DOH 320-039

Environmental Radiation Program

Hanford Environmental Oversight Program 2004 Data Summary Report

February 2006

Washington State Department of
Health

Division of Environmental Health

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Contents

Figures

Tables

Acronyms

ALARA	As Low As Reasonably Achievable
ALE	Arid Land Ecology Reserve
CFR	Code of Federal Regulations
CSB	Canister Storage Building
CVDF	Cold Vacuum Drying Facility
DOE	Department of Energy (United States)
DOH	Department of Health (Washington State)
DNR	Department of Natural Resources
DWS	Drinking Water Standard
EML	Environmental Measurement Laboratory
LLD	Lower Limits of Detection
MAPEP	Mixed Analyte Proficiency Evaluation Program
MDA	Minimum Detectable Activity
NCRP	National Council on Radiation Protection and Measurements
PHL	Public Health Laboratories
PNNL	Pacific Northwest National Laboratory
PUREX	Plutonium Uranium Extraction Facility
QATF	Quality Assurance Task Force of the Pacific Northwest
SI	International Scientific Units
TEDF	Treated Effluent Disposal Facility
TLD	Thermoluminescent Dosimeters
TPA	Tri-Party Agreement
TWRS	Tank Waste Remediation System
WAC	Washington Administrative Code

Summary

The Washington State Department of Health (DOH) has operated an environmental radiation monitoring program since 1961. The early program looked primarily at atmospheric fallout and off-site environmental impacts related to Hanford operations. Currently, DOH conducts radiological surveillance in many geographical areas of the state and routinely splits (co-samples) environmental samples with state-licensed and federal environmental monitoring programs.

Since 1985, the Washington State Department of Health's Hanford Environmental Oversight Program has participated with the U.S. Department of Energy (DOE) in the collection of environmental samples on or near the Hanford Site. The purpose of the program is to independently verify the quality of DOE environmental monitoring programs at the Hanford Site, and to assess the potential for public health impacts. This report is a summary of the data collected for the Hanford Environmental Oversight Program in 2004.

The Oversight Program's objectives are met through collection and analysis of environmental samples and interpretation of results. DOH samples are either split or colocated with samples collected by DOE contractors, and the results are compared to verify the quality of the DOE monitoring programs at Hanford. In 2004, samples of air, groundwater, surface water, riverbank seep water, drinking water, discharge water, sediment, soil, food and farm products, fish and wildlife, and vegetation were collected. In addition, ambient external radiation levels were measured using radiation dosimeters.

This report uses the categories of 'good', 'fair', and 'poor' to describe the agreement between DOH and DOE contractor results. Generally there is good agreement between data split between DOH and DOE contractors. The good agreement between this limited split data gives confidence that the remainder of the DOE environmental radiation data are valid.

The DOH and DOE contractor data are not expected to be in exact agreement for every sample because of the statistical nature of radioactive decay and the fact that samples collected from the field are not homogenous. In addition to a few samples where the concentrations are similar but do not exactly match, there are a few categories of samples that display a systematic disagreement, and are categorized as fair or poor agreement.

The agreement between DOH and DOE contractor results is fair for gross beta and uranium activity in air samples, fair for gross alpha and gross beta activity in water samples, poor for I-129 activity in water samples, and fair for uranium activity in sediment and soil samples. In the case of uranium, the discrepancy is due to a difference in laboratory analytical methods. For the case of gross beta in air, the difference in sampling intervals may contribute to the discrepancy. For the other cases, the discrepancy indicates a probable difference in laboratory procedures.

In addition, the agreement between DOH and DOE for tritium concentrations in 2004 wine samples was anomalously poor. Historically, tritium concentrations in wine are in good agreement.

Most environmental samples analyzed by DOH have radioactivity concentrations either below detection limits or consistent with background. A few samples have concentrations elevated above background; however, in most cases the concentrations are very small and are consistent with historical trends.

For example, Tc-99, Sr-90, uranium isotopes, and tritium were detected above background levels in some Hanford Site and Hanford boundary water samples. A variety of radionuclides were found above background levels in some Hanford Site soil samples and in some sediment samples from behind Columbia River dams that are downriver of the Hanford Site. Strontium 90 was found in small concentrations in some farm products, wildlife, and vegetation samples. Again, all elevated concentrations found in 2004 are consistent with historical trends.

Tritium concentrations in 100K Area groundwater wells have displayed large fluctuations over the last several years, and this trend continued in 2004. DOH will continue to monitor these wells in the future due to their proximity to the Columbia River.

While Hanford operations have resulted in radionuclides entering the environment, the data from the DOH Oversight Program indicate that public exposure to radioactivity from Hanford is far below regulatory limits.

1. Introduction

Chapter 70.98 of the Revised Code of Washington designates the Washington State Department of Health (DOH) as the state agency with the responsibility to protect human health and the environment from the effects of ionizing radiation. To meet this legislative mandate, DOH conducts radiological monitoring throughout the state, placing emphasis on major nuclear facilities with known or potential radiological impacts associated with the facility operations, decommissioning, or cleanup. This report summarizes environmental radiation sampling results from the Department of Health's Hanford Environmental Oversight Program.

From 1943 until the mid 1980s, the primary mission of the U.S. Department of Energy's (DOE) Hanford Site was the production of plutonium for nuclear weapons. Operations resulted in releases of radioactivity to the environment. Today, weapons production operations have ceased, and the current mission of the Site includes cleanup of radioactive waste originating from the plutonium production era. DOE has extensive monitoring programs to characterize and track this contamination as it moves through the environment. The primary purpose of the DOH Hanford Environmental Oversight Program is to provide oversight of the DOE monitoring programs.

The primary objectives of the oversight program are:

- To independently verify the quality of the U.S. Department of Energy monitoring programs at the Hanford Site by conducting split, colocated, and independent sampling at locations having the potential to release radionuclides to the environment or locations which may be impacted by such releases.

- To use the DOH oversight data to assess impacts to the public by comparing radionuclide concentrations in samples potentially impacted by Hanford with concentrations in background samples. With the primary role of oversight, the DOH monitoring program is not intended to completely characterize environmental radiation from the Hanford Site, nor is it intended to find and report the highest environmental contaminant concentrations.

- To address public concerns related to environmental radiation at Hanford.

This report presents the results of environmental radiation measurements made by the Washington State Department of Health's Hanford Environmental Oversight Program for the calendar year 2004.

Section 2 describes the Hanford Environmental Oversight Program, including a discussion of laboratory qualifications and how to interpret the results presented in this report. Environmental results are presented in Section 3. Tutorial information on radiation is found in Appendix A. The laboratory lower limits of detection are listed in Appendix B. Appendix C lists a glossary of radiation terms. Appendix D is a list of analytes (i.e., the radionuclides that are detected and measured by laboratory analysis).

2. The Hanford Environmental Oversight Program Description

The objectives of the Oversight Program (see Section 1. Introduction) are met through collection and analysis of environmental samples and interpretation of results. DOH samples are either split or colocated with samples collected by the DOE contractors. In 2003, samples were split with the Pacific Northwest National Laboratory (PNNL), Duratek, and Waste Management Federal Services (WMFS).

Split samples are prepared by dividing a sample into two parts. Colocated samples are those samples that are collected adjacent to the DOE contractor sample. In each case, the DOH sample is sent to the Washington State Public Health Laboratory (PHL) in Shoreline, Washington for radiochemical analysis. Results of the DOH analyses are compared to the DOE contractor results to assess the quality of the federal monitoring program at the Hanford Site. In addition, the results are compared to historical data to identify trends, and are used to identify impacts to public health and the environment.

2.1 Laboratory Qualifications

Analytical techniques are based on laboratory standard operating procedures (Appendix B). The PHL serves as a regional reference laboratory and, as such, operates under a rigorous quality assurance program. This program contains quality control elements, which help ensure the laboratory's high analytical proficiency and accuracy. Laboratory quality control includes analysis of samples distributed by the federal government's quality assurance programs; split samples distributed on a smaller scale between cooperating federal, state and private laboratories; and internal procedures related to the counting facilities and analytical techniques. Collectively, the PHL’s quality assurance program encompasses:

- Personnel requirements and qualifications
- Quality control
- Sample handling and custody requirements
- Analytical methods
- Equipment calibration and maintenance
- Data reporting
- Records management and archiving
- Corrective action

The PHL participates in three intercomparison programs: DOE’s Environmental Measurement Laboratory (EML) intercomparison, the Mixed Analyte Proficiency Evaluation Program (MAPEP), and the Quality Assurance Task Force of the Pacific Northwest (QATF) intercomparison. These programs provide an independent check of laboratory proficiency for analyzing environmental samples. Additionally, the laboratory proficiency is checked through the analysis of standard reference samples. Reference material is generally any environmental media containing known quantities of radioactive material in a solution or homogenous matrix.

2.2 Interpretation of Results

Environmental radiation data are reported as the number of radiation decays per minute per unit quantity of sample material. Most results are reported in units of picocuries. A picocurie equals 2.22 decays per minute. Airborne radioactivity is expressed as picocuries per cubic meter ($pCi/m^{3)}$; radioactivity in liquids such as water and milk is expressed as picocuries per liter (pCi/L); and radioactivity in solid material such as soil, vegetation, and food is expressed as picocuries per gram (pCi/g). Ambient gamma radiation is expressed as radiation exposure, measured in milliroentgens per day (mR/day). Radiation exposure is discussed in Appendix A, and the units used to quantify radioactivity and exposure are defined in Appendix C.

2.2.1 Uncertainty in Radioactivity Measurements

All radioactivity measurements (i.e., counting the number of decays per unit time) have an associated uncertainty. Counting uncertainty is the dominant source of measurement uncertainty. Counting uncertainty is an estimate of the possible range of radioactivity results due to the fact that radioactive decay is a random process. The uncertainties reported within this report are primarily counting uncertainties, although for gamma emitting radionuclides the uncertainty associated with calibrating the detector is included. The uncertainties are given as "2-sigma" uncertainty. A 2-sigma uncertainty means there is 95% confidence that the true concentration in the sample lies somewhere between the measured concentration minus the uncertainty and the measured concentration plus the uncertainty.

2.2.2 Detection Limits

The laboratory is capable of measuring very small amounts of radioactivity in environmental samples, but there is a limit below which a sample’s radiation cannot be distinguished from background radiation. This limit is called the lower limit of detection, and depends on several factors including the sample size, analytical method, counting time, and background radiation. Appendix C lists the typical lower limits of detection that are achievable by the PHL.

2.2.3 Background and Negative Results

The environmental results are reported as net sample activity, which is defined as gross sample activity minus background activity. Gross sample activity and background activity are measured separately. Gross sample activity results from the sum of radioactivity in the environmental sample and background radiation originating from sources outside of the sample. Background activity is measured by counting the radioactivity in a blank sample.

A negative net sample activity is occasionally reported for environmental samples. When the amount of radioactivity in the sample is very small, the random nature of radioactive decay may result in a gross sample activity that is less than the background activity. In this case, the net result will be negative. In most cases, negative results have an associated uncertainty range that includes zero activity. A negative result indicates that radioactivity in the sample was not detected at concentrations above the detection limit.

The net sample activity represents the best estimate of the true value of the sample activity. Therefore, to prevent biased reporting, DOH reports the net sample activity even when the result is negative (as opposed to reporting a value of "zero" or "not detected"). The negative results are included in statistical analyses of data to look for systematic bias in laboratory procedures and to provide a more accurate measure of analytical detection limits.

2.2.4 Techniques for Comparison of DOH and DOE Contractor Data

Since the primary purpose of the DOH Hanford Environmental Oversight Program is to verify DOE environmental monitoring programs, DOH either splits samples or collects colocated samples with DOE contractors. The DOH and DOE samples are independently analyzed and the results compared. Two techniques are used to compare the data; qualitative comparisons and linear regression analysis.

2.2.4.1 Qualitative Comparisons

All of the colocated or split data are sorted by sample type and radionuclide. Then, for each sample type and radionuclide, all of the DOH and DOE contractor data for each sample location are plotted on a graph and visually inspected to qualitatively assess the agreement of the data. The results of the assessment are discussed in the text of the report. When necessary or helpful to the reader, figures of the graphical representation of the data are included in the report.

2.2.4.2 Regression Analysis and Scatter Plots

In addition to qualitative assessment, linear regression analysis is used to compare DOH and DOE data when appropriate. In this report, regression analysis is carried out when a) there is a sufficient amount of data to analyze, b) the data are consistently greater than the detection limit, and c) the data are sufficiently correlated.

Assuming there is a sufficient amount of data above the detection limit for a meaningful regression analysis, each of the split or colocated DOH and DOE results for a given sample type and radionuclide are formed into an (x, y) pair. The x-value represents the DOH result and the y-value represents the DOE result for a particular sample. The paired data for all samples of a given sample type and radionuclide are plotted on a two-dimensional scatter plot. The correlation coefficient R is then calculated for the set of (x, y) pairs. R can vary from -1 to +1. A value near ± 1 implies a strong correlation, while a value near 0 implies a weak or no correlation.

If the two data sets are sufficiently correlated (in this report, the criterion is $R > 0.75$), the best-fit straight line that describes the relationship between the two monitoring programs is determined. The parameters that describe the straight line are the slope and y-intercept. The functional form of the straight line is $y = ax + b$, where a is the slope and b is the y-intercept.

If the results between the DOH and DOE monitoring programs were in perfect agreement, the slope of the best-fit line would be 1, and the y-intercept would be 0. A zero value for the y-intercept means that if DOH measures zero activity, then DOE also measures zero for the same sample. A non-zero y-intercept indicates an overall offset between DOH and DOE results. The slope is simply the ratio of the DOH and DOE results.

If a regression analysis is carried out, a scatter plot (x, y paired data) of the DOH and DOE split or colocated sample data is presented in this report. Also shown in the plot are straight lines representing the ideal case where the data sets are in perfect agreement, and the best-fit straight line. The slope and y-intercept of the best-fit straight line are shown in the plot legend.

If the two data sets are not sufficiently correlated ($R < 0.75$), it is not meaningful to find a best-fit straight line describing the relationship between the two data sets. In this case, the comparison is limited in this report to a qualitative assessment.

3. Environmental Monitoring Results

This section presents the DOH and DOE contractor results for the Hanford Environmental Oversight Program. The types of samples collected are intended to encompass all of the potential public exposure pathways. These samples include air (Section 3.1); groundwater, riverbank seep water, surface water, and discharge water (Section 3.2); dosimeters measuring external gamma radiation (Section 3.3); sediment (Section 3.4); food and farm products (Section 3.5); fish and wildlife (Section 3.6); and vegetation (Section 3.7). Each of these sample types is discussed in the sub-sections below. Note that the figures for each sub-section are located at the end of the sub-section.

3.1 Air Monitoring

Major Findings:

- The DOH and DOE contractor colocated bi-weekly gross beta results are in fair agreement. The data follow the same trends, but there is a small systematic discrepancy between the data sets. A different sampling frequency between DOH and DOE contractors likely contributes to differences in results.
- The DOH and DOE contractor colocated quarterly and semi-annual composite air sample results are in good agreement for all radionuclides, except for isotopes of uranium. The discrepancy in uranium concentrations originates from a difference in DOH and DOE contractor laboratory analytical methods.
- The gross beta results are consistent with background air concentrations.
- The DOH quarterly and semi-annual composite air concentrations are below detection limits for most radionuclides. However, uranium was consistently detected in composite air samples, and Pu-239/240 was detected in two samples. In all cases, the concentrations are small, and are consistent with historical results.

3.1.1 Purpose and General Discussion

Atmospheric releases of radioactive material from the Hanford Site are a potential source of human exposure. DOH and DOE contractors monitor radioactivity in air to determine if the Hanford Site is contributing to airborne contamination. DOH collects air samples that are colocated with PNNL and Duratek. In addition to oversight of the DOE monitoring program, DOH evaluates Hanford impacts by comparing radioactivity in air at locations upwind and downwind of operating and contaminated facilities.

Sources of Hanford airborne emissions include resuspension of contaminated soil (for example, caused by wind or cleanup activities) and escape of radioactive particulates and gasses. Sources of natural airborne radioactivity include natural radon gas and its decay products, resuspension of soil containing natural radionuclides such as uranium-234, 238 and potassium-40, and radioactive atoms such as beryllium-7 and tritium that are generated in the atmosphere by interactions with cosmic radiation.

3.1.2 Monitoring Locations

In 2004, DOH collected air samples colocated with PNNL at five locations. These locations include Wye Barricade, Prosser Barricade, Battelle Complex, and Station 8 that are located in the prevailing downwind direction of most Hanford Site operating and contaminated facilities; and Yakima Barricade that is in the prevailing upwind direction of operating and contaminated facilities.

DOH also collected air samples colocated with Duratek at four locations, three of which are near operating facilities that have the potential to emit radionuclides to the air. These locations include a tank farm in the 200 Area (C Farm), the Environmental Restoration Disposal Facility (ERDF-SE), and the K Area fuel storage basins (KE Basin). The fourth colocated site is at the Wye Barricade. All the DOH colocated air sampling sites are shown in Figure 3.1.1.

3.1.3 Monitoring Procedures

Airborne particles are sampled by continuously drawing air through a filter. DOH collects the filter at each sample location once a week, while PNNL and Duratek collect their colocated filters every other week (bi-weekly). The filters are stored for three days and then analyzed for gross beta activity. The storage period allows naturally occurring short-lived radionuclides to decay that would otherwise obscure detection of radionuclides potentially present from Hanford Site emissions.

The amount of radioactive material collected on a filter in a one or two-week time period is typically too small to accurately detect concentrations of individual radionuclides. In order to increase the sensitivity and accuracy so that individual radionuclide concentrations can be determined, the weekly (or bi-weekly) filter samples for a three or six-month period are dissolved and combined into quarterly or semi-annual composite samples. The composite samples are analyzed for gamma emitting radionuclides and isotopes of uranium and plutonium. A summary of the 2004 colocated monitoring program is shown in Table 3.1.1.

Type of Air Sample	DOH/PNNL	DOH/Duratek
Weekly (or Bi-Weekly) Filter	Gross Beta	Gross Beta
Quarterly Composite Filter	Co-60; Cs-134, 137; U-234, 235, 238	
Semi-Annual Composite Filter		Co-60; Cs-134, 137; Pu-238, 239/240; U-234, 235, 238

Table 3.1.1 Radionuclides Monitored in Air Samples

3.1.4 Comparison of DOH and Contractor Data

Weekly/Bi-Weekly Results

The DOH and PNNL gross beta concentrations in bi-weekly colocated air samples are in fair agreement, as the data follow the same trend at each of the monitoring locations. As an example, the DOH and PNNL data at Station 8, which is located in the general downwind direction from Hanford on the opposite side of the Columbia River, are shown in Figure 3.1.2.

The scatter plots and regression analyses for 2004 and historical DOH and PNNL gross beta concentrations are shown in Figures 3.1.3 and 3.1.4. The scatter plots show the data from all sites that are colocated with PNNL. These plots indicate the data follow the same general trend. However, the data show significant scatter about the theoretical line where the DOH and PNNL results are identical, with differences up to a factor of two being common. In addition, there is a small systematic bias between the DOH and PNNL results. The regression analysis indicates that PNNL on average reports slightly higher concentrations at the lower range of results, while DOH on average reports slightly higher concentrations at the upper range.

The DOH and Duratek gross beta concentrations in bi-weekly colocated air samples are in fair agreement, as the data follow the same trend at each of the monitoring locations. As an example, DOH and Duratek data at C Farm are shown in Figure 3.1.5.

The scatter plots and regression analyses for 2004 and historical DOH and Duratek gross beta concentrations (Figures 3.1.6 and 3.1.7) show that differences up to a factor of two between DOH and Duratek concentrations are common, and that there appears to be a small systematic bias similar to that seen with the DOH and PNNL data.

In general, the DOH and DOE contractor data sets are not expected to match identically because the sampling frequencies are different, and therefore the results correspond to an averaging of the air concentration over different time periods. A preliminary analysis indicates that the different sampling frequency is responsible for a significant component of the differences in the DOH and DOE contractor results. Future annual reports will address this issue in more detail.

Quarterly Composite Results

DOH and PNNL analyzed colocated quarterly composite air samples for Co-60, Cs-134, and Cs-137 at Battelle Complex, Prosser Barricade, Station 8, Wye Barricade, and Yakima Barricade. Samples were analyzed for isotopes of uranium at Station 8 and Wye Barricade.

The DOH and PNNL Co-60, Cs-134, and Cs-137 quarterly composite concentrations are in good agreement, with all results below the detection limits listed in Appendix B. The agreement is only fair for isotopes of uranium due to a systematic discrepancy between the two data sets. The U-238 concentrations are shown in Figure 3.1.8. The PNNL uranium concentrations are systematically less than those reported by DOH. The results for U-234 are similar. The agreement is good for U-235; however, all concentrations are below detection limits.

The discrepancy between DOH and PNNL uranium concentrations in air exists historically, and originates from different laboratory procedures. DOH completely dissolves samples prior to analysis and reports uranium present in the entire sample, whereas the contractor laboratory reports only the uranium that can be leached from the sample surface.

The historical DOH and PNNL quarterly composite U-238 concentrations for the years 1999 through 2004 are shown in Figure 3.1.9, and the corresponding scatter plot is shown in Figure 3.1.10. The discrepancy appears for samples in which DOH measures U-238 concentrations greater than the detection limit of 2.5E-5 pCi/m^3. In these cases, the corresponding PNNL data do not confirm the elevated DOH results. The scatter plot clearly shows that DOH consistently reports higher concentrations than PNNL.

Semi-Annual Composite Results

DOH and Duratek analyzed colocated semi-annual composite air samples at C Farm, ERDF-SE, and KE Basin. The DOH and Duratek airborne concentrations are in good agreement for Co-60, Cs-134, Cs-137, U-235, Pu-238, and Pu-239/240, with most results below detection limits). The Pu-239/240 concentrations, a few of which are above the detection limit of 0.000005 pCi/m^3, are shown in Figure 3.1.11.

The U-234 and U-238 concentrations are only in fair agreement, as the Duratek concentrations are systematically less than those reported by DOH. As with the DOH and PNNL composite data, the bias originates from a known difference in laboratory procedures. The DOH and Duratek U-238 data are shown in Figure 3.1.12. The U-234 data are similar.

3.1.5 Discussion of DOH Results

The gross beta results at all sites show a trend of higher concentration during the winter months, typically October through February. These higher gross beta activities are attributed to increased concentrations of radon decay products due to decreased atmospheric mixing during the winter months when there is decreased atmospheric heating. The annual cycle of increased gross beta activity in the winter months can easily be seen in Figure 3.1.13, which shows gross beta activity at Wye Barricade over the last decade from 1994 through 2004.

Gross beta results from locations upwind and downwind of the Hanford Site are compared to determine if Hanford is impacting air quality. Yakima Barricade is an upwind location, while Wye Barricade, Prosser Barricade, Battelle Complex, and Station 8 are downwind locations where the public may potentially be exposed. The minimum, maximum, and annual average concentrations for these sites are shown in Table 3.1.2, along with the statistics for locations on the Hanford Site (C Farm, ERDF-SE, and KE Basin).

The average air concentrations at upwind sites and downwind sites are not significantly different, indicating that Hanford is not impacting air quality at locations where the public may be exposed. In addition, the average air concentration at the locations near operating facilities is also not significantly different from the upwind site. For the year 2004, all of the weekly DOH gross beta results ranged between 0.002 and 0.084 pCi/m^3, with an annual average of 0.019 pCi/m^3.

Site	DOH (pCi/m^3)			Contractor (pCi/m^3)			
	Min	**Max**	**Average**	**Name**	**Min**	**Max**	**Average**
Battelle Complex	0.002	0.084	0.021	PNNL	0.007	0.044	0.018
C Farm	0.006	0.079	0.021	Duratek	0.008	0.057	0.019
ERDF-SE	0.005	0.070	0.018	Duratek	0.000	0.043	0.012
KE Basin	0.005	0.072	0.020	Duratek	0.007	0.054	0.018
Prosser B.	0.006	0.076	0.020	PNNL	0.006	0.041	0.016
Station 8	0.003	0.075	0.015	PNNL	0.002	0.053	0.016
Wye B.	0.005	0.073	0.019	PNNL	0.008	0.045	0.016
Yakima B.	0.005	0.051	0.019	PNNL	0.006	0.038	0.015

Table 3.1.2 Summary Statistics for Gross Beta Concentrations in Air

All of the DOH results for Co-60, Cs-134, Cs-137, Pu-238, and U-235 concentrations in composite air samples are below laboratory detection limits (see Appendix B). Uranium-234 and U-238 were detected in several samples with concentrations ranging from the detection limit of approximately 0.00001 pCi/m^3 to 0.00007 pCi/m^3. Plutonium-239/240 was detected at the detection limit of 0.000005 pCi/m^3 at the ERDF facility and at 0.000017 pCi/m^3 near the KE Basin of the 100K Area. Plutonium-239/240 has been detected at concentrations just above the detection limit for several years at these locations.

These uranium and plutonium concentrations are very small, and are only at most a few times greater than the detection limits. Continuous breathing of air with a Pu-239/240 concentration of 0.000017 pCi/m^3 would result in an annual radiation dose of approximately 0.07 mrem/yr. Both the U.S. Environmental Protection Agency (40 CFR Part 61) and Washington State (Chapter 246-247 WAC) limit radiation dose to the public from air emissions to 10 mrem/year. The maximum radionuclide concentrations detected in DOH composite air samples are all several orders of magnitude less than EPA Concentration Levels for Environmental Compliance (as listed in 40 CFR Part 61, Appendix E, Table 2).

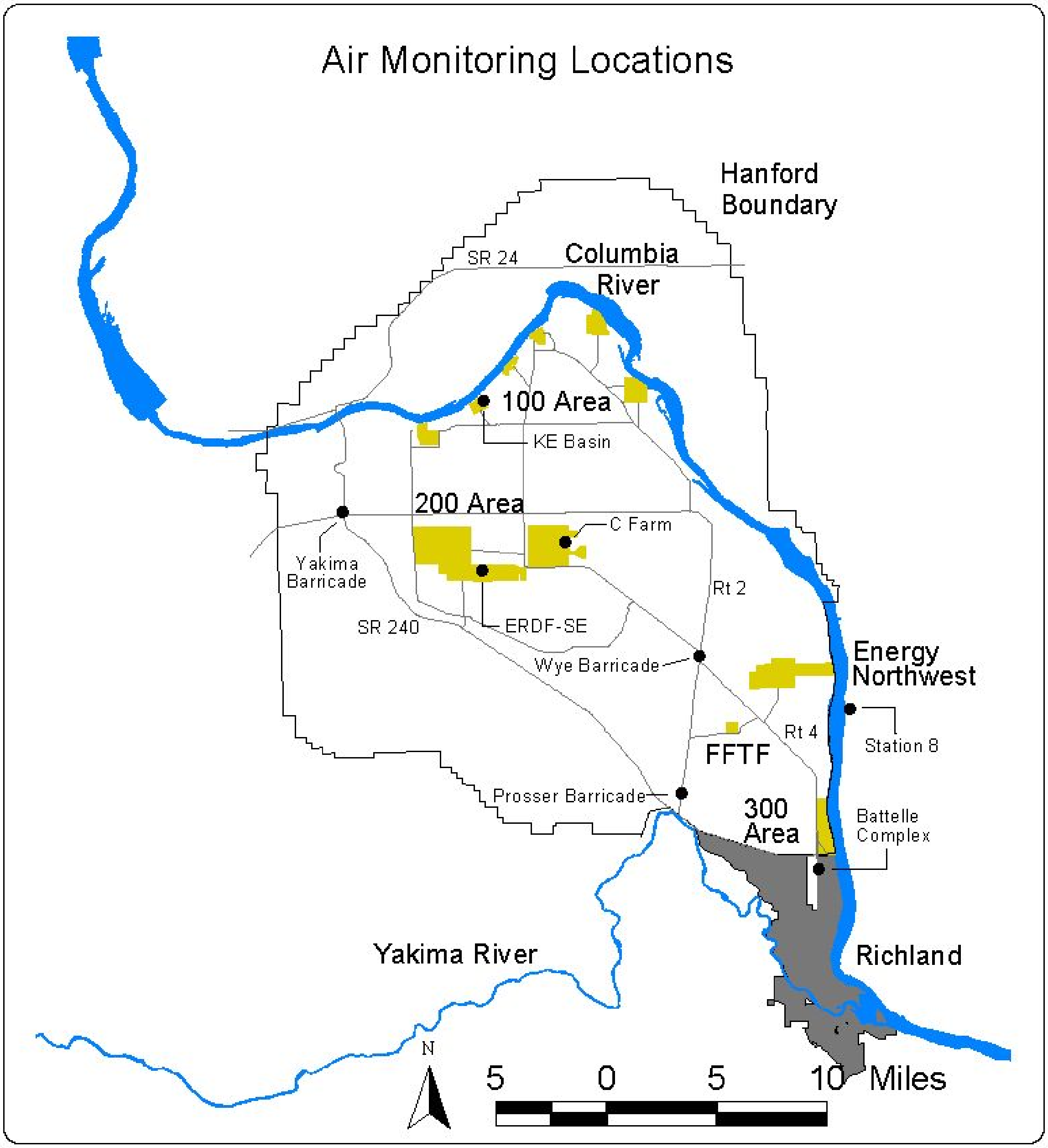

Figure 3.1.1 Air Monitoring Locations

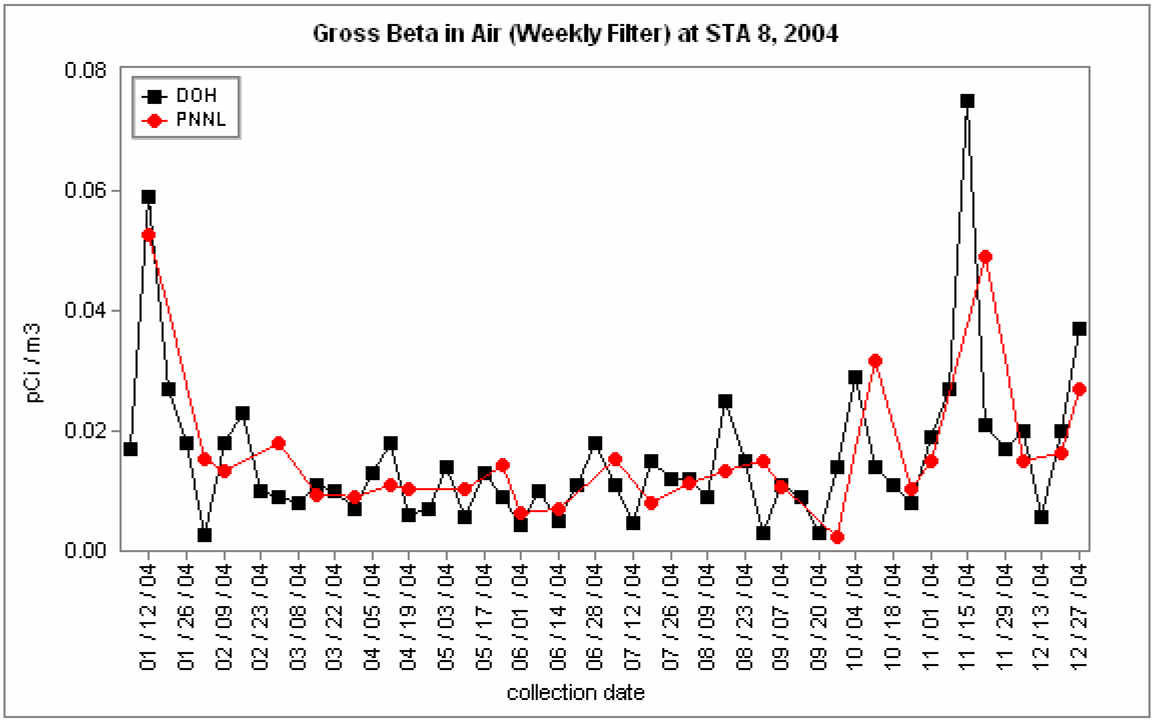

Figure 3.1.2 DOH and PNNL Gross Beta Concentrations in Air at Station 8

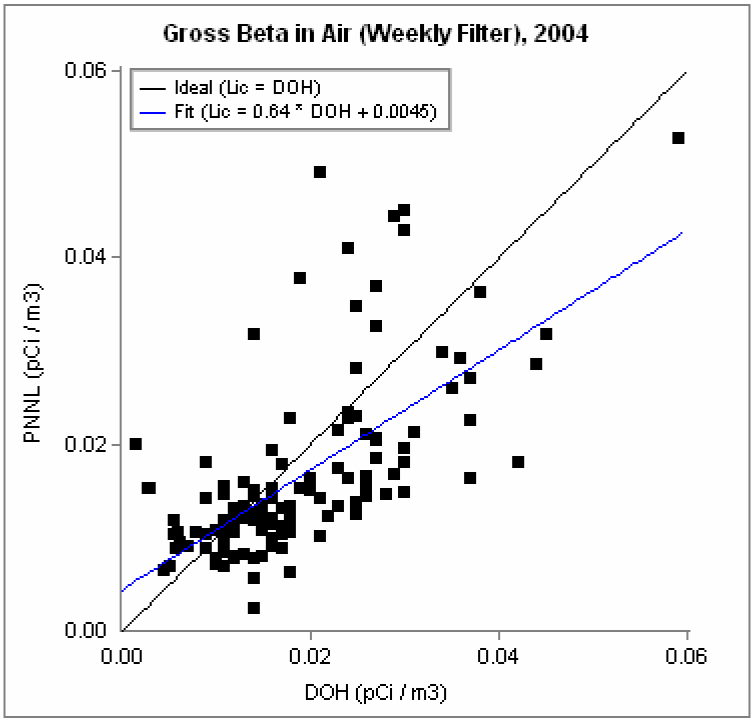

Figure 3.1.3 DOH and PNNL Scatter Plot for Gross Beta Concentrations in Air (2004)

