Summary

Billions of liters of liquid waste, some containing radionuclides and hazardous chemicals, have been released to the ground on the Hanford Site since 1944. A portion of these contaminants was trapped above the water table and some reached groundwater. The U.S. Department of Energy (DOE) monitors groundwater on the Hanford Site to track the spread of these contaminants. Groundwater is being remediated at seven sites that were identified as requiring immediate action. This report summarizes results of monitoring for fiscal year 1999.

State and federal regulations require groundwater monitoring for protection of human health and the environment. This report fulfills reporting requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA), specific Washington Administrative Codes, and the *Atomic Energy Act of 1954* as implemented by DOE orders. This report also summarizes results of groundwater monitoring conducted to assess the effects of remediation or interim measures conducted in accordance with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA).

Groundwater Flow

The water-table map for March 1999 indicates that groundwater in the unconfined aquifer 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. During fiscal year 1999, water levels continued to drop beneath the 200 Areas, causing some monitoring wells to go dry. Replacement wells were installed in the most critical locations.

In part of the 200 East Area, water levels have dropped below the top of a fine-grained confining unit so that there is no unconfined aquifer. The uppermost aquifer there is a confined aquifer in the Ringold Formation. Groundwater flow in this confined aquifer is affected by a mound remaining from past discharges to the B Pond. There seems to be an upward gradient between this aquifer and the unconfined aquifer.

Water levels declined beneath the central Hanford Site in fiscal year 1999, causing some wells to go dry. Replacement wells are needed.

The fiscal year 1999 potentiometric map for the upper basalt-confined aquifer is similar to previous maps. The potentiometric map indicates that, south of Umtanum Ridge and Gable Mountain, groundwater generally flows from west to east across the Hanford Site, through the overlying sediment, and into the Columbia River. In the region northeast of Gable Mountain, there is insufficient well coverage to clearly define flow directions. The groundwater is believed to flow southwest and discharge primarily to underlying confined aquifer systems in the Umtanum Ridge-Gable Mountain structural area. A region of increased hydraulic head associated with recharge from agricultural activities north and east of the Columbia River has been observed for deeper, confined aquifer systems and is believed to be mirrored in the upper basalt-confined aquifer system north of Gable Mountain. Water levels in this aquifer in the central and western portions of the Hanford Site declined in fiscal year 1999, responding to a reduction in artificial recharge from liquid waste disposal. Water levels in the eastern portion of the Hanford Site increased in fiscal year 1999 because of large-scale irrigation activities in areas east of the Columbia River.

Groundwater Contamination

Monitoring wells were sampled during fiscal year 1999 to satisfy requirements of RCRA, CERCLA, Washington Administrative Code, and DOE orders. There were 623 wells sampled during the period.

Most of the contamination in the groundwater today resulted from the discharge of high volumes of relatively low-concentration effluents into cribs, ponds, and ditches in the past. New groundwater contamination may result from these inactive sources if contamination that has been immobile in the vadose zone is mobilized by increased infiltration of water from man-made or natural sources, e.g., in areas of gravel cover with no vegetation. Though there may be short-term variability in the concentrations of contaminants derived from these past sources, concentrations are expected to decline overall through radioactive decay, chemical degradation, and dispersion. A few sites still have the potential to add new contamination to groundwater, e.g., single-shell tanks, K Basins, and state-permitted disposal facilities. In the past few years, mobile fractions of waste from leaking single-shell tanks have been detected in groundwater. Tritium leaks from K Basins also have been detected in the past decade.

The Hanford Groundwater Monitoring Project sampled 623 wells during fiscal year 1999. Tritium, nitrate, and iodine-129 are the most widespread contaminants.

The extent of major radionuclides at levels above the interim drinking water standards is shown in Figure S.1. The map is based on data from wells that monitor near the top of the unconfined aquifer. Iodine-129, strontium-90, technetium-99, tritium, and uranium were present at levels above the standards. Minor radiological contamination included carbon-14 (100 K Area) cesium-137 and plutonium (200 East Area near the 216-B-5 injection well). Derived concentration guide[(a)] levels were exceeded for strontium-90 in the 100 K, 100 N, and 200 East areas (near the 216-B-5 injection well). The derived concentration guide for uranium was exceeded near U Plant. The derived concentration guide for tritium was exceeded in one well that monitors fuel storage basins in the 100 K Area and in one well near cribs that received effluent from the Plutonium-Uranium Extraction (PUREX) Plant. The derived concentration guide for plutonium was exceeded in one well in the 200 East Area (near the 216-B-5 injection well). Results for individual constituents are summarized below.

In fiscal year 1999, ~254 square kilometers of the aquifer were contaminated at levels above drinking water standards. This is a slightly larger area than in fiscal year 1998.

The extent of major chemical constituents at levels above the primary maximum contaminant levels is shown in Figure S.2. The map is based on data from wells near the top of the unconfined aquifer. Carbon tetrachloride, nitrate, and trichloroethylene were the most widespread. Chloroform, chromium, cis-1,2-dichloroethylene, cyanide, fluoride, and other metals also were present at levels above their maximum contaminant levels. Results for individual constituents are summarized below.

The area of contaminant plumes with concentrations exceeding a maximum contaminant level or drinking water standard was estimated to be ~254 square kilometers in fiscal year 1999. This is an increase of ~4% compared to fiscal year 1998. The fiscal year 1999 plumes equate to a volume of ~1.4 billion cubic meters. The volume estimate has a high uncertainty because of a lack of knowledge about the vertical extent of contaminant plumes. Plume thickness is estimated to

(a) The derived concentration guide is based on an exposure standard of 100 millirem per year and is the amount of an individual radionuclide that would lead to that dose through ingestion under specified intake scenarios.

be 20 meters, except in the 100, 300, and Richland North areas, where it is estimated to be 5 meters. The porosity of the aquifer is not well-characterized; for the purpose of the calculation, the porosity was assumed to be 30%. The estimate did not include water in the vadose zone.

Limited data are available on contamination deeper in the Ringold Formation near the 200 Areas. Carbon tetrachloride and tritium have been detected in these deeper units.

Tritium

Tritium was present in many Hanford Site waste streams discharged to the soil column and is the most mobile and most widely distributed radionuclide onsite. It has a relatively short half-life (12.3 years).

The most prominent tritium plume originated in the 200 East Area near the PUREX Plant and is migrating downgradient to the southeast. This plume discharges to the Columbia River along a stretch that extends from the Old Hanford Townsite to the 300 Area. Tritium concentrations near the Columbia River are highest in wells near the Old Hanford Townsite, where they are greater than 100,000 pCi/L. Concentrations in these wells are about half of what they were in the 1980s and are expected to continue to decline.

Tritium is very mobile in groundwater. The largest plume originates in the 200 East Area and extends to the southeast, where concentrations exceed the drinking water standard near the Columbia River. Levels are generally declining due to radioactive decay.

Another tritium plume from the 200 East Area has moved northward between Gable Mountain and Gable Butte. A smaller plume between the 200 East and 200 West Areas has its source near the 200 West Area's Reduction-Oxidation (REDOX) Plant. This plume is moving relatively slowly because the aquifer has a relatively low permeability. Additional plumes of tritium originated in the 100 Areas, exceeding the drinking water standard locally.

