4.7 External Radiation Surveillance

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External radiation is defined as radiation originating from a source outside the body. External radiation fields consist of a natural component and an artificial, or manmade, component. The natural component can be divided into 1) cosmic radiation; 2) primordial radionuclides in the earth's crust (primarily potassium-40, thorium-232, and uranium-238); and 3) an airborne component, primarily radon and its progeny. The manmade component consists of radionuclides generated for or from nuclear medicine, power, research, waste management, and consumer products containing nuclear materials. Environmental radiation fields may be influenced by the presence of radionuclides deposited as fallout from atmospheric testing of nuclear weapons or those produced and released to the environment during the production or use of nuclear fuel. During any year, external radiation levels can vary from 15% to 25% at any location because of changes in soil moisture and snow cover (National Council on Radiation Protection 1987).

The interaction of radiation with matter results in energy being deposited in matter. This is why your hand feels warm when exposed to a light source (e.g., flame, light bulb, sun). Ionizing radiation energy deposited in a mass of material is called radiation absorbed dose. A special unit of measurement, called the rad, was introduced for this concept in the early 1950s, and more recently, an International System (SI) unit called the gray (Gy) has been defined: 1 Gy is equivalent to 100 rad (American Society for Testing and Materials 1993).

One device for measuring radiation absorbed dose is the thermoluminescent dosimeter. Thermoluminescent dosimeters absorb and store energy of direct radiation within the thermoluminescent material. By heating the material under controlled laboratory conditions, this stored energy is released as light, which is measured and related to the amount of direct radiation. Thermoluminescence, or light output exhibited by thermoluminescent dosimeters, is proportional to the amount of radiation exposure (X), which is measured in units of roentgen (R). The exposure is multiplied by a factor of 0.98 to convert to a dose (D) in rad to soft tissue (U.S. Department of Health, Education and Welfare 1970). This conversion factor relating R to rad is, however, assumed to be unity (1) throughout this report for consistency with past reports. This dose is further modified by a quality factor, Q = 1 for beta and gamma radiation, and the product of all other modifying factors (N). N is assumed to be 1 to obtain dose equivalence (H), measured in rem. The sievert (Sv) is the SI equivalent of the rem.

$$D\ (\text{rad}) = X\ (\text{R}) * 1.0$$
$$H\ (\text{rem}) = D * N * Q$$

To convert to SI units of gray and sievert, divide rad and rem by 100, respectively.

In 1997, environmental external radiation exposure rates were measured at locations on and off the Hanford Site using thermoluminescent dosimeters and pressurized ionization chambers. Exposure rates measured by the pressurized ionization chambers are reported in units of microroentgens per hour. External radiation and surface contamination surveys at these locations were also performed with portable radiation survey instruments. This section describes how external radiation was measured, how surveys were performed, and gives the results of these measurements and surveys.

4.7.1 External Radiation Measurements

In 1995, the Harshaw 8800 series system replaced the former Hanford standard environmental dosimeter system. The new environmental dosimeter consists of two TLD-700 and two TLD-200 chips. This dosimeter also provides both shallow- and deep-dose measurement capabilities. Thermoluminescent dosimeters are positioned approximately 1 m (3.3 ft) above the ground at 24 locations onsite (Figure 4.7.1), four around the site perimeter, in eight nearby and two distant communities (Figure 4.7.2),