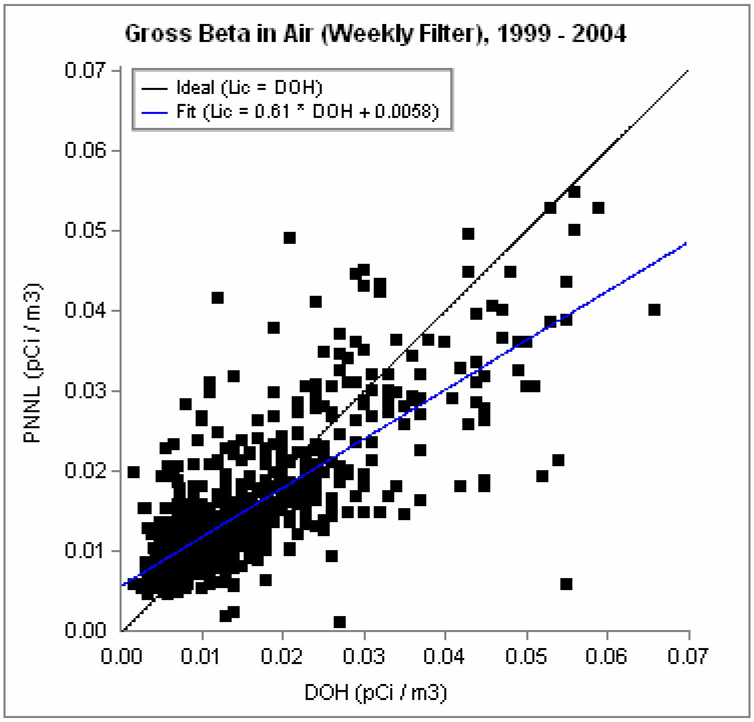

Figure 3.1.4 DOH and PNNL Scatter Plot for Historical Gross Beta Concentrations in Air

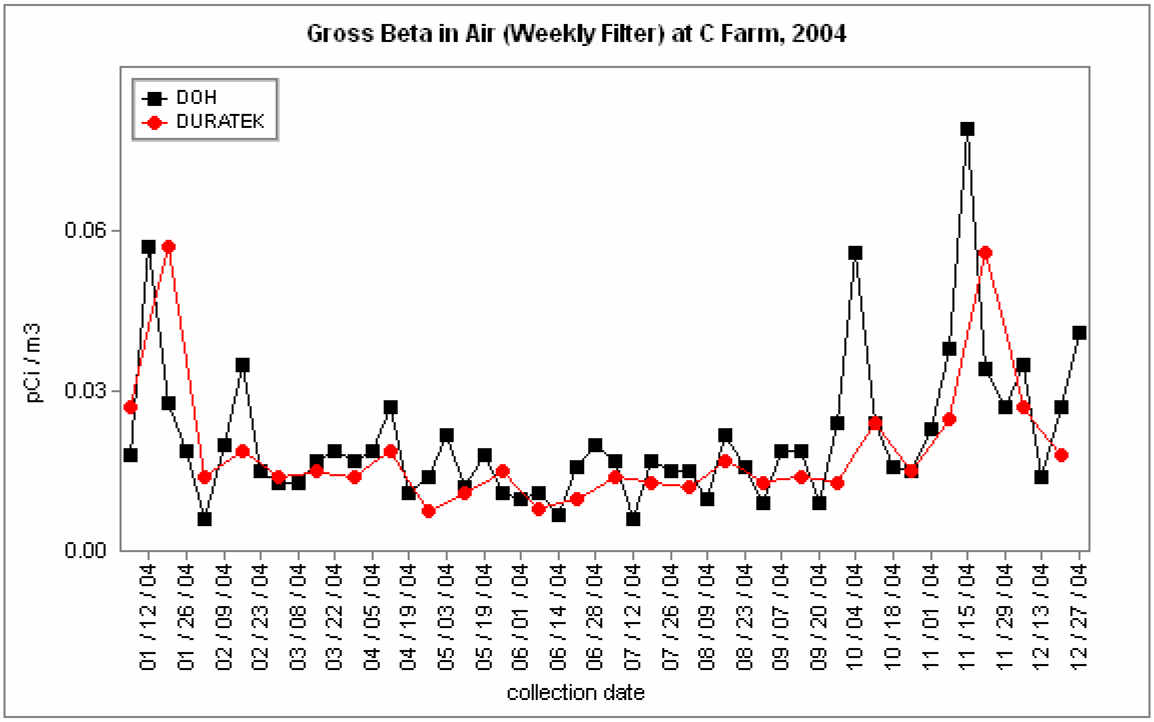

Figure 3.1.5 DOH and Duratek Gross Beta Concentrations in Air at C Farm

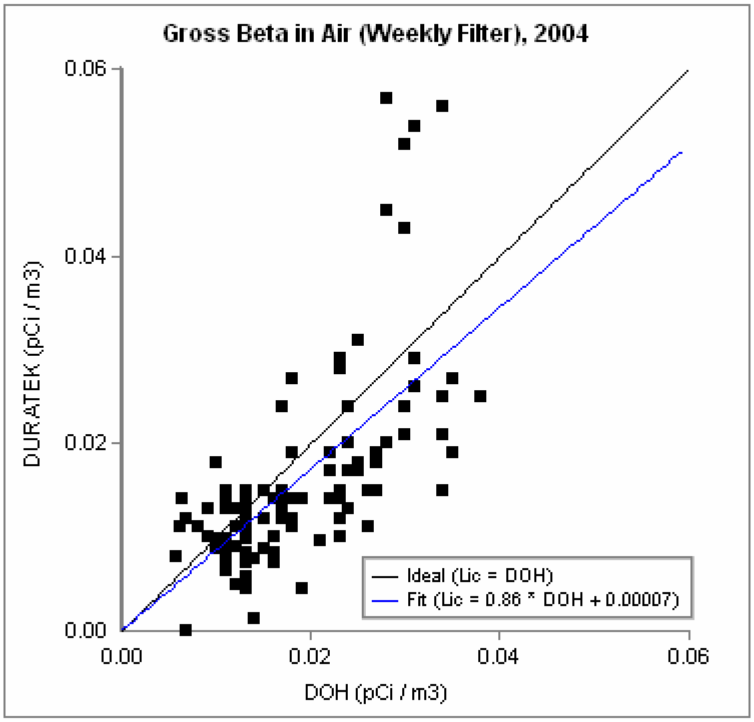

Figure 3.1.6 DOH and Duratek Scatter Plot for Gross Beta Concentrations in Air (2004)

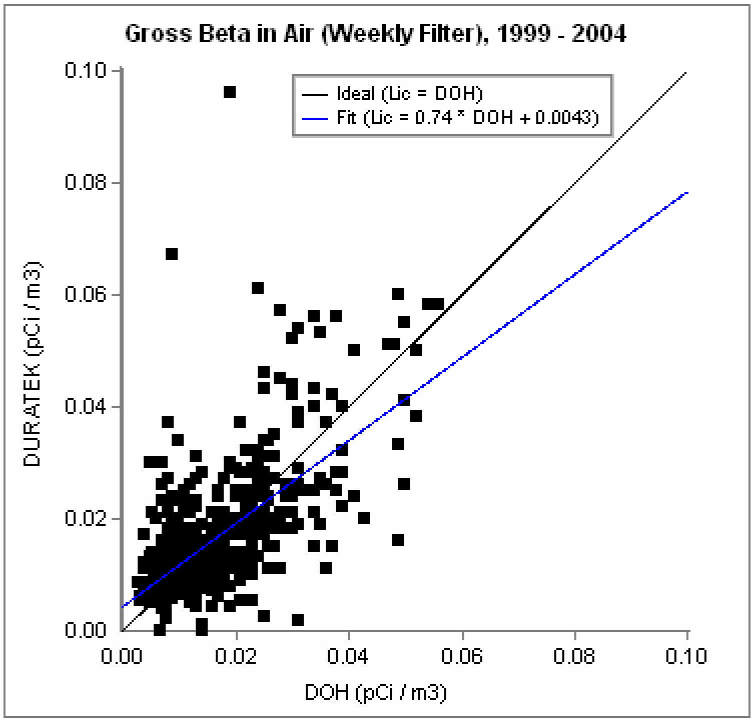

Figure 3.1.7 DOH and Duratek Scatter Plot for Historical Gross Beta Concentrations in Air

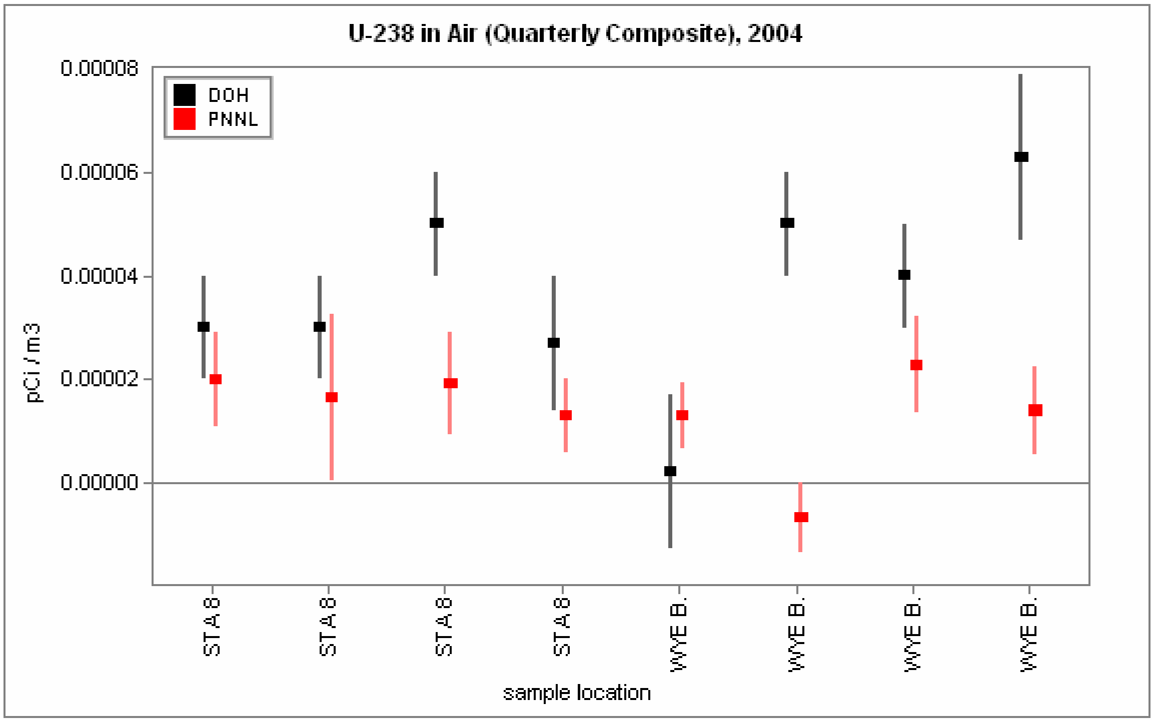

Figure 3.1.8 DOH and PNNL U-238 Concentrations in Quarterly Composite Air Samples

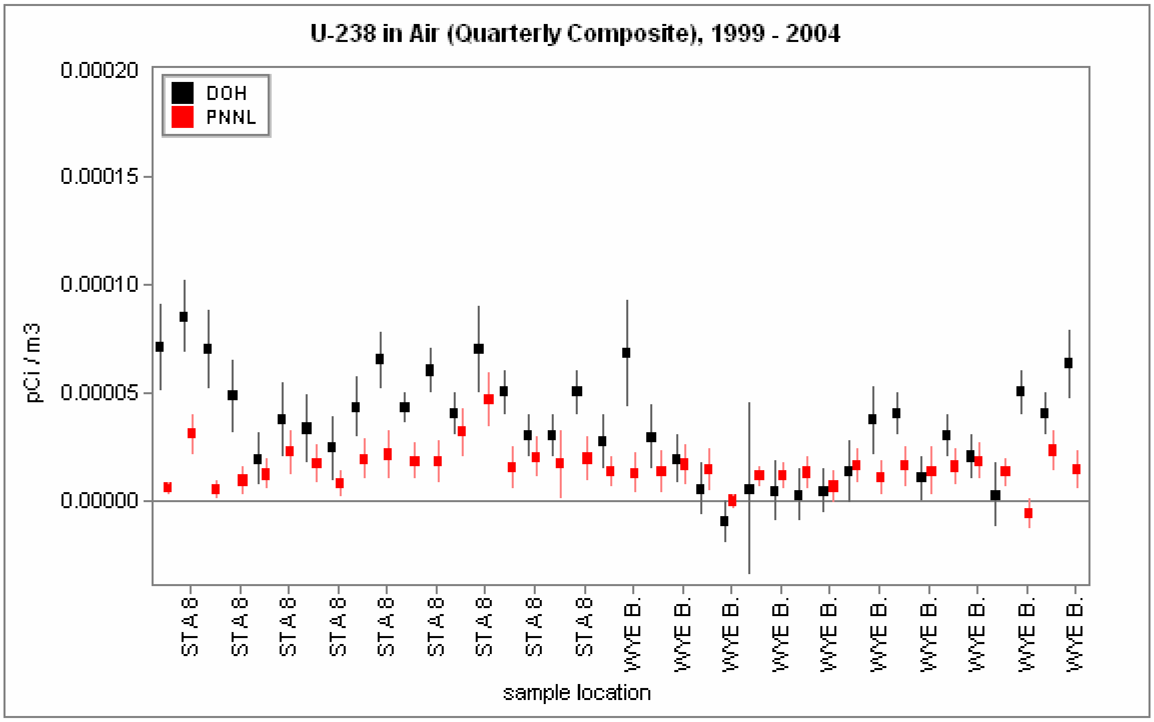

Figure 3.1.9 DOH and PNNL Historical U-238 Concentrations in Quarterly Composite Air

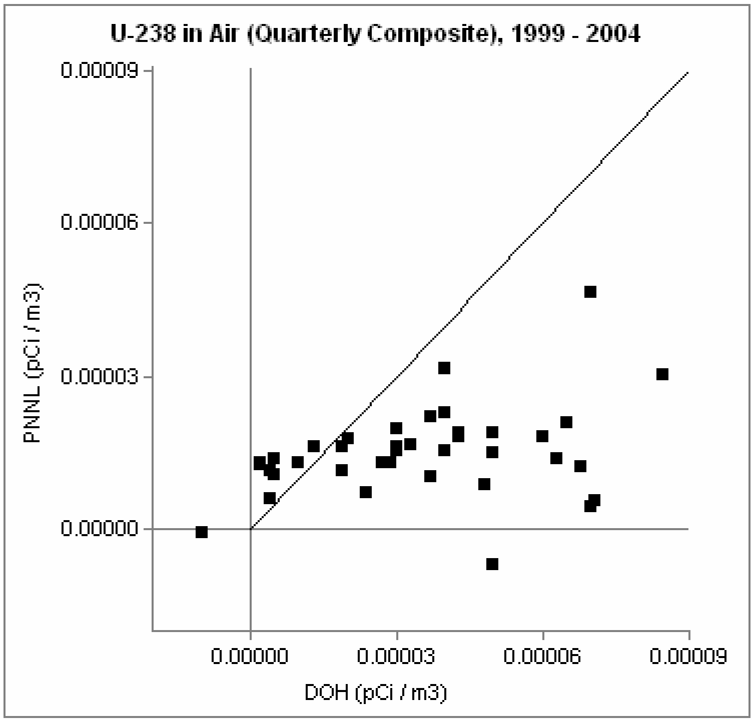

Figure 3.1.10 DOH and PNNL Scatter Plot for Historical U-238 Concentrations in Air

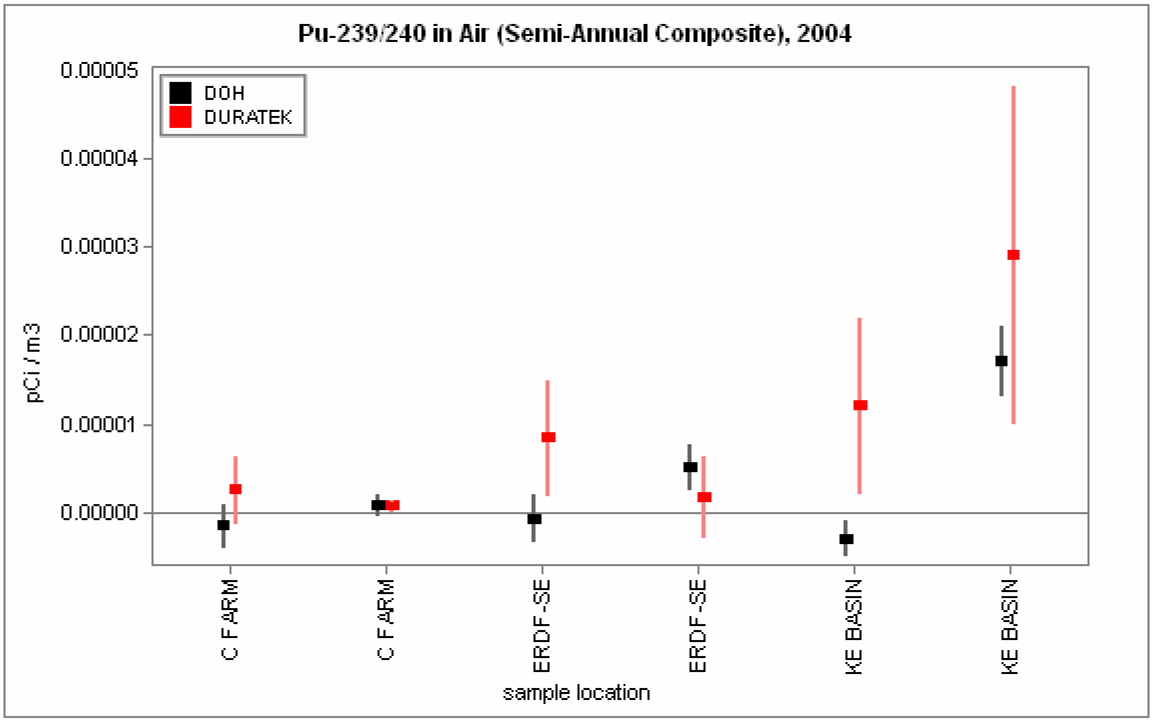

Figure 3.1.11 DOH and Duratek Pu-239/240 Concentrations in Semi-Annual Composite Air Samples

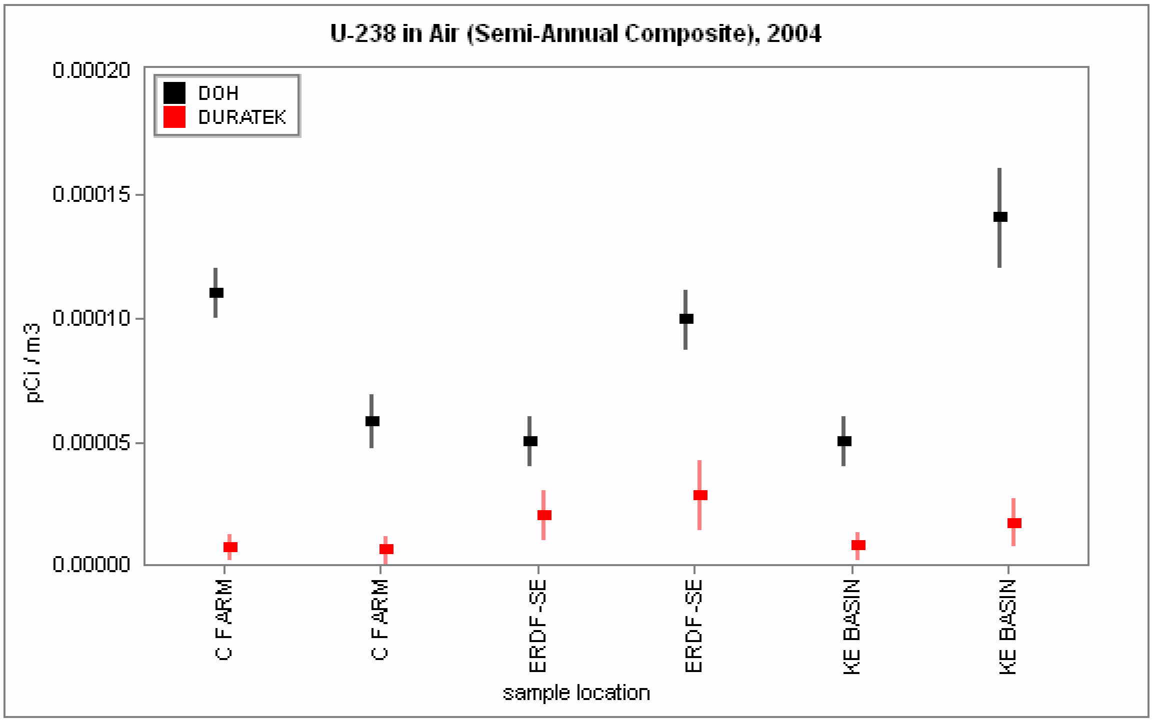

Figure 3.1.12 DOH and Duratek U-238 Concentrations in Semi-Annual Composite Air

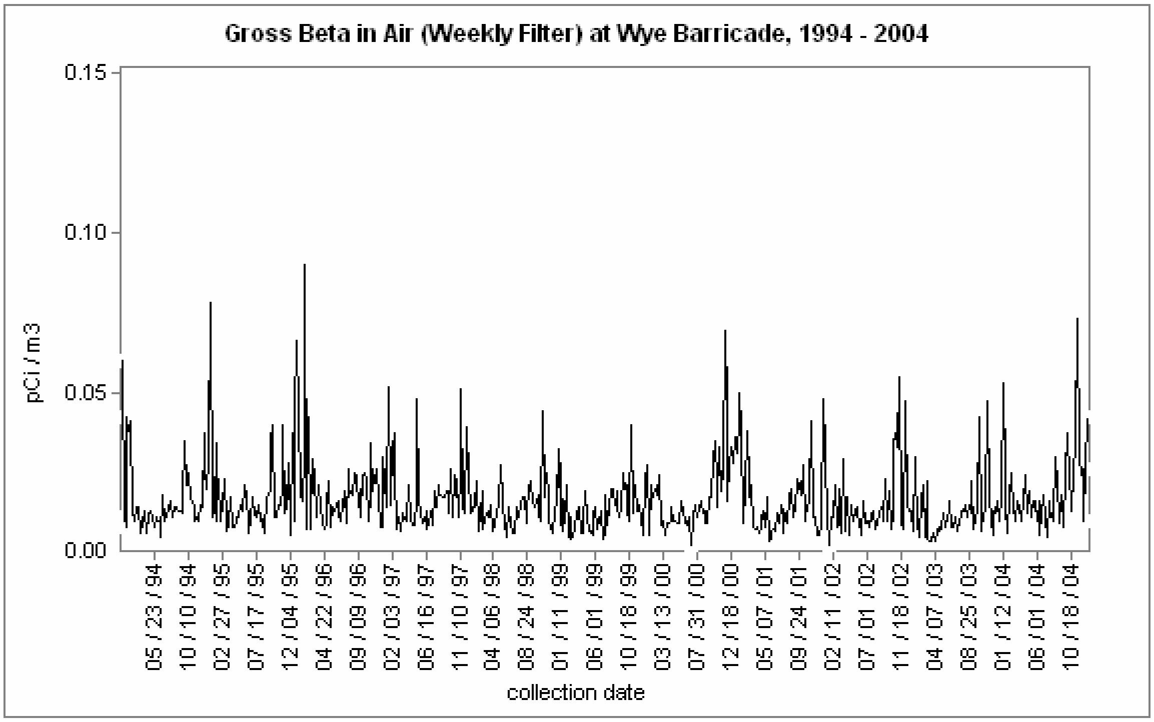

Figure 3.1.13 DOH Historical Gross Beta Concentrations in Air at Wye Barricade

3.2 Groundwater, Riverbank Seep, and Surface Water Monitoring

Major Findings:

- The DOH and PNNL split water results are in good agreement for most radionuclides analyzed in water samples. The agreement for I-129 is poor, and a small systematic bias exists in the gross alpha and gross beta results. The DOH and DOE split TEDF discharge water results are in good agreement.
- Radionuclides were detected in groundwater in the vicinity of known groundwater plumes, and in riverbank seep water and Columbia River surface water in the vicinity of plumes known to be entering the Columbia River.
- DOH detected H-3, Sr-90, Tc-99, and isotopes of uranium in Hanford water samples. Most concentrations in 2004 samples are consistent with historical results. I-129 concentrations are increasing in groundwater well 699-35-70, and H-3 concentrations are fluctuating in 100K Area groundwater wells.
- Radionuclide concentrations in drinking water samples are all below federal standards.
- Radionuclide concentrations in TEDF discharge water samples are all below Washington State standards.

3.2.1 Purpose and General Discussion

Operations at the Hanford Site have resulted in contaminated groundwater and Columbia River water. Radioactive contaminants have leached from waste sites in the soil to groundwater beneath the Site, and then have migrated with groundwater to the Columbia River. Occasionally, groundwater enters the Columbia River through riverbank seeps.

Human exposure to contaminants can occur directly through ingestion of, or swimming in, contaminated water; or indirectly through ingestion of plants, animals, or fish that have been exposed to contaminated water. Radioactive contaminants are monitored by collecting samples from inland groundwater wells, riverbank seeps, and Columbia River water.

DOH splits groundwater, surface water, riverbank seep water, and drinking water samples with PNNL. PNNL monitors radioactivity in water to track contaminant plumes in groundwater, and to evaluate impacts to the public and environment. While the DOH program does not sample enough groundwater wells to track groundwater plumes, the riverbank seep and Columbia River data are adequate to understand impacts to the public. In addition, DOH and DOE split discharge water samples from an effluent treatment facility.

3.2.2 Monitoring Locations

Groundwater

DOH and PNNL split 24 groundwater samples from 19 groundwater wells in 2004. Most well locations sampled are on the Hanford Site, either within contaminated plumes, near waste sites, or along the Columbia River shoreline. A few of the well locations are off the Hanford Site, located just south of Hanford in the northern part of Richland and just across the Columbia River in Franklin County. Figure 3.2.1 shows the locations of the groundwater sampling sites.

Groundwater sampling is conducted in the 100, 200, 300, 400, and 600 Areas of the Hanford Site. The 100 Area consists of nine retired reactors and support facilities located along the Columbia River. Tritium (H-3) and Sr-90 are contaminants commonly found in groundwater beneath the reactor facilities. A primary objective of the groundwater collection in the 100 Area is to monitor contaminants that may enter the Columbia River. At the 100K Area, groundwater is sampled to evaluate potential changes as spent nuclear fuel, shield water, and sludge are removed from the 100 KE Fuel Storage Basin.

The 200 Area consists of retired reactor fuel processing facilities located in the center of the Hanford Site on the central plateau. Common groundwater contaminants include H-3, I-129, Tc-99, uranium, and Sr-90. A primary objective of groundwater collection in the 200 Area is to track plume movement and monitor potential leaks from waste storage tanks.

The 300 Area consists of retired reactor fuel fabrication facilities located adjacent to the Columbia River. Groundwater contains tritium originating from the 200 Area and uranium originating from past 300 Area fuel fabrication activities. A primary objective of the groundwater collection in the 300 Area is to monitor contaminants at the southern boundary of the Hanford Site, which is close to the City of Richland’s drinking water wells.