Tritium exceeded its 2 million pCi/L derived concentration guide in one well near cribs that received effluent from the PUREX Plant (3.87 million pCi/L) and in one well in 100 K Area (2.36 million pCi/L). Concentrations in the PUREX well appear to be decreasing gradually, while concentrations in the 100 K Area well are highly variable. One well at Waste Management Area TX-TY equalled the derived concentration guide for tritium.

In January 1999, a sample from well 699-13-3A, located downgradient of the 618-11 burial ground in the southeastern 600 Area, contained 1.86 million pCi/L of tritium. This value was the first tritium data from this well and was far higher than concentrations in surrounding wells. The concentration was confirmed by re-analysis, and a sample collected in January 2000 contained 8.1 million pCi/L of tritium. A special investigation of the groundwater at the 618-11 burial ground is being undertaken in fiscal year 2000 to define the source of the high tritium results.

Tritium contamination has been detected in confined aquifers beneath the 200 Areas. Concentrations exceeded the drinking water standard in several wells that monitor a confined aquifer in the Ringold Formation near 200 East Area. Levels below the standard were detected in the upper basalt-confined aquifer.

Iodine-129

The presence of iodine-129 in groundwater is significant because of its relatively low, 1-pCi/L interim drinking water standard; its long-term releases from nuclear fuel processing facilities; and its long half-life (16 million years). However, iodine-129's relatively low-fission yield and long half-life limit its concentration in Hanford Site groundwater. Iodine-129 is transported in groundwater as the anionic iodide (I^-) species that is very mobile. Waste containing iodine-129 was historically disposed of in the 200 Areas. Extensive

plumes exceed the drinking water standard in the 200 Areas and in downgradient portions of the 600 Area. The major plume extends toward the southeast from the 200 East Area. Concentrations remain below the drinking water standard in wells near the Columbia River, but may increase in the future as the plume moves downgradient. A smaller plume of iodine-129 is moving toward the north between Gable Mountain and Gable Butte.

The highest concentration of iodine-129 detected in fiscal year 1999 was 47 pCi/L at Waste Management Area TX-TY.

Extensive plumes of groundwater contaminated with iodine-129 exceeded the drinking water standard in the 200 Areas and in downgradient portions of the 600 Area.

Technetium-99

Technetium-99 is produced as a high-yield fission product and is present in waste streams associated with fuel processing. Technetium-99 is transported in groundwater as an anionic pertechnicate (TcO_4^-) species that is highly mobile. Technetium-99 tended to be associated with uranium through the fuel processing cycle, but uranium is less mobile in groundwater on the Hanford Site.

The 200 West Area had the highest technetium-99 concentrations detected in fiscal year 1999 (48,000 pCi/L). In this area, the largest plume is associated with U Plant, and the plume is migrating to the east into the 600 Area. A groundwater pump-and-treat system is operating near U Plant in an attempt to contain the plume. Technetium-99 also is elevated in wells monitored for the B, BX, BY, S, SX, T, TX, and TY single-shell tank farms. These sites are undergoing RCRA assessment investigations.

Elevated technetium-99 levels apparently associated with the BY cribs (200 East Area) continued to be detected in fiscal year 1999. The maximum annual average near the BY cribs in fiscal year 1999 was 5,700 pCi/L.

A well completed in the basalt-confined aquifer near the BY cribs had technetium-99 at levels above the 900-pCi/L drinking water standard in fiscal year 1998 (average of 1,500 pCi/L, which is within the historical range). However, this well was not sampled in fiscal year 1999.

Technetium-99 is a mobile contaminant that exceeds the drinking water standards in small plumes. The highest concentrations in fiscal year 1999 were in the 200 West Area, where uranium is also present. The goal of a groundwater pump-and-treat system in that area is to prevent the plume from spreading.

Uranium

Uranium contamination on the Hanford Site has numerous potential sources, including fuel fabrication, fuel processing, and uranium recovery from separations activities. Uranium mobility is dependent on Eh, pH, and the presence of carbonate; its migration is slower than that of tritium and technetium-99. At the Eh/pH conditions found in the unconfined aquifer, U(VI) is the most mobile state.

The U.S. Environmental Protection Agency (EPA) proposed a 20-µg/L maximum contaminant level for uranium. Uranium was detected at concentrations above this level in the 100 H, 100 F, 200, and 300 areas. Contamination in the 100 H, 100 F, and 200 East areas is very localized.

The highest concentrations detected in fiscal year 1999, exceeding the derived concentration guides for uranium isotopes, were in the 200 West Area near the 216-U-1 and 216-U-2 cribs. This plume extends into the 600 Area to the east. Like technetium-99, this plume is the target of a pump-and-treat system.

Another area of elevated uranium concentrations is observed in the 300 Area, downgradient of the 316-5 process trenches and ponds. Uranium contamination appears to be moving from the vicinity of the process trenches toward the southeast.

Strontium-90

Strontium-90 is produced as a high-yield fission product and is present in waste streams associated with fuel processing; it was released also by fuel element failures during reactor operations. Strontium-90 is of concern because of its moderately long half-life (28.8 years), its potential for concentrating in bone tissue, and the relatively high energy of the beta decay from its yttrium-90 radioactive decay product.

In fiscal year 1999, strontium-90 exceeded the 8-pCi/L interim drinking water standard in wells in all of the 100 and 200 areas and near the former Gable Mountain Pond. Strontium-90 exceeded the 1,000-pCi/L derived concentration guide in wells in the 100 K, 100 N, and 200 East areas. Levels declined to just below the derived concentration guide near the former Gable Mountain Pond.

The most widespread strontium-90 contamination is in the 100 N Area, and is the target of a pump-and-treat system. The plume did not change significantly in fiscal year 1999. Strontium-90 is of concern because of its moderately long half-life (28.8 years) and its potential to concentrate in animal and human bones.

The most widespread, high strontium-90 concentrations continued to be detected in the 100 N Area. The overall extent of the strontium-90 plume in the 100 N Area is not changing perceptibly but concentrations in seeps discharging to the Columbia River continue to exceed the drinking water standard. The goal of a pump-and-treat system in the 100 N Area is to reduce the movement of strontium-90 toward the Columbia River.

Carbon-14

Carbon-14 exceeded the 2,000-pCi/L interim drinking water standard in two small plumes near waste disposal facilities adjacent to the KW and KE reactor buildings. The maximum concentration in fiscal year 1999 was 15,600 pCi/L, about the same as in recent years.

Cobalt-60

Cobalt-60 is a neutron activation product typically associated with waste generated by the processing of irradiated fuel or with reactor cooling water. Cobalt-60 is predominantly present as a divalent cation that is strongly adsorbed onto Hanford Site sediment and is rarely observed in groundwater unless combined with other chemicals. Wells consistently show the presence of detectable cobalt-60 north of the 200 East Area, in an area that is affected by waste disposed to the BY cribs. However, levels have declined because of its relatively short half-life (5.3 years).

