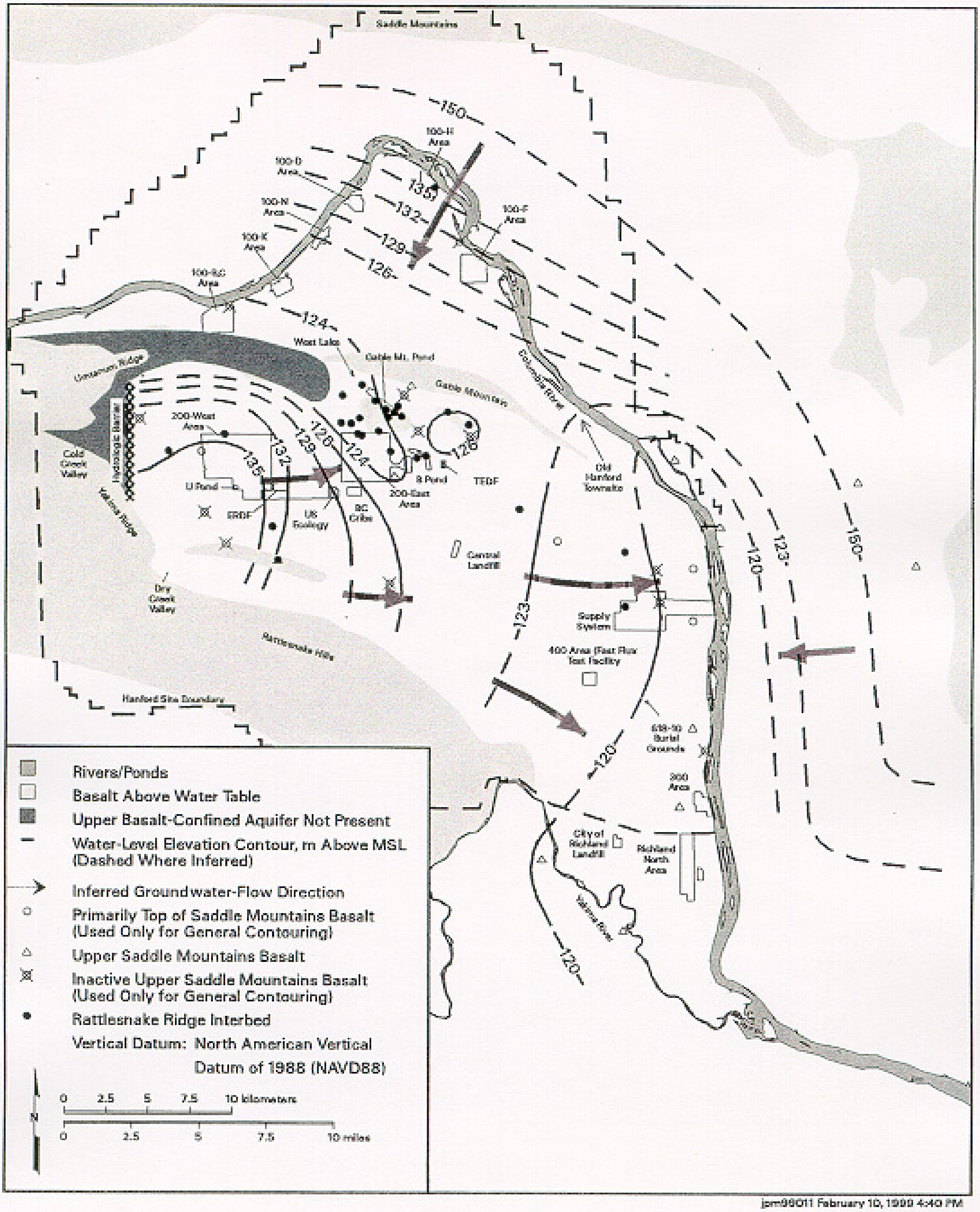


Figure 4-14. Water Table Change Map for 1944 - 1979.

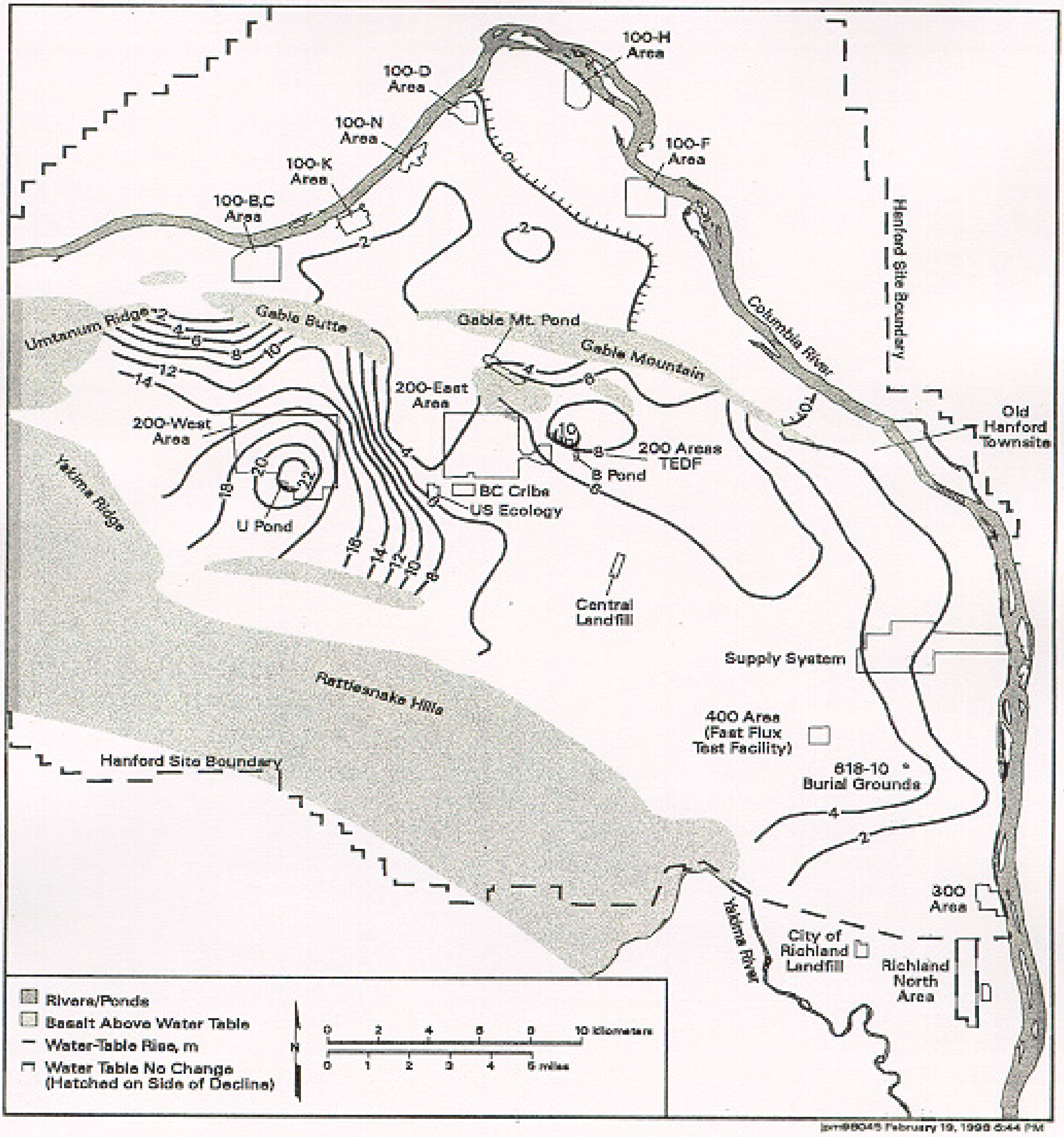
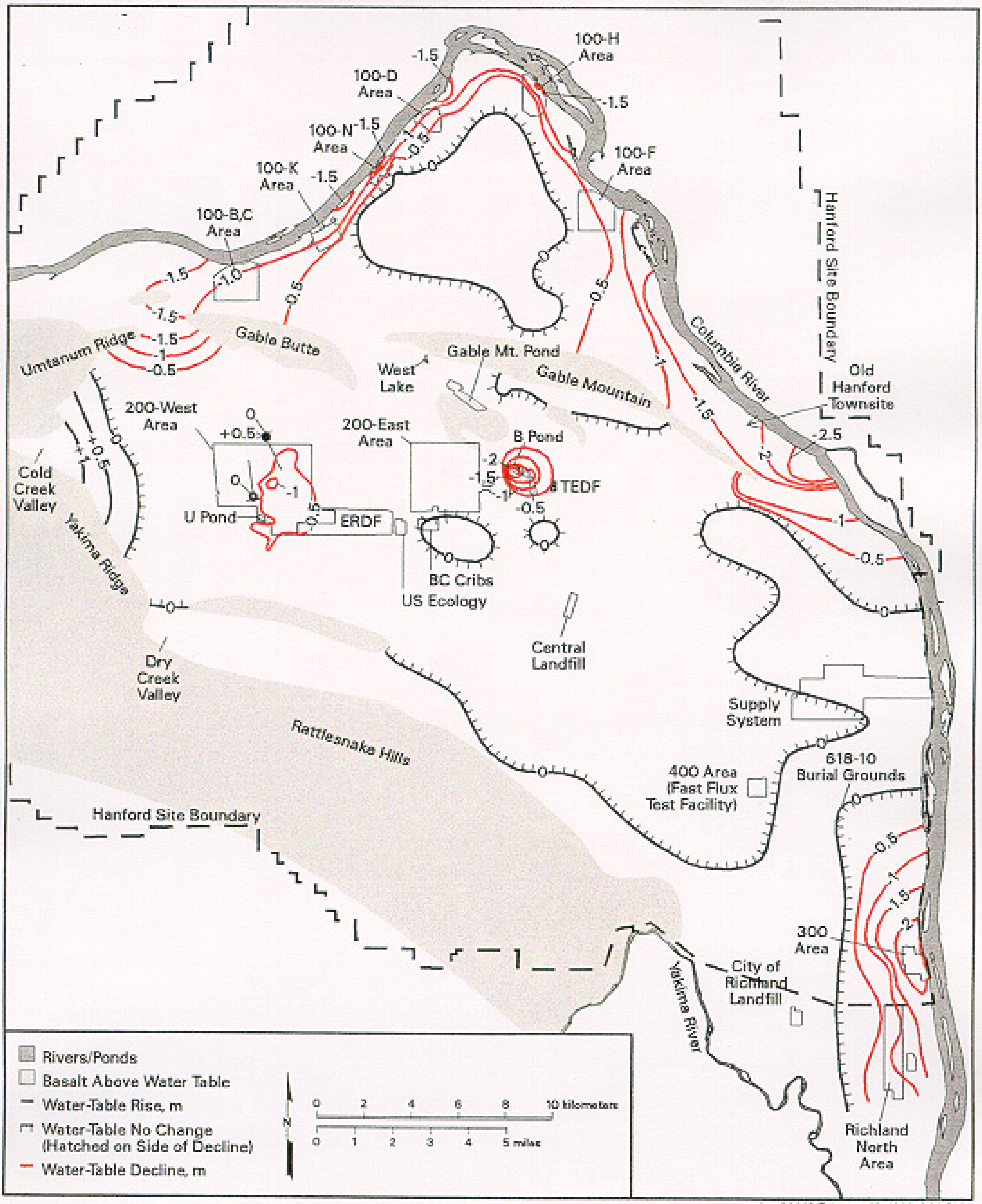


Figure 4-15. Water Table Change Map for 1997 - 1998.



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Studies indicate that local recharge to the shallow basalts results from infiltration of precipitation and runoff along the margins of the Pasco Basin. Regional recharge of the deep basalts is thought to result from interbasin groundwater movement that originates northeast and northwest of the Pasco Basin in areas where the Wanapum and Grande Ronde Basalt outcrops are extensive (Neitzel 1997). Groundwater is discharged from the shallow basalt to the overlying unconfined aquifer and the Columbia River. In some cases, well bores may have allowed water movement between the unconfined aquifer and the confined aquifer.

The major recharge sources of the Hanford and Ringold formations are as follows: inflow from Dry Creek, which average 0.035 cm/s; inflow from Cold Creek, which averages 0.028 cm/s; and inflow around Rattlesnake Hills, which averages 0.032 cm/s.

4.3.2.3 Groundwater Quality. The quality of the groundwater at the Hanford Site has been affected by many of the activities related to the production of nuclear materials. Due to the arid climate, natural recharge of the groundwater on the Hanford Site is low. Artificial recharge has occurred in the past from the disposal of liquid waste associated with processing operations in the 100, 200, and 300 Areas, which created mounds of water underlying discharge points. Large areas underlying the Hanford Site have elevated levels of both radiological and nonradiological constituents. The liquid effluents discharged into the ground have carried with them a variety of radionuclides and chemicals that move through the soil column at differing rates, eventually entering the groundwater and forming plumes of contamination (see text box, *"Hanford Site Quick Facts: Principal Groundwater Contaminants"*).

Hanford Site Quick Facts: Principal Groundwater Contaminants

- chromium
- nitrate
- trichloroethylene
- fluoride
- carbon tetrachloride
- cyanide
- tetrachloroethylene
- chloroform
- cis-1, 2-dichloroethylene
- cobalt-60
- strontium-90
- tritium
- uranium
- cesium-137
- carbon-14
- iodine-129
- plutonium
- technetium-99

4.3.2.3.1 Unconfined Aquifer. As part of the continuing environmental monitoring program at the Hanford Site, groundwater monitoring reports are published in the *Hanford Site Environmental Report* (PNNL 1996b), and in the *Hanford Site Groundwater Monitoring Report* (PNNL 1998), which are issued each calendar year. The shallow, unconfined aquifer in the Pasco Basin and on the Hanford Site contains waters of a dilute (less than or approximately 350 mg/L total dissolved solids) calcium bicarbonate chemical type. Other principal constituents include sulfate, silica, magnesium, and nitrate. Variability in chemical composition exists within the unconfined aquifer because of natural variation in the composition of the geologic strata, and irrigation and other agricultural practices north, east, and west of the Hanford Site, and on the Hanford Site, because of liquid waste disposal.

The uppermost aquifer beneath most of the Hanford Site is unconfined and is composed of unconsolidated to semi-consolidated sediments deposited on the basalt bedrock. In some areas, deeper parts of the aquifer are locally confined by layers of silt and clay. Confined aquifers occur within the underlying basalt flows and associated sedimentary interbeds. Groundwater in the unconfined aquifer system generally moves from recharge areas along the western boundary of the Site to the east and north toward the Columbia River, which is the major discharge area. This natural flow pattern was altered by the formation of groundwater mounds created by the discharge of large volumes of wastewater at disposal facilities. These mounds are declining, and groundwater flow is gradually returning to earlier patterns.

Water levels are monitored across the Hanford Site and to the east and north of the Columbia River. The purpose of these measurements is to monitor changes in the water table elevations that affect the direction and velocity of groundwater flow and transport of contaminants, and to assess impacts of the changes on monitoring networks. A Site water table map for June

1998 was constructed and used to infer groundwater-flow directions (see Figure 4-13). Water levels over most of the Site declined during fiscal year 1998, continuing the trend caused by reduction in liquid effluent disposal. Water levels are also measured in wells completed in the upper basalt-confined aquifer. Several areas showed declines in the confined-aquifer potentiometric surface associated with declines in the water table of the overlying unconfined aquifer (PNNL 1998).

Radioactive and nonradioactive liquid effluents were discharged to the environment from facilities in the 100 and 300 Areas, as well as facilities in the Central Plateau (PNNL 1996b). Contamination of the groundwater exceeds drinking water standards in more than 220 km^2 (85 mi^2) of the Hanford Site. The U.S. Department of Energy, Richland Operations Office (RL) has committed to implement the best available technology and all known and reasonable methods of prevention, control, and treatment for several of the effluent streams, and to obtain permits for the waste streams under the “State Waste Water Discharge Permit Program,” *Washington Administrative Code* (WAC) 173-216. The goal associated with the use of best available technology is to eliminate, minimize, or treat effluents discharged to the ground.

4.3.2.3.2 Confined Aquifer. The uppermost confined aquifer (Rattlesnake Ridge) was sampled to determine what extent of groundwater contamination occurred from interaction between the confined and unconfined aquifers. Groundwater samples from selected confined aquifer wells were analyzed for a variety of radionuclides and hazardous chemicals. In most cases, no indication of contamination was observed. Detection of radionuclides in well 299-E33-12 (the Central Plateau) was attributed to contamination by high-salt waste that migrated by density flow into the borehole when it was open to both the unconfined and the confined aquifer during drilling (PNNL 1996b). The 1995 samples from well 299-E33-12 contained up to 458 pCi/L of tritium, similar to levels detected since 1982. The 1995 samples from this well also contained cobalt-60 at levels up to 31.4 pCi/L, nitrate at levels up to 11 mg/L, technetium-99 at levels up to 1,560 pCi/L, and cyanide at levels up to 20.7 µg/L. Although all of these constituents are indicators of contamination, only nitrate and technetium-99 were detected at levels greater than drinking water standards.

The upper basalt-confined aquifer system is defined as the groundwater occurring within basalt fractures and joints, interflow contacts, and intercalated sedimentary interbeds within the upper Saddle Mountains Basalt. The thickest and most widespread sedimentary unit is the Rattlesnake Ridge Interbed. Groundwater is confined by the dense, low-permeability, interior portions of basalt flows and by Ringold Formation silt and clay units overlying the basalts.

In 1993, hydraulic head distribution and flow dynamics of the upper basalt-confined aquifer system were evaluated and reported in PNL-8869, which identified the following prominent hydrologic features:

- A broad recharge mound extending northeastward from Yakima Ridge in the 200 West Area

- A small recharge mound (now subsiding) immediately east of the 200 East Area in the vicinity of B Pond

- A subsurface hydrogeologic barrier (i.e., an impediment to groundwater flow), believed to be related to faulting, near the mouth of Cold Creek Valley

- A region of low hydraulic head (potential discharge) in the Umtanum Ridge-Gable Mountain structural area

- A region of high hydraulic head to the north and east of the Columbia River associated with recharge attributed to agricultural activities.

Recharge to the upper basalt-confined aquifer system is believed to result from precipitation and surface water infiltration where the basalt and interbeds are exposed at ground surface. Recharge also may occur through the unconfined aquifer system where a downward hydraulic gradient exists between the unconfined and upper basalt-confined aquifers. Hydraulic communication with overlying and underlying aquifers is believed to cause the region of low hydraulic head found in the Umtanum Ridge-Gable Mountain structural area (these relationships are given in more detail in PNL-8869). Maps of the upper basalt-confined and unconfined aquifer potentiometric surfaces indicate that a downward hydraulic gradient from the unconfined aquifer to the upper basalt-confined aquifer occurs in the western portion of the Hanford Site, in the vicinity of the B Pond recharge mound, as well as in the regions north and east of the Columbia River (see PNL-6313, PNL-8869, PNL-10082, PNNL-11470, PNNL-12067, WHC-EP-0142-3, WHC-EP-0142-4, and WHC-EP-0394-3). In the vicinity of B Pond, however, a recent acceleration in head decline within the unconfined aquifer system may soon lead to a reversal in the vertical hydraulic gradient between the unconfined and upper basalt-confined aquifer systems in this region. In other areas of the Hanford Site, the hydraulic gradient is upward from the upper basalt-confined aquifer to the unconfined aquifer system.

Figure 4-13b, constructed by manual contouring, presents a regional approximation of the potentiometric surface for the upper basalt-confined aquifer system based on water-level measurements taken during June 1998. Measurements in the Rattlesnake Ridge Interbed were primarily used to construct this map, though additional measurements in the upper Saddle Mountains Basalt were used for general contouring. The datum used was NAVD88, which is approximately 1 m higher than the NGVD29 datum used in previous versions of this map (e.g., PNL-8869, PNL-10817, and PNNL-11793).

With some exceptions, the major potentiometric map features shown in Figure 4-13b are nearly the same as those exhibited for 1996, as reported in Section 5.5 of PNNL-11470 and Section 3.10 of PNNL-11793. The potentiometric map indicates that, south of the Umtanum Ridge-Gable Mountain structural area, groundwater flows from west to east across the Site toward the Columbia River, which represents the regional discharge area for groundwater-flow systems. In the region northeast of Gable Mountain, the potentiometric contours suggest that groundwater flows southwest and discharges primarily to underlying confined aquifer systems in the Umtanum Ridge-Gable Mountain structural area (PNL-8869). This increased hydraulic head region is associated with recharge from agricultural activities north and east of the Columbia River and has been observed for deeper, confined aquifer systems. Therefore, the Columbia River does not represent a major discharge area for upper basalt-confined groundwater in the northern portion of the Hanford Site.

Water levels in almost all wells monitoring the upper basalt-confined aquifer system declined from June 1997 to June 1998. The greatest declines occurred near the B Pond (well 699-42-40C) and in the eastern portion of the site (wells 699-26-15C and 699-42-E9B). However, water levels in well 699-42-E9B are known to be affected by stage fluctuations in the Columbia River. The river stage was higher than normal during 1996 and 1997 but returned to normal during 1998, thus accounting for the water-level decline in well 699-42-E9B. For this reason, short-term water-level fluctuations in this well and in other wells near the river (i.e., wells 199-H4-2 and 399-5-2) mask long-term trends in the upper basalt-confined aquifer system. Water levels in confined aquifer wells near the northern boundary of the 200 East Area and immediately east of the 200 East Area near B Pond continue to show a decline, falling in the range of approximately 0.1 to 0.7 m from June 1997 to June 1998. Water levels in confined aquifer wells near the 200 West Area also continue to show a decline of approximately 0.1 to 0.4 m/yr. Water levels in wells located between Gable Mountain and the northern boundary of the

200 East Area fell approximately 0.1 to 0.3 m from June 1997 to June 1998. These declines are a response to curtailed effluent-disposal activities in the 200 Areas and are consistent with water-level declines in the overlying unconfined aquifer system.

4.3.2.4 Vadose Zone. The vadose zone is the area between the land surface and the top of the groundwater table. The vadose zone represents the pathway for contaminants to the groundwater for surface and near-surface releases, leaks, and spills of contaminated liquids. The length of time it takes contaminated material to travel through the vadose zone depends on a number of factors including: (1) the depth to the groundwater, (2) characteristics of vadose zone sediment, and (3) chemical interaction of the contaminated material with the soil and subsoil.

Historically, radioactive contamination was released into the vadose zone sediment (the unsaturated sediment between the ground surface and the top of the unconfined groundwater aquifer) at Hanford from several hundred effluent discharge sites (e.g., cribs and ditches) and from leaks and spills from single-shell radioactive waste tanks. These releases, leaks, and spills represent the largest quantity of radioactive contamination released to the environment from Hanford operations (Dirkes and Hanf 1997).

Soil vapor extraction continued in the 200-ZP-2 Operable Unit as a CERCLA expedited response action to remove the carbon tetrachloride source from the vadose zone. The mix of extraction wells was changed periodically during fiscal year 1998 to improve performance based on a 1997 rebound study. In fiscal year 1998, 777 kg (1,717 lbs.) of carbon tetrachloride were removed, resulting in a total of 75,490 kg (166,455 lbs) since remediation began in 1992 (PNNL1998).

In 1998, results from 1997 spectral gamma logging of boreholes surrounding the B-BX-BY single-shell tank farm in the 200 East Area became available. The logging was to detect changes in the distribution of man-made radionuclides in the sediments associated with liquid waste disposal facilities adjacent to the tank farm. Spectral gamma logging also was performed at boreholes around the Plutonium Finishing Plant liquid disposal facilities to ascertain any changes in subsurface radionuclide distribution since last logging. Also, baseline characterization logging of all drywells in the BX, C, S, and TY tank farms was completed and the results reported in 1998. In addition, 10 new groundwater-monitoring wells were installed and logged by spectral gamma-ray methods. Historical gross gamma logs from boreholes near the SX, BX, BY, and TY tank farms were analyzed to locate mobile radionuclides.

Directional well drilling was tested at two sites. The holes were completed, but boulder gravels at one site presented difficulties in drilling and sampling. Control of drilling fluids also presented an obstacle that must be overcome before using this technique to address vadose zone contamination.

Sediment samples from new vadose-zone or groundwater wells were collected and analyzed for contaminants and physical properties. A vadose-zone borehole near the SX tank farm was extended to groundwater and sediments were analyzed for radionuclides. Cesium-137 contamination decreased with depth and was undetectable at the water table (PNNL 1998).

4.3.2.4.1 Surface Disposal. Radioactive and hazardous waste disposed to the soil column have been the dominant contributor to groundwater contamination at Hanford. Even though disposal of untreated waste water stopped in 1995, movement of contaminant in the soil column beneath historical effluent disposal sites still occurs. Large volumes (1,600 billion L [426 billion gal]) of low-level liquid waste were discharged to surface ponds and ditches. In addition 53 billion L (14 billion gal) of low- and intermediate-level liquid waste were discharged to the subsurface in reverse wells, french drains, cribs, and tile fields (PNNL 1997b).

Early in the Hanford Site's production history, when the bismuth phosphate process was used, the radioactive supernatant from the tanks was discharged directly to soil-column disposal sites. As a result, over 450 million L (120 million gal) of high-level radioactive liquid wastes were discharged to the vadose zone via cribs, trenches, and french drains. Although this disposal practice was terminated over 30 years ago, the residual liquid held in the soil-pore spaces can continue to be a long-term source of groundwater contamination, especially if a source of moisture is available to transport the mobile waste constituents. Some of these sources of moisture include enhanced infiltration from the coarse gravel covering, removal of vegetation, and leaking water lines (Dirkes and Hanf 1998).

4.3.2.4.2 Tank Farms. Contamination was released to the near-surface and subsurface sediment at Hanford Site tank farms as the result of tank leaks, spills, or radioactive effluents on the ground surface, as well as pipe leaks and airborne releases of particulate matter through tank ventilation and access ports. Of the 149 single-shell, and 28 double-shell tanks, 67 single-shell tanks are known or assumed to leak. The estimated volume to date of radioactive waste leakage from single-shell tanks is 2.3 million to 3.5 million L (600,000 to 900,000 gal). A Los Alamos study in 1998 used historical information and new leak models to better define the volume, chemical composition, and radioactive components of leaks from tanks SX-108, SX-109, SX-111, and SX-112. The study estimated that past leaks from the four single-shell tanks likely total between 757,000 and 1,514,00 L (200,000 and 400,000 gal)– about six times more that previous estimates. has recently been reassessed. Airborne releases and surface spills created contaminated plumes in the vadose zone that are generally confined to the near-surface regime, but in some cases surface contamination is known to have migrated deeper into the vadose zone. Pipeline leaks have also occurred either near the ground surface or at a maximum depth of 6 m (20 ft). In some cases, contamination from pipeline leaks has also migrated into the vadose zone; however, tank leaks created the deepest contamination plumes (Dirkes and Hanf 1998).

Spectral gamma log data show that cesium-137 is the most abundant and highly concentrated man-made radionuclide in the vadose zone of several of the tank farms. It was previously believed the cesium-137 was relatively immobile in the sediment and was not expected to migrate more than a few meters from the base of the tanks. In 1996, cesium-137 contamination was detected at relatively high concentrations deeper than expected (as deep as 73 m [240 ft]).

Cobalt-60 has also been detected but at a much lower concentration than cesium-137. Cobalt-60 has been found at depths of between 15 and 50 m (50 to 165 ft) and as trace amounts at depths close to the water table at 69 and 71 m (225 to 234 ft). Cobalt-60 was detected at a depth of 65 m (213 ft), immediately above the water table and within the capillary fringe. Some of the cobalt-60 contamination was detected below the Early Palouse/Plio-Pleistocene interval, which has been considered a barrier to downwardly migrating fluids and groundwater. Additional contaminants detected in the vadose zone as detected in monitoring wells include europium-154, antimony-125, uranium-235, uranium-238, potassium-40, and thorium-232 (Dirkes and Hanf 1998).

4.3.2.4.3 Plutonium Finishing Plant. The spent-process solutions from the Plutonium Finishing Plant contained carbon tetrachloride, nitric acid, and isotopes of plutonium and americium (transuranic waste). Liquid waste discharges to cribs and trenches in the Plutonium Finishing Plant area resulted in the accumulation of an estimated 20,000 Ci of plutonium-239 and americium-241 in the underlying soil column. Based on relative hazard, the Plutonium Finishing Plant’s cribs are some the most significant sources of radioactive contamination in the vadose zone at the Hanford Site.

Transuranic concentration in the soil of >100,000 pCi/g were found immediately beneath the tile fields to a depth of 6 m (20 ft). Transuranics were also found in sediment at depths of 20 to 30 m (66 to 98 ft). Although transuranics are normally expected to be retained in the first few meters of surface sediment, the combination of high acidity and the presence of complexants apparently allowed the transuranics at these sites to penetrate deeper into the soil column.

In addition to transuranics, between 1955 and 1973, the 200 West Area's cribs also received 570,000 to 920,000 kg (1.2 million to 2 million lb) of carbon tetrachloride. Carbon tetrachloride was discovered in the groundwater near the plant in the mid-1980s and was later found to be widespread in the 200 West Area. If left unchecked, the carbon-tetrachloride would significantly increase the extent of groundwater contamination because of vapor-phase transport through soil-pore space or by downward migration through the vadose zone as a dense nonaqueous-phase liquid or dissolved in natural recharge water.

Soil vapor extraction is being used to remove the carbon tetrachloride source from the vadose zone as part of the 200 West Area carbon tetrachloride expedited response action. Approximately 75,000 kg (165,000 lb) of carbon tetrachloride have been removed from the subsurface since extraction operations started in 1992 (Dirkes and Hanf 1998).

4.3.2.4.3 Other Liquid Waste Disposal Sites. Along the Columbia River in the vicinity of the now inactive and closed reactors, once-through cooling waters were routinely disposed into cribs and trenches. The disposed cooling water contained low levels of fission and neutron activation products and very low level of some chemicals and actinides. The biggest concern is the impacts of chromate, nitrate, strontium-90, and tritium to groundwater. Leakage from fuel-storage basins in the 100-K Area also contributes potentially significant inventories of fission products and transuranics to the soil column. Thus both historical waste disposal sites and fuel-storage basin leakage are potential vadose-zone sources (Dirkes and Hanf 1998).

4.3.2.4.4 Vadose Zone Monitoring**.** Two programs currently under way at Hanford characterize and monitor radionuclides in the vadose zone. One program focuses on vadose zone monitoring near single-shell radioactive waste tanks and the other involves monitoring near historical effluent disposal sites, which include cribs, ponds, ditches, injection wells, and french drains. Both programs were designed to characterize and monitor gamma-emitting radionuclides in the vadose zone and focused on establishing existing baseline conditions. Once a baseline is established for a particular tank or effluent discharge site, the facility can be monitored for either long-term or short-term changes. The intent of long-term monitoring is to detect changes over a 5- to 10-year period than can be used for predictive risk assessment. Short-term monitoring is used to identify recent changes in the vadose zone caused by current operations and tank leaks (PNNL 1997b).

In 1994, the tank farms vadose zone baseline characterization project was begun to perform an initial baseline characterization of the vadose zone gamma-emitting contamination at Hanford Site tank farms. Under the baseline characterization program, approximately 800 pre-existing monitoring boreholes surrounding the single-shell tanks are being logged with gamma-ray logging methods. Borehole logging is used to identify the locations and sizes of the contamination plumes. Once the baseline is established for a particular tank, that tank can be monitored over time (PNNL 1997b).

4.3.3 Water Use

Water use in the Pasco Basin is primarily from surface diversion, with groundwater diversions accounting for less than 10 percent of the total use (DOE 1988a). Historically, industrial, agricultural, and municipal usage represented about 32, 50, and 9 percent, respectively. Until recently, the Hanford Site used about 81 percent of the water withdrawn for industrial purposes. However, because of the N Reactor shutdown, and considering other data (PNL 1991a), these percentages now approximate 13 percent for industrial, 75 percent for agricultural, and 12 percent for municipal uses, with the Hanford Site accounting for about 41 percent of the water withdrawn for industrial use (DOE 1995e). The first downstream drinking water intake below the Hanford Site is the City of Richland intake.

The largest categories of wells in the Pasco Basin are those used for domestic purposes (approximately 50 percent). Agricultural wells, used for irrigation and stock supply, constitute the second-largest category of well use (about 24 percent for the Pasco Basin). Industrial users account for only about 3 percent of the wells (DOE 1995e).

Most of the water used by the Hanford Site is withdrawn from the Columbia River. The water distribution systems supplying river water are located at the 100-B, 100-D, 200, and 300 Areas at Energy Northwest (formerly known as WPPSS). In addition, wells supply water to the 400 Area and a variety of low-use facilities at remote locations. The 700 and 1100 Areas are supplied with water by the City of Richland.

Regional effects of water-use activities are apparent in some areas where the local water tables have declined because of withdrawals from wells. In other areas, water levels in the shallow aquifers have risen because of artificial recharge mechanisms, such as excessive application of imported irrigation water or impoundment of streams. Waste water ponds on the Hanford Site have artificially recharged the unconfined aquifer below the 200 East and 200 West Areas. The increase in water table elevations was most rapid from 1950 to 1960 and slowed down substantially between 1970 and 1980, when only small increases in water table elevations occurred. Waste water discharges from the 200 West Area were reduced significantly in 1984, with an accompanying decline in water table elevations.

The Vernita Bar Settlement Agreement, executed June 16, 1988, established a minimum Columbia River flow below Priest Rapids Dam to protect salmon spawning habitat. This Agreement was signed by the Washington Public Utility Districts in Chelan, Grant, and Douglas counties; the Bonneville Power Administration (BPA); National Marine Fisheries Service; WDFW; Oregon Department of Fish and Wildlife; Yakama Nation; the Confederated Tribes of the Umatilla Indian Reservation; and the Colville Confederated Tribes. The Agreement was then approved by the Federal Energy Regulatory Commission as a condition of the license for the Priest Rapids Dam. This minimum flow is in effect from about December 15 to May 31 each year to hold flows down during the fall (which would limit the area of fall chinook salmon spawning to the lower elevations of the Vernita Bar), and then to provide sufficient flows during the winter and spring to assure the survival of the eggs and newly hatched fish. The Vernita Bar Agreement limits river flow in the fall to 1,960 m^3/s (70,000 ft^3/s). The post-spawning flows are determined annually, based on field surveys that identify when, where, and to what extent spawning has occurred (NPS 1994).

4.3.3.1 Water Rights. Water rights in the state of Washington are determined by the Washington State Superior Courts and regulated by Ecology. Water sources relevant to the discussion in this document include the Columbia River and underground aquifers on the Hanford Site.

The DOE's past and present water withdrawals at the Hanford Site are based on the

“Federal Reserved Water Rights” doctrine. This doctrine, developed as case law from U.S. Supreme Court rulings, holds that the Federal government, when it withdraws public domain lands for the purpose of the creation of a Federal reservation, necessarily withdraws unappropriated water rights sufficient to meet the needs for which the reservation was created. The date of priority of these rights is the date of creation of the reservation. In the case of the Hanford Site, this date is 1943. It is the general rule that Federal reserved water rights cease to exist when the Federal reservation ceases to be used for the purposes for which it was created. The limited exception to the rule is reflected in the *U.S. v. Powers*, 305 U.S. 527 (1939), wherein the Court allowed that a purchaser of agricultural land on an Indian reservation may be entitled to a portion of Federal reserved water rights where the use of the property did not change.

The Federal government has not established its own water rights regulation. Instead, it uses the regulatory procedures outlined in the State water rights laws to document the extent of its rights. There has been no general adjudication in the State of Washington of the water rights in the Columbia River and, therefore, the reserved water right of the Hanford Site has not been documented. The quantity of that right, however, would be equal to the maximum amounts used at Hanford during its operation, up to the amount of unappropriated water in the Columbia River as of 1943.

In a report titled, *Hanford Land Transfer* (Ecology 1993), Ecology indicated that if water rights were attached to privately owned parcels of land acquired in fee by the Federal government for the creation of Hanford in 1943, those water rights may continue to be attached to these parcels of land. Ecology has indicated that it has not taken action to extinguish these rights, although under Washington law appropriative water rights are subject to be extinguished if unused for a period of five years.

Further complications exist regarding non-Federal water rights claims at the Hanford Site. The first is the issue of groundwater contamination at Hanford. The second is that the date for filing a water rights claim in the Hanford sub-basin, for both Columbia River water and groundwater, expired in 1992. No claims for water rights under state law appear to have been filed within the required time period (NPS 1994).

4.4 Air Resources

This section addresses the general air resources at the Hanford Site and the surrounding region. Included in this section are discussions on climate and meteorology, ambient air quality, and atmospheric dispersion.

4.4.1 Climate and Meteorology

The Hanford Site climate is classified as mid-latitude semiarid or mid-latitude desert, depending on the climatological classification scheme used. Summers are warm and dry, with abundant sunshine. Large diurnal temperature variations result from intense solar heating during the day and radiational cooling at night. Daytime high temperatures in June, July, and August periodically exceed 38EC (100EF). Winters are cool, with occasional precipitation. Outbreaks of cold air associated with modified arctic air masses can reach the area and cause temperatures to drop below -18EC (0EF). Overcast skies and fog occur periodically (PNNL 1996a).

Topographic features have a significant impact on the climate of the Hanford Site. All air masses that reach the region undergo some modification during their passage over the complex topography of the Pacific Northwest. The climate of the region is strongly influenced by the Pacific Ocean and the Cascade Range to the west. The relatively low annual average rainfall of 16.1 cm (6.3 in.) at the Hanford Meteorological Station (HMS) is caused largely by the rain shadow created by the Cascade Range. These mountains limit much of the maritime influence of the Pacific Ocean, resulting in a more continental-type climate than would exist if the mountains were not present. Maritime influences are experienced in the region during the passage of frontal systems and as a result of movement through gaps in the Cascade Range (e.g., the Columbia River Gorge).

The Rocky Mountains to the east and the north also influence the climate of the region. These mountains play a key role in protecting the region from the more severe winter storms and the extremely low temperatures associated with the modified arctic air masses that move southward through Canada. Local and regional topographical features (e.g., the Yakima Ridge and the Rattlesnake Hills) also impact meteorological conditions across the Hanford Site (PNNL 1996a). In particular, these features have a significant impact on wind directions, wind speeds, and precipitation levels.