The 400 Area is the location of the Fast Flux Test Facility, a liquid sodium cooled test reactor that ceased operation in 1993 and is currently being deactivated. Tritium originating from the 200 Area is a common contaminant found in 400 Area groundwater. The primary objective of groundwater monitoring in this area is to assess impacts to the primary drinking water source for this area.

The 600 Area includes all the land outside the operational areas of the Hanford Site. Tritium originating from the 200 Area is a common contaminant found in 600 Area groundwater. The major objective of sampling 600 Area groundwater is to assess the nature and extent of plumes originating in the 200 Area that may be moving off-site.

Riverbank Seeps

Groundwater enters the Columbia River through riverbank seeps. Historically, the predominant areas for discharge of riverbank seep water to the Columbia River were located at the reactors in the 100 Area, the Old Hanford Townsite, and the 300 Area. DOH and PNNL split five Columbia River riverbank seep samples in 2004. Sample locations included the 100K and 100N reactor areas, the Old Hanford Townsite (Spring 28.2), and the 300 Area. Figure 3.2.1 shows the locations of the riverbank seep sampling sites.

Surface and Discharge Water

DOH and PNNL split 23 surface water samples in 2004. Twenty-one of the samples were collected from the Columbia River - two from near Priest Rapids Dam located upstream of Hanford, four from the 100N Area, three from the 100F Area, four from the Old Hanford Townsite, four from the 300 Area, and four from near the Richland drinking water pumphouse. Two of the samples were collected from irrigation canals, one located across the Columbia River at Riverview, and the other at the southern boundary of the Hanford Site at the Horn Rapids irrigation pumping station. Figure 3.2.1 shows the locations of the surface water sampling sites.

The Priest Rapids Dam location is upstream of the Hanford Site, while the remaining surface water sites are downstream of areas that may be impacted by Hanford. A comparison of contaminant concentrations at these sites gives an indication of Hanford's impact on the Columbia River.

DOH conducts discharge effluent monitoring at the 310 Treated Effluent Disposal Facility (TEDF) as acknowledged in the Aquatic Lands Sewer Outfall Lease No. 20-013357. This agreement between the Department of Natural Resources (DNR) and DOE requires DOH to provide oversight of the discharge effluent monitoring program by splitting approximately 15% of the samples.

The TEDF was constructed as part of a Tri-Party Agreement Milestone to cease discharges to the 300 Area Process Trenches. The facility began operation in December 1994, and effluent sampling has been conducted since that time. DOH and DOE split two discharge samples in 2004.

Drinking Water

Drinking water is supplied to DOE facilities on the Hanford Site by numerous water systems, most of which use water from the Columbia River. One of these systems, in the 400 Area (the Fast Flux Test Facility [FFTF]), uses groundwater from the unconfined aquifer beneath the site. Typically, DOH and PNNL split one or more drinking water samples each year. In 2004, one sample was split from the FFTF. In addition, DOH collected drinking water samples from the LIGO Facility, the White Bluffs sub-station, and from the Edwin Markham elementary school in Pasco.

3.2.3 Monitoring Procedures

Groundwater

DOH groundwater samples were collected by DOE contractors who follow standard operating procedures that call for purging the well prior to sampling. Groundwater samples were collected from the upper, unconfined aquifer. The samples were analyzed for radionuclides that are most likely present in the area, based on previous sampling and review of radiological contaminants present nearby. Most samples were analyzed for gross alpha, gross beta, tritium, and gamma emitting radionuclides. Specific analyses for Sr-90, I-129, Tc-99, and isotopes of uranium were added where appropriate.

Riverbank Seeps

Columbia River seep samples were collected in the fall when the river flow is typically the lowest. This ensures that riverbank seep water contains primarily groundwater instead of Columbia River water stored in the riverbank during high flow rates. The seeps have a very small flow rate and are collected with the aid of a small pump. All seep samples were split with PNNL in the field and analyzed as unfiltered samples. All samples were analyzed for gross alpha, gross beta, gamma emitting radionuclides, and H-3. Specific analyses for Sr-90, Tc-99, and isotopes of uranium were added where appropriate.

Surface and Discharge Water

Columbia River surface water is monitored by collecting samples at several points spanning the width of the river. This technique is known as transect sampling. Columbia River samples are also collected from near the Hanford shoreline at locations where known groundwater plumes are near the river. In addition, Columbia River water is collected at Richland. Finally, surface water samples are collected from irrigation pumping stations located at Horn Rapids and Riverview.

Samples were split in the field and analyzed unfiltered. All samples were analyzed for isotopes of uranium and H-3. Analyses for gross alpha, gross beta, gamma emitting radionuclides, Sr-90, and Tc-99 were added where appropriate. Discharge samples from the 310 Treated Effluent Disposal Facility were analyzed for gross alpha, gross beta, gamma emitting radionuclides, and H-3.

Drinking Water

Drinking water is monitored by sampling tap water. The samples were analyzed for gross alpha, gross beta, gamma emitting radionuclides, and H-3.

Summary

A summary of the split water samples is presented in Table 3.2.1.

Water Matrix	Analytes	Number of Sample Sites	Number of Samples
Groundwater	C-14, Co-60, Cs-134, Cs-137, gross alpha, gross beta, H-3, I-129, Sb-125, Sr-90, Tc-99, Total U, U-234, U-235, U-238	19	24
Riverbank Seep	Co-60, Cs-137, gross alpha, gross beta, H-3, Sr-90, Tc-99, U-234, U-235, U-238	5	5
Surface Water	Co-60, Cs-137, gross alpha, gross beta, H-3, Sr-90, Tc-99, U-234, U-235, U-238	22	23
Discharge Water	gross alpha, gross beta	1	2
Drinking Water	gross alpha, H-3	1	1

Table 3.2.1 Summary of Split Water Samples

3.2.4 Comparison of DOH and Contractor Data

In 2004, DOH split groundwater, surface water, riverbank seep water, and drinking water samples with PNNL. In addition, DOH split discharge water samples with DOE. The analysis of the split water sample results is discussed below. See section 2.2.4.2 for a discussion of scatter plots and regression analyses that are used to assess these data.

Gamma Emitting Radionuclides

Gamma emitting radionuclides also emit beta particles, and in some cases; for example, I-129, the beta particle is more important from the standpoint of health impacts. In this report, however, the term *gamma emitting radionuclide* often refers to the fact that radioactivity concentrations were obtained by measuring gamma ray activity using gamma spectroscopy. This is the case for the sections comparing DOH and DOE contractor data.

The DOH and PNNL concentrations of gamma emitting radionuclides in water samples are in good agreement for all radionuclides except I-129. All Co-60, Cs-134, Cs-137, and Sb-125 results in split samples reported by DOH and PNNL are in agreement and are below the DOH detection limit of 2 pCi/L (5 pCi/L for Sb-125).

Historically, DOH and PNNL split water results are in good agreement for all gamma emitting radionuclides except I-129. In cases where I-129 is detected, DOH typically reports concentrations significantly lower than those reported by PNNL. This can be seen in Figure 3.2.2 where historical split results from groundwater well 699-35-70 are shown. On average, the DOH I-129 concentrations at this well are one-third of the concentrations reported by PNNL.

There are also problems in cases in which I-129 is not detected. First, the DOH results appear to have a negative bias. Figure 3.2.3 shows historical split I-129 concentrations in groundwater for samples in which the results are below the DOH detection limit of 0.8 pCi/L. For a set of data with concentrations below the detection limit, a scatter about zero is expected, ideally with an equal number of results above and below zero. However, the figure indicates a disproportionate number of negative DOH results, indicating a negative bias (see section 2.2.3 for a discussion of negative results). The data appear to have a negative offset of approximately -0.5 pCi/L.

Second, it appears from the figure that PNNL reports detected concentrations of I-129 for well 699-41-1A. The PNNL concentrations at this well are greater than the minimum detectable activity (MDA, not shown in the figure), indicating a detection. However, the results are tagged as not detected at the specified detection limit, despite the fact that the results are greater than the reported MDA. This discrepancy suggests that PNNL's I-129 MDA is not correctly calculated, as it cannot be used to determine whether a result is considered detected or not.

DOH plans to investigate the problems associated with I-129 analysis and report on the findings in the Hanford Environmental Oversight Program 2005 Data Summary Report, which will be issued in 2006.

Gross Alpha and Gross Beta

The DOH and PNNL gross alpha concentrations in water samples are in fair agreement. The split gross alpha results in all water samples are shown in Figure 3.2.4, where it can be seen that the DOH and PNNL data follow the same trend. However, a systematic bias is revealed upon close inspection of the data.

Figure 3.2.5 shows a scatter plot for historical DOH and PNNL gross alpha concentrations in water samples. This scatter plot, and all others in this section, show data for all water samples, which include groundwater, surface water, and riverbank seep water. The figure shows that DOH disproportionately reports higher concentrations than PNNL, as indicated by the data points to the right of the solid black line. This discrepancy is currently under investigation.

The DOH and PNNL gross beta concentrations in water samples are in fair agreement. The split gross beta results in groundwater are shown in Figure 3.2.6, where it can be seen that the DOH and PNNL data follow the same trend. However, a systematic bias is revealed upon close inspection of the data.

Figure 3.2.7 shows a scatter plot for historical DOH and PNNL gross beta data, with DOH concentrations below 10 pCi/L. Figure 3.2.8 shows a scatter plot for historical data, with DOH concentrations between 10 and 125 pCi/L. Finally, Figure 3.2.9 shows a scatter plot for historical data with DOH concentrations above 125 pCi/L. Inspection of these figures indicate that when gross beta concentrations are below 10 pCi/L, PNNL typically reports concentrations similar to or greater than DOH. When concentrations are between 10 and 125 pCi/L, there is a systematic bias in the results in which PNNL typically reports concentrations significantly less than DOH. For concentrations above 125 pCi/L, PNNL typically reports concentrations greater than those reported by DOH. This discrepancy is currently under investigation.

H-3, Sr-90, and Tc-99

The DOH and PNNL tritium (H-3) concentrations in water samples are in good agreement. Figure 3.2.10 shows H-3 results in split water samples for cases where concentrations are less than 20,000 pCi/L. As can be seen, the agreement between DOH and PNNL results is good. Figure 3.2.11 shows H-3 results in split water samples for cases where concentrations are greater than 20,000 pCi/L. The DOH and PNNL data follow the same trend for these higher concentrations, however the PNNL results are consistently up to 20% less than the DOH results. This phenomenon has been observed historically, as shown in the scatter plot of historical H-3 water sample results. The regression analysis indicates that PNNL results are typically 8% less than those reported by DOH.

The DOH and PNNL Sr-90 concentrations in water samples are in good agreement. Figure 3.2.13 shows Sr-90 results for water samples collected in 2004, with concentrations above the DOH detection limit of 0.7 pCi/L, and Figure 3.2.14 shows a scatter plot for historical DOH and PNNL Sr-90 results in all split water samples. The regression analysis indicates that on average, DOH and PNNL report similar Sr-90 concentrations. Historically, the DOH and PNNL split Sr-90 results in water are in good agreement.

The DOH and PNNL Tc-99 concentrations in water samples are in good agreement, as can be seen in Figure 3.2.15, which shows Tc-99 results for all water samples split in 2004. Figure 3.2.16 shows a scatter plot for historical DOH and PNNL Tc-99 results in water samples. The regression analysis indicates that on average, DOH and PNNL report similar Tc-99 concentrations. Historically, the DOH and PNNL split Tc-99 results in water are in good agreement.

Uranium Isotopes

The DOH and PNNL isotopic uranium concentrations in water samples are in good agreement. Figure 3.2.17 shows U-238 results for water samples collected in 2004 with concentrations above 0.6 pCi/L. Most of the samples have concentrations below 0.6 pCi/L, and the agreement in these data is also good. Figure 3.2.18 shows a scatter plot for historical DOH and PNNL U-238 results in water samples. The regression analysis indicates that on average, DOH and PNNL report similar U-238 concentrations. The results for U-234 are similar to those for U-238, and most of the U-235 results are below detection limits. Historically, the DOH and PNNL split uranium results in water are in good agreement.

The DOH and DOE gross alpha and gross beta concentrations for the two discharge water samples collected at the TEDF (300 DNR) facility are in good agreement. Historically, the DOH and DOE contractor discharge water concentrations are in good agreement. Figure 3.2.19 shows the historical gross alpha concentrations.

3.2.5 Discussion of DOH Results

In addition to the split water samples discussed above, DOH collected and analyzed drinking water samples from the LIGO Facility, the White Bluffs sub-station, and from the Edwin Markham elementary school in Pasco, and groundwater samples from wells 199-H4-4 and 699-35-70. Results from these additional DOH samples are included in the discussion below.

Concentrations of gamma emitting radionuclides in most 2004 water samples reported by DOH were below detection limits. The gamma emitting radionuclides reported by DOH include Co-60, Cs-134, Cs-137, I-129, and Sb-125. Detection limits are listed in Appendix B. The only detectable radionuclide was I-129, detected in groundwater from well 699-35-70 at 28 pCi/L. DOH typically detects I-129 in this well, however, the I-129 concentrations have been steadily increasing since 2003 (Figure 3.2.20). All other 2004 results for gamma emitting radionuclides are similar to historical data.

DOH typically analyzes samples from groundwater well 199-K-109A for C-14, Pu-238, and Pu-239/240, and samples from well 399-1-17A for Pu-238 and Pu-239/240. All concentrations of these radionuclides from samples collected in 2004 are below the detection limits listed in Appendix B, except for one of the Pu-239/240 results at well 399-1-17A. A Pu-239/240 concentration of 0.09 +/- 0.04 pCi/L was detected in June 2004. However, a subsequent sample collected in December 2004 was below the detection limit of 0.06 pCi/L.

DOH routinely detects H-3, Sr-90, Tc-99, isotopes of uranium, gross alpha, and gross beta in Hanford water samples. These radionuclides are detected in areas of known groundwater plumes or in areas where groundwater plumes are known to be entering the Columbia River. In 2004, most concentrations reported by DOH for these radionuclides were consistent with historical results.

DOH detected H-3 in groundwater wells at concentrations ranging from below the detection limit to 331,000 pCi/L (well 699-35-70). Concentrations above 20,000 pCi/L were detected in wells 199-K-109A, 199-K-27, 199-N-14, 699-26-33, 699-35-70, 699-41-1A, and 699-60-60. Tritium (H-3) concentrations in most well samples were consistent with historical results, with the exception of wells 199-K-109A and 199-K-27, where concentrations increased sharply in 2003 and then decreased in 2004. Historical H-3 concentrations at well 199-K-109A are shown in Figure 3.2.21. DOH will continue to monitor these wells in the future to determine if H-3 concentrations are increasing in 100K Area groundwater.

DOH detected H-3 in most of the riverbank seep water samples, with a maximum concentration of 51,000 pCi/L from a seep at the Old Hanford Townsite. H-3 concentrations at the other seeps were less than 10,000 pCi/L. These results are consistent with historical DOH riverbank seep results. Tritium was also detected in several of the Columbia River surface water samples, with a maximum concentration of 1,200 pCi/L at the Old Hanford Townsite. Tritium was detected in TEDF discharge water at 150 pCi/L, and in FFTF drinking water at 3,500 pCi/L.

DOH detected Sr-90 in groundwater wells at concentrations ranging from below the detection limit to 2,300 pCi/L. The highest concentrations were detected at wells 199-K-109A and 199-N-14, where the 2004 results are consistent with historical concentrations at these locations. Concentrations of Sr-90 in riverbank seep water ranged from below the detection limit to 3 pCi/L at a seep in the 100K Area. Strontium-90 was not detected in the 100N Area seep water sample. Concentrations of Sr-90 in all other water samples, including Columbia River surface water from the 100N Area, were below the detection limit.

DOH detected Tc-99 in groundwater wells at concentrations ranging from below the detection limit to 165 pCi/L. The highest concentrations were detected at wells 199-H4-4, 699-41-1A, and 699-60-60. The 2004 results at 699-41-1A and 699-60-60 are consistent with historical concentrations at these locations, however the 2004 result of 165 pCi/L at 199-H4-4 is a sharp increase over concentrations less than 10 pCi/L measured in 2002 - 2003. Concentrations of Tc-99 in riverbank seep water ranged from 15 pCi/L at the 300 Area to 55 pCi/L at the Old Hanford Townsite. Concentrations of Tc-99 in Columbia River surface water samples were all below the detection limit.

DOH detected total uranium (the sum of all uranium isotopes) concentrations in groundwater ranging from below the detection limit to 19 pCi/L at 199-H-4 and 41 pCi/L at 399-1-17A. 2004 results at these wells are consistent with historical results.

Total uranium concentrations of 35 and 48 pCi/L were detected in riverbank seep water from the 300 Area. These concentrations are consistent with historical results. The total uranium concentrations in all Columbia River surface water samples were similar to background values of approximately 0.3 to 0.7 pCi/L. Elevated uranium concentrations were not detected in Columbia River surface water samples in 2004. 2004 surface water concentrations are similar to historical results.

Gross alpha and gross beta analyses are for the purpose of screening, and are generally indicative of the presence of uranium isotopes and Sr-90, respectively. For samples where both gross alpha and uranium concentrations were analyzed, the gross alpha concentrations were typically consistent with the sum of concentrations from all uranium isotopes. For samples where both gross beta and Sr-90 concentrations were analyzed, gross beta concentrations were typically consistent with twice the Sr-90 concentrations (gross beta analysis detects the beta emissions from both Sr-90 and its daughter, Y-90).

Summary

Radionuclides detected in groundwater wells include H-3, I-129, Sr-90, Tc-99, and isotopes of uranium. Most radionuclide concentrations in 2004 were similar to historical data, and were detected in the vicinity of known groundwater plumes.

Radionuclides detected in riverbank seep water include H-3, Sr-90, Tc-99, and isotopes of uranium. Most radionuclide concentrations in 2004 were similar to historical data, and were detected in the vicinity of where groundwater plumes are known to be entering the Columbia River.

Radionuclides detected in surface water include H-3 and isotopes of uranium. Most radionuclide concentrations were either below detection limits or were similar to background concentrations detected at Priest Rapids Dam upstream of the Hanford Site. Elevated H-3 concentrations were detected in near-shore Columbia River surface water from the Old Hanford Townsite. However, all surface water concentrations were below EPA drinking water standards.

Radionuclides detected in drinking water samples include H-3. However, all concentrations were below EPA drinking water standards (20,000 pCi/L for H-3).

Radionuclides detected in discharge water include H-3. All concentrations were below limits set by the Department of Natural Resources. These limits are: 15 pCi/L gross alpha, 50 pCi/L gross beta, and 20,000 pCi/L H-3.

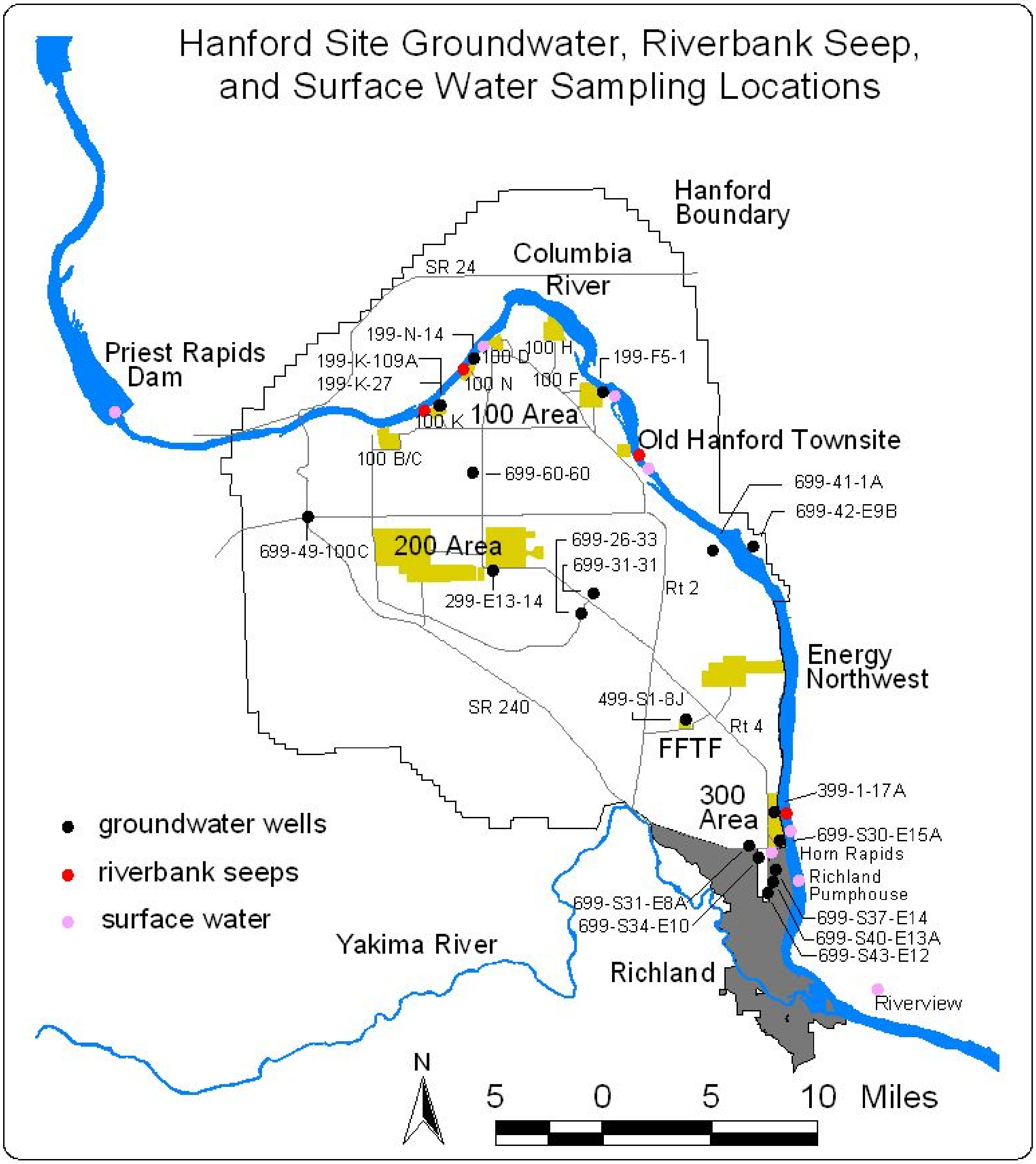

Figure 3.2.1 Water Monitoring Locations

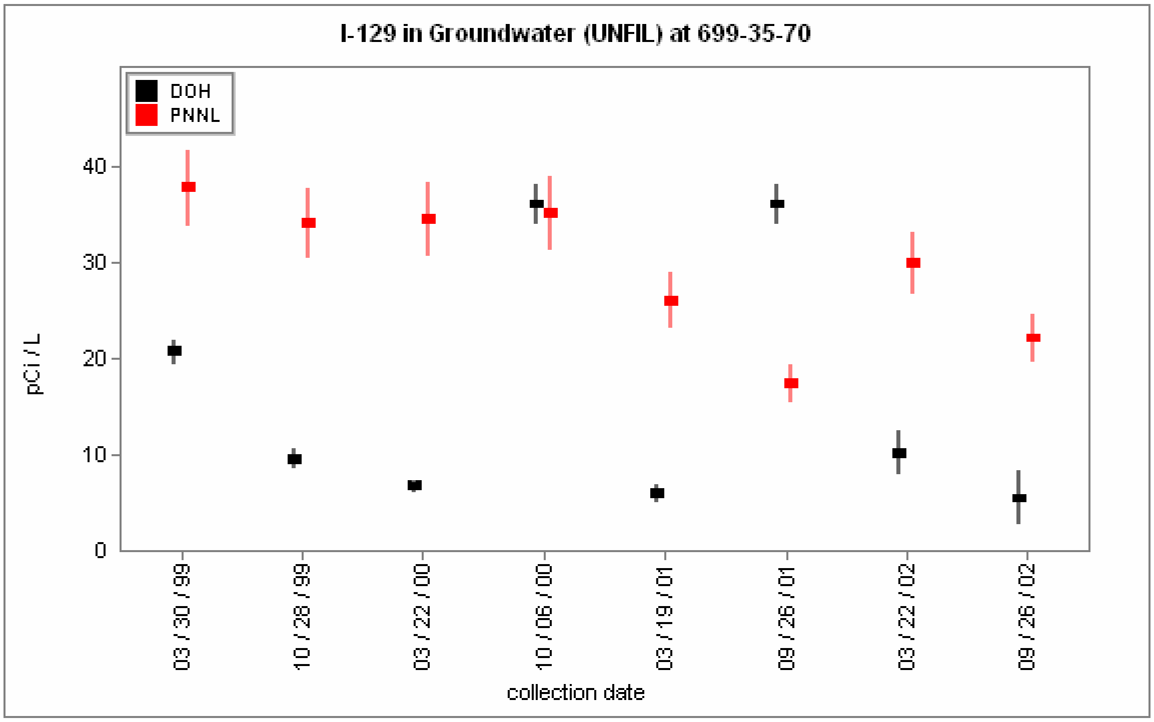

Figure 3.2.2 DOH and PNNL Historical I-129 Concentrations in Groundwater Well 699-35-70

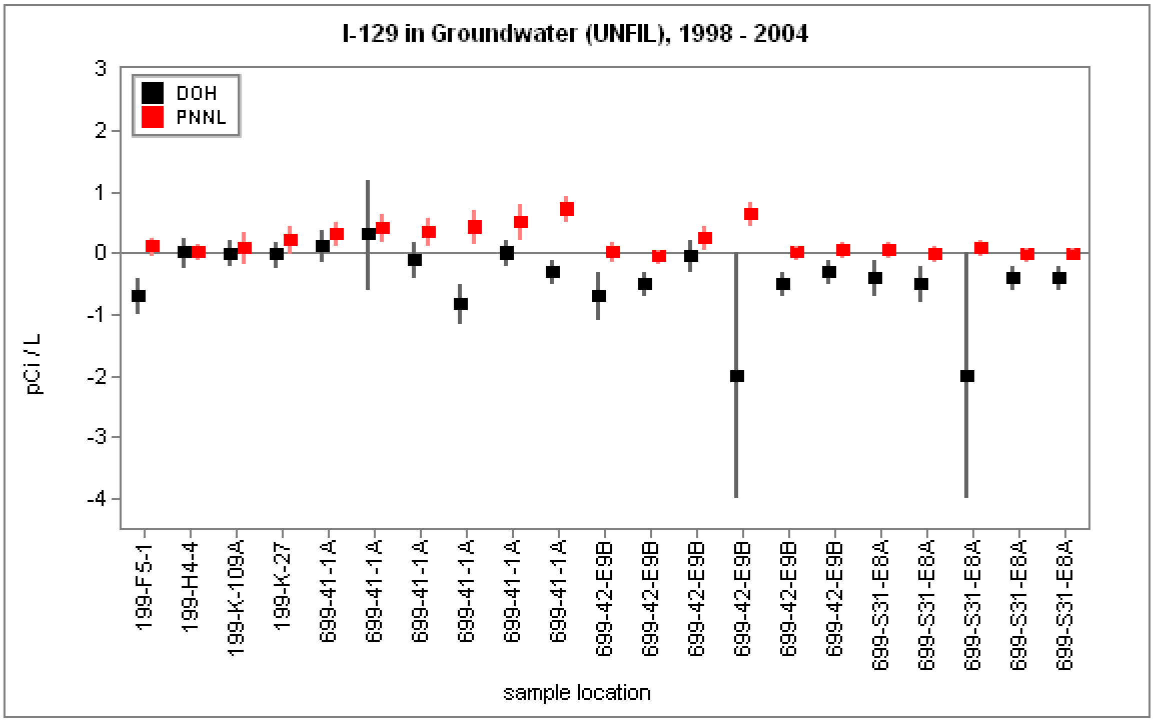

Figure 3.2.3 DOH and PNNL Historical Nondetectable I-129 Concentrations in Groundwater

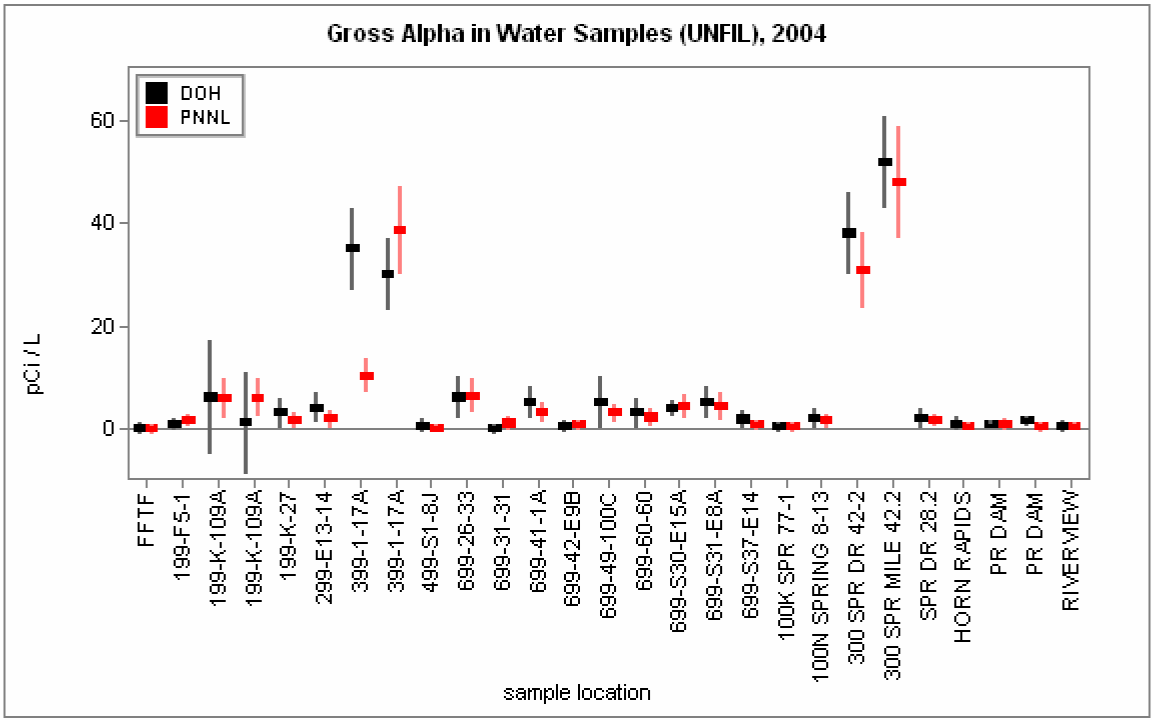

Figure 3.2.4 DOH and PNNL Gross Alpha Concentrations in All Water Samples

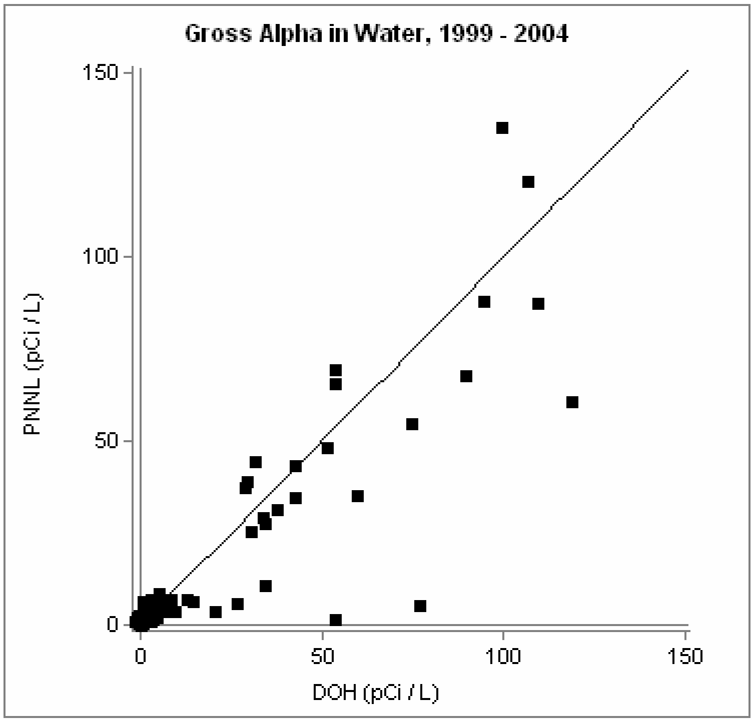

Figure 3.2.5 DOH and PNNL Scatter Plot for Historical Gross Alpha Concentrations in All Water Samples