In fiscal year 1999, cobalt-60 continued to be detected north of the 200 East Area but remained below the drinking water standard.

In fiscal year 1999, the maximum annual average cobalt-60 detected in this vicinity remained below the 100-pCi/L interim drinking water standard. Cobalt-60 in this area appears to be highly mobile, probably because of the presence of a soluble cobalt-cyanide (or ferrocyanide) complex associated with the plume originating in the BY cribs.

Cesium-137

Cesium-137 is produced as a high-yield fission product, is present in waste streams associated with fuel processing, and has been released in reactor areas by fuel element failures. The concentration of cesium-137 in fiscal year 1999 reached 1,840 pCi/L in a well near the 216-B-5 injection well, which is in line with

the historical trend for the well. The interim drinking water standard for cesium-137 is 200 pCi/L.

Cesium-137 is a potential contaminant of concern at the S and SX single-shell tank farms. However, it was not detected in in fiscal year 1999 in this area. It appears that the contamination is dominantly sorbed to particulate matter and does not seem to be a significant groundwater contaminant.

Plutonium

Plutonium was present in waste streams associated with fuel processing. The derived concentration guide for plutonium-239 is 30 pCi/L. There is no explicit interim drinking water standard for plutonium-239; however, the maximum contaminant level for gross alpha (15 pCi/L) is applicable. Alternatively, if the derived concentration guide, which is based on a 100-millirem dose standard, is converted to the 4-millirem dose equivalent used for the interim drinking water standard, 1.2 pCi/L would be the relevant guideline. Plutonium generally binds strongly to sediment, so its mobility in groundwater is limited.

Plutonium contamination is limited to an area adjacent to the 216-B-5 injection well in the 200 East Area.

The only significant detection of plutonium in fiscal year 1999, as in previous years, was associated with the 216-B-5 injection well in the 200 East Area. The maximum plutonium-239/-240 concentration detected near this injection well in fiscal year 1999 was 66 pCi/L, about the same as last year.

Nitrate

Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical processing operations. Like tritium, nitrate was present in many waste streams and is mobile in groundwater. Additional sources of nitrate are located off the Hanford Site to the south and west.

Nitrate is the widest spread chemical contaminant in groundwater on the Hanford Site. However, the largest portions of the plumes are below the drinking water standard.

Nitrate was measured at concentrations greater than the maximum contaminant level (45 mg/L) in wells in all operational areas. Although elevated nitrate levels were found throughout the extensive plume that originates from the vicinity of the PUREX Plant in the 200 East Area, only proportionally small areas contained nitrate at levels above the maximum contaminant level. Concentrations in wells near the Columbia River at the Old Hanford Townsite are below the maximum contaminant level and have been steady for the past 10 years. Another plume originates at facilities associated with B Plant and migrates northward.

Extensive nitrate contamination extends into the 600 Area from the vicinity of U Plant in the 200 West Area. A large nitrate plume in the 200 West Area is located near T Plant, while smaller amounts of contamination are found near the Plutonium Finishing and REDOX plants. Two relatively small areas greater than the maximum contaminant level were detected near the 400 Area and Energy Northwest (formerly the Washington Public Power Supply System). Nitrate contamination in the Richland North Area apparently has a source off the Hanford Site.

Chromium

A major source for chromium was the sodium dichromate used as a corrosion inhibitor in cooling water for reactors in the 100 Areas. Chromium also was used for decontamination in the 100, 200, and 300 areas and for oxidation-state control in the REDOX Plant processes in the 200 West Area. Chromium was elevated in each of the 100 Areas, but the major plumes

exceeding the 100-µg/L maximum contaminant level are related to operations in the 100 K, 100 D, and 100 H Areas.

Hexavalent chromium is a hazard to some aquatic life. Therefore, interim actions are under way to pump and treat groundwater in 100 K, 100 D, and 100 H areas to reduce the amount of chromium reaching the Columbia River.

Hexavalent chromium was detected in the Columbia River substrate adjacent to these areas and is a hazard to some aquatic life. Therefore, interim actions are under way to pump and treat groundwater in these areas to reduce the amount of chromium reaching the Columbia River. Data from new wells in the southwestern 100 D Area helped define the chromium plume in that region in fiscal year 1999. That plume, with concentrations greater than 1,000 µg/L, is being treated in situ by a method of reduction/oxidation manipulation.

Chromium concentrations also exceeded the maximum contaminant level near T Plant and the 216-S-10 pond and ditch in the 200 West Area. Chromium continued to exceed the maximum contaminant level in one well south of the 200 East Area. Other wells in the area also have elevated chromium, though levels are below the maximum contaminant level. The source of this plume has not been identified.

Data from new wells in fiscal year 1999 helped define the chromium plume in the southwestern 100 D Area. An innovative method to clean up this plume will be expanded in fiscal year 2000.

Carbon Tetrachloride

Carbon tetrachloride contamination exceeds the 5-µg/L maximum contaminant level beneath much of the 200 West Area. The plume extends beyond the area boundary and forms the most widespread organic contaminant plume on the Hanford Site. The contamination is principally from waste disposal operations associated with the Plutonium Finishing Plant, where it was used in plutonium processing. Concentrations in the central part of the plume remained above 2,000 µg/L in fiscal year 1999. A groundwater pump-and-treat system is operating in this area to prevent the central portion of the plume from spreading. There appears to be a shift in the maximum concentrations toward the pumping wells, and the treated water is displacing the plume in the vicinity of the injection wells, located west of the area.

Groundwater beneath the 200 West Area is contaminated with carbon tetrachloride. A pump-and-treat system prevents the center of the plume from spreading.

The total area of the carbon tetrachloride plume at the top of the unconfined aquifer in fiscal year 1999 (5-µg/L contour) was ~11.5 square kilometers, compared to 11.4 in fiscal year 1998. In some areas, concentrations of carbon tetrachloride decrease with depth, but data collected in recent years indicate that in other areas carbon tetrachloride is present at higher concentrations deeper in the Hanford/Ringold sediment than at the water table. Therefore, the extent of the plume at the water table may not reflect the extent in deeper parts of the aquifer system.

Carbon tetrachloride has been detected in wells that monitor far below the water table. Further study is needed to determine its distribution with depth.

Chloroform

The 200 West Area chloroform plume is associated with the carbon tetrachloride plume and is

believed to be a degradation product of carbon tetrachloride. A concentration of 140 µg/L was detected in 200 West Area in fiscal year 1999. The maximum contaminant level for chloroform is 100 µg/L (total trihalomethanes).

Trichloroethylene

Trichloroethylene was used on the Hanford Site in the 1960s and 1970s as a degreasing compound. Concentrations of trichloroethylene exceeded the 5-µg/L maximum contaminant level in fiscal year 1999 in wells in the 100 K, 100 F, 200 West, 300, and Richland North areas. It also was detected in wells near the Solid Waste Landfill, but levels were below the maximum contaminant level.

Trichloroethylene was used to remove grease. It is present in small plumes in the 100 K, 100 F, 200 West, 300, and Richland North areas.

