DOH 320-032

Environmental Radiation Program

2003 External Radiation Survey Along the Columbia River Shoreline of the Hanford Site's 100 Area

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Summary

External radiation dose rates were measured on the Columbia River and along the Columbia River shoreline adjacent to the retired reactors at the Hanford Site's 100 Area. Measurements were carried out simultaneously by the Pacific Northwest National Laboratory (PNNL) and the Washington State Department of Health (DOH). The PNNL and DOH results are in good agreement. Dose rates along the 100-K, 100-D, 100-H, and 100-F shoreline adjacent to the reactors are similar to background dose rates measured at a control location upriver of the Hanford Site near the Vernita Bridge. Dose rates along the 100-B/C, 100-N, and D-Island shorelines averaged approximately twice background, with maximum dose rates approximately four times greater than background. The maximum annual radiation dose to a person using this portion of the Columbia River is less than limits for the public set by both the Department of Energy and the Washington State Department of Health. Dose rates adjacent to the 100-N Area have decreased by a factor of two from dose rates measured six years earlier in 1997.

Acknowledgements

The authors would like to acknowledge Robert Fulton for driving the boat during data collection, David Merrill and Mike Priddy for their help in data collection, Eileen Kramer for text processing, and Bruce Napier for reviewing this report. Funding for Pacific Northwest National Laboratory's participation in this study was from the Public Safety and Resource Protection Program and the Surface Environmental Surveillance Project under contract DE-AC06-76RLO1830 with the Department of Energy.

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1. Introduction

The Hanford Reach of the Columbia River, that portion of the river which borders the Hanford Site in eastern Washington, is widely used for recreational boating and fishing. The 100 Area, which borders a portion of the Hanford Reach at the north end of the Hanford Site (see map in Figure 1), consists of six areas that contain nine retired nuclear reactors and their ancillary facilities, as well as over 400 waste sites.

During reactor operations, large amounts of cooling water flowed through reactor cores and became contaminated with radionuclides and hazardous chemicals. Soil near the reactors became contaminated with radionuclides when contaminated reactor cooling water was disposed in cribs and trenches. Cobalt-60 (Co-60) and cesium-137 (Cs-137) are common radionuclide contaminants found in disposal site soils that emit gamma (photon) radiation which contributes to external radiation fields in the vicinity near the reactors.

This study measured external radiation dose rates on June 27, 2003 along the Columbia River shoreline adjacent to Hanford's 100 Area. The purpose of the study was to determine dose rates that may be encountered by people using this portion of the river. In addition, this report presents external dose rates previously measured near Vernita Bridge (data collected September, 2001, and reported in PNNL-13692), D-Island (data collected September, 2002), and the 100-N Area (data collected September, 1997, and reported in PNNL-11933). The 1997 and 2003 results at 100-N Area are compared in this report to determine if external dose rates have decreased over time in this area.

For many years, radiation levels on the Columbia River adjacent to the 100-N Area (see map in Figures 1 and 5) have been greater than background levels. Cobalt-60 and Cs-137 contaminants located in the 1301-N and 1325-N liquid waste disposal facilities (see Figure 5) contribute to the elevated radiation levels. Contaminated soil was removed from the 1325-N waste site during 2000 and 2001. The 1301-N waste site has yet to undergo remediation. Therefore, natural decay of Co-60 and Cs-137, along with remediation of the 1325-N waste site are expected to result in lower external dose rates in 2003 than those measured in a previous 1997 study. The results of the two studies are compared in this report.

External radiation is defined as radiation originating from a source external to the body. External radiation consists of a natural component and a manmade component. The natural component consists of radiation originating from outer space (cosmic radiation), from radionuclides that exist naturally in the earth's surface, and from airborne radon and radon decay products. The manmade component at Hanford consists of radiation originating from radionuclides associated with the legacy of nuclear weapons production. In addition, radionuclides deposited as worldwide fallout from atmospheric testing of nuclear weapons contribute to the manmade component of external radiation.

The results of this external radiation study are presented as radiation dose rates, expressed in the traditional units of microrem per hour (μrem/hr). The International System of

Units (SI units) for dose rate is micro-Sievert per second (μSv/s). To convert from μrem/hr to μSv/s, divide the dose rate by 360,000.

Radiation dose quantifies the amount of energy deposited in the human body as a result of radiation passing through the body. External dose rates along the 100 Area shoreline are the sum of the natural component and any manmade component that may be present. External dose rates due to Hanford contaminants are determined by comparing dose rates measured along the 100 Area shoreline to dose rates at a background location where only the natural and weapons fallout components contribute.

2. Monitoring Procedures

For the data collected in this study, two Bicron Corporation Tissue Equivalent Survey Meters, model MICRO REM, were used to collect external dose rates. Both instruments were calibrated using a National Institute of Standards and Technology (NIST) traceable Cs-137 source. One meter was owned and operated by the Washington State Department of Health (DOH), and the other was owned and operated by the Pacific Northwest National Laboratory (PNNL). Both microrem meters were connected to a Trimble global positioning system (GPS) to collect latitude and longitude coordinate data simultaneously with the dose rate data. Coordinate and dose rate data were collected every second and stored in a Trimble model TSC1 data logger.

The equipment was loaded onto a boat and set up to collect data as the boat moved on the Columbia River past the 100 Area reactor sites. The DOH and PNNL microrem meters were placed side-by-side on the boat. In addition, the equipment was used to collect data along the 100-N Area shoreline. In this case, the equipment collected data while being walked along the high water mark of the river near the 100-N reactor and its associated waste sites. Upon completion of data collection, the coordinate and dose rate data were transferred to a computer, and then imported into mapping software to generate the figures that appear in this report.

One goal of this report was to compare the dose rate data collected at 100-N Area in 2003 with the dose rate data collected at the same site in 1997. However, the 1997 data were collected with different instrumentation. In 1997, a Reuter-Stokes pressurized ionization chamber (PIC), model RSS-121, was used to collect radiation exposure rate data. Coordinate data were collected with the same instrumentation as described above. The 2001 dose rate data near Vernita Bridge were also collected with a PIC.

A PIC measures exposure rate in units of micro-Roentgen per hour (μR/hr), which is a measure of the energy deposited by photon radiation in a volume of air. A microrem meter measures tissue equivalent dose rate in units of μrem/hr, which is a measure of the energy deposited in a tissue equivalent plastic scintillator. Because the PIC and microrem meter measure different quantities, and because their intrinsic detection efficiencies are different, the two instruments will give different numerical results while in the same radiation field.

To compare the 1997 100-N and 2001 Vernita Bridge PIC results with the 2003 microrem results, the two instruments were calibrated against each other. The calibration employed a newer Reuter-Stokes PIC model RSS-131. The RSS-131 is similar to the RSS-121, except that it comes equipped with its own data logging capability, thereby eliminating the need for the Trimble data logger. For the comparison, the microrem meter, as described above, was placed beside the RSS-131 PIC at the 100-N Area shoreline on March 4, 2004, and both instruments simultaneously collected data for approximately 30 minutes.