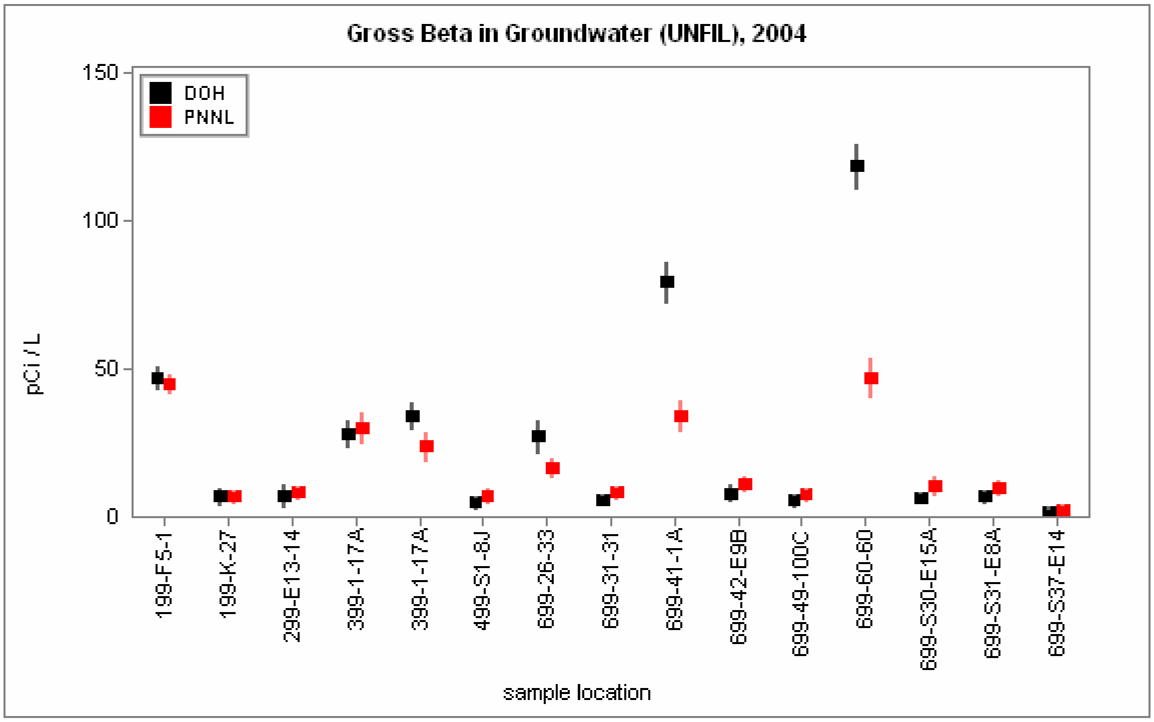

Figure 3.2.6 DOH and PNNL Gross Beta Concentrations (results less than 125 pCi/L) in Groundwater Samples

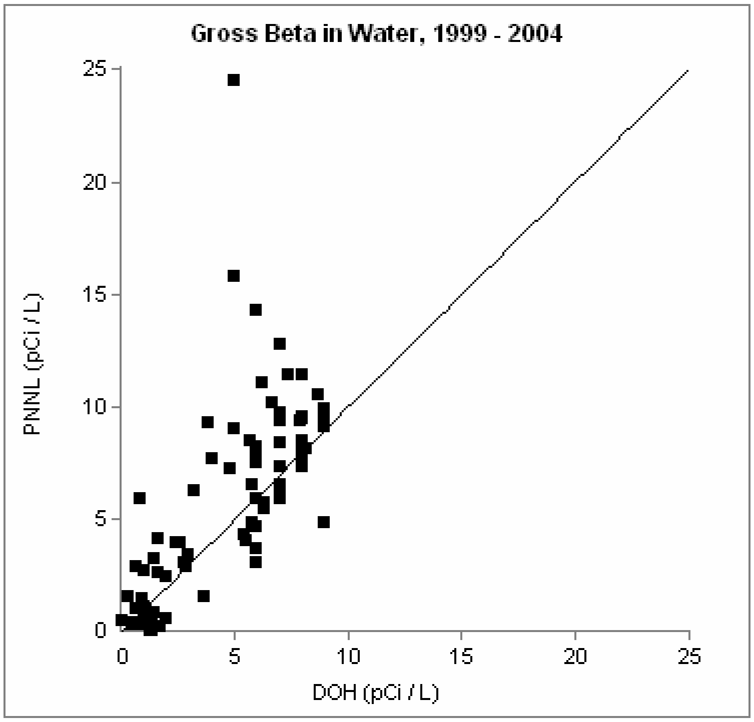

Figure 3.2.7 DOH and PNNL Scatter Plot for Historical Gross Beta Concentrations in Water Samples (DOH result less than 10 pCi/L)

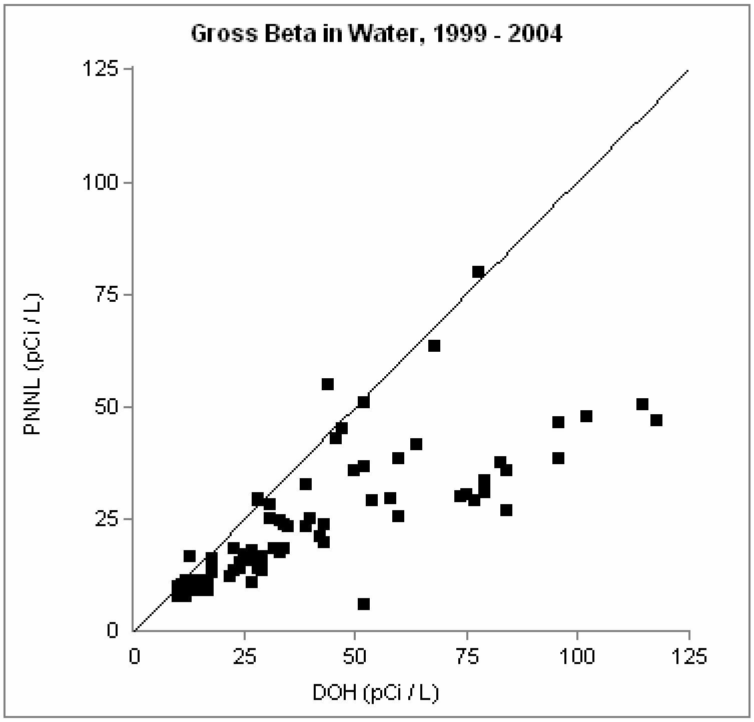

Figure 3.2.8 DOH and PNNL Scatter Plot for Historical Gross Beta Concentrations in Water Samples (DOH result between 10 and 125 pCi/L)

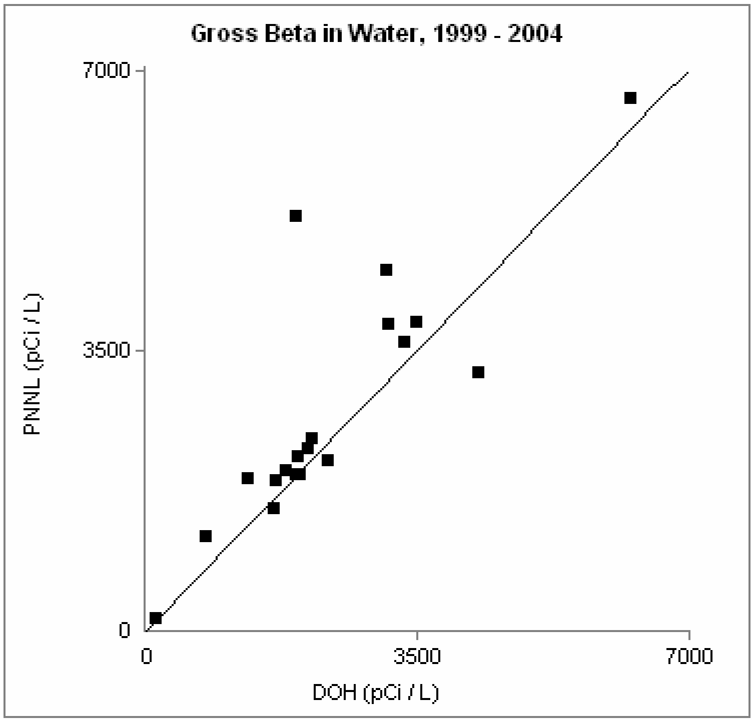

Figure 3.2.9 DOH and PNNL Scatter Plot for Historical Gross Beta Concentrations in Water Samples (DOH result greater than 125 pCi/L)

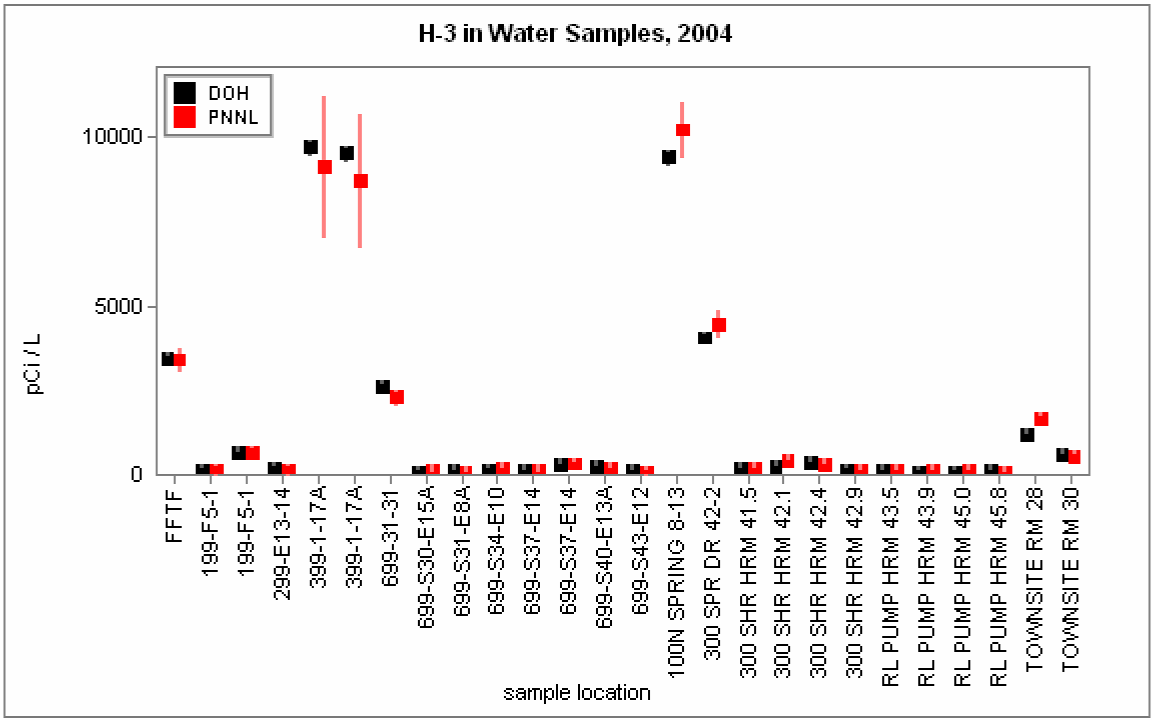

Figure 3.2.10 DOH and PNNL H-3 Concentrations in Water Samples for Concentrations Less Than 20,000 pCi/L

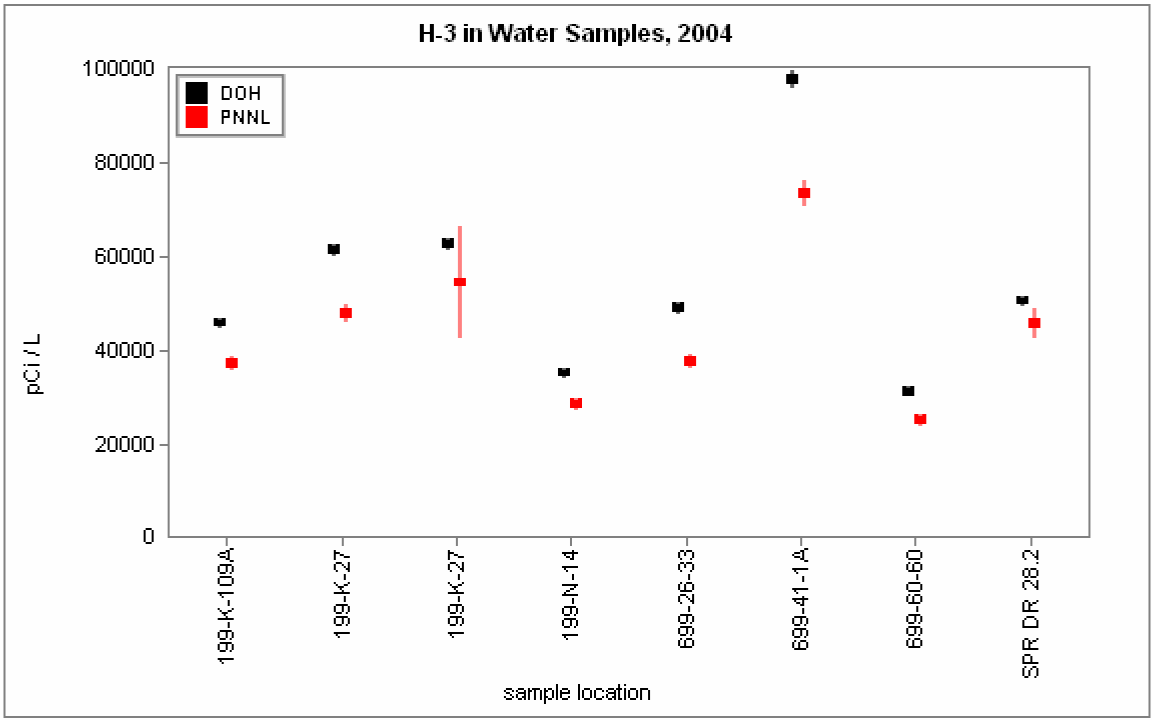

Figure 3.2.11 DOH and PNNL H-3 Concentrations in Water Samples for Concentrations Greater Than 20,000 pCi/L

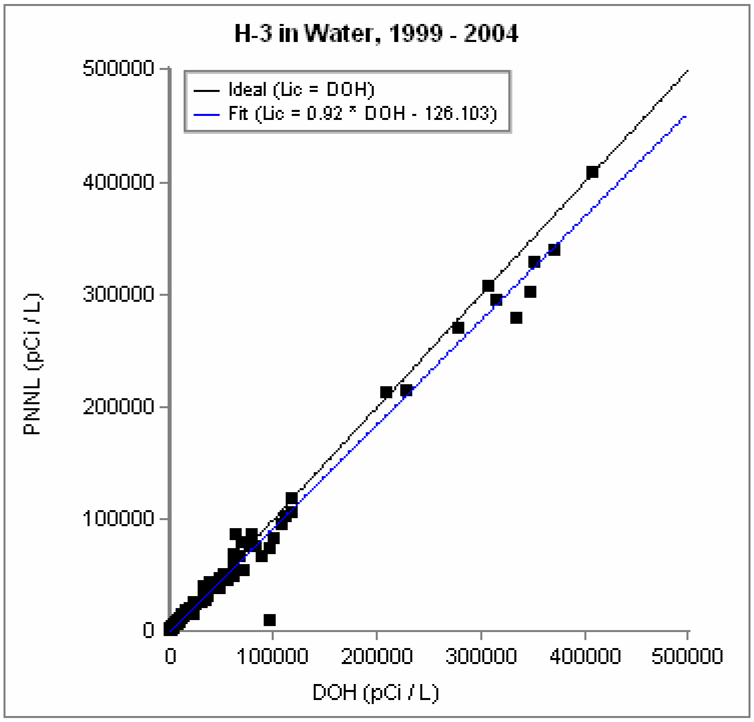

Figure 3.2.12 DOH and PNNL Scatter Plot for Historical H-3 Concentrations in Water

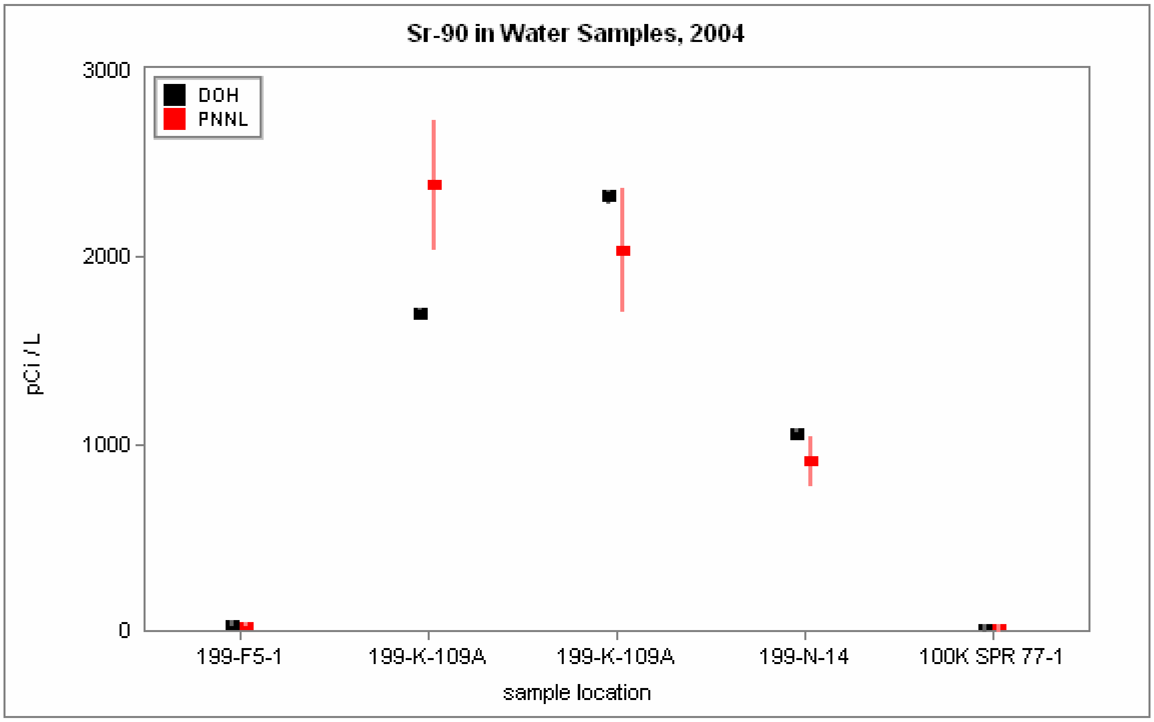

Figure 3.2.13 DOH and PNNL Sr-90 Concentrations in Water Samples for Concentrations Greater Than the DOH Detection Limit of 0.7 pCi/L

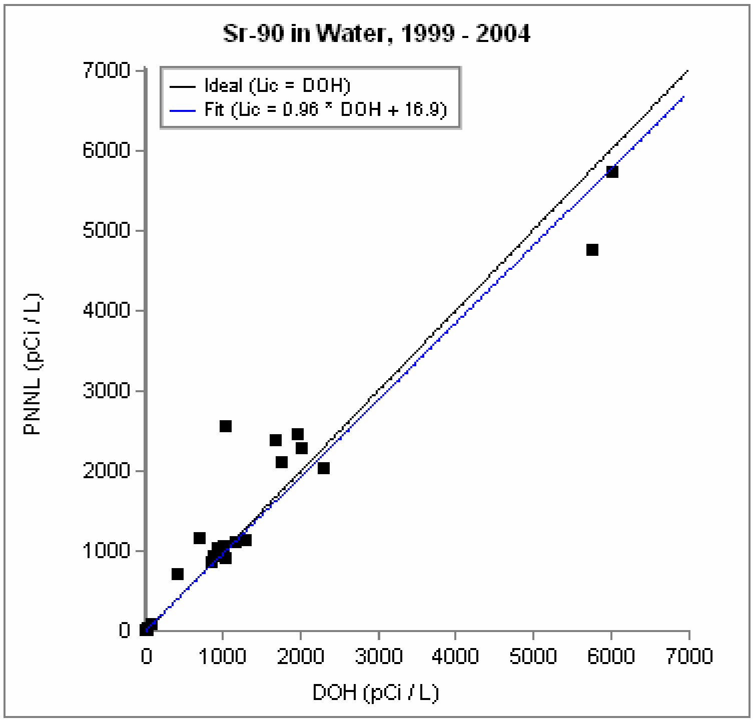

Figure 3.2.14 DOH and PNNL Scatter Plot for Historical Sr-90 Concentrations in Water

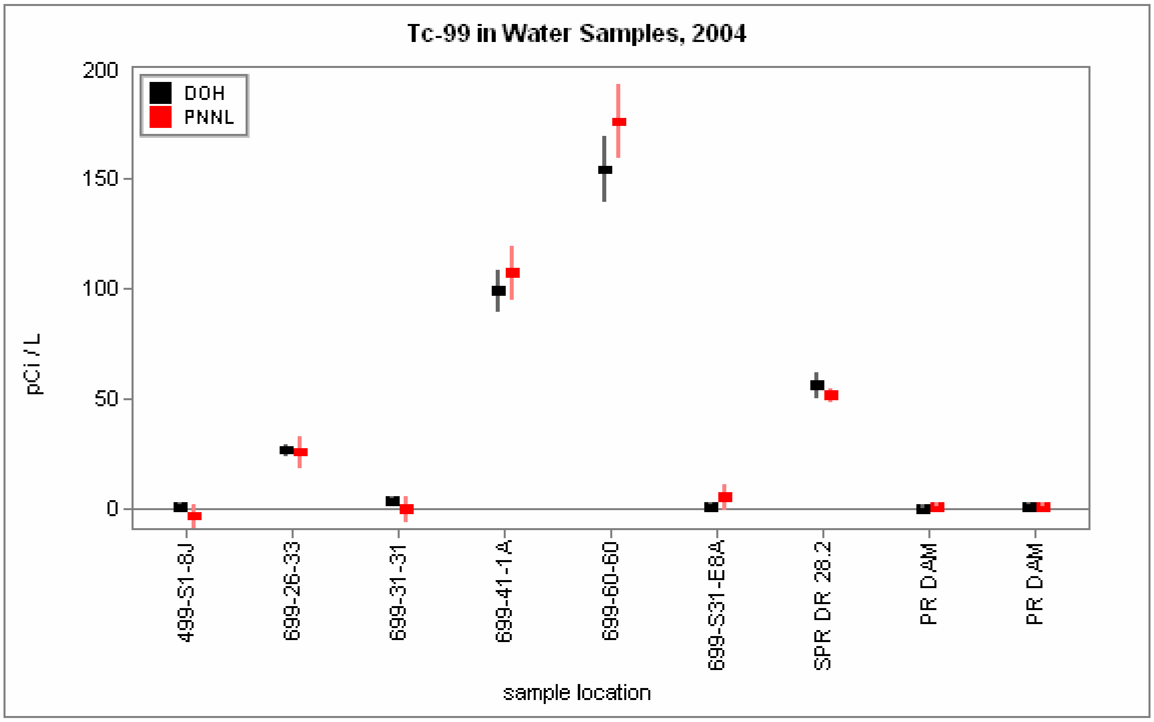

Figure 3.2.15 DOH and PNNL Tc-99 Concentrations in Water Samples

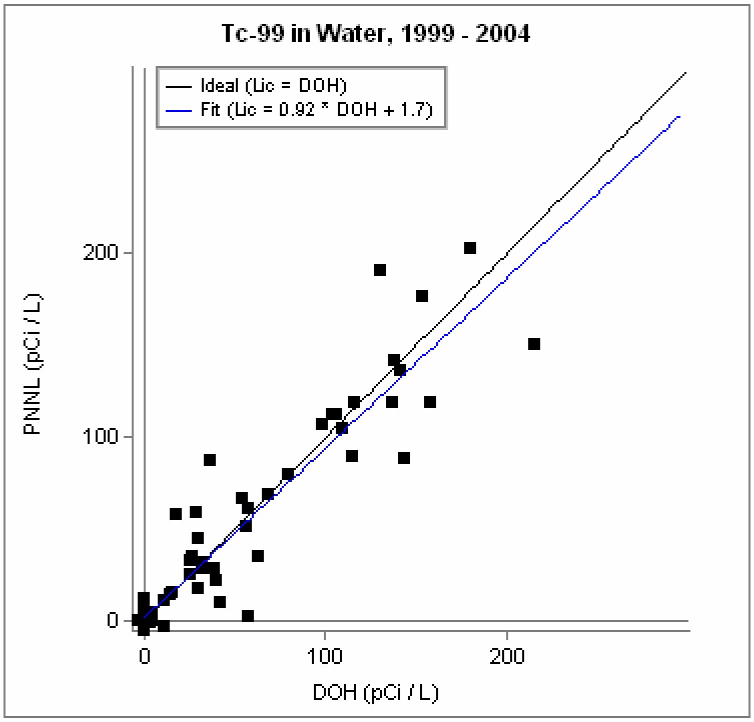

Figure 3.2.16 DOH and PNNL Scatter Plot for Historical Tc-99 Concentrations in Water

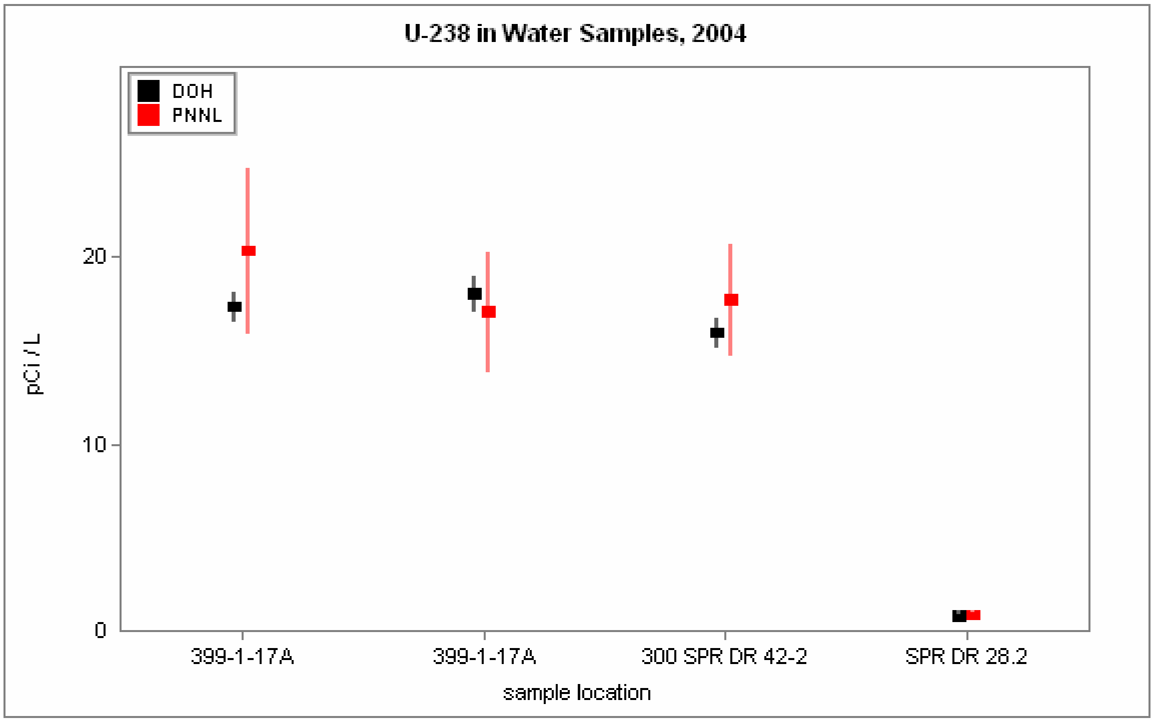

Figure 3.2.17 DOH and PNNL U-238 Concentrations in Water Samples for Concentrations Greater Than 0.6 pCi/L