Concentrations of trichloroethylene exceeded the maximum contaminant level in the 200 West Area to the west of T Plant and east of U Plant. Trichloroethylene is also associated with the carbon tetrachloride plume near the Plutonium Finishing Plant.

Trichloroethylene exceeded the maximum contaminant level in one of the point-of-compliance wells for the 1100-EM-1 Operable Unit and was detected in other wells near Siemens Power Corporation and Horn Rapids Landfill. The plume appears to be moving toward the northeast and concentrations are declining.

cis-1,2-Dichloroethylene

Concentrations of cis-1,2-dichloroethylene remained high in a well that monitors the bottom of the unconfined aquifer near the 316-5 process trenches in the 300 Area. The average cis-1,2-dichloroethylene concentration in this well in fiscal year 1999 was 150 µg/L (maximum contaminant level is 70 µg/L). The source of this constituent is believed to be anaerobic biodegradation of trichloroethylene.

Tetrachloroethylene

Tetrachloroethylene exceeded the 5-µg/L maximum contaminant level in a single well in the 300 Area in fiscal year 1999, with a concentration of 7 µg/L. A plume of tetrachloroethylene was detected in six wells in the 300 Area in fiscal year 1998, but rapidly decreased.

Cyanide

Cyanide contamination is present north of the 200 East Area and is believed to have originated from wastes containing ferrocyanide that were disposed in the BY cribs. Wells containing cyanide often contain concentrations of several radionuclides, including cobalt-60. Cobalt-60 appears to be chemically complexed and mobilized by cyanide or ferrocyanide. Cyanide concentrations exceeded the 200-µg/L maximum contaminant level in only one well in fiscal year 1999, with a maximum value of 291 µg/L, a slight decrease from fiscal year 1998.

Cyanide was associated with waste discharged to the BY cribs near 200 East Area. In groundwater it exceeded the drinking water standard in one well in fiscal year 1999.

Fluoride

Fluoride was detected above the 4,000-µg/L maximum contaminant level in one well near the T Plant waste disposal facilities in the 200 West Area. The highest concentration was 4,960 µg/L. A concentration of ~5,000 µg/L from a source off the Hanford Site was detected in a well in the Richland North Area.

Ingestion Risk and Dose Estimate

Groundwater is not a primary source of drinking water for most Hanford Site workers. However, comparison to drinking water standards provides perspective for contaminant levels. Interim drinking water standards use the methods 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 millirem per year from consumption of each individual constituent. Similarly, derived concentration guides provide estimates of radiological concentration that could result in a 100-millirem per year 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.

A person's potential dose from drinking contaminated water is the sum of the doses from the individual radionuclides. The highest dose estimates on the Hanford Site are restricted to parts of the 100 K, 100 N, and 200 areas. Groundwater is not used for drinking in these areas.

Figure S.3 shows the cumulative dose estimates from ingestion of groundwater from the unconfined aquifer on the Hanford Site. These estimates were made by adding the effects of all major radionuclides in Hanford Site groundwater: carbon-14, cesium-137, iodine-129, plutonium, strontium-90, technetium-99, tritium, and uranium. 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 estimates presented in Figure S.3 show that areas above the 100-millirem per year dose standard are restricted to localized parts of the 100 K, 100 N, and 200 areas and a location around a single well downgradient of the 618-11 burial ground. Portions of the 100, 200, 300, and 600 areas exceed 4 millirem per year.[(a)]

The hazard quotient describes health hazards associated with noncarcinogenic substances. The highest hazard quotient on the Hanford Site is in a small part of the 200 West Area.

Figure S.4 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 adding concentrations of the radionuclides listed above plus carbon tetrachloride, chloroform, cis-1,2-dichloroethylene, hexavalent chromium, nitrate, and trichloroethylene. The calculation assumes that a person weighing 70 kilograms consumes 2 liters of groundwater every day for

(a) EPA drinking water standards for radionuclides in 40 CFR Part 141 were derived based on a 4-millirem per year dose standard using Maximum Permissible Concentrations in water specified in National Bureau of Standards Handbook 69 (U.S. Department of Commerce, as amended August 1963). The area exceeding drinking water standards in Figure S.1 is based on the EPA regulatory requirement. However, the areas in Figure S.3 corresponding to a dose greater than 4 millirem per year were calculated using a more recent dosimetry system adopted by DOE and other regulatory agencies (as implemented in DOE Order 5400.5 in 1993). If both dosimetry systems were equivalent, one would expect the area above 4 millirem per year in Figure S.3 to be the same as the area exceeding interim drinking water standards (see Figure S.1), or to show a slightly larger area exceeding 4 millirem per year (i.e., if two or more radionuclides were individually below the drinking water standards, but added up to exceed 4 millirem per year). In fact, the areas above 4 millirem per year on Figure S.3 are more restricted than the area above the drinking water standard in Figure S.1 because of differences in the dosimetry systems adopted by EPA and DOE.

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.

Figure S.5 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 toxicity other than cancer (in Hanford Site groundwater, these include hexavalent chromium, nitrate, strontium, and uranium). The calculation assumes that a person weighing 70 kilograms consumes 2 liters of groundwater every day for 30 years (DOE/RL-91-45, Rev. 3; IRIS 1997). The only locations with hazard quotients above 5 are small portions of the 100 H and 200 West areas. Values between 1 and 5 are present in the 100 K, 100 D, 100 F, 200 West, and 200 East areas and from offsite contamination in the Richland North Area.

Groundwater Remediation

Groundwater remediation conducted in accordance with CERCLA was performed at the following sites:

100-KR-4 Operable Unit, 100 K Area — An interim action to address chromium contamination near the 116-K-2 trench continued in fiscal year 1999. Groundwater is extracted from six wells between the trench and the Columbia River, treated to remove chromium, and injected into wells upgradient of the trench. A capture zone model indicates that significant portions of the plume are being captured. The mass of chromium in the aquifer also is being reduced.

100-NR-2 Operable Unit, 100 N Area — Groundwater continued to be extracted from wells near the 1301-N liquid waste disposal facility, treated to remove strontium-90, and injected into wells near the 1325-N liquid waste disposal facility. The extraction wells create a hydraulic barrier intended to reduce the volume of contaminated groundwater reaching the Columbia River.

Pump-and-Treat System

The goal of the pump-and-treat systems on the Hanford Site is to prevent the worst contaminants from spreading. These systems removed the following contaminants in fiscal year 1999:

- 1,300 kilograms of carbon tetrachloride
- 63 kilograms of hexavalent chromium
- 4,900 kilograms of nitrate
- 0.2 curie of strontium-90
- 22 kilograms of uranium
- 7.8 kilograms of technetium-99.

100-HR-3 Operable Unit, 100 D Area — An interim action pump-and-treat system continued in fiscal year 1999. The system removes chromium-contaminated groundwater from wells near the Columbia River and pipes it to the 100 H Area for treatment and injection. The hydraulic effects of groundwater extraction are estimated to result in containment of the plume along ~400 meters of shoreline. A demonstration of in situ redox manipulation technology continued in fiscal year 1999 and the technology will be expanded in fiscal year 2000. The project's goal is to create a permeable treatment zone in the subsurface where chemical-reducing agents will turn the highly soluble hexavalent chromium to an insoluble state.