From the two data sets, a calibration factor was determined to convert the PIC exposure rate data to dose rate. For each second of data, the ratio of the PIC value divided by the microrem meter value was calculated, and then the average value of the ratio was determined to be 1.1 for the entire data set. All the 2001 Vernita Bridge and 1997 100-N exposure rate data were divided by 1.1 to convert into dose rate units of μrem/hr.

3. Analysis and Results

The locations for external radiation dose rate monitoring (Figure 1) include a background control area on the Columbia River upstream of Vernita Bridge (referred to in this report as Vernita Bridge), which is upstream of the Hanford Site; and locations along the Hanford side of the Columbia River shoreline adjacent to all the reactors in the 100 Area. At all locations, dose rates were measured on the Columbia River, while at 100-N additional measurements were made on land near the high water mark where a person might access the shoreline. In addition, dose rates were measured on D-Island near the 100-D Area.

The external dose rate results for Vernita Bridge, 100-B/C Area, 100-K Area, 100-N Area, 100-D Area, 100-H Area, 100-F Area, and D-Island are shown in Figures 2 through 10. Each of these figures shows a map of the particular location along with the dose rate data. Each dose rate measurement is shown as a color coded point located on the map at the position where the measurement was taken. The color codes are described in the legend of each figure, and they indicate the value of the dose rate measured in μrem/hr. The color codes are identical in all figures, except for figures 5, 7, and 10 where the maximum dose rate is 14 μrem/hr instead of 13 μrem/hr.

For most of the measurements, data were collected simultaneously using PNNL and DOH instruments located side-by-side. Since the location of the PNNL and DOH data are the same and would overlap on the maps, all the PNNL data was slightly displaced so it would appear separately on the maps.

The maps show the Columbia River at its average river stage (water level). At the time of data collection, the water level was lower than average, exposing land where water is shown in the maps. For all the figures, the water boundary in the maps is not necessarily where the water boundary was located on the day of monitoring. Therefore, some of the data collected on land misleadingly appear to be on the river. This effect is most prominent at Vernita Bridge and D-Island (Figures 2, 7, and 10).

The external radiation dose rates at the background control area near Vernita Bridge are shown in Figure 2. The data collected on the river range from 0 to 6 μrem/hr, with an average of 3 μrem/hr. The data collected on land range from 7 to 9 μrem/hr, with an average of 8 μrem/hr. It is expected that external radiation dose rates on the river are lower than those on land because the river water shields radiation originating from natural sources in the earth's crust.

The external dose rates on the river at 100-K, 100-D, 100-H, and 100-F (Figures 4, 7, 8, and 9, respectively) are not distinguishable from those on the river at the background location near Vernita Bridge.

Results on the river near the 100-B/C Area (Figure 3) and the 100-N Area (Figure 5) range from background up to four times greater than the background average of 3 μrem/hr. A maximum dose rate of 11 μrem/hr was measured at 100-B/C and 100-N areas. The primary source of elevated dose rates near 100-N Area is Co-60 and Cs-137 contaminants in the 1301-N and 1325-N Liquid Waste Disposal Facilities. The most likely source of elevated dose rates along the 100-B/C Area include an old ash pit which might contain natural radionuclides, and retention basins and an outfall which contain residual radioactivity from reactor operations.

The maximum dose rate on the river of 11 μrem/hr is 8 μrem/hr greater than the average dose rate on the river at the background location near Vernita Bridge. The radiation dose above background experienced by a person using this portion of the river can be assessed by multiplying the dose rate above background by the time spent in the area. As an example, a fisherman who spends 4 hours per day, 20 days per year in this area would receive an additional dose of 640 μrem (0.64 millirem) above background (8 μrem/hr ∗ 80 hr). A person spending 24 hours per day for an entire year in this area, which represents the maximum possible annual dose, would receive an additional dose of 70 millirem per year above the background at Vernita Bridge.

In addition to the data collected on the river, data were also collected on land near the high water mark at the 100-N Area (Figure 5) and on D-Island (Figures 7 and 10). Note that data was collected on land at D-Island, during a low water river stage which exposed the land, even though it appears to be over water in the figure. A maximum dose rate of 14 μrem/hr, or 6 μrem/hr greater than the average dose rate on land at the background location, was measured on the shore at 100-N Area and on D-Island. A person spending 24 hours per day for an entire year in these areas, which represents the maximum possible annual dose, would receive an additional dose of 53 millirem per year above background.

The elevated dose rates on D-Island are possibly due to "risers", which are small vent tubes, approximately one inch in diameter, extending toward the soil surface from large subsurface effluent pipes. A photograph of two risers is shown in Figure 11. Two large effluent pipes extend from the 100-D reactor area, under the near-Hanford side of the Columbia River channel, up and through the upstream end of D-Island buried 2 meters below grade, and back down into the far-Hanford side of the Columbia River channel.

During reactor operations, reactor effluent water was released to the river through these effluent pipes. As contaminated reactor water flowed through the effluent pipes, the risers and surrounding soil on D-Island became contaminated. Both reactors in 100-D Area were shut down in the mid 1960s. In the early 1990s a decision was made to remove and plug the vent tubes to prevent public exposure and further release of contamination.

Dose rates on the Columbia River near the 100-N Area shoreline measured in 2003 and 1997 are shown in Figures 5 and 6, respectively. As discussed above, the 1997 data were measured with a PIC in units of μR/hr and then converted to μrem/hr for this report. Comparison of Figures 5 and 6 indicate a clear decrease in dose rate from 1997 to 2003. Analysis of the data collected on the river adjacent to the 1301-N Liquid Waste Disposal Facility indicated a decrease from an average of 9 μrem/hr to an average of 6 μrem/hr.

Dose rates measured along the 100-N shoreline by PNNL and DOH thermoluminescent dosimeters (TLDs) have also decreased from levels measured in 1997 to current day (see Figure 12). The high in 1997 was approximately 22 μrem/hr; the high in 2003 was approximately 12 μrem/hr (see Figure 12). These TLD results corroborate the 1997 PIC and 2003 microrem meter results.

4. Conclusions

External radiation dose rates were measured along the Columbia River shoreline adjacent to the retired reactors at the Hanford Site's 100 Area. Measurements carried out simultaneously by the Pacific Northwest National Laboratory and the Washington State Department of Health are in good agreement.

Dose rates along the 100-K, 100-D, 100-H, and 100-F shoreline adjacent to the reactors are similar to background dose rates measured at a control location upriver of the Hanford Site near the Vernita Bridge. Dose rates along the 100-B/C and 100-N shorelines, and on D-Island ranged from background to approximately four times greater than background.

The maximum dose rates measured in this study were on the Columbia River adjacent to the 100-B/C and 100-N Areas, on the shoreline at 100-N Area, and on D-Island. The maximum dose rate above background was 8 μrem/hr, which leads to a maximum annual dose of 70 millirem above the control location's annual background dose. This maximum annual external dose is below the limit to the public of 100 mrem/yr set in DOE Order 5400.5. The maximum annual external dose is also below the 100 mrem/yr public dose limit set by DOH (Washington Administrative Code Chapter 246-221-060) for it's licensed facilities.

