5.7 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, nuclear power, nuclear research, nuclear waste management, and consumer products. Environmental radiation fields may be influenced by the presence of radionuclides deposited as fallout from past atmospheric testing of nuclear weapons or those produced and released to the environment during the production or use of nuclear fuel. The interaction of radiation with matter results in energy being deposited in matter. 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.

External radiation exposure rates were measured at locations on and off the Hanford Site using thermoluminescent dosimeters (TLDs). External radiation and contamination surveys were also performed with portable radiation survey instruments at locations on and around the Hanford Site. This section describes how external radiation was measured, how surveys were performed, and the results of these measurements and surveys.

External Radiation Measurements

Thermoluminescence, or light output exhibited by TLDs, 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 (USDHEW 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 Seivert, Sv, is the SI equivalent of the rem.

$$D\ (rad) \approx X\ (R) * 1.0$$
$$H\ (rem) = D * N * Q$$

To convert to SI units of Gy and Sv, divide rad and rem by 100, respectively.

An environmental TLD comprises three plastic cards that each hold four LiF (TLD 700) chips and one calcium fluoride:dysprosium (TLD 200) chip. TLDs are positioned 1 m (3.3 ft) above the ground at various locations both on and off the Hanford Site. The TLDs are collected and read quarterly; those located along the Columbia River shoreline at the 100-N Area are processed monthly. The 12 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 TLD was in the field. The three TLD 200 chips are included to determine doses in the event of a radiological emergency.

The TLDs are positioned at numerous locations onsite (Figure 5.7.1), around the Site perimeter, in nearby and distant communities, (Figure 5.7.2), and along the Hanford Reach of the Columbia River (Figure 5.7.3). All community and most of the onsite and perimeter locations are collocated with air monitoring stations. These locations were selected based on historical determinations of the highest potentials for public exposures (access areas, downwind population centers) from past and current Hanford operations.

Dose rates were also measured using both TLDs and survey instruments at three community-operated stations located at Edwin Markham Elementary School north of Pasco, Basin City Elementary School in Basin City, and Leslie Groves Park in Richland (Figure 5.7.2).

Twenty-eight TLD locations have been established on the Columbia River shoreline, from upstream of