A test of an in situ method to immobilize chromium in groundwater in the 100 D Area was successful, and the method will be expanded in fiscal year 2000.

100-HR-3 Operable Unit, 100 H Area — An interim action pump-and-treat system continued in fiscal year 1999. The system removes chromium from wells in the central 100 H Area, treats it to remove chromium, and injects the water into wells in the southwestern part of the area. Computer simulations indicate that most of the plume is being captured, but a

portion continues to pass between the extraction wells into the Columbia River. An additional extraction well was installed in fiscal year 1999 and is scheduled to begin operating in 2000 to improve contaminant capture.

200-UP-1 Operable Unit, 200 West Area — An interim action pump-and-treat system, designed to contain and treat the elevated technetium-99 and uranium, continued to operate in fiscal year 1999. Technetium-99 concentrations are below the remediation goal of 9,000 pCi/L in all but two wells. Uranium concentrations remained above the remediation goal of 480 µg/L in almost all wells, even after treatment of 425.6 million liters of groundwater and 5 years of operation.

200-ZP-1 Operable Unit, 200 West Area — An interim action pump-and-treat system continued to operate to prevent further movement of carbon tetrachloride, chloroform, and trichloroethylene from the high concentration portion of the carbon tetrachloride plume and to reduce contaminant mass. Treatment of the contaminated water resulted in the removal of 1,290 kilograms of carbon tetrachloride in fiscal year 1999. Since initiation of pump-and-treat operations, August 1994 through September 1999, more than 864.2 million liters of water have been treated, resulting in removal of 3,386 kilograms of carbon tetrachloride. The system appears to be containing and capturing the portion of the plume with the highest concentrations.

Groundwater Monitoring of RCRA Treatment, Storage, and Disposal Units

RCRA groundwater monitoring continued at 25 waste management areas. At the end of fiscal year 1999, 16 were being monitored under indicator evaluation programs and do not appear to adversely affect groundwater with hazardous constituents. One (120-D-1 ponds) was clean closed in fiscal year 1999, meaning that no waste was left in place and no further groundwater monitoring is required. The others were monitored under assessment or corrective-action programs. The following summarizes the highlights of RCRA monitoring during fiscal year 1999.

Four single-shell tank waste management areas were monitored under interim status assessment investigations. At the T, TX, and TY single-shell tank farms (200 West Area), technetium-99 and other contaminants are increasing in many wells, apparently as a result of changing directions of groundwater flow. Waste Management Area S-SX (200 West Area) had increases and decreases in technetium-99 as a result of movement of the contaminant plume. No cesium-137 or strontium-90 was detected in any of the RCRA wells at Waste Management Area S-SX. Waste Management Area B-BX-BY (200 East Area) appears to have three distinct areas of contamination, based on chemical fingerprints, plume locations, and trends.

The 183-H solar evaporation basins (100 H Area) and the 316-5 process trenches (300 Area) were monitored under final status requirements during fiscal year 1999. The 183-H basins have contaminated the groundwater with chromium, nitrate, technetium-99, and uranium at levels exceeding applicable concentration limits. Corrective action is directed by the CERCLA program, and an interim remedial action (pump-and-treat system) for chromium continued in fiscal year 1999. Groundwater monitoring to meet RCRA requirements continues during the remediation.

The 316-5 process trenches and other nearby sources contaminated groundwater with cis-1,2-dichloroethylene, trichloroethylene, and uranium at

RCRA Monitoring

RCRA monitoring at the Hanford Site included

- 2 sites under corrective action
- 6 sites under groundwater quality assessments
- 1 site clean closed in fiscal year 1999
- 16 sites under indicator evaluation.

levels above their respective concentration limits. However, the corrective-action monitoring plan has not been approved, and monitoring continues under the compliance plan. Natural attenuation of the contaminants is the corrective action chosen in the CERCLA record of decision. Groundwater monitoring continues in accordance with RCRA.

Changing water levels have affected the adequacy of some RCRA groundwater monitoring networks. In some areas, flow directions have changed since the networks were designed, and some wells have gone dry because of a declining water table. In the 200 West Area, monitoring networks for Waste Management Areas T and TX-TY could be inadequate for RCRA monitoring and need additional wells. Dry wells at the 216-S-10 pond and ditch and the 216-U-12 crib have caused their monitoring networks to be considered inadequate, and replacement wells may be required. In the 200 East Area, the Liquid Effluent Retention Facility is monitored by only two downgradient wells because the water table is dropping to near the bottom of the aquifer. Ecology has granted a waiver from the requirements for three downgradient wells while alternative methods of monitoring are being investigated. The adequacy of monitoring networks for Waste Management Areas A-AX and C are uncertain because of uncertainties in flow direction. Resolution of these uncertainties will be addressed in revised monitoring plans. Inadequacies in existing monitoring networks, where identified, are being evaluated on the basis of regulatory compliance, technical efficacy in terms of actual risk, and in the context of the closure or corrective-action plans of the respective facility.

Well Installation

In fiscal year 1999, eight new wells were installed (or begun) for RCRA groundwater monitoring. Sixteen new wells were installed in the 100 Areas for activities related to environmental restoration. One well was installed to support characterization for a proposed immobilized low-activity waste repository and another for vadose zone characterization at the SX Tank Farm.

Six wells were decommissioned (sealed with grout) in fiscal year 1999 because they were no longer used or were in poor condition. Approximately 110 well maintenance activities were carried out during fiscal year 1999. These activities included well or pump repair, cleaning, and maintenance.

Twenty-six new wells were installed in fiscal year 1999 and six old wells were sealed.

Modeling

Numerical simulations of groundwater flow and contaminant movement are used to predict future conditions and to assess the effects of remediation systems. One site-wide model and several local-scale models were applied to the Hanford Site in fiscal year 1999.

The site-wide, three-dimensional model underwent an external technical peer review in fall 1998. Pacific Northwest National Laboratory (PNNL) plans to implement the following modifications to the model to address peer review comments:

(1) Investigate alternative conceptual models that reflect different credible combinations of boundary conditions and interpretations of the hydrogeologic framework.

(2) Develop a model framework that includes uncertainties associated with prescribed processes, physical features, initial and boundary conditions, system stresses, field data, and model parameter values. This framework will ultimately be used to assess uncertainty in results produced by the range of alternative site-wide groundwater conceptual and numerical models.

(3) Repeat the inverse calibration of the site-wide groundwater model to incorporate many of the changes arising from the peer review and incorporate new information. In addition, perform an inverse calibration of each alternative conceptual model.

Other groundwater models were applied in the design and evaluation of pump-and-treat activities aimed at remediation of contaminated groundwater in the 100 and 200 West areas. These models were used to estimate the area affected by the pump-and-treat operations at different times. Results of the models were used to optimize pumping rates and to choose locations for additional pumping wells.

Vadose Zone

Subsurface source characterization and vadose zone monitoring, soil-vapor monitoring, sediment sampling and characterization, and vadose zone remediation were conducted in fiscal year 1999.