Climatological data are available for the HMS, which is located between the 200 East and 200 West Areas. Data collected at this location since 1945 (PNL 1994b) are representative of the general climatic conditions for the region and describe the specific climate of the Central Plateau. Local variations in the topography of the Hanford Site may cause some aspects of the climate to differ significantly from those of the HMS (see text box, *"Hanford Site Quick Facts: Meteorology"*). For example, winds near the Columbia River are different from those at the HMS. Similarly, precipitation along the slopes of the Rattlesnake Hills differs from that at the HMS.

Hanford Site Quick Facts: Meteorology

- Average annual precipitation: 16.1 cm (6.3 in.)
- Prevailing wind direction: Northwest
- Average monthly temperature: January - 0.9EC (30EF); July - 24.6EC (76EF)

4.4.1.1 Wind. Prevailing wind directions on the 200 Area Plateau are from the northwest during all months of the year; southwesterly winds occur less frequently. Summaries of wind direction indicate that winds from the northwest quadrant occur most often during the winter and summer. During the spring and fall, the frequency of southwesterly winds increases with a corresponding decrease in northwest flow. Winds blowing from other directions (e.g., the northeast) display minimal variation from month to month. Monthly average wind speeds are lowest during the winter months, averaging 10 to 11 km/hr (6 to 7 mi/hr), and highest during the summer, averaging 13 to 15 km/h (8 to 9 mi/hr). Wind speeds that are well above average are usually associated with southwesterly winds. However, the summertime drainage winds generally are northwesterly and can frequently gust to 50 km/hr (30 mi/hr). These winds are most prevalent over the northern portion of the Hanford Site (PNNL 1996a).

4.4.1.2 Temperature and Humidity. Nine separate temperature measurements are made at the 125-m (410-ft) tower at the HMS. Temperatures also are measured at the 2-m (6.5-ft) level on the twenty-six 9.1-m (30-ft) towers located on and around the Hanford Site. The three 60-m (200-ft) towers have temperature-measuring instrumentation at the 2-, 10-, and 60-m (6.5-, 33-, and 200-ft) levels. The temperature data from the 9.1- and 61-m (30- and 200-ft) towers are telemetered to the HMS.

Ranges of daily maximum and minimum temperatures vary from normal maxima of 2EC (35EF) in late December to 35EC (95EF) in late July (PNL 1994b). On the average, 52 days during the summer months have maximum temperatures greater than or equal to 32EC (90EF), and 12 days have maxima greater than or equal to 38EC (100EF). From mid-November through early March, minimum temperatures average less than or equal to 0 EC (32EF), with the minima in late December and early January averaging -6EC (21EF). During the winter, on average, three days have minimum temperatures less than or equal to -18EC (0EF); however, only about one winter in two experiences such temperatures. The record maximum temperature is 45EC

(113EF), and the record minimum temperature is -31EC (-23EF). For the period of 1946 through 1998, the average monthly temperatures ranged from a low of -0.9EC (30EF) in January to a high of 24.6EC (76EF) in July. During the winter, the highest monthly average temperature at the HMS was 6.9EC (44EF) in February 1958, and the record average lowest temperature was -11.1EC (12EF) during January 1950. During the summer, the record highest monthly average temperature was 27.9EC (82EF) in July 1985, and the record lowest temperature was 17.2EC (63EF) in June 1953.

Relative humidity and dew-point temperature measurements are made at the HMS and at the three 60-m (200-ft) tower locations. The annual average relative humidity at the HMS is 54 percent. It is highest during the winter months, averaging about 75 percent, and lowest during the summer, averaging about 35 percent. Fog reduces the visibility to 9.6 km (6 mi) during an average of 47 days/yr and to less than 0.4 km (0.25 mi) during an average of 25 days/yr. Other phenomena causing restrictions to visibility (i.e., visibility less than or equal to 9.6 km [6 mi]) include dust, blowing dust, and smoke from field burning. There are few such days; an average of 5 days/yr have dust or blowing dust and less than 1 day/yr has reduced visibility from smoke (Neitzel 1998).

4.4.1.3 Precipitation. The average annual precipitation at the HMS is 16 cm (6.3 in). Winter monthly average snowfall ranges from 0.8 cm (0.32 in) in March to 13.7 cm (5 in) in December. The seasonal record snowfall of 142 cm (56 in.) occurred in the winter of 1992-1993. During the months of December, January, and February, snowfall accounts for about 38 percent of all precipitation (PNNL 1996a). Days with greater than 1.3 cm (0.50 in) precipitation occur on average less than one time each year. Rainfall intensities of 1.3 cm/hr (0.50 in./hr) persisting for 1 hour are expected once every 50 years (Neitzel 1998).

4.4.1.4 Severe Weather. Severe weather on the Hanford Site may include a variety of meteorological events, which include severe winds, blowing dust, hail, fog, ash falls, extreme temperatures, temperature inversions, and blowing and drifting snow. The HMS climatological summary and the National Severe Storms Forecast Center database list only 24 separate tornado occurrences within 161 km (100 mi) of the Hanford Site from 1916 to 1995 (PNNL 1996a). Only one of these tornadoes was observed within the boundaries of the Hanford Site (on the extreme western edge), and no damage resulted. The estimated probability of a tornado striking a point at the Hanford Site is 9.6×10^{-6}/yr (PNNL 1996a). Because tornadoes are infrequent and generally small in the Pacific Northwest (and hurricanes do not reach this area), risk from severe winds normally are associated with thunderstorms or the passage of strong cold fronts. The greatest peak wind gust was 130 km/hr (81 mi/hr), recorded at 15 m (50 ft) above ground level at the HMS. Extrapolations based on 35 years of observations indicate a return period of about 200 years for a peak gust in excess of 145 km/hr (90 mi/hr) at 15 m (50 ft) above ground level.

4.4.1.5 Atmospheric Stability. Atmospheric dispersion is a function of wind speed, duration and direction of wind, atmospheric stability, and mixing depth. Dispersion conditions generally are good if winds are moderate to strong, if the atmosphere is of neutral or unstable stratification, and if there is a deep mixing layer. Good dispersion conditions associated with neutral and unstable stratification exist about 56 percent of the time. Less favorable dispersion conditions might 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 exists about 66 percent of the time. Less favorable conditions also occur periodically for surface and low-level releases in all seasons from about sunset to about 1 hour after sunrise, as a result of ground-based temperature inversions and shallow mixing layers (PNNL 1996a).

4.4.2 Air Quality

The EPA has set National Ambient Air Quality Standards (NAAQS) that define levels of air quality that are necessary to protect the public health (primary standards) and the public welfare (secondary standards). Regional air quality is generally good, with the occasional exception due to blowing dust.

4.4.2.1 Regional Air Quality. Air quality in the Hanford region is well within the state and Federal standards for criteria pollutants, except that short-term particulate concentrations occasionally exceed the 24-hour "particulate matter nominally 10 microns or less" (PM_{10}) standard. Because the highest concentrations of airborne particulate material are generally a result of natural events, the area has not been designated nonattainment[1] with respect to the PM_{10} standard.

Particulate concentrations can reach relatively high levels in eastern Washington State because of extreme natural events (e.g., dust storms, volcanic eruptions, and large brushfires) that occur in the region. "Rural fugitive dust" from extreme natural events was not considered when estimating the maximum background concentrations of particulates in the area east of the Cascade Mountain crest and when determining Washington State ambient air quality standards. In the past, the EPA has exempted the rural fugitive dust component of background concentrations when considering permit applications and enforcement of air quality standards. However, the EPA is now investigating the prospect of designating parts of Benton, Franklin, and Walla Walla counties as a nonattainment area for PM_{10}. Windblown dust has been identified as a particularly large problem in this area.

Ecology has been working with the EPA and the Benton County Clean Air Authority under a MOA to characterize and document the sources of PM_{10} emissions and develop appropriate control techniques in the absence of formally designating the area nonattainment. At this time, the parties are characterizing the sources of PM_{10} emissions and working through other items in the MOA. A final decision on this issue will be made by the EPA, when the final results of the PM_{10} characterization analysis are received (PNNL 1996a).

Ecology conducted the only offsite monitoring (for PM_{10}) near the Hanford Site in 1996. PM_{10} was monitored at one location in Benton County – at Columbia Center – located approximately 17 km (10.5 mi) south-southwest of the 300 Area, in Kennewick, Washington. During 1996, the 24-hour PM_{10} standard established by the State of Washington, 150 $\mu g/m^3$, was not exceeded. The Site did not exceed the annual primary standard, 50 $\mu g/m^3$, during 1996. The arithmetic mean for 1996 was 21 $\mu g/m^3$ at Columbia Center (Neitzel 1998).

During the past 10 years, carbon monoxide, sulfur dioxide, and nitrogen dioxide have been monitored periodically in communities and commercial areas southeast of the Hanford Site. These urban measurements are used to estimate the maximum background pollutant concentrations for the Hanford Site. Because these measurements were made in the vicinity of local sources of pollution, they might overestimate maximum background concentrations for the Hanford Site or at the Hanford Site boundaries. Concentrations of toxic chemicals, as listed in 40 CFR 60.1, are not measured and, therefore, are not available for the Hanford Site.

4.4.2.2 Hanford Site Nonradiological Air Quality. The *Clean Air Act* (CAA) requires that Federal activities may not cause or contribute to new violations of air quality standards, exacerbate existing violations, or interfere with timely attainment or required interim emission

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[1] A nonattainment area is an area where measured concentrations of a pollutant are above the primary or secondary NAAQS.

reductions towards attainment (40 CFR 93.150). A determination of conformity of general Federal actions to state or Federal implementation plans must accompany any major Federal action where air quality might be impacted. Because of the administrative nature of this EIS, and the absence of any on-site nonattainment area, this EIS is exempt from a conformity determination (40 CFR 93.153).

The NAAQS, set by EPA, must be met at the Hanford Site boundary or other publicly accessible locations (i.e., highways on the Hanford Site). The standards define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health and welfare. Standards exist for sulfur oxides (measured as sulfur dioxide), nitrogen dioxide, carbon monoxide, total suspended particulates (TSP), PM_{10}, lead, and ozone. The standards specify the maximum pollutant concentrations and frequencies of occurrence that are allowed for specific averaging periods (e.g., the concentration of carbon monoxide when averaged over 1 hour is allowed to exceed 40 mg/m^3 only once a year). The averaging periods vary from 1 hour to 1 year, depending on the pollutant.

An exception to the rule for using the Hanford Site boundary as the point of compliance for air pollution can occur if a nonattainment area occurs within 100 km (62 mi) of any significant new source that could be built or any revision to an operating source. As a requirement for new sources in attainment or unclassifiable areas, WAC 173-400-113 mandates that "allowable emissions from the proposed new source or modification will not delay the attainment date for an area not in attainment nor cause or contribute to a violation of any ambient air quality standard." The Wallula PM_{10} nonattainment area is within 100 km (62 mi) of all parts of the Hanford Site (62 FR 3800).

Because the Hanford Site is in an attainment area, this type of action is exempt from conformity determinations for Federal actions. Federal conformity rules (40 CFR 93) require agencies to determine that the proposed Federal action is in conformity with the specific requirements pursuant to the agency's affirmative obligation under Section 176(c) of the CAA.

In addition to ambient air quality standards, the EPA has established standards for the Prevention of Significant Deterioration (PSD) of air quality. PSD standards provide maximum allowable increases in concentrations of pollutants for areas already in compliance with NAAQS. The PSD standards are expressed as allowable increments in atmospheric concentrations of specific pollutants (nitrogen dioxide, sulfur dioxide, and PM_{10}) (40 CFR 52). Different PSD standards exist for Class I areas (where degradation of ambient air quality is restricted) and Class II areas (where moderate degradation of air quality is allowed).

The closest Class I areas to the Hanford Site are as follows:

- Mount Rainier National Park, approximately 160 km (100 mi) west of the Hanford Site
- Goat Rocks Wilderness Area, approximately 145 km (90 mi) west of the Hanford Site
- Mount Adams Wilderness Area, approximately 150 km (95 mi) southwest of the Hanford Site
- Alpine Lakes Wilderness Area, approximately 175 km (110 mi) northwest of the Hanford Site.

If the Hanford Reach is given Congressional status as a Wild and Scenic River with the Wahluke Slope added as a wildlife refuge, then it would be eligible for Class 1 air shed status.

The PSD standards are presented in Table 4-3. The Hanford Site, which is located in a

Class II area, operates under a PSD permit (Permit No. PSD-X80-14) issued by the EPA in 1980. This permit provides specific limits for emissions of nitrogen oxide from the Plutonium-Uranium Extraction (PUREX) and the Uranium-Trioxide plants, which are now closed and are being decommissioned.

Table 4-3. Maximum Allowable Increases for Prevention of Significant Deterioration of Air Quality (40 CFR 52).

Pollutant	Averaging Time	Class I	Class II
Particulate matter[a] (PM_{10}) ($\mu g/m^3$)	Annual	4	17
	24 hours	8	30
Sulfur dioxide ($\mu g/m^3$)	Annual	2	20
	24 hours	5	91
	3 hours	25	512
Nitrogen dioxide ($\mu g/m^3$)	Annual	2.5	25

[a] PM_{10} is defined as particulate matter nominally 10 microns or less.

State and local governments have the authority to impose standards for ambient air quality that are more stringent than the national standards. Washington State has established more stringent standards for sulfur dioxide and TSP. In addition, Washington State has established standards for other pollutants, such as fluoride, that are not covered by national standards. The state standards for carbon monoxide, nitrogen dioxide, ozone, PM_{10}, and lead are identical to the national standards. Table 4-4 summarizes the relevant air quality standards (Federal and supplemental state standards).

Emission inventories for permitted pollution sources in Benton County are routinely compiled by the Benton County Clean Air Authority. The annual emission rates for Hanford Site sources are reported to Ecology by DOE (Table 4-5).

Monitoring of nitrogen oxides was discontinued after 1990, mostly because of the end of operations at the PUREX facility. Monitoring of TSP was discontinued in early 1988 when the Basalt Waste Isolation Project ended (for which those measurements were required).

4.5 Biological Resources

As a Federal land manager, DOE is responsible for conserving fish, wildlife, and plant populations and their habitats on the Hanford Site. Information about these natural resources is presented below.

Figures 4-16, 4-17, and 4-18 show priority habitats and priority species within Washington State as identified by the WDFW. Because biological resources are temporal, they may not be found in the same place from year to year or require the same mitigation steps at different times of the year. Also, because many of the siting data used to develop these maps were obtained from incidental sightings (e.g., driving [road] surveys) as opposed to thorough surveying, areas with no record sighting are not necessarily devoid of the species. For these reasons, biological resources are generally inventoried prior to the undertaking of specific projects.

Table 4-4. National and Washington State Ambient Air Quality Standards.

Pollutant[a]	National Primary	National Secondary	Washington State
Total suspended particulates			
Annual geometric mean	NS	NS	60 µg/m³
24-hour average	NS	NS	150 µg/m³
PM_{10} (fine particulates)			
Annual arithmetic mean	50 µg/m³	50 µg/m³	50 µg/m³
24-hour average	150 µg/m³	150 µg/m³	150 µg/m³
$PM_{2.5}$			
Annual arithmetic mean	15 µg/m³	--	--
24-hour average	65 µg/m³	--	--
Sulfur dioxide			
Annual average	0.03 ppm	NS	0.02 ppm
24-hour average	0.14 ppm	NS	0.10 ppm
3-hour average	NS	0.50 ppm	NS
1-hour average	NS	NS	0.40 ppm[b]
Carbon monoxide			
8-hour average	9 ppm	9 ppm	9 ppm
1-hour average	35 ppm	35 ppm	35 ppm
Ozone			
1-hour average	---	0.12 ppm	0.12 ppm
8-hour average	0.08 ppm[c]	---	---
Nitrogen dioxide			
Annual average	0.05 ppm	0.05 ppm	0.05 ppm
Lead			
Quarterly average	1.5 µg/m³	1.5 µg/m³	1.5 µg/m³
Fluoride			
30-day average			0.84 mg/m³
7-day average			1.7 mg/m³
24-hour average			2.9 mg/m³
12-hour average			3.7 mg/m³
VOCs			Source-specific standards

[a] Annual standards are never to be exceeded; short-term standards are not to be exceeded more than once per year unless otherwise noted (Ecology 1994).

[b] 0.25 ppm not to be exceeded more than twice in any 7 consecutive days; not to be exceeded more than 1 day per calendar year.

[c] Based on a 3-year average of the annual fourth highest daily maximum 8-hour average.

NS = no standard
ppm = parts per million
µg/m³ = micrograms per cubic meter
VOC = volatile organic compound

Table 4-5. Nonradioactive Constituents Discharged to the Atmosphere, 1995[a] (Dirkes and Hanf 1996).

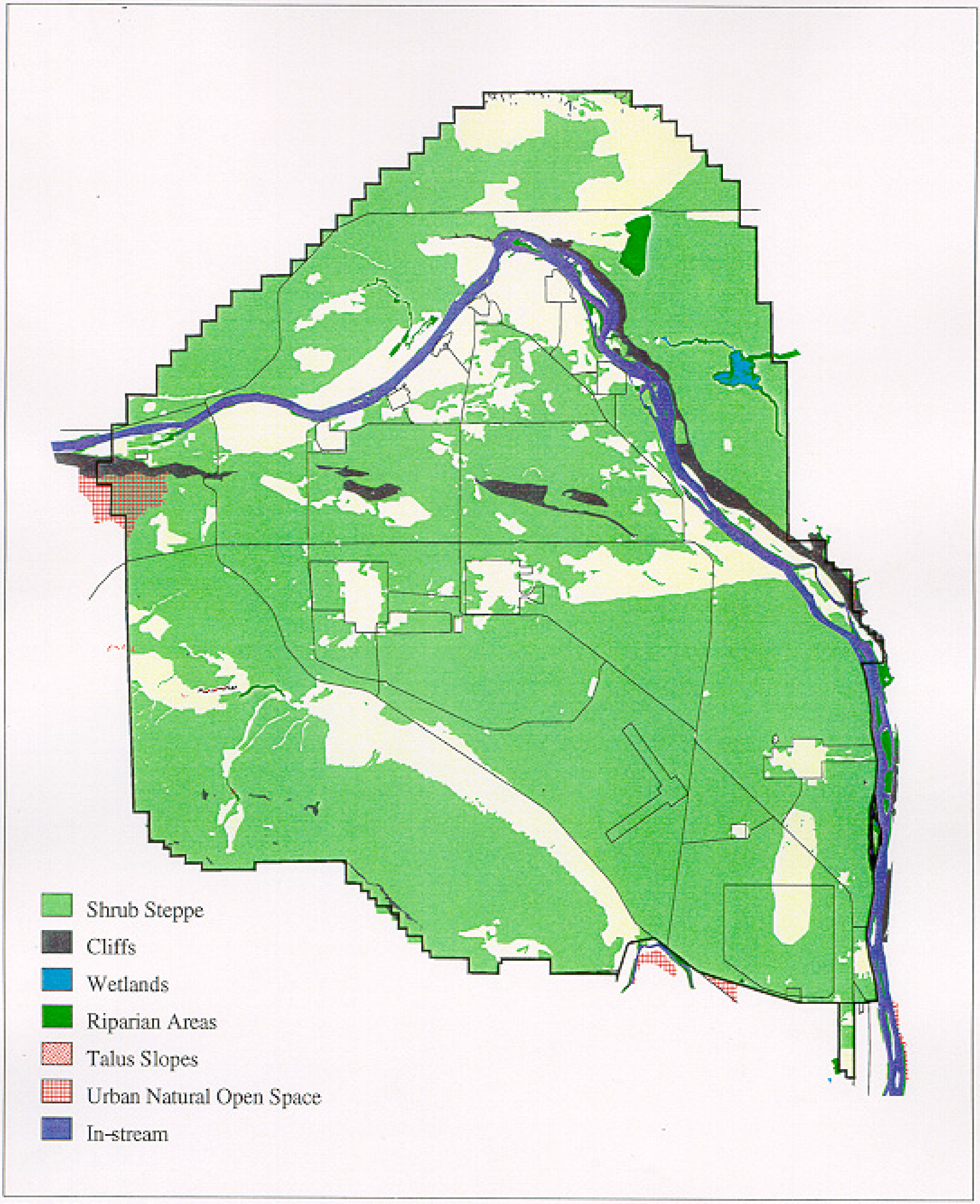
Constituent	Release (kg)		
	200 East Area	200 West Area	300 Area
Particulate matter	3.40×10^{2}	8.02×10^{1}	1.43×10^{4}
Nitrogen oxides	1.77×10^{5}	2.82×10^{4}	4.69×10^{4}
Sulfur oxides	2.25×10^{5}	3.53×10^{4}	2.34×10^{5}
Carbon monoxide	6.43×10^{4}	1.01×10^{4}	4.25×10^{3}
Lead	1.62×10^{2}	2.53×10^{1}	2.52×10^{1}
Volatile organic compounds[b]	6.43×10^{2}	1.00×10^{2}	2.38×10^{2}
Ammonia[c]	6.18×10^{3}	1.53×10^{3}	NM
Arsenic	1.73×10^{2}	2.70×10^{1}	1.48×10^{1}
Beryllium	2.33×10^{1}	3.64×10^{0}	5.46×10^{1}
Cadmium	1.37×10^{1}	2.18×10^{0}	2.74×10^{1}
Carbon tetrachloride[d]	NM	NE	NM
Chromium	5.01×10^{2}	7.83×10^{1}	1.67×10^{1}
Cobalt	NE	NE	1.57×10^{1}
Copper	3.15×10^{2}	5.02×10^{2}	3.62×10^{1}
Formaldehyde	7.05×10^{1}	1.25×10^{1}	5.27×10^{1}
Manganese	6.93×10^{2}	1.08×10^{2}	9.63×10^{0}
Mercury	5.11×10^{0}	8.08×10^{1}	4.16×10^{0}
Nickel	4.12×10^{2}	6.43×10^{1}	3.03×10^{2}
Polycyclic organic matter	NE	6.00×10^{2}	7.14×10^{3}
Selenium	6.26×10^{1}	9.84×10^{0}	4.94×10^{0}
Vanadium	4.31×10^{1}	7.79×10^{0}	3.93×10^{2}

[a] The estimate of volatile organic compound emissions do not include emissions from certain laboratory operations; NM = not measured; NE = no emissions.
[b] Produced from burning fossil fuels for steam generation.
[c] Ammonia releases are from the 200 East Area tank farms, 200 West Area tank farms, and the operation of the 242-A Evaporator.
[d] Does not include carbon tetrachloride Vapor Extraction Project releases from passively ventilated wells.

The block of habitat directly south of the 200 East and West Areas contains high-quality habitat and some of the Hanford Site's best sage sparrow and loggerhead shrike habitat. However, since some of these areas have never been officially surveyed for these species, the species frequently do not show up on maps even though they most likely occur there. Figure 4-17 shows some, but not all, historic bald eagle nesting sites but does not include current or recent bald eagle nest locations which can't be shown because of their sensitivity to disturbance. Similarly, Figure 4-18 shows some, but not all, great blue heron occurrences.

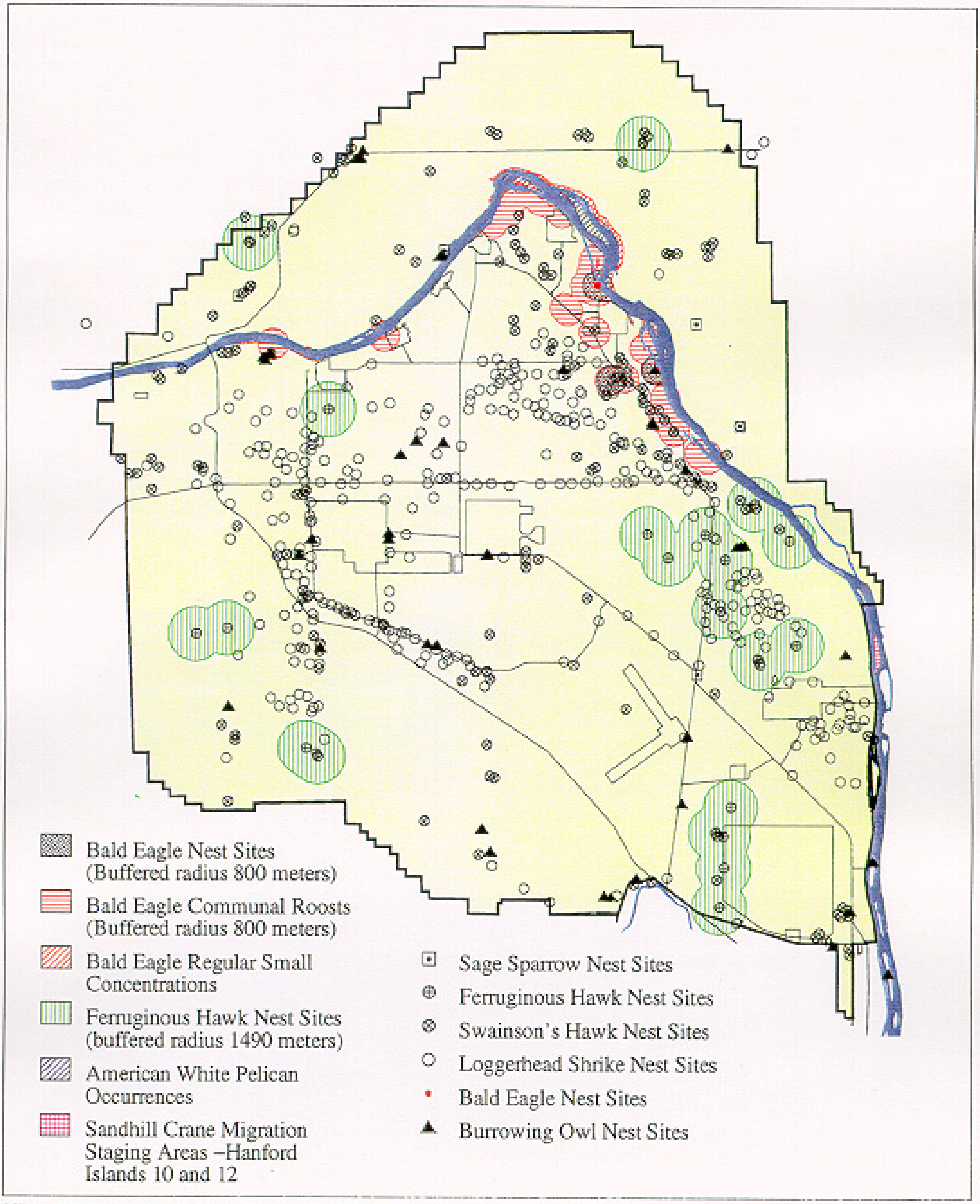
Counties and cities may use information prepared by the WDFW to classify and designate locally important habitats and species. While these priorities are those of the Department, they and the data on which they are based may be considered by counties and cities when developing their land-use plans under the *Growth Management Act* (GMA) (WAC 365-180-080).

Figure 4-16. WDFW Priority Habitats on the Hanford Site.



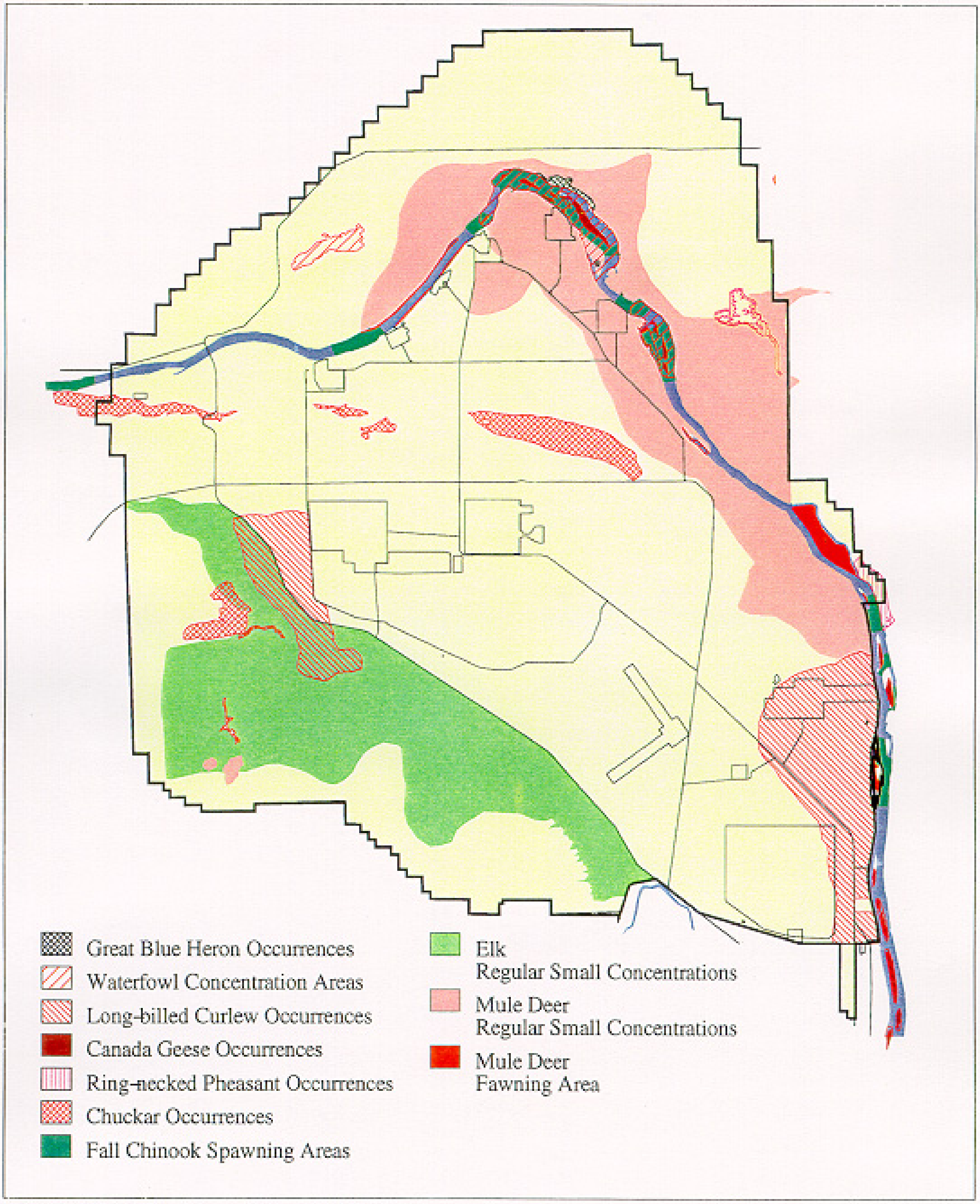
BHI:rpp 07/06/98 draft_2/wadfw1.aml   Database: 03-AUG-1998

Figure 4-17. WDFW Priority Species: State Listed and Candidates.



BHI:rpp 07/06/98 draft_2/wadfw2.aml Database: 03-AUG-1998

Figure 4-18. WDFW Priority Species: Vulnerable Aggregations and Species of Recreation, Commercial, and/or Tribal Importance.



BHI:rpp 07/07/98 draft_2/wadfw3.aml Database: 31-AUG-1998

The Hanford Site is located within a region known as the Columbia Basin ecoregion, which occupies an extensive area south of the Columbia River between the Cascade Range and Blue Mountains in Oregon and roughly two-thirds of the area of Eastern Washington. This region has been botanically characterized as a shrub-steppe ecosystem, with various shrub and bunchgrass associations playing dominant roles. The region is often referred to as high desert, northern desert shrub, or desert scrub (Franklin and Dyrness 1973).

Settlement during the late 19th and early 20th century has resulted in significant changes to vegetation patterns through activities such as farming, dam development, and regional settlement. The State of Washington is rapidly losing much of its remaining steppe habitat and losses are projected to be high for the next 50 years. It has been estimated that approximately 60 percent of the original acreage (4.2 million ha/10.4 million ac) (42,000 km^2/ 16,250 mi^2) of shrub-steppe vegetation in Washington has been lost, primarily to agriculture (DOE-RL 1996c) (see text box, *"What is Shrub-Steppe?"*).

> ***What is Shrub-Steppe?***
>
> The shrub-steppe ecosystem is a vegetation zone occupying most of central and southeastern Washington, part of northeastern Oregon, and portions of Idaho, Utah, and Nevada. It is a region whose native, pre-settlement vegetation consisted primarily of shrubs, perennial bunchgrasses, and a variety of forbs. Typical shrubs include several sagebrush species, rabbitbrush, and bitterbrush. Dominant grasses were bluebunch wheatgrass, Idaho fescue, needle-and-thread grass, and Sandberg's bluegrass. Before European settlement, at least 4.2 million hectares (10.4 million acres) of unaltered shrub-steppe habitat covered much of central and southeastern Washington. With the advent of dryland wheat farming, intensive livestock grazing, irrigation, and altered fire regimes, the landscape is changed to such an extent that the amount of natural shrub-steppe remaining is a small fraction of the original acreage. The average cover of big sagebrush was about 10 percent prior to the introduction of livestock into Washington. Because livestock do not eat it, sagebrush often increases in density in grazed areas, replacing most other plants in badly degraded ranges. Hanford is unique in that it contains large expanses of relatively undisturbed shrub-steppe vegetation and has become a refuge for the native species and habitats comprising the shrub-steppe.

An illustration of this habitat alteration can be seen through the use of satellite-based remote sensing data, which can provide images of land surfaces and existing vegetation cover. Using these data, the WDFW has developed land cover classification maps (historic and current) of a portion of the Columbia Basin ecoregion (Figures 4-19 and 4-20, respectively). As indicated in Figure 4-20, the Hanford Site and the Department of Defense Yakima Training Center (located to the west of the Hanford Site) contain the largest remaining remnant of shrub-steppe vegetation in the Columbia Basin.

The Hanford Site is a relatively large, undisturbed area of shrub-steppe habitat that contains numerous plant and animal species adapted to the semi-arid environment in the region. The Hanford Site consists of mostly undeveloped land, with widely spaced clusters of industrial buildings located along the western shoreline of the Columbia River and at several locations in the interior of the Hanford Site. The industrial buildings are interconnected by roads, railroads, and electrical transmission lines. The major facilities and activities occupy about 6 percent of the total available land area, and their impact on the surrounding ecosystems is minimal from direct discharges or releases attributable to DOE. Most of the Hanford Site has not experienced tillage or livestock grazing since the early 1940s. The Columbia River flows through the Hanford Site, and although the river flow is not directly impeded by dams within the Hanford Site, the historical daily and seasonal water fluctuations have been changed by dams upstream and downstream of the Hanford Site (Cushing 1995).

The Columbia River and other water bodies on the Hanford Site provide valuable habitat for aquatic organisms. Several large portions of the Site are administered in a manner to protect and preserve biological resources, such as the ALE Reserve and the Wahluke Slope (Figure 4-21).

Figure 4-19. Historic Distribution and Extent of Land Cover Classes within a Portion of the Columbia Basin Ecoregion (DOE-RL 1996c).

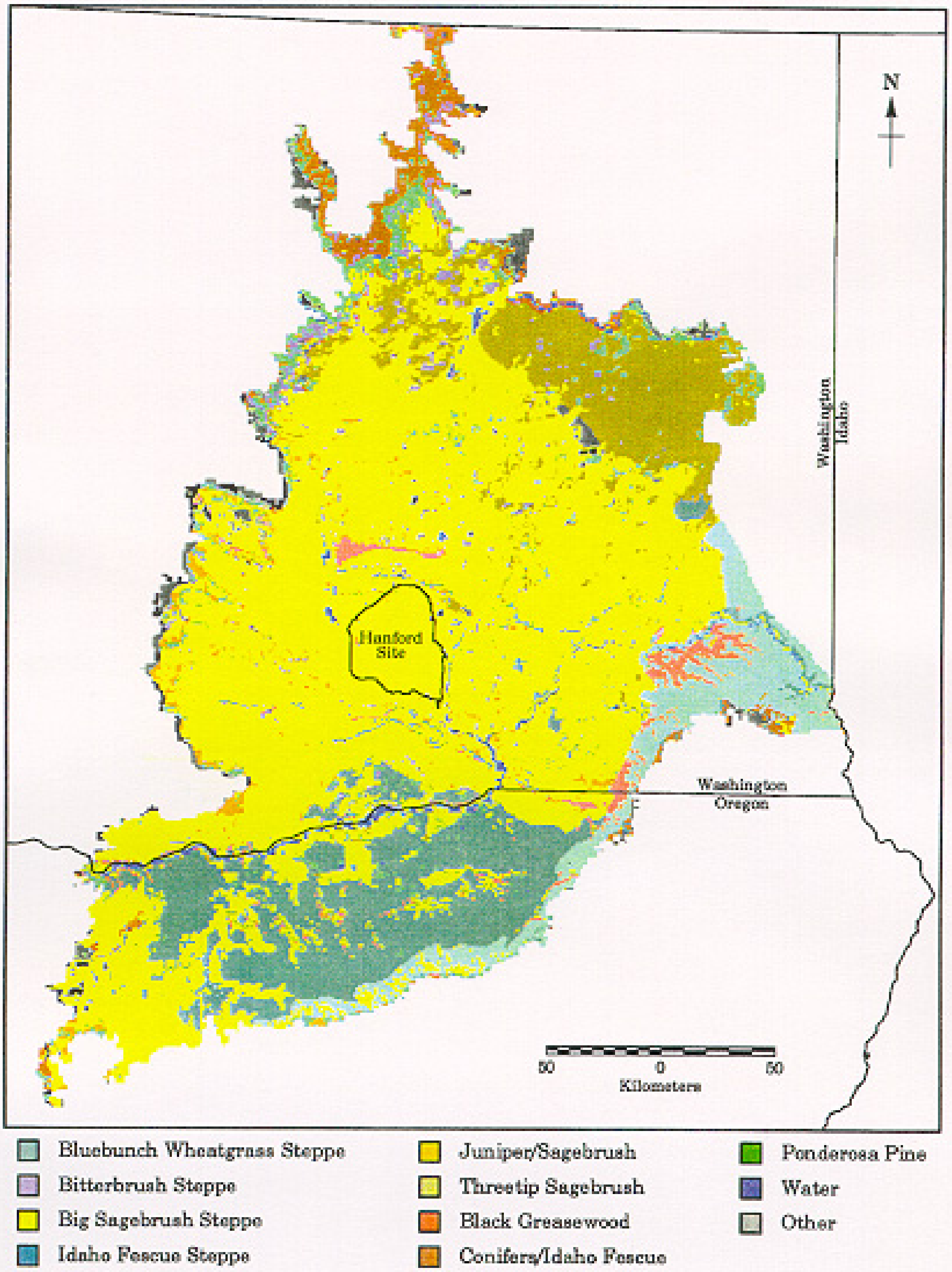


Figure 4-20. Current Distribution and Extent of Land Cover Classes within a Portion of the Columbia Basin Ecoregion (DOE-RL 1996c).