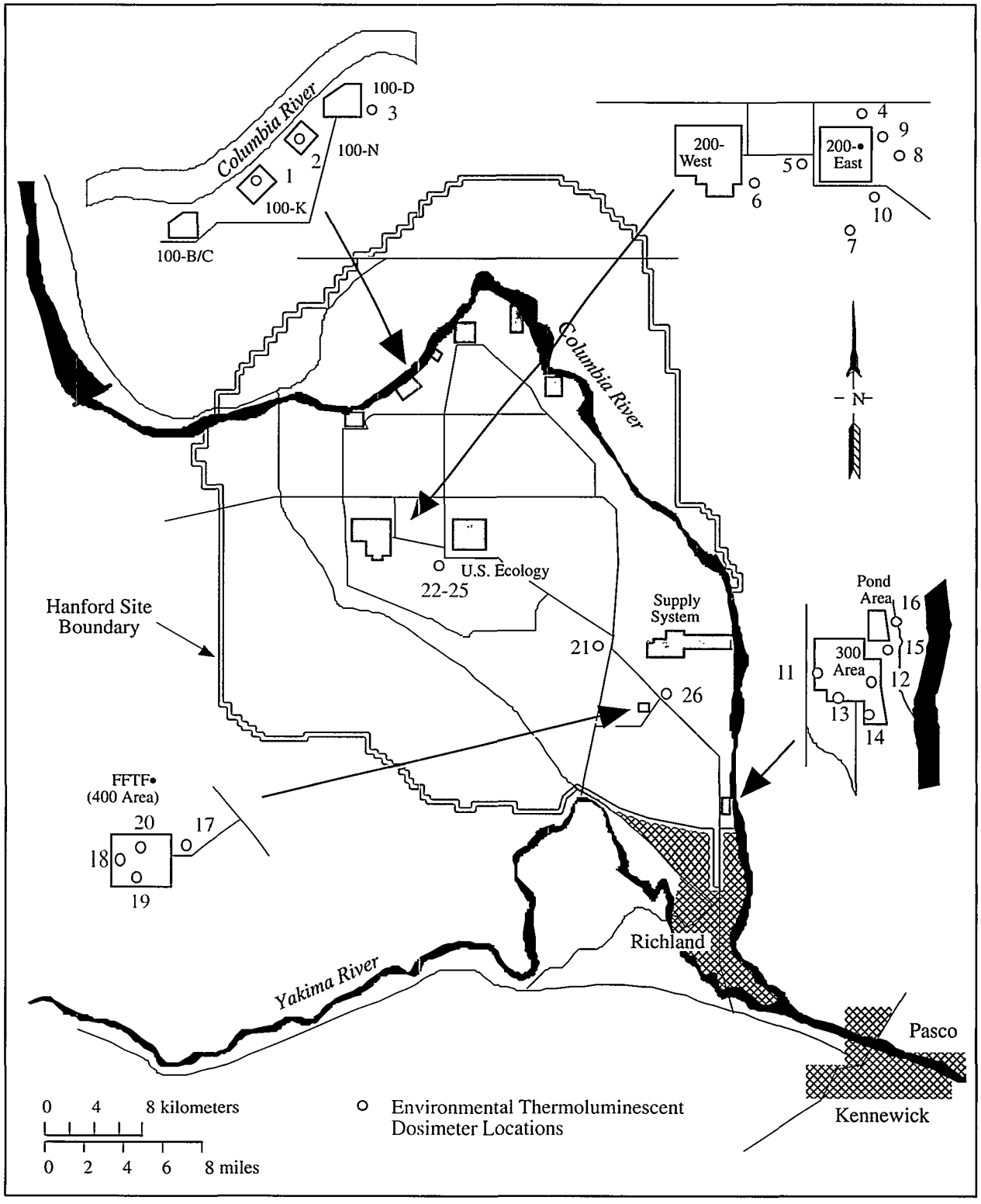

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Figure 5.7.1 Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Site, 1994