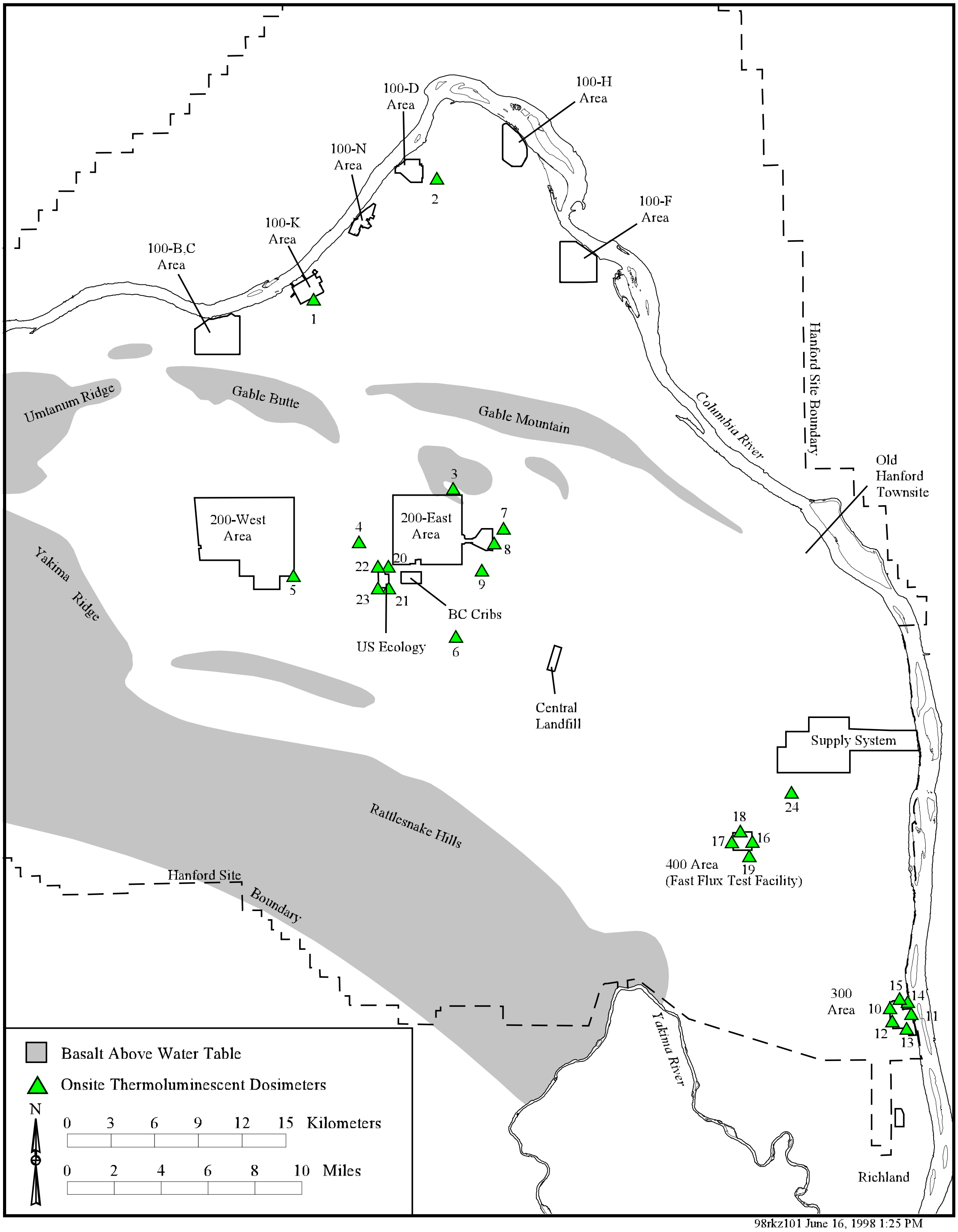

Figure 4.7.1. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Site, 1997

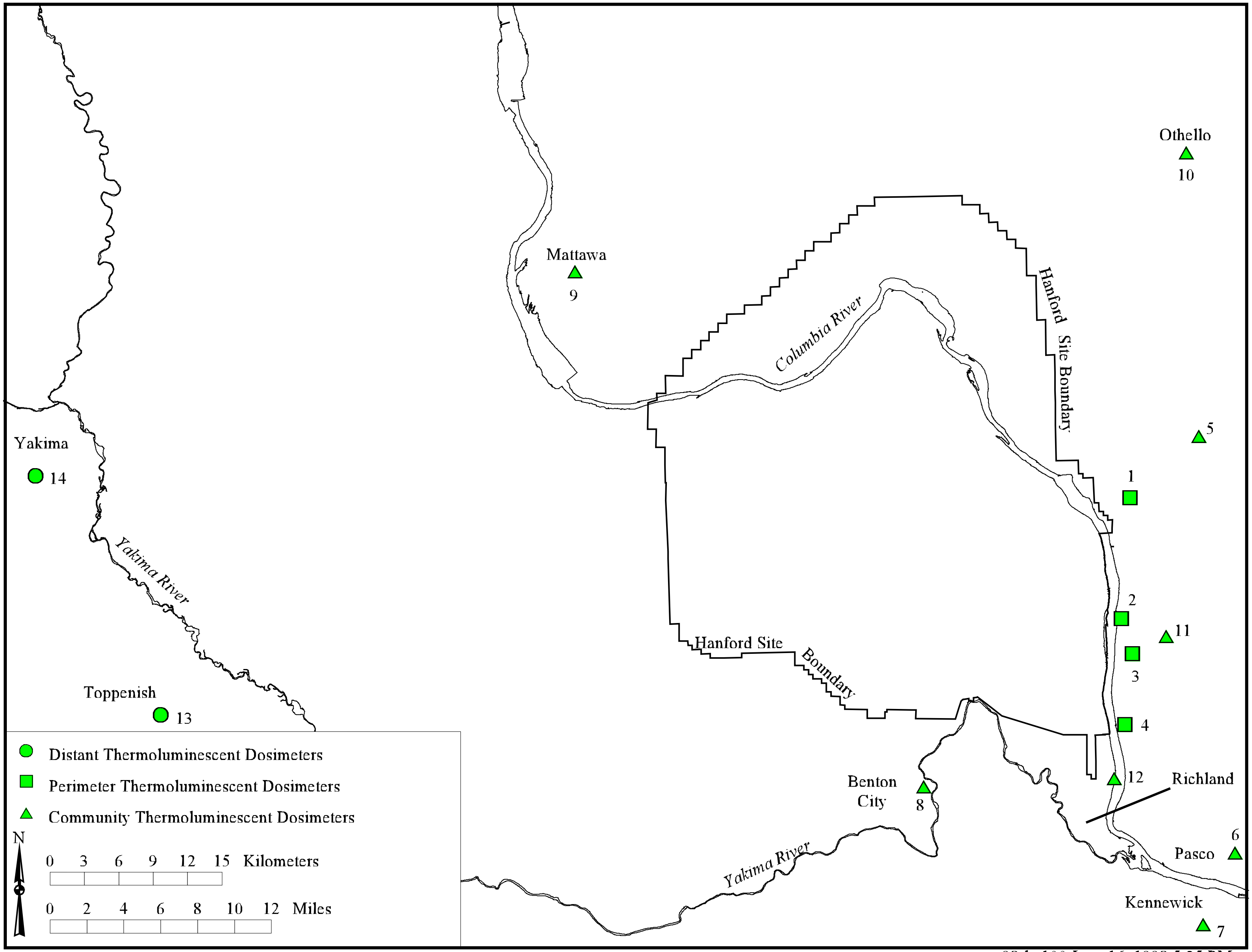

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Figure 4.7.2. Thermoluminescent Dosimeter Locations and Station Numbers for Community, Distant, and Perimeter Sites, 1997

and 28 locations along the Columbia River (Figure 4.7.3). The thermoluminescent dosimeters are collected and read quarterly. The two TLD-700 chips at each location are used to determine the average total environmental dose at that location. The average dose rate is computed by dividing the average total environmental dose by the length of time the thermoluminescent dosimeter was in the field. Quarterly dose equivalent rates (in millirems per day) at each location were converted to annual dose equivalent rates (millirems per year) by averaging the quarterly dose rates and multiplying by 365 d/yr. The two TLD-200 chips are included to determine doses in the event of a radiological emergency.

All community and most of the onsite and perimeter locations are collocated with air monitoring stations. The onsite and perimeter locations were selected based on historical determinations of the highest potentials for public exposures (access areas, downwind population centers) from past and current Hanford Site operations. The two background stations in Yakima and Toppenish were chosen because they are generally upwind and distant from the site.

Twenty-eight thermoluminescent dosimeter locations were established along the Columbia River shoreline (see Figure 4.7.3), from upstream of the 100-B Area to just downstream of Bateman Island at the mouth of the Yakima River. The general public has access to most of this shoreline. In March 1997, the number of thermoluminescent dosimeters along the rivershore was reduced to 24. The locations discontinued were just below the 100-N stack, on the opposite shore from the 100-D Area, near the old Hanford ferry landing, and on the north end of Wooded Island. Data collected from these locations prior to their elimination from the network are included in the data analysis.