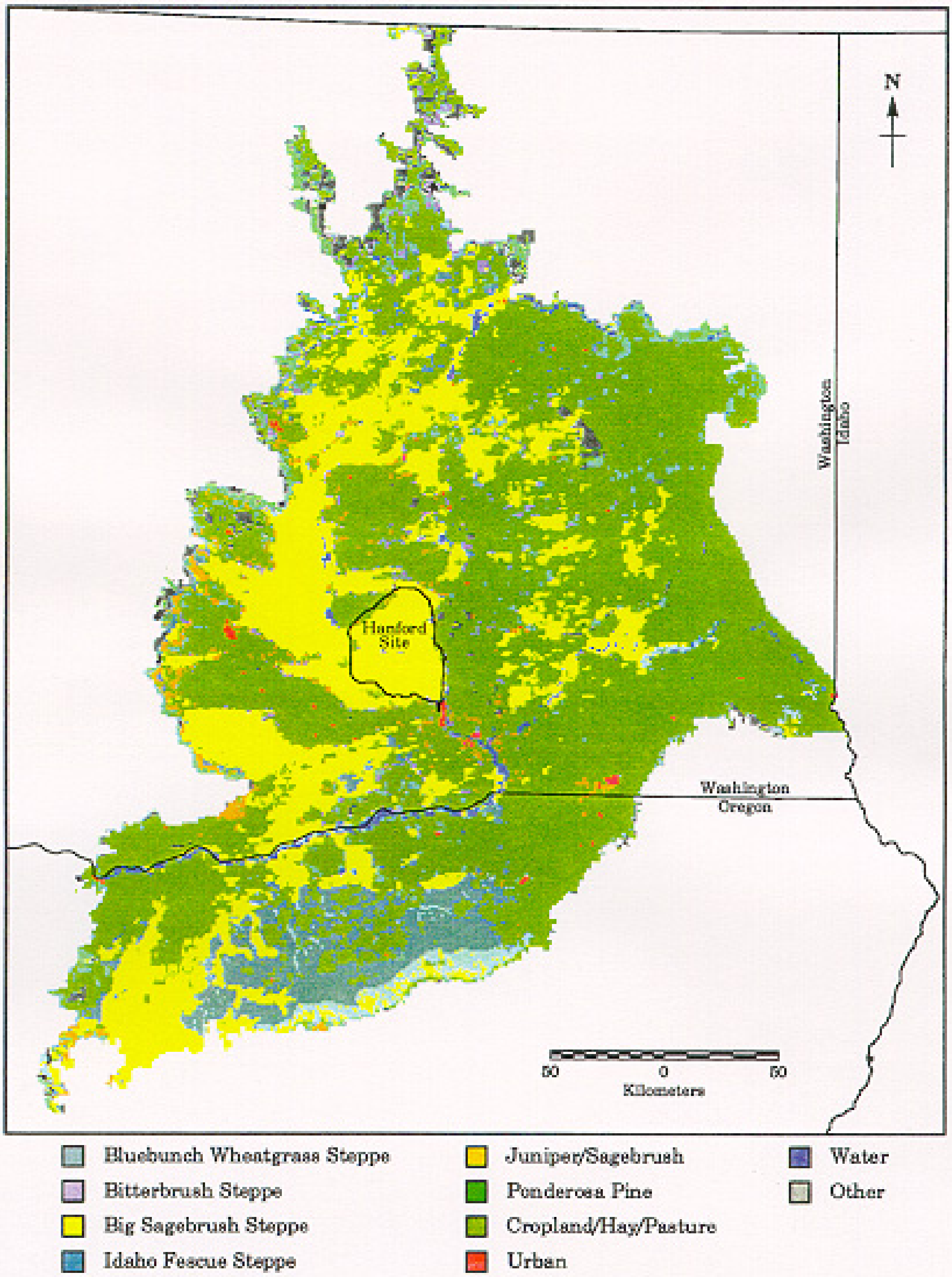
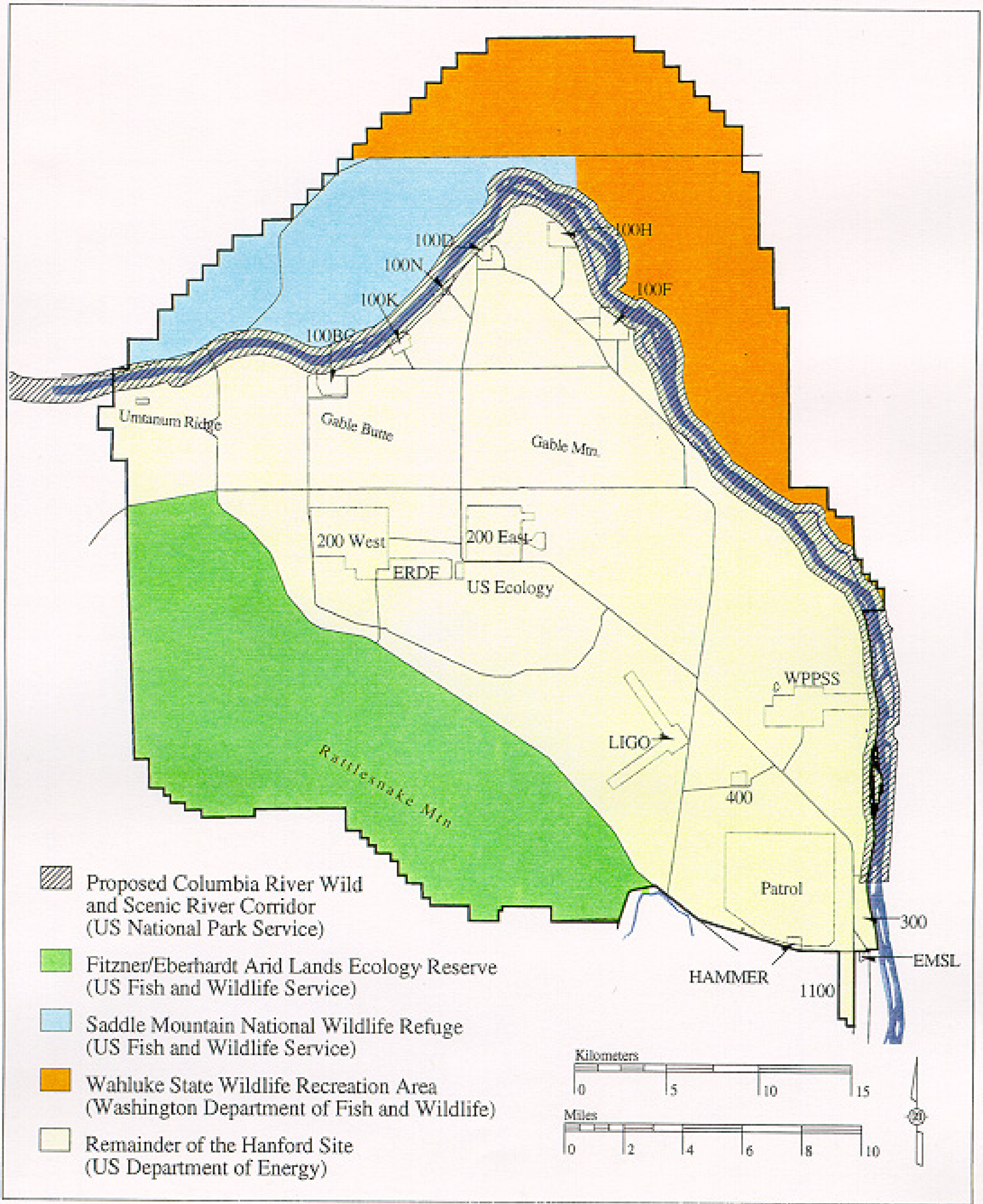


Figure 4-21. Designated Administrative Areas for the Hanford Site.



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4.5.1 Administrative Designations for Natural Resource Protection

In 1977, the U.S. Energy Research and Development Agency (a predecessor to DOE) designated the entire Hanford Site as one of seven National Environmental Research Park (NERP) sites located in the United States. In addition, two other portions of the Hanford Site are administered under special designations.

The Wahluke Slope encompasses approximately 365 km^2 (140 mi^2) and is administered as two wildlife areas known as the Saddle Mountain NWR and the Wahluke Wildlife Recreation Area. Under an agreement made between the WDFW and the USFWS in April 1999, the Wahluke State Wildlife Recreation Area will be combined with the Saddle Mountain NWR and managed as a unit by the USFWS. These areas are operated under the terms of a permit issued by the AEC on November 30, 1971, to provide for management of Hanford lands north and east of the Columbia River.

According to the terms of the permit, the USFWS is required to keep the lands managed as the Saddle Mountain NWR closed to all public access. The closure ensured a security zone for the N Reactor and encompassed an area within a 8.8-km (5.5-mi) radius of the reactor (NPS 1994). Although N Reactor is being decommissioned and doesn't require an extensive buffer, the K Basins still require an exclusion zone until the spent nuclear fuel is removed from the basins.

The ALE Reserve has been used for ecological research dating back to 1952, but it was not until 1967 that the Richland Office of the AEC established the ALE Reserve by administrative order (PNL 1993b). As a result of a Federal interagency cooperative agreement, the ALE Reserve was designated as the Rattlesnake Hills Research Natural Area in 1971. The ALE Reserve currently retains its status as an administratively protected environment and as a valuable ecological study site. Through a MOA with DOE, the USFWS is responsible for management and protection of the ALE Reserve.

4.5.2 Terrestrial Vegetation and Habitats

The Hanford Site has been botanically characterized as a shrub-steppe ecosystem. In the early 1800s, the dominant plant in the area was big sagebrush with an understory of perennial bunchgrasses, especially Sandberg's bluegrass and bluebunch wheatgrass. With the advent of horses in the 1700s and settlement in the 1800s that brought livestock grazing and crop raising, the natural vegetation mosaic was opened to a persistent invasion by non-native annual species, especially cheatgrass. Of the 590 species of vascular plants recorded for the Hanford Site, approximately 20 percent of all species are considered nonnative. Cheatgrass is the dominant nonnative species. It is an aggressive colonizer and has become well established across the site (Neitzel 1998). Today, cheatgrass is the dominant plant on fields that were cultivated 50 years ago. Cheatgrass is also well established on rangelands at elevations less than 244 m (800 ft) (Cushing 1995).

The dryland areas of the Hanford Site were treeless in the years before land settlement; however, for several decades before 1943, trees were planted and irrigated on most of the farms to provide windbreaks and shade. Some of the trees died when the farms were abandoned in 1943, but others have persisted, presumably because their roots are deep enough to contact groundwater. Today these trees serve as nesting platforms for several species of birds (e.g., hawks, owls, ravens, magpies, and great blue herons), and as night roosts for wintering bald eagles (Cushing 1995). The vegetation mosaic of the Hanford Site currently consists of a variety of diverse plant communities.

The State of Washington has designated large and small blocks of shrub-steppe as priority habitat because these areas possess unique or significant value to many species. The State identifies priority habitats based on the quality of the habitat with respect to the following attributes: comparatively high fish and wildlife density; comparatively high fish and wildlife species diversity; important fish and wildlife breeding habitat; important fish and wildlife seasonal ranges; important fish and wildlife movement corridors; limited availability; high vulnerability to habitat alteration; and unique or dependent species (WDFW 1995). Although Washington State priority habitat designations have no associated legal requirements for habitat protection, DOE Order 430.1 (DOE 1995c) requires that DOE consider ecosystem management and preservation values during all phases of Hanford Site operations.

The DOI National Biological Service identifies native shrub and grassland steppe in Washington and Oregon as an endangered ecosystem (with an 85 to 98 percent decline) (DOI 1995). Almost 600 species of plants have been identified on the Hanford Site (PNNL 1996a). The dominant plants are big sagebrush, rabbitbrush, cheatgrass, and Sandberg's bluegrass, with cheatgrass providing half of the total plant cover on much of the Hanford Site. Cheatgrass and Russian thistle, annuals introduced to the United States from Eurasia in the late 1800s, invade areas where the ground surface has been disturbed. Mosses and lichens appear on undisturbed soil surface; lichens commonly grow on the shrub stems and on basalt outcrops. The important desert shrubs, big sagebrush and bitterbrush, are widely spaced and usually provide less than 20 percent canopy cover. The important native understory plants are grasses, especially Sandberg's bluegrass, Indian ricegrass, June grass, and needle-and-thread grass.

As compared to other semi-arid regions in North America, primary productivity is relatively low and the number of vascular plant species also is low. This situation is attributed to the low annual precipitation (16 cm [6 in.]), the low water-holding capacity of the rooting substrate (sand), and the hot, dry summers and occasionally very cold winters.

The 100 Areas are located in the vicinity of the Columbia River and encompass both riparian and upland habitats. Riparian habitats are found along the shoreline, slack water, and slough areas. Riparian vegetarian includes both woody and herbaceous species. Common plant species occurring in the riparian zone include black cottonwood, mulberry, willow, dogbane, and a variety of grasses and forbs (Cushing 1992). Scattered groves of white mulberry, black locust, Siberian elm, apricot, juniper, and willow were noted in an ecological investigation within the 100-BC-5 and 100-HR-3 operable units (WHC 1992c). The upland vegetation within the 100 Areas is dominated by the non-native annuals, cheatgrass, and tumble mustard on former agricultural lands that were abandoned in 1943 (DOI 1995).

More than 100 species of plants have been identified on the Central Plateau (Cushing 1992). Common plant species include sagebrush, rabbitbrush, cheatgrass, and Sandberg's bluegrass. The dominant vegetation type consists of big sagebrush with an understory of cheatgrass and Sandberg's bluegrass (PNNL 1996a). Cheatgrass provides approximately 50 percent of total plant cover. Most of the waste disposal and storage sites are covered by non-native vegetation or are kept in a vegetation-free condition.

In recent years, a die-off of big sagebrush has been noted on the Hanford Site. A preliminary investigation of the nature and extent of die-off has been conducted. Although the cause remains unknown, early indications focus on the possibility that the die-off might be the result of disease or weather-related stress. The die-off area is estimated to be 1,776 ha (4,390 ac) (Cushing 1992).

Other vegetation within the Central Plateau includes wetland species associated with man-made ditches and ponds on the Central Plateau and introduced perennial grasses (e.g., Siberian wheatgrass) that were planted to revegetate disturbed areas. Wetland species (e.g., cattail and reeds) and trees (e.g., willow, cottonwood, and Russian olive) are established around some of these ponds (PNNL 1996a). However, several of the ponds have been decommissioned, resulting in the elimination of wetland habitat as the supply of industrial waste water feeding the ponds was terminated.

Sixteen different plant community types have been identified on the Wahluke Slope. Cheatgrass and other nonnative species dominate, most likely because of disturbances caused by military training activities, historical livestock grazing, dry soil, and multiple fires. However, the Wahluke Slope still possesses extensive remnants of the original shrub-steppe ecosystem. For example, the most extensive and highest quality antelope bitterbrush and Indian ricegrass plant community in the State of Washington is found on the Wahluke Slope (TNC and Pabst 1995). In 1994, The Nature Conservancy discovered a new plant species of the genus *Lesquerella*. In 1997 field surveys, eight new populations of four taxa were located on the Wahluke Unit Columbia Basin Wildlife Area. All of these populations were located on the White Bluffs. One of the new *Gilia leptomeria* populations is the largest currently known in Washington. Also, the remainder of the only known occurrence of *Lesquerella tuplashensis* was mapped and counted. These discoveries, along with its high habitat quality, illustrate the potential ecological value of the Wahluke Slope.

4.5.2.1 Newly Documented Plant Species. During a 1997 rare plant survey of the Hanford Site conducted by The Nature Conservancy, a total of 35 new populations were found of 14 rare plant taxa identified in Washington as either endangered, threatened, sensitive, or Review Group 1 by the State of Washington. (Review Group 1 includes taxa for which more field work is needed to assess their rarity and the degree to which they are threatened.) One species was newly documented at the Hanford Site, and 10 occurrences of eight taxa were revisited and remapped. Finally, a population of an unlisted plant species, previously unknown from Washington, was discovered. A brief review of significant findings from the 1997 survey in regard to individual species is provided below.

- ***Eriogonum codium*** – Previous to biodiversity surveys, this species was undescribed. It is listed as endangered by the state of Washington and identified as a species of concern by the USFWS. Originally discovered during 1995, the only known occurrence of *Eriogonum codium* was resurveyed, remapped, and recounted during 1997. A total of 5200 plants was estimated to be present. Long-term demographic monitoring was initiated on this species in 1997.

- ***Lesquerella tuplashensis*** **–** Previous to biodiversity surveys, this species also was undescribed, and is listed as endangered by the state of Washington and identified as a species of concern by the USFWS. During 1997 the remainder of the only known occurrence of *Lesquerella tuplashensis* was mapped and counted. The total count of adult plants was estimated to be 50,000 plants. Infestations of a noxious weed, *Centaurea solstitialis* (yellow starthistle), were located within the middle portion of the *Lesquerella* population. Long-term demographic monitoring was initiated on this species in 1997.

Hanford Site populations of two previously undocumented plant species were identified during 1997 field surveys. The two species are described below:

- ***Camissonia minor*** -- This annual species has a scattered distribution within the Columbia Basin. Its range includes most western states. In Washington, it is at the northern end of its range and is known from only Benton and Kittitas Counties. *Camissonia minor* generally occurs on very dry, often barren, and sometimes disturbed sites. Six relatively small populations were documented. On the Hanford Site, *Camissonia minor* occurred in conjunction with a number of other rare plant species. In Washington State, it is currently placed in Review Group 1.

- ***Myosurus* x *clavicaulis*** – This annual species (little mousetail; an "x" before the species name indicated that the species evolved as a hybrid of two other species) was previously unknown in the State of Washington. Its assumed range included Baja California, California, and Oregon. *Myosurus* x *clavicaulis* typically inhabits vernal pools. It occurred on the Hanford Site at a single vernal pool location (see Section 4.3.1). The species also was located during the 1997 field season at five additional vernal pool sites in northeastern Washington. At some locales in the Central Valley of California, the taxonomic status of *Myosurus* x *clavicaulis* is complicated by the presence of other species of *Myosurus*, whose hybrids produce progeny identical to *Myosurus* x *clavicaulis*. At Hanford, however, the *Myosurus* x *clavicaulis* population was self-sustaining and did not occur in the presence of its parental species. The species has no current conservation status in Washington; however, *Myosurus* x *clavicaulis* will be recommended for future tracking by the Washington Natural Heritage Program.

The two major vegetation types occurring along the Hanford Reach of the Columbia River are riparian and upland (NPS 1994). Riparian habitats are found along the shoreline, slack water and slough areas, and on islands in the river. Riparian vegetation at these locations includes both woody and herbaceous species maintained by the high water table immediately adjacent to the river. Common plant species occurring in the riparian zone include black cottonwood, mulberry, willow, dogbane, and a variety of grasses and forbs (Cushing 1992). Sensitive habitats within the riparian zone include islands and cobbled shorelines occurring as a narrow band along the Hanford Reach. Plant species occurring in these areas include perennial summer-blooming forbs adapted to seasonal changes in water levels (NPS 1994). Upland habitats along the Hanford Reach are composed of shrub-steppe vegetation similar to that found on the rest of the Hanford Site.

The ALE Reserve supports one of the largest remnants of relatively undisturbed shrub-steppe ecosystem in the State of Washington. Vegetation on the ALE Reserve includes largely undisturbed stands of several plant communities (e.g., sagebrush-bluebunch wheatgrass, blue bunch wheatgrass, sagebrush-Sandberg's bluegrass, sagebrush-bitterbrush-needle-and-thread grass, cheatgrass, and cottonwoods and willows) (PNL 1993c). Extensive wildfires have removed the shrub component from large areas of the ALE Reserve. These areas now support stands of perennial bunchgrasses at the upper elevations and cheatgrass and bunchgrasses at the lower elevations (PNL 1993c).

Special topographic features of the Hanford Site include Gable Butte and Gable Mountain north of the Central Plateau and an extensive series of active sand dunes in the southeast portion of the Site. Vegetation occurring on scree slopes, outcrops, and scarps on Gable Butte and Gable Mountain is limited to scattered individuals or groups of plants. Plant species include squaw currant, bluebunch wheatgrass, rock buckwheat, and thyme buckwheat. Rigid sagebrush occurs at the Hanford Site only on Gable Mountain and Umtanum Ridge (PNL 1993c).

4.5.2.2 Fire. Plant communities within the shrub-steppe have evolved in the presence of natural wildfires. Typically, shrubs are killed by fire, but the perennial bunchgrasses are not killed. The severity of the damage depends upon the intensity and extent of the fire. Hot fires incinerate entire shrubs and damage grass crowns. Less intensive fires leave dead shrub stems standing with prompt recovery of grasses and forbs. The most recent and extensive wildfire on

Figure 4-22. Distribution of Vegetation Types and Cover Classes on the Hanford Site.

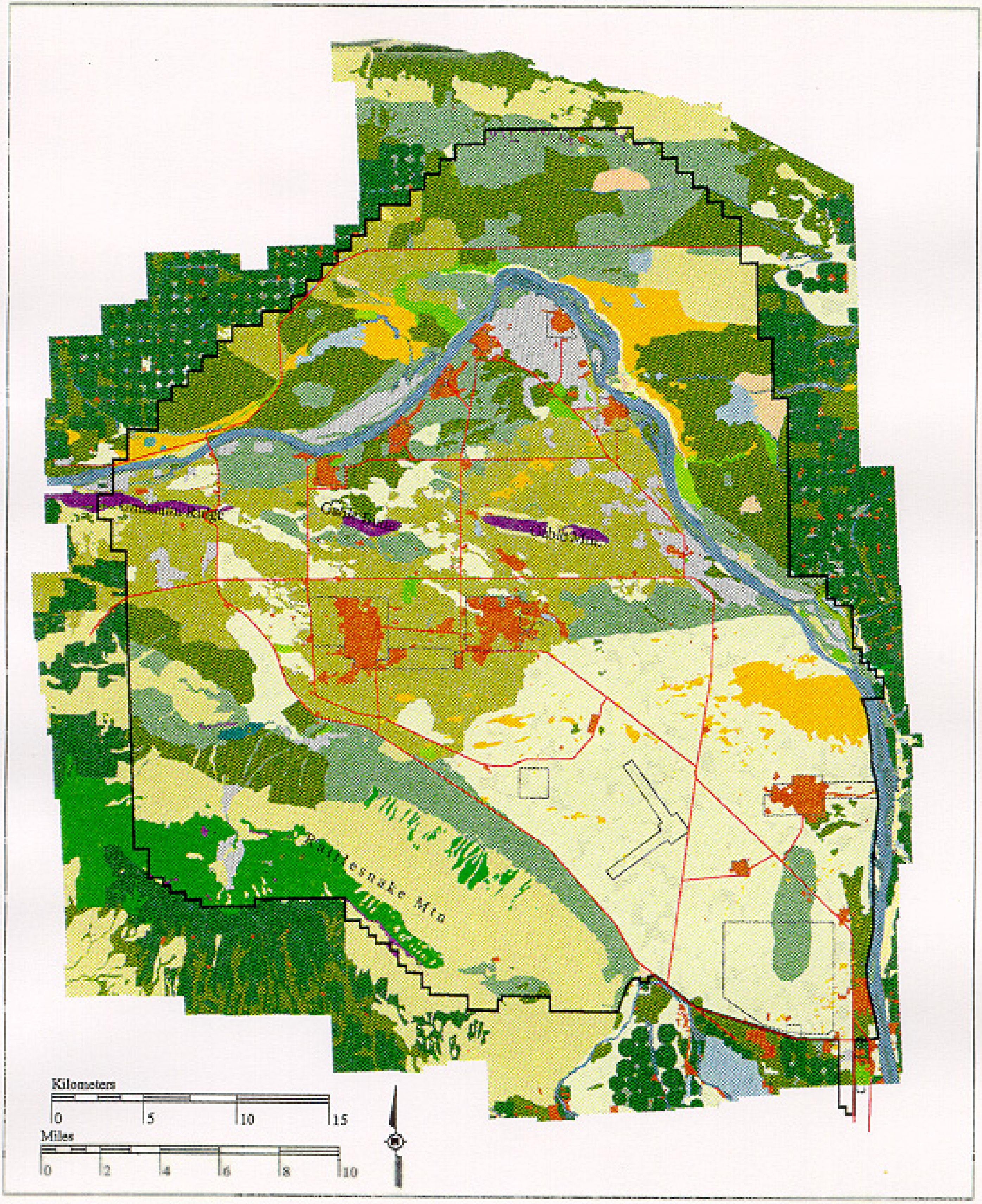


Figure 4-22. Distribution of Vegetation Types and Cover Classes on the Hanford Site (Legend).

- Post-Fire Shrub-Steppe on the Columbia River Plain
- Rabbitbrush / Bunchgrasses
- Rabbitbrush / Cheatgrass
- Big Sagebrush / Bunchgrasses –Cheatgrass
- Big Sagebrush –Spiny Hopsage / Bunchgrasses –Cheatgrass
- Threetip Sagebrush / Bunchgrasses
- Spiny Hopsage / Bunchgrasses
- Spiny Hopsage / Cheatgrass
- Black Greasewood / Sandberg's Bluegrass
- Winterfat / Bunchgrasses
- Winterfat / Cheatgrass
- Snow Buckwheat / Indian Ricegrass
- Bunchgrasses
- Cheatgrass –Sandberg's Bluegrass
- Planted Non-native Grass
- Bitterbrush / Bunchgrasses Sand Dune Complex
- Bitterbrush / Cheatgrass
- Alkali Saltgrass –Cheatgrass
- Riparian
- Basalt Outcrops
- Agricultural Areas
- White Bluffs Cliffs
- Buildings / Parking Lots / Gravel Pits / Disturbed Areas
- Abandoned Old Fields and Farms
- Riverine Wetlands and Associated Deepwater Habitats
- Non-Riverine Wetlands and Associated Deepwater Habitats

the Hanford Site occurred in the summer of 1998 and burned approximately 4,047 ha (10,000 ac). Previous fires occurred in 1957, 1973, and 1981, and 1984 (see Figure 4-22). The presence of non-native plant species and changing land-use practices have altered the frequency and severity of wildfires. Less frequent and more severe fires have reduced the ability of the native habitat to recover from fire, as well as the development of late successional shrub-steppe habitat.

4.5.2.3 Weeds. Non-native weedy species have invaded many areas on the Hanford Site. In particular, weeds have invaded areas that have been disturbed by natural (e.g., fire) and human factors (e.g., pre-Hanford agricultural activities, road and facility construction, etc.). The weed species include, but are not limited to, cheatgrass; Russian thistle; Russian, spotted, and diffuse knapweed; yellow star thistle; Rush skeletonweed; and puncture vines. Cheatgrass and Russian thistle, annuals introduced from Eurasia in the late 1800s, invade areas where the ground surface has been disturbed.

4.5.3 Wildlife

Major habitat types occurring on the Hanford Site include basalt outcrops, scarps and screes, riparian and riverine areas, shrub-steppe, sand dunes and blowouts, and abandoned fields (PNL 1993c). These habitat types support a variety of wildlife.

4.5.3.1 Mammals. Approximately 40 species of mammals have been identified on the Hanford Site (PNNL 1996a). The major predator inhabiting the Hanford Site is the coyote, which ranges all across the Hanford Site. Coyotes have been a major cause of destruction for the nests of Canadian geese on Columbia River islands, especially islands upstream from the abandoned Hanford townsite. Bobcats, cougars, and badgers also inhabit the Hanford Site in low numbers.

Black-tailed jackrabbits are common on the Hanford Site and are mostly associated with mature stands of sagebrush. Cottontail rabbits also are common but appear to be more closely associated with the buildings, debris piles, and equipment laydown areas associated with the onsite laboratory and industrial facilities.

Townsend's ground squirrels occur in colonies of various sizes scattered across the Hanford Site. The most abundant mammal inhabiting the Site is the Great Basin pocket mouse. The mouse occurs all across the Columbia River plain and on the slopes of the surrounding ridges. Other small mammals include the deer mouse, harvest mouse, grasshopper mouse, montane vole, vagrant shrew, and Merriam's shrew.

The Hanford Site has 14 species of bats that are known to be or are potential inhabitants, most of which may be present year-round (PNL 1993d). The pallid bat frequents deserted buildings and is thought to be the most abundant. Other species include the hoary bat, silver-haired bat, California brown bat, little brown bat, Yuma brown bat, and Pacific western big-eared bat.

A herd of Rocky Mountain elk is present on the ALE Reserve. It is believed these animals migrated to the reserve from the Cascade Mountains in the early 1970s. This herd grew from approximately eight animals in 1975 to approximately 420 animals in December 1996 (after the hunting season).[1] Current projections indicate that the elk herd is composed of approximately 800 animals and is still growing. The herd tends to congregate on the ALE Reserve in the winter and disperses during the summer months onto the Site proper, private land to the west of the ALE Reserve, and the Yakima Firing Center. Although lack of water and the high level of human activity presumably inhibit the elk from using other areas of the Hanford Site, the elk are occasionally seen

[1] Personal communication with Brett Tiller, Pacific Northwest National Laboratory, September 22, 1997.

on the 200 Area Plateau and have been sighted at the White Bluffs boat launch. Despite the arid climate, these elk appear to be very healthy; antler and body size for some age classes are among the highest recorded for this species (Neitzel 1997). In addition, reproductive output of this species is also among the highest recorded.

Mule deer are found throughout the Hanford Site, although areas of highest concentrations are on the ALE Reserve and along the Columbia River. Deer populations on the Hanford Site appear to be relatively stable. Islands in the Hanford Reach are used extensively as fawning sites by the deer (Neitzel 1997) and are a very important habitat for this species. Hanford Site deer frequently move offsite and are killed by hunters on adjacent public and private lands (Neitzel 1997).

4.5.3.2 Birds. In general, bird species on the Hanford Site include a variety of raptors, songbirds, and other species associated with riparian, riverine, and upland habitats. The Nature Conservancy recently summarized its findings for birds and mammal surveys. These surveys fall short of the number of species that have been documented on site historically. For example, 178 species were observed in the bird surveys in 1997. This number falls short of the 246 species identified historically (Neitzel 1998). Species of birds found at or near the Hanford Site include common species and accidental species.

Twenty-six species of raptors have been sighted on the Hanford Site, 11 of which are known to nest on the Hanford Site (PNL 1981). The nesting species include the great horned owl, long-eared owl, short-eared owl, barn owl, burrowing owl, northern harrier, ferruginous hawk, Swainson's hawk, red-tailed hawk, prairie falcon, and American kestrel. In 1994, nesting by red-tailed, Swainson's, and ferruginous hawks included 41 nests located across the Hanford Site in relation to high voltage transmission towers, trees, cliffs, and basalt outcrops. In recent years the number of nesting ferruginous hawks on the Hanford Site has increased, as a result in part to their acceptance of steel powerline towers in the open grass and shrubland habitats (Neitzel 1998).

Raptors that may occur year-round on the Hanford Site are the northern harrier, red-tailed hawk, golden eagle, prairie falcon, American kestrel, barn owl, great horned owl, long-eared owl, and burrowing owl (Fitzner and Gray 1991). Raptors use a variety of habitats for nesting and foraging at the Hanford Site. Depending on raptor size and species, prey may include small mammals, birds, reptiles (e.g., snakes), and insects.

Passerine species known to occur in the shrub-steppe vegetation on the Hanford Site include the loggerhead shrike, sage sparrow, western meadowlark, grasshopper sparrow, horned lark, and sage thrasher. The western meadowlark, sage sparrow, and horned lark are the most abundant shrub-steppe passerine bird species that breed on the Hanford Site (Rickard and Poole 1989). The western meadowlark and horned lark nest on the ground in the open, while shrub-steppe species (e.g., the sage sparrow, sage thrasher, and loggerhead shrike) require sagebrush or bitterbrush for nesting habitat.

Common upland game species that occur in shrub and grassland habitat include the 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 WDFW and PNNL during late winter and early spring 1993, and biodiversity inventories conducted by The Nature Conservancy in 1997 did not reveal presence of western sage grouse in sagebrush-steppe habitat at ALE (Neitzel 1998). The McGee Ranch area is viewed by the WDFW as habitat critical to the natural re-establishment of sage grouse populations on the ALE Reserve by providing a habitat corridor to the U.S. Army's

Yakima Training Center.

In addition to upland bird species, numerous species associated with wetlands and riparian habitats are found along the Columbia River and at isolated wetlands on the Hanford Site. Ring-billed and California gulls, Forster's terns, and Canadian geese all form nesting colonies on islands in the Hanford Reach. Large numbers of swallows depend on the Columbia River riparian areas during the summer months, eating flying aquatic insects such as caddis flies and collecting mud from wetted areas to build their nests. The Hanford Site is located in the Pacific flyway and, during the spring and fall months, the Hanford Reach serves as a resting area for neotropical migrants, migratory waterfowl, and shorebirds. During the fall and winter months, large numbers of migratory ducks and geese find refuge along the Hanford Reach. Other species observed during winter months include white pelicans, double-crested cormorants, and common loons.

4.5.3.3 Reptiles and Amphibians. Fifteen species of reptiles and amphibians are known to occur on the Hanford Site (PNNL 1996a). The side-blotched lizard is the most abundant reptile and can be found throughout the Hanford Site. Short-horned and sagebrush lizards are also common in selected habitats. The most common snakes are the gopher snake, the yellow-bellied racer, and the Pacific rattlesnake, all of which are found throughout the Hanford Site. Striped whipsnakes and desert night snakes are rarely found, but some sightings have been recorded for the Site. Toads and frogs (e.g., Great Basin spadefoot toad, Woodhouse's toad, bullfrog, and the Pacific tree frog) are found near the permanent water bodies and along the Columbia River.

4.5.3.4 Insects. Many species of insects occur throughout all habitats on the Hanford Site. Butterflies, grasshoppers, and darkling beetles are among the more conspicuous of the approximately 1,500 species of insects that have been identified from specimens collected on the Hanford Site. The actual number of insect species occurring on the Hanford site may reach as high as 15,000. The recent surveys performed by The Nature Conservancy included the collection of 30,000 specimens and have resulted in the identification of 42 new taxa and 172 new findings in the State of Washington (Neitzel 1998). Insects are more readily observed during the warmer months of the year (see text box, *"Hanford Site Quick Facts: Wildlife"*).

Hanford Site Quick Facts: Wildlife

- 44 species of fish
- 40 species of mammals
- Approximately 238 species of birds
- 15 species of reptiles and amphibians
- Approximately 1,500 species of insects

4.5.4 Terrestrial Wildlife and Habitat

Terrestrial wildlife species use both shoreline riparian and shrub-steppe habitats occurring along the Columbia River and on the islands occurring in the Hanford Reach. Wildlife reported to use the Hanford Reach include 184 species of birds, 36 species of mammals, nine species of reptiles, and four species of amphibians (NPS 1994). Canada geese use the islands along the Hanford Reach extensively for nesting. Studies on the nesting habits of geese that use the Hanford Site have been ongoing since 1953. These studies indicate a general decline over the years in the number of nests on the islands in the Hanford Reach because of heavy predation by coyotes (PNNL 1996a). Mule deer use the islands and other riparian areas for fawning habitat. Wildlife occurring on the shoreline habitat includes 46 species that use willow communities and 49 species that use grass areas (NPS 1994).

Terrestrial wildlife species found in the 100 Areas generally are the same species found across the Hanford Site (Cushing 1992). Coyotes occurring along the Columbia River reportedly feed on carp and small mammals such as the Great Basin pocket mouse, northern pocket gopher, Nuttall's cottontail, and black-tailed jack rabbit (Fitzner and Gray 1991). Mule deer may occur almost anywhere on the Hanford Site but prefer habitats along the Columbia River where riparian areas provide abundant food and cover. Mule deer forage on mulberry, Russian olive, and cottonwood trees, and shrubs such as willow (WHC 1992c).

Wildlife likely to occur in riparian habitat adjacent to the Columbia River includes a variety of birds, mammals, reptiles, and amphibians (Fitzner and Gray 1991). The three known species of amphibians at the Hanford Site use riparian habitat along permanent water bodies and the Columbia River. Medium-size mammals using riparian habitat are the muskrat, raccoon, beaver, weasel, skunk, otter, and porcupine; small mammals include the vagrant shrew and montane meadow mouse. Upland birds likely to occur in habitats in the 100 Areas along the Columbia River are the California quail and ring-necked pheasant (Cushing 1992). Trees along the river, including those found in the 100 Areas, provide habitat for several species of birds. These include the great blue heron, which has colonial nest sites (rookeries) near the White Bluffs ferry landing, and the bald eagle, which uses selected trees for perching and night roosts during the winter (PNNL 1996a).

Terrestrial wildlife species common to the Hanford Site also can be found in the Central Plateau (Cushing 1992). A characterization study of small mammals that occur near the 100-B/C cribs (located south of the 200 East Area) resulted in five species being trapped: Great Basin pocket mouse, deer mouse, northern grasshopper mouse, sagebrush vole, and western harvest mouse (PNL 1977). The Great Basin pocket mouse represented more than 90 percent of the mammals caught. Medium and large-size mammals that may occur in the Central Plateau include rabbits, coyotes, badgers, and mule deer (PNL 1977). Mammals potentially using areas associated with ponds and ditches in the 200 East and 200 West Areas include muskrats, porcupines, and raccoons.

