PNL-8789, Addendum 1

MEASUREMENT OF ENVIRONMENTAL RADIATION EXPOSURE RATES FROM VERNITA, HANFORD REACH, AND RICHLAND AREA SHORES

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SUMMARY

Environmental radiation exposure rate measurements are taken on and around the Hanford Site for Pacific Northwest Laboratory's[(a)] Hanford Site Surface Environmental Surveillance Project. The Hanford Site is a U.S. Department of Energy site near the city of Richland, Washington. In 1992, as part of this project, environmental radiation exposure rate measurements were taken from shoreline and island areas ranging from Vernita, along the Hanford Reach, down to the Richland Pumphouse (Cooper and Woodruff 1993). Measurements were taken primarily at locations known or expected to have elevated exposure rates as determined by examination of aerial photographs depicting radiation exposure measurements (EG&G 1990). As expected, results from the 1992 survey indicated radiation exposure rates taken from the Hanford Reach area were elevated in comparison to the measurements taken from the Vernita area with ranges of 8 to 28 μR/hr and 4 to 11 μR/hr, respectively.

In January 1994, additional shoreline radiation exposure rate measurements were taken from the Vernita, Hanford Reach, and Richland areas. The 1994 measurements were taken to determine the relationship of radiation exposure rates along the Richland area shores when compared to Vernita and Hanford Reach area exposure rates (measurements along the Richland area were not collected during the 1992 survey). This report discusses the 1994 results and is an addendum to the report that discussed the 1992 survey, *Investigation of Exposure Rates and Radionuclide and Trace Metal Distributions Along the Hanford Reach of the Columbia River*, PNL-8789 (Cooper and Woodruff 1993).

The 1994 radiation exposure measurements from the Vernita area (14 sites) ranged from 8 to 11 μR/hr. Hanford Reach area (19 sites) measurements ranged from 8 to 15 μR/hr, and Richland area (16 sites) measurements ranged from 7 to 10 μR/hr.

An analysis of variance indicated a significant location interaction at a p-value of 0.0014. To determine differences between paired locations a

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post-hoc comparison of location means was performed on log transformed data using the Scheffé's F-test. This test indicated a significant difference between Hanford Reach and Richland area means with a mean difference of 0.075 μR/hr and a p-value of 0.0014. No significant difference was found between Hanford Reach and Vernita area means; the mean difference was 0.031 μR/hr and the p-value was 0.3138. Also, no significant difference was found between Vernita and Richland area means with a mean difference of 0.044 μR/hr and a p-value of 0.1155.

ACKNOWLEDGMENTS

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ACRONYMS AND ABBREVIATIONS

ANOVA	analysis of variance
GPS	Geographical Positioning System
PIC	Pressurized Ionization Chamber