Dose rates adjacent to the 100-N Area liquid waste disposal facilities have decreased from an average of 9 to an average of 6 μrem/hr from 1997 to 2003. Thermoluminescent dosimeter data corroborate the decrease measured in this study. The decrease in dose rate is most likely due to a combination of radioactive decay and cleanup efforts at the 1325-N liquid waste disposal facility. The planned remediation of the 1301-N liquid waste disposal facility, along with continued radioactive decay, is expected to lead to even lower external dose rates in the near future.

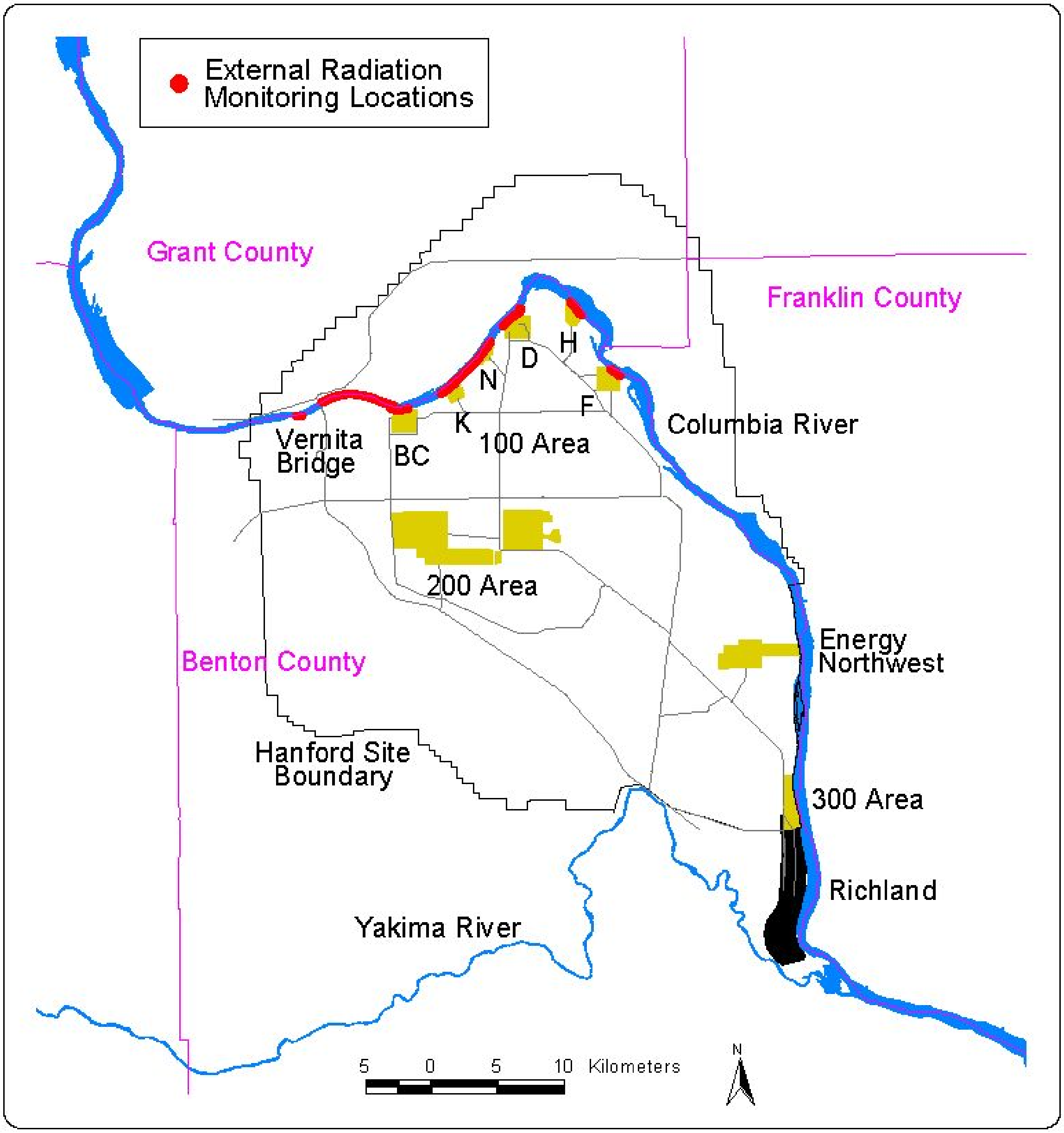

Figure 1. External Radiation Monitoring Locations

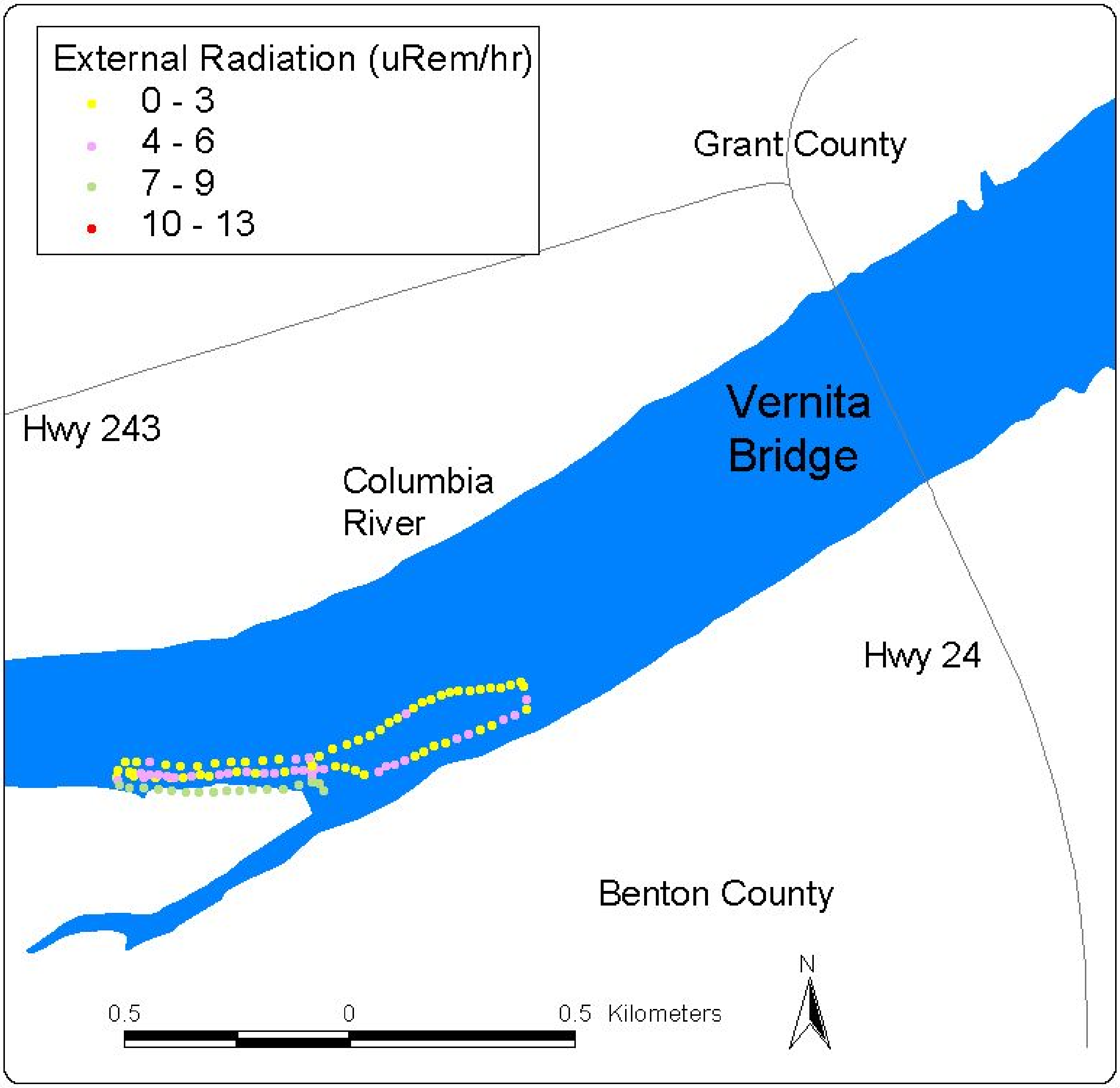

Figure 2. External Dose Rates Near Vernita Bridge (September, 2001)

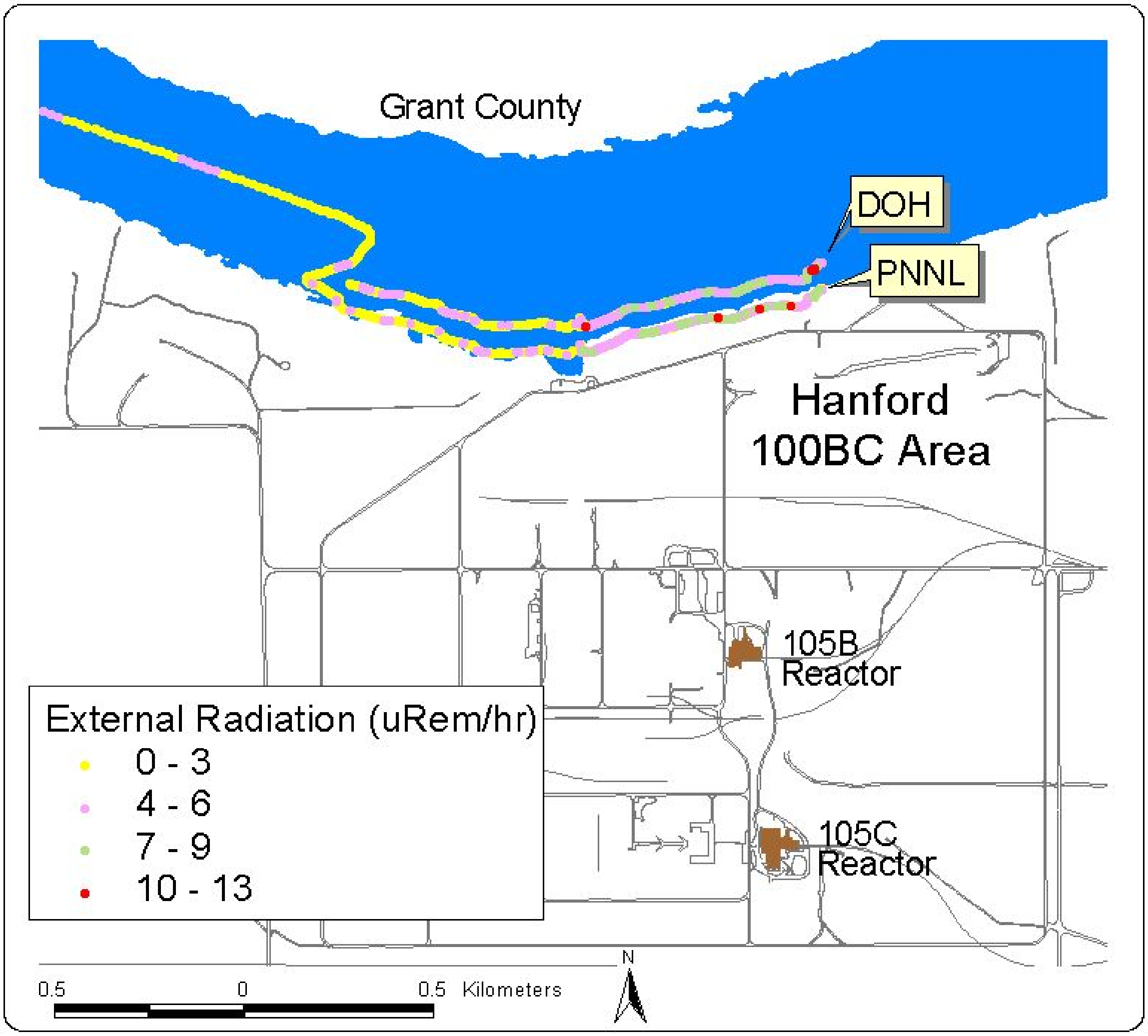

Figure 3. External Dose Rates at the 100-B/C Area Shoreline (June, 2003)