Many common bird species, such as the western meadowlark and sage sparrow, are likely to occur on the Central Plateau where suitable habitats exist. Thirty-seven species of terrestrial birds were recorded during surveys conducted in the 200 East and 200 West Areas of the Hanford Site in 1986 (Schuller et al. 1993). Bird studies associated with waste water ponds in the Central Plateau reveal that a large number of species, particularly waterfowl, use these ponds during migration (PNL 1977).

Unique habitats can be found on Columbia River islands, sand dunes, the cliffs of White Bluffs, and on Gable Butte and Gable Mountain situated north of the Central Plateau (Figure 4-23). The Gable Butte and Gable Mountain unique habitats include basalt outcrops, scarps, and scree slopes. Birds likely to occur in these habitats are the prairie falcon, rock wren, poorwill, and chukar; small mammals include the yellow-bellied marmot and wood rat; reptiles include rattlesnakes, gopher snakes, and horned lizards (PNL 1993c).

4.5.5 Species of Concern on the Hanford Site

Species of concern on the Hanford Site include federally listed threatened or endangered species, state-listed threatened or endangered species, and state candidate species (see text box, *"Hanford's Federal Threatened and Endangered Species"*).

Hanford's Federal Threatened and Endangered Species

Several federally threatened or endangered species might be found at the Hanford Site, including the following:

- Steelhead (Upper Columbia River run)
- Chinook salmon (Upper Columbia River spring-run)
- Steelhead (Middle Columbia River run)
- Aleutian Canada goose*
- Bald eagle*
- Peregrine falcon[1]
- Ute Ladies'-tresses

*To be delisted within two years.
[1]Was delisted August 25, 1999.

Figure 4-23. Plant Communities of Concern on the Hanford Site.

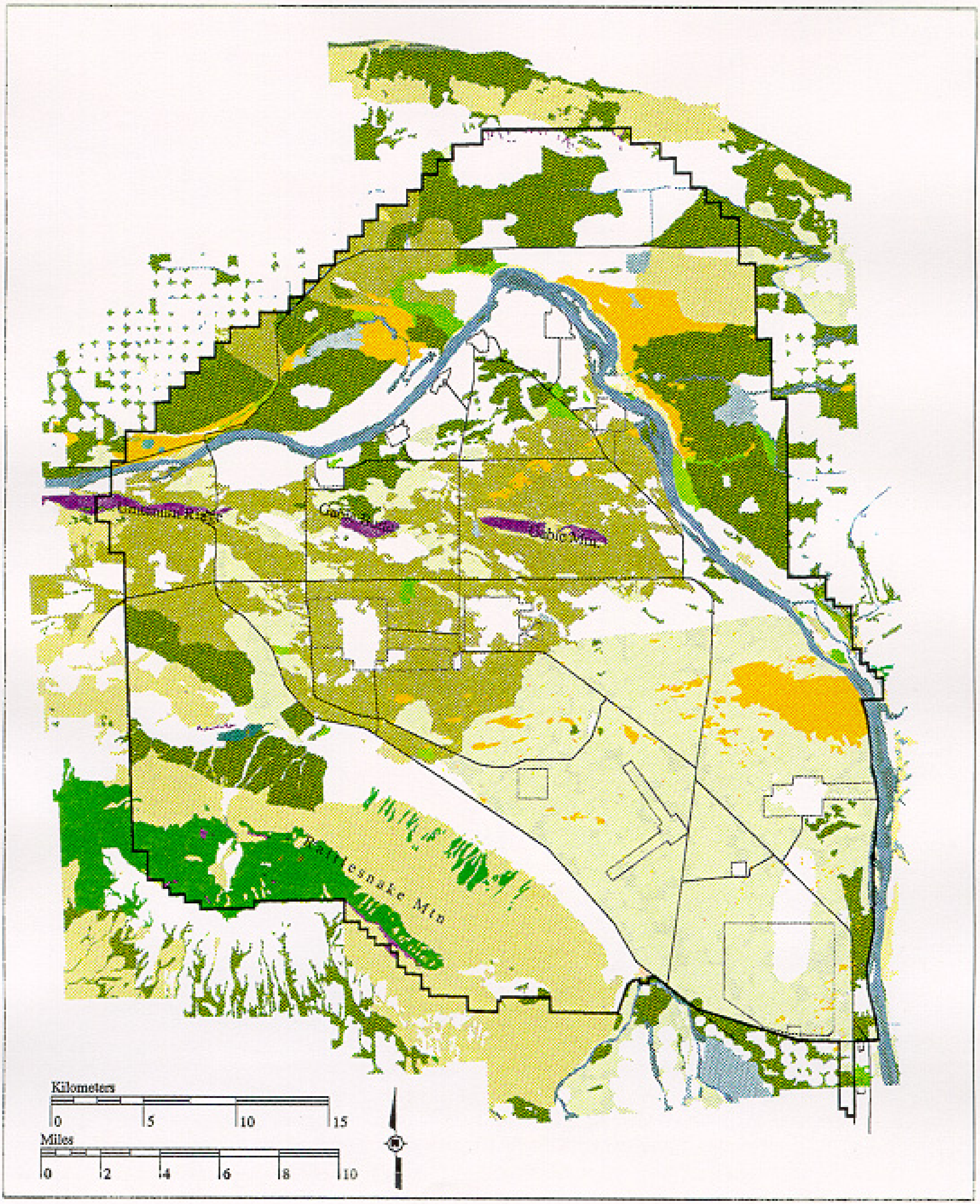


Figure 4-23. Plant Communities of Concern on the Hanford Site (Legend).

- Post-Fire Shrub-Steppe on the Columbia River Plain
- Rabbitbrush / Bunchgrasses
- Big Sagebrush / Bunchgrasses –Cheatgrass
- Big Sagebrush –Spiny Hopsage / Bunchgrasses –Cheatgrass
- Threetip Sagebrush / Bunchgrasses
- Spiny Hopsage / Bunchgrasses
- Spiny Hopsage / Cheatgrass
- Black Greasewood / Sandberg's Bluegrass
- Winterfat / Bunchgrasses
- Winterfat / Cheatgrass
- Snow Buckwheat / Indian Ricegrass
- Bunchgrasses
- Planted Non-native Grass
- Bitterbrush / Bunchgrasses Sand Dune Complex
- Bitterbrush / Cheatgrass
- Alkali Saltgrass –Cheatgrass
- Riparian
- Basalt Outcrops
- White Bluffs Cliffs
- Riverine Wetlands and Associated Deepwater Habitats
- Non-Riverine Wetlands and Associated Deepwater Habitats

- Habitats of Low Value
  - Rabbitbrush / Cheatgrass
  - Cheatgrass –Sandberg's Bluegrass
  - Agricultural Areas
  - Abandoned Old Fields and Farms
  - Buildings / Parking Lots / Gravel Pits / Disturbed Areas

No plants or mammals listed in “Federal List of Endangered and Threatened Wildlife and Plants” (50 CFR 17) are known to occur on the Hanford Site. There are, however, two species of birds, two fish species (two ESU for steelhead) and one suspected plant that are federally listed, and several species of plants and animals are under consideration for formal listing by the State of Washington.

Candidate species occurring on the Hanford Site are considered in the preparation of DOE NEPA documentation. Species of concern occurring on the Hanford Site are listed in Tables 4-6 and 4-7; the tables also include definitions of each category of species of concern.

No federally listed threatened or endangered plant species occur on the Hanford Reach. Nine species of Hanford Site plants are included in the Washington State listing as threatened or endangered (see Table 4-6). Columbia milk-vetch occurs on dry-land benches along the Columbia River near Priest Rapids Dam, Midway, and Vernita; it also has been found atop Umtanum Ridge and in Cold Creek Valley near the ALE Reserve. Dwarf evening primrose has been found north of Gable Mountain, near the Vernita Bridge, Ringold, and on steep talus slopes near Priest Rapid Dam, Midway, and Vernita. Yellowcress occurs in the wetted zone of the water's edge along the Hanford Reach. Northern wormwood is known to occur near Beverly and could inhabit the northern shoreline of the Columbia River across from the 100 Areas. Umtanum desert buckwheat and White Bluffs bladderpod occur on the Hanford Site and no where else in the world. Leoflingia occurs north of Gable Mountain (Neitzel et al. 1998).

Wildlife species of concern that may occur along the Hanford Reach include several species of birds associated with riparian and aquatic habitat (PNL 1993c), the Upper Columbia River spring-run chinook salmon and the Upper and Middle Columbia River runs of steelhead from the confluence of the Yakima River and upstream. The Federal government lists the Aleutian Canada goose, the bald eagle, and Middle Columbia River steelhead as threatened, and the Upper Columbia River steelhead, and Upper Columbia River spring-run chinook salmon as endangered. The State of Washington lists, in addition to the peregrine falcon and Aleutian Canada goose, include the white pelican, sandhill crane, and pygmy rabbit as endangered, and the ferruginous hawk and the bald eagle as threatened. The peregrine falcon is a casual migrant to the Hanford Site and does not nest there. The bald eagle is a regular winter resident and forages on dead salmon and waterfowl along the Columbia River; it does not nest on the Hanford Site although it has attempted to for the past several years (see Table 4-7) (Neitzel et al. 1998).

The bald eagle, a Federal and Washington State threatened species, is the only federally listed wildlife species known to regularly use the 100 Areas. Bald eagles use groves of trees (e.g., black locust, white poplar, and Siberian elm) along the Hanford Reach for winter perching, night roosts, and nesting sites (DOE-RL 1994b). Buffer zones around primary night roosts and nest sites have been established in consultation with the USFWS. While the night-roost locations are consistent from year to year, the nesting sites have varied and are readjusted in consultation with the USFWS each year (see Figure 4-24).

Steelhead and salmon are regulated as evolutionary significant units (ESUs) by the National Marine Fisheries Service based on their historic geographic spawning areas. The Upper Columbia River steelhead ESU was listed as threatened in August 1997. Adult steelhead migrate upstream through the Hanford Reach to spawn in upriver tributaries and juvenile pass through the Hanford Reach on their outward migration to the sea. In March 1999, Upper Columbia River spring run chinook salmon ESU were added as endangered, and the Middle Columbia River steelhead ESU were added as threatened. These races of salmonids utilize habitat in the mid-Columbia River and its tributaries.

Table 4-6. Plant Species of Concern Occurring on the Hanford Site (adapted from PNNL 1996a). (2 pages)

Common Name	Scientific Name	Federal Status	State Status
Ammania	*Ammania robusta*		R1
Annual Paintbrush	*Castilleja exilis*		R1
Bristly Combseed	*Pectocarya setosa*		W
Bristly cryptantha	*Cryptantha spiculifera (= C. interrupta)*		S
Brittle prickly-pear	*Opuntia fragilis*		R1
Canadian St. John wort	*Hypericum majus*		S
Chaffweed	*Centunculus minimus*		R1
Columbia milk-vetch	*Astragalus columbianus*		T
Columbia river mugwort	*Artemisia lindleyana*		E
Columbia yellowcress	*Rorippa columbiae*		E
Coyote tobacco[a]	*Nicotiana attenuata*		S
Crouching milkvetch	*Astragalus succumbens*		W
Dense sedge[a]	*Carex densa*		S
Desert Cryptantha	*Cryptantha scoparia*		R1
Desert dodder	*Cuscuta denticulata*		S
Desert evening primrose	*Oenothera caespitosa*		S
Dr. Bill's Locoweed	*Astragalus conjunctus var. novum*		R1
Dwarf evening primrose	*Oenothera pygmaea*		T
False pimpernel	*Lindernia dubia anagallidea*		R2
Few-flowered collinsia[a]	*Collinsia sparsiflora var. bruciae*		S
Fuzzy beardtongue	*Penstemon eriantherus whitedii*		R1
Geyer's milkvetch	*Astragalus geyeri*		S
Gray cryptantha	*Cryptantha leucophaea*		S
Great Basin Gilia	*Gilia leptomeria*		R1
Hedge Hog Cactus	*Pediocactus sempsonii var. robustior (=P. nigrispinus)*		R1
Hoover's desert parsley	*Lomatium tuberosum*		T
Kittitas Larkspur	*Delphinium multiplex*		W
Loeflingia	*Loeflingia squarrosa var. squarrosa*		T
Medic milkvetch[a]	*Astragalus speirocarpus*		W
Northern wormwood[b]	*Artemisia campestris borealis var. wormskioldii*		E

Table 4-6. Plant Species of Concern Occurring on the Hanford Site (adapted from PNNL 1996a). (2 pages)

Common Name	Scientific Name	Federal Status	State Status
Palouse milkvetch[a]	*Astragalus arrectus*		S
Palouse thistle	*Cirsium brevifolium*		W
Piper's daisy	*Erigeron piperianus*		S
Purple Mat	*Nama densum var. parviflorum*		R1
Robinson's onion	*Allium robinsonii*		W
Rosy balsamroot	*Balsamorhiza rosea*		W
Rosy calyptridium	*Calyptridium roseum*		S
Scilla onion	*Allium scillioides*		W
Shining flatsedge	*Cyperus bipartitus (rivularis)*		S
Small-flowered evening primrose	*Camissonia (Oenothera) minor*		R1
Small-flowered Hemicarpha	*Lipocarpha (=Hemicarpha) aristulata*		R1
Smooth cliffbrake	*Pellaea glabella simplex*		W
Southern mudwort	*Limosella acaulis*		W
Stalked-pod milkvetch	*Astragalus sclerocarpus*		W
Suksdorf's monkeyflower	*Mimulus suksdorfii*		S
Thompson's sandwort[a]	*Arenaria franklinii thompsonii*		R2
Toothcup	*Rotala ramosior*		R1
Umtanum desert buckwheat	*Eriogonum codium*		E
Ute ladies'-tresses[a]	*Spiranthes diluvialis*	T	
White Bluffs bladderpod	*Lesquerella tuplashensis*		E
White eatonella	*Eatonella nivea*		T
Winged combseed	*Pectocarya linearis*		R1

[a] May inhabit the Hanford Site but have not been recently collected, or the known collections are questionable in terms of location and/or identification.

[b] Likely not currently occurring on the Hanford Site.

R1 = Review Group 1. Taxa for which there are insufficient data to support listing as threatened, endangered, or sensitive.

R2 = Review Group 2. Taxa with unresolved taxonomic questions; once resolved these taxa could qualify for listing as endangered, threatened, sensitive.

S = Sensitive. Taxa that are vulnerable or declining, and could become threatened or endangered without active management or removal of threats.

T = Threatened; a species native to Washington State likely to become endangered within the foreseeable future throughout significant portions of its range within the state without cooperative management or the removal of threats. Threatened species are designated in WAC 232-12-011.

E = Endangered; a species native to Washington State that is seriously threatened with extinction throughout all or a significant portion of its range within the state. Endangered species are designated in WAC 232-12-014.

Table 4-7. Wildlife Species of Concern Occurring on the Hanford Site (adapted from Cushing 1995).

Common Name	Scientific Name	Federal Status	State Status
Molluscs			
Columbia pebble snail	*Fluminicola* (= *Lithoglyphus*) *columbiana*		C
Shortfaced lanx	*Fisherola* (= *Lanx*) *nuttalli*		C
Fish			
Steelhead (Upper Columbia River run)	*Onchorhynchus mykiss*	E	
Steelhead (Middle Columbia River run)	*Onchorhynchus mykiss*	T	
Chinook salmon (Upper Columbia spring run)	*Onchorynchus tshawytscha*	E	
Birds			
Aleutian Canada goose[b]	*Branta canadensis leucopareia*	T	E
American white pelican	*Pelecanus erythrorhynchos*		E
Bald eagle	*Haliaeetus leucocephalus*	T	T
Ferruginous hawk	*Buteo regalis*		T
Peregrine falcon[b]	*Falco peregrinus*		E
Sandhill crane[b]	*Grus canadensis*		E
Burrowing owl	*Athene cunicularia*		C
Common loon	*Gavia immer*		C
Flammulated owl[b]	*Otus flammeolus*		C
Golden eagle	*Aquila chrysaetos*		C
Lewis' woodpecker[b]	*Melanerpes lewis*		C
Loggerhead shrike	*Lanius ludovicianus*		C
Northern goshawk[b]	*Accipiter gentilis*		C
Sage sparrow	*Amphispiza belli*		C
Sage thrasher	*Oreoscoptes montanus*		C
Western sage grouse[b]	*Centrocercus urophasianus*		C
Insects			
Columbia River tiger beetle[b]	*Cicindela columbica*		C
Juniper hairstreak	*Mitoura siva*		C
Silver-bordered bog fritillary	*Boloria selene atrocastalis*		C
Reptiles			
Striped whipsnake	*Masticophis taeniatus*		C
Mammals			
Merriam's shrew	*Sorex merriami*		C
Pacific (Townsend's) western big-eared bat[b]	*Corynorhinus townsendii* (also known as *Plecotus townsendii)*		C
Pygmy rabbit[a]	*Brachylagus idahoensis*		E
Washington ground squirrel	*Spermophilus washingtoni*		C

[a] Likely not occurring on the Hanford Site.
[b] Reported as possibly occurring on the Hanford Site.
C = Candidate; a native species that the state or Federal Departments of Fish and Wildlife has enough substantial information on biological vulnerability to support proposals to list them as endangered or threatened species.
E = Endangered; a species that is seriously threatened with extinction throughout all or a significant portion of its range. Endangered species are designated in WAC 232-12-014 or 50 CFR 17.
T = Threatened; a species that is likely to become endangered within the foreseeable future throughout significant portions of its range without cooperative management or the removal of threats. Threatened species are designated in WAC 232-12-011 or 50 CFR 17.

4.5.6 Aquatic Species and Habitat

There are two primary types of natural aquatic habitats on the Hanford Site: (1) the Columbia River, which flows along the northern and eastern edges of the Hanford Site; and (2) the small spring-streams and seeps located mainly in the Rattlesnake Hills. Several artificial water bodies, both ponds and ditches, have been formed as a result of waste water disposal practices associated with the operation of the reactors and separation facilities. These bodies of water are temporary and will vanish with cessation of activities, but while present, the ponds form established aquatic ecosystems (except the West Pond), complete with representative flora and fauna. The West Pond, also known as West Lake, is created by a rise in the water table in the Central Plateau and is not fed by surface flow; thus, the pond is alkaline and has low species diversity.

Forty-four species of fish representing 13 families are known to occur in the Hanford Reach (PNNL 1996a). Of these species, chinook salmon, sockeye salmon, coho salmon, steelhead, and Pacific lamprey use the Columbia River as a migration route to upstream spawning areas. Other fish of importance to sport fishermen are whitefish, sturgeon, small-mouth bass, catfish, walleye, and perch. Large populations of rough fish also are present, including carp, shiners, suckers, and squawfish (PNNL 1996a).

The Hanford Reach represents the only remaining significant mainstream Columbia River spawning habitat for stocks of Upper Columbia River summer/fall-run chinook salmon and white sturgeon (PNL 1990a). Since 1948, an annual census of salmon spawning on the Hanford Reach indicates that over 60 percent of fall chinook spawning occurs at Vernita Bar and the Locke Island area near White Bluffs (PNL 1993c). The numbers of fall chinook spawning sites (redds) in the Hanford Reach increased between the late 1940s and the 1980s. In 1988, the Hanford Reach served as the spawning area for 50 to 60 percent of the total fall chinook salmon runs in the Columbia River (Figure 4-25) (PNNL 1996a).

The Upper Columbia River run of steelhead has been federally listed as endangered. These fish spawn in and migrate through the Hanford Reach. Recent population estimates indicate that Upper Columbia River steelhead run has declined to fewer than 1,400 fish, prompting listing by the National Marine Fisheries Service (62 FR 43974). On March 16, 1999, the Upper Columbia River spring-run chinook salmon was added as endangered, and the Middle Columbia River steelhead was added as threatened.

1 **Figure 4-24. Bald Eagle Primary Night Roosts and Nest**
2 **Sites (PNNL database).**

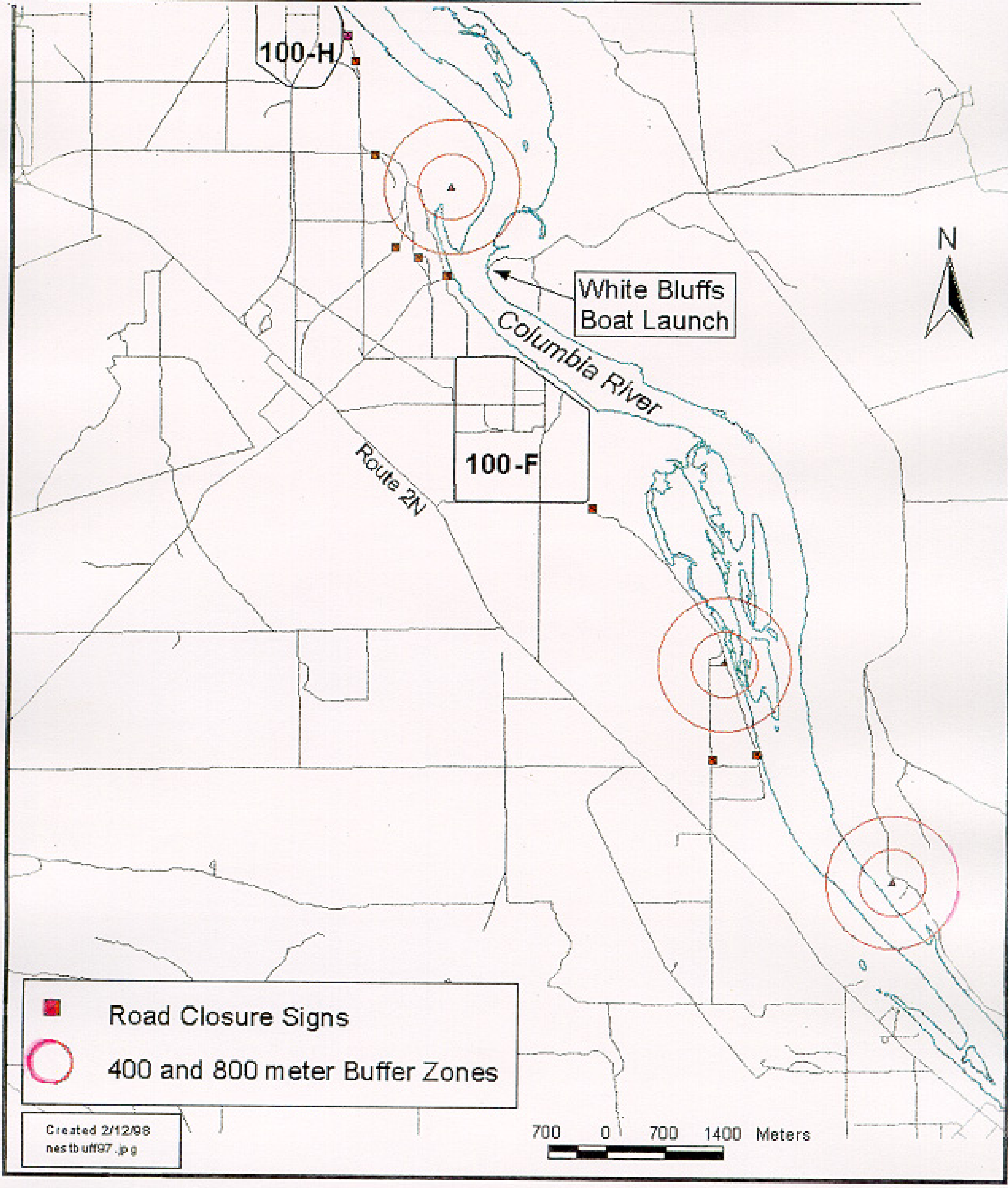
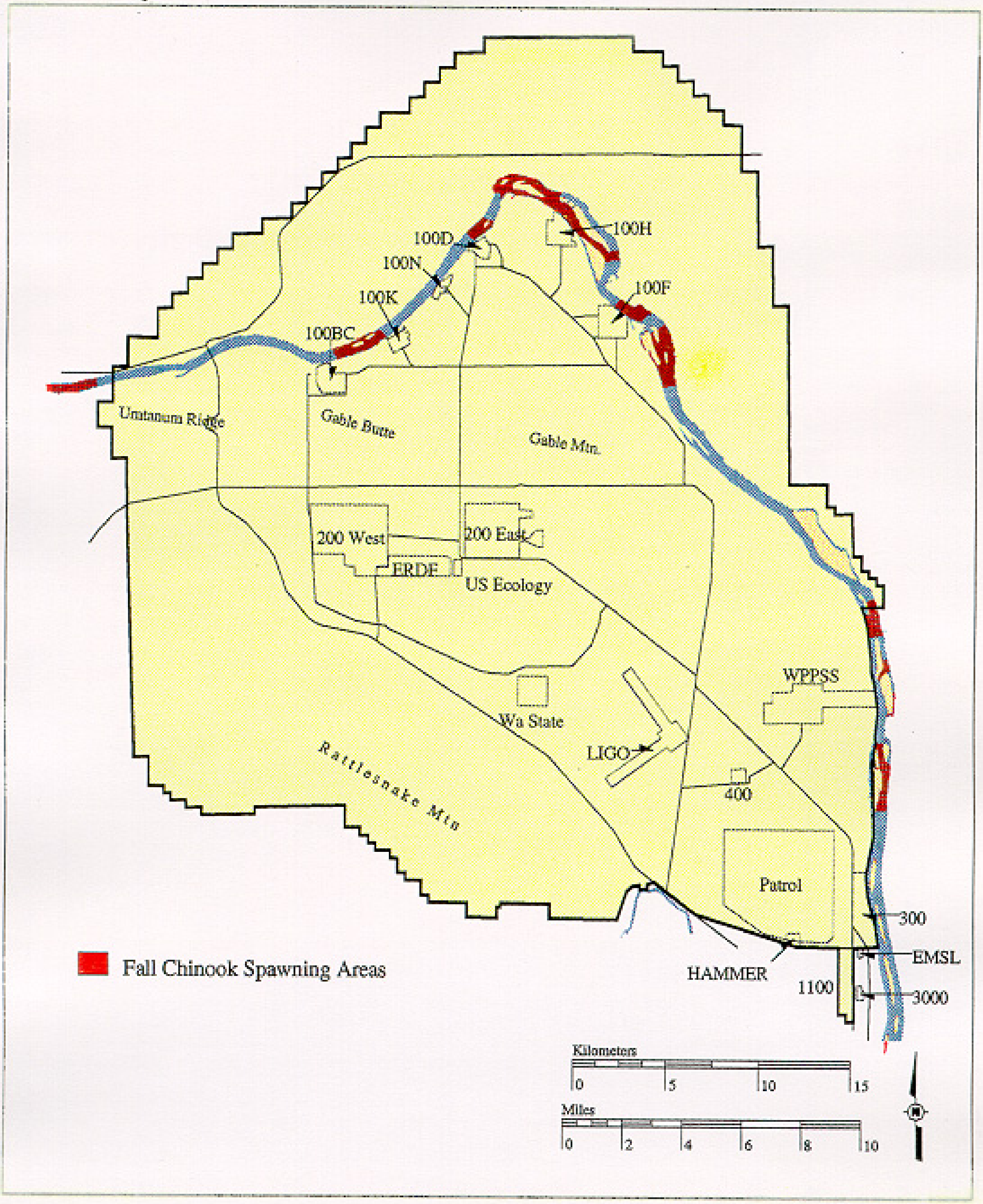


Figure 4-25. Key Fall Chinook Salmon Spawning Areas.



Steelhead follow a life cycle similar to salmon, but with one distinct difference; salmon die after spawning, but steelhead migrate back to the ocean and a small percentage return in subsequent years to spawn again. Little is known about the quality and quantity of steelhead spawning, rearing, and adult holding habitat in the Hanford Reach. Counts from 1972 and 1988 indicate that about 20,000 steelhead passed McNary Dam but did not pass Priest Rapids or Ice Harbor Dam. Some of these fish would enter the Yakima River while others would be caught in the Hanford Reach sport fishery. The remainder represent potential spawners. A substantial number of steelhead do terminate their migration in the Hanford Reach.

Aquatic plants in the Hanford Reach include water milfoil, waterweed, pondweed, Columbia yellowcress, watercress, and duckweed (PNNL 1996a). Aquatic plants generally are more prevalent where currents are less swift (e.g., in slack water areas like sloughs) (WHC 1992c). Aquatic plants are important to resident fish because they provide food, cover, and spawning areas for a variety of species. Water milfoil, an aggressive introduced aquatic plant, is becoming a nuisance in the Columbia River because of its rapid growth and lack of natural control.

Other aquatic species found in the Hanford Reach include a variety of microflora, zooplankton, and benthic invertebrates. Microflora include both sessile types (periphyton) and free-floating types (phytoplankton). Microflora species include diatoms, golden or yellow-brown algae, green algae, blue-green algae, red algae, and dinoflagellates. Dominant zooplankton taxa include *Bosmina*, *Diaptomus*, and *Cyclops*. Benthic invertebrate taxa occurring in the Hanford Reach include insect larvae such as caddis flies, midge flies, black flies, snails, freshwater sponges, limpets, and crayfish (PNNL 1996a).

The small spring-streams, such as Rattlesnake and Snively Springs, contain diverse biotic communities and are extremely productive (PNNL 1996a). Dense blooms of watercress occur and are not lost until a major flash flood occurs. The aquatic insect production is fairly high as compared to that in mountain streams (PNNL 1996a). The macrobenthic biota varies from site to site and is related to the proximity of colonizing insects and other factors.

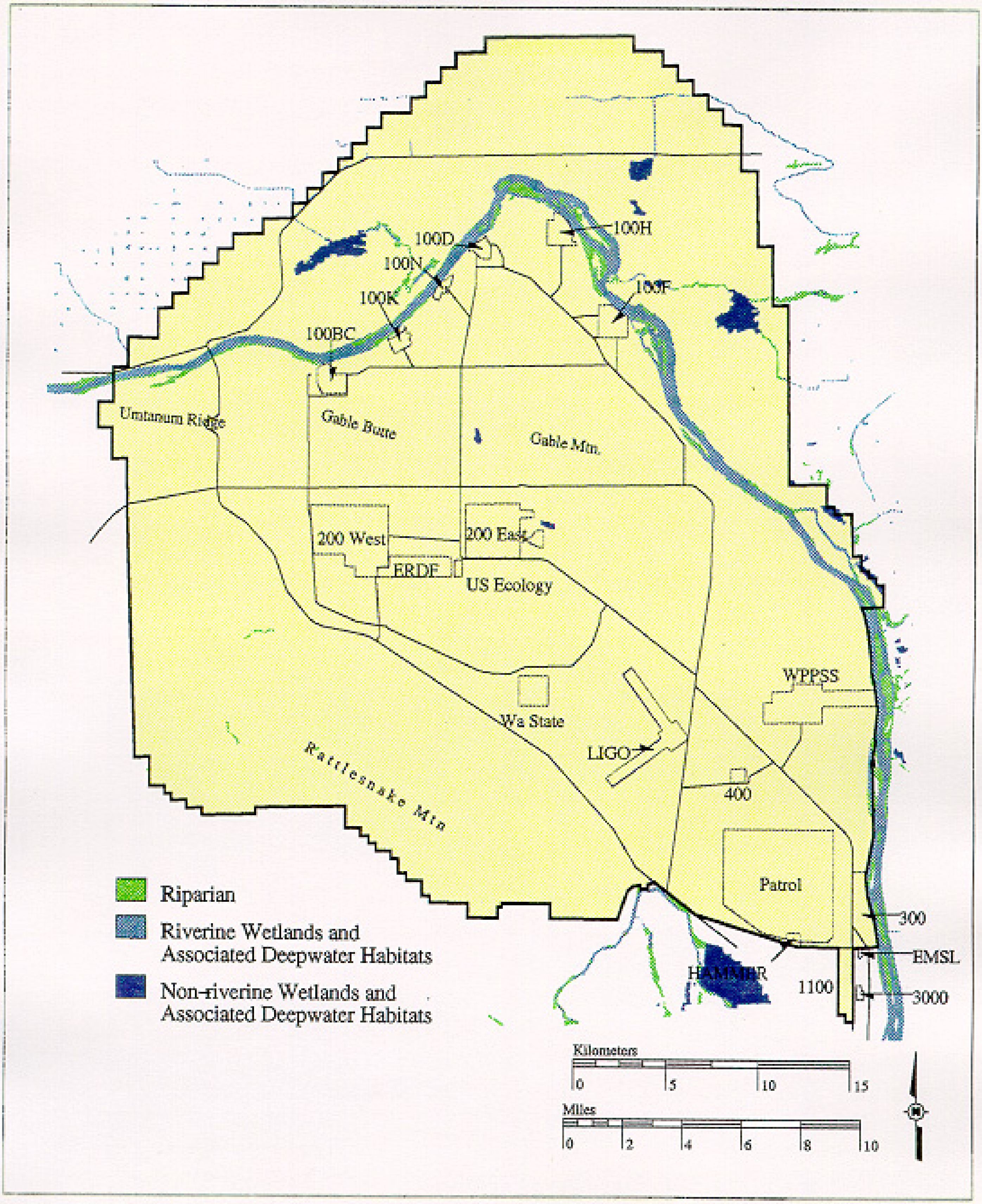
4.5.7 Wetland Habitat

Wetlands include transitional lands occurring between terrestrial and aquatic ecosystems (Figure 4-26) where the water table usually is close to the surface or where shallow water covers the surface. The primary jurisdictional wetlands found on the Hanford Site occur along the Hanford Reach and include the riparian and riverine habitats located along the river shoreline. Riparian habitat includes the uplands immediately adjacent to the Hanford Reach or its backwater sloughs and supports vegetation typical of a high water table (NPS 1994). Common riparian species found along the Hanford Reach include a variety of woody and herbaceous plant species.

Other wetland habitats found on the Hanford Site are associated with man-made ponds and ditches occurring on the Hanford Site, including the B Pond Complex located near the 200 East Area and a small cooling and waste water pond in the 400 Area. The B Pond complex was constructed in 1945 to receive cooling water from facilities in that area. Since that time, effluent flow to the B Pond has halted. One lobe of the pond received cooling water until very recently; the rest of the B Pond complex is slowly reverting to a shrub-steppe ecosystem.

The West Lake, a shallow, highly saline, and alkaline pond located southwest of Gable Mountain, fluctuates in size with changes in the water table (PNL 1991b) and is currently less than 2 ha (5 ac) in size. Unlike other ponds on the Hanford Site, West Lake does not receive direct effluent discharges from Hanford Site facilities (PNL 1993a). Wetland vegetation found at West Lake is limited to scattered patches of emergent macrophytes, such as cattails and bulrushes.

Figure 4-26. Wetlands on the Hanford Site.



4.5.8 Biological Resources Management

The DOE is currently in the process of developing and implementing an overall management strategy for the conservation of fish, wildlife, and plant populations and their habitats on the Hanford Site. The Draft *Hanford Site Biological Resources Management Plan* (BRMaP) (DOE-RL 1996c) was developed to provide DOE and its contractors with a consistent approach to protect biological resources and to monitor, assess, and mitigate impacts from Hanford Site development, and environmental cleanup and restoration activities. The primary purposes of the BRMaP are (1) to support DOE Hanford missions; (2) to provide a mechanism for ensuring compliance with laws that relate to the management of potential impacts to biological resources; (3) to provide a framework for ensuring appropriate biological resource goals, objectives, and tools are in place to make DOE an effective steward of the Hanford Site biological resources; and (4) to implement an ecosystem management approach for biological resources on the Site.

Plant communities of concern have been identified for the Hanford Site using classifications from BRMaP. These classifications associate different management actions (i.e., monitoring, impact assessment, mitigation, and preservation) with particular sets of biological resources. The BRMaP classifies Hanford Site biological resources into four levels of management concern (Figure 4-27), which can be summarized as follows:

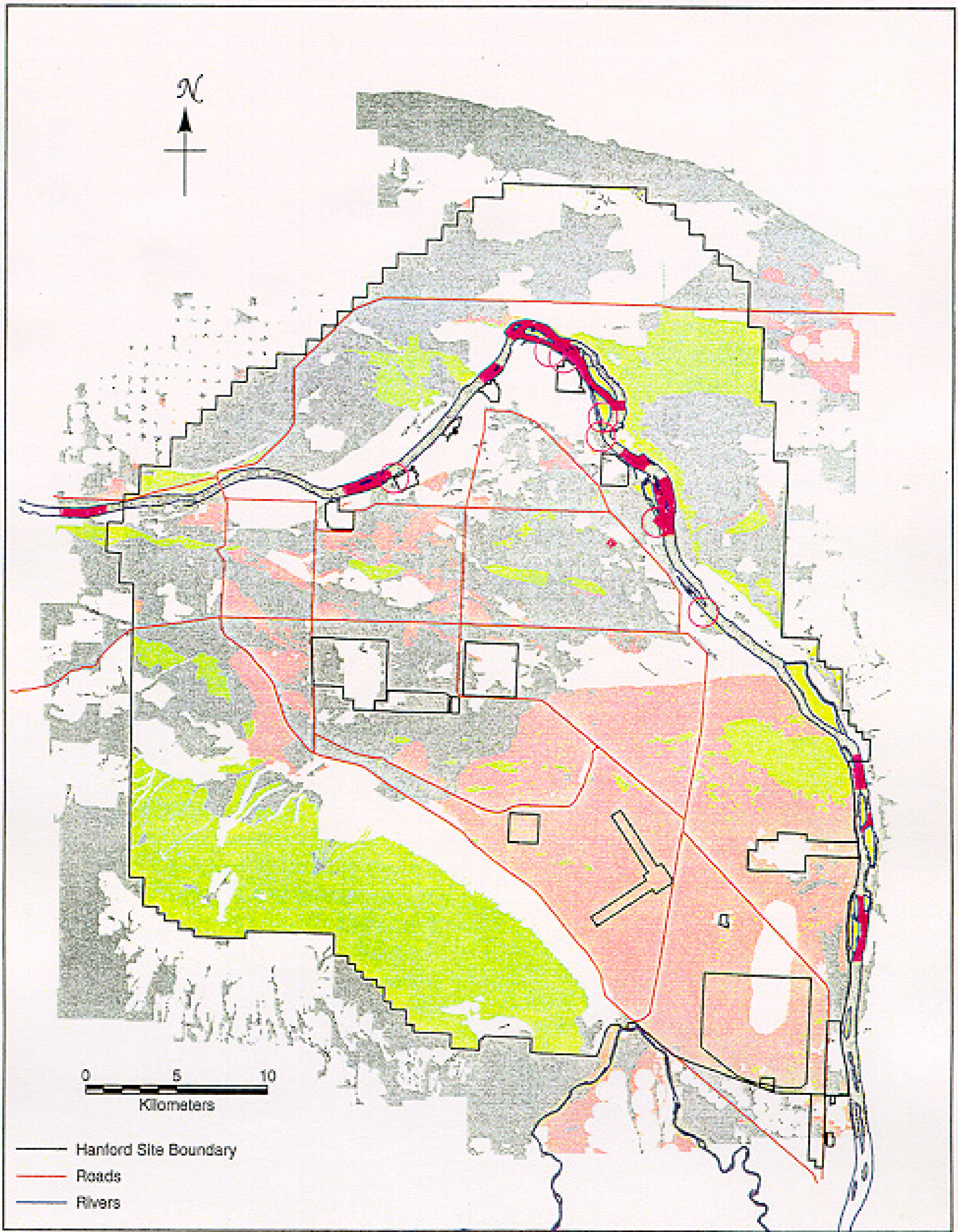
- **Level I** biological resources are resources that require some level of status monitoring because of the recreational, commercial, or ecological role or previous protection status of the resources. Level I includes Washington State Monitor 3 species (DOE-RL 1996).