Waste sites in the 100 Areas are being excavated to remove contaminated sediment. Significant activities related to the vadose zone during fiscal year 1999 included

- soil sampling and analysis to support remediation of the 116-C-1 process effluent trench and the 1301-N and 1325-N cribs and trenches
- sampling and analysis to select a waste site for initial deployment of technology for in situ reduction of hexavalent chromium
- laboratory studies to measure the distribution coefficient and the leachability of chromium in 100 Areas sediment to support future remedial action goals and plans.

Several vadose zone characterization and monitoring activities were undertaken at the 200 Areas in fiscal year 1999, including

- sample collection and characterization of deep vadose zone contamination at the SX Tank Farm
- preliminary temperature and neutron capture borehole logging at the SX Tank Farm
- baseline spectral gamma-ray logging at two single-shell tank farms
- spectral gamma-ray logging at specific retention facilities in the 200 East Area, which are some of the most significant potential sources of remaining vadose zone contamination
- remediation and monitoring of carbon tetrachloride in the 200 West Area, where 972 kilograms of carbon tetrachloride were removed from the vadose zone in fiscal year 1999.

In fiscal year 1999, several vadose zone related activities were accomplished which have potential applicability across the Hanford Site:

- 175 lysimeters were inventoried and described.
- Four years of field data from the Hanford Site prototype surface barrier were analyzed and interpreted. Those data have important applicability to contaminated sites that may be left in place and monitored during natural attenuation.
- Tritium and helium-3/helium-4 were obtained from vadose zone sediment to extrapolate concentrations in the soil to concentrations in groundwater.

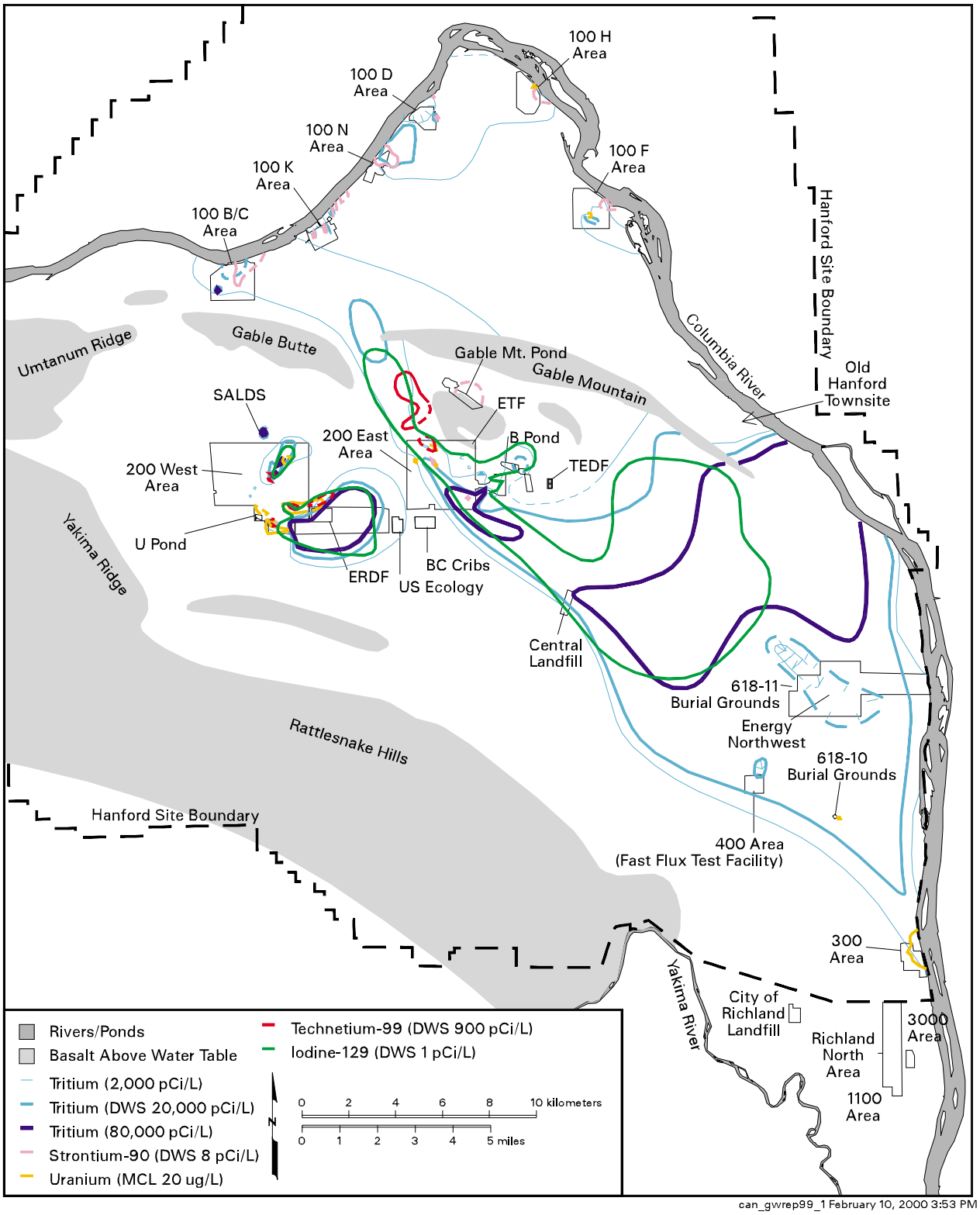

Figure S.1. Distribution of Major Radionuclides in Groundwater at Concentrations Above Maximum Contaminant Levels or Interim Drinking Water Standards, Fiscal Year 1999