4.7.2 External Radiation Results

Thermoluminescent dosimeter readings have been converted to dose equivalent rates by the process described above. Table 4.7.1 shows maximum and mean dose rates for perimeter and offsite locations measured in 1997 and the previous 5 years. External dose rates reported in Tables 4.7.1 through 4.7.3 include the maximum and mean dose rate (±2 standard error of the mean) for all locations within a given location classification and the mean dose rate (±2 standard error of the mean) for each class. The mean dose rates were computed by averaging the annual means for each location within a location classification. Locations were classified (or grouped) based on their distance from the site.

The annual external radiation dose rates measured in 1997 were given in Table 4.7.1. The perimeter dose rate was 89 ± 10 mrem/yr, while in 1996, the mean was 88 ± 10 mrem/yr and the 5-year perimeter mean was 97 ± 5 mrem/yr. The mean background external radiation dose rate (at distant communities) in 1997 was 67 ± 1 mrem/yr compared to the 1996 background average of 71 ± 1 mrem/yr (Section 4.7 in PNNL-11472) and the 5-year mean background dose rate was 83 ± 7 mrem/yr. The background results may be biased low because the background dosimeters are located within fenced areas, for security reasons, and these areas are paved, which shields the dosimeters from some portion of the terrestrial component. The variation in dose rates may be partially attributed to changes in natural background radiation that can occur as a result of changes in annual cosmic radiation (up to 10%) and terrestrial radiation (15% to 25%) (National Council on Radiation Protection 1987). Other factors possibly affecting the annual dose rates reported here may include variations in the sensitivity of individual thermoluminescent dosimeter zero-dose readings, fading, random errors in the readout equipment, procedural errors (PNL-7124), and changes in station locations. These changes include, but are not limited to, the discontinuation of thermoluminescent dosimeter locations or the moving of a station to avoid continual vandalism. Figure 4.7.4 graphically displays a comparison of dose rates between onsite, perimeter, and distant thermoluminescent dosimeter locations from 1992 through 1997.

Locations of the thermoluminescent dosimeters positioned along the Columbia River shoreline were shown in Figure 4.7.3, with Table 4.7.2 showing the measured dose rates for those locations. Dose rates were highest near the 100-N Area shoreline, approximately 1.5 times the typical shoreline dose rates. The high rates measured in the 100-N Area historically have been attributed to past waste management practices in that area (PNL-3127). The maximum dose rate from the 100-N Area shoreline was 178 mrem/yr taken in the fourth quarter at the station located at the 100-N springs. The general public does not have legal access to the 100-N Area shoreline but does have access to the adjacent Columbia River. The dose implications associated with this access are discussed in Section 5.0, "Potential Radiological Doses from 1997 Hanford Operations."