- **Level II** biological resources require consideration of potential adverse impacts from planned or unplanned Hanford Site actions for compliance with procedural and substantive laws such as NEPA, CERCLA, and the *Migratory Bird Treaty Act of 1918*. Mitigation of potential impacts by avoidance and/or minimization is appropriate for this level; however, additional mitigation actions are not required. Level II resources include Washington State Monitor 1 and 2 species and early successional habitats.

- **Level III** biological resources require mitigation because the resource is listed by the State of Washington; is a candidate for Federal or state listing; is a plant, fish, or wildlife species with unique or significant value; has a special administrative designation (e.g., the ALE Reserve); or is environmentally sensitive. When avoidance and minimization are not possible, or application of these measures still results in adverse residual impacts above a specified threshold value, mitigation by rectification and/or compensation is required. Maintenance of Level III resource values may prevent more restrictive and costly management prescriptions in the future. Level III resources include Washington State candidate and sensitive species, threatened and endangered species, Federal candidate species, wetlands and deep-water habitats, and late-successional habitats.

- **Level IV** biological resources that justify preservation as the primary management option because these resources are federally protected or have regional and national significance. The plant communities and habitats that are defined as belonging to this level are of such high quality and/or rarity that damages to these resources cannot be mitigated except through compensatory mitigation by acquiring and protecting in-kind resources. The legally protected species that are included in Level IV cannot be impacted without the concurrence of the USFWS, so these types of impacts do not jeopardize the continued existence of the

Figure 4-27. Composite Map of Level II, Level III, and Level IV Biological Resources.



Map Created: September 1996/Pacific Northwest National Laboratory

Level II Resources

Level III Resources (Species-Based Resources Not Separately Shown)

Level IV Habitat-Based Resources

Level IV Species-Based Resources

species. Level IV resources include Federal threatened and endangered species and those species proposed for listing, rare habitats such as the White Bluffs, active and stabilized sand dunes, and basalt outcrops.

The BRMaP provides a broad, but comprehensive, direction that specifies DOE biological resource policies, goals, and objectives and prescribes how they would be met. Two subordinate implementing documents outline specific management actions necessary to meet the policies, goals, and objectives, as described below:

- The *Ecological Compliance Assessment Management Plan* (DOE-RL 1995a) outlines the methods to be used to evaluate and quantify environmental impacts.

- The Draft *Hanford Site Biological Resources Mitigation Strategy Plan* (BRMiS) (DOE-RL 1996) is designed to aid DOE in balancing its primary missions of environmental restoration, technology development, and economic diversification with its stewardship responsibilities for the biological resources it administers. The BRMiS would (1) ensure consistent and effective implementation of mitigation recommendations and requirements; (2) ensure that mitigation measures for biological resources meet the responsibilities of DOE under both the *National Environmental Policy Act of 1969* (NEPA) and the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA); (3) enable Hanford Site development and cleanup projects to anticipate and plan for mitigation needs through early identification of mitigation requirements; (4) provide guidance to Hanford personnel in implementing mitigation in a cost-effective and timely manner; and (5) preserve Hanford biological resources while facilitating balanced development and Site restoration activities.

These draft management plans are currently in trial use at the Hanford Site for a one-year period. The plans are presented as guidance, not requirements. The plans have been issued to various resource agencies, organizations, and stakeholders for review and comment, and it is expected that once comments are received and on-the-ground implementation experience is gained, the plans would be revised and issued as Hanford Site requirements.

4.5.9 Biodiversity

The principles of ecosystem management and sustainable development are the foundation upon which DOE manages its lands and facilities. Comprehensive plans guide land- and facility-use decisions by addressing ecological, social, and cultural factors, as well as Site mission and economics. This DOE policy would result in land and facility uses that support DOE's mission at Hanford, while stimulating the economy and protecting the environment (CEQ 1993).

Biodiversity, a critical component of comprehensive land-use planning, has been defined as the diversity of ecosystems, species, and genes, and the variety and variability of life (CEQ 1993). Major components of biodiversity are plant and animal species, micro-organisms, ecosystems and ecological processes, and the inter-relationships between and among these components. Biodiversity also is a qualitative measure of the richness and abundance of ecosystems and species in a given area (NPS 1994).

Features contributing to biodiversity on the Hanford Site include one of the largest undisturbed tracts of native shrub-steppe habitat left in Washington State and the Hanford Reach, which is the last free-flowing nontidal stretch of the Columbia River in the United States (PNNL 1996a). Other influencing factors include topographic features such as Rattlesnake Mountain, Gable Butte, and Gable Mountain; a variety of soil textures ranging from sand to silty and sandy loam; and most importantly, the lack of human use and development over much of the Hanford Site. Specialized terrestrial habitats contributing to the biodiversity of the Hanford Site include areas of sagebrush-steppe, basalt outcrops, scarps (cliffs), scree slopes, and sand dunes. Aquatic components of biodiversity are mainly associated with the Columbia River and include aquatic habitat, wetland and riparian areas, and riverine habitat along Hanford Reach shoreline and islands in the Columbia River. Ecologically important plant and animal species on the Hanford Site include species of concern; commercial and recreational wildlife species (e.g., anadromous fish, mule deer, and upland game birds); and plant species used as a source of food, medicine, fiber, and dye by native peoples of the Columbia Basin (WHC 1992d).

In 1992, DOE and The Nature Conservancy entered into a Memorandum of Understanding that called for a cooperative and coordinated inventory of plants, animals, and ecologically significant areas at the Hanford Site. In 1994, DOE awarded The Nature Conservancy a grant to conduct a partial inventory of the Hanford Site on the ALE Reserve and the Wahluke Slope. The inventory, which was conducted from March 1994 to March 1995, showed that the Hanford Site supports a rich mosaic of relatively unaltered and increasingly uncommon native habitats, the quality and extent of which are unequaled within the Columbia Basin (TNC and Pabst 1995). Significant numbers of plant, bird, and insect species, many of which are rare or in declined numbers in Washington State, were found to be associated with or dependent on these habitats. The Hanford Site serves as a genetic bank for both the common and unusual plants and animals that comprise the shrub-steppe ecosystem. This initial inventory can provide only a rough indication of the quality of biodiversity that is to be found on the main part of the Hanford Site, which is more extensively disturbed than the ALE Reserve or the Wahluke Slope. Additional inventories are being performed of the main part of the Hanford Site and may include studies of small mammals, reptiles and amphibians, and nonvascular plants.

The central portion of the Hanford Site has not been farmed or grazed by livestock for over 50 years, allowing the Hanford Site to serve as a refuge for various plant and animal species (PNNL 1996a). However, the invasion and spread of non-native plant species into previously disturbed areas represents a potential threat to biodiversity through displacement of native species, simplification of plant communities, and fragmentation of habitat. Introduced plant species account for approximately 21 percent of the vascular plants found on the Hanford Site and include species such as cheatgrass, Russian thistle, and most of the tree species found on the Hanford Site (WHC 1992f). Most of the disturbed areas on the Hanford Site, including abandoned farmland and areas burned by wildfire, are dominated by nearly pure stands of cheatgrass where the native shrub component has been modified severely or replaced altogether (Cushing 1992).

Human activities may have profound effects on the biodiversity of an ecosystem or community. Among other factors, these human activities include habitat modification or destruction and habitat fragmentation. Destruction or modification of a habitat can occur when undisturbed areas are harvested or converted to other uses, such as agriculture or industrial facilities. Habitat fragmentation occurs when disturbed areas break up a large community into smaller isolated undisturbed areas. When fragmentation occurs, biodiversity is impacted because the smaller undisturbed areas may not be capable of supporting the same number of species. The edges of the undisturbed area also may be strongly affected by proximity to the disturbed area, further reducing the size of the area that is truly undisturbed. Furthermore, the disturbed areas may serve as migration barriers for some species, effectively blocking recolonization of areas where small localized extinctions have occurred. Areas such as the Hanford Site serve to preserve regional biodiversity by providing refuges for species that have been eliminated by human activities in the surrounding region.

4.6 Cultural Resources

The Hanford Site is known to be rich in cultural resources, with numerous, well-preserved archaeological sites representing the period since American Indian contact with Euro-Americans, and the period prior to that contact. These periods are often referred to as "prehistoric" and "historic," but these terms do not recognize the fact that members of Tribal Nations have maintained an active oral history for a long period of time that predates the contact with Euro-Americans. For this reason, the EIS will use the terms "post-contact" and "pre-contact" to describe these periods when appropriate. Management of the Hanford Site cultural resources follows the Draft *Hanford Cultural Resources Management Plan* (CRMP) (DOE-RL 1999) and is conducted for DOE by the Cultural Resources staff of the Environmental Restoration Contractor team, in partnership with the Fluor Daniel Hanford, Inc., staff historian and the Hanford Cultural Resources Laboratory (HCRL) of PNNL (see text box, *"Hanford Site Quick Facts: Cultural Resources*").

> ***Hanford Site Quick Facts: Cultural Resources***
>
> About 8 percent of the Hanford Site has been surveyed. From those surveys, 964 cultural resource sites and isolated finds have been recorded to date. Each find of one or more features (nonportable, nondiscrete artifacts), or of three or more artifacts within 10 m (33 ft) of each other, will be designated as a site and duly recorded in the files of the Washington State Office of Archaeology and Historic Preservation. All other objects are isolated finds (i.e., isolates). Forty-nine properties are listed on the National Register.

The CRMP, which was approved by the State Historic Preservation Office (SHPO) in 1989, was developed to establish guidance for the identification, evaluation, recordation, curation, and management of archaeological, historic, and traditional cultural resources as individual entities or as contributing properties within a district. The plan specifies methods of consultation with affected Tribes and Tribal Historic Preservation Officers, government agencies, and interested parties, and includes strategies for the preservation and/or curation of representative properties, archives, and objects.

Cultural resources are defined as any district, Site, building, structure, or object considered to be important to a culture, subculture, or community for scientific, traditional, religious or other reasons. For the purpose of this Final HCP EIS, these resources are divided into several categories: pre-contact and post-contact archaeological resources, architectural resources, and traditional (American Indian) cultural resources. Significant cultural resources are those that are eligible or potentially eligible for listing in *The National Register of Historic Places* (National Register) (NPS 1988).

Consultation is required to identify the traditional cultural properties that are important to maintaining the cultural heritage of American Indian Tribes. Under separate treaties signed in 1855, the Confederated Tribes and Bands of the Yakama Nation and the Confederated Tribes of the Umatilla Indian Reservation ceded lands to the United States that include the present Hanford Site. Under the treaties, the Tribes reserved the right to fish at usual and accustomed places in common with the citizens of the territory, and retained the privilege of hunting, gathering roots and berries, and pasturing horses and cattle upon open unclaimed land. The Tribes also reserved the right to erect temporary buildings at usual and accustomed places. The Treaty of 1855 with the Nez Perce Tribe includes similar reservations of rights, and the Hanford Reach is identified as the location of usual and accustomed places. The Wanapum People are not signatory to any treaty with the United States and are not a federally recognized Tribe; however, the Wanapum People were historical residents of the Hanford Site, and their interests in the area have been acknowledged.

The methodology for identifying, evaluating, and mitigating impacts to cultural resources is defined by Federal laws and regulations including the *National Historic Preservation Act of 1966*, the *Archaeological Resources Protection Act of 1979*, the *Native American Graves Protection and Repatriation Act of 1990*, and the *American Indian Religious Freedom Act of 1978*. A project affects a significant resource when it alters the characteristics of the property, including relevant features of its environment or use, that qualify it as significant according to the National Register criteria. These effects may include those listed in 36 CFR 800.9. Impacts to traditional American Indian properties can be determined only through consultation with the affected American Indian groups.

In 1995, 964 cultural resource sites and isolated finds were recorded in the files of the Hanford Cultural Resources Laboratory (HCRL) (PNNL 1996a). Forty-eight archaeological sites and one building are included on the National Register. National Register nominations have been prepared for several archaeological districts and sites considered to be eligible for listing on the National Register. While many significant cultural resources have been identified, only a small portion of the Hanford Site has been surveyed by cultural resource specialists and few of the known sites have been evaluated for their eligibility for listing in the National Register. Many additional cultural resources may remain unidentified. Cultural resource reviews are conducted when projects are proposed in areas that have not been previously surveyed. About 100 to 120 reviews were conducted annually through 1991; this figure rose to more than 360 reviews during 1995 (PNNL 1996a).

4.6.1 Pre-Contact Archaeological Resources

People have inhabited the middle Columbia River region since the end of the glacial period. More than 8,000 years of precontact human activity in this largely arid environment have left extensive archaeological deposits. Certain areas inland from the river show evidence of concentrated human activity, and recent surveys indicate extensive, although dispersed, use of arid lowlands for hunting. Graves are common in various settings, as are spirit quest monuments (Neitzel et al. 1998). Throughout most of the region outside of Hanford, 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 the remainder of the resources. Within the Hanford Site, from which the public is restricted, archaeological resources found in the Hanford Reach and on adjacent plateaus and mountains have been spared some of the disturbances that have befallen other sites. The Hanford Site is, thus, a *de facto* reserve of archaeological information of the kind and quality that has been lost elsewhere in the region.

Currently, about 320 prehistoric archaeological sites have been recorded on the Hanford Site. Forty eight of these sites are included on the National Register of Historic Places; two are single sites and the remainder are located in seven archaeological districts. In addition, several National Register nominations are pending and nine individual archaeological sites have been determined to be eligible for listing. Archaeological sites include the remains of numerous pithouse villages, campsites and graves, spirit quest monuments, hunting camps, game drive complexes, quarries, hunting and kill sites, and small temporary camps (Neitzel et al. 1998).

Recorded sites were found during archaeological reconnaissance projects conducted between 1926 and 1968. Systematic archaeological surveys conducted from the middle 1980s through 1995 are responsible for the remainder. The 100 Areas were surveyed in the early 1990s, revealing other archaeological sites (DOI 1995a).

4.6.2 American Indian Cultural Resources

In pre-contact and early contact periods, the Hanford Reach was populated by American Indians of various Tribal affiliations. The Wanapum People and the Chamnapum Band lived along the Columbia River from south of Richland upstream to Vantage (DOI 1995a). Some of their descendants still live nearby at Priest Rapids, and others have been incorporated into the Yakama and Umatilla Reservations. Palus People, who lived on the lower Snake River, joined the Wanapum, Nez Perce, and Chamnapum to fish the Hanford Reach, and some inhabited the east bank of the river (DOI 1995a). Walla Walla and Umatilla People also made periodic visits to fish in the area. These people retain traditional secular and religious ties to the region, and many have knowledge of the ceremonies and lifeways of their culture. The Washani, or Seven Drums religion, which originated among the Wanapum on what is now the Hanford Site, is still practiced by many people on the Yakama, Umatilla, Warm Springs, and Nez Perce Reservations. Native plant and animal foods, many of which are abundant on the Hanford Site, are used in the ceremonies performed by sect members of this religion, as well as other American Indians who conduct traditional activities (Neitzel et al. 1998).

During public scoping of this EIS, Tribal governments emphatically expressed an interest in renewing their use of these resources in accordance with the Treaties of 1855. The DOE is attempting to address the Tribal governments' concerns by allowing access for the purposes of religious activities and gathering foods and medicines to the extent that these activities are consistent with DOE missions. From a traditional American Indian viewpoint, nature is intrinsically spiritual, as sacredness is embedded in natural phenomena, landforms, plants, and animals. People are one of the thousands of species in a single interconnected system of species relationships. This system of relationships is considered to be based on a sense of reciprocity, and a threat to the land or environment can be perceived as a threat to the entire culture. Impacts to the natural landscape also might be considered impacts to the self-identity of a Tribal community.

Spirituality is expressly interwoven in the Tribal community's way of life. This attachment to land and water means that sacred sites are not always confined or precisely located and are numerous and diverse in form (DOI 1995a).

The Hanford Site possesses traditional cultural significance for many members of Columbia Plateau Tribes. Certain sites demonstrate traditional cultural significance for the following reasons:

- American Indians associate certain locations with traditional beliefs about their origin, their cultural history, or the nature of the world.

- American Indian religious practitioners historically have gone, and continue to go, to these locations to perform ceremonial activities in accordance with traditional cultural rules.

- American Indians make use of natural resources in the conduct of traditional activities. Use can be as food, medicine, barter and exchange items (currency), and for artistic and religious purposes. The act and method of gathering, processing, and exchange and use can all carry important cultural significance.

4.6.3 Post-Contact Archaeological and Architectural Resources

The first Euro-Americans who came to this region were Lewis and Clark, who traveled along the Columbia and Snake rivers during their 1803 to 1806 exploration of the Louisiana Territory. Lewis and Clark were followed by fur trappers, military units, and miners who also passed through on their way to more productive lands upriver and downstream and across the Columbia Basin. It was not until the 1860s that merchants set up stores, a freight depot, and the White Bluffs Ferry on the Hanford Reach. Chinese miners began to work the gravel bars for gold. Cattle ranches opened in the 1880s and farmers soon followed. Several small, thriving towns, including Hanford, White Bluffs, and Ringold, were established along the riverbanks in the early 20th century. Other ferries were established at Wahluke and Richland. The towns and nearly all other structures were razed after the U.S. government acquired the land for the original Hanford Engineer Works in the early 1940s (Neitzel 1997).

A total of 390 post-contact archaeological sites, 89 post-contact isolated finds, and numerous post-contact properties have been recorded by the HCRL on the Hanford Site. Of these sites, one is included in the National Register. Properties from the pre-Hanford Site era include semi-subterranean structures near McGee Ranch; the Hanford Irrigation and Power Company pumping plant at Coyote Rapids; the Hanford Irrigation Ditch; the old Hanford townsite, pumping plant, and high school; Wahluke Ferry; the White Bluffs townsite and bank; the Richland Ferry; Arrowsmith townsite; a cabin at East White Bluffs ferry landing; the White Bluffs road; the Chicago, Milwaukee, St. Paul, and Pacific Railroad (Priest Rapids-Hanford Line) and associated whistle stops; and the Bruggerman fruit warehouse (Cushing 1995). Historic archaeological sites, including the East White Bluffs townsite and associated ferry landings and an assortment of trash scatters, homesteads, corrals, and dumps, have been recorded by the HCRL since 1987. Minor test excavations have been conducted at some of the historic sites, including the Hanford townsite locality. In addition to the recorded sites, numerous unrecorded areas of gold mine tailings along the river bank and the remains of homesteads, farm fields, ranches, and abandoned U.S. Army installations are scattered over the entire Hanford Site.

More recent historic structures are the defense reactors and associated materials processing facilities that are present on the Hanford Site. The first reactors (B, D, and F) were constructed in 1943 as part of the Manhattan Project. Plutonium for the first atomic explosion and the bomb that destroyed Nagasaki to end World War II was produced at the B Reactor. Additional reactors and processing facilities were constructed after World War II during the Cold War. All reactor containment buildings still stand, although many ancillary structures have been removed. The B Reactor is listed on the National Register and was given the National Historic Landmark Award (Cushing 1995). About 45 other buildings have been evaluated for National Register eligibility by the SHPO.

A Historic Buildings Task Force was established to coordinate future evaluations among DOE and the Hanford Site contractors. This task force established the Hanford Site Historic District, identified all contributing and noncontributing buildings and structures within the District, and prepared an Historic Buildings Programmatic Agreement to direct the documentation of the contributing properties.

After negotiation, the Programmatic Agreement was approved by the Advisory Council on Historic Preservation, the SHPO, and DOE in August 1996. The Programmatic Agreement outlines the methods agreed to by these parties to preserve and protect significant historical resources on the Hanford Site. The Programmatic Agreement stipulates that DOE will document the contributing historic buildings and structures identified in Appendix C of the Programmatic Agreement, which includes about 190 buildings considered to be historically significant. These buildings will require mitigation (i.e., to document the historical character of the building) prior to activities that might adversely affect historic characteristics. The Programmatic Agreement also identifies the form of mitigation required and exemptions to the requirement for mitigation. Evaluation and mitigation will proceed for the identified buildings in accordance with the Programmatic Agreement.

The Programmatic Agreement allows for: the exemption of property types from review and documentation requirements; the exemption of classes of action from review; the designation of an Historic District; the mitigation of all actions on Site, up to and including demolition of properties, through production of a Site-wide process/events history. Provisions in the Programmatic Agreement are implemented through the “Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan.”

For the purpose of this discussion, the cultural resources present along the Columbia River and in the 100 Areas are considered together. This allows a discussion of sensitive cultural resources, without providing information sufficient to allow the discovery and/or adverse impact of these resources by unauthorized personnel. Much of the following information has been obtained from the *Hanford Site National Environmental Policy Act (NEPA) Characterization* (PNNL 1996a).

Intensive field surveys were completed in the 100 Areas from 1991 to 1993. Much of the surface area within and near the 100 Areas fencelines has been disturbed by the industrial activities that have taken place during the past 50 years. Numerous archaeological sites have been encountered, and many are potentially eligible for the National Register. A complete inventory of 100 Area buildings and structures was completed during fiscal year 1996. The former community of Wahluke, which was at the landing of a ferry of the same name, is situated on the north bank of the river.

The principal post-contact site in the vicinity is the East White Bluffs ferry landing and former townsite, which has been considered for nomination to the National Register. The site was the upriver terminus of shipping during the early and mid-19th century. It was at this point that supplies for trappers, traders, and miners were off-loaded, and commodities from the interior were transferred from pack trains and wagons to river boats. The first store and ferry of the mid-Columbia region were located at this site. A log cabin, thought by some to have been a blacksmith shop in the mid-19th century, still stands. The structure has been recorded according to standards of the Historic American Buildings Survey. The only remaining structure associated with the White Bluffs townsite (near the railroad) is the White Bluffs Bank. A revised historic property inventory form for the bank was completed in 1995. Two Manhattan Project buildings, 105-F and 108-F, remain in the 100-F Area. The 108-F Biology Laboratory, originally a chemical pump house, has been determined eligible for the National Register.

In the vicinity of 100-F, post-contact sites were recorded during 1992, 1993, and 1995 and include 20th century farmsteads, household dumps, and military encampments. None of the sites have been evaluated for eligibility to the National Register. Only three buildings associated with the Cold War era remain in this area. These buildings were inventoried and evaluated in 1996.

In the 100-K Area, historic sites containing the remains of farms are found in the nearby area; four historic sites and three isolated finds have been recorded as of 1994. Two important linear features, the Hanford Irrigation Ditch and the former Priest Rapids-Hanford railroad, also are present in the 100-K Area. Remnants of the Allard community and the Allard pump house at Coyote Rapids are located west of the K Reactor compound. The Historic Buildings Task Force has recommended that the 105-KW Reactor and the 1706-KE and 1706-KER water recirculation study facilities be listed in the National Register.

Knowledge about the archaeology of the 100-N Area is based largely on reconnaissance-level archaeological surveys conducted within the last 30 years (PNNL 1996a). These surveys are not complete inventories of the areas covered. Intensive surveys of surrounding areas were conducted during 1991. The Hanford Generating Plant vicinity also has been surveyed intensively for archaeological resources.

The most common evidence of activities now found near the 100-N Area consists of gold mine tailings on riverbanks and archaeological sites where farmsteads once stood. The significance of the 100-N buildings, their role in the Cold War, and their eligibility for listing in the National Register, have been documented through *The Hanford Site N Reactor Buildings Task Identification and Evaluation of Historic Properties* (BHI 1996a), which was conducted during fiscal year 1995. Buildings 105-N, 109-N, 155-N, 185-N, and 1112-N have been determined eligible for the National Register by DOE and the SHPO. Additional determinations for contributing buildings have been submitted to the SHPO, as well as a mitigation plan for the 100-N Reactor complex.

An archaeological survey conducted of all undeveloped portions of the 200 East Area and a 50 percent random sample conducted of undeveloped portions of the 200 West Area have indicated no findings of archaeological sites (PNL 1990b). However, some small sites are known to exist within the boundaries of the 200 East and 200 West Area (PNL 1990b). The only evaluated historic site is the old White Bluffs freight road that crosses diagonally through the 200 West Area. The road, which was originally an American Indian trail, has been in continuous use as a transportation route since pre-contact history and has played a role in Euro-American immigration, regional development, agriculture, and the recent Hanford Site operations. As such, the property has been determined to be eligible for the National Register, although the segment that passes through the 200 West Area is considered to be a noncontributing element. A 100-m (328-ft) restricted zone has been created to protect the road from uncontrolled disturbance. In addition, 49 buildings in the 200 East and 200 West Areas have been evaluated; nine of these buildings have been determined as eligible for the National Register.

Most of the 300 Area has been highly disturbed by industrial activities. Five recorded archaeological sites including campsites, house pits, and a historic trash scatter are recorded at least partially within the 300 Area; any more may be located in subsurface deposits. The historic site contains debris scatter and road beds associated with farmsteads. One archaeological site is recognized as eligible for listing in the National Register. The majority of the buildings in the 300 Area were constructed in the Manhattan Project and Cold War eras (1943 through 1989). A total of 158 buildings/structures in the 300 Area have been inventoried on historic property inventory forms. Of that number, 47 buildings/structures have been determined eligible for the National Register as contributing properties within the Historic District recommended for mitigation (Neitzel et al. 1998).

Most of the 400 Area has been subjected to intensive development-related construction activities. Archaeologists surveying the site in 1978 were able to find only 12 ha (30 ac) that were undisturbed. No cultural resources were found within that small area and no sites have been recorded or are known to exist within 2 km (1.2 mi) of the 400 Area (Cushing 1995). The FFTF and its associated structures have been evaluated by the Historic Buildings Task Force. Buildings 405, 4703, and 4710 have been recommended as contributing properties to the Hanford Site Historic District.

The 600 Area contains diverse cultural resource sites and traditional cultural properties. Project-driven surveys have been conducted throughout the area, but much of the 600 Area remains unsurveyed.

Five anti-aircraft artillery sites have been determined eligible for the National Register. Because of the proposed remediation of these sites, mitigation to reduce the adverse effects will be carried out. The Central Shops Complex, in the 600 Area, was determined to be ineligible for the National Register in 1995 (Cushing 1995).

Historic cultural resources have been identified in or near the 1100 Area. These resources include remnants of homesteads and agricultural structures predating the establishment of the Hanford Site.

4.7 Socioeconomic Environment

Activity on the Hanford Site plays a dominant role in the socioeconomics of the Tri-Cities and other parts of Benton and Franklin counties. The Tri-Cities serves as a market center for a much broader area of eastern Washington, including Adams, Columbia, Grant, Walla Walla, and Yakima counties. The Tri-Cities also serves parts of northeastern Oregon, including Morrow, Umatilla, and Wallowa counties. Socioeconomic impacts of changes at Hanford are mostly confined to the immediate Tri-Cities community and Benton and Franklin counties (and Yakima County, to a lesser extent) (PNL 1984; PNL 1987). However, because of the significance of the wider agricultural region and surrounding communities in the Tri-Cities economic base, this section briefly discusses the wider region as well (Figure 4-28). Table 4-8 summarizes the regional (Benton and Franklin counties) jobs from 1995 to 1996.

Due to the changing Hanford mission, it has been necessary to develop a facility transition plan. The first step would be conversion, which transitions the process from facilities that were developed to support DOE's nuclear production mission to either new Federal or private development. There have been many obstacles to the successful implementation of a facility reuse plan. The objectives of a successful conversion are as follows:

- Retraining and re-employment of those who have lost jobs, directly or indirectly, as a result of the Federal mission change

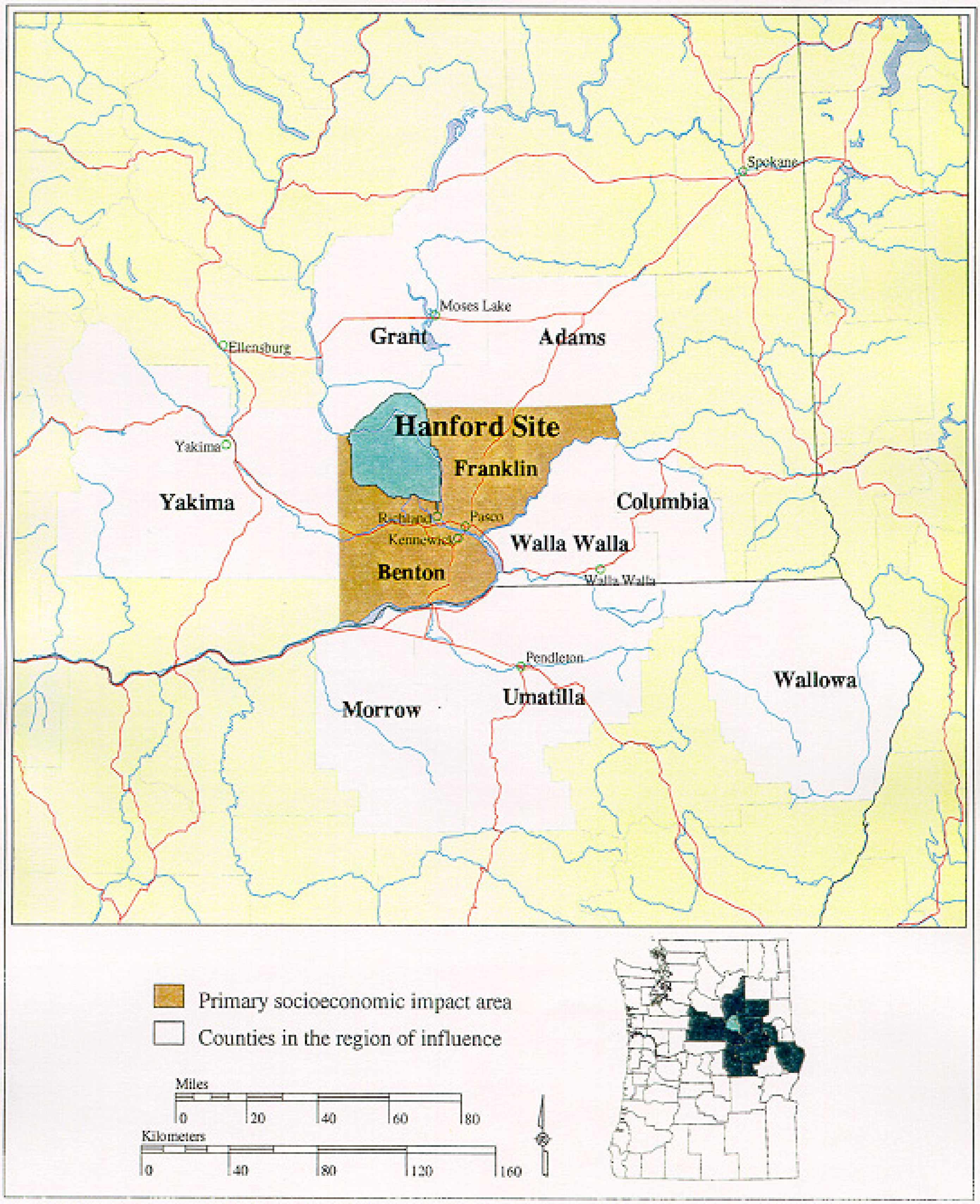
- Creation of jobs to replace the revenue lost directly through reductions in payroll taxes and property taxes, as well as through indirect impacts, such as lost sales tax revenue

- Reuse of the facilities on the Hanford Site so the local government might generate revenue to cover the costs involved in its newly acquired responsibilities of maintaining and servicing those facilities, such as the provision of police and fire services and municipal utilities (e.g., water service)

- Using the closure as an opportunity to revitalize the local community

- Mitigating the impacts on the community at large, both from the business and social service perspectives.

Figure 4-28. Areas of Washington and Oregon Where Socioeconomic Resources Might Be Affected (DOE 1995b).



BHLrpp 02/11/98 clup/socioecon1.aml Database: 03-AUG-1998

Table 4-8. Nonagricultural Workers in Benton and Franklin Counties, 1996 to 1997 (Neitzel et al. 1998).

Industry	1996 Annual Average	1997 Annual Average	% Change 1996-1997
Nonagricultural wage laborers	70,200	70,100	-0.1
Manufacturing	5,800	5,700	-1.7
Construction	4,100	4,100	-0.0
Public utilities	2,900	9000	[b]
Wholesale and retail trade	15,600	16,100	3.2
Finance, insurance, and real estate	2,200	2,200	0.0
Services	26,100	19,600	[b]
Government	13,400	13,500	0.7
Agricultural[a]	5,500		

[a] Source: TRIDEC Tri-City demographics.
[b] Reflects change in reporting.

There are several steps that a community may have to take to achieve the objectives of a successful conversion, including some of those outlined below:

- Improvement of marketing of facilities (i.e., buildings, transportation, and utilities) to new employers
- Training of potential employees
- Negotiation of property transfer and leases
- Negotiation of care and custody agreements
- Supporting environmental remediation to enable the transfer of property
- Acquisition of funding for continued conversion efforts (e.g., planning and implementation)
- Conducting feasibility studies to assist in the successful implementation of specific components of the reuse plan, such as the creation of a historic district or educational programs.

The Hanford Community is working on the Hanford facilities reuse problem through a collation of local cities, port districts, and counties, with assistance from DOE's Office of Worker and Community Transition.

4.7.1 Demographics

Estimates for 1996 placed population totals for Benton and Franklin counties at 134,100 and 43,900, respectively (Neitzel et al. 1998). When compared to the 1990 census data in which Benton County had 112,560 residents and Franklin County population totaled 37,473, the current population totals reflect the continued growth occurring in these two counties.

The 1997 estimates distributed the Tri-Cities population as follows: Richland, 36,500; Pasco, 35,300; and Kennewick, 49,090. The combined populations of Benton City, Prosser, and West Richland totaled 13,905 in 1997 (see text box, *"Hanford Site Quick Facts:*

Hanford Site Quick Facts: Populations (1996 Estimates)

- Kennewick: 48,010
- Richland: 35,990
- Pasco: 22,370

Populations [1996 Estimates]"). The unincorporated population of Benton County was 34,555. In Franklin County, incorporated areas other than Pasco have a total population of 3,385. The unincorporated population of Franklin County was 15,215 (Neitzel et al. 1998).

Benton and Franklin counties accounted for 2.4 percent of the population in Washington State (Neitzel et al. 1998). In 1997, the population demographics of Benton and Franklin counties were quite similar to those found within the State of Washington. In 1997, 54.1 percent of the population of Benton and Franklin counties was under the age of 35, compared to 50.3 percent for the State of Washington. In general, the population of Benton and Franklin counties is somewhat younger than that of Washington State. The 0- to 14-year-old age group accounts for 26.5 percent of the total bi-county population as compared to 22.6 percent for Washington State. In 1996, the 65-year-old and older age group constituted 9.6 percent of the population of Benton and Franklin counties compared to 11.5 percent for the State of Washington.

4.7.1.1 Demographics of Minority Populations. Demographic information obtained from the U.S. Bureau of Census was used to identify minority populations and low-income communities within an 80-km (50-mi) radius surrounding the Hanford Site. For the evaluation of environmental justice impacts, the area defined by this 80-km (50-mi) radius is considered the zone of potential impact.

4.7.1.1.1 Definitions. The demographic analysis used the following definitions to develop community characteristics:

- Census tract -- An area defined for the purpose of monitoring census data that is usually comprised of between 2,500 and 8,000 persons, with 4,000 persons being ideal. When first delineated, census tracts are designed to be homogeneous with respect to population characteristics, economic status, and living conditions. Census tracts do not cross county boundaries. Spatial census tract size varies widely depending on the density of settlement. Census tract boundaries are delineated with the intention of being maintained over a long period of time so statistical comparisons can be made from census to census.

- Census block group -- An area defined for the purpose of monitoring census data that generally consists of between 250 and 550 housing units.

- Minority populations -- A group of people and/or communities experiencing common conditions of exposures or impact that consists of persons classified by the U.S. Bureau of Census as Negro/Black/African American, Hispanic, Asian and Pacific Islander, American Indian, Eskimo, Aleut, and other non-White persons, based on self-classification by the people according to the race with which they most closely identify. For the purposes of analysis, minority populations are defined as those census tracts within the zone of impact where the percent minority population exceeds the percentage minority population within the entire zone of impact. Census tracts where the percent minority population exceeds 50 percent are also considered minority populations. In the case of migrant or dispersed populations, a minority population consists of a group that is greater than a 50 percent minority.

- Low-income community -- An area where the median household income is 80 percent or more below the median household income for the metropolitan statistical area (urban) or county (rural). The 80 percent threshold was used based on definitions used by the U.S. Department of Housing and Urban Development.

- Population base -- Census tracts were included in the analysis if 50 percent of the geographic area of the tract fell within the 80-km (50-mi) radius of the Hanford Site.