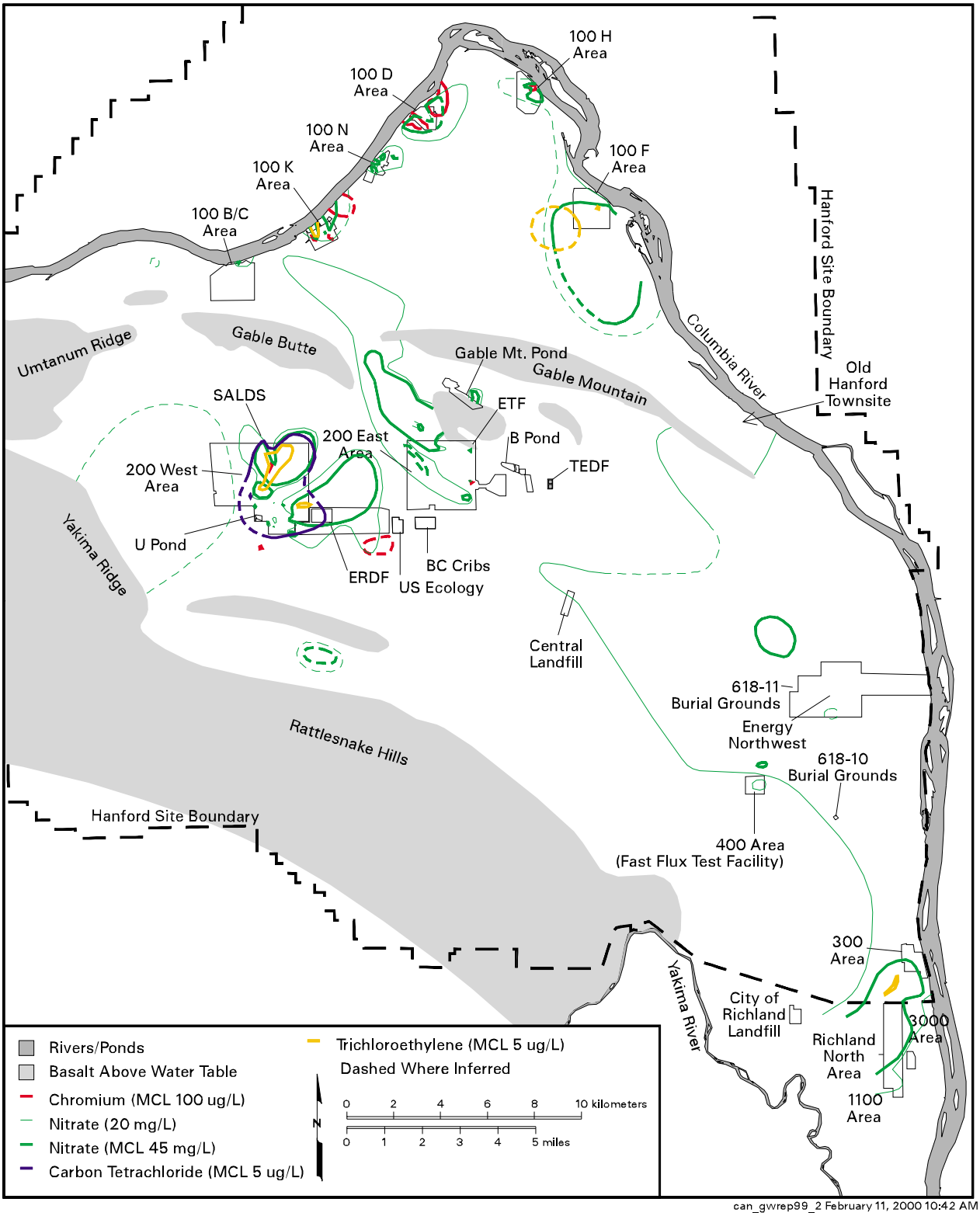

Figure S.2. Distribution of Major Hazardous Chemicals in Groundwater at Concentrations Above Maximum Contaminant Levels, Fiscal Year 1999

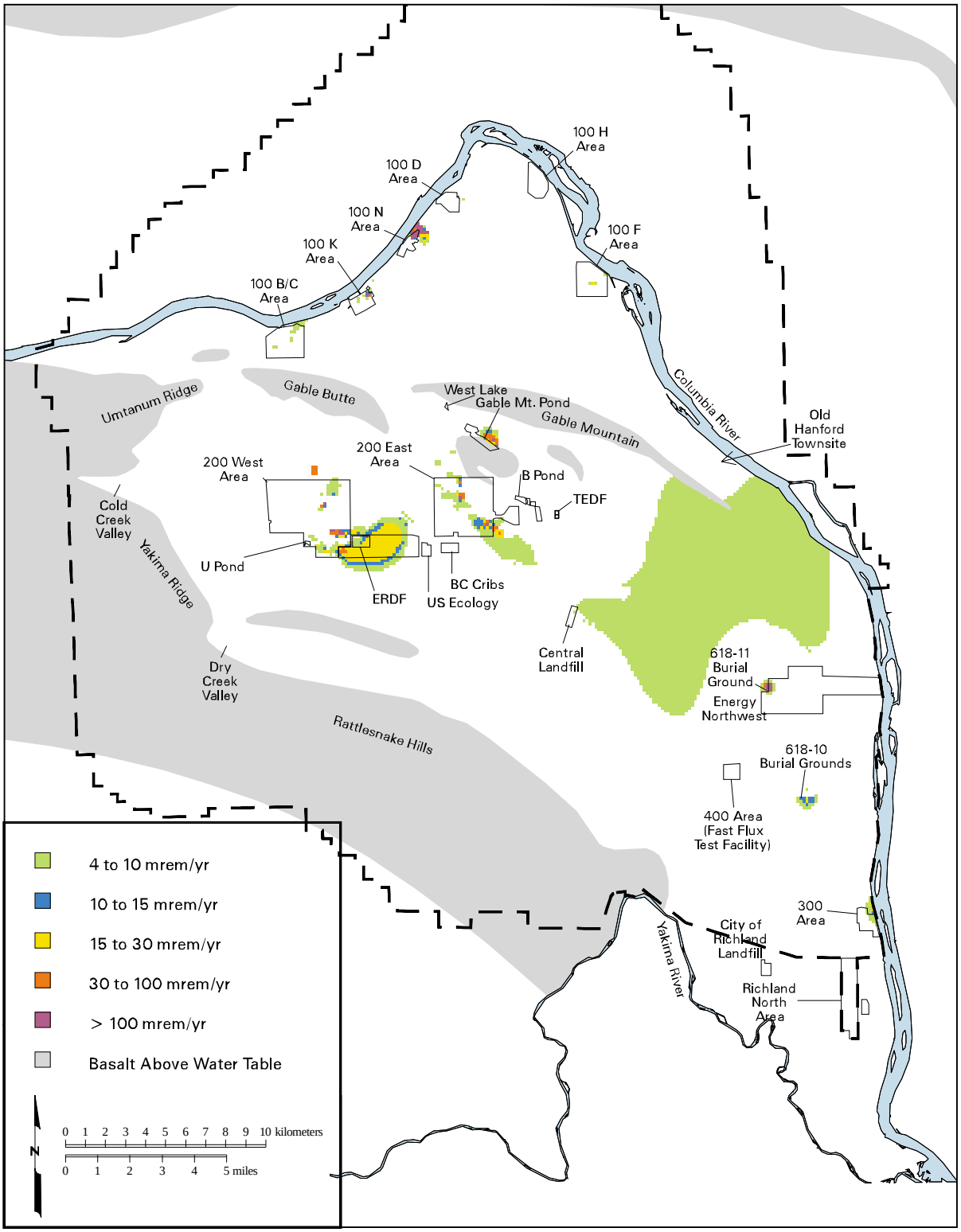

Figure S.3. Potential Dose Estimates from Ingestion of Groundwater, Fiscal Year 1999