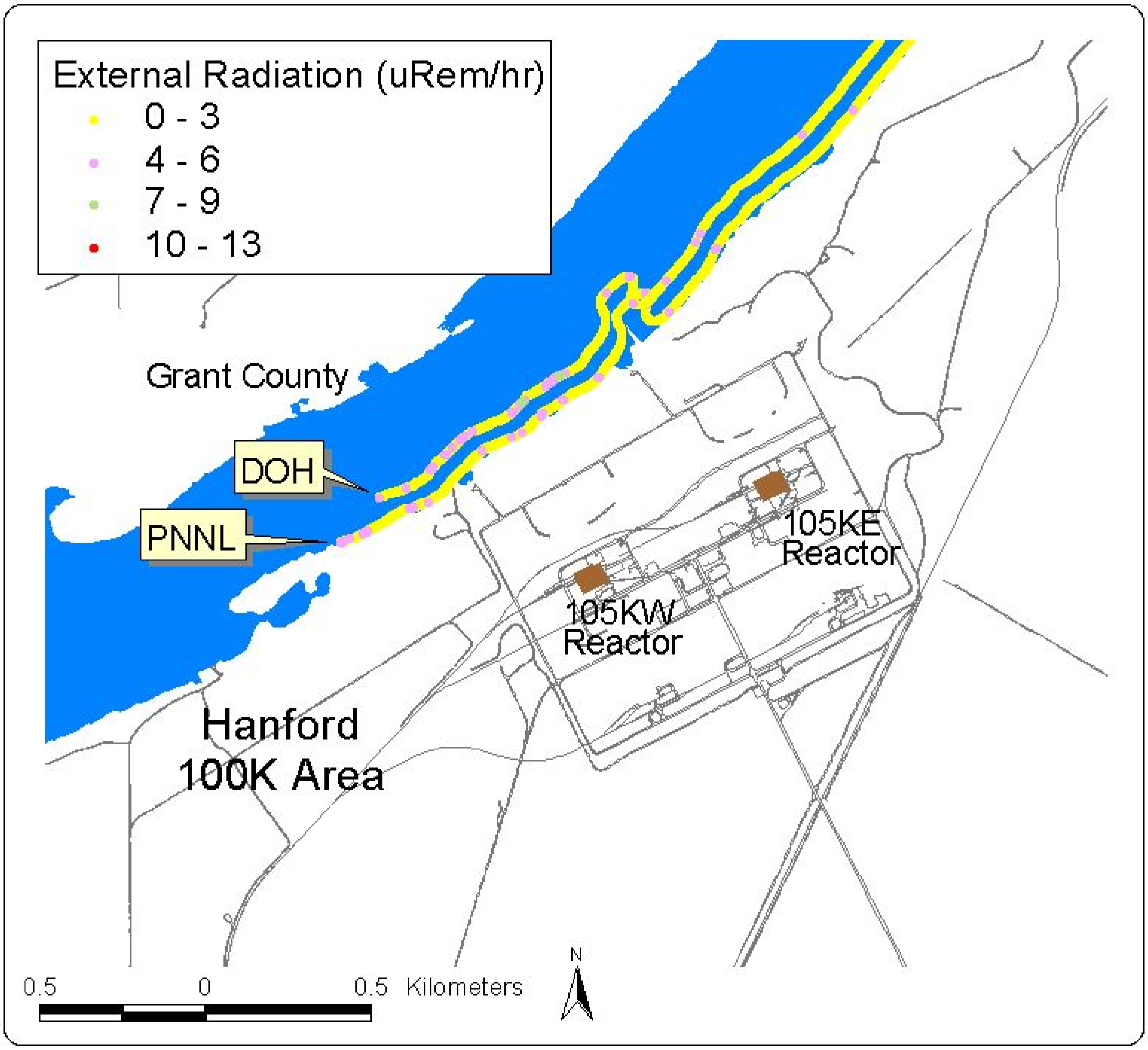

Figure 4. External Dose Rates at the 100-K Area Shoreline (June, 2003)

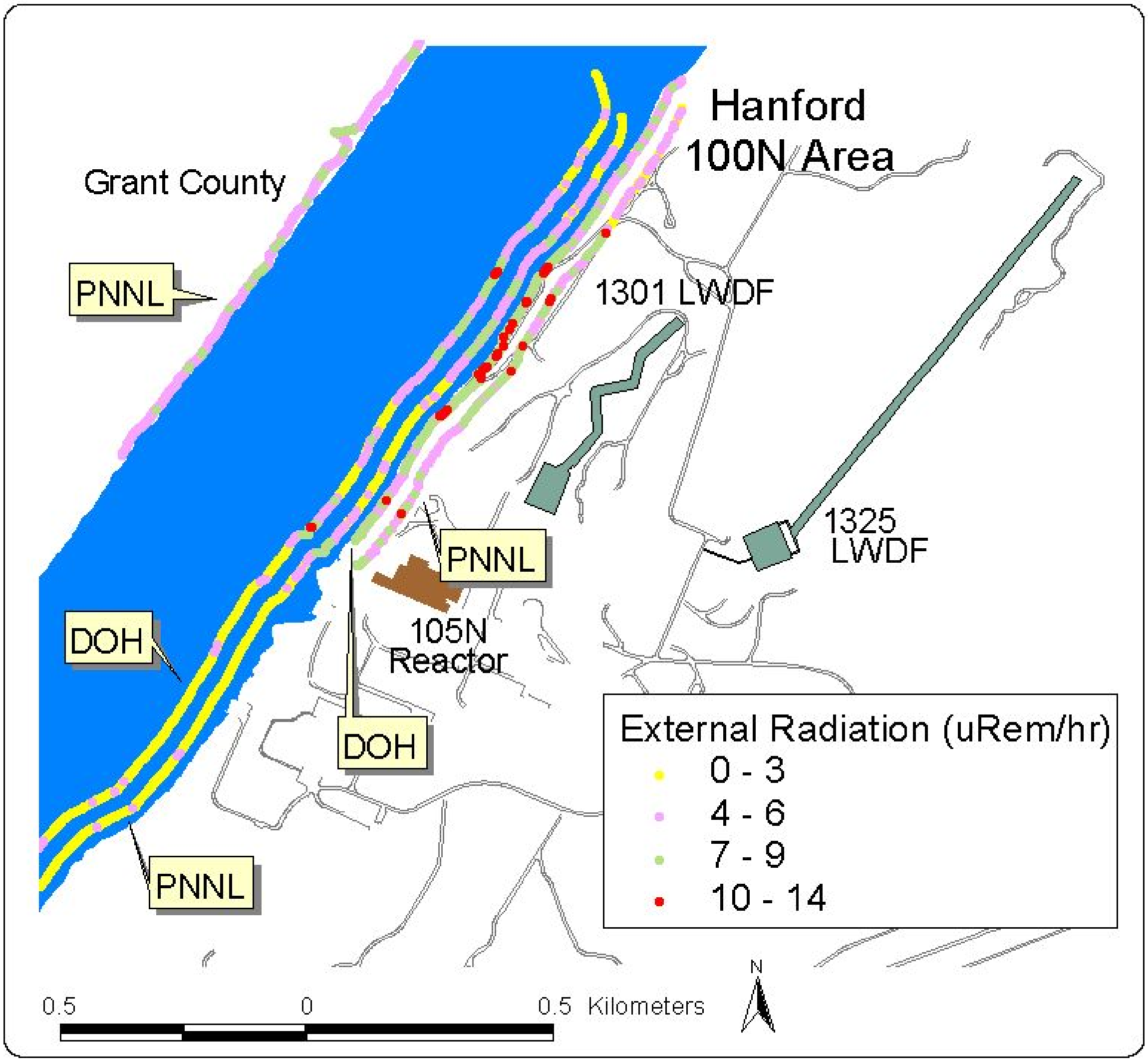

Figure 5. External Dose Rates at the 100-N Area Shoreline (June, 2003)