4.7.1.1.2 Minority and Low-Income Populations Near Hanford. Demographic maps were prepared using 1990 census data resolved to the census group tract level (USBC 1992).

A total population of approximately 384,000 people reside within an 80-km (50-mi) radius of the Hanford Site. The minority population within the area consists of approximately 95,000 people and represents approximately 25 percent of the population in the assessment area. The ethnic composition of the minority population is primarily Hispanic (approximately 80 percent) and American Indian (8 percent). Census tracts where the percentage of minority persons within the population exceeds 20 percent are located to the southwest and northeast of the Hanford Site and within the City of Pasco, Washington (Neitzel et al. 1998).

The low-income population within the 80-km (50-mi) area of impact represents approximately 42 percent of the households in the area of impact. Census tracts where the percentage of the population consisting of low-income households exceeds 25 percent are principally located to the southwest and north of the Hanford Site and within the City of Pasco, Washington (Neitzel et al. 1998). Considerable overlap between low-income populations and minority populations exists in the vicinity of the Hanford Site.

4.7.1.1.3 Limitations of Demographic Data. Characterization of minority and low-income populations residing within a geographical area is sensitive to the basic definitions and assumptions used to identify those populations. Consequently, the number of individuals identified as minority and/or low-income individuals within the population around a particular site may vary from analysis to analysis. Several different approaches to identification of minority and low-income populations have been used in recent DOE EISs. The approach presented in this EIS is consistent with the approach used in the *Hanford Site National Environmental Policy Act (NEPA) Characterization* (Neitzel et al. 1998). Other demographic studies may use different assumptions and, consequently, report a different total population, minority population, or low-income population depending on the assumptions used to identify each population.

4.7.2 Economics

This section summarizes pertinent economic activity within the region of interest, including information on the general economy, employment, income, and impact of the Hanford Site. Historically, the primary industries within the region have been related to agriculture — a multitude of crops encompassing many fruits, vegetables, and grains are grown each year.

4.7.2.1 Employment in the Tri-Cities. Three major sectors have been the principal driving forces of the economy in the Tri-Cities since the early 1970s: (1) DOE and Hanford Site contractors; (2) Energy Northwest (formerly known as WPPSS) in its construction and operation of nuclear power plants; and (3) agriculture, including a substantial food-processing industry. 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 from the Tri-Cities. In addition to direct employment and payrolls, these major sectors also support a sizable number of jobs in the local economy through the procurement of equipment, supplies, and business services.

- ***DOE and Hanford Contractors*** -- An average of 11,104 employees worked for DOE and its Hanford contractors in 1997. This number is down from over 19,000 in 1994 due to downsizing activities, which has reduced employment at Hanford by 7,700 through FY 1996 (source: Hanford Site Internet homepage). In addition to downsizing by Hanford contractors in 1996, DOE created a new Project Hanford Team in an effort to produce cleanup results more cost effectively over a shorter time period, and to help diversify and stabilize the Tri-Cities economy. This team is made up of the overall management contractor Fluor Daniel Hanford Company, Fluor's six major subcontractors, and six newly created "enterprise companies." Fluor Daniel Hanford Company is responsible for integrating and directing cleanup tasks. The actual cleanup work is conducted by the six subcontractors. The "enterprise companies" provide services to the six major subcontractors.

As of December 31, 1997, the official employment count for Hanford was 10,690, which includes Fluor Daniel Hanford Company; Fluor's six major subcontractors, Pacific Northwest National Laboratory, Bechtel Hanford, Inc., Hanford Environmental Health Foundation, ICF Kaiser; and local DOE employees. The "enterprise companies," which have a combined employment of just over 2,200, were not included in this count. The Hanford payroll has a widespread impact on the Tri-Cities and state economies, in addition to providing direct employment.

- ***Energy Northwest (formerly known as WPPSS)*** – Although activity related to nuclear power plant construction ceased with the completion of the WNP-2 reactor in 1983, Energy Northwest (formerly known as WPPSS) continues to be a major employer in the Tri-Cities area. Headquarters personnel based in Richland oversee the operation of one generating facility and perform a variety of functions related to two mothballed nuclear plants and one generating facility. In 1995 and 1996, downsizing activities at Energy Northwest headquarters decreased employment to about 1,164 workers (down from more than 1,900 in 1994). Energy Northwest activities generated a payroll of approximately $81 million in the Tri-Cities during 1996. Alternate uses or decommissioning of the two mothballed Washington Nuclear Plants (WNP-1 and WNP-4) are expected to begin in the next few years. These activities are expected to reduce the number of employees necessary to maintain these facilities (PNNL 1996a).

- ***Agriculture*** -- In 1996, agricultural activities in Benton and Franklin counties were responsible for approximately 10,446 jobs, or 13 percent of the total employment in the area. According to the U.S. Department of Commerce Regional Economic Information System, about 2,317 people were classified as farm proprietors in 1995. Farm proprietors' income, according to this same source, was estimated to be $69 million (Neitzel et al. 1998).

In 1997, the counties of Benton, Franklin, and Walla Walla counties averaged 7,448 seasonal farm workers, ranging from 1,809 workers during the winter pruning season to 17,221 workers at the peak of harvest. An estimated average of 6,553 seasonal workers were classified as local (ranging from 1,251 to 14,388); an average of 64 were classified as intrastate (ranging from 0 to 355); and an average of 832 were classified as interstate (ranging from 122 to 2,830). Most intrastate workers resided elsewhere in Benton, Franklin, Walla Walla, and Yakima counties, although the peak harvest season saw an influx of workers from around eastern and central Washington.

Area farms and ranches generate a sizable number of jobs in supporting sectors, such as agricultural services (e.g., application of pesticides and fertilizers or irrigation system development) and sales of farm supplies and equipment. 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 items such as potato products, canned fruits and vegetables, wine, and animal feed.

In addition to the three major employment sectors (Hanford-related, power marketing, and agricultural), five other employers in 1996 were readily identified as contributors to the economic base of the Tri-Cities economy: (1) Iowa Beef Processing Inc., which employed 1,500 workers (this company lies outside of Benton and Franklin counties, but most of the workforce resides in the Tri-Cities); (2) Lamb Weston, which employed 1,700 workers; (3) Siemens Nuclear Power Corporation, which employed 730 workers; (4) Boise Cascade/Paper Group, which employed 511 workers (like Iowa Beef Processors, Boise Cascade's Wallula mill lies outside both Benton and Franklin counties, but most of its workforce resides in the area); and (5) Burlington Northern Santa Fe Railroad, which employed 350 workers. Approximately 4791 workers were employed by these businesses in Benton and Franklin counties in 1997 (Neitzel et al. 1998).

4.7.2.1.1 Tourism. The Tri-Cities Visitors and Convention Bureau reported that approximately 214 conventions were held in the Tri-Cities in 1997, with 66,150 attending visitors spending an estimated $22 million.

Overall tourism expenditures in the Tri-Cities were roughly $184 million in 1995, with travel-generated employment of about 3,220 and an estimated $34 million in payroll in Benton and Franklin counties.

4.7.2.1.2 Retirees. Although Benton and Franklin counties have a relatively young population (approximately 54 percent under the age of 35), 17,141 people over the age of 65 resided in Benton and Franklin counties in 1997. The portion of the total population 65 years and older in Benton and Franklin counties accounts for 9.6 percent of the total population, slightly below that of the State of Washington (11.5 percent). 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 individual savings.

Although information on private pensions and savings is not available, data is available regarding the magnitude of government transfer payments. The U.S. Department of Commerce Regional Economic Information System has estimated transfer payments by various programs at the county level. A summary of estimated major government pension benefits received by the residents of Benton and Franklin counties in 1995 is shown in Table 4-9.

Table 4-9. Government Retirement Payments in Benton and Franklin Counties in 1995 ($ million) (Neitzel et al. 1998).

Source	Benton County	Franklin County	Total
Social security (including survivors and disability)	139.3	41.5	180.8
Railroad retirement	4.1	4.6	8.7
Federal civilian retirement	13.4	2.9	16.3
Veterans pension and military retirement	20.8	4.2	25.0
State and local employee retirement	33.2	6.5	39.7
Total	210.8	60.2	269.5

About two-thirds of the social security payments go to retired workers; the remainder of the payments are for disability and other types of payments. The historical importance of government activity in the Tri-Cities area is reflected in the relative magnitude of the government employee pension benefits as compared to total payments (Neitzel et al. 1998).

4.7.2.2 Income Sources. Total personal income is comprised of all forms of income received by the populace, including wages, dividends, and other revenues. Per capita income is roughly equivalent to total personal income divided by the number of people residing in the area. Median household income is the point at which half of the households have an income greater than the median and half of the households have less. The source for total personal income and per capita income was the U.S. Department of Commerce Regional Economic Information System, while median income figures for Washington State were provided by the Office of Financial Management (PNNL 1996a).

In 1995, the total personal income for Benton County was $2,952 million, Franklin County was $747 million, and the State of Washington was $129.1 billion. Per capita income in 1995 for Benton County was $22,072, Franklin County was $16,356, and Washington State was $23,709. Median household income in 1995 for Benton County was estimated to be $43,562, Franklin County was estimated $31,141, and the State of Washington was estimated at $39,206 (Neitzel et al. 1998).

4.7.2.3 Hanford Site Employment. An average of 11,140 employees worked for DOE and its Hanford contractors in 1997 (Neitzel et al. 1998). Future downsizing in Hanford Site employment is anticipated, although the extent of this downsizing is unknown at this time.

In 1996, Hanford employment accounted directly for 20 percent of total nonagricultural employment in Benton and Franklin counties and about 0.7 percent of all statewide nonagricultural jobs. In 1997, the Hanford Site total wage payroll was $537 million and accounted for a significant percentage of the payroll dollars earned in the area (Neitzel et al. 1998) (see text box on next page, *"Hanford Site Quick Facts: Economic Multipliers"*).

Previous studies have revealed that each Hanford job supports about 1.2 additional jobs in the local service sector of Benton and Franklin counties (about 2.2 total jobs) and about 1.5 additional jobs in the state service sector. Similarly, each dollar of Hanford income supports about 2.1 dollars of total local incomes and about 2.4 dollars of total statewide incomes. Based on these multipliers, Hanford directly or indirectly accounts for more than 40 percent of all jobs in Benton and Franklin counties (Neitzel et al. 1998).

Hanford Site Quick Facts: Economic Multipliers

Each Site job supports:

- 1.2 jobs in the local service sector
- 1.5 jobs in the state service sector

Each Site dollar supports:

- 2.1 dollars in total local incomes
- 2.4 dollars in total state incomes

Based on employee residence records as of December 1997, 93 percent of the direct employment of Hanford is comprised of residents of Benton and Franklin counties. Approximately 76 percent of the employment is comprised of residents who reside in one of the Tri-Cities. More than 37 percent of the employment is comprised of Richland residents, 30 percent of Kennewick residents, and 9 percent of Pasco residents. West Richland, Benton City, Prosser, and other areas in Benton and Franklin counties account for 17 percent of total employment. Table 4-10 contains the estimated percent of Hanford employees residing in each of the counties within the region of influence.

Table 4-10. Hanford Employee Residences by County.

County	Percent of Employees in Residence (%)
Adams	0.18
Benton	84.16
Columbia	0.01
Franklin	9.07
Grant	0.25
Walla Walla	0.21
Yakima	5.08
Morrow	0.01
Umatilla	0.01

The DOE and Hanford Site contractors procured nearly $298 million of goods and services (45.6 percent of total procurements of $653 million) from Washington firms in 1993. About 18 percent of Hanford Site orders were filled by Tri-Cities firms.

The DOE and Hanford Site contractors paid a total of $10.9 million in state taxes on operations and purchases during fiscal year 1988 (the most recent year available). Estimates show that Hanford employees paid $27.0 million in state sales tax, use taxes, and other taxes and fees in fiscal year 1988. In addition, the Hanford Site paid $0.9 million to local governments in Benton, Franklin, and Yakima counties in local taxes and fees (PNNL 1996a).

4.7.3 Emergency Services

Police protection in Benton and Franklin counties is provided by county sheriff departments, local municipal police departments, and the Washington State Patrol Division, which is headquartered in Kennewick. Table 4-11 shows the number of commissioned officers and patrol cars in each department in April 1997. The Kennewick, Richland, and Pasco municipal departments maintain the largest staffs of commissioned officers with 73, 50, and 44, respectively.

Table 4-11. Police Personnel in the Tri-Cities for 1998 (Neitzel et al. 1998).

Area	Commissioned Officers	Reserve Officers	Patrol Cars
Kennewick Municipal	73	15	45
Pasco Municipal	44	33	15
Richland Municipal	50	13	13
West Richland Municipal	12	10	11
Benton County Sheriff	47	15	55
Franklin County Sheriff	19	17	22

Table 4-12 indicates the number of firefighting personnel, both paid and unpaid, on the staffs of fire districts in the area.

Table 4-12. Fire Protection in the Tri-Cities for 1998 (Neitzel et al. 1998).

Station	Firefighting Personnel	Volunteers	Total	Service Area
Kennewick	63	0	63	City of Kennewick
Pasco	30	0	30	City of Pasco
Richland	48	0	48	City of Richland
BCRFD 1	9	94	103	Kennewick Area
BCRFD 2	3	37	40	Benton City
BCRFD 4	5	30	35	West Richland

BCRFD = Benton County Rural Fire Department

The Hanford Fire Department, operated by Hanford Site contractors for DOE, has 93 firefighters who are trained to dispose of hazardous waste and to fight chemical fires, in addition to their regular firefighting duties. During a 24-hour duty period, the 1100 and 300 Areas have seven firefighters; the 200 East and 200 West Areas have eight firefighters; the 100 Areas have five firefighters; and the 400 Area, which includes Energy Northwest (formerly known as WPPSS), has six firefighters (Neitzel et al. 1997). To perform their responsibilities, each station has access to a hazardous material response vehicle that is equipped with chemical fire-extinguishing equipment, an attack truck that carries foam and Purple-K dry chemical, a mobile air truck that provides air for respirators, and a transport tanker that supplies water to six brushfire trucks. The Hanford Fire Department owns five ambulances and maintains contact with local hospitals.

4.7.4 Health Care

The Tri-Cities have three major hospitals, all of which offer general medical services and include a 24-hour emergency room, basic surgical services, intensive care, and neonatal care.

Kadlec Medical Center, located in Richland, has 124 beds and functioned at 54 percent capacity (6,055 admissions) in 1997. Non-Medicare and Medicaid patients accounted for 60 percent of their annual admissions in 1997. An average stay of 4.04 days per admission was reported for 1997.

Kennewick General Hospital maintains a 46.7 percent occupancy rate of its 70 beds with 4,670 admissions in 1995. Non-Medicare and Medicaid patients in 1997 represented 45.6 percent of its total admissions. An average stay of 3.2 days per admission was reported in 1997.

Our Lady of Lourdes Health Center, a 132-bed medical facility located in Pasco, provides acute, sub-acute, skilled nursing and rehabilitation, and alcohol and chemical dependency services. Our Lady of Lourdes also operates the Carondolet Psychiatric Care Center, a 32-bed psychiatric hospital located in Richland, which provides a significant amount of outpatient and home health services. For calender year 1997, Our Lady of Lourdes had a total of 4,528 admissions, of which 35 percent were non-Medicare and Medicaid admissions. An average acute care length of stay of 3.0 days was reported (Neitzel et al. 1998).

4.7.5 Housing

In 1996, 91 percent of all housing (44,488 total units) in the Tri-Cities was occupied. Single-unit housing, which represents nearly 58 percent of the total units, has a 95 percent occupancy rate throughout the Tri-Cities. Multiple-unit housing, defined as housing with two or more units, has an occupancy rate of 85 percent. Pasco had the lowest occupancy rate in all categories of housing with 89 percent, followed by Kennewick with 90 percent, and Richland with 92 percent. Mobile homes, which represent 11 percent of the housing-unit types, have the lowest occupancy rate at 84 percent. Table 4-13 shows a detailed listing of total units and occupancy rate by type in the Tri-Cities.

Table 4-13. Total Units and Occupancy Rates, 1996 Estimates (Neitzel et al. 1998).

City	All Units	Rate (%)	Single Units	Rate (%)	Multiple Units	Rate (%)	Manufactured Homes	Rate (%)
Richland	15,859	92	10,722	96	4,284	84	853	88
Pasco	8,419	89	4,104	95	2,956	85	1,359	83
Kennewick	20,210	90	10,887	95	6,660	85	2,241	84
Total for Tri-Cities	44,488	91	27,213	95	13,900	85	4,875	84

Recent Hanford Site downsizing has resulted in occupancy rates lower than in the recent past throughout the Tri-Cities. Statistics from February 1996 indicated that the Tri-Cities apartment occupancy rates are significantly lower: Richland apartment occupancy was 80.2 percent, Kennewick apartment occupancy was 85.4 percent, and Pasco apartment occupancy was 83.7 percent (TCH 1996a).

4.7.6 Human Services

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

The Tri-Cities also are served by a large number of private agencies and voluntary human services organizations. The United Way, which is an umbrella fund-raising organization, incorporates 22 participating agencies offering more than 46 programs. These member agencies had a cumulative budget total of $23 million in 1997. In addition, there were 488 organizations that received funds as part of the United Way-Franklin County donor designation program (Neitzel et al. 1998).

4.7.7 Educational Services

Primary and secondary education are served by the Tri-Cities and Kiona-Benton School Districts. The combined 1997 fall enrollment for all districts was approximately 32,500 students, an increase 1.7 percent from the 1996 total of 31,970 students. The 1997 total includes 8,974 from the Richland School District, 8,066 students from the Pasco School District, 13,745 students from the Kennewick School District, and 1,715 from Kiona-Benton. Private schools total approximately 3,000 students. In 1997, Richland was operating over capacity at the elementary level, at capacity at their middle schools, and slightly under capacity at the high school level. A bond issue was recently passed to build a new elementary school, which should open in 1999. Pasco was at capacity for primary education but has room for more students at the secondary level. Pasco also passed an elementary school bond issue, and currently has three buildings under construction. Kennewick and Kiona-Benton schools are operating at capacity (Neitzel et al. 1998).

Post-secondary education in the Tri-Cities area is provided by a junior college, Columbia Basin College (CBC), and the Tri-Cities branch campus of Washington State University (WSU-TC). WSU-TC offers a variety of upper-division, undergraduate, and graduate degree programs. The 1997 fall/winter enrollment was approximately 6,869 at CBC and 1,334 at WSU-TC. Many of the programs offered by these two institutions are geared toward the vocational and technical needs of the area. Currently, 27 associate degree programs are available at CBC, and WSU-TC offers 10 undergraduate and 16 graduate programs, as well as access to eight additional graduate programs via satellite (Neitzel et al 1998).

4.7.8 Transportation

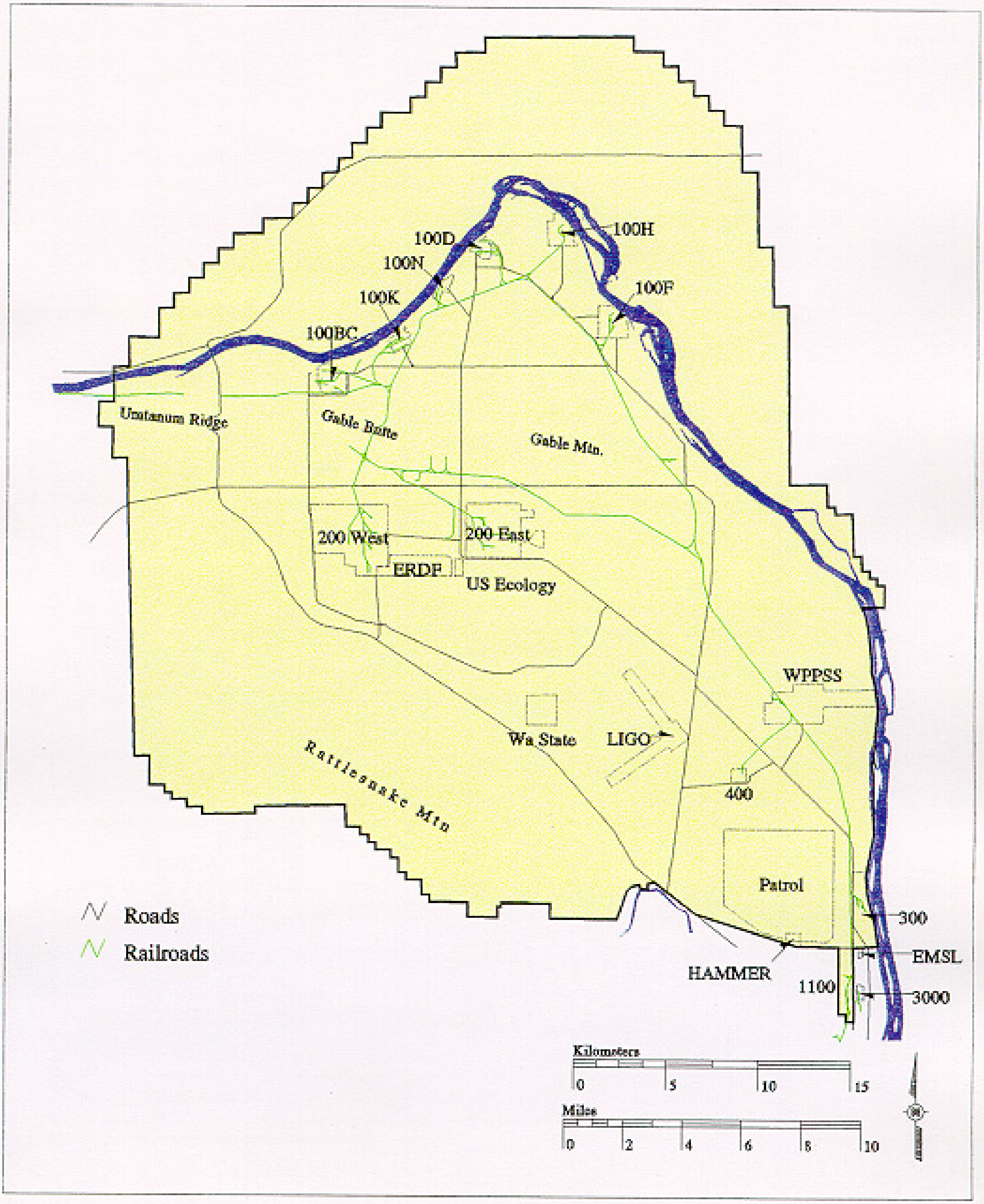
The Tri-Cities serve as a regional transportation and distribution center with major air, land, and river connections (Figure 4-29). The Tri-Cities have direct rail service, provided by Burlington Northern Santa Fe and Union Pacific, which connects the area to more than 35 states. Union Pacific operates the largest fleet of refrigerated rail cars in the United States and is essential to food processors that ship frozen food from this area. Passenger rail service is provided by Amtrak, which has a station in Pasco (Neitzel et al. 1997).

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 (325.5-mi)-long commercial waterway, which 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 (PNNL 1996a).

Daily air passenger and freight services connect the area with most major cities through the Tri-Cities Airport, which is located in Pasco. The airport is currently served by one national and three commuter-regional airlines. There are two runways: a main and minor crosswind. The main runway is equipped for precision instrumentation landings and takeoffs. Each runway can accommodate landings and takeoffs by medium-range commercial aircraft, such as the Boeing 727-200 and Douglas DC-9. The Tri-Cities Airport handled approximately 182,978 passengers in 1997, which is up 4.3 percent from 1996. Projections indicate that the terminal can serve nearly 300,000 passengers annually. Two additional airports, located in Richland and Kennewick, are limited to serving private and airfreight aircraft (Neitzel et al. 1998).

The regional transportation network in the Hanford vicinity (Figure 4-29) includes the areas in Benton and Franklin counties from which most of the commuter traffic associated with the Hanford Site originates. Interstate highways that serve the area are I-82, I-182, I-84, and I-90. Interstate-82 is 8 km (5 mi) south-southwest of the Hanford Site. Interstate-182, a 24-km (15-mi)-long urban connector route, located 8 km (5 mi) south-southeast of the Hanford Site, provides an east-west corridor linking I-82 to the Tri-Cities area. Interstate-90, located north of the Hanford 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 and I-84. I-84, located south of the Hanford Site in Oregon, is the major link to Portland and extends eastward. SR 224, south of the Hanford Site, serves as a 16-km (10-mi) link between I-82 and SR 240.

Figure 4-29. Transportation Network on the Hanford Site (DOE-RL 1990a).



SR 24 enters the Hanford Site from the west, continues eastward across the northern-most portion of the Hanford Site, and intersects SR 17 approximately 24 km (15 mi) east of the Hanford Site boundary. SR 17 is a north-south route that links I-90 to the Tri-Cities and joins U.S. Route 395, which continues south through the Tri-Cities. SR 14 connects with I-90 at Vantage, Washington, and provides ready access to I-84 at several locations along the Oregon and Washington border. SRs 240 and 24 traverse the Hanford Site and are maintained by Washington State. Other roads within the Hanford Site are maintained by DOE (PNNL 1996a).

4.7.9 Utilities

The principal source of water in the Tri-Cities and the Hanford Site is the Columbia River. The potable water systems of Richland, Pasco, and Kennewick drew a large portion of the 50.6 billion L (13.43 billion gal) used in 1996 from the Columbia River. Each city operates its own supply and treatment system. The Richland water supply system derives about two-thirds of the water used from the Columbia River, while the remainder is split between a well field in North Richland and other groundwater wells. Total usage by the City of Richland in 1997 was 26.1 billion L (6.9 billion gal). This usage represents approximately 65 percent of the maximum supply capacity. The City of Pasco system also draws water from the Columbia River. In 1995, Pasco consumed 9.5 billion L (2.6 billion gal). The Kennewick system uses two wells and the Columbia River as a water supply. These wells serve as the sole source of water between November and March and can provide approximately 43 percent of the total maximum supply of 30 billion L (8 billion gal). Total 1997 usage in Kennewick was 12.7 billion L (3.36 billion gal). (Neitzel et al. 1998).

The major incorporated areas of Benton and Franklin counties are served by municipal wastewater treatment systems, whereas the unincorporated areas are served by onsite septic systems. The Richland waste water treatment system is designed to treat a total capacity of 45.5 million L/day (12 million gal/day) and processed an average flow of 23.5 million L/day (6.2 million gal/day) in 1997. The Kennewick system similarly has significant excess capacity; with a treatment capability 32.9 million L/day (8.7 million gal/day) and 1997 usage of 19.3 million L/day (5.13 million gal/day). The Pasco waste treatment system processed an average 4.9 million L/day (1.3 million gal/day), while the system is capable of treating 16.3 million L/day (4.3 million gal/day) (Neitzel et al. 1998)

Natural gas, provided by the Cascade Natural Gas Corporation, serves a small portion of Tri-Cities residents, with 6,182 residential customers in April 1998 (Neitzel et al. 1998).

In the Tri-Cities, electricity is provided by the Benton County Public Utility District, Benton Rural Electrical Association, Franklin County Public Utility District, and City of Richland Energy Services Department. All of the power provided by these utilities in the local area is purchased from the BPA, a Federal power marketing agency. The average rate for residential customers served by the four local utilities is approximately $0.049/kWh. Electrical power for the Hanford Site is purchased wholesale from the BPA. Energy requirements for the Hanford Site during fiscal FY 1997 exceeded 319 million kWh, for a total cost of nearly $7.7 million (Neitzel et al. 1998).

In the Pacific Northwest, hydropower (and to a lesser extent, coal and nuclear power), constitute the regional electrical generation system. The system is capable of delivering approximately 20,300 average megawatts of guaranteed energy; of that amount, approximately 62 percent is derived from hydropower, 16 percent from coal, and less than 7 percent from nuclear plants. One commercial nuclear power plant (WNP-2) remains in service in the Pacific Northwest, with an average generating capability of 833 megawatts. The Trojan Nuclear Power Plant in Oregon was permanently shut down on January 4, 1993, and is being buried at Hanford's commercial low-level waste (LLW) facility.

The regional electrical power system, more than any other system in the nation, is dominated by hydropower. In a given peak-demand hour, the hydropower system is capable of providing nearly 30,000 megawatts of capacity. Variable precipitation and limited storage capabilities alter system output from 12,300 average megawatts under critical water conditions to 20,000 average megawatts in record high-water years. The reliance on hydroelectric power in the Pacific Northwest means that the system is more constrained by seasonal variations in peak demand than in meeting momentary peak demand.

Additional constraints on hydroelectric production are measures designed to protect and enhance the production of salmon, as many salmon runs have dwindled to the point of being threatened or endangered. These measures, outlined by the Northwest Power Planning Council (NPPC) Columbia River Basin Fish and Wildlife Program, include minimum flow levels and a "water budget," which refers to water in the Columbia and Snake rivers that is released to speed the migration of young fish to the sea. Generation capacity of the hydroelectric system is decreased with these measures, as less water is available to pass through the turbines.

Throughout the 1980s, the Pacific Northwest had a surplus of electric power. This surplus has been exhausted, however, and the system only supplies enough power to meet regional electricity needs. In the 1991 Northwest Power Plan, the NPPC set a goal of purchasing more than 1,500 megawatts of energy savings by the year 2000 to help the existing system meet the rising electricity demand. The NPPC estimates that the Pacific Northwest will need an additional 2,000 megawatts over 1991 consumption by the turn of the century (PNNL 1996a).

4.7.10 Site Infrastructure

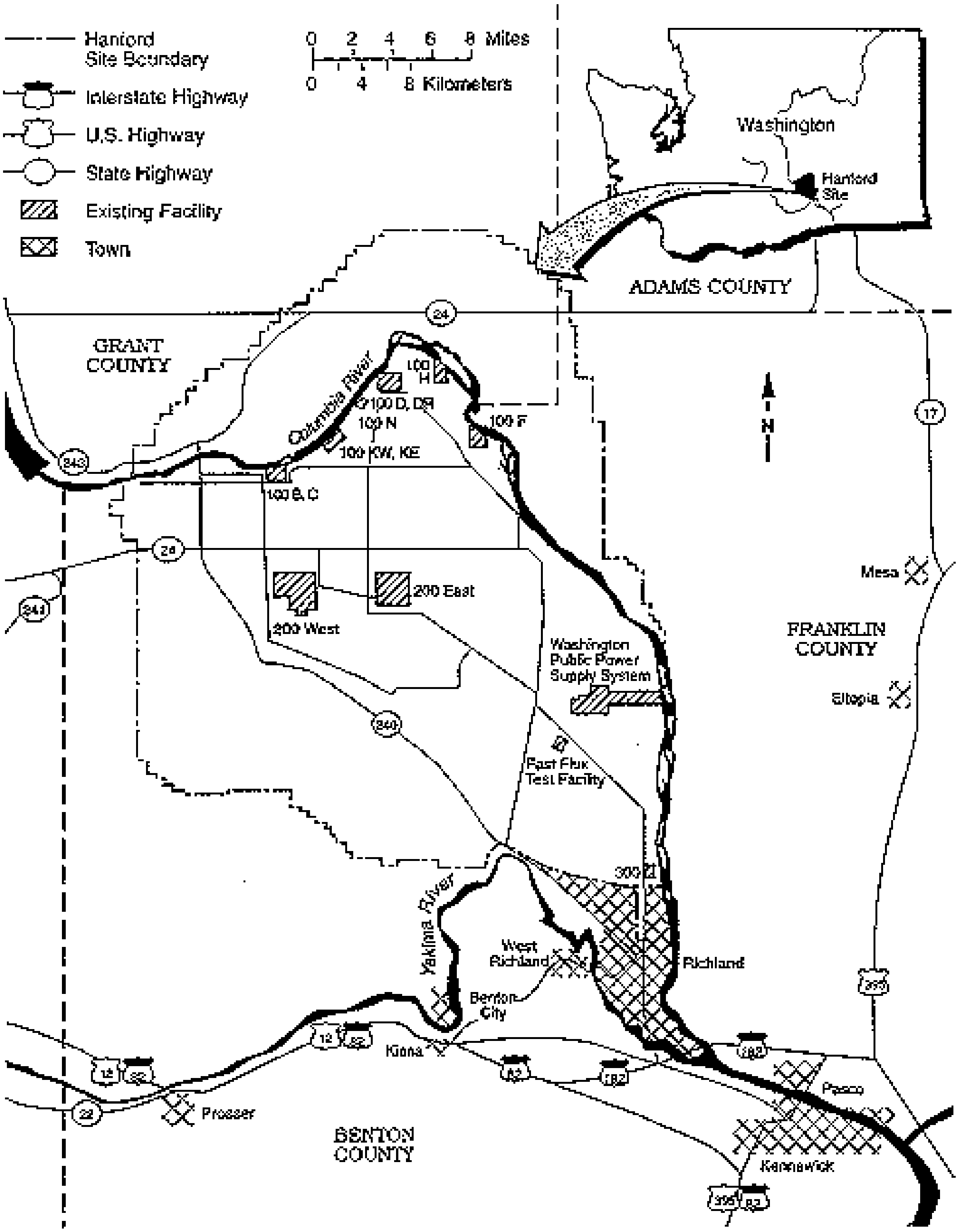
The Hanford Site infrastructure is a significant resource for furthering industrial development of the region. Key elements of this infrastructure include facilities, road and rail systems, utilities, and support services (DOE-RL 1994a).

4.7.10.1 Facilities. Onsite programmatic (60 percent) and general purpose facilities (40 percent) provide 600,000 m^2 (6.5 million ft^2) of space. General purpose facilities include offices, laboratories, shops, warehouses, and other facilities. The programmatic space supports an evaporator, filter, waste recovery, waste treatment, waste storage, and R&D laboratories. Many of these facilities are over 30 years old; however, upgrades and expansion of some facilities could occur as remediation progresses.

4.7.10.2 Road and Rail Systems. The transportation network is well developed on the Hanford Site with approximately 460 km (approximately 288 mi) of roads onsite (Figure 4-29). SR 24 crosses the Hanford Site primarily on the Wahluke Slope. SR 240 crosses the Hanford Site on the southwest and serves as the boundary between the ALE Reserve and the rest of the Site. A Site access road from SR 240 to the 200 West Area was completed in December 1994. Upgrades are planned for road capacities north of the Wye Barricade in support of remediation activities. Road maintenance will continue on all active roads. The 1100 Area roads were recently upgraded to improve traffic circulation and access.

There are approximately 204 km (127 mi) of rail line on the Hanford Site (see Figure 4-30). The rail system begins at the Richland Junction (Columbia Center), where it joins the Union Pacific commercial tracks and runs to the abandoned Chicago, Milwaukee, St. Paul, and Pacific right-of-way near the Vernita Bridge, located on the north boundary of the Hanford Site. Approximately 35 km (22 mi) of track are in "out-of-service" condition. The in-service track accommodates 4,000 movements of 1,500 rail cars annually. A railroad spurline from the 1100 Area to the City of Richland's Horn Rapids Industrial Park is planned to serve new industrial development in the Park. The Hanford railroad between the Richland Junction and Horn Rapids Road was has been transferred from DOE to the Port of Benton along with the 1100 Area.

Figure 4-30. Transportation Routes in the Vicinity of the Hanford Site.



4.7.10.3 Utilities. The Hanford Site water system includes numerous buildings, pumps, valve houses, reservoirs, wells, and a distribution piping system that delivers water from the Columbia River to all areas of the Hanford Site. The export water system, which is the largest, delivers water to the 100, 200, and parts of the 600 Areas from the Columbia River (Figure 4-31). The 300 Area and Energy Northwest (formerly known as WPPSS) also draw water directly from the Columbia River. Water is purchased from the City of Richland for the 700, 1100, and intermittently provided to the 300 Area, while the 400 Area and part of the 600 Area draw some water from groundwater wells.

The BPA, a Federal power marketing agency, sells electricity to the Hanford Site and the agencies that serve the Tri-Cities. The BPA provides electrical power to three distinct systems on the Hanford Site (Figure 4-32). The systems are located in the 100, 200, 300, and 400 Areas. Power for the 700 and 1100 Areas is provided by the City of Richland. Major upgrades or replacements of these systems to accommodate Hanford Site remediation are being implemented or planned.

The DOE has recently replaced the 200 East Area, 200 West Area, and 300 Area centralized steam plants by individual package boilers at specific facilities to supply heat and process steam. The steam in the 200 Areas is produced by oil-fired package boilers, while steam in the 300 Area is produced by natural gas-fired package boilers. A new underground natural gas line was installed from south Richland to the 300 Area to supply natural gas in support of operating the 300 Area package boilers. With these changes, the Hanford railroad is no longer needed to transport coal to the steam plants.

4.7.10.4 Support Services. Other support services on the Hanford Site include sewers, fire stations, telecommunications, landfills, and safeguards and security. Businesses in the City of Richland provide a number of important services such as laundry of radioactively contaminated protective clothing.

4.7.10.4.1 Sewer. Sanitary wastes in the 200 East and 200 West Areas are currently disposed of through septic tanks and drain fields. A central collection and treatment evaporation plant is being constructed in the 200 East and 200 West Areas to handle the sanitary sewer system. The sewer system in the 300 Area was recently connected to the City of Richland's sewer system. The 400 Area septic tank and drain field were recently closed and sanitary sewer effluent liquid was rerouted to the Energy Northwest (formerly known as WPPSS) sanitary sewer system.

4.7.10.4.2 Fire Stations. Fire stations are located in the 100, 200, and 300 Areas. Water supply, alarm, and sprinkler system upgrades are planned for the 300 Area laboratory and general support buildings. New and upgraded fire protection systems are planned for the 100-K Area facilities currently in use for interim fuel storage.

4.7.10.4.3 Telecommunications. A new fiber optic communications network was recently installed on the Hanford Site. This system provides a fully connected internal network of shared computing resources and capabilities to support future voice and data communication requirements.

4.7.10.4.4 Environmental Restoration Disposal Facility. A 65 ha (160 ac) landfill operates directly south of the 200 East and 200 West Areas to address the disposal of radioactive, hazardous, asbestos, polychlorinated biphenyls (PCBs), and mixed wastes resulting from the remediation of operable units on the Hanford Site. The facility can be expanded as needed, to a maximum of 414 ha (1.6 mi^2).

Figure 4-31. Export Water System for the Hanford Site (DOE-RL 1990a).