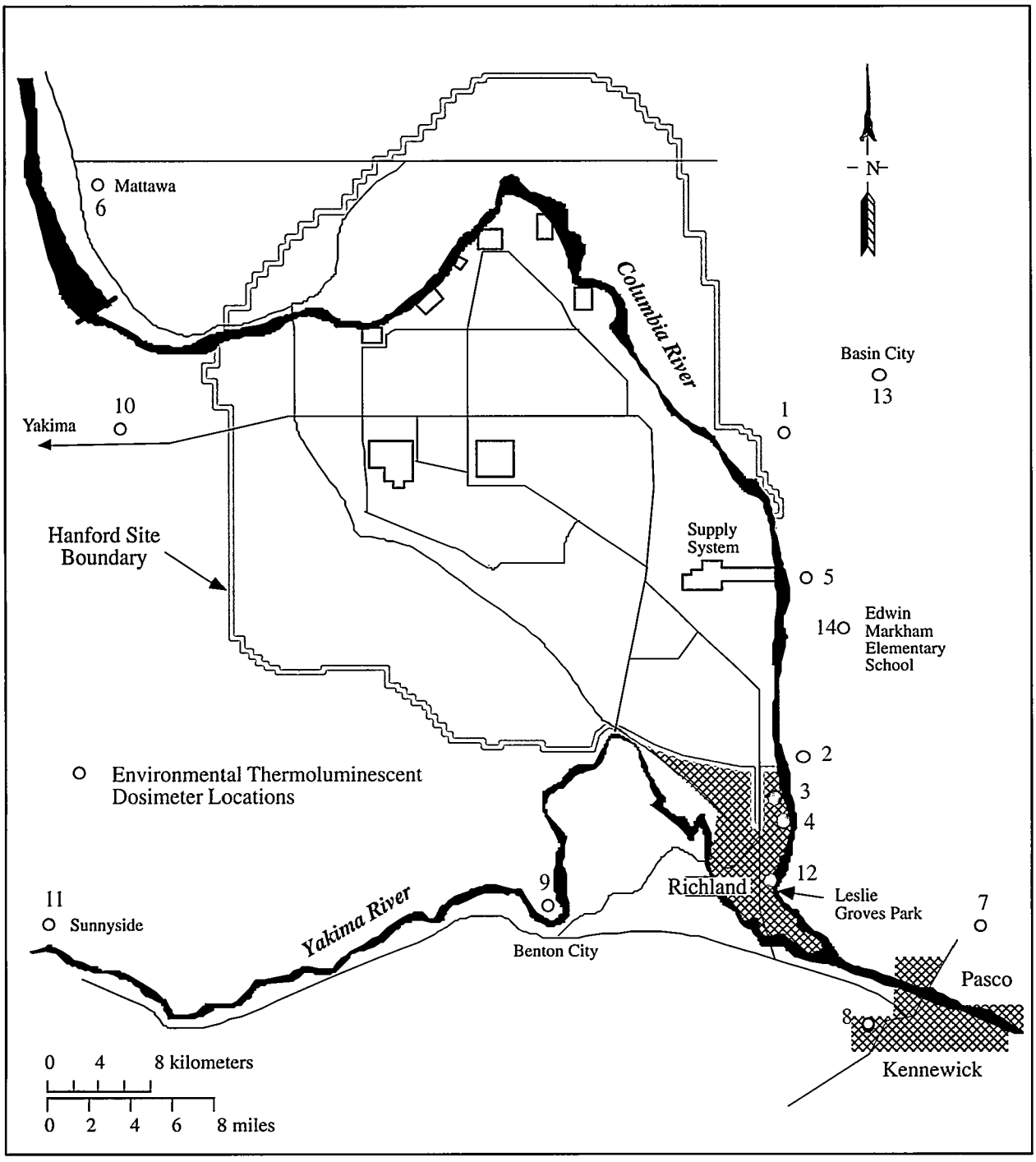

Figure 5.7.2 Thermoluminescent Dosimeter Locations and Station Numbers for Community, Distant, and Perimeter Sites, 1994