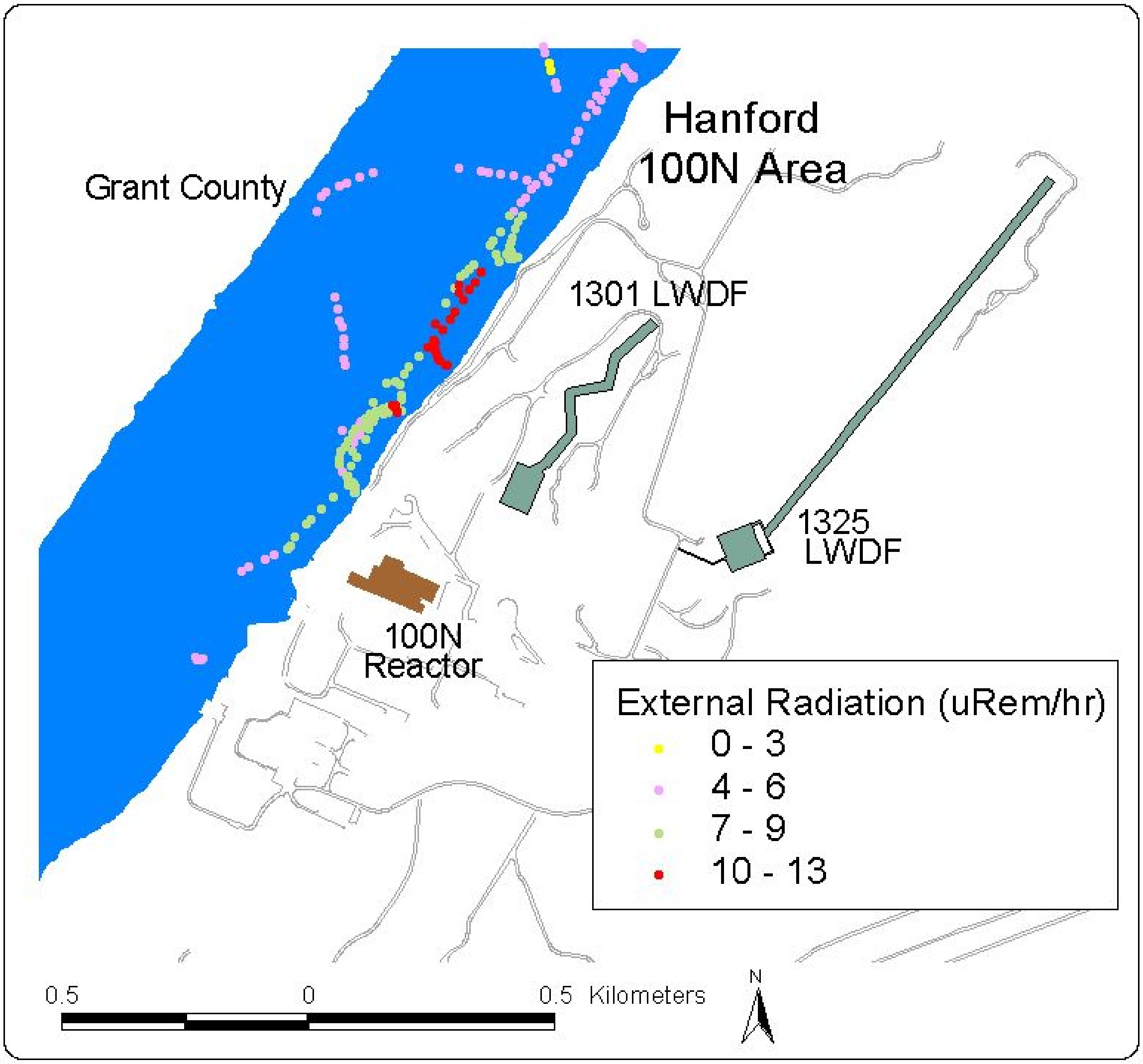

Figure 6. External Dose Rates at the 100-N Area Shoreline (September, 1997)

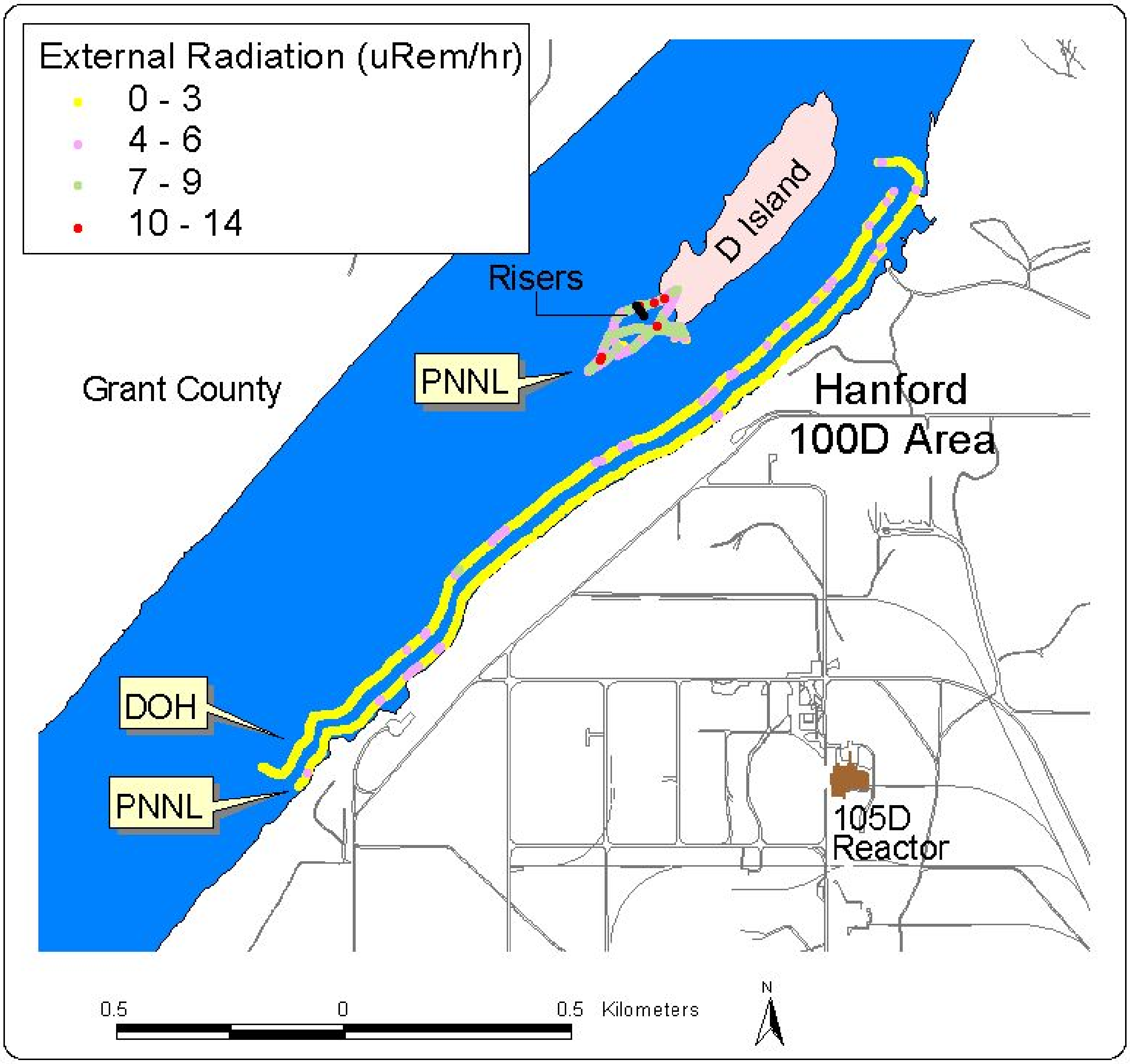

Figure 7. External Dose Rates at the 100-D Area Shoreline (June, 2003)