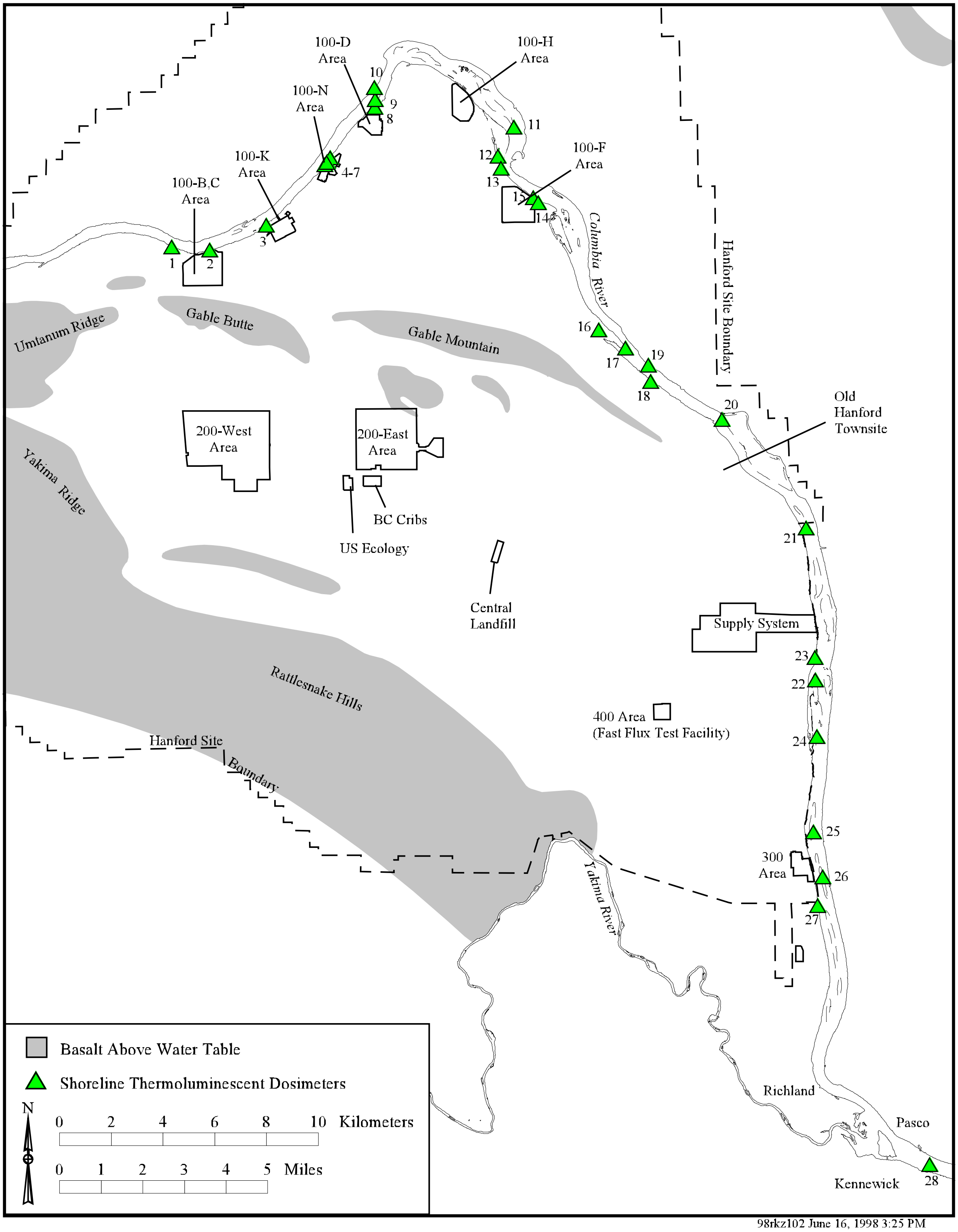

Figure 4.7.3. Thermoluminescent Dosimeter Locations and Station Numbers on the Columbia River, 1997

Table 4.7.1. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations, 1997 Compared to Previous 5 Years

		1997		1992-1996		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Perimeter	1 - 4	95 ± 3	89 ± 10	25	121 ± 8	97 ± 5
Community	5 - 12	86 ± 4	74 ± 9	37	106 ± 8	86 ± 4
Distant	13 - 14	68 ± 2	67 ± 1	11	100 ± 5	83 ± 7

(a) ±2 standard error of the mean.
(b) All station locations are shown on Figure 4.7.2.
(c) Maximum annual average dose rate for all locations within a given distance classification.
(d) Means computed by averaging annual means for each location within each distance classification.

Table 4.7.2. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters Along the Hanford Reach of the Columbia River, 1997 Compared to Previous 5 Years

		1997		1992-1996		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Typical shoreline	1 - 24	102 ± 1[e]	85 ± 3	125	141 ± 11	100 ± 3
100-N Shoreline	25 - 28	153 ± 31	121 ± 22	20	324 ± 39	189 ± 24
All shoreline	1 - 28	153 ± 31	90 ± 6	145	324 ± 39	113 ± 6

(a) ±2 standard error of the mean.
(b) All locations are shown on Figure 4.7.3.
(c) Maximum annual average dose rate for all locations within a given distance classification.
(d) Means computed by averaging the annual means for each location within each distance classification.
(e) Single quarter's data; error term is two times the counting error for that single measurement.

Table 4.7.3 summarized the results of 1997 measurements on the site, which are grouped by operational area. The average dose rates in all operational areas were higher than average dose rates measured at background locations. The highest average dose rate onsite was seen in the 600 Area and was due to waste disposal activities at US Ecology Inc., a non-DOE facility.