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FIGURES

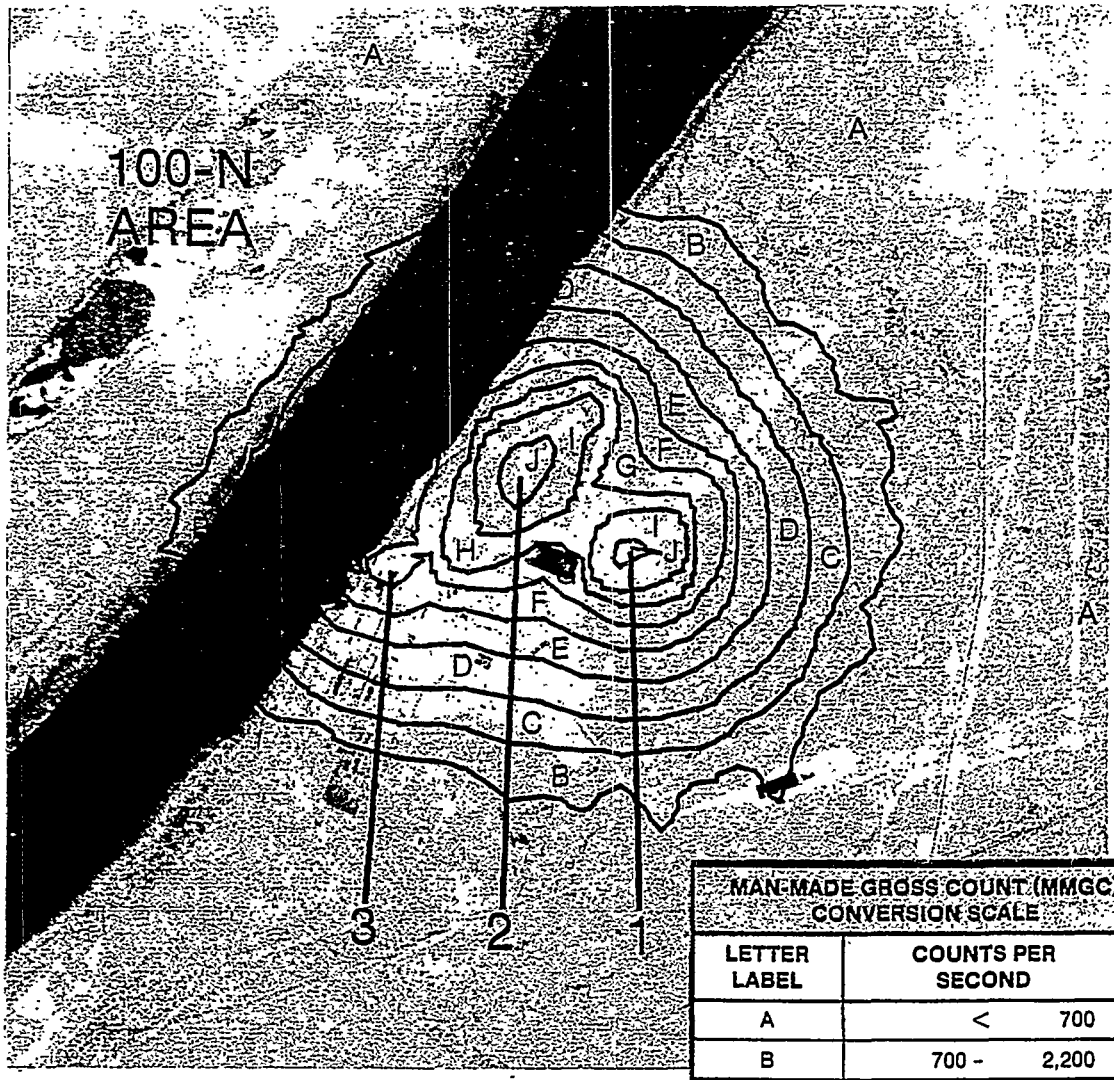
TABLES

1.0 INTRODUCTION

Environmental radiation exposure rate measurements are taken on and around the Hanford Site for Pacific Northwest Laboratory's Hanford Site Environmental Surveillance Project. The Hanford Site is a U.S. Department of Energy site near the city of Richland, Washington. The most recent aerial radiological survey of the Hanford Site was conducted in 1988 (EG&G 1990). The aerial survey indicated that previously identified areas of elevated radioactivity continued to exist as a result primarily of longer lived radionuclide depositions in soils and sediments. During July to October 1992, environmental radiation exposure measurements were taken along the Columbia River shores near the Vernita area, and along the Hanford Reach area downstream to the Richland Pumphouse (Cooper and Woodruff 1993). Measurements were taken primarily at locations known or expected to have elevated exposure rates as determined by examination of aerial photographs depicting radiation exposure measurements (EG&G 1990). The results from the 1992 survey indicated radiation exposure rates taken from the Hanford Reach area were elevated in comparison to the measurements taken from the Vernita area.

The field measurements in 1992 were conducted to identify current external exposure rates and potential sources of human health risks due to increased levels of ionizing radiation. Areas with elevated radiation exposure rates, which are small relative to the overall length of Columbia River shoreline along Hanford, were given sampling priority. The areas with elevated exposure rates were identified by examining aerial photographs which were overlaid with radiation exposure rate isopleths as measured by EG&G (EG&G 1990). For example, Figure 1.1 shows the EG&G aerial photograph taken over the 100-N area. The isopleths surrounding the sources of radiation are labelled according to intensity with category A (<700 count/sec) areas having the lowest radiation exposure levels.