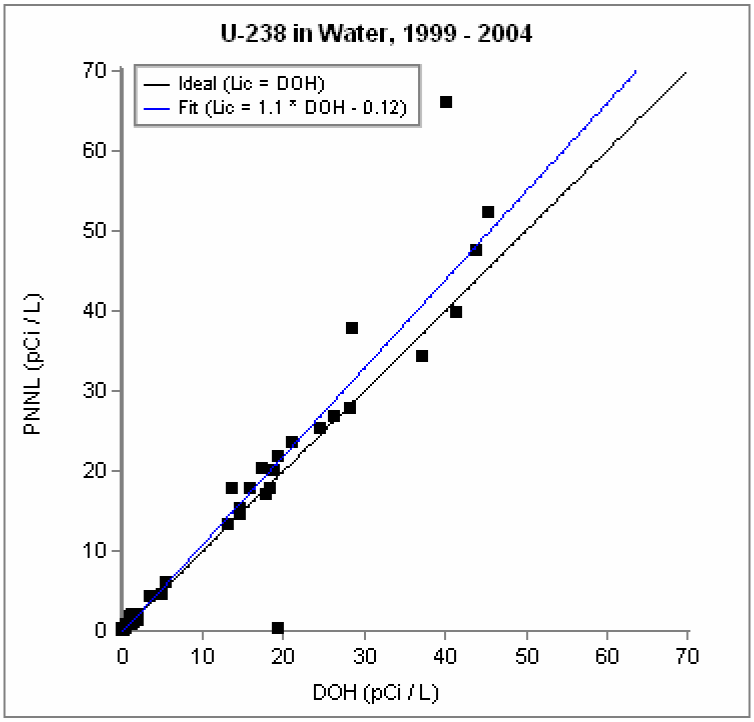

Figure 3.2.18 DOH and PNNL Scatter Plot for Historical U-238 Concentrations in Water

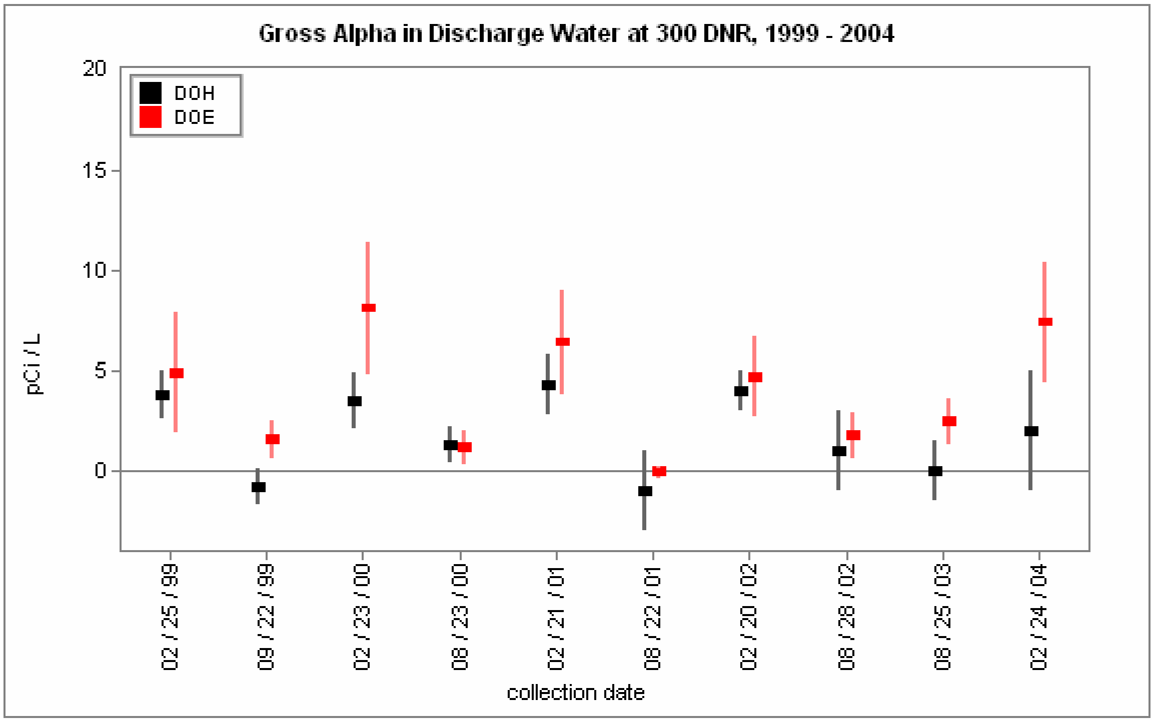

Figure 3.2.19 DOH and DOE Historical Gross Alpha Concentrations in Discharge Water at the TEDF Facility

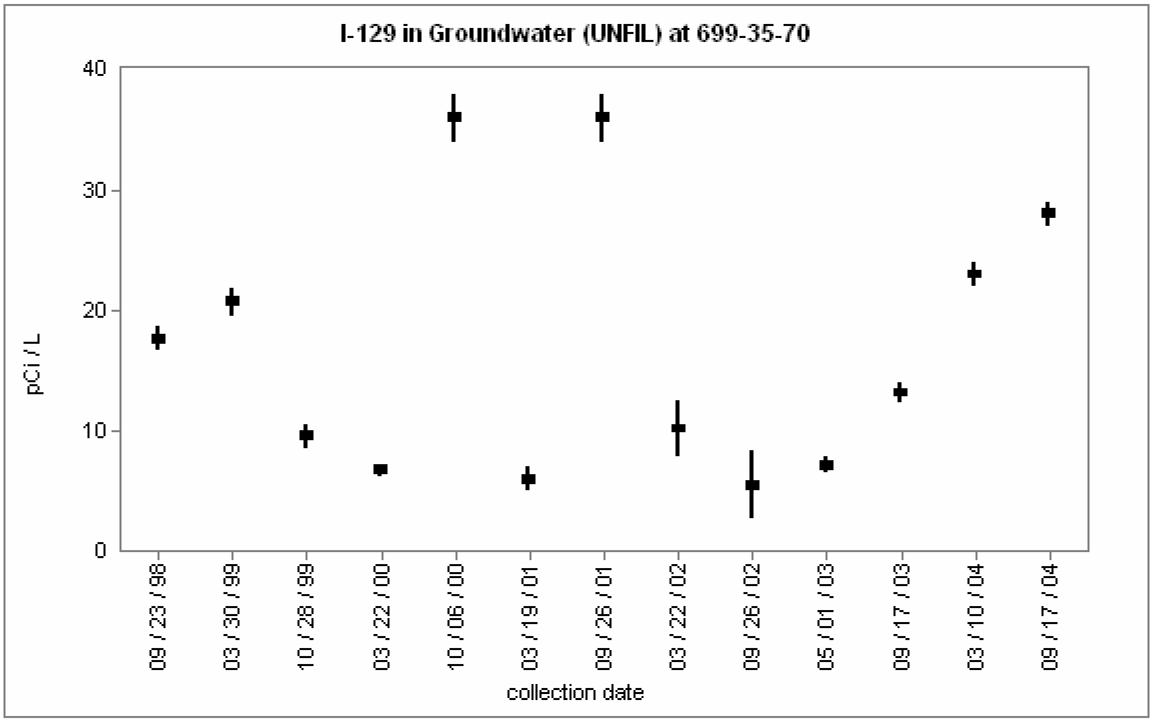

Figure 3.2.20 Historical I-129 Concentrations in Groundwater Well 699-35-70

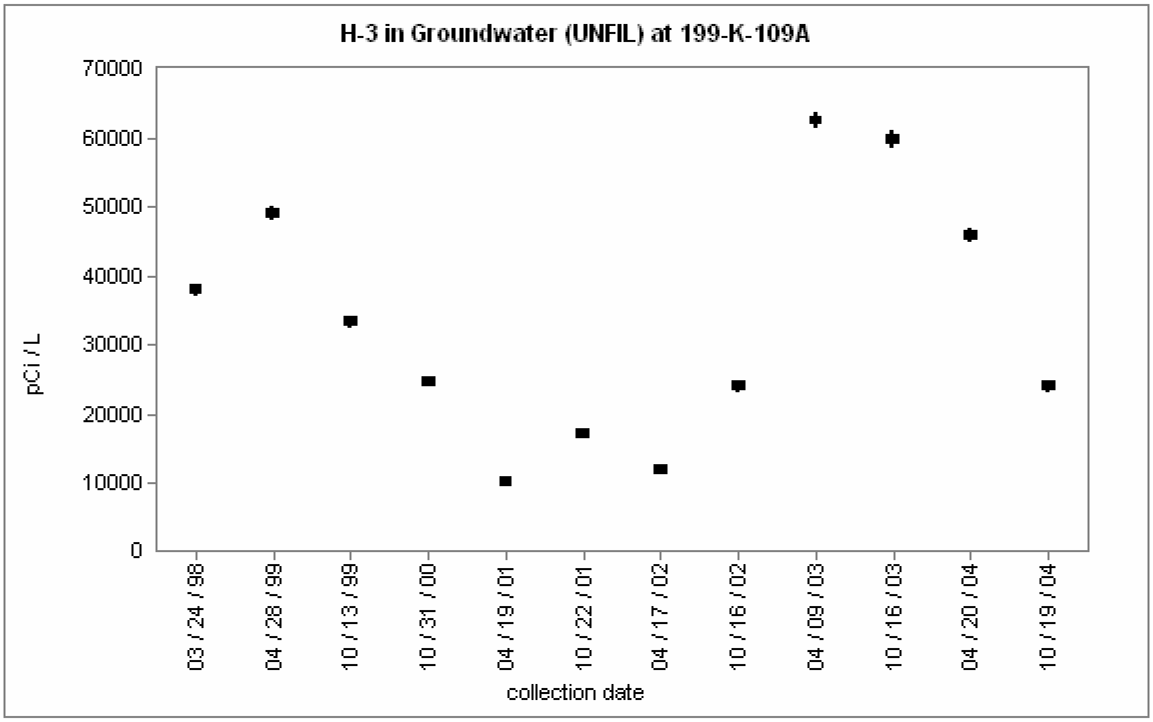

Figure 3.2.21 Historical H-3 Concentrations in Groundwater Well 199-K-109A

3.3 External Gamma Radiation Monitoring

Major Findings:

- The DOH and DOE contractor results are in good agreement.
- Radiation exposure rates at DOH TLD locations on the Hanford Site range from background to 1.5 times higher than exposure rates at perimeter and distant locations.
- The portion of exposure rate that is above background is below regulatory limits at all DOH TLD locations.

3.3.1 Purpose and General Discussion

The Department of Health and DOE contractors monitor external gamma radiation levels with Thermoluminescent Dosimeters (TLDs). TLDs measure the time-integrated exposure to gamma radiation at their location. Sources of background gamma radiation include natural cosmic and terrestrial radiation as well as fallout from atmospheric testing of nuclear weapons. Contamination from the Hanford Site may contribute to man-made sources of gamma radiation. In addition to oversight of the DOE monitoring program, DOH compares on-site and off-site TLD results to determine if Hanford is impacting workers or the public.

3.3.2 Monitoring Locations

In 2004, DOH operated 25 ambient gamma radiation monitoring sites under the Hanford Environmental Oversight Program, five of which are colocated with Duratek, and 20 of which are colocated with PNNL. The site locations are shown in Figure 3.3.1. Thirteen of the TLD sites are located near Hanford operational or contaminated facilities. Three sites (Yakima and Wye Barricades, and Ligo Facility) are located on the Hanford Site, but away from contaminated areas. Six of the sites (Stations 4, 6, 8, and 56, Byer’s Landing; and Benton County Shops) are located just outside the Hanford Site perimeter. The remaining three sites (Othello, Toppenish, and Yakima Airport) are significantly distant from the Hanford Site. Many of the TLD sites are colocated with air monitoring sites.

3.3.3 Monitoring Procedures

TLDs are deployed on a quarterly basis, with the TLDs retrieved at the end of each calendar quarter. The DOH TLDs are sent to the State Public Health Laboratory where the time-integrated gamma radiation exposure is determined for the three month period. The results are then converted to an average daily radiation exposure rate and reported in units of milliroentgen per day (mR/day). At the same time the TLDs are retrieved, a new TLD is placed at each site.

3.3.4 Comparison of DOH and Contractor Data

Note that the DOH third quarter TLD results at all sites are not reported because of damage to these TLDs prior to laboratory analysis.

The DOH and Duratek TLD results for the five colocated sites are shown in Figure 3.3.2, and the DOH and PNNL TLD results at the sites near operational or contaminated facilities are shown in Figure 3.3.3. Each of these figures show the first, second, third, and fourth quarter results for each site. As can be seen, there is good agreement between the DOH and DOE contractor results, as the two data sets follow the same trends. However, close inspection of the figures indicates that the Duratek and PNNL dose rates are typically slightly higher than those reported by DOH.

DOH/Duratek and DOH/PNNL scatter plots for the colocated TLD sites are shown in Figures 3.3.4 and 3.3.5, respectively. The x-coordinate of each point represents the DOH result, while the y-coordinate represents the contractor result. Ideally, if the DOH and contractor results were identical, all the points would fall on a straight line, with slope equal to unity and y-intercept equal to zero (shown as the solid black line in the figure). The small discrepancy between DOH/Duratek and DOH/PNNL results is seen in the scatter plots by the preponderance of points to the left of the solid black line, which indicates that the DOE contractor is reporting slightly higher exposure rates (about 10%) than DOH. This discrepancy is small, and is not considered significant.

3.3.5 Discussion of DOH Results

The quarterly external radiation exposure rates at locations on the Hanford Site near operational or contaminated areas range from 0.18 to 0.29 mR/day, with an average of 0.23 mR/day. The average exposure rate at perimeter locations is 0.22 mR/day, and at distant locations is 0.19 mR/day. The exposure rates at the distant locations are slightly lower than the perimeter locations, most likely due to different concentrations of naturally occurring radioactivity at the distant locations. The exposure rates at locations near operational or contaminated areas are similar to those at perimeter locations.

The highest annual average exposure rate at any site, 0.26 mR/day measured at 100N-1, is slightly higher than the average perimeter exposure rate of 0.22 mR/day. A person spending 365 days at this location would receive 15 mR greater than the annual exposure at the Site perimeter. An exposure rate of 15 mR/year, or approximately 15 mrem/year, is well below radiation exposure limits for workers, and is also below the DOE limit of 100 mrem/yr to the public from DOE operations. There is no public access to this location on the Hanford Site.

Historical DOH TLD data were examined for all of the TLD sites to determine if any new trends are present. All sites, except 100N-1, show consistent exposure rates over time. The historical data for site 100N-1 are shown in Figure 3.3.6. Exposure rates at this site have been decreasing over time due to the natural decay of Co-60 surface contamination (half life = 5 years) at the 100N Area. With the recent cleanup of contaminated surface soil, exposure rates over the past few years now appear constant at rates only slightly higher than those at perimeter locations.

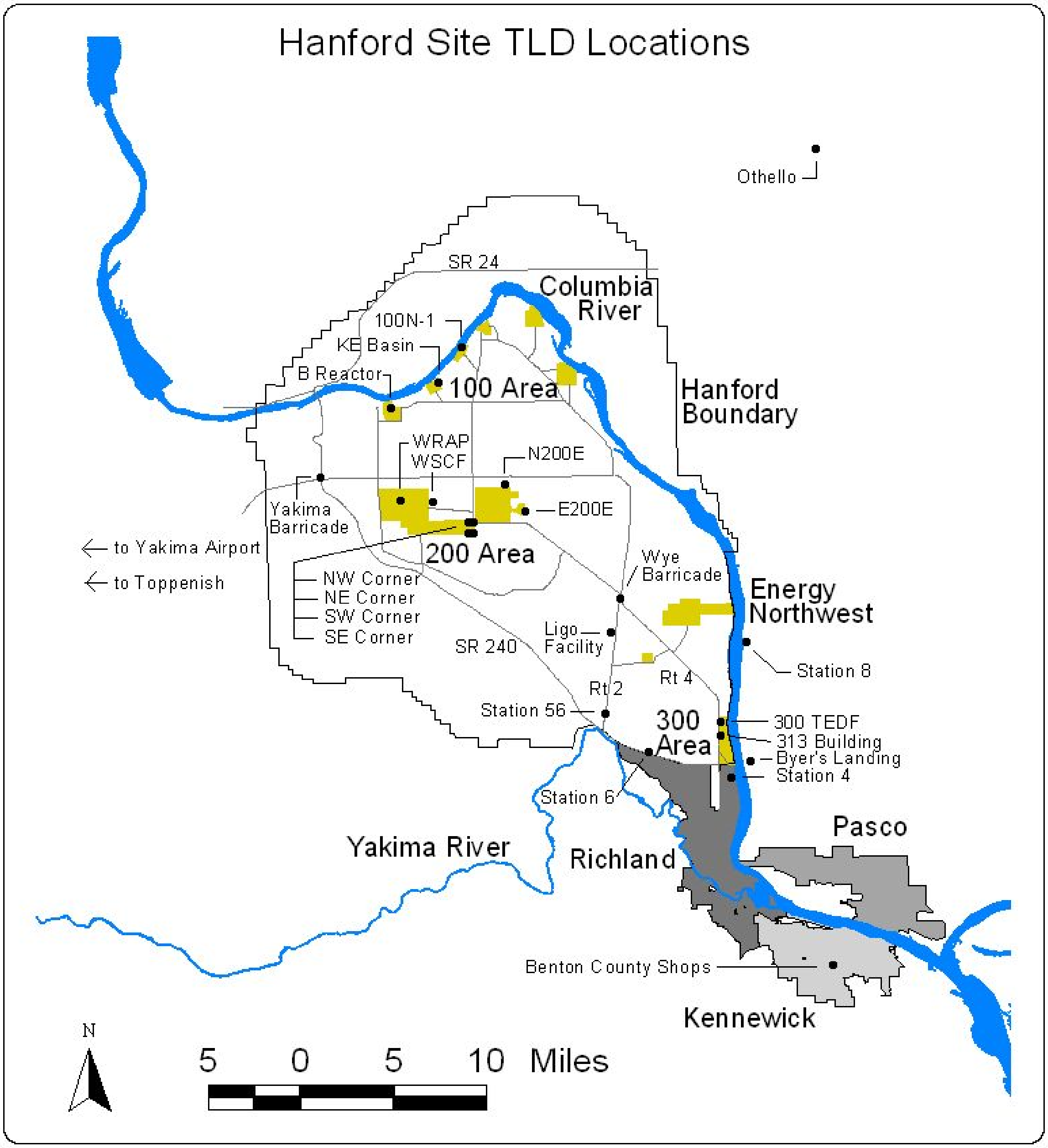

Figure 3.3.1 External Radiation Monitoring (TLD) Locations

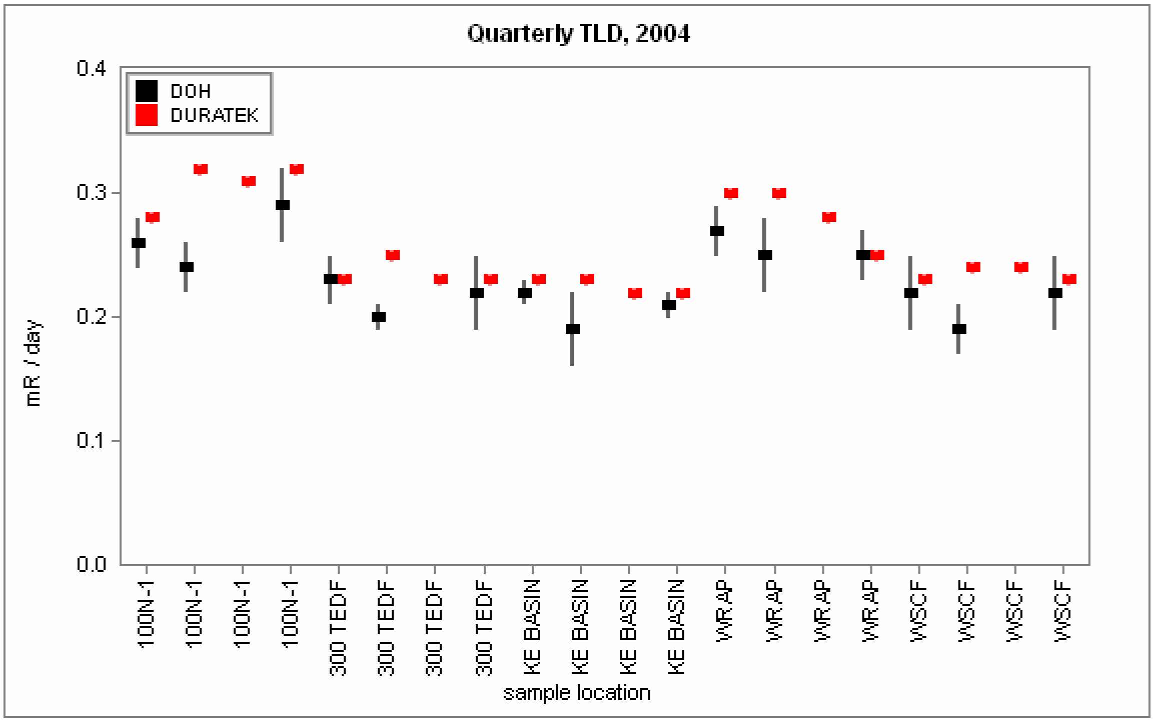

Figure 3.3.2 DOH and Duratek Quarterly TLD Results

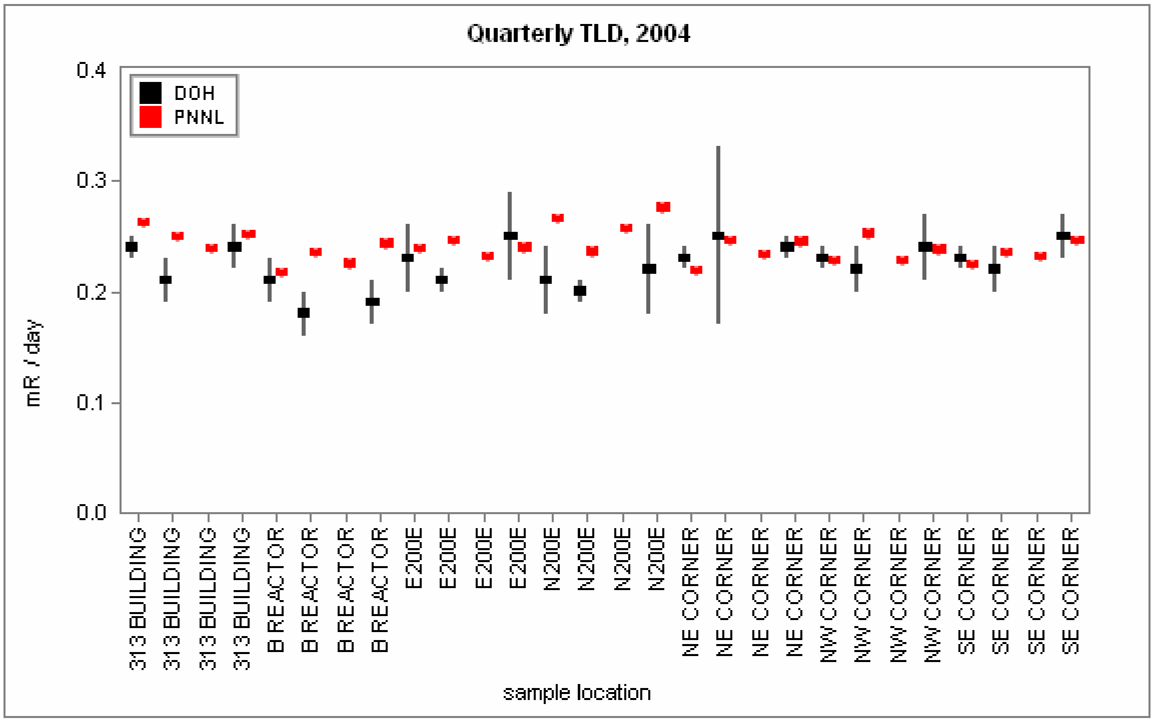

Figure 3.3.3 DOH and PNNL Quarterly TLD Results at Sites Near Operational or Contaminated Facilities

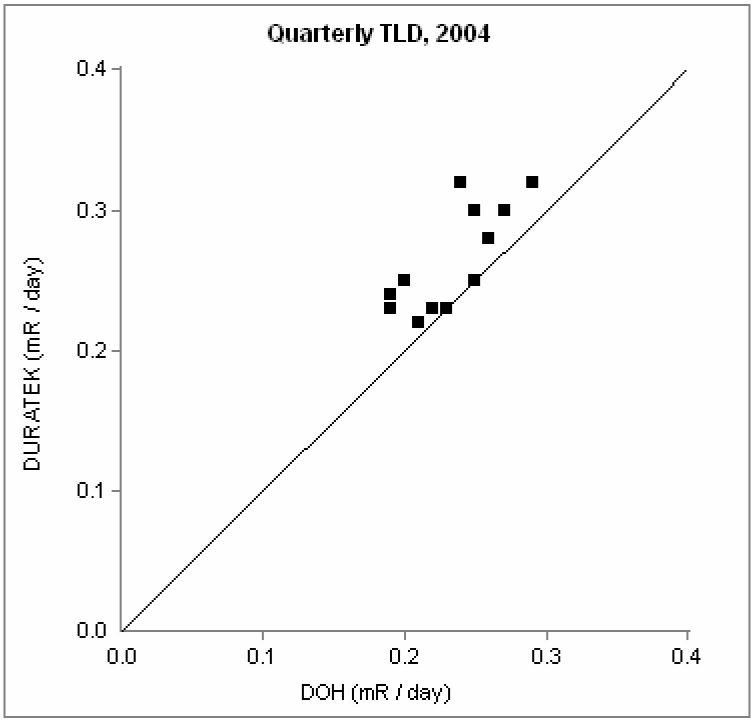

Figure 3.3.4 DOH and Duratek Scatter Plot for TLD Results

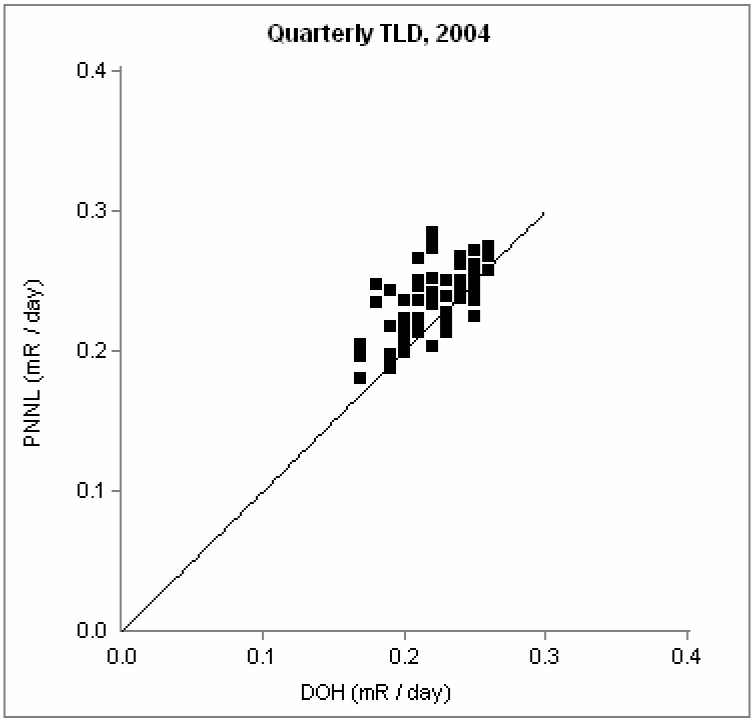

Figure 3.3.5 DOH and PNNL Scatter Plot for TLD Results

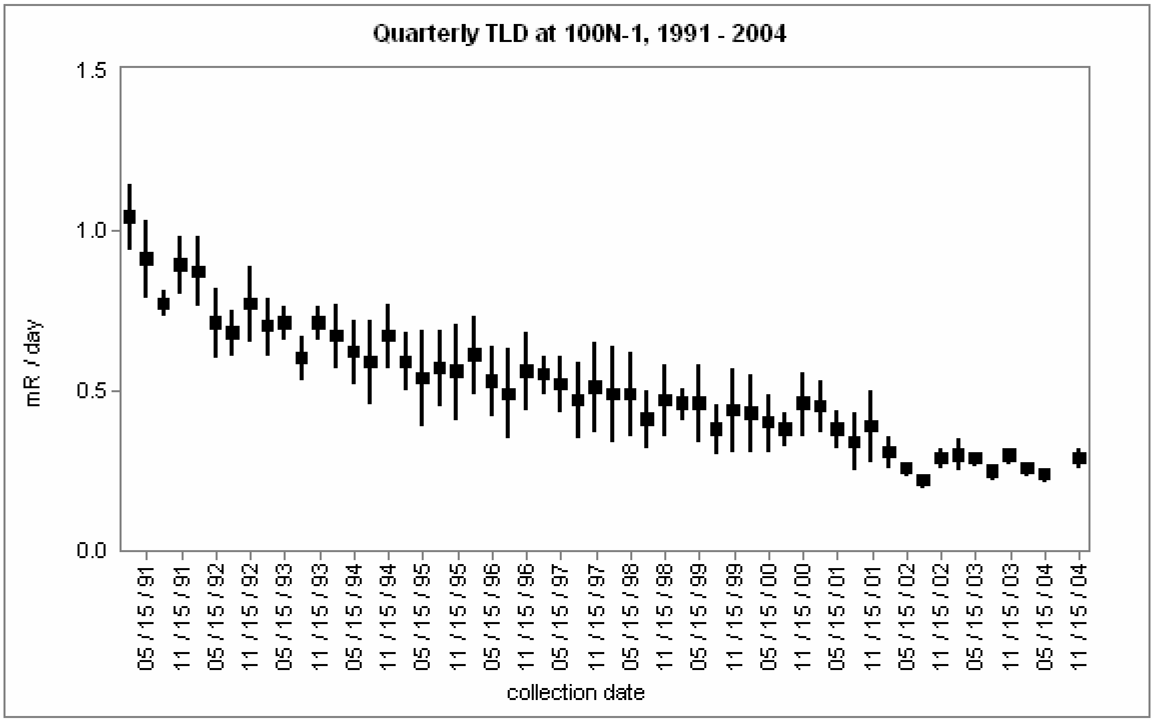

Figure 3.3.6 Historical DOH TLD Results at Location 100N-1 in the 100N Area

3.4 Soil and Sediment Monitoring

Major Findings:

- DOH and PNNL results in sediment are in good agreement for all radionuclides, except for isotopes of uranium. The discrepancy in uranium results is understood, and originates from a difference in DOH and PNNL laboratory analytical methods.
- Concentrations of radionuclides in most sediment and soil samples are either consistent with those at background locations or are in the range of activity that has been historically observed at Hanford.

3.4.1 Purpose and General Discussion

Contaminated soil and river sediments are a potential source of radiation exposure for people and biota in the environment. Human exposure may result from direct exposure to contaminated soil/sediment; ingestion of contaminated soil/sediment; ingestion of water contaminated by sediment resuspension; inhalation of contaminants resuspended in air; or ingestion of fish, animals, plants, or farm products exposed to contaminated soil and sediments.