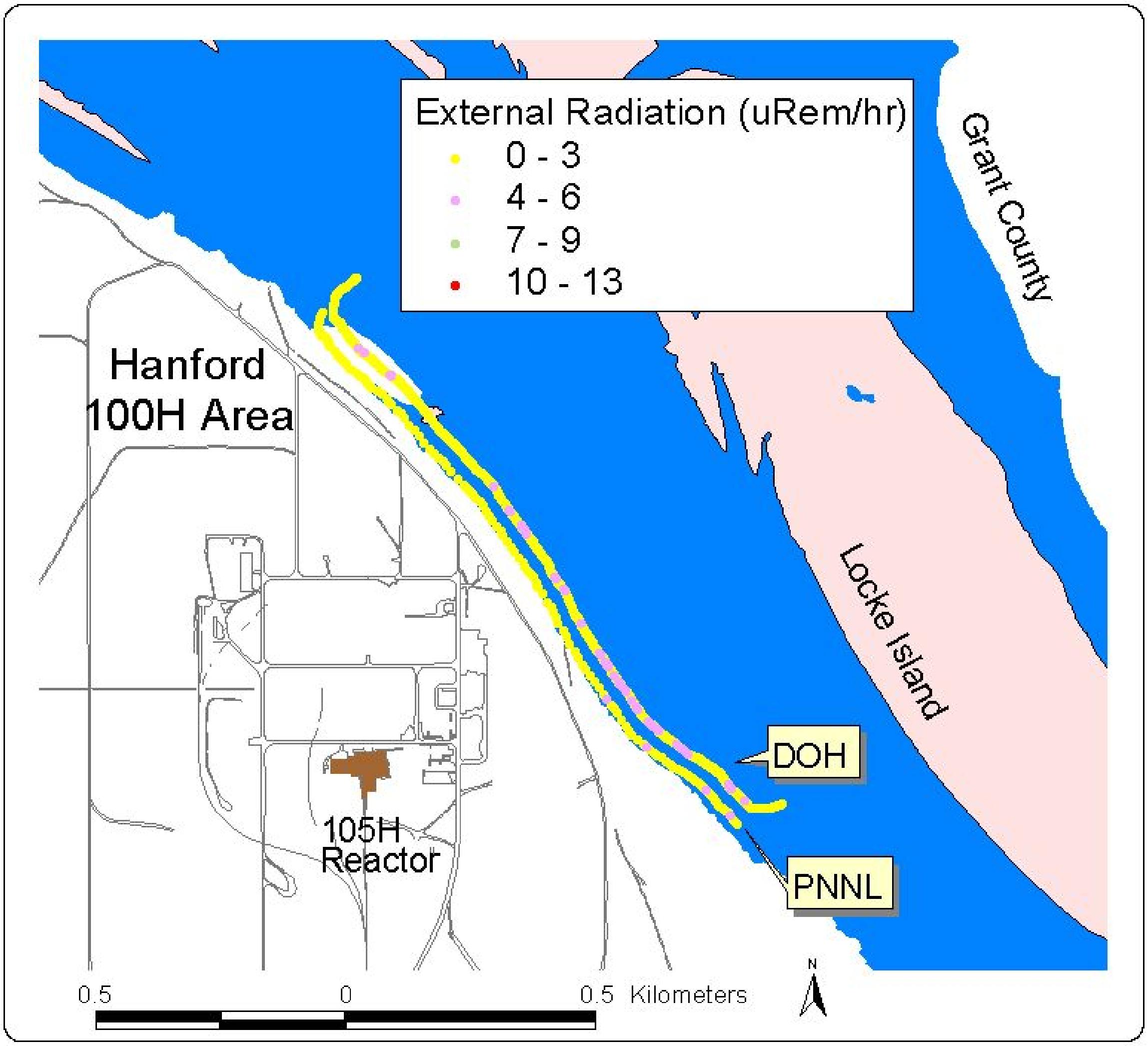

Figure 8. External Dose Rates at the 100-H Area Shoreline (June, 2003)

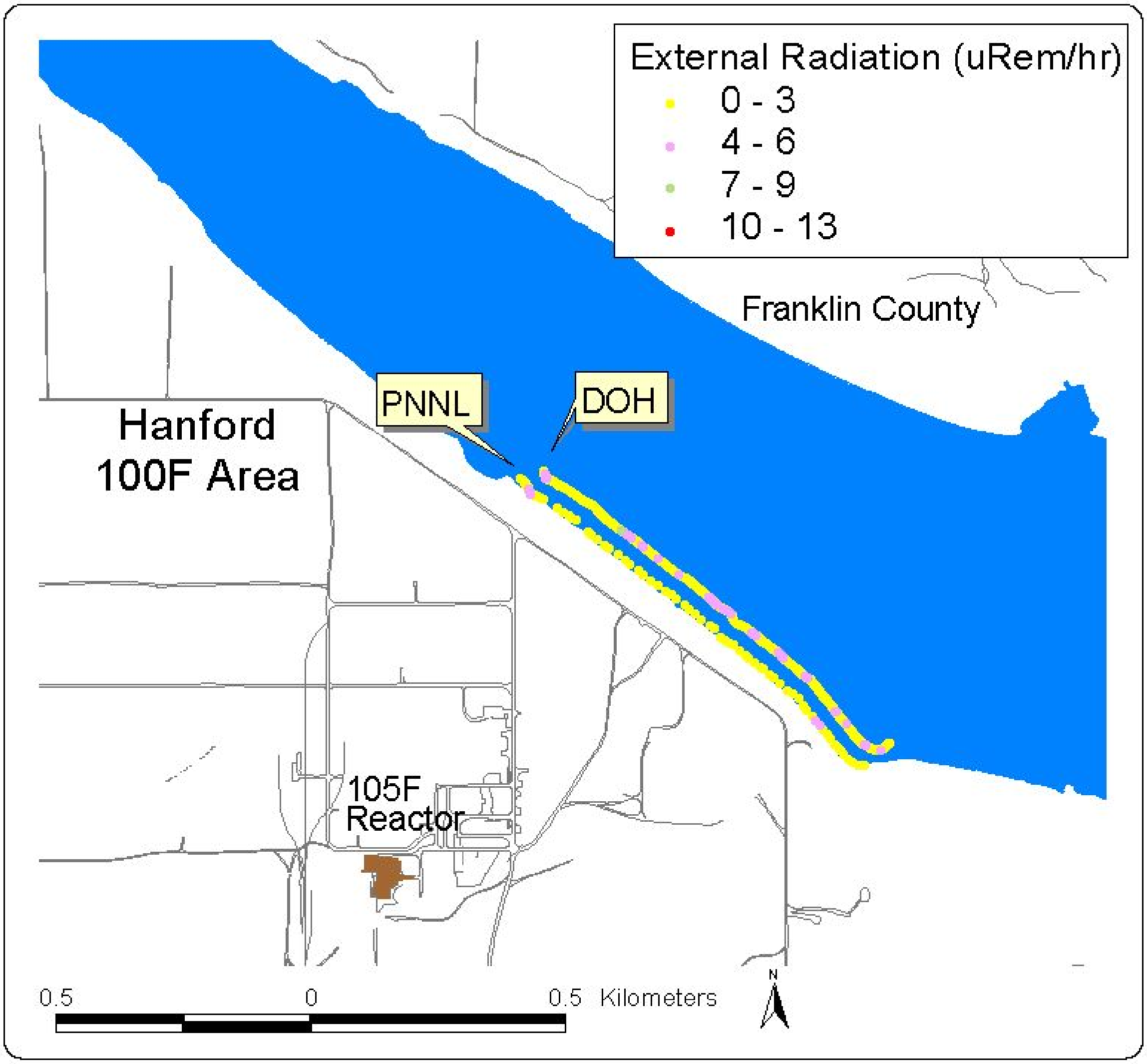

Figure 9. External Dose Rates at the 100-F Area Shoreline (June, 2003)