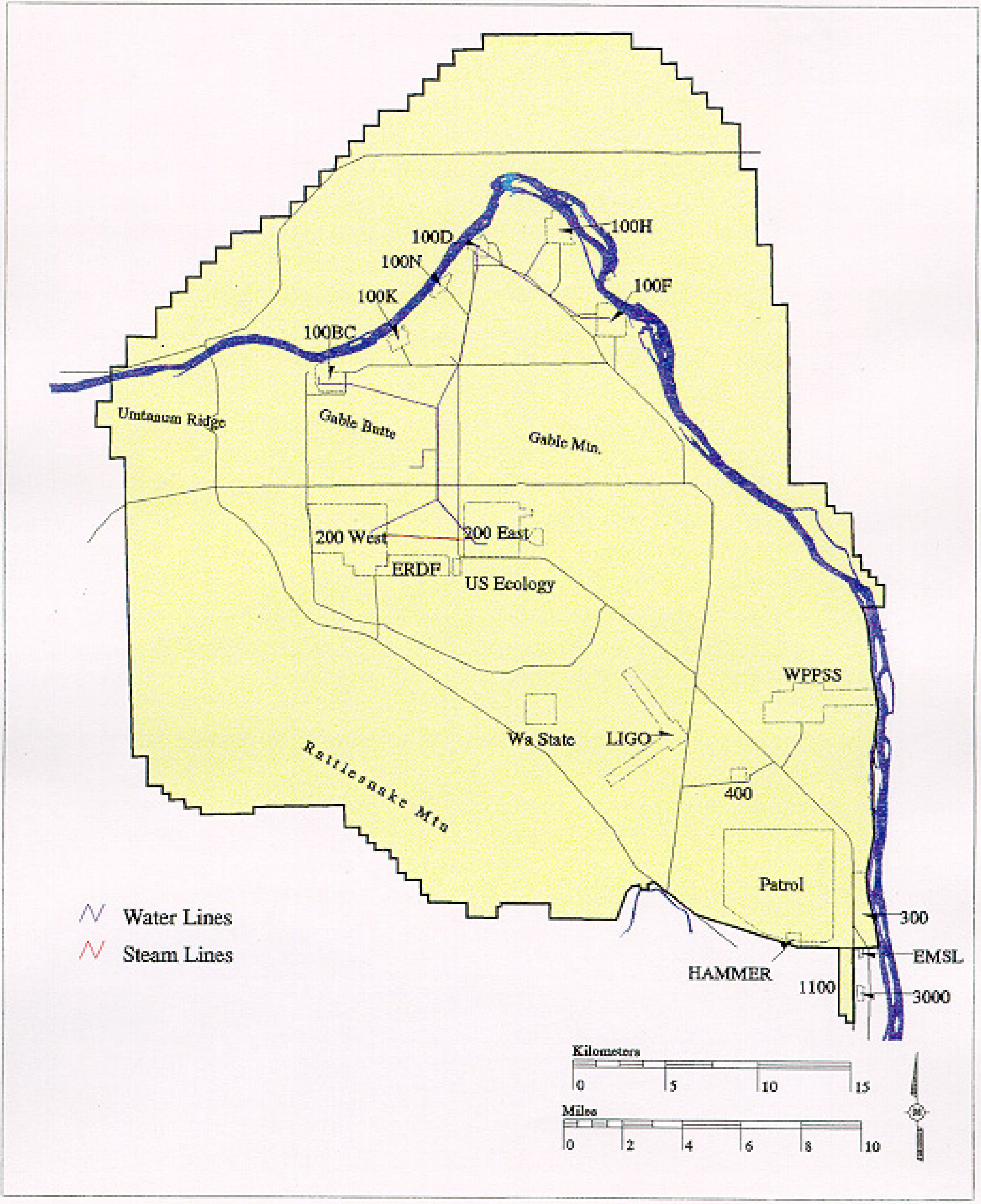
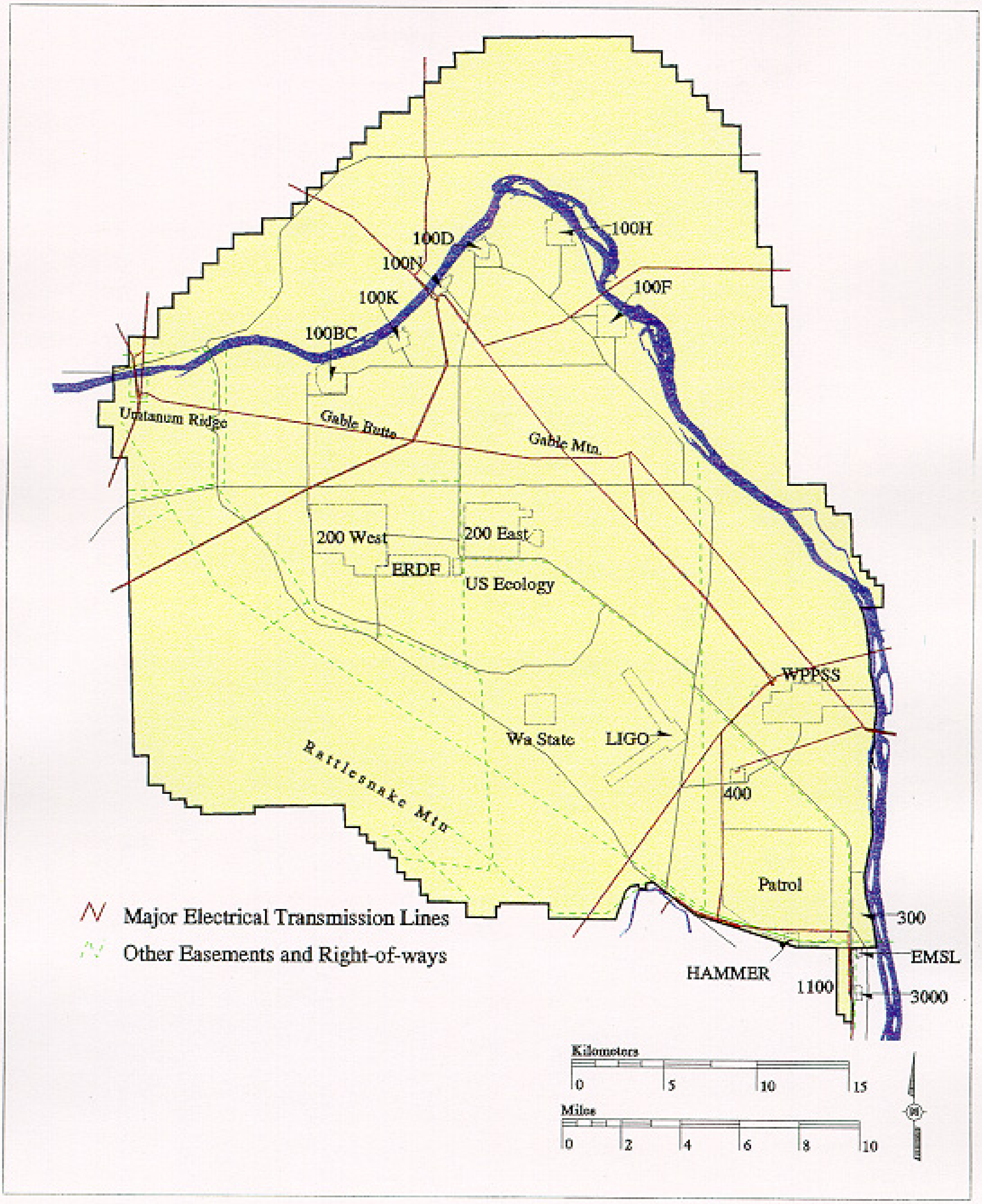


Figure 4-32. Electrical System for the Hanford Site (DOE-RL 1990b).



4.7.10.4.5 Safeguards and Security. A security force is employed onsite and a number of systems are in place to control Hanford Site access, and protect classified and business-sensitive information, property and personnel. The Benton County Sheriff's Office provides traffic enforcement, criminal enforcement, and investigations onsite.

4.8 Visual and Aesthetic Resources

The land in the vicinity of the Hanford Site is generally flat with little relief. Rattlesnake Mountain, rising to 1,060 m (3,477 ft) above mean sea level, forms the southeastern boundary of the Hanford Site. Gable Mountain and Gable Butte are the highest land forms within the Hanford Site (Figure 4-33). The view toward Rattlesnake Mountain is visually pleasing, especially in the springtime when wildflowers are in bloom. Large rolling hills are located to the west and north.

The Columbia River, flowing across the northern part of the Site and forming the eastern boundary, is generally considered scenic, with its contrasting blue against a background of dark basaltic rocks and desert sagebrush. The White Bluffs, steep whitish-brown bluffs adjacent to the Columbia River, are a striking natural feature of the landscape (see text box, *"Hanford Site Quick Facts: Visual and Aesthetic Resources"*).

Hanford Site Quick Facts: Visual and Aesthetic Resources

Prominent natural features include the Columbia River, Saddle Mountains, Gable Butte, Rattlesnake Mountain, White Bluffs, and Gable Mountain.

SR 24 provides public access through the northern portion of the Hanford Site, primarily on the north side of the Columbia River. Viewsheds along this highway include limited views of the Columbia River when the road drops down into the river valley, crosses the river over the Vernita Bridge, and climbs up out of the valley to a level plateau north of the river. A turnout on the north side of the river offers views of the river and the B and C Reactors, with an interpretive sign located nearby. A rest stop along the road just to the south of the river provides views of the Umtanum Ridge to the west, the Saddle Mountains to the north, and the Columbia River valley to the east and west.

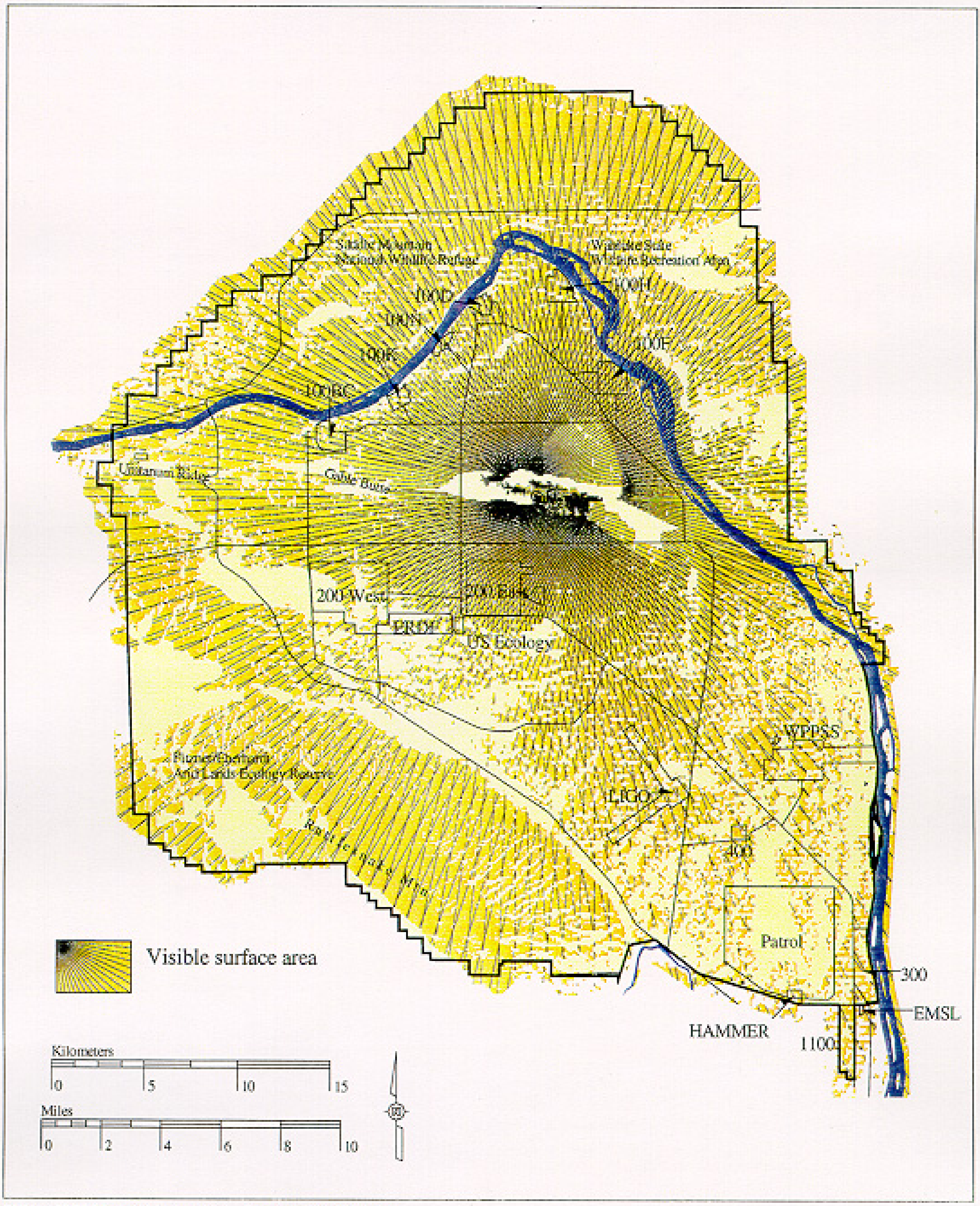
4.9 Noise

This EIS defines noise as "any undesirable or unwanted sound or audible disturbance that interferes with normal activity." Typically, intrusive noise events are those that disrupt normal human activity, especially verbal communication. Under certain circumstances, people are willing to endure noise as a trade-off for accomplishing some meaningful activity or because certain noises represent tangible evidence of progress. In the context of transportation systems, a certain amount of noise also is usually considered tolerable.

4.9.1 Public Health Implications

Noise impacts on public health usually are analyzed in terms of a dose-response relationship because noise effects are cumulative. Prolonged exposure to loud noises can impair hearing. The impairment can be temporary or permanent, depending on intensity and duration of the noise. Normally, hearing degeneration does not occur if the duration of the event is brief. Off-property noise impacts are the sound-exposure levels that interfere with normal speech, disrupt sleep, or produce secondary effects such as increased levels of stress among community members.

Figure 4-33. Viewshed from Gable Mountain.



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4.9.2 Hanford Site Sound Levels

Most industrial facilities on the Hanford Site are located far enough away from the Site boundary that noise levels at the boundary are not measurable or are barely distinguishable from background noise levels. Modeling of environmental noises has been performed for commercial reactors and traffic on SR 240 through the Hanford Site. These data are not concerned with background levels of noise and are not reviewed here.

Two studies of environmental noise were performed at the Hanford Site. One study reported environmental noise measurements taken in 1981 during Site characterization of the Skagit/Hanford Nuclear Power Plant Site (Cushing 1995). The second consisted of a series of Hanford Site characterization studies performed in 1987 that included measurement of background environmental noise levels at five locations on the Hanford Site. Noise can be disruptive to wildlife and studies have been performed to compile noise data in remote areas.

Recently, the potential impact of traffic noise resulting from Hanford Site activities has been evaluated for a draft environmental impact statement (EIS) addressing the siting of a proposed New Production Reactor (Cushing 1995). While the draft EIS did not include any new baseline measurements, it did address the traffic component of noise and provides modeled “baseline” measurements of traffic noise for the Hanford Site and adjacent communities. Baseline noise estimates were determined for two locations: SR 24, leading from the Hanford Site west to Yakima; and State Highway 240, south of the Site and west of Richland where maximum traffic volume exists. Traffic volumes were predicted based on the presence of both operational and construction work forces. Noise levels were expressed in Leq for one-hour periods in dBA at a receptor located 15 m (49 ft) from the road. Adverse community responses would not be expected at increases of 5 dBA over background noise levels.

To provide noise data for the Energy Northwest (formerly known as WPPSS) plants, measurements of environmental noise were taken in June 1981 before the construction of the Energy Northwest plants on the Hanford Site. Monitoring was conducted at 15 sites, showing point noise levels reading ranging from 30 to 60.5 dBA. The corresponding values for more isolated areas ranged from 30 to 38.8 dBA. Measurements taken in the vicinity of the sites where Energy Northwest (formerly known as WPPSS) was constructing nuclear power plants ranged from 50.6 to 64 dBA, reflecting operation of construction equipment. Measurements taken along the Columbia River near the intake structures for WNP-2 were 47.7 and 52.1 dBA, compared to more remote river noise levels of 45.9 dBA (measured about 4.8 km [3 mi] upstream of the intake structures). Community noise levels from point measurements in North Richland (at Horn Rapids Road and Stevens Road [Route 240]) were 60.5 dBA, which was largely attributed to traffic.

To support the Basalt Waste Isolation Project, background noise levels were determined at five sites located within the Hanford Site. Noise levels are expressed as equivalent sound levels for 24 hours (Leq-24). The average noise level for these five sites was 38.8 dBA on the dates tested. The wind was identified as the primary contributor to background noise levels, with winds exceeding 19 km/hr (12 mi/hr) significantly affecting noise levels. This study concluded that background noise levels in undeveloped areas at the Hanford Site are generally in the range of 24 to 36 dBA (Cushing 1992). Periods of high wind, which normally occur in the spring, would elevate background noise levels.

In addition to the project-driven studies described above, the Hanford Environmental Health Foundation has monitored noise levels resulting from several routine operations performed in the field at the Hanford Site. These included well drilling, pile driving, compressor operations, and water-wagon operation. Occupational sources of noise propagated in the field from outdoor activities ranged from 74.8 to 125 dBA (PNNL 1996a).

4.10 Environmental Monitoring Programs

Environmental surveillance at the Hanford Site consists of monitoring for potential radiological and nonradiological constituents and includes monitoring of external radiation, air, surface water, groundwater, soil, vegetation, wildlife, and regional food and farm products. Monitoring is performed to ensure protection of human health and safety and is conducted in compliance with DOE Order 5400.1, *General Environmental Protection Program* (DOE 1990a), and DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE 1993a). A detailed discussion of the Hanford Site environmental monitoring program is found in the *Hanford Site Environmental Monitoring Plan* (DOE-RL 1991a), and monitoring data are presented in annual reports, such as the *Hanford Site Environmental Report for Calendar Year 1995* (PNNL 1996b).

The Hanford Environmental Health Foundation (HEHF) provides occupational health services to Hanford personnel through health risk management and occupational health monitoring. The HEHF's Health Risk Management Program is used to identify and analyze the hazards that Hanford personnel face in the work environment and bring an awareness to worker health and safety issues at Hanford. HEHF's occupational health services provide occupational medicine and nursing, medical monitoring and surveillance, ergonomics assessment, exercise physiology, case management, psychology and counseling, fitness for duty evaluations, health education, infection control, immediate health care, industrial hygiene, and health, safety, and risk assessments.

4.11 Contamination

Three operating areas of the Hanford Site (the 100, 200, and 300 Areas) are still included on the EPA's National Priorities List (NPL), while the 1100 Area has been fully remediated and removed from the EPA's NPL. Radioactive and hazardous materials have been disposed to the ground throughout the period of active Hanford Site operations, resulting in extensive contamination of the vadose zone and groundwater.

Under the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 1989), the more than 1,000 inactive waste disposal and unplanned release sites were grouped into groundwater and source operable units, based on geographic proximity or similarity of waste disposal history. In addition, a number of *Resource Conservation and Recovery Act of 1976* (RCRA) treatment, storage, and/or disposal (TSD) units are included in the Tri-Party Agreement, which will be closed or permitted to operate in accordance with the State of Washington's "Dangerous Waste Regulations" (WAC 173-303). Some of these waste sites and TSD units are sources of environmental contamination.

The DOE holds interim status for the operation of hazardous waste management facilities by virtue of having submitted a RCRA Part A application to EPA on November 18, 1980. On November 6, 1985, DOE submitted a RCRA Part B application to Ecology and the EPA Region 10 for the TSD of hazardous wastes at Hanford. Supplemental and revised RCRA applications have been submitted to Ecology in accordance with the schedule established in the Tri-Party Agreement. A final status permit covering several units at the Hanford Site was issued in August 1994. This permit will be amended over a period of years to add additional interim status TSD units.

Hanford surface waste sites, based on data from the Hanford Geographic Information System (HGIS) and Waste Information Data System (WIDS) database, are shown in Figure 4-34. Included is vadose zone contamination, primarily in the 100, 200, and 300 Areas. The vadose zone contamination, while not necessarily occurring from all waste sites, is a result of the disposal of wastes to surface disposal structures such as the following:

- **Tanks and vaults** – Used to store radioactive liquid wastes generated by uranium and plutonium processing activities in the 200 Areas. Tanks include catch tanks, settling tanks, and storage tanks. The catch tanks are generally associated with diversion boxes and other transfer units and were designed to accept overflow and spills; wastes collected in catch tanks were transferred to storage tanks. Settling tanks were used to settle particulates in liquid wastes prior to transfer to cribs. Storage tanks were used to collect and store large quantities of liquid wastes. Storage tanks include single-shell tanks and double-shell tanks.

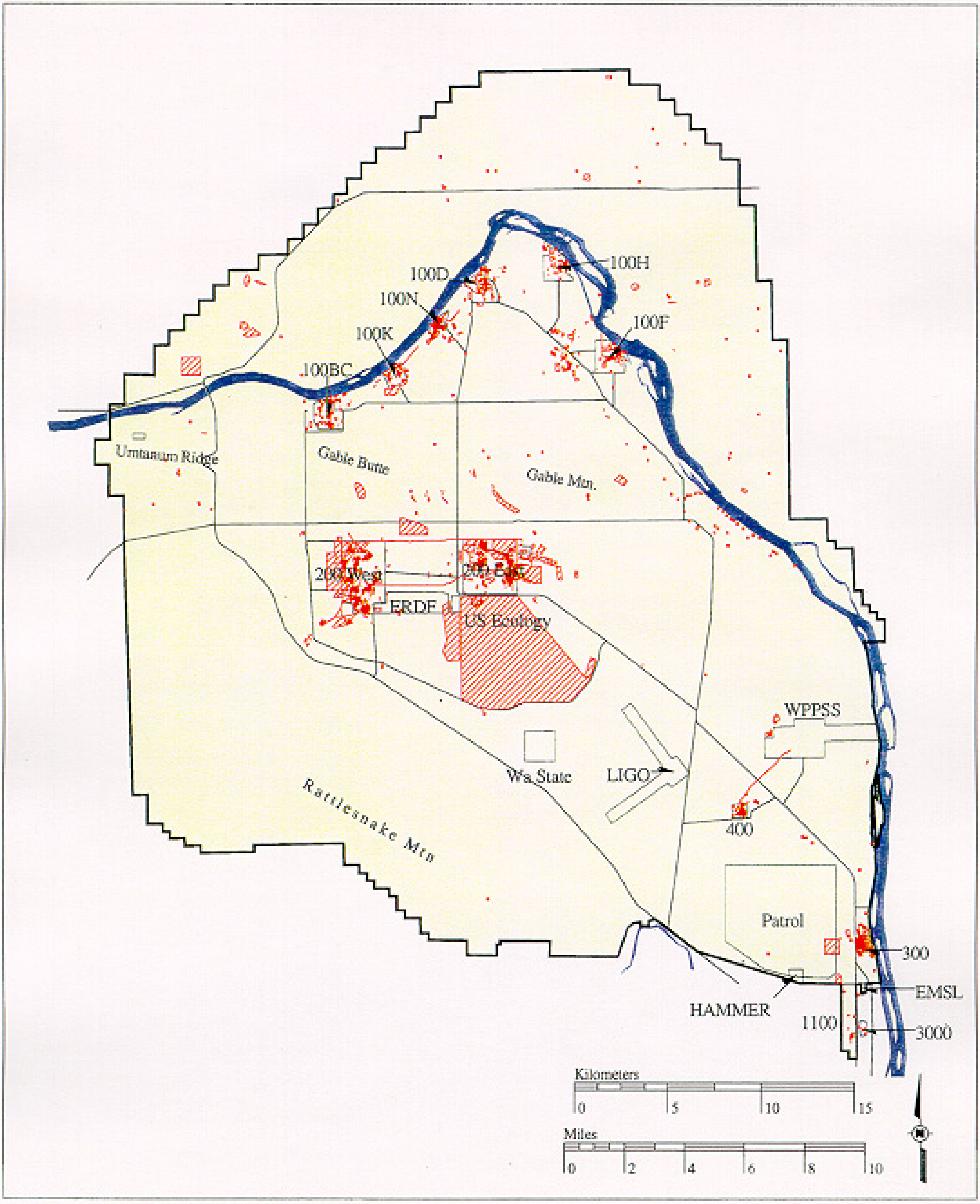
- **Vaults** – Typically are deep underground concrete structures that contain tanks as well as associated pumps, valves, and agitators. Vaults do not hold wastes but instead provide containment for other types of storage features and associated plumbing.

- **Cribs and drains** – Were designed to percolate low-level radioactive process waste into the ground without exposing the waste to the open air. Cribs and drain fields are shallow excavations that were either backfilled with permeable material or held open by wooden structures, both of which are covered with an impermeable layer. Water flows directly into the backfilled material or covered open space and percolates into the soil. French drains generally deliver waste water at a greater depth (up to 12.2 m [40 ft]) and are constructed of steel or concrete pipes that are either left open or filled with gravel.

- **Ponds, ditches, and trenches** – Were designed to percolate high volumes of low-level liquid wastes into the soil. Ditches are long, unlined excavations used to convey wastes to the ponds. Trenches are generally open, unlined, shallow excavations used for disposal of low-liquid discharges, such as sludge, which has a high salt content. Trenches were used for short periods and were deactivated when the discharge rate exceeded the soil infiltration rate.

- **Burial grounds** – Were used for disposal of solid wastes. Although the burial grounds received a variety of contaminated debris and solid wastes packed in barrels and boxes, there is currently no evidence of vadose zone contamination occurring from the disposal of solid wastes in burial grounds. Vadose contamination typically occurs when there is a driving force for the contamination, such as is found with the disposal of liquids.

Figure 4-34. Hanford Surface Waste Sites (Past and Present).



BHI:rpp 04/30/98 clup/wastesite1.aml Database: 30-APR-1998

4.11.1 Hanford Groundwater Contamination

There are a variety of contaminants present in the groundwater of the Hanford Site (Figures 4-35 and 4-36 and Table 4-14). The extent of major radionuclides at levels above the interim drinking water standards (DWSs) is shown in Figure 4-35. Tritium, iodine-129, technetium-99, and strontium-90 were present at levels above EPA or State of Washington interim DWSs. Uranium exceeded EPA's proposed maximum contaminant level (MCL). Minor radiological contamination DWS included carbon-14 (in the 100-K Area), cesium-137, and plutonium (in the 200 East Area, near injection well 216-B-5). Derived concentration guide levels (DCGLs) were exceeded for strontium-90 in the 100-K, 100-N, and 200 East Areas (near injection well 216-B-5), and near the former Gable Mountain Pond. The DCGL for uranium was exceeded near U Plant. The DCGL for tritium was exceeded in one well near cribs that received effluent from the Plutonium-Uranium Extraction (PUREX) Plant, and in another well near waste management area TX-TY. The DCGL for plutonium was exceeded in one well in the 200 East Area (near injection well 216-B-5). Cobalt-60 levels exceeded the 100 pCi/L interim DWS in recent years but were below the DWS in fiscal year 1998 (PNNL 1998).

The extent of major chemical constituents at levels above the primary MCLs is shown in Figure 4-36. Nitrate, carbon tetrachloride, and trichloroethylene were the most widespread. Chloroform, cis-1,2-dichloroethylene, cyanide, fluoride, chromium, and other metals also were present at levels above their MCLs. Tetrachloroethylene exceeded its 5 µg/L MCL in the 300 Area in fiscal year 1998 for the first time since the 1980s (PNNL 1998).

The area of Hanford contaminant plumes with concentrations exceeding an MCL or DWS was estimated to be approximately 245 million m^2 (95 mi^2) in fiscal year 1998. This equates to a volume of approximately 1.4 billion m^3, which is the same as fiscal year 1997. The volume estimate has a high uncertainty because of a lack of knowledge of the vertical extent of contaminant plumes. Plume thickness is estimated to be 20 m (66 ft), except in the 100 and 300 Areas and the North Richland area, where the plume is estimated to be 5 m (16 ft). The porosity of the aquifer is not well-characterized; for the purpose of the calculation, the porosity was assumed to be 30 percent. This estimate does not include water in the vadose zone.

Tritium, iodine-129, and nitrate plumes originating in the Central Plateau are quite widespread, reaching the Columbia River to the east. Other contaminants are not as widespread but exist in the groundwater at many different locations. Examples of these contaminants include strontium-90, uranium, technetium-99, and chromium. Contaminant plume migration is affected in part by the degree to which individual contaminants are mobile in groundwater and in part on hydrogeologic conditions. Natural groundwater flow at the Hanford Site has been altered in some areas due to past Hanford Site operations; this alteration is due in large part to groundwater mounds that were created by extensive artificial recharge at some wastewater disposal facilities. Although these groundwater mounds are dissipating, groundwater flow patterns are still affected by past wastewater discharges on the Hanford Site

.***4.11.1.1 Groundwater Ingestion Dose and Risk Estimates.*** Results of groundwater monitoring are compared to the DWSs for individual radiological constituents (see Table 5-14). These interim DWSs use the methodology set out in 40 CFR 141, 40 CFR 142, and 40 CFR 143 to estimate the concentration in water that could result in a potential radiological dose of 4 mrem/yr from consumption of each individual constituent. Similarly, DCGLs provide estimates of activities that could result in a 100 mrem/yr dose, as defined in DOE Order 5400.5. However, the potential dose is actually the sum of the doses from the individual constituents. An estimate of this cumulative dose, which could result from consumption of groundwater from different onsite locations, can be calculated from the extent of contamination.

Figure 4-35. Distribution of Radionuclides in Groundwater within the Hanford Site (PNNL 1998).

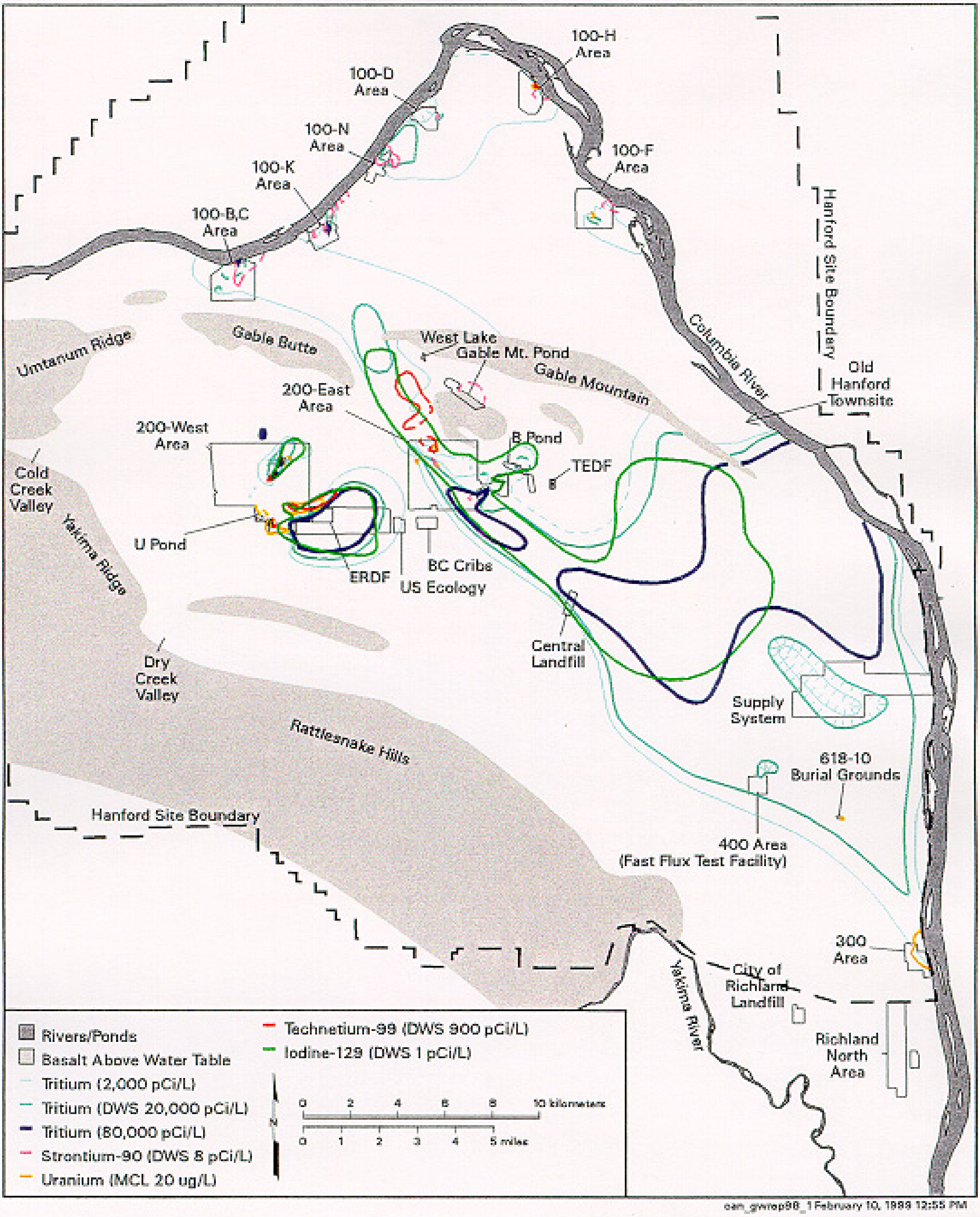


Figure 4-36. Distribution of Hazardous Chemicals of Concern in Groundwater within the Hanford Site (PNNL 1998).

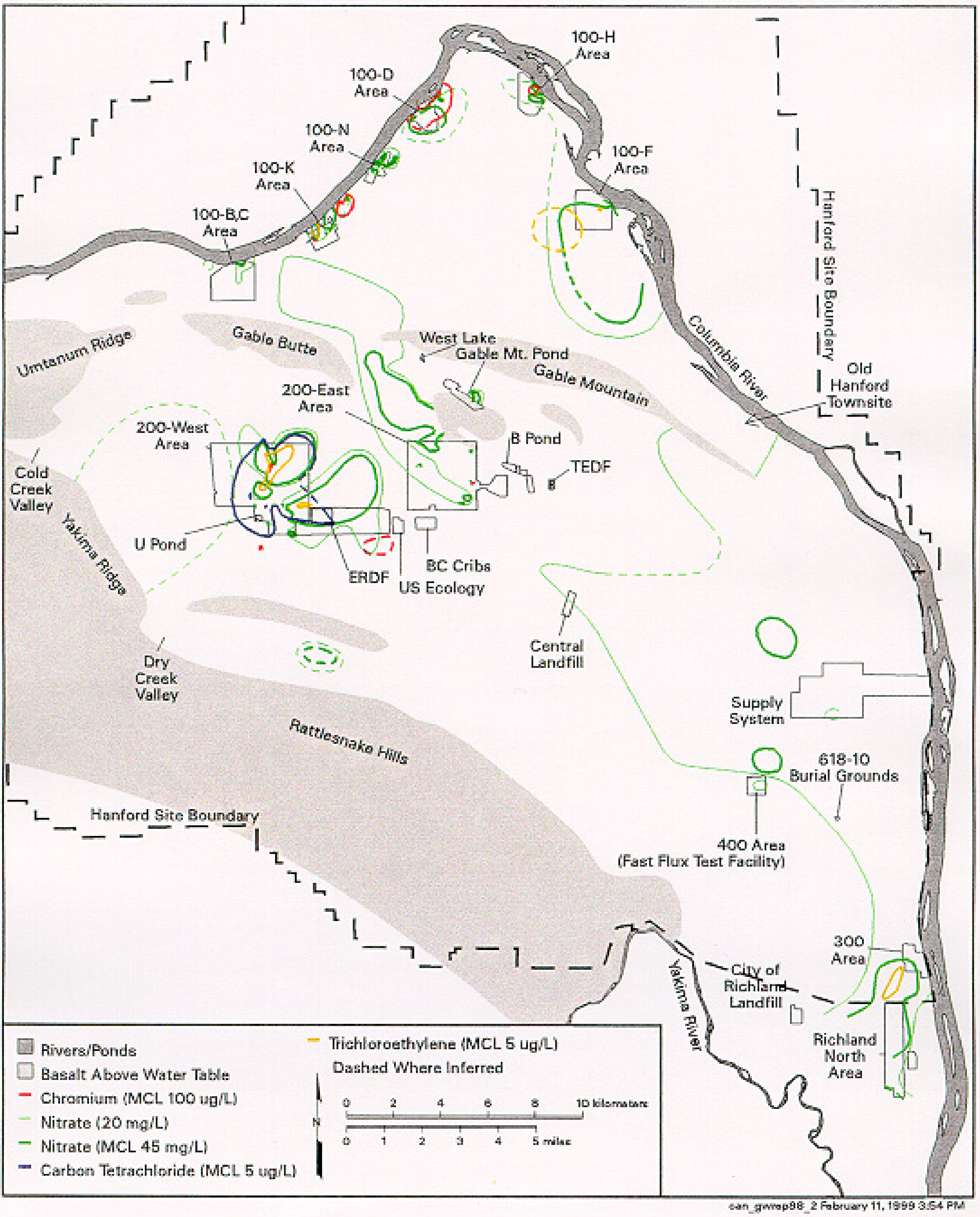


Table 4-14. Detected Concentrations Greater Than Drinking Water Standards: 1995 Groundwater Sampling Rounds (adapted from PNL 1995). (2 pages)

Area Name	Plume Constituent	Units	Maximum Plume Concentration	EPA DWS	Washington Water Quality Standard
100-B/C	Chromium	ug/L	>50.0	100	50
	Strontium-90	pCi/L	56.7	8	8
	Tritium	pCi/L	28,000	20,000	20,000
100-D/DR	Chromium	ug/L	1,360	100	50
	Nitrate	mg/L	205	45	45
	Strontium-90	pCi/L	44.0	8	8
	Tritium	pCi/L	69,000	20,000	20,000
100-F	Chromium	ug/L	82.4	100	50
	Nitrate	mg/L	110.0	45	45
	Uranium	ug/L	133.0	20	20
	Strontium-90	pCi/L	20.5	8	8
	Tritium	pCi/L	98,300	20,000	20,000
	Trichloroethylene	ug/L	27.0	5	N/A
100-H	Chromium	ug/L	300.0	100	50
	Nitrate	mg/L	730.0	45	45
	Strontium-90	pCi/L	28.0	8	8
100-KE/KW	Chromium	ug/L	210.0	100	50
	Nitrate	mg/L	110.0	45	45
	Strontium-90	pCi/L	803.0	8	8
	Tritium	pCi/L	1,040,000	20,000	20,000
	Trichloroethylene	ug/L	20.0	5	N/A
100-N	Chromium	ug/L	200.0	100	50
	Cobalt-60	pCi/L	732.0	100	N/A
	Nitrate	mg/L	65	45	45
	Strontium-90	pCi/L	4,030	8	8
	Tritium	pCi/L	74,200	20,000	20,000
200 East	Chromium	ug/L	73.0	100	50
	Nitrate	mg/L	120.0	45	45
	Cyanide	ug/L	39.5	200	200
	Strontium-90	pCi/L	9,740	8	8
	Cesium-137	pCi/L	2,310	10	10
	Tritium	pCi/L	3,370,000	20,000	20,000
	Cobalt-60	pCi/L	40.1	100	N/A
	Iodine-129	pCi/L	11.8	1	1
	Plutonium-239/240	pCi/L	2,670	1	N/A
	Technetium-99	pCi/L	3,700	900	900
	Uranium	ug/L	64.3	20	20

Table 4-14. Detected Concentrations Greater Than Drinking Water Standards: 1995 Groundwater Sampling Rounds (adapted from PNL 1995). (2 pages)

Area Name	Plume Constituent	Units	Maximum Plume Concentration	EPA DWS	Washington Water Quality Standard
200 West	Cesium-137	pCi/L	21.8	10	10
	Cobalt-60	pCi/L	13.2	100	N/A
	Cyanide	ug/L	20.0	200	200
	Chromium	ug/L	500.0	100	50
	Nitrate	mg/L	1,700	45	45
	Fluoride	mg/L	5.1	4	4
	Tritium	pCi/L	2,400,000	20,000	20,000
	Iodine-129	pCi/L	86.1	1	1
	Technetium-99	pCi/l	23,700	900	900
	Uranium	ug/L	2,720	20	20
	Carbon tetrachloride	ug/L	5,200	5	0.3
	Chloroform	ug/L	107.0	100	7
	Strontium-90	pCi/L	14.5	8	8
	Trichloroethylene	ug/L	44	5	N/A
300 Area	Chromium	ug/L	<100.0	100	50
	Uranium	ug/L	150	20	20
	Trichloroethylene	ug/L	6.1	5	N/A
600 Area (All Other Areas)	Cyanide	ug/L	110.0	200	200
	Chromium	ug/L	>100.0	100	50
	Nitrate	mg/L	100	45	45
	Strontium-90	pCi/L	994.0	8	8
	Technetium-99	pCi/L	4,310	900	900
	Tritium	pCi/L	257,000	20,000	20,000
	Trichloroethylene	ug/L	25	5	N/A

DWS = drinking water standard
EPA = U.S. Environmental Protection Agency
ug/L = 1 part per billion (ppb) or microgram per liter
mg/L = 1 part per million (ppm) or milligram per liter
pCi/L = picocurie per liter
N/A = not applicable

Figure 4-37 shows the cumulative dose estimates from ingestion of groundwater from the unconfined aquifer system on the Hanford Site. These estimates were made by summing the interpolated carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, plutonium, tritium, and uranium activities in groundwater. The automatic interpolation process sometimes resulted in peak grid values that were lower than the measured maximum values because it averaged in other lower values. In these cases, the value at the grid node closest to the measured peak value was increased to match the measured peak. Factors to convert activities to ingestion dose equivalents were taken from DOE Order 5400.5. The dose presented in Figure 4-37 represents the cumulative dose equivalent from all major radionuclides in Hanford Site groundwater.