4.7.3 Radiation Survey Results

In 1997, hand-held survey instruments were used to perform radiation surveys at selected Columbia River shoreline thermoluminescent dosimeter locations. These surveys provided a coarse screening for elevated radiation fields. The surveys showed that radiation levels at the selected locations were comparable to levels observed

Table 4.7.3. Dose Rates (mrem/yr[a]) Measured by Thermoluminescent Dosimeters on the Hanford Site, 1997 Compared to Previous 5 Years

		1997		1992-1996		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
100 Areas	1 - 2	86 ± 1	78 ± 16	12	108 ± 11	91 ± 7
200 Areas	3 - 9	92 ± 6	86 ± 4	37	121 ± 10	97 ± 3
300 Area	10 - 15	82 ± 2	80 ± 1	30	110 ± 18	92 ± 4
400 Area	16 - 19	83 ± 6	81 ± 2	20	111 ± 18	94 ± 5
600 Area	20 - 24	131 ± 26	94 ± 21	24	183 ± 16	110 ± 11
Combined Onsite	1 - 24	131 ± 26	85 ± 5	123	183 ± 16	97 ± 3

(a) ±2 standard error of the mean.
(b) All locations shown on Figure 4.7.1.
(c) Maximum annual average dose rate for all locations within a given area classification.
(d) Means computed by averaging the annual means for each location within each distance classification.

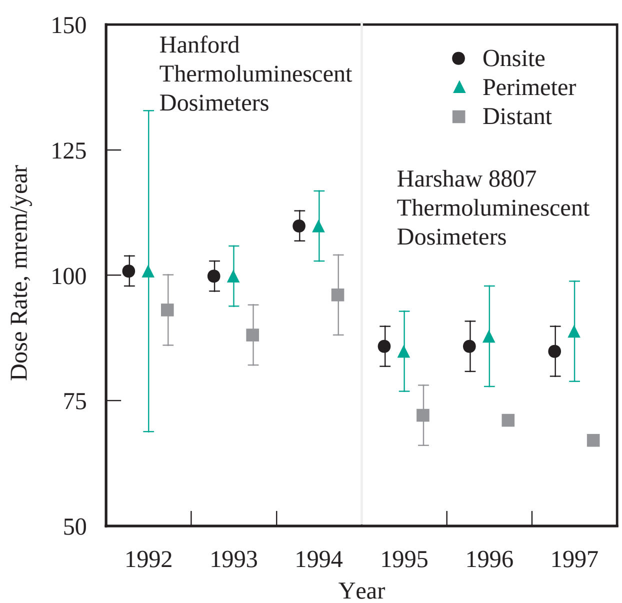

Figure 4.7.4. Annual Average Dose Rates (±2 standard error of the mean), 1992 Through 1997

at the same locations in previous years. The highest levels were seen along the Columbia River shoreline in the 100-N Area and ranged from 7 to 30 mrem/h. The 30 mrem/h reading corresponded with the highest quarterly thermoluminescent dosimeter reading for the 100-N Trench location. Survey information is not included in the 1997 data volume (PNNL-11796), but is maintained in the Surface Environmental Surveillance Project files at Pacific Northwest National Laboratory and can be provided on written request.

4.7.3.1 Gamma Radiation Measurements

During 1997, gamma radiation levels in air were continuously monitored at four community-operated air monitoring stations (Section 7.4, "Community-Operated Environmental Surveillance Program"). These stations were located in Leslie Groves Park in Richland, at Edwin Markham Elementary School in north Franklin County, at Basin City Elementary School in Basin City, and at Heritage College in Toppenish (see Figure 4.1.1). Measurements were collected to determine ambient gamma radiation levels near and downwind of the site and upwind and distant from the site, to display real-time exposure rate information to the public living near the station, and to be an educational aid for the teachers who manage the stations.

Measurements at the Basin City and Edwin Markham Schools were obtained using Reuter-Stokes Model S-1001-EM19 pressurized ionization chambers connected to Reuter-Stokes RSS-112 Radiation Monitoring Systems. Data were collected every 5 seconds, and an average reading was calculated and recorded on an electronic data card every 30 minutes. Data cards were exchanged monthly. Readings at the Leslie Groves Park and Heritage College stations were collected every 10 seconds with a Reuter-Stokes Model RSS-121 pressurized ionization chamber, and an average reading was recorded every hour by a flat panel computer system located at the station. Data were obtained monthly from the computer via modem. Data were not collected at every station every month because of problems with recording instruments. The data collected at each station each month are summarized in Table 4.7.4.