Radionuclides in soil and sediment originate from many sources, including natural terrestrial sources, atmospheric fallout from nuclear weapons tests, and contaminated liquid and gaseous effluents. In addition, contaminants can reach Columbia River sediments from erosion of contaminated soil and flow of contaminated groundwater. Cesium-137, Sr-90, and plutonium isotopes are radionuclides consistently seen in soil or sediments since they exist in worldwide fallout as well as in effluents from the Hanford Site. Uranium, also consistently seen in soil and sediment, occurs naturally in the environment in addition to being present from Hanford operations.

3.4.2 Monitoring Locations

In 2004, 13 soil samples and 20 Columbia River sediment samples were split with PNNL. The soil samples were collected from the 100 Area, 200 Area, 300 Area, the Fast Flux Test Reactor, and several sites distant from Hanford. The sediment samples were collected upstream of Hanford at Priest Rapids Dam, on the Hanford Site at the 100F Area slough and the 300 Area, and downriver of Hanford at the John Day and McNary Dams.

Priest Rapids Dam, being upstream from Hanford, is considered a background location. McNary Dam is the first dam downstream from Hanford, and therefore is expected to have the highest radionuclide concentrations. Sediment locations within the Hanford boundary change from year to year and are chosen to monitor areas where contaminants may be discharged into the river, areas where deposits could accumulate, or areas where the public may gain access to the shoreline. In 2004, on-site sediment sample locations included the 100F and 300 Areas.

3.4.3 Monitoring Procedures

Soil samples were collected by compositing four one-square foot areas, each excavated to a depth of one inch. The composited samples were split with PNNL or Duratek and dried prior to analysis. Samples were analyzed for radionuclides that are most likely present in the area sampled. This includes gamma-emitting radionuclides, Sr-90, isotopic uranium, and isotopic plutonium.

Sediment samples represent surface sediments and were collected with either a clam-shell style sediment dredge or, in the case of shoreline sediments, a plastic spoon. Sediment samples were collected by PNNL and then split with DOH. The samples were first dried, then analyzed for gamma emitting radionuclides, strontium 90, isotopic uranium, and isotopic plutonium. Analytical methods for soil and sediment are identical.

3.4.4 Comparison of DOH and Contractor Data

The DOH and PNNL split soil and sediment concentrations for gamma emitting radionuclides (Co-60, Cs-137, Eu-152, Eu-154, Eu-155, Ru-106, and Sb-125) are in good agreement. As an example, the split Cs-137 results in sediment samples are shown in Figure 3.4.1. Except for Cs-137 and Eu-152, most of the results are below detection limits.

The split Sr-90 results, shown in Figure 3.4.2, are in good agreement, although there is a significant difference in detection limits as indicated by the size of the uncertainty bars in the figure. All but one of the DOH results are considered detected, as the concentrations are above the DOH detection limit of 0.002 pCi/g. However, the PNNL detection limit is much larger, and therefore the PNNL results are considered below their detection limit; likewise, the DOH results are below the PNNL detection limit.

Most of the split results for the alpha emitting radionuclides Am-241, Pu-238, and Pu-239/240 are in good agreement. The split Pu-238 results in sediment are shown in Figure 3.4.3, and the split Pu-239/240 results in sediment are shown in Figure 3.4.4. A few of the plutonium results have a small disagreement.

The DOH and PNNL split soil and sediment results for isotopes of uranium are in fair agreement. The split U-238 results in soil for 2004 are shown in Figure 3.4.5. In addition, the historical U-238 results for both soil and sediment (1999 through 2004) are shown in a scatter plot in Figure 3.4.6. The slope of the best-fit straight line to the data indicates that on average, the PNNL U-238 concentrations are approximately 80% of the concentration reported by DOH. The agreement for U-234 and U-235 is similar.

This discrepancy in uranium results for sediment originates from different laboratory procedures. DOH completely dissolves soil and sediment samples prior to analysis and reports uranium present in the entire sample, whereas the contractor laboratory reports only the uranium that can be leached from the surface of the soil or sediment granules. A similar discrepancy is seen in the U-235 and U-234 soil results (not shown).

3.4.5 Discussion of DOH Results

DOH collected several additional sediment samples beyond those split with PNNL. The results from these additional samples, along with the DOH results from the split samples, are discussed in this section.

Radionuclides consistently identified by DOH in soil and sediment samples collected in 2004 include Cs-137, U-234, U-235, and U-238. Uranium-233 (lower limit of detection approximately 0.1 pCi/g), was not detected in any of the sediment samples. The Cs-137 results are attributed to world-wide fallout as a result of nuclear weapons testing, and most of the uranium results are attributed to natural background.

Concentrations of Cs-137 in sediment ranged from 0.02 to 0.6 pCi/g, with most samples at 0.3 pCi/g. The concentrations in soil ranged from below the detection limit to 1.5 pCi/g, with the maximum concentration from a site near the 200 Area. All Cs-137 concentrations are consistent with historical results, and most are similar to those measured at the background location at Priest Rapids Dam

Concentrations of U-234 and U-238 in sediment were typically near 1.2 pCi/g, which is consistent with concentrations at the background location near Priest Rapids Dam. The maximum concentration of 3 pCi/g was found in two samples from the 300 Area shoreline. Higher uranium concentrations in sediment are expected from the 300 Area, since a known uranium groundwater plume is entering the Columbia River at this location. Historical U-238 concentrations in 300 Area sediment are shown in Figure 3.4.7.

Concentrations of U-234 and U-238 in soil were typically near 0.6 pCi/g, which is consistent with background. Uranium 235 concentrations in sediment and soil ranged between 0.02 and 0.04 pCi/g, which is just above the detection limit of 0.02 pCi/g.

Other radionuclides identified in some of the sediment and soil samples include Am-241, Eu-152, Pu-238, Pu-239/240, and Sr-90. Americium 241 was detected at 0.04 pCi/g in a soil sample from near the 200 Area. The 2004 result at this site is consistent with historical results.

DOH detected Eu-152 in several sediment samples, with concentrations ranging from 0.05 to 0.15 pCi/g. The maximum concentration was found at McNary Dam, where Eu-152 is historically found in sediment (see Figure 3.4.8). Europium-152 was not detected in sediment at the Priest Rapids Dam background location. A concentration of 0.05 pCi/g was found in a 100K Area soil sample. All 2004 Eu-152 concentrations in sediment and soil are consistent with historical results.

Plutonium-238 is rarely detected by DOH in sediment samples. However, concentrations of 0.01 pCi/g were detected in 2004 at McNary Dam and the background location at Priest Rapids Dam. Historically, Pu-238 has been occasionally found at similar concentrations at these locations. There is no significant difference in sediment Pu-238 concentrations from sites upstream (Priest Rapids) and downstream (McNary) of

Hanford. All other Pu-238 results in sediment and soil are below the detection limit of 0.005 pCi/g.

Plutonium 239/240 is often detected by DOH in sediment and soil samples, as it is typically found in the environment originating from worldwide fallout of nuclear weapons testing. Sediment concentrations from samples collected in 2004 ranged from below the detection limit of 0.005 pCi/g to 0.025 pCi/g, and soil concentrations ranged from below the detection limit to 0.35 pCi/g. In both cases, the concentrations found in 2004 are consistent with historical results.

The highest Pu-239/240 concentration in sediment was found at the background location near Priest Rapids Dam. Historical Pu-239/240 concentrations in sediment at Priest Rapids and McNary Dam are shown in Figures 3.4.9 and 3.4.10, respectively. Note from the figures that there is no significant difference in sediment concentrations from the site upstream (Priest Rapids) and downstream (McNary) of Hanford. The average Pu-239/240 concentration at both locations is approximately 0.009 pCi/g.

The highest Pu-239/240 concentration of 0.35 pCi/g in soil was found at a site near the 200 Area. The concentration measured in 2004 at this site is consistent with historical results, and is elevated compared to concentrations typically found in soil, which range from below the detection limit to 0.03 pCi/g.

Strontium 90 concentrations in sediment samples collected in 2004 ranged from below the detection limit to 0.03 pCi/g, with the highest concentration found at the background location near Priest Rapids Dam. Strontium-90, which is found in the environment from world-wide fallout of nuclear weapons testing, has been historically detected by DOH at Priest Rapids Dam (upstream of Hanford) and McNary Dam (downstream of Hanford), as seen in Figure 3.4.11. Note that there is no significant difference in concentrations between the upstream and downstream sites. Strontium-90 was not reported in any of the DOH soil samples.

Cobalt 60, Eu-154, and Eu-155 were not detected in any of the DOH sediment and soil samples collected in 2004.

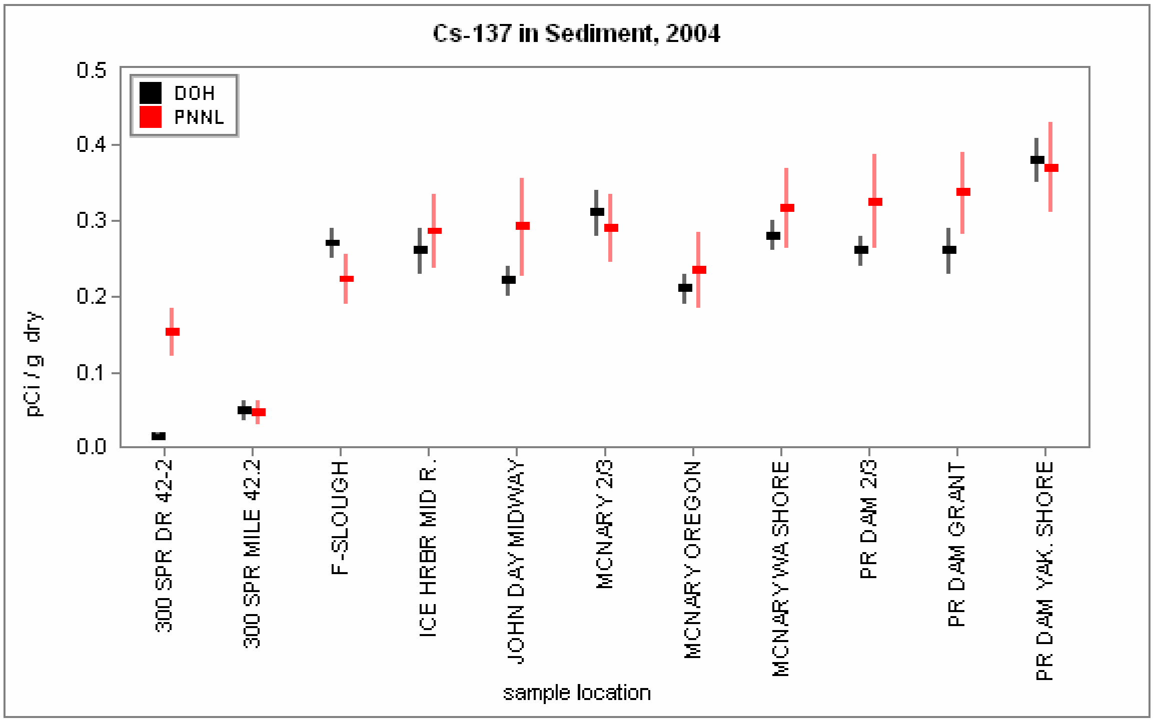

Figure 3.4.1 DOH and PNNL Cs-137 Concentrations in Columbia River Sediment

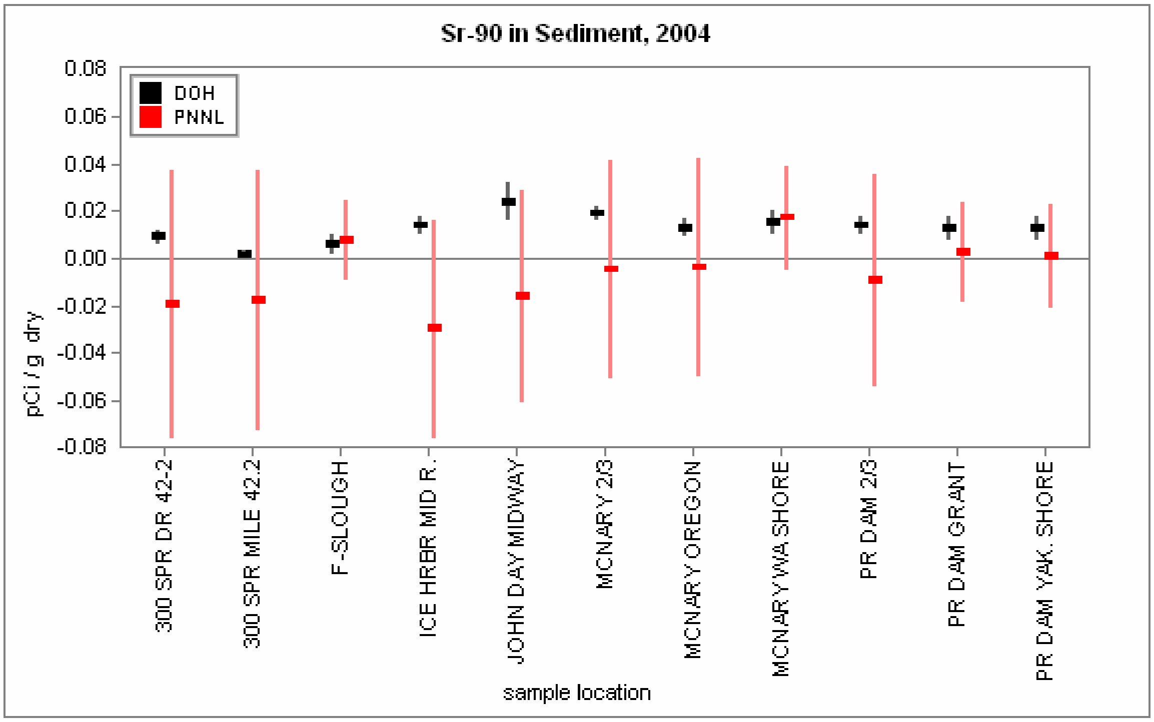

Figure 3.4.2 DOH and PNNL Sr-90 Concentrations in Sediment

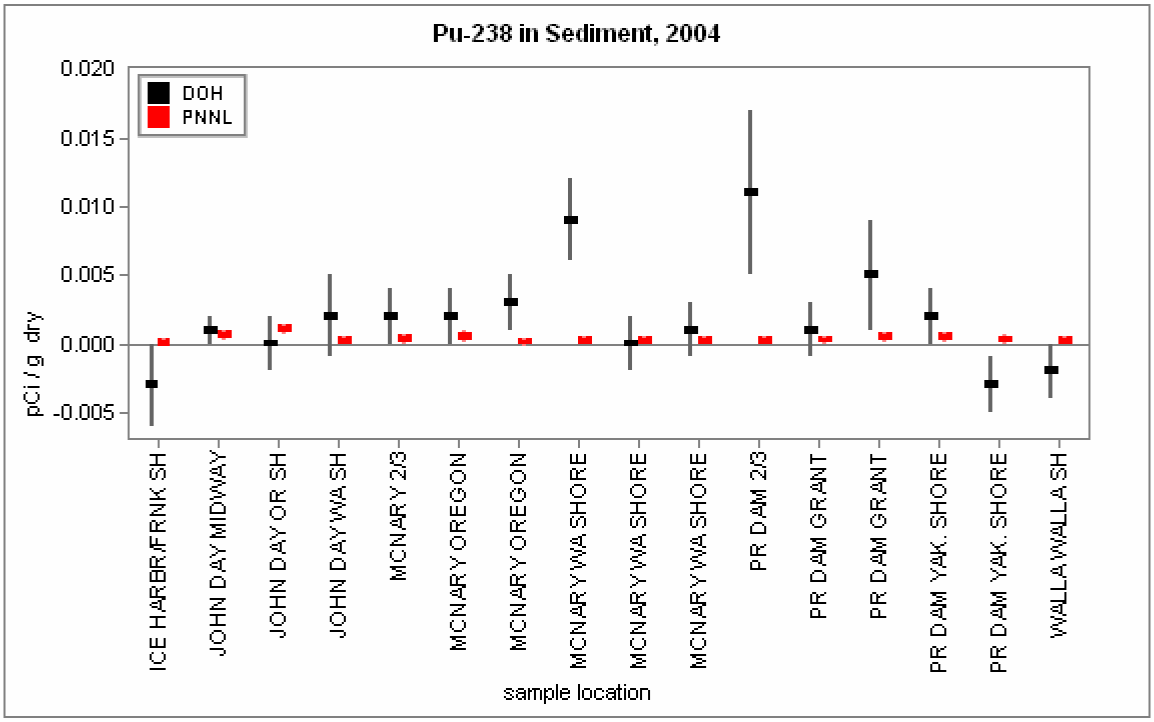

Figure 3.4.3 DOH and PNNL Pu-238 Concentrations in Sediment

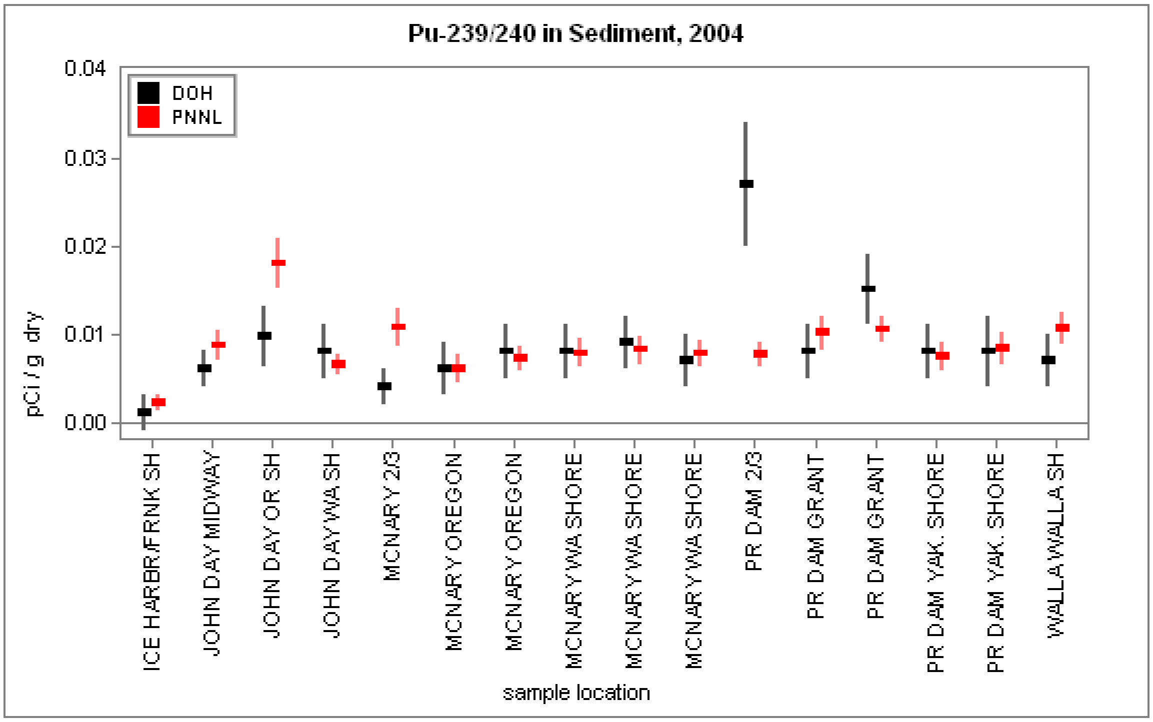

Figure 3.4.4 DOH and PNNL Pu-239/240 Concentrations in Sediment

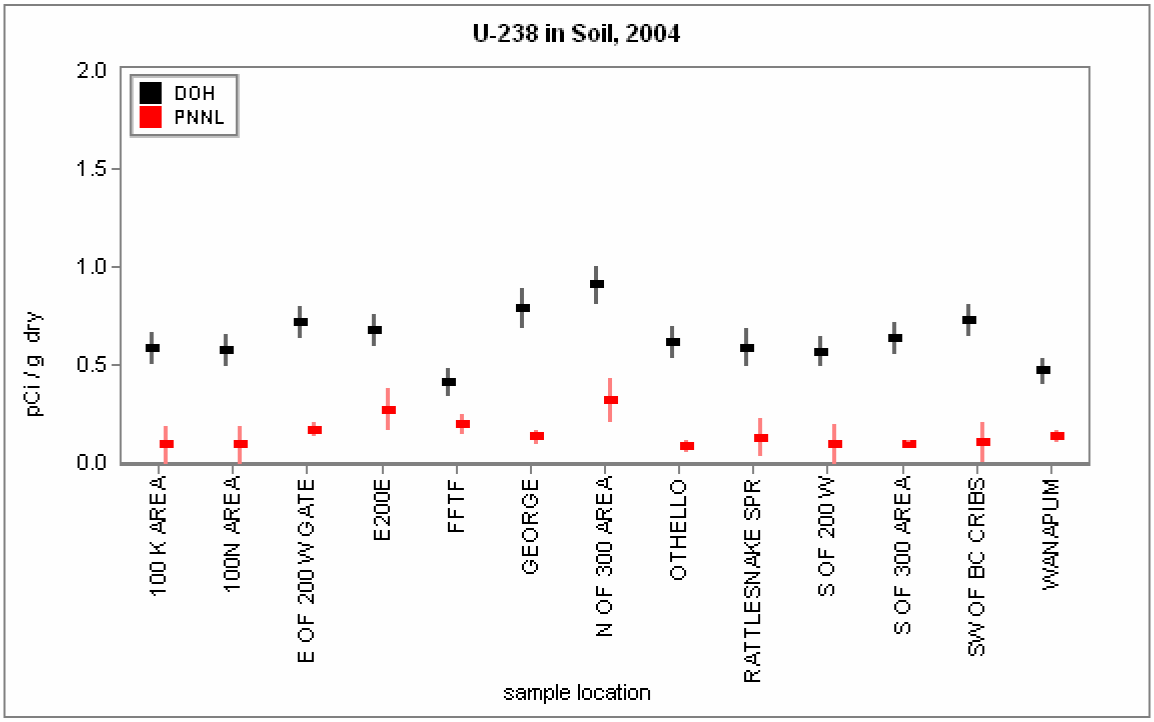

Figure 3.4.5 DOH and PNNL U-238 Concentrations in Sediment

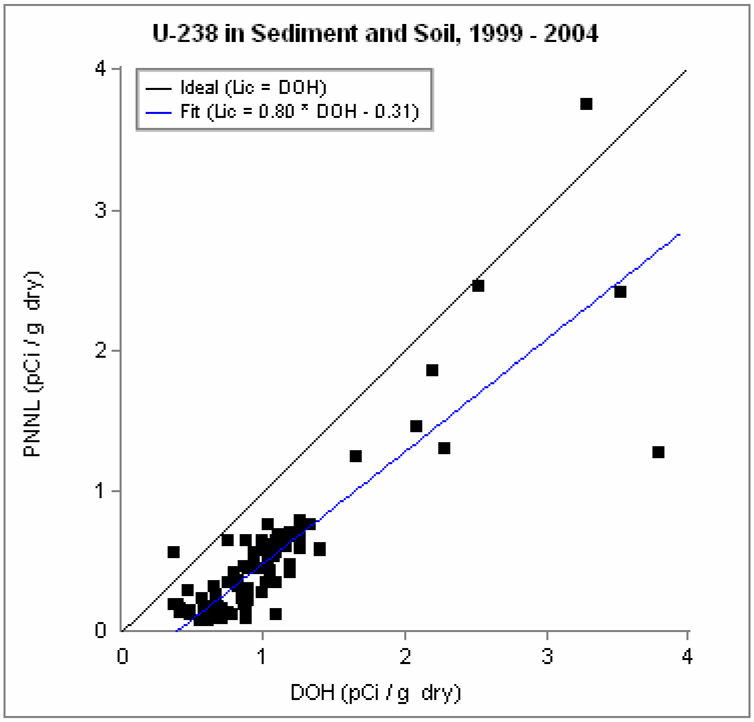

Figure 3.4.6 DOH and PNNL Scatter Plot for U-238 Concentrations in Sediment

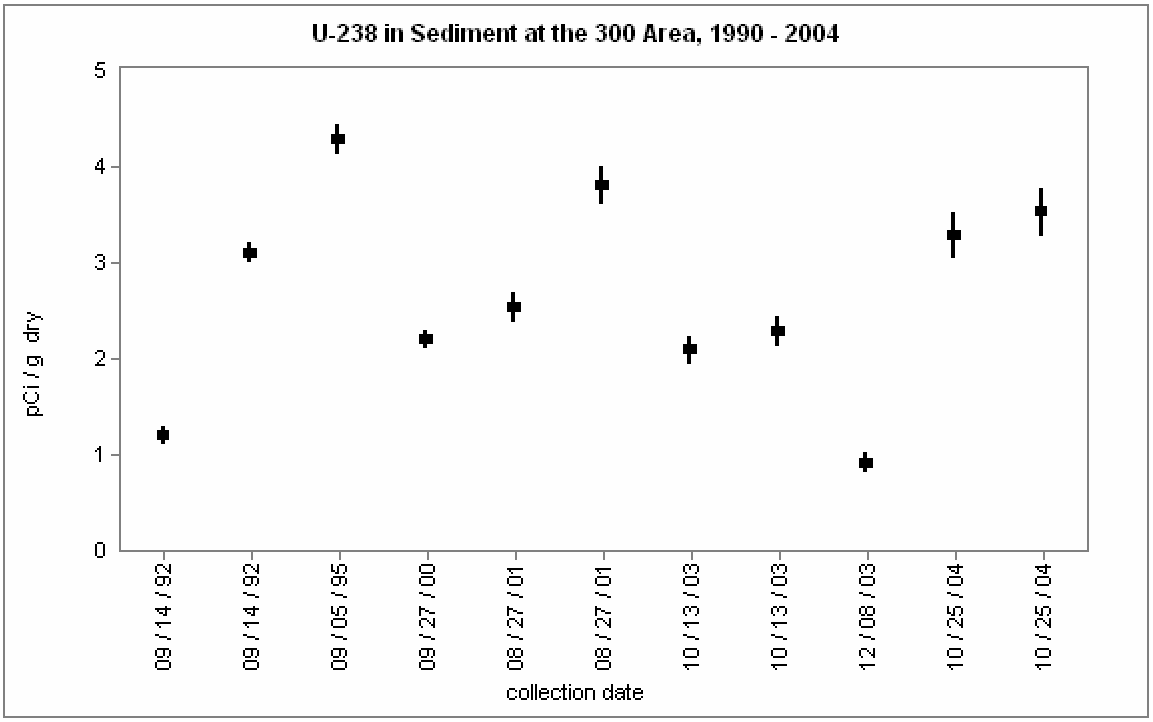

Figure 3.4.7 Historical DOH U-238 Concentrations in Sediment at the 300 Area

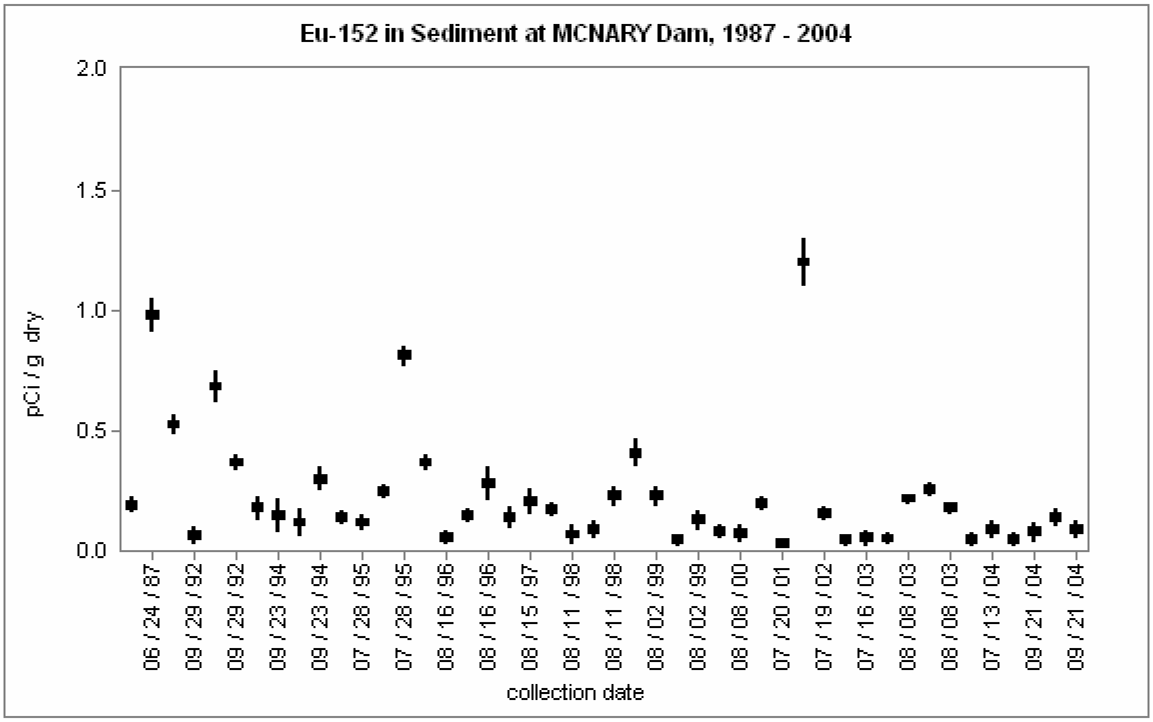

Figure 3.4.8 Historical DOH Eu-152 Concentrations in Sediment at McNary Dam

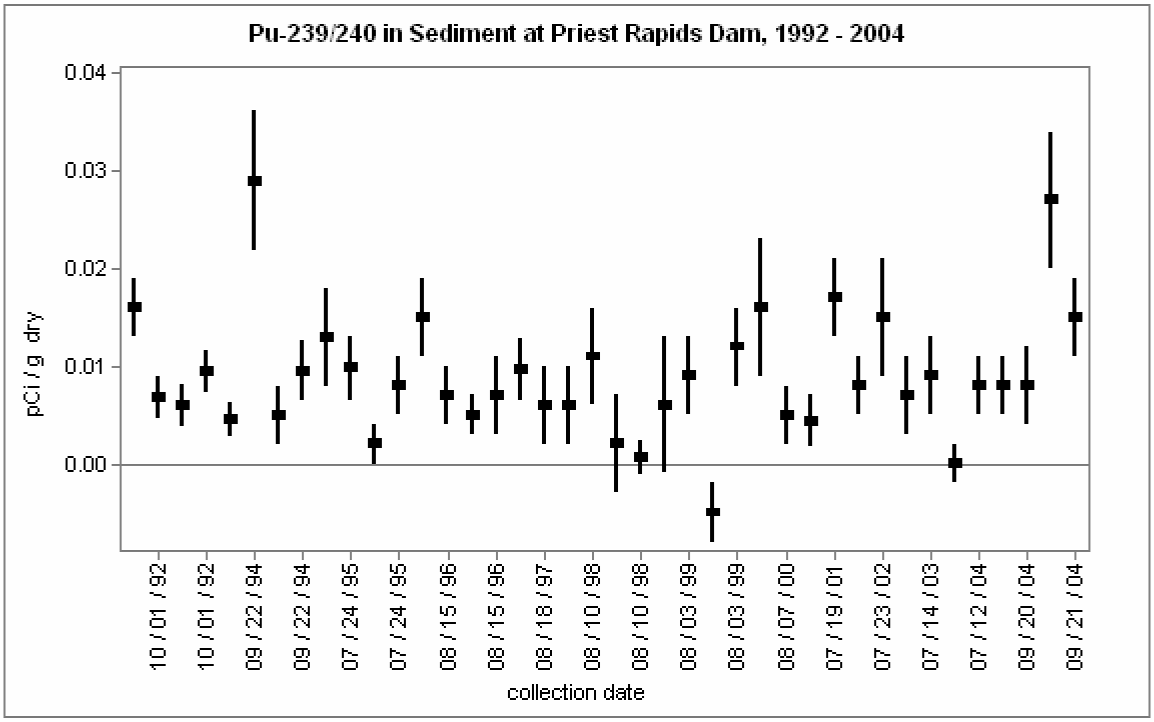

Figure 3.4.9 Historical Pu-239/240 Concentrations in Sediment at Priest Rapids Dams