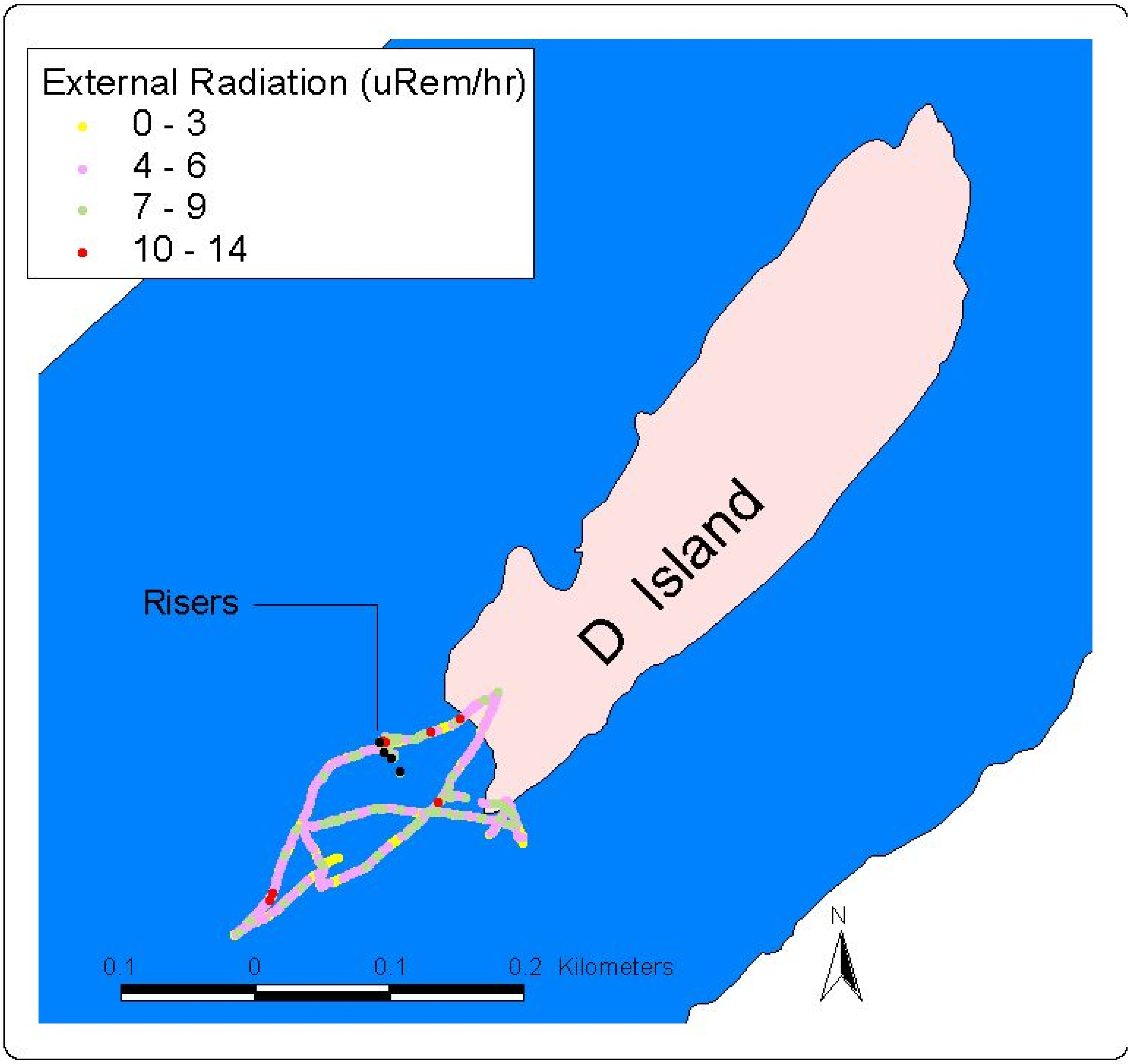

Figure 10. External Dose Rates on D-Island Near the 100-D Area (September, 2002)

Figure 11. Risers on D-Island Near the 100-D Area

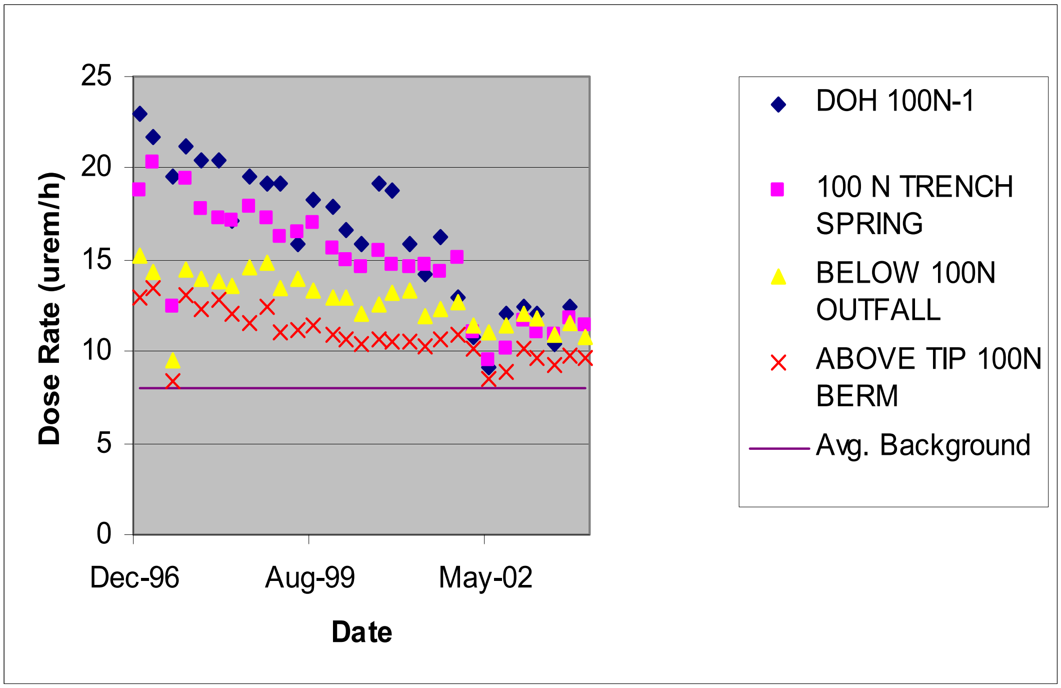

Figure 12. DOH and PNNL TLD Results at 100-N Area Shoreline, 1997 through 2003