The 1992 field data characterized areas along the Hanford Reach rather well but because field data was not collected from the Richland area the downstream comparisons of exposure rates could not be made. In addition, because Hanford Reach measurements were intentionally biased high, comparisons



MAN-MADE GROSS COUNT (MMGC) CONVERSION SCALE	
LETTER LABEL	COUNTS PER SECOND
A	< 700
B	700 - 2,200
C	2,200 - 7,000
D	7,000 - 22,000
E	22,000 - 70,000
F	70,000 - 220,000
G	220,000 - 700,000
H	700,000 - 2,200,000
I	2,200,000 - 7,000,000
J	7,000,000 - 22,000,000

The data shown here have been processed in a manner that suppresses the natural background. The results are displayed as relative levels of man-made radionuclide activity. It is nearly impossible to convert the relative levels of activity to a meaningful exposure rate because of the complex distribution of the nuclides.

FIGURE 1.1. 1988 EG&G Aerial Radiological Survey of the 100-N Area

indicated exposure levels to be elevated along the Hanford Reach area, with respect to the Vernita area.

In January and February 1994, so that more representative comparisons between locations could be made, additional field measurements were taken from the Vernita, Hanford Reach, and Richland areas. The 1994 measurements were taken to determine the relationship of radiation exposure rates along the Richland area shores when compared to Vernita and Hanford Reach area exposure rates. This report discusses the 1994 results and is an addendum to the report that discussed the 1992 survey, *Investigation of Exposure Rates and Radionuclide and Trace Metal Distributions Along the Hanford Reach of the Columbia River*, PNL-8789 (Cooper and Woodruff 1993).

2.0 STUDY DESCRIPTION

The objective of this current study, performed during January and February 1994, was to examine the differences in radiation exposure rate measurements taken from Vernita, Hanford Reach, and Richland areas.

2.1 LOCATIONS

The 49 samples were taken from the Vernita area (14 sites), Hanford Reach area (19 sites), and Richland area (16 sites), at shoreline areas 2 to 10 m from the water's edge (Figures 2.1 through 2.3). To provide an appropriate level of spatial coverage and variability, the locations were selected by systematically choosing locations from aerial photographs of the survey areas.

2.2 SAMPLING METHODS

At each sample location, measurements were taken with a Reuter-Stokes, RSS-112, Pressurized Ionization Chamber (PIC) radiation detection instrument. The PIC is a 30.5-cm cube, 8-L spherical ionization chamber weighing 10.4 kg. The ionization chamber is filled to a pressure of 25 atmosphere with ultra-high purity argon. The gamma ray energy response curve for the PIC is relatively flat from 0.07 to 10 MeV.

In addition, a Trimble Pro-lite Geographical Positioning System (GPS) was used for determining geographical locations. The system is a six-channel GPS consisting of a datalogger, antenna, and a 12-v power source. The entire system weighs about 7 kg and is carried in a backpack with the antenna positioned over the shoulder of the wearer.

At each sample location, the PIC was placed on a tripod 0.5-m high. The PIC collected a data point every 5 sec over a span of 2 min. The 24 data points were internally averaged by the PIC and a final exposure rate value was generated.

The GPS antenna was positioned near the tripod and allowed to collect 200 satellite location records. The records were processed with Pfinder software developed by Trimble Navigation Inc. The Pfinder software averaged the 200 records to produce a single position record for each sample location. The GPS