The dose estimates presented in Figure 4-37 show that areas above the 100 mrem/yr dose standard are restricted to localized parts of the 100-K, 100-N, and 200 Areas. Areas above

4 mrem/yr are more restricted than the area above the interim DWS for individual constituents because the dose map used more recent conversion factors than those used in calculating the interim DWSs. Dose estimates for portions of the 100, 200, 300, and 600 Areas exceed 4 mrem/yr.

Figure 4-38 illustrates the estimated lifetime incremental cancer risk that would be experienced by a person drinking water contaminated with chemicals and radionuclides at concentrations that have been measured in groundwater across the Hanford Site. Cancer-risk estimates were made by summing interpolated groundwater concentrations of the radionuclides listed above plus carbon tetrachloride, chloroform, trichloroethylene, cis-1,2-dichloroethylene, nitrate, and hexavalent chromium. The calculation assumes that a person weighing 70 kg (154 lbs) consumes 2 L (0.5 gal) of groundwater every day for 30 years (DOE/RL-91-45, Rev. 3; IRIS 1997). Cancer risks exceeding 0.0001 are present in portions of the 100, 200, 300, and 600 Areas, and this contour closely resembles the cumulative dose map (see Figure 4-37). An additional area of cancer risk >0.0001 is observed in the 200 West Area, a result of the carbon tetrachloride plume.

Figure 4-39 shows the estimated hazard quotient that would be experienced by an individual drinking water contaminated with chemicals at concentrations that have been measured in groundwater across the Hanford Site. The hazard quotient relates the potential human health hazards associated with exposure to noncarcinogenic substances or carcinogenic substances with systemic toxicities other than cancer (in Hanford Site groundwater, these include nitrate, hexavalent chromium, uranium, and strontium). The calculation assumes that a person weighing 70 kg (154 lbs) consumes 2 L (0.5 gal) of groundwater every day for 30 years (DOE/RL-91-45, Rev. 3; IRIS 1997). The only part of the Hanford Site with a >5 hazard quotient is a small portion of the 200 West Area. Hazard quotients >0.3 are present in all of the operational areas and in parts of the 600 Area, primarily those areas with nitrate contamination.

4.11.2 Columbia River Contamination

The Columbia River has received radiological and chemical contamination as a result of past operations at the Hanford Site. Columbia River water that was used to cool the Hanford Site nuclear production reactors subsequently was contaminated with chemical and radiological constituents. The contaminated water entered the Columbia River primarily through direct effluent discharge. In addition to direct discharges of contaminated cooling water, the Columbia River received and continues to receive contaminants indirectly through soil column waste disposal units, leaks from pipelines, and possibly leaks from tanks that are carried by the groundwater and discharged through springs and seeps along the shoreline (DOE 1993a).

Sediments in the Columbia River contain low levels of Hanford radionuclides (i.e., cobalt-60, uranium-238, and europium-154) and metals; and radionuclides from nuclear weapons testing fallout, which collect in slack water habitats. Analyses of sediments showed detectable, though low, levels of metals in Columbia River sediments. Chromium concentrations in sediment along the Hanford Reach appeared to be slightly elevated when compared to upstream samples (PNNL 1996c).

Contaminated areas within the Columbia River are generally located in slack water areas, such as sloughs and portions of the islands. These contaminated areas have been identified by aerial gamma-ray surveys. Riverbed sediments and floodplain soils of the Hanford Reach constitute a sink for many of the pollutants released to the environment by past Hanford operations. Shoreline activities that affect the flow of the Columbia River could remobilize contaminants entombed within river sediments.

Figure 4-37. Potential Dose Estimates from Ingestion of Groundwater, Fiscal Year 1998 (PNNL 1998).

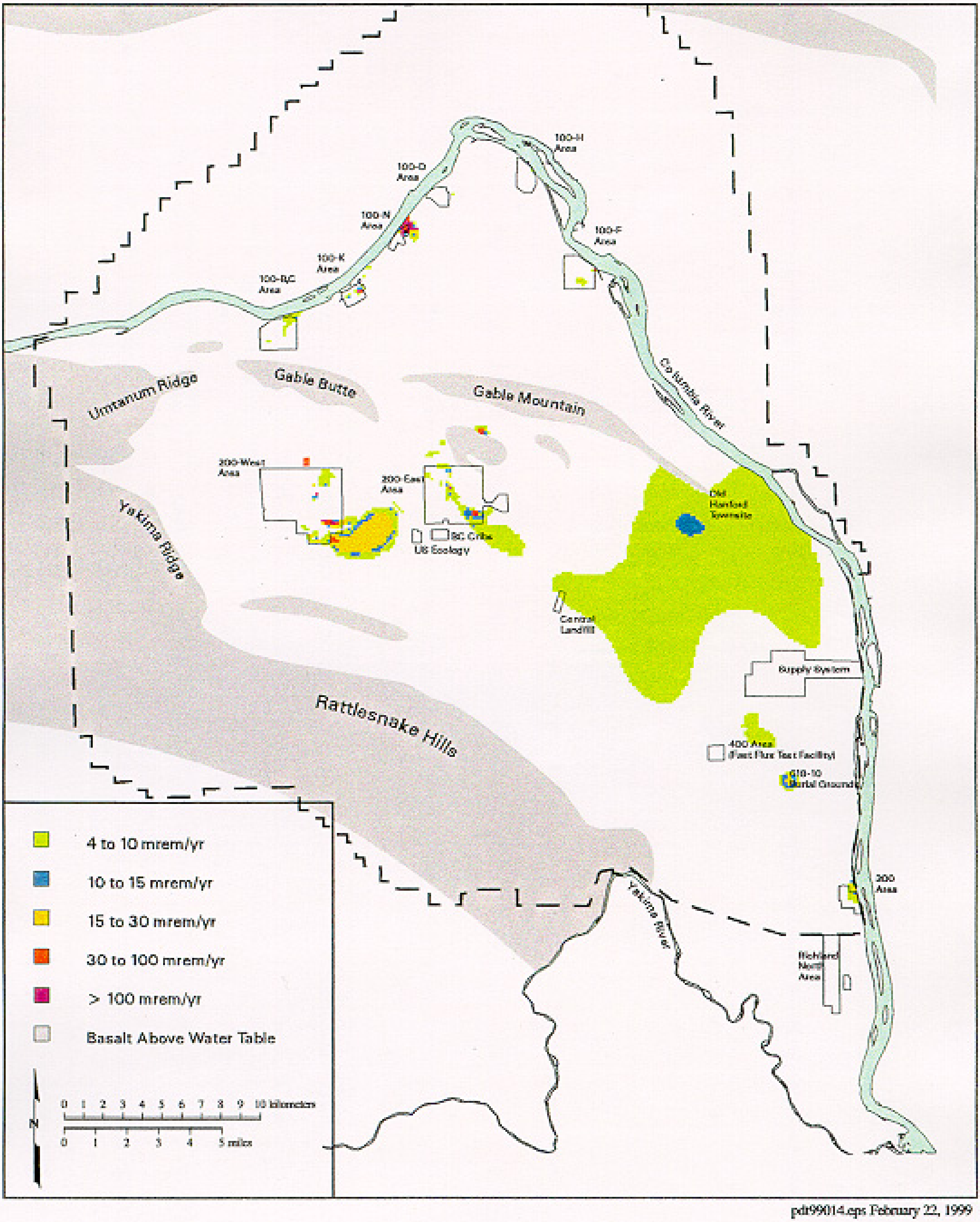


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Figure 4-38. Potential Cancer Risk Estimates from Ingestion of Groundwater, Fiscal Year 1998 (PNNL 1998).

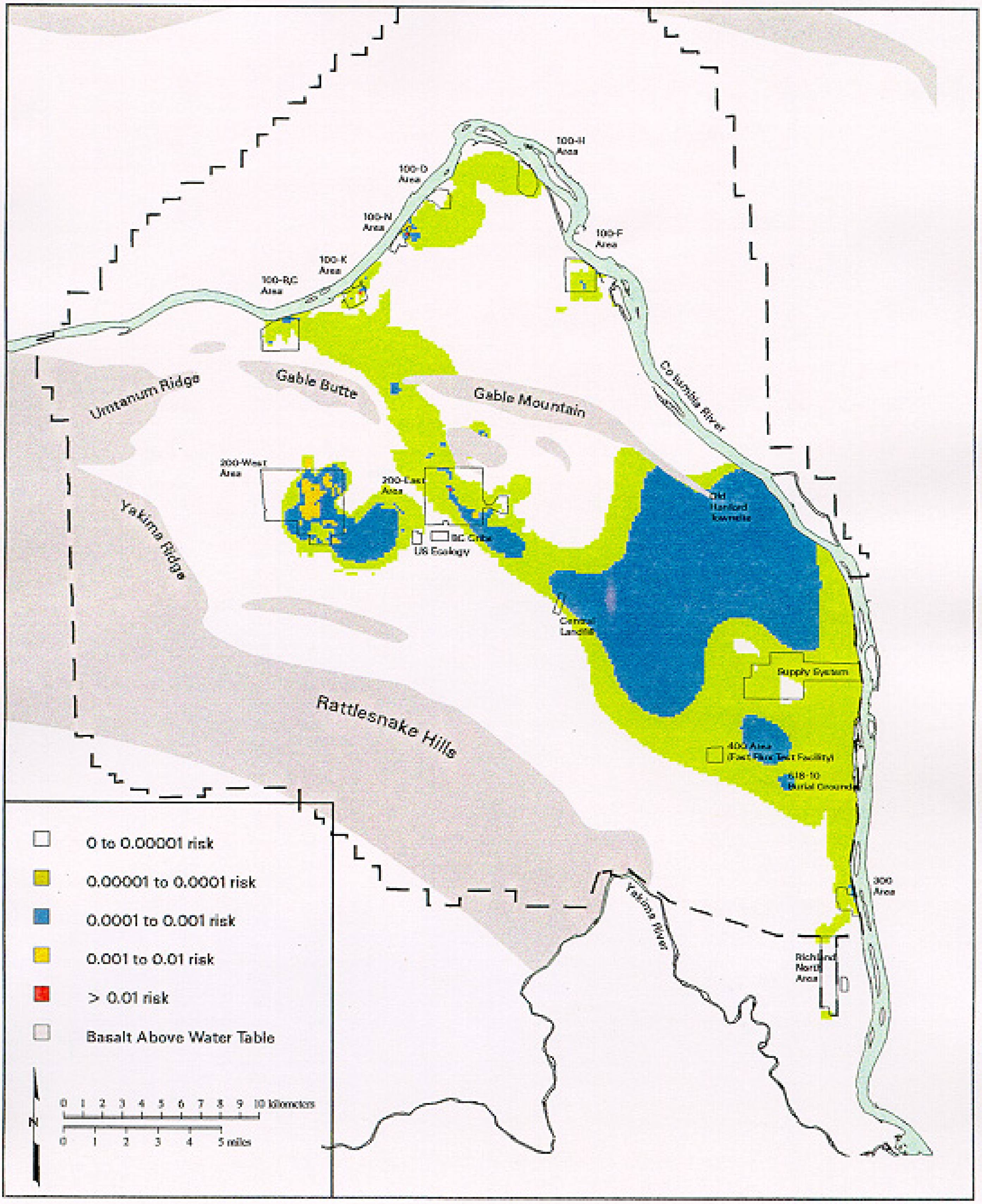

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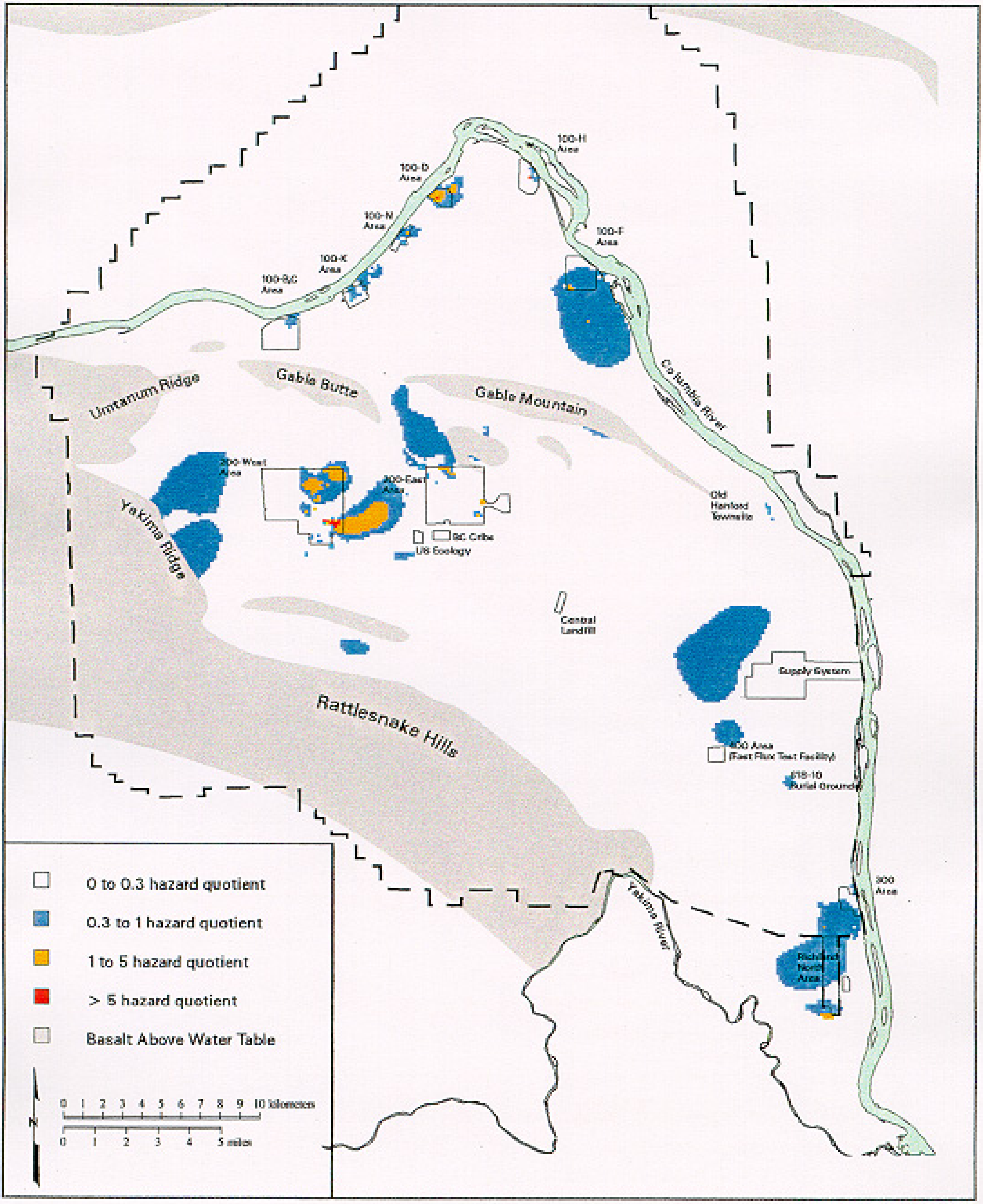
Figure 4-39. Potential Hazard Quotient Estimates from Ingestion of Groundwater, Fiscal Year 1998 (PNNL 1998).



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River water used for cooling flowed through the Hanford reactor to the Columbia River, carrying nuclear fission products and neutron-activated stellites (i.e., cobalt-60 particles). The extent and amount of discrete cobalt-60 particles in the river have never been thoroughly investigated and the actual amount of neutron-activated material transported to the Columbia River is not known. Based on Stokes Law and the physical properties of sand and stellite (Sula 1980; Cooper 1995), cobalt-60 particles (stellite) entrained into the river bedload have preferentially settled in areas dominated by sand-size grains. The sandy areas of the Hanford Reach have never been thoroughly examined for the presence of radionuclides. For example, the sandy portion of D Island has not received a detailed survey for discrete radioactive particles (WDOH 1996). Randomly placed surveys have been conducted, but the deposition of cobalt-60 particles by the Columbia River may not be a random process, and use of a random sampling pattern may actually underestimate the concentration of cobalt-60 particles in the Columbia River shoreline.

Due to shielding by soil, water, vegetation, and air (as well as the motion of the detector), aerial gamma-ray surveys lack the sensitivity and resolution required to aid in the determination of concentration of cobalt-60 particles. The non-random distribution of the cobalt-60 particles into discrete areas and the presence of water within the detector's "field of view" (Sula 1980) further reduces the utility of aerial gamma-ray surveys in determining the potential for cobalt-60 particles.

4.11.3 Soil Contamination

The 100 Areas include nine retired plutonium production reactors, effluent lines from each reactor complex, 33 surplus facilities, more than 200 WIDS database past-practice waste sites, and six TSD units. Extensive contamination exists in some areas of surface soils, subsurface soils, and groundwater (EPA 1995a). Strontium-90, tritium, nitrate, and chromium are detected at many of the 100 Area operable units.

The Central Plateau has been used for fuel reprocessing, waste management, and disposal activities and is the most extensively contaminated area at the Hanford Site. More than 400 WIDS database past-practice waste sites, 13 TSD units, and numerous groundwater contaminant plumes occur in the 200 Areas. This area is the site of the Hanford Central Waste Complex and the Tank Waste Remediation System facilities, which support present and future Hanford waste management activities (EPA 1995a). There have been known releases from the Central Waste Complex to the soil column. Contaminants include extensive groundwater plumes of technetium-99, iodine-129, nitrate, tritium, uranium-238, and chlorinated hydrocarbons (e.g., carbon tetrachloride, chloroform, and trichloroethylene). Carbon tetrachloride in particular poses a complex remediation problem; it is estimated that about 580 to 920 metric tons (640 to 1,014 tons) of carbon tetrachloride have been disposed to the vadose zone where it exists in a vapor phase above the water table, a liquid phase above and below the water table, and as a solute within the water.

The 600 Area presents a diverse range of existing contamination. Parts of the 600 Area vadose zone are essentially uncontaminated, while nearby operating areas, such as the 300 Area, present significant environmental remediation challenges. Several small, isolated surface waste sites have been remediated as expedited response actions under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA). Extensive groundwater contamination (i.e., nitrate, tritium, technetium-99, and iodine-129) occurs in the 600 Area.

Although some information on soil contamination is available, DOE recognizes that a comprehensive and integrated vadose zone characterization effort is needed at the Hanford Site to adequately assess risk during waste retrieval and treatment activities, and eventual closure of the 200 Area tank farms. Therefore, in April 1996, DOE brought together Hanford's Vadose Zone Expert Panel, comprised on representatives from state government, national laboratories, and the private sector. The Panel was convened primarily to assess how cesium-137 reached depths of

39 m (130 ft) in the vadose zone under the SX tank farm. An integrated vadose zone program plan for the entire Hanford Site is under development (DOE-RL 1998). This project will account for the entire waste inventory on the Hanford Site. Better understanding of vadose zone transport mechanisms may require land-use restrictions where soil contamination is left at depth after remediation.

4.11.4 Hanford Site Protective Safety Buffer Zones

Existing and planned waste disposal sites, waste processing facilities, and hazardous or radiological materials storage facilities are found throughout the Hanford Site. To protect the public from routine or accidental releases of radiological contaminants and/or hazardous materials, protective measures for waste remediation, processing, and disposal facilities are required by DOE Order 420.1 Facility Safety, DOE Order 151.1, *Comprehensive Emergency Management System* (DOE 1996f), and Occupational Safety and Health Administration (OSHA) regulations 29 CFR 1910.120, “Hazardous Waste Operations and Emergency Response (Site Safety and Control Plan),” 29 CFR 1910.119, “Process Safety Management (PSM) Rule” the PSM complement, EPA’s Risk Management Planning (RMP) under the Clean Air Act, 40 CFR 68.10(a), and WAC 246-247. These buffer zones limit public exposure to radiological and hazardous chemicals from routine operations and accidents. A methodology that used the air dispersion model GXQ with 95-percent meteorological conditions based on the Nuclear Regulatory Commission’s Regulatory Guide 1.145 was developed to determine the location, size, shape, and characteristics of the buffer zones needed for the Hanford Site, using existing safety analysis reports, hazard assessments, and emergency planning zone studies. This methodology allows decision makers to restrict potential land uses in areas where hazardous or radioactive material handling could pose an unacceptable risk to human health. Actual DOE facility siting decisions would be made with site-specific wind data at 99.5-percent meteorological conditions.

Buffer zones necessary to protect human health and safety in potential accidents are divided into two main components — an inner exclusive-use zone (EUZ) and an emergency planning zone (EPZ).

- DOE Orders 420.1 and 5480.23, along with the guidance document DOE-ST-3009, require that a hazard analysis be developed as the basis for a conclusion that off-site personnel are sufficiently protected from accidents at a nuclear facility. That conclusion is to be reached through analysis showing that the estimated individual dose off-site from any design basis accident or evaluation basis accident would be less than some guideline amount. No guideline value has been issued by DOE, but a value of 25 rem committed effective dose equivalent (CEDE) is frequently used by DOE’s contractors in the absence of a specified value (DNFSB/TECH-20). The EUZ is an area designated for operation activities associated with a waste site or facility. In DOE O 420.1, Section 4.1.1.2, *Design Requirements*, each DOE nuclear facility is required to “be sited and designed in such a manner that gives adequate protection for the health and safety of the public and for workers, including those at adjacent facilities, from the effects of potential facility accidents involving the release of radioactive materials (DOE Order 420.1).”

  Hanford contractors have interpreted this requirement as to maintain a public buffer zone where 25 rem would not be exceeded in the event of an unmitigated low probability accident (10^{-4} to 10^{-6}), where 5 rem would not be exceeded in the event of an unmitigated medium probability accident (10^{-2} to 10^{-4}), or where 0.5 rem would not be exceeded in the event of an unmitigated high probability accident (10^{-2} to 1) (WHC-85M00-JCVK-95008). The EUZ is reserved for DOE or other hazardous operations with severely restricted public access. This zone extends from the facility fence line to a distance at which threats to the public from routine and accidental releases diminish to the point where public access can be routinely allowed while ensuring the intent of DOE O 420.1 is achieved. The EUZ is located inside the EPZ.

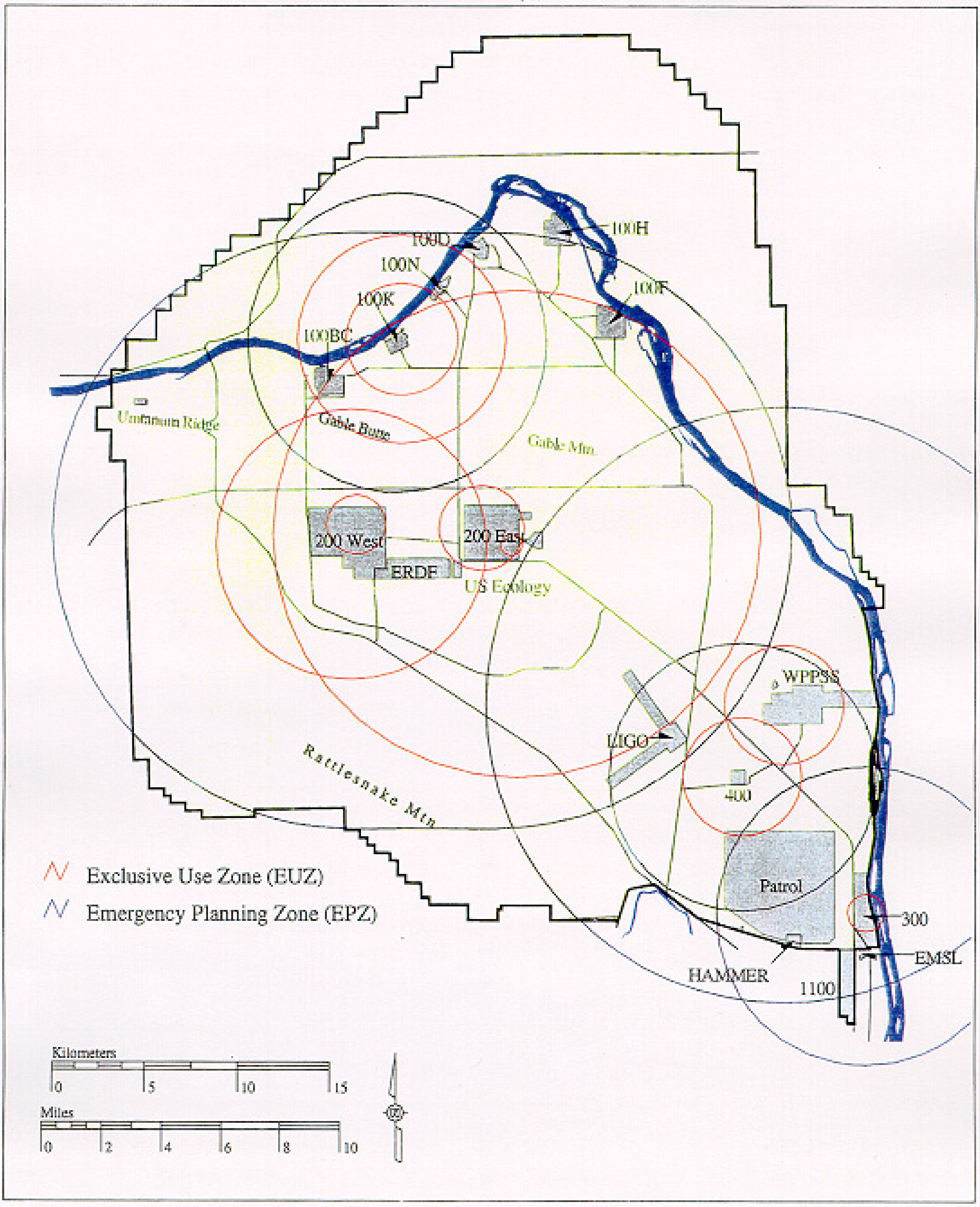
- The EPZ is an area surrounding a facility for which emergency planning and preparedness efforts are carried out per DOE's *Comprehensive Emergency Management System Order* (DOE Order 151.1) to ensure that prompt and effective actions can be taken to minimize the impact to onsite personnel, public health and safety, and the environment in the event of an operational emergency. The EPZ begins at the boundary of the facility and ends at a distance for which special planning and preparedness efforts are no longer required. Access restrictions are not required within an EPZ; however, DOE would be responsible for ensuring adequate planning and preparedness efforts.

The protective buffer zones for the Hanford Site (Figure 4-40) were established using boundaries calculated for individual limiting facilities (i.e., facilities with accidents of maximum potential public health impact). Accidents initiated by sabotage are not applicable to EPZs. Information about the limiting facilities, controlling contaminants, and credible accidents is presented in Table 4-15.

In addition to the known risks (e.g., K-Basins could have the fuel elements removed in about six years), RODs for the Hanford Site burial grounds are upcoming. It is very difficult to adequately characterize heterogenous burial grounds created over 40 years ago (e.g., in a surprise to everyone, the 618-4 burial ground had 1500 barrels of uranium fines packed in mineral oil). In the spirit of DOE O 420.1's defense in depth policy, it is prudent for DOE to reserve land for operational safety and/or remediation/stewardship buffer zones until the known risks and the unknown risks are dispositioned. The boundaries provide a conservative buffer zone based on risk and consequence management that is expected to be sufficient to address protective zone needs for the multiple facilities present in each area on the Hanford Site. As the cleanup mission progresses, the extent of these EUZ's is expected to shrink in size and eventually migrate inward to the Central Plateau. This expectation is reflected in section 6.3.1, *Overall Policy*, number 5, *Reduce exclusive use zone (EUZ) areas to maximize the amount of land available for alternate uses while still protecting the public from inherently hazardous operations*.

In an effort to consider non-Hanford protective buffer zone requirements that could be affected by Hanford Site public access and land-use decisions, the emergency preparedness needs of Energy Northwest (formerly WPPSS) were considered. Under U.S. Nuclear Regulatory Commission procedures, the Energy Northwest WNP-2 Reactor requires a 16-km (10-mi) EPZ and a 1.9-km (1.2-mi) EUZ.

Figure 4-40. Protective Safety Buffer Zones.



BHI:rpp 04/2296 clup/sar1.aml Database: 21-OCT-1998

Table 4-15. Protective Safety Buffer Zones (Exclusive Use Zones and Emergency Planning Zones).

Limiting Facility	Coordinates WASP-X	Coordinates WASP-Y	EUZ Boundary (m)	Credible Accident	Controlling Contaminant	EPZ Boundary (m)	Limiting Accident	Controlling Contaminant
100-K Area								
K-Basin	569184.3	146717	3,000	Chlorine cylinder valve failure	Cl	8,100	Sabotage	Cl, Pu, Cs-137
			5,600	Fuel processin g for dry storage	Cs-137			Sr-90, Am-241
200 West Area								
PFP	566474.3	135652.7	7,300	Seismic event with ventilation	Pu	16,100	Waste tank sabotage and PFP seismic accident	Pu, Am-241
Tank Farms	566777	136734.1	1,600	Single-shell tank hydrogen deflagrati on	Cs-1373	16,100	Waste tank sabotage and PFP seismic accident	Pu, Am-241
200 East Area								
B Plant/WESF	573504.9	136548.1	2,300	Cross-contamina tion from K-3 to K-1 filter banks	Sr-90, Cs-137	16,100	Waste tank sabotage	Pu, Am-241
Tank Farms	575422.2	136203.9	13,150	Double-shell tank filter blowout	Cs-137	16,100	Waste tank sabotage	Pu, Am-241
Limiting Proposed Facility - Tank Waste Vitrification Plant	575118.1	135636.9	600	Earthquak e	Am-241	16,100	Waste tank sabotage	Pu, Am-241

Table 4-15. Protective Safety Buffer Zones (Exclusive Use Zones and Emergency Planning Zones).

Limiting Facility	Coordinates WASP-X	Coordinates WASP-Y	EUZ Boundary (m)	Credible Accident	Controlling Contaminant	EPZ Boundary (m)	Limiting Accident	Controlling Contaminant
300 Area								
324 Bldg. B-Cell	594247.4	115784.7	1,000	Earthquake 324 Bldg. w/o B-cell upset	Sr-90		(315 Bldg. accident dominates)	
315 Bldg.	594480.3	115761.7		(324 Bldg. accident dominates)		8,100	1,920 lbs. chlorine incident in the 315 Bldg.	Cl
400 Area								
FFTF	587604.9	123117.5	3,200	Sodium Storage Safety Class 2	Sodium hydroxide	7,300	Sodium sabotage	Sodium hydroxide

[a] If K Basin fuel is not stable enough to move to the 200 Area before processing for dry storage, this larger EUZ may be needed.
[b] The 324 B-cell accident dominated the credible (>10^{-6} probability) accident calculations for the 300 Area EUZ; the 315 Building chlorine accident dominated the incredible (<10^{-6} probability) accident calculations for the 300 Area EPZ.
EPZ = emergency planning zone
EUZ = exclusive use zone
FFTF = Fast Flux Test Facility
PFP = Plutonium Finishing Plant
WESF = Waste Encapsulation and Storage Facility

Within portions of the EUZ, certain types of public access would be restricted, while other types of public access within that same area might be acceptable. Six different types of public access have been defined for the EUZ (WHC 85M00-JCVK-95008). These types of access are presented below:

- ***Very Limited Access*** -- Very limited access, such as passing through on transportation corridors. Special arrangements would be required to leave the designated access point. The evacuation time for this type of access would be no more than 30 minutes. The maximum amount of time the maximally exposed individual (MEI)[1] would spend in this area is estimated to be about 100 hr/yr.

- ***Restricted Routine Access*** -- This type of access area would include activities such as industrial and commercial usage of a specifically designated area. It could also include short special interest uses, such as short nature trails. All users of the area must have ready access to transportation to facilitate a rapid evacuation. Evacuation time for this type of access would be no more than 1 hour. The maximum amount of time the MEI would spend in this area is estimated to be about 3,000 hr/yr.

- ***Restricted Short-Term Access*** -- This type of access may include locations adjacent to transportation corridors. Public access might involve short stops to view sights or engage in short duration activities. Access to areas more than 0.4 km (0.25 mi) from a

[1] The maximally exposed individual (MEI) is defined as a hypothetical person who lives near the Hanford Site, who, by virtue of location and living habits, could receive the highest possible dose.

designated access point would be prohibited. The evacuation time for this type of access would be no more than 1.5 hours. The maximum amount of time the MEI would spend in this area is estimated to be about 200 hr/yr.

- ***Moderately Restricted Periodic Access*** -- This type of access would allow for periodic activities, such as limited agricultural activities. Public access to this area would tend to be more periodic and seasonal. No permanent residences, schools, or hospitals would be allowed. The evacuation time for this type of access would be no more than 2 hours. The maximum amount of time the MEI would spend in this area is estimated to be about 3,000 hr/yr.

- ***Moderately Restricted Occasional Access*** -- This type of access area would allow for more diverse activities for a longer, but controlled, periods of time than those defined for the Moderately Restricted Periodic Access areas. For example, overnight stays for short periods would be allowed. The evacuation time for this type of access would be no more than 2.5 hours. The maximum amount of time the MEI would spend in this area is estimated to be about 1,000 hr/yr.

- ***Moderately Restricted Access*** -- This type of access requires only minimal access restrictions to ensure timely evacuation. This type of access would consider limited residential-type usage of the area and could accommodate small schools and commercial businesses. The evacuation time for this type of access would be 2.5 hours. The maximum amount of time the MEI would spend in this area is estimated to be about 8,700 hr/yr.

In addition to DOE's desire for land to isolate from the public hazardous processes and facilities that could produce a 25 rem radiological dose under an accident condition, the current Hanford Site boundary has been used to identify and design safety class systems, structures and components that are required to keep an accident from exceeding 500 mrem at the Site boundary. The current Site boundary is also the point-of-compliance for protection of the public to assure that routine releases from all DOE activities are less than 100 mrem (DOE Order 5400.5), and that not more than 10 mrem is from airborne sources (40 CFR 61) or that not more than 4 mrem are from groundwater sources (40 CFR 141). In addition to radiological accident conditions, DOE also uses the current Hanford Site boundary to protect the public from potential hazardous chemical accidents such as a chlorine gas leak. If the CLUP policies and implementing procedures on EUZs are adopted in the ROD, then DOE expects to use DOE's annual review of safety and environmental permitting documentation to be the basis for implementing the EUZ policies (see Chapter 6).