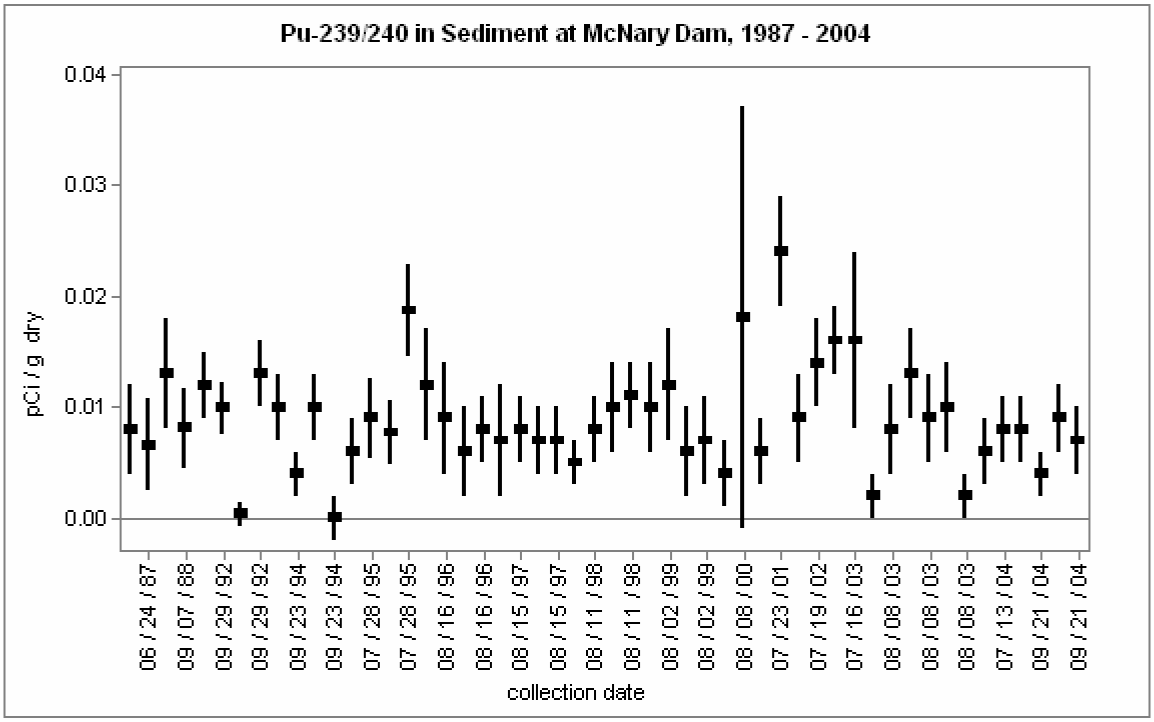

Figure 3.4.10 Historical Pu-239/240 Concentrations in Sediment at McNary Dam

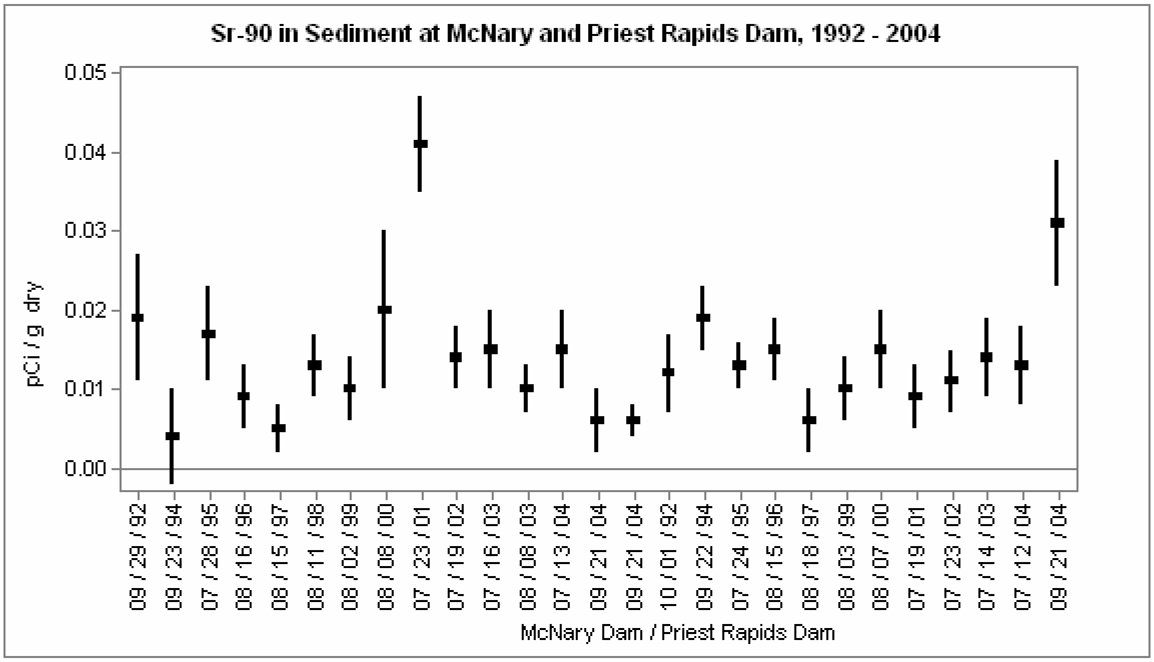

Figure 3.4.11 Historical Sr-90 Concentrations in Sediment at McNary and Priest Rapids Dams

3.5 Farm Products Monitoring

Major Findings:

- Most DOH and DOE contractor results are in good agreement.
- Most radioactivity concentrations measured by DOH are below detection limits. Sr-90 and H-3 were detected in a few samples at very low concentrations that are consistent with historical results.

3.5.1 Purpose and General Discussion

The Department of Health and DOE contractors monitor farm products; i.e., food and wine, to determine if airborne contamination has deposited on plants that may be consumed by people. The food products, radionuclides analyzed, and number of samples for 2004 are listed in Table 3.5.1.

Farm Product	Analyte	Number of Samples
Grapes	Co-60, Cs-137, Sr-90	2
Asparagus	Co-60, Cs-137, Sr-90, U-234, U-235, U-238	3
Leafy Vegetables	Co-60, Cs-137, Sr-90	1
Wine	Co-60, Cs-137, H-3	4

Table 3.5.1 Radionuclides Analyzed in Food and Farm Products

3.5.2 Monitoring Locations

All of the farm products were collected at locations which are nearby, but off-site of the Hanford Reservation. Samples were collected from farms located in the areas of Riverview, Sagemoor, Horse Heaven Hills, Richland, Pasco, Zillah, and Sunnyside. Most sample locations were in the prevailing downwind direction (to the southeast) from the Site.

3.5.3 Monitoring Procedures

Farm product samples were collected by PNNL and then split with DOH. Samples are generally collected once a year, in the fall when the products are being harvested. DOH and PNNL independently analyze the samples and then compare results. Results for wine are reported in pCi/L, while all other results are reported in pCi/g wet weight.

3.5.4 Comparison of DOH and Contractor Data

Most of the DOH and PNNL radionuclide concentrations reported for split food and wine samples are in good agreement. The PNNL result for Sr-90 in the leafy vegetable sample is twice the concentration reported by DOH. All other Sr-90 results are in good agreement, as shown in Figure 3.5.1. Historically, most of the DOH and PNNL Sr-90 results are in good agreement.

The results for H-3 in wine samples are in poor agreement, as shown in Figure 3.5.2. For these samples, the DOH results are significantly higher than the concentrations reported by PNNL. Historically, most of the DOH and PNNL split wine sample results are in good agreement, as can be seen in Figure 3.5.3. DOH will closely assess the upcoming 2005 results to see if the disagreement seen in 2004 continues.

3.5.5 Discussion of DOH Results

All of the Co-60, Cs-137, and uranium concentrations reported by DOH for farm product samples collected in 2004 are below the detection limits listed for food in Appendix B. Strontium-90 was detected at 0.02 pCi/g in the leafy vegetable sample. Historically, DOH occasionally detects small concentrations of Sr-90 in farm products around the Hanford Site, with concentrations ranging from 0.01 to 0.1 pCi/g. Tritium concentrations in wine samples ranged from 60 to 310 pCi/L. These concentrations are very small and are 100 times less than federal drinking water standards. The food and farm product results for all radionuclides analyzed in 2004 are consistent with historical DOH results.

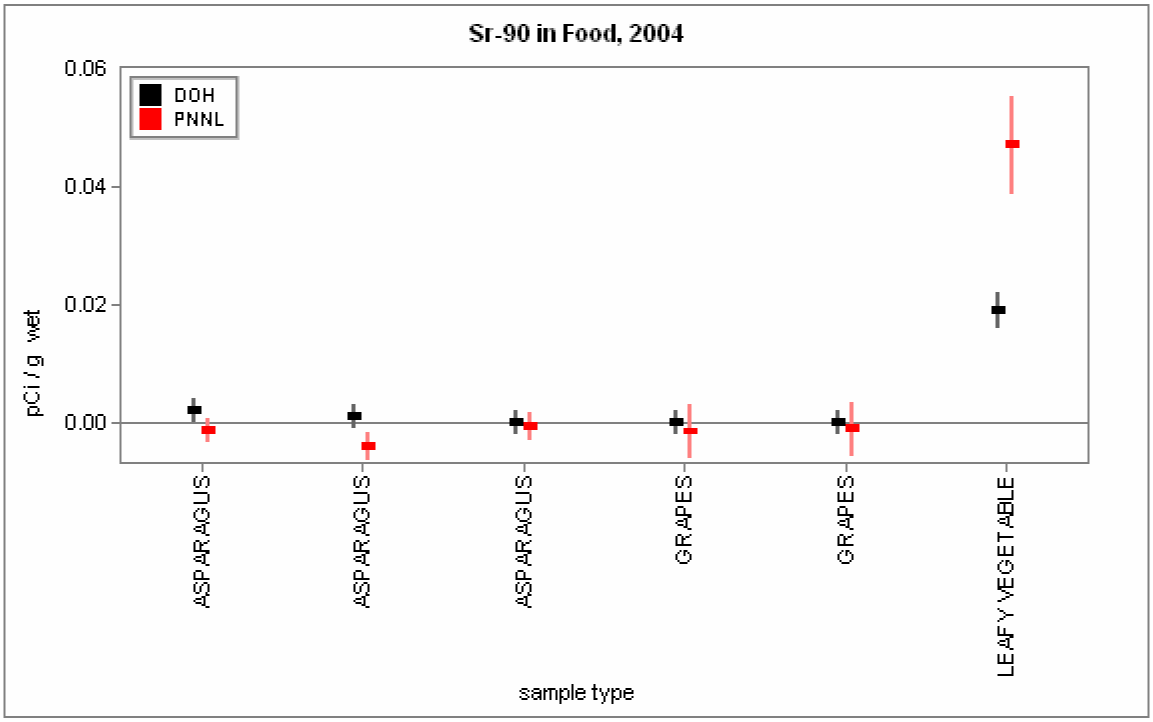

Figure 3.5.1 DOH and PNNL Sr-90 Concentrations in Food

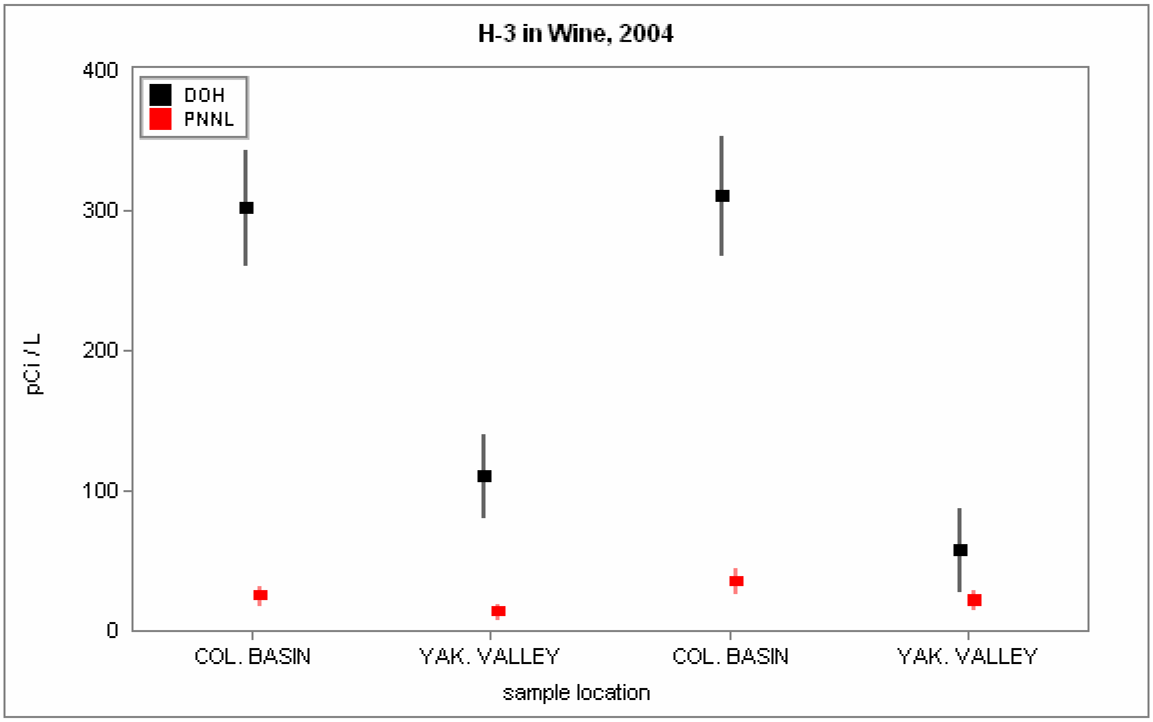

Figure 3.5.2 DOH and PNNL H-3 Concentrations in Wine

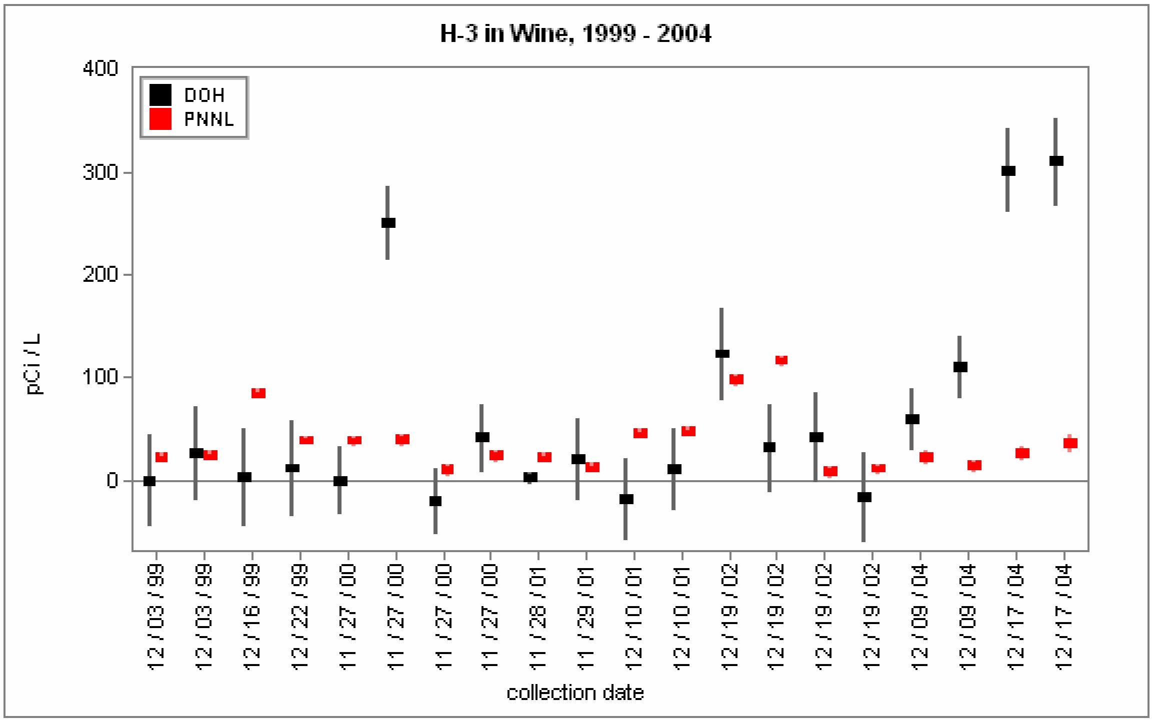

Figure 3.5.3 DOH and PNNL Historical H-3 Concentrations in Wine

3.6 Fish and Wildlife Monitoring

Major Findings:

- DOH and PNNL results are in good agreement for gamma emitting radionuclides, and are in good to poor agreement for Sr-90.
- Most of the DOH results are below detection limits. Cs-137 and Sr-90 in an Olympia, Washington deer sample were elevated compared to samples collected from Hanford.

3.6.1 Purpose and General Discussion

The Department of Health and DOE contractors monitor fish and wildlife to determine if contaminants have migrated into the food chain. Contaminants in fish arise from fish swimming in contaminated water and ingesting contaminated sediments. Contaminants in wildlife arise from ingestion of contaminated soil, vegetation, or water. In 2004, DOH split three wildlife samples and two fish samples. The type of samples, radionuclides analyzed, and number of samples are listed in Table 3.6.1.

Sample Type	Analyte	Number of Samples	Sample Location
Deer Bone	Sr-90	2	100N, Olympia
Deer Meat	Co-60, Cs-137	2	100N, Olympia
Quail Bone	Sr-90	1	100D Area
Quail Meat	Co-60, Cs-137	1	100D Area
Carp Carcass	Sr-90	2	100D, 300 Areas
Carp Meat	Co-60, Cs-137	2	100D, 300 Areas

Table 3.6.1 Radionuclides Analyzed in Fish and Wildlife

3.6.2 Monitoring Locations

The sample locations are listed in Table 3.6.1 and include the 100D, 100N, and 300 Areas, and a background location in Olympia, Washington. The fish sample (carp) was collected from the Columbia River adjacent to the 100D Area. No fish or game bird samples from background locations were collected for split analysis in 2004.

3.6.3 Monitoring Procedures

Fish and wildlife samples were collected and split by PNNL. Carcass and bone samples were analyzed for Sr-90, while the meat samples were analyzed for gamma emitting radionuclides, primarily Co-60 and Cs-137.

3.6.4 Comparison of DOH and Contractor Data

Most DOH and PNNL radionuclide concentrations reported for split fish and wildlife samples are in good agreement. The DOH and PNNL Co-60 and Cs-137 results in fish and wildlife are in good agreement, with most concentrations below the DOH detection limit of 0.008 pCi/g. The split Sr-90 results range from good to poor agreement, as can be seen in Figure 3.6.1. The poor Sr-90 agreement has been observed historically, as can be seen in Figure 3.6.2 which shows DOH and PNNL Sr-90 concentrations in deer bone and carp carcass samples collected from 1999 to 2004.

3.6.5 Discussion of DOH Results

All but one of the DOH Co-60 and Cs-137 fish and wildlife results are below the detection limit of 0.008 pCi/g. Cesium-137 was detected at 0.015 pCi/g in the meat of a deer collected from Olympia, Washington. The source of this Cs-137 is most likely worldwide fallout from nuclear weapons testing. Sr-90 was detected at 1.1 pCi/g in the Olympia deer sample, at 0.1 pCi/g in the 100N deer sample, and at 0.03 pCi/g in the 100D carp sample. These concentrations from samples collected in 2004 are consistent with historical fish and wildlife results.

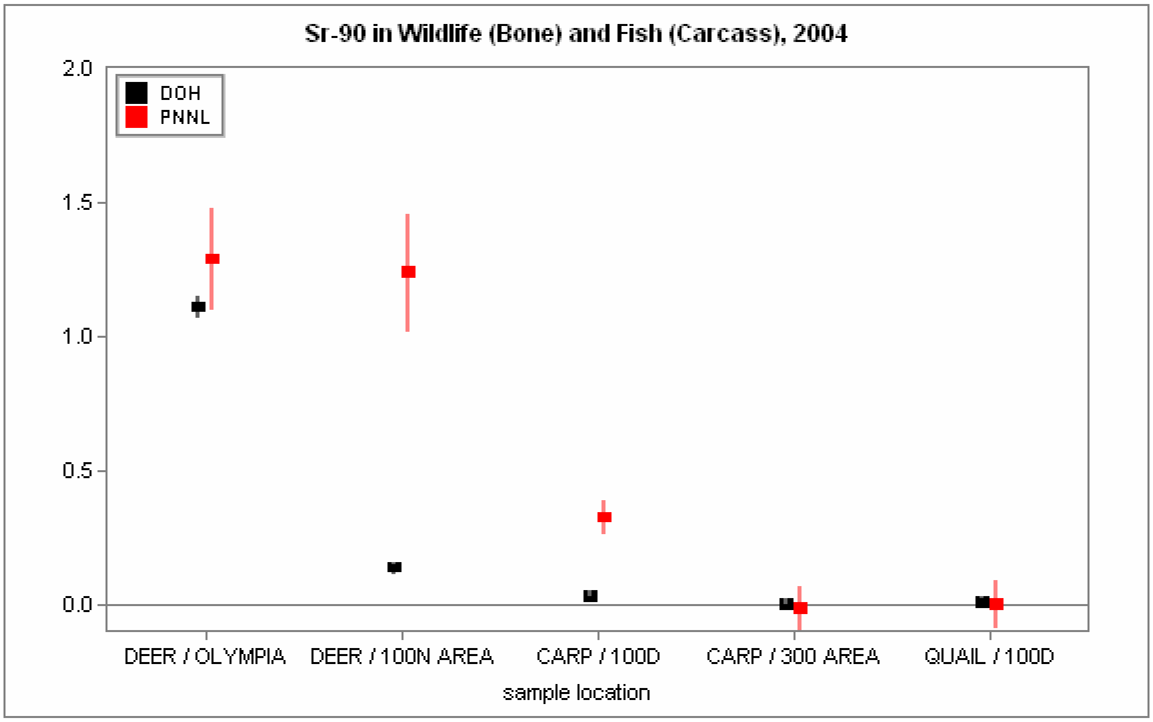

Figure 3.6.1 DOH and PNNL Sr-90 Concentrations in Fish and Wildlife

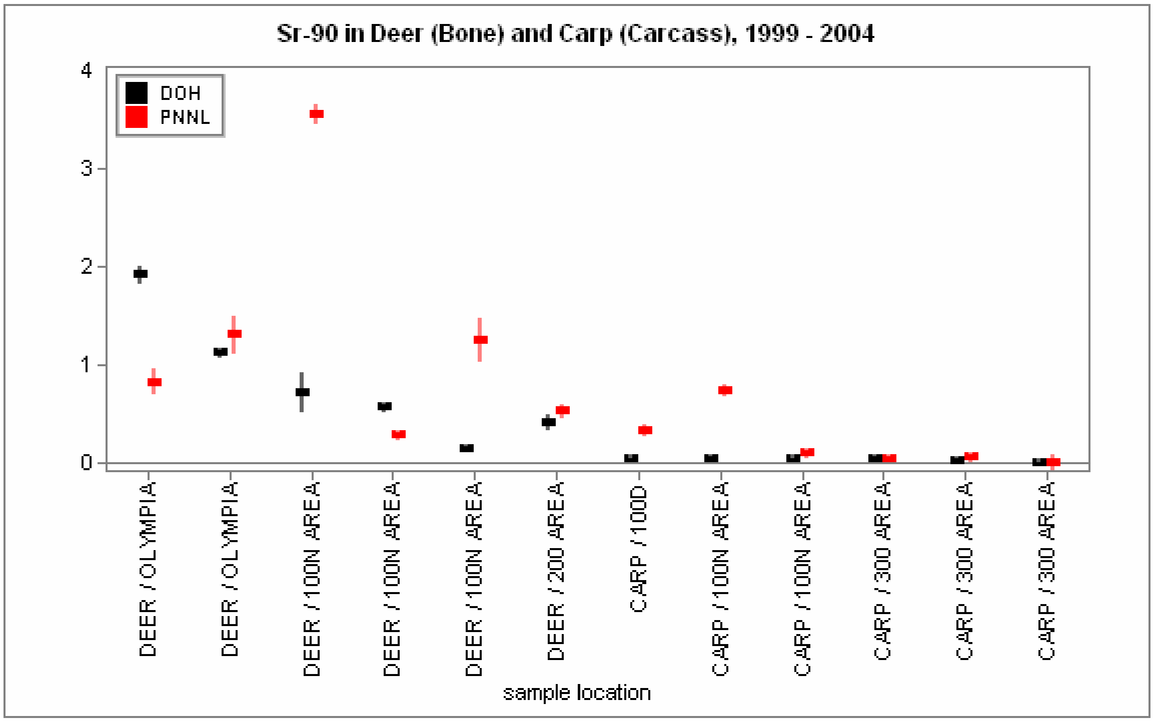

Figure 3.6.2 DOH and PNNL Historical Sr-90 Concentrations in Deer Bone and Carp Carcass Samples

3.7 Vegetation Monitoring

Major Findings:

- DOH and DOE contractor results are in good agreement.
- Concentrations of gamma emitting radionuclides, as well as Pu-238 and Pu-239/240, are below detection limits.
- Low concentrations of Sr-90 and uranium were detected in grass samples, with on-site concentrations similar to or less than off-site concentrations.

3.7.1 Purpose and General Discussion

The Department of Health and DOE contractors monitor vegetation to evaluate contaminants that are incorporated into plants that, in turn, may be consumed by animals and potentially reach the public. Contaminants in vegetation arise from airborne deposition and from soil to plant transfer via root uptake. In 2004, DOH split seven vegetation samples with PNNL. The type of vegetation, radionuclides analyzed, and number of samples are listed in Table 3.7.1.

Type of Vegetation	Analyte	Number of Samples
Grass	Co-60, Cs-137, Pu-238, Pu-239/340, Sr-90, U-234, U-235, U-238	7

Table 3.7.1 Radionuclides Analyzed in Vegetation

3.7.2 Monitoring Locations

Four grass samples were collected on the Hanford Site (one each from 100-K Area, 100-N Area, 300 Area, and the Old Hanford Townsite), and three samples were collected off-site from the towns of George, Othello, and Wanapum.

3.7.3 Monitoring Procedures

The vegetation samples were collected in the summer of 2004 and split with PNNL. DOH and PNNL independently analyzed the samples, and then compared results. The results are reported in pCi/g.

3.7.4 Comparison of DOH and Contractor Data

All of the DOH and PNNL split vegetation results are in good agreement. As an example, the DOH and PNNL U-238 results in grass samples are shown in Figure 3.7.1.

3.7.5 Discussion of DOH Results

Concentrations of gamma emitting radionuclides (including Co-60 and Cs-137), Pu-238, and Pu-239/240 in vegetation samples are all below the detection limits listed in Appendix B. Strontium-90 concentrations in grass samples are shown in Figure 3.7.2. The standard DOH detection limit, as listed in Appendix B, is 0.05 pCi/g, however, the detection limit for these samples was 0.01 pCi/g. The highest Sr-90 concentrations were detected in grass samples off the Hanford Site, and likely originate from worldwide fallout. The Sr-90 concentrations in on-site grass samples are less than the detection limit.

Uranium was detected in all grass samples, with U-238 and U-234 concentrations ranging from 0.002 to 0.01 pCi/g. The concentrations from on-site grass samples are similar to those from off-site samples, and likely originate from root uptake of natural uranium.