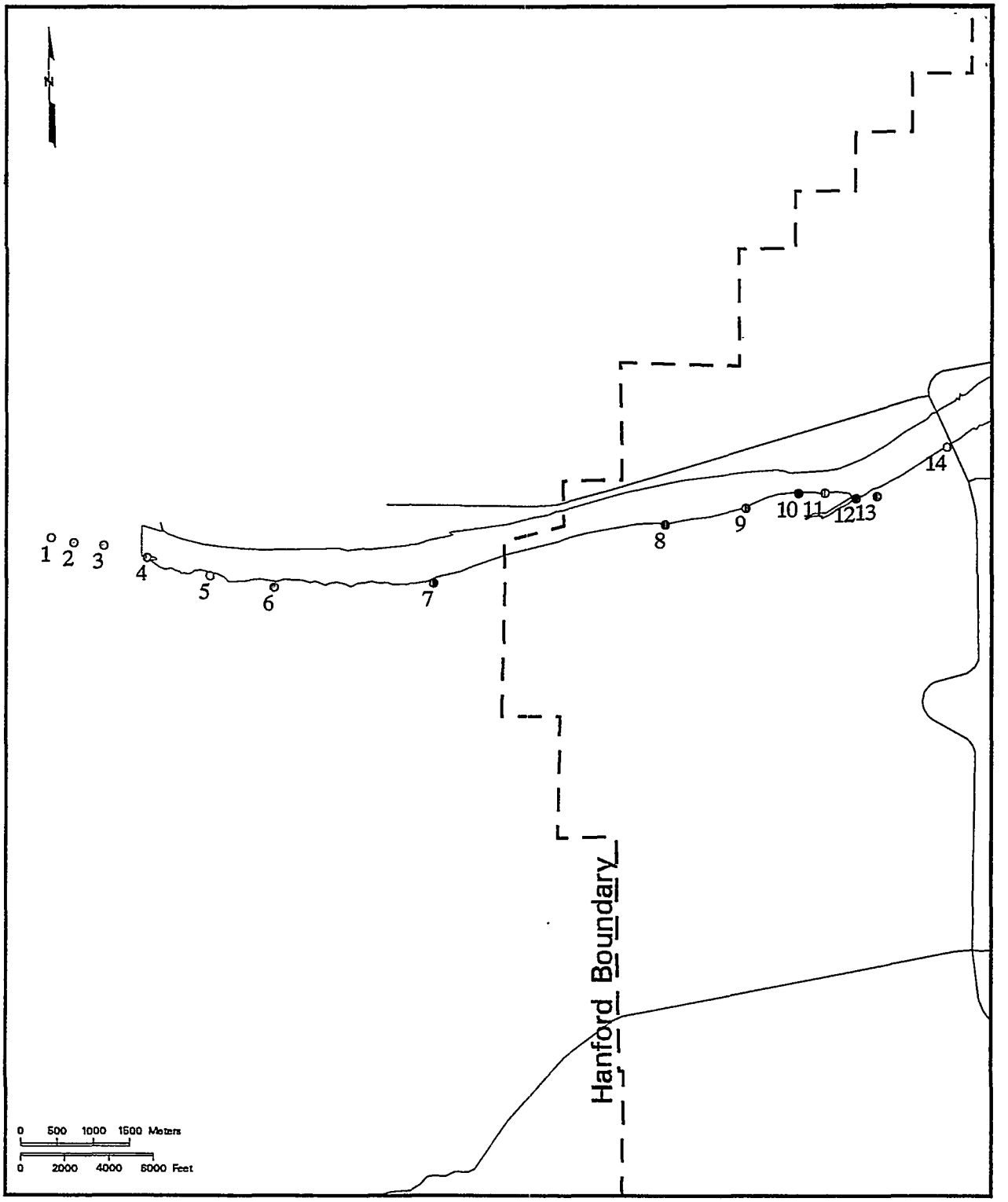


FIGURE 2.1. Sample Locations at the Vernita Area

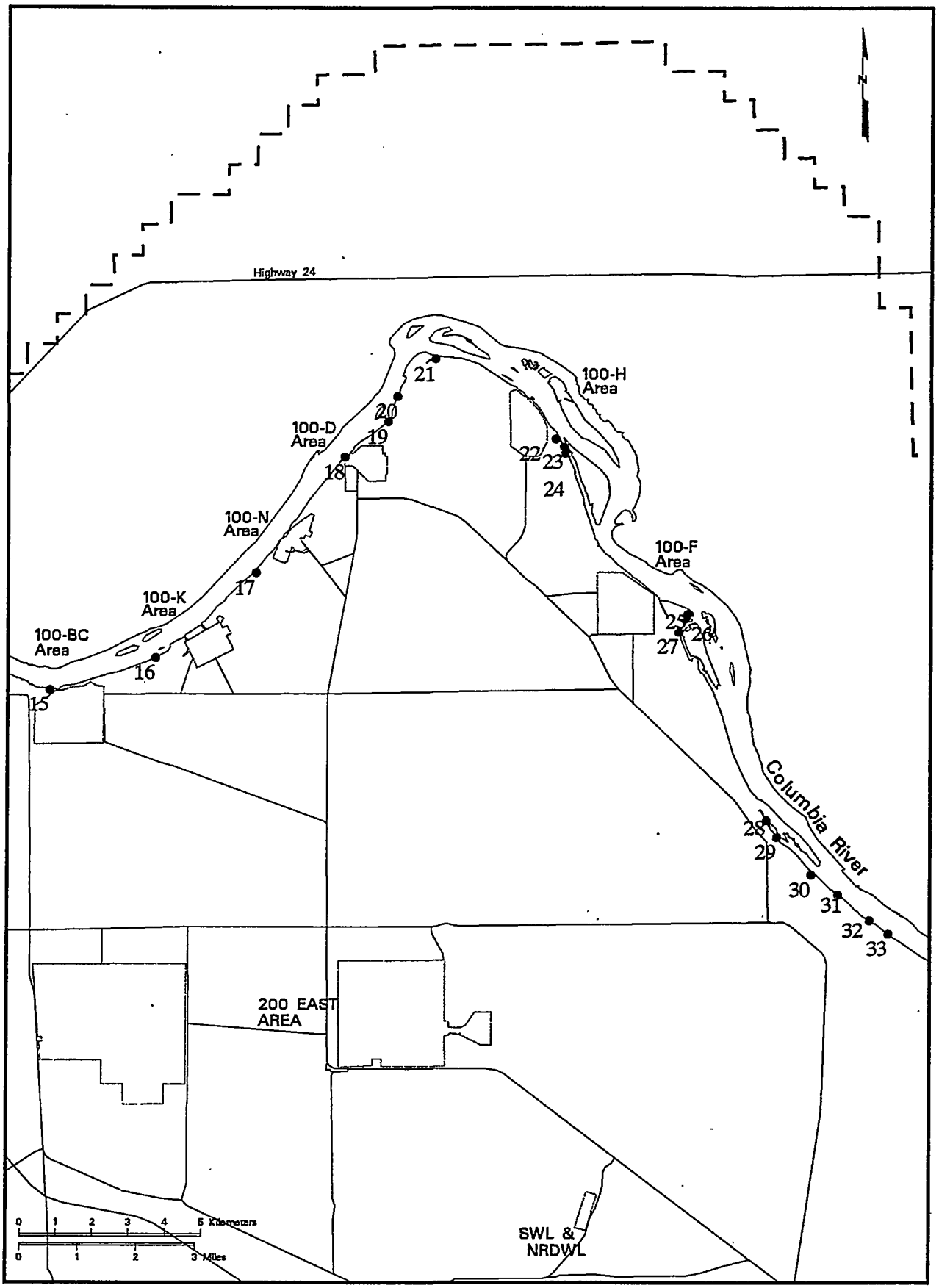


FIGURE 2.2. Sample Locations at the Hanford Reach

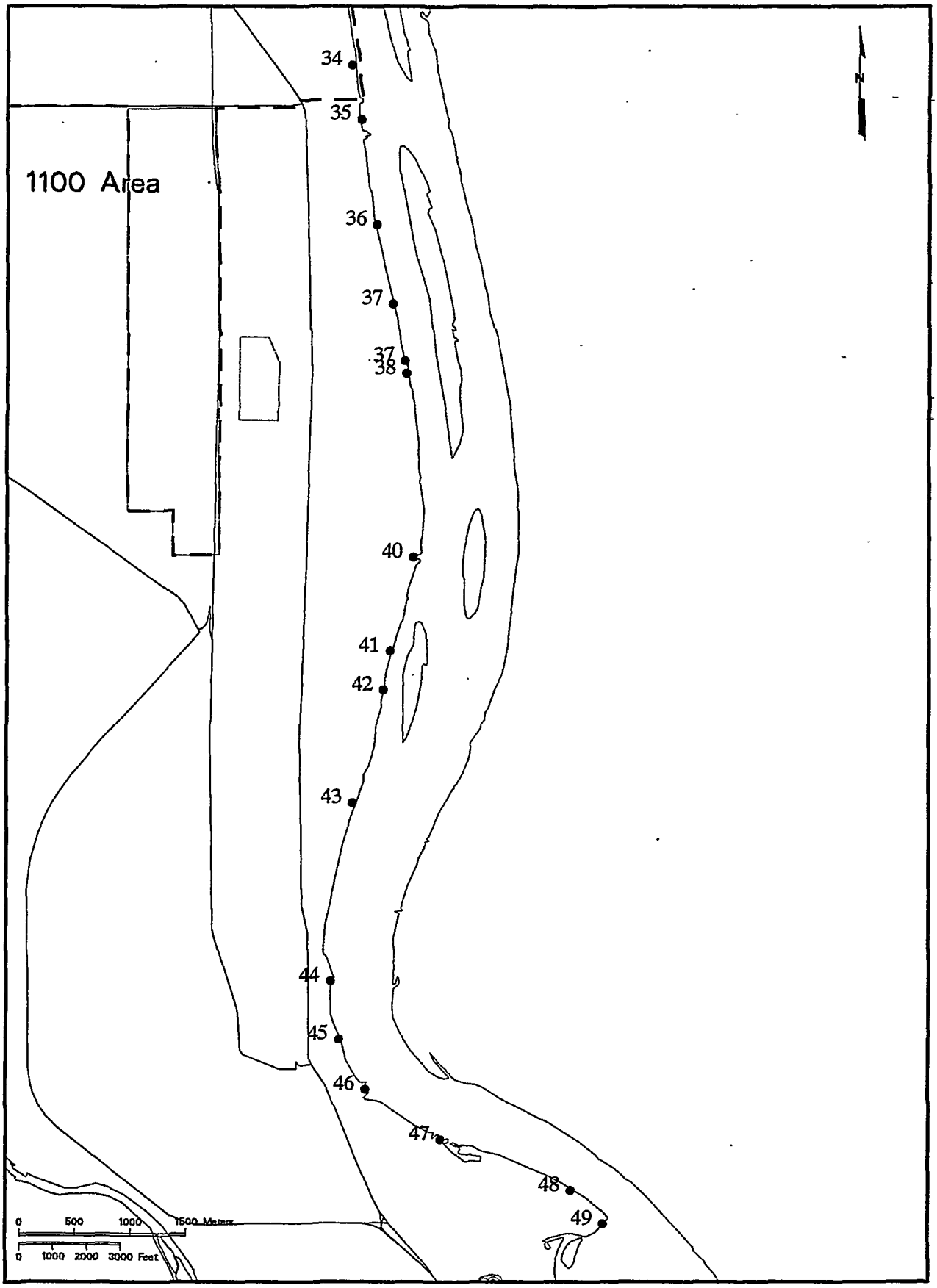


FIGURE 2.3. Sample Locations at the Richland Area

positional data was not differentially corrected. Differential correction typically yields 2- to 5-m circular error probability, which is defined as 50% of the collected points are within a 2- to 5-m radius circle on a horizontal plane. The uncorrected data for the above GPS is estimated at a circular error probability of 100 m.

The GPS positional data was converted to an Archinfo format and transferred to Archinfo on a Sparc10 SUN[(a)] workstation. The GPS positions were overlaid on the appropriate base map (i.e., Vernita, Hanford Reach, or Richland area).

[(a)]SUN is a registered trademark of SUN Microsystems, Mountain View, California

3.0 RESULTS AND DISCUSSION

All radiation exposure measurements, collected at Vernita, Hanford Reach, and Richland area shorelines, are presented in Table A-1. In addition, Figure A-1 depicts the radiation exposure field measurements taken at each location. GPS positional records are listed in Table A-2.