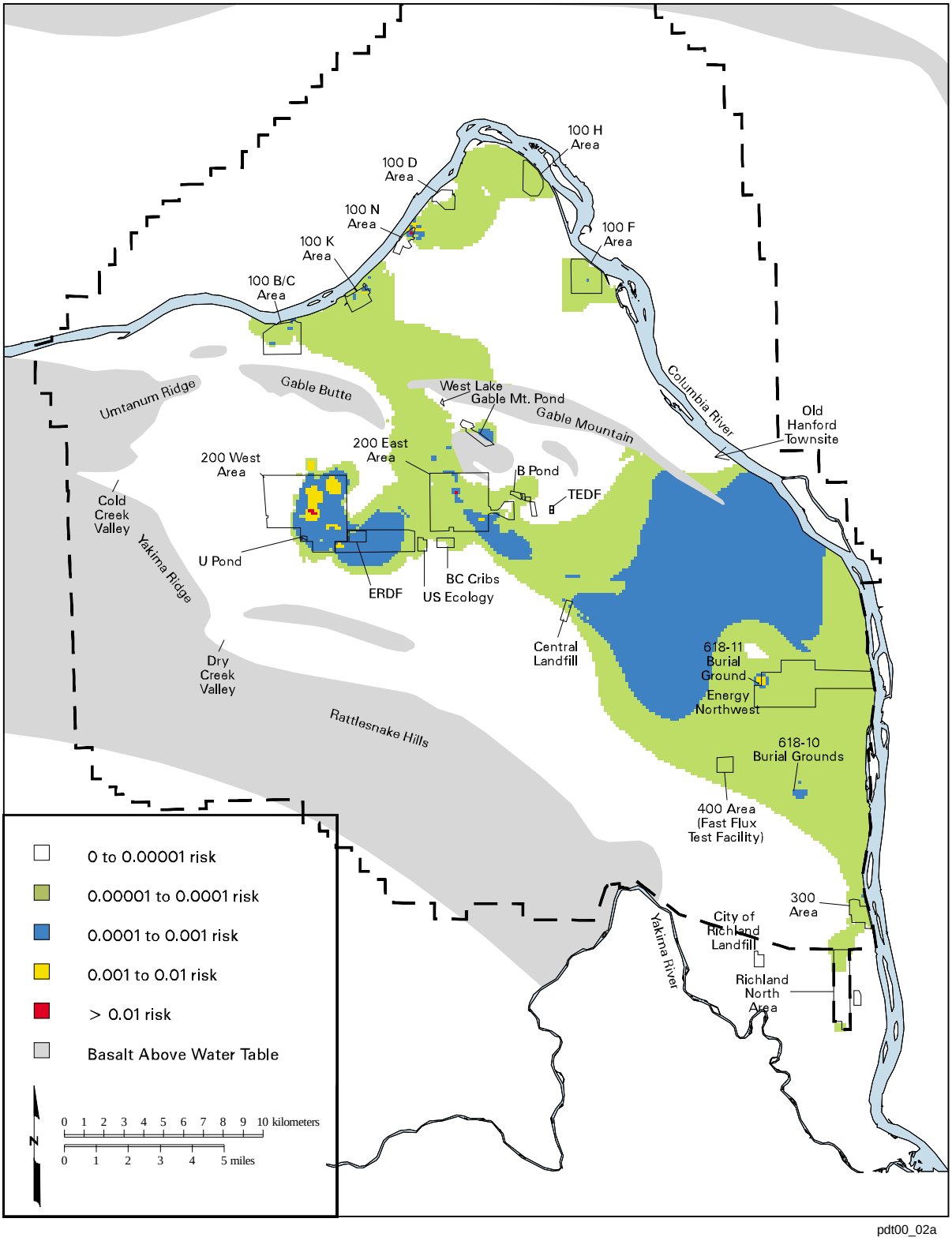

Figure S.4. Cancer-Risk Estimates from Ingestion of Groundwater, Fiscal Year 1999

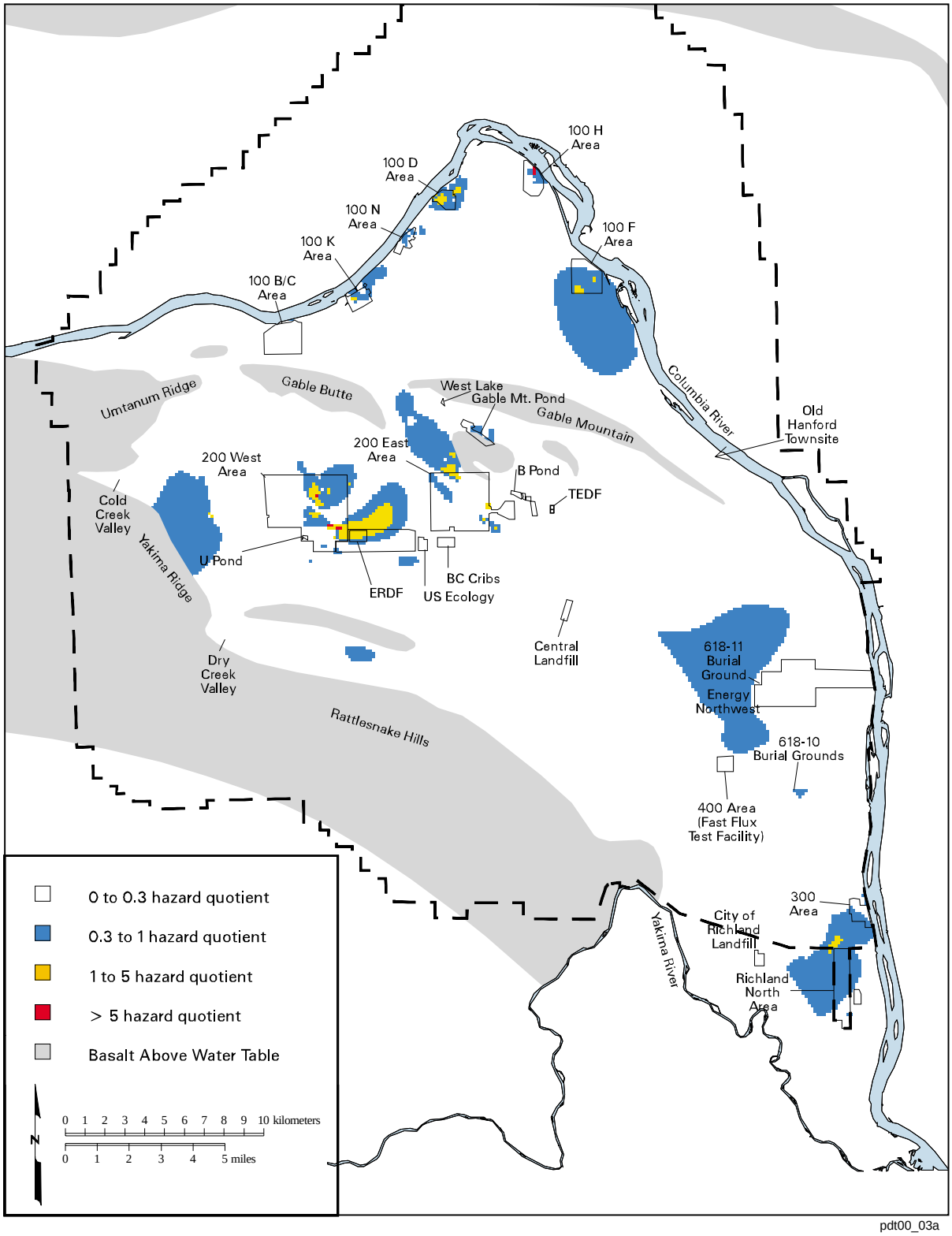

Figure S.5. Hazard Quotient Estimates from Ingestion of Groundwater, Fiscal Year 1999