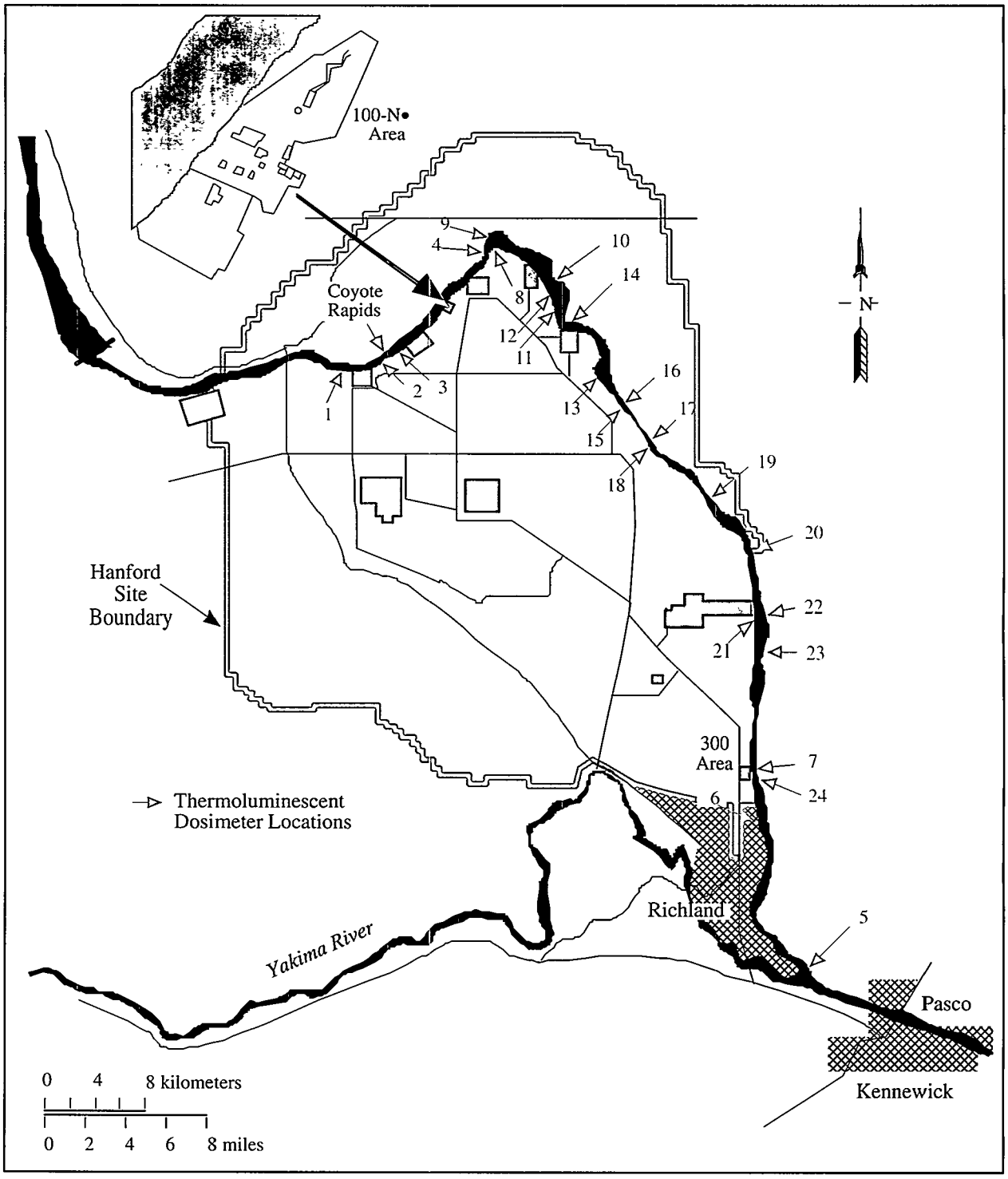

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Figure 5.7.3 Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Reach of the Columbia River, 1994

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. Historically, dose rates measured along the shoreline have been higher than typical background rates. Sula (1980) attributed these elevated rates to cobalt-60 and europium-154 deposited in shoreline sediments as a result of liquid releases to the Columbia River during past reactor operations in the 100 Areas.

External Radiation Results

Perimeter and offsite locations, primarily downwind of the Site and near population centers, were monitored with TLDs. TLD exposures have been converted to dose equivalent rates by the process described above. Table 5.7.1 shows maximum and average dose rates for perimeter and offsite locations measured in 1994 and the previous 5 years. Quarterly dose rates (mrem/day) at each location were converted to annual dose equivalent per year by averaging the quarterly dose rates and multiplying by 365 days/yr. Dose rates reported in Tables 5.7.1 through 5.7.3 represent the maximum annual average dose rate ($\pm$ 2 standard error of the mean) for all locations within a given area. Mean dose rates for each area were computed by averaging annual means for each location within the area. The error term is ± 2 standard error of the mean.

Perimeter dose rates for 1994 were similar to those observed in 1993. In 1994, the average perimeter external radiation dose rate was 110 $\pm$ 7 mrem/year while in 1993, the average was 100 $\pm$ 6 mrem/year. Variations in natural background radiation can occur as a result of changes in annual cosmic radiation (up to 10%) and terrestrial radiation (15 to 25%, NCRP 1987). Other factors possibly affecting annual dose rates reported here may include variations in the sensitivity of individual TLDs zero-dose readings, fading, random errors in the readout equipment or procedures (Rathbun 1989), and changes in TLD station locations.

The average background external radiation dose rate (at distant locations) was 96 $\pm$ 8 mrem/year as compared to the perimeter average of 110 $\pm$ 7 mrem/year. This difference in average dose rates may be due to natural geographic variations in terrestrial radiation (the soils at many of the perimeter locations are rich in potassium-40 and thorium isotopes [Rathbun 1989]) and variations resulting from human activity. Human activities affecting the average dose rates may include landscape modifications such as buildings and other

Table 5.7.1 Average and Maximum Dose Rates Measured by Thermoluminescent Dosimeters (TLDs) at Perimeter and Offsite Locations, 1994 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1994			1989-1993	
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum	Mean[c]
Perimeter	1 - 5	120 ± 17	110 ± 9.2	53	110 ± 3.0	91 ± 2.6
Nearby communities	6 - 9	110 ± 16	97 ± 6.2	34	96 ± 9.6	83 ± 3.0
Distant communities	10 - 11	100 ± 11	96 ± 8.3	19	96 ± 6.8	82 ± 3.5
COES stations	12 - 14	100 ± 15	100 ± 4.6	9	100 ± 20	87 ± 5.3

(a) Quarterly integrated readings in mR/d were converted to annual dose equivalent rates (mrem/yr).
(b) All locations are shown in Figure 5.7.2.
(c) Maximum annual average dose rate ($\pm$ 2 standard error of the mean) for all locations within a given area.
(d) Means ± 2 standard error of the mean computed by averaging annual means for each location within the area.

Table 5.7.2 Average and Maximum Dose Rates Measured Along the Hanford Reach of the Columbia River, 1994 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1994			1989-1993	
Location	Map Location [b]	Maximum [c]	Mean[d]	No. of Samples	Maximum	Mean[c]
Typical shoreline area	1 - 24	140 ± 25	110 ± 5.2	87	170 ± 160	100 ± 3.8
100-N shoreline[e]	25 - 28	250 ± 22	200 ± 38	18	360 ± 31	240 ± 31
All shoreline		250 ± 22	130 ± 14	105	360 ± 31	130 ± 12

(a) Quarterly integrated readings in mR/d were converted to annual dose equivalent rates (mrem/yr).
(b) All locations are shown in Figure 5.7.3.
(c) Maximum annual average dose rate (± 2 standard error of the mean) for all locations within a given area.
(d) Means ±2 standard error of the mean computed by averaging annual means for each location within the area.
(e) Monthly integrated exposure readings in mR/d converted to annual dose equivalent rates in mrem/yr.