PIC measurements taken from Vernita, Hanford Reach, and Richland areas ranged from 8 to 11 μR/hr, 8 to 15 μR/hr, and 7-10 μR/hr, respectively (Table 3.1). Mean values were 9.1 μR/hr, 9.8 μR/hr, and 8.2 μR/hr for the three locations. The highest exposure measurement taken with the PIC was 15 μR/hr and occurred at location 22 near the White Bluffs Slough. Locations 22 through 28 were slightly higher than other Hanford Site measurements (Table A.1). This minor increase in exposure rates along the eastern stretch of the Hanford Reach may be attributed to different historical deposition patterns than occurred on the upper section of the Hanford Reach. Standard deviations of 0.92 μR/hr, 1.83 μR/hr, and 0.75 μR/hr indicate the data collected from the Richland and Vernita areas is less variable than that collected at Hanford Reach area locations with Richland area data being the least variable.

The frequency histogram of the PIC data indicated a slight positive skewness to the distribution. A log transformation was applied to the data before analysis. To determine the significance of location interactions on the radiation exposure rate measurements, an analysis of variance (ANOVA) was performed (Table 3.2). The ANOVA indicated a significant location interaction at a p-value of 0.0014.

Because the ANOVA indicated a location effect, a post-hoc comparison of group means (i.e., location means) was performed to further define differences between locations. The Scheffé's F-test was chosen for multiple mean comparisons. This test is a conservative multiple comparison test and is very forgiving to violations of certain assumptions associated with multiple comparisons of means (e.g., unequal sample sizes, heterogeneous variances).

The Scheffé's F-test indicated elevated Hanford Reach measurements, i.e., a significant difference between Hanford Reach and Richland area means with a

mean difference of 0.075 μR/hr and a p-value of 0.0014 (Table 3.3). No significant difference was found between Hanford Reach and Vernita area measurements with a mean difference of 0.031 μR/hr and a p-value of 0.3138. Also, no significant difference was found between Vernita and Richland area measurements with a mean difference of 0.044 μR/hr and a p-value of 0.1155.

TABLE 3.1. Descriptive Statistics Grouped by Location for 1994 Reuter Stokes PIC (μR/hr) Field Measurements

	Vernita	Hanford Reach	Richland	Total
Mean	9.1	9.8	8.2	9.1
Median	9	9	8	9
Std. Dev.	0.92	1.83	0.75	1.47
Std. Error	0.25	0.42	0.19	0.21
Count	14	19	16	49
Minimum	8	8	7	7
Maximum	11	15	10	15
Variance	0.84	3.36	0.56	2.16
Coef. Var.	0.10	0.19	0.09	0.16

TABLE 3.2. Analysis of Radiation Exposure Rate Variances (ANOVA)

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Location	2	0.049	0.025	7.605	0.0014
Residual	46	0.149	0.003		

TABLE 3.3. Scheffé's F-test for Mean Differences (Effect: Location)

Locations Compared	Mean Diff.	P-Value
Hanford Reach, Richland	0.075	0.0014
Hanford Reach, Vernita	0.031	0.3138
Vernita, Richland	0.044	0.1155

From examination of the descriptive statistics (Table 3.1) and the Scheffé's F-test (Table 3.3), Richland area measurements are lower and less variable than the measurements from the Vernita and Hanford Reach areas. Because Richland is downstream from historical Hanford radioactive source terms, differences in Hanford Reach and Richland area exposure rates are expected. Historical contamination deposits, as well as fallout from atmospheric tests, along the Richland area shores have been identified through the use of both ground surveys (Sula 1980) and aerial surveys. The growth in the Richland area from the 1940s to the present has led to the reconstruction of the Columbia River shorelines along the Richland area. The removal of radioactive deposits and the reduction of source terms combined with the general reconstruction of the urban shorelines have contributed to the reduction of exposure rates along the shores of the Richland area.

From Table 3.1, Vernita area standard deviation and mean value vary somewhere between the Hanford Reach and Richland area measurements. With Vernita being both upwind and upstream of the Hanford Site, it is reasonable to expect environmental exposure rates to be somewhat lower than the exposure rates found on Hanford.