The measurements recorded at Basin City, Edwin Markham, and Leslie Groves Park during the year were similar and at background levels. The readings recorded at Heritage College were also within normal limits but were, on average, slightly lower than readings measured near the Hanford Site.

Monthly average exposure rates ranged from 6.9 mR/h at Heritage College in December to 8.7 mR/h at Edwin Markham during 7 months of the year (see Table 4.7.4). Average monthly readings at the stations near Hanford were consistently between 8.1 and 8.7 mR/h, and readings at Heritage College ranged between 6.9 and 8.1 mR/h. These dose rates were consistent with dose rates measured by the thermoluminescent dosimeters at these locations (Table 4.7.5).

Table 4.7.4. Average Exposure Rates Measured by Pressurized Ionization Chambers at Four Offsite Locations, 1997

	Average Exposure Rate, μR/h[(a)] (number of readings)[(b)], at Sampling Locations[(c)]			
Month	Leslie Groves Park[(d)]	Basin City[(e)]	Edwin Markham[(e)]	Toppenish[(d)]
January	8.6 ± 0.024 (585)	8.3 ± 0.013 (1,334)	8.7 ± 0.017 (1,304)	6.9 ± 0.019 (743)
February	8.5 ± 0.020 (633)	8.2 ± 0.011 (1,327)	8.7 ± 0.011 (1,334)	7.5 ± 0.011 (672)
March	8.4 ± 0.018 (743)	8.2 ± 0.008 (1,507)	8.7 ± 0.009 (1,488)	7.7 ± 0.014 (357)
April	8.4 ± 0.015 (600)	8.2 ± 0.009 (1,557)	8.7 ± 0.009 (1,433)	7.9 ± 0.014 (510)
May	8.3 ± 0.015 (720)	8.1 ± 0.014 (859)	8.6 ± 0.010 (1,444)	7.8 ± 0.014 (733)
June	8.3 ± 0.011 (720)	8.1 ± 0.006 (1,451)	8.6 ± 0.007 (1,816)	7.8 ± 0.010 (694)
July	8.2 ± 0.016 (510)	8.1 ± 0.008 (1,479)	8.5 ± 0.010 (1,259)	7.8 ± 0.014 (720)
August	8.3 ± 0.021 (387)	8.3 ± 0.007 (1,482)	8.5 ± 0.013 (1,774)	7.9 ± 0.012 (655)
September	8.4 ± 0.020 (720)	ND[(f)]	8.7 ± 0.018 (655)	8.0 ± 0.016 (618)
October	8.4 ± 0.020 (744)	8.4 ± 0.016 (652)	8.7 ± 0.010 (1,497)	8.0 ± 0.020 (682)
November	8.5 ± 0.041 (720)	ND	ND	8.1 ± 0.025 (920)
December	8.5 ± 0.036 (744)	8.4 ± 0.024 (102)	ND	8.1 ± 0.026 (744)

(a) Averages are ±2 standard error of the mean.
(b) Number of 30- or 60-minute averages used to compute monthly average.
(c) Sampling locations are illustrated in Figure 4.1.1.
(d) Readings are stored every 60 minutes. Each 60-minute reading is an average of 360 individual measurements.
(e) Readings are stored every 30 minutes. Each 30-minute reading is an average of 360 individual measurements.
(f) ND = No data collected; equipment or power problems.

Table 4.7.5. Quarterly Exposure Rates Measured by Thermoluminescent Dosimeters at Four Offsite Locations, 1997

	Exposure Rate, μR/h[(a)], at Sampling Locations[(b)]			
Quarter Ending	Leslie Groves Park	Basin City	Edwin Markham	Toppenish
March	9.3 ± 0.79	9.2 ± 0.00	9.1 ± 0.04	7.4 ± 0.13
June	8.3 ± 0.08	NS[(c)]	7.9 ± 0.13	7.8 ± 0.54[(d)]
September	NS	9.3 ± 0.67	9.0 ± 0.58	7.8 ± 0.04
December	8.4 ± 0.04	8.8 ± 0.021	8.3 ± 0.04	7.8 ± 0.50

(a) ±2 standard deviations of the exposure rate.
(b) Sampling locations shown on Figure 4.1.1.
(c) NS = No sample; thermoluminescent dosimeters missing.
(d) Collected on July 1, 1997.