Table 5.7.3 Average and Maximum Dose Rates for Thermoluminescent Dosimeter (TLD) Locations on the Hanford Site, 1994 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1994			1989-1993	
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum	Mean
100 Areas[e]	1 , 3	110 ± 11	110 ± 16	14	120 ± 35	92 ± 6.3
200 Areas	4 - 10	120 ± 10	110 ± 4.1	32	110 ± 3.2	94 ± 3.1
300 Area	11 - 16	110 ± 18	100 ± 3.1	24	110 ± 6.9	92 ± 3.1
400 Area	17 - 20	110 ± 18	110 ± 3.6	19	110 ± 15	91 ± 4.6
600 Area	21 - 26	160 ± 16	120 ± 19	35	180 ± 16	100 ± 8.6

(a) Quarterly integrated readings in mrem were converted to annual dose equivalent rates.
(b) Locations are identified in Figure 5.7.1.
(c) Maximum annual average dose rate (± 2 standard error of the mean) for all locations within a given area.
(d) Means ±2 standard error of the mean computed using pooled quarterly data.
(e) Location 2 was discontinued after the first calendar quarter. Reading was 120 mrem/yr.

construction, which may shield a portion of the terrestrial component. Figure 5.7.4 graphically displays a comparison between, and trends of, onsite, perimeter, and distant TLD locations during 1989 through 1994. Year-to-year variability is possible for these reasons, and 10% variability is possible (NCRP 1987).

Figure 5.7.3 shows locations of TLDs positioned along the Columbia River shoreline, and Table 5.7.2 shows the maximum and average measured dose rates for shoreline locations. Dose rates were highest near the 100-N Area shoreline, two times higher than typical shoreline dose rates. The high rates measured in the 100-N Area are attributed to past waste management practices in that area. The 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 6.0 "Potential Doses from 1994 Hanford Operations."

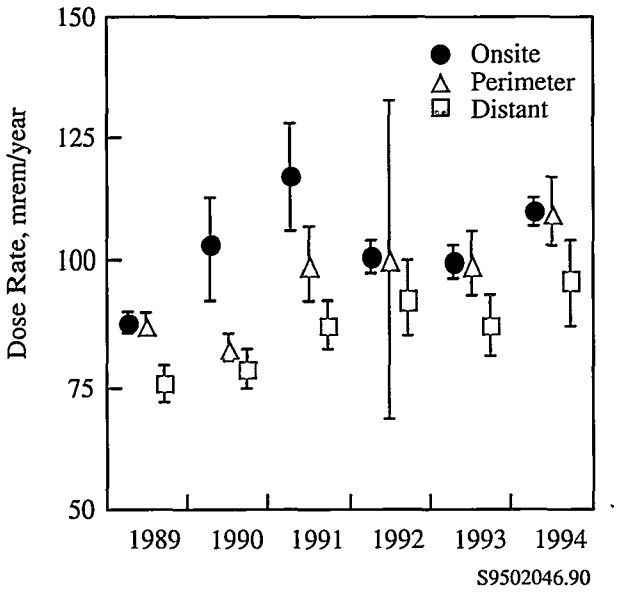

Figure 5.7.4 Annual Average Dose Rates (± 2 standard error of the mean), 1989 Through 1994. As a result of figure scale, some uncertainties are concealed by point symbol.

Figure 5.7.1 displays the 28 onsite locations of TLDs in 1994. Table 5.7.3 summarizes the results of 1994 measurements, which are grouped by operational area. The average dose rates in all operational areas were higher than 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.

Radiation Survey Results

In 1994, radiation surveys were conducted at selected Columbia River shoreline locations.

Hand-held survey instruments were used to perform radiation surveys at certain Columbia River shoreline TLD locations. These surveys provided a coarse screening for elevated radiation fields. The surveys showed that radiation levels were comparable to levels observed 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 4 to 40 mrem/h. Survey results are not included in the 1994 data volume (Bisping 1995), but are maintained in the Surface Environmental Surveillance Project files at PNL.