The differences in Vernita and Richland area measurements can be attributed to differences in geologic makeup - rock outcrops are very predominate along the Vernita area shores. Differences in measurements can also be attributed to differences in nuclear fallout soil distributions - the undisturbed soils along the Vernita area shores should contain a slightly higher concentration of fallout materials than most areas along the Richland area shore.

The highest radiation exposure measurement in this study was 15 μR/hr (White Bluffs Slough). Typical natural radiation exposure levels across the United States are very variable. For example, exposure measurements taken at various U.S. cities range from 6.4 μR/hr in Aiken, South Carolina to 21.4 μR/hr in Rolesville, North Carolina, (Eisenbud 1973). Natural radiation exposure levels differ from place to place mainly because of changes in elevation, in the concentrations of natural terrestrial radioactivity, and to some extent in precipitation rates. Natural background exposure rates around

the Hanford area are generally lower than other locations because of low precipitation rates and low elevation as is evident in the Richland area mean value of 8.2 μR/hr.

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APPENDIX A

1994 Environmental Radiation Exposure Rate Field Measurements and Geographical Positions of Sample Locations

APPENDIX A

TABLE A.1. 1994 Environmental Radiation Exposure Rate Field Measurements Taken With a Reuter-Stokes RSS-112 PIC

Area	Sample Location	Exposure Rate (μR/hr)
Vernita	1	9
Vernita	2	9
Vernita	3	8
Vernita	4	9
Vernita	5	9
Vernita	6	8
Vernita	7	8
Vernita	8	9
Vernita	9	9
Vernita	10	9
Vernita	11	9
Vernita	12	11
Vernita	13	11
Vernita	14	9
Hanford Reach	15	9
Hanford Reach	16	8
Hanford Reach	17	9
Hanford Reach	18	8
Hanford Reach	19	8
Hanford Reach	20	8
Hanford Reach	21	9
Hanford Reach	22	15
Hanford Reach	23	11
Hanford Reach	24	12
Hanford Reach	25	10
Hanford Reach	26	11
Hanford Reach	27	10
Hanford Reach	28	11
Hanford Reach	29	9

TABLE A.1. (cont'd)

Area	Sample Location	Exposure Rate (μR/hr)
Hanford Reach	30	10
Hanford Reach	31	8
Hanford Reach	32	9
Hanford Reach	33	12
Richland	34	10
Richland	35	8
Richland	36	9
Richland	37	8
Richland	38	8
Richland	39	9
Richland	40	8
Richland	41	8
Richland	42	7
Richland	43	8
Richland	44	7
Richland	45	9
Richland	46	8
Richland	47	8
Richland	48	8
Richland	49	8

TABLE A.2. Geographical Positions of Sample Locations from from Vernita, Hanford Reach, and Richland Areas

Datum and Coordinate System	NAD 83 UTM, Zone 11, meters	
Sample Location	Easting	Northing
1	278590	5168046
2	278900	5167967
3	279307	5167909
4	279903	5167788
5	280743	5167431
6	281610	5167234
7	283795	5167193
8	287020	5167858
9	288123	5168082
10	288854	5168255
11	289211	5168247
12	289634	5168116
13	289936	5168119
14	290867	5168824
15	296682	5168303
16	299622	5169073
17	302476	5171246
18	305045	5174321
19	306255	5175273
20	306544	5175926
21	307662	5176902
22	310868	5174566
23	311091	5174340
24	311119	5174157
25	314293	5169592
26	314233	5169437
27	314034	5169105
28	316215	5163774
29	316486	5163296
30	317377	5162215

TABLE A.2. (cont'd)

Datum and Coordinate System	NAD 83 UTM, Zone 11, meters	
Sample Location	Easting	Northing
31	318097	5161627
32	318932	5160884
33	319438	5160489
34	325564	5135893
35	325633	5135401
36	325729	5134452
37	325846	5133736
38	325927	5133219
39	325938	5133105
40	325932	5131455
41	325737	5130618
42	325630	5130271
43	325294	5129258
44	325054	5127655
45	325117	5127125
46	325307	5126663
47	325961	5126201
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