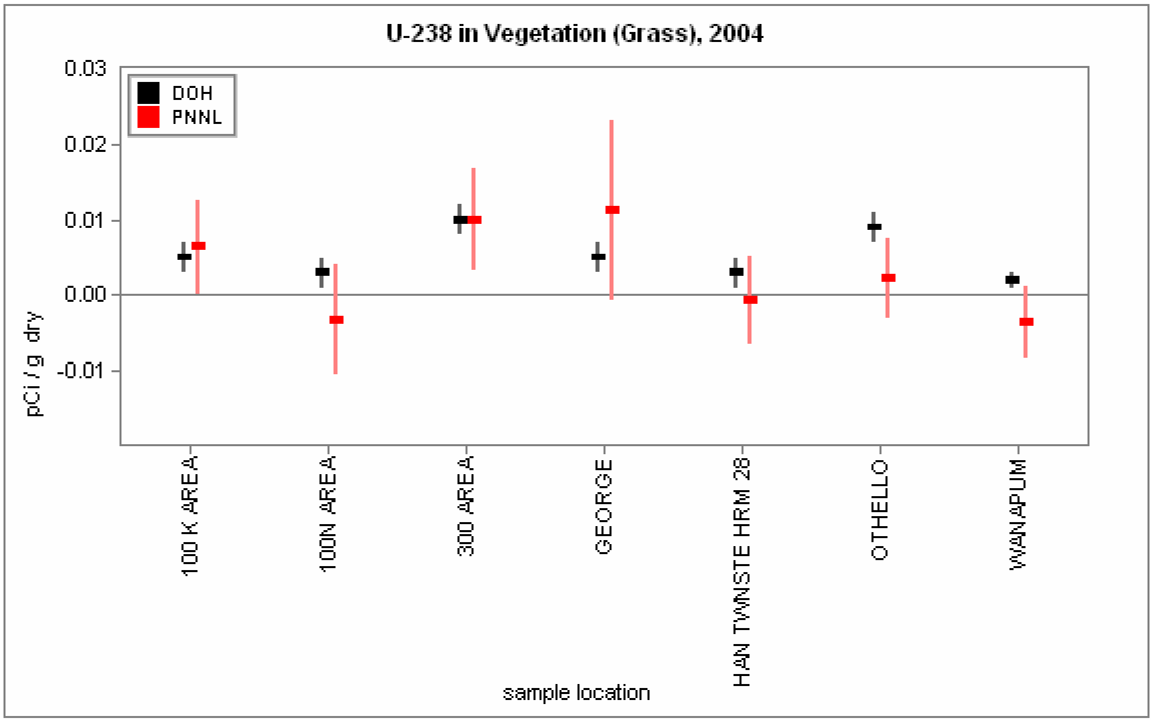

Figure 3.7.1 DOH and PNNL U-238 Concentrations in Grass Samples

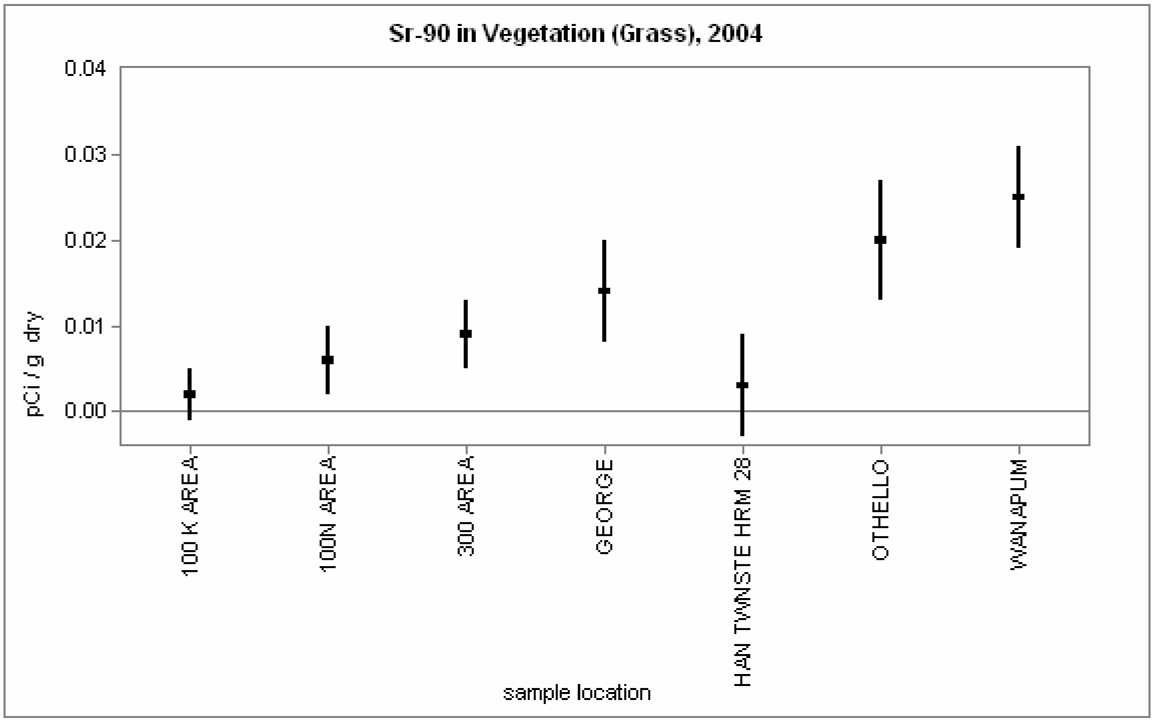

Figure 3.7.2 DOH Sr-90 Concentrations in Grass Samples

4. Summary of Discrepancies Between DOH and DOE Contractor Results

Categories of ‘good’, ‘fair’, and ‘poor’ are used to describe the agreement between DOH and DOE contractor results. This section summarizes all data described as fair or poor.

The DOH and DOE Contractor colocated bi-weekly gross beta results in air samples are in fair agreement. The data follow the same trends, but there is a small systematic discrepancy between the two data sets. At the lower end of the range of reported concentrations, DOE consistently reports higher values than DOH. At the upper end of the range of concentrations, DOH consistently reports higher values than DOE. In most cases, the discrepancy is less than a factor of two. This discrepancy observed in 2004 is also evident in historical DOH and DOE results.

The DOH and DOE colocated composite uranium results in air samples are in fair agreement. The data generally follow the same trends, however, DOE consistently reports concentrations that are significantly lower than the concentrations reported by DOH. This discrepancy, which is observed in historical data, results from different laboratory procedures.

The DOH and DOE split gross alpha and gross beta results in water samples are in fair agreement. The data generally follow the same trends, but a systematic discrepancy is observed between the two data sets. For the gross alpha results, DOE often reports concentrations that are less than values reported by DOH. For the gross beta results, DOE often reports higher concentrations than DOH when the concentrations are low, and often reports lower concentrations than DOH when the concentrations are high. This discrepancy observed in 2004 is also evident in historical DOH and PNNL results.

DOH and DOE split I-129 results in water samples are in poor agreement. The disagreement found in 2004 is consistent with historical results.

The DOH and DOE split uranium results in sediment and soil samples are in fair agreement. The data generally follow the same trends, however, a systematic discrepancy is observed between the two data sets. DOE typically reports uranium concentrations that are significantly lower than the values reported by DOH. This discrepancy, which is observed in historical data, results from different laboratory procedures.

Historically, DOH and DOE results for Sr-90 concentrations in farm product, fish and wildlife, and vegetation samples range from good to fair to poor agreement. In 2004, most of the Sr-90 results were in agreement, with a few samples showing discrepancies.

Historically, there is good agreement between DOH and DOE for H-3 concentrations in wine. However, in 2004 the agreement was poor, with DOH reporting higher concentrations than those reported by DOE.

The uranium discrepancies discussed above are understood, and originate from different laboratory procedures. All other discrepancies are under investigation, and the findings will be discussed in future annual reports.

Appendix A - Radiation Tutorial

A.1 Radiation and Radioactivity

Radioactivity from natural sources is found throughout nature, including in air, water, soil, within the human body, and animals. Naturally occurring radioactivity originates from the decay of primordial terrestrial sources such as uranium and thorium. Other sources are continually produced in the upper atmosphere through interactions of atoms with cosmic rays. These naturally occurring sources of radiation produce the background levels of radiation to which humans are unavoidably exposed.

Radioactivity is the name given to the phenomenon of matter emitting ionizing radiation. Radiation emitted from the nucleus of an atom is termed nuclear radiation. Atoms that emit radiation are termed *radioactive*. The three most common types of radiation are:

- Alpha – A particle consisting of two protons and two neutrons emitted from the nucleus of an atom. These charged particles lose their energy very rapidly in matter and are easily shielded by small amounts of material, such as a sheet of paper or the surface layer of skin. Alpha particles are only hazardous when they are internally deposited.

- Beta – An electron emitted from the nucleus of an atom. These charged particles lose their energy rapidly in matter, although less so than alpha radiation. Beta radiation is easily shielded by thin layers of metal or plastic. Beta particles are generally only hazardous when they are internally deposited.

- Gamma – Electromagnetic radiation, or photons, emitted from the nucleus of an atom. Gamma radiation is best shielded by thick layers of lead or steel. Gamma energy may cause an external or internal radiation hazard. (X-rays are similar to gamma radiation but originate from the outer shell of the atom instead of the nucleus).

In the past century, exposure of people to radiation has been influenced by the use and manufacture of radioactive materials. Such uses of radioactive materials include the healing arts, uranium mining and milling operations, nuclear power generation, nuclear weapons manufacturing and testing, and storage and disposal of nuclear wastes. Radiation levels were most altered by residual fallout from nuclear weapons testing. The United States ceased atmospheric testing following adoption of the 1963 Nuclear Test Ban Treaty and exposure has been decreasing since then.

Radioisotope and *radionuclide* are interchangeable terms used to refer to radioactive isotopes of an element. An element is delineated by its chemical name followed by its atomic number, which is the sum of its number of protons and neutrons. For example, carbon-12, which is the most naturally abundant form of carbon, consists of six protons and six neutrons for a total of twelve. Carbon-13 and carbon-14, which consist of six protons and seven and eight neutrons respectively, are also found in nature. These forms of carbon are called isotopes of carbon. If an isotope is radioactive it is called a radioisotope. In the example given, carbon-12 and carbon-13 are non-radioactive isotopes of carbon. Carbon-14 is radioactive, and is therefore a radioisotope of carbon.

All radioisotopes will eventually decay, by emitting radiation, and will become non-radioactive isotopes. For example, carbon-14 decays to nitrogen-14. An important property of any radioisotope is the half-life. Half-life is the amount of time it takes for a quantity of any radioisotope to decay to one-half of its original quantity.

In the example above, carbon-14 has a half-life of 5,730 years. Thus, one gram of pure carbon-14 would transform into 1/2 gram of carbon-14 and 1/2 gram of nitrogen-14 after 5,730 years. After another 5,730 years, for a total of 11,460 years, 1/4 gram of carbon-14 and 3/4 grams of nitrogen-14 would remain. This decay process would continue indefinitely until all of the carbon-14 had decayed to nitrogen-14.

Heavier radioisotopes often decay to another radioisotope, which decays to another radioisotope, and so on until the decay process culminates in a non-radioactive isotope. This sequence of decays is called a decay chain. Each of the isotopes produced by these decays is called a decay product. For example, uranium-238 decays to thorium-234, which decays to protactinium-234, and so on, until the decay chain ends with non-radioactive lead-206.

A.2 Radiological Units and Measurement

From the perspective of human health, exposure to radiation is quantified in terms of radiation dose. Radiation dose measures the amount of energy deposited in biological tissues. Commonly, units of the roentgen, rad, and rem are used interchangeably to quantify the radiation energy absorbed by the body. The international scientific units (SI) for rad and rem are gray and sievert, respectively. There is no SI unit for roentgen.

The roentgen is a measure of radiation exposure in air, rad is a measure of energy absorbed per mass of material, and rem is a unit that relates radiation exposure to biological effects in humans. See the glossary (Appendix D) for more complete definitions of these terms.

The quantity of radioactivity in material is measured in curies. A curie (Ci) is a quantity of any radionuclide that undergoes an average transformation rate of 37 billion transformations per second. One curie is the approximate activity of 1 gram of radium. The SI unit for activity is the becquerel which is equal to one disintegration per second.

Human radiation doses are expressed in units of rems or seiverts. Since radiation doses are often small, units of millirem (mrem) or milliseivert (mSv) are commonly used. A mrem is one-thousandth of a rem. Table A.1 shows the average annual dose for the United States from both natural and artificial sources. Natural sources account for 82% of the annual dose to the U.S. population, with radon being the dominant natural dose contributor at 55%.

Source		Dose (mrem/yr)	Dose (mSv/yr)	Percent of Total
Natural	Radon	200	2.0	55
	Cosmic	27	0.27	8
	Terrestrial	28	0.28	8
	Internal	39	0.39	11
	Total Natural	300	3	82%
Artificial	Medical X-Ray	39	0.39	11
	Nuclear Medicine	14	0.14	4
	Consumer Products	10	0.1	3
	Total Artificial	63	0.63	18%
Other	Occupational	0.9	< 0.01	< 0.3
	Nuclear Fuel Cycle	< 1	< 0.01	< 0.03
	Fallout	< 1	< 0.01	< 0.03
	Miscellaneous	< 1	< 0.01	< 0.03
	Grand Total	363	3.63	100%

Table A.1 Annual Effective Dose Equivalent (NCRP 93)

It is well established that very high radiation doses, in the neighborhood of 300,000 to 500,000 mrem, are fatal. At lower, but still high doses (above approximately 20,000 mrem), the primary biological impact is an increased risk of cancer.

The health effects of radiation are substantially better known than those of most other carcinogens because, in addition to animal data, there is a wealth of human data. However, virtually all the evidence on the harmful effects of radiation comes from observations of the effects from high doses or high dose rates. The primary source of information on the health effects of radiation comes from studies of the survivors of the Japanese atomic bombings. Other sources include radiation accidents, occupational exposures, and medical exposures.

Most exposures to radiation workers and the general public, however, involve low doses; i.e., lifetime doses of less than approximately 20,000 mrem above natural background. The health effects of exposure to low doses of radiation are too small to unambiguously measure. In the absence of direct evidence of the harmful effects of radiation at low doses, estimates of health effects are made by extrapolation from observations at high doses. There is much controversy and disagreement about the procedure for such an extrapolation. The conventional procedure traditionally has hypothesized a linear extrapolation of the high dose health effects data to a point of zero dose, zero risk.

Typically, radiation doses associated with exposure to environmental contamination are very small, and the health effects from these exposures are not known with a reasonable degree of certainty.

Appendix B - Laboratory a priori Lower Limits of Detection

Air Cartridge (pCi/m^3)

	Nuclide	Volume (m^3)	Method*	Standard LLD (100 min.)
Gamma	I-131*	450	INGe	2.00E-02

Air Filter (pCi/m^3)

	Nuclide	Volume (m^3)	Method	Standard LLD (100 min.)
Beta	Gross	450	αβ Cntr	1.00E-03

Quarterly Composite Air Filter (pCi/m^3)

	Nuclide	Volume (m^3)	Method	Standard LLD (400 min.)
Gamma	Be-7	5200	INGe	8.00E-02
	Co-60	5200	INGe	1.00E-03
	Cs-134	5200	INGe	2.00E-03
	Cs-137	5200	INGe	1.00E-03
				Standard LLD (1000 min.)
Alpha	Nat U	5200	Alpha Spec	2.50E-05
	U-234	5200	Alpha Spec	2.50E-05
	U-235	5200	Alpha Spec	1.00E-05
	U-238	5200	Alpha Spec	2.50E-05

Semi-Annual Composite Air Filter (pCi/m^3)

	Nuclide	Volume (m^3)	Method	Standard LLD (400 min.)
Gamma	Be-7	10400	INGe	4.00E-02
	Co-60	10400	INGe	5.00E-04
	Cs-134	10400	INGe	1.00E-03
	Cs-137	10400	INGe	5.00E-04

Semi-Annual Composite Air Filter (pCi/m^3) Continued

	Nuclide	Volume (m3)	Method	Standard LLD (1000 min.)
Alpha	Nat U	10400	Alpha Spec	1.25E-05
	U-234	10400	Alpha Spec	1.25E-05
	U-235	10400	Alpha Spec	5.00E-06
	U-238	10400	Alpha Spec	1.25E-05
	Pu-238	10400	Alpha Spec	5.00E-06
	Pu-239/240	10400	Alpha Spec	5.00E-06

Food (pCi/g)

	Nuclide	Mass (g)	Method	Standard LLD (1000 min.)
Alpha	Nat U	20	Alpha Spec	2.00E-03
	U-234	20	Alpha Spec	1.50E-02
	U-235	20	Alpha Spec	1.00E-03
	U-238	20	Alpha Spec	2.00E-03
	Pu-238	20	Alpha Spec	3.00E-03
	Pu-239	20	Alpha Spec	2.00E-03
	Th-230	20	Alpha Spec	5.00E-03
	Th 232	20	Alpha Spec	2.00E-03
	Am-241	20	Alpha Spec	2.00E-03
	Ra – 226	20	αβ Cntr	6.00E-04

Milk (pCi/L)

	Nuclide	Volume (L)	Method	Standard LLD (400 min.)
Gamma	K-40	3	INGe	3.00E+01
	I-131	3	INGe	2.00E+00
	Cs-134	3	INGe	2.00E+00
	Cs-137	3	INGe	2.00E+00
	Ba-140	3	INGe	9.00E+00
				Standard LLD (1000 min.)
	I-131	4	IXR/INGe	7.00E-01
				Standard LLD (100 min.)
Beta	Sr-90	1	Nitric Acid/ αβ Cntr	7.00E-01

Meat (pCi/g)

	Nuclide	Mass (g)	Method	Standard LLD (1000 min.)
Gamma	K-40	400	INGe	1.40E-01
	Mn-54	400	INGe	7.00E-03
	Co-58	400	INGe	7.00E-03
	Co-60	400	INGe	8.00E-03
	Cs-137	400	INGe	6.00E-03
	I-131	400	INGe	2.00E-02
	Ra-226(DA)	400	INGe	2.50E-01
	Am-241(GA)	400	INGe	2.00E-02
Alpha	Nat U	10	Alpha Spec	4.00E-03
	U-234	10	Alpha Spec	3.00E-03
	U-235	10	Alpha Spec	2.00E-03
	U-238	10	Alpha Spec	3.00E-03
	Pu-238	10	Alpha Spec	5.00E-03
	Pu-239	10	Alpha Spec	4.00E-03
	Am-241	10	Alpha Spec	4.00E-03
Beta	Sr-90 (bone)	5	Nitric Acid/ αβ Cntr	2.00E-01

Shellfish (pCi/g)

	Nuclide	Mass (g)	Method	Standard LLD (400 min.)
Gamma	I-131	400	INGe	6.00E-03
	Co-60	400	INGe	6.00E-03
	K-40	400	INGe	1.00E-01

Soil/Sediment (pCi/g)

	Nuclide	Mass (g)	Method	Standard LLD (1000 min.)
Alpha	Nat U	1	Alpha Spec	4.00E-02
	U-234	1	Alpha Spec	3.00E-02
	U-235	1	Alpha Spec	2.00E-02
	U-238	1	Alpha Spec	3.00E-02
	Pu-238	10	Alpha Spec	5.00E-03
	Pu-239	10	Alpha Spec	4.00E-03
	Th-230	1	Alpha Spec	4.00E-02
	Th 232	1	Alpha Spec	4.00E-02
	Am-241	10	Alpha Spec	4.00E-03
	Ra - 226	1	αβ Cntr	1.00E-01
	Ra-226(DA)	600	INGe	2.00E-02
				Standard (100 min.)
Alpha	Gross	0.1	αβ Cntr	4.00E+01
				Standard LLD (1000 min.)
Gamma	K-40	600	INGe	1.50E-01
	Mn-54	600	INGe	1.00E-02
	Co-60	600	INGe	1.00E-02
	Zn-65	600	INGe	2.00E-02
	Zr-95	600	INGe	1.00E-02
	Ru-103	600	INGe	1.50E-02
	Ru-106	600	INGe	1.00E-02
	Sb-125	600	INGe	2.00E-02
	Cs-134	600	INGe	1.20E-02
	Cs-137	600	INGe	1.50E-02
	Ce-144	600	INGe	5.00E-02
	Eu-152	600	INGe	1.50E-02
	Eu-154	600	INGe	1.50E-02
	Eu-155	600	INGe	2.00E-02
	Ra-226(DA)	600	INGe	1.00E-01
	Am-241(GA)	600	INGe	2.00E-02
	Tot U(GA)	600	INGe	2.00E-01
				Standard (100 min.)
Beta	Sr-90	150	Nitric Acid/	1.80E-03
	Tc-99	10	3M/LS	2.00E-01
	Gross beta	0.4	αβ Cntr	1.50E+00

Vegetation (pCi/g except H-3 which is expressed as pCi/L)

	Nuclide	Mass (g)	Method	Standard LLD (1000 min.)
Alpha	Nat U	10	Alpha Spec.	8.00E-03
	U-234	10	Alpha Spec.	6.00E-03
	U-238	10	Alpha Spec.	6.00E-03
	Pu-238	10	Alpha Spec.	5.00E-03
	Pu-239	10	Alpha Spec.	4.00E-03
	Am-241	10	Alpha Spec.	4.00E-03
Gamma	K-40	100	INGe	3.00E-01
	Mn-54	100	INGe	4.00E-02
	Co-60	100	INGe	4.00E-02
	Zn-65	100	INGe	1.50E-01
	Zr-95	100	INGe	2.00E-01
	Ru-106	100	INGe	4.00E-01
	Cs-137	100	INGe	4.00E-02
	I-131	100	INGe	4.00E-02
	Am-241(GA)	100	INGe	2.00E-01
				Standard LLD (100 min.)
Beta	Gross	0.4	αβ Cntr	1.50E+00
	Sr-90	20	Nitric Acid/ αβ Cntr	5.00E-02
	Tc-99	5	3M/LS	1.50E+00
	Nuclide	Volume (L)	Method	Standard LLD (200 min.)
	C-14	0.0002	Oxid/LS	3.00E+02
	H-3	0.002	LS	5.00E+02

Water (pCi/L)	Nuclide	Volume (L)	Method	Standard LLD (1000 min.)	Standard LLD (100 min.)
Alpha	Nat U	0.5	Alpha Spec	1.30E-01	
	U-234	0.5	Alpha Spec	8.00E-02	
	U-235	0.5	Alpha Spec	6.00E-02	
	U-238	0.5	Alpha Spec	8.00E-02	
	Ra-226	0.5	αβ Cntr		2.00E-01
	Pu-238	0.5	Alpha Spec	8.00E-02	
	Pu-239	0.5	Alpha Spec	6.10E-02	
	Th-230	0.5	Alpha Spec	1.00E-01	
	Th 232	0.5	Alpha Spec	1.00E-01	
	Am-241	0.5	Alpha Spec	8.00E-02	

				Standard LLD (1000 min.)
Gamma	Am-241	3	INGe	1.00E+01
	Ba-140	3	INGe	9.00E+00
	Ce-144	3	INGe	1.30E+01
	C0-58	3	INGe	1.50E+00
	Co-60	3	INGe	2.00E+00
	Cr-51	3	INGe	1.60E+01
	Cs-134	3	INGe	2.00E+00
	Cs-137	3	INGe	2.00E+00
	Eu-152	3	INGe	5.00E+00
	Eu-154	3	INGe	5.00E+00
	Eu-155	3	INGe	8.00E+00
	Fe-59	3	INGe	3.00E+00
	I-129	3	IXR/LEP	8.00E-01
	I-131	3	INGe	2.00E+00
	K-40	3	INGe	3.00E+01
	Mn-54	3	INGe	1.50E+00
	Nb-95	3	INGe	2.00E+00
	Ru-103	3	INGe	2.00E+00
	Ru-106	3	INGe	1.50E+01
	Sb-125	3	INGe	5.00E+00
	Sn-113	3	INGe	2.00E+00
	Zn-65	3	INGe	3.00E+00
	Zr-95	3	INGe	2.00E+00

Water (pCi/L) Continued

	Nuclide	Volume (L)	Method	Standard LLD (200 min.)	Standard LLD (100 min.)
Beta	H-3	0.010	Dist/LS	6.00E+01	
	C-14	0.010	LS	1.50E+02	
	Sr-90	1	Nitric Acid/ αβ Cntr		7.00E-01
	Tc-99	0.5	3M/LS		4.00E+00
Gross	Alpha	0.1	αβ Cntr		4.00E+00
	Beta	0.5	αβ Cntr		1.00E+00

*LLD for Air Cartridge is 3 days

METHOD

Preparation Methods

IXR = Ion Exchange Resin
Nitric Acid
3M = 3M Ion Exchange Disks
Oxid = Oxidation

Counting Methods

INGe = Intrinsic Germanium Detector
αβ Cntr = Alpha, Beta Counter
Alpha Spec = Alpha Spectrometry
LS = Liquid Scintillation
LEP = Low Energy Photon Detector

Formulas

A. Random Uncertainty

$$RU = 1.96((\text{gross sample cpm}/T_1) + (\text{BKGCPM}/T_2))^{1/2}/((E)(2.22)(V)(Y)(D))$$

B. Uncertainty (standard error) of the sample mean (U)

$$U = s/(n)^{1/2}$$

C. Lower Limit of Detection (LLD)

$$LLD = 4.66S/((2.22)(E)(V)(Y)(D))$$

D. Definitions

2.22 = conversion factor from dpm to picocuries
BKGCPM = background counts per minute
D = decay factor = $e^{-(\ln 2/T1/2)(t)}$
E = counting efficiency: counts per disintegration
LLD = the a priori determination of the smallest concentration of radioactive material sampled that has a 95 percent probability of being detected, with only five percent probability that a blank sample will yield a response interpreted to mean that radioactivity is present above the system background.
n = number of samples analyzed (number of data points).
RU = random uncertainty at the 95 percent confidence level (sometimes referred to as counting error)
s = sample standard deviation
S = one standard deviation of the background count rate (which equals $(\text{BKG}/T_2)^{1/2}$)
sample cpm = counts per minute of sample
t = elapsed time between sample collection and counting
T_1 = sample count time
T_2 = background count time
$T_{1/2}$ = half-life of radionuclide counted
U = uncertainty (standard error) of the sample mean
V = volume in liters (or mass in grams) of sample
Y = fractional radiochemical yield (when applicable)

Appendix C - Glossary of Terms

Alpha Particle	A heavy particle emitted from the nucleus of an atom. It consists of two protons and two neutrons, which is identical to the nucleus of a helium atom without orbital electrons. These heavy charged particles lose their energy very rapidly in matter. Thus, they are easily shielded by paper or the surface layer of skin. Alpha particles are only hazardous when they are internally deposited.
Analyte	The specific radioisotope measured in a radiochemical analysis. For example, tritium, Sr-90, and U-238 are analytes.
Background (Background Radiation)	Radiation that occurs naturally in the environment. Background radiation consists of cosmic radiation from outer space, radiation from the radioactive elements in rocks and soil, and radiation from radon and its decay products in the air we breathe.
Baseline Samples	Environmental samples taken in areas unlikely to be affected by any facilities handling radioactive materials.
Becquerel	A unit, in the International System of Units (SI), of measurement of radioactivity equal to one transformation per second.
Beta Particle	A high-speed particle emitted from the nucleus, which is identical to an electron. They can have a –1 or +1 charge and are effectively shielded by thin layers of metal or plastic. Beta particles are generally only hazardous when they are internally deposited.
CFR	Code of Federal Regulations

Curie	The basic unit of activity. A quantity of any radionuclide that undergoes an average transformation rate of 37 billion transformations per second. One curie is the approximate activity of 1 gram of radium. Named for Marie and Pierre Curie, who discovered radium in 1898.
Decay, Radioactive	The decrease in the amount of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, often accompanied by gamma radiation.
Detection Level	The minimum amount of a substance that can be measured with a 95% confidence that the analytical result is greater than zero.
DOH	Department of Health or Washington State Department of Health
Dose	A generic term that means absorbed dose, equivalent dose, effective dose, committed equivalent dose, committed effective dose, or total effective dose.
DWS	Drinking Water Standard
Fallout	Radioactive materials that are released into the earth's atmosphere following a nuclear explosion or atmospheric release and eventually fall to earth.
Gamma Ray	Electromagnetic waves or photons emitted from the nucleus of an atom. They have no charge and are best shielded by thick layers of lead or steel. Gamma energy may cause an external or internal radiation hazard. (X-rays are similar to gamma radiation but originate from the outer shell of the atom instead of the nucleus).

Gross Alpha / Gross Beta	A screening test that reports alpha particle activity in a sample. The test is not intended to identify specific radioisotopes. The tests are primarily used to evaluate trends. In addition, screening tests are used to determine if further radioisotope specific analysis is necessary; and if radioisotope analyses has been carried out, to determine if the activities from specific radioisotopes account for all of the activity found in the screening test.
Half-life	The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years. Also called physical half-life.
ICRP	International Commission on Radiation Protection
Ionizing Radiation	Any radiation capable of displacing electrons from atoms or molecules, thereby producing ions. Examples: alpha, beta, gamma, x-rays, and neutrons.
Isotope	One of two or more atoms with the same number of protons, but different numbers of neutrons, in the nuclei.
Lower Limit of Detection (LLD)	The smallest amount or concentration of a radioactive element that can be reliably detected in a sample.
NCRP	National Council for Radiation Protection
PHL	Public Health Laboratory
pCi (picocurie)	10^{-12} curies (one trillionth of a curie)
PNNL	Pacific Northwest National Laboratory
QATF	Quality Assurance Task Force

Quality Assurance	All those planned and systematic actions necessary to provide adequate confidence that a facility, structure, system, or component will perform satisfactorily and safely in service.
Quality Control	A component of Quality Assurance; comprises all those actions necessary to control and verify that a material, process, or product meets specified requirements.
Quality Factor (Q)	A numerical factor assigned to describe the average effectiveness of a particular kind (and sometimes energy) of radiation in producing biological effects on humans.
Rad	The special unit of absorbed dose. It is a measure of the energy absorbed per mass of material. One rad is equal to an absorbed dose of 0.01 J kg^{-1} (1 rad = 0.01 gray).
Radioactivity	The process of undergoing spontaneous transformation of the nucleus, generally with the emission of alpha or beta particles, often accompanied by gamma rays. The term is also used to designate radioactive materials.
Radioisotope	A radioactive isotope; i.e., an unstable isotope that undergoes spontaneous transformation, emitting radiation. Approximately 2500 natural and artificial radioisotopes have been identified.
Radionuclide	A radioactive nuclide.
Rem	The special unit of dose equivalent. The dose equivalent in rem is equal to the absorbed dose in rad multiplied by a quality factor that accounts for the biological effect of the radiation. (1 rem = 0.01 sievert).
Replicate Sample	Two or more samples from one location that are analyzed by the same laboratory.

Roentgen	A unit of exposure to ionizing radiation. It is that amount of gamma or x-rays required to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen, German scientist who discovered x-rays in 1895.
Split Sample	A sample from one location that is divided into two samples and analyzed by different laboratories.
TLD	Thermoluminescent Dosimeters
U.S. DOE	United States Department of Energy
WAC	Washington Administrative Code
X-ray	Electromagnetic waves or photons emitted from the outer shell of the atom instead of the nucleus. They have no charge and are best shielded by thick layers of lead or steel. X-ray energy may cause an external or internal radiation hazard.

Appendix D - List of Analytes

Am-241	Americium-241
Be-7	Beryllium-7
C-14	Carbon-14
Cm-244	Curium-244
Co-60	Cobalt-60
Cs-137	Cesium-137
Eu-152	Europium-152
Eu-154	Europium-154
Eu-155	Europium-155
H-3	Hydrogen-3
I-129	Iodine-129
K-40	Potassium
NO2+NO3	Nitrite + Nitrate
Pu-238	Plutonium-238
Pu-239/240	Plutonium-239/240
Ru-106	Ruthenium
Sb-125	Antimony
Sr-90	Strontium-90
Tc-99	Technetium-99
Total U	Total Uranium
U-234	Uranium-234
U-235	Uranium-235
U-236	Uranium-236
U-238	Uranium-238