Environmental Radiation Monitoring and Assessment Program

Hanford Environmental Oversight Program 2007 Data Summary Report

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Division of Environmental Health

Environmental Radiation Monitoring and Assessment Program

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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 2007.

The Oversight Program's objectives are met through collection and analysis of environmental samples and interpretation of results. DOH samples are either split or collocated with DOE contractors, and the results are compared to verify the quality of the DOE monitoring programs at Hanford. Samples of air, groundwater, surface water, riverbank seep water, drinking water, discharge water, sediment, 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 qualitatively describe the agreement between DOH and DOE radioactivity concentrations in environmental media. 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 homogeneous. 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 only fair for gross beta and uranium activity in air samples, gross beta activity in effluent treatment discharge water samples, uranium activity in sediment samples, and Sr-90 activity in vegetation samples. In the case of uranium in sediment samples, the discrepancy is due to a known difference in laboratory analytical methods. For the case of gross beta in air, the difference in sampling intervals and sampling equipment may contribute to the

discrepancy. For the other cases, the discrepancies are under investigation, and are likely related to differences in laboratory procedures and sample collection protocol.

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, C-14, H-3 (tritium), I-129, Sr-90, Tc-99, and isotopes of uranium were detected above background levels in some Hanford Site and Hanford boundary water samples. A variety of radionuclides, including Cs-137, Eu-152, Pu-239/240, Sr-90, and isotopes of uranium, were found above background levels in some Columbia River sediment samples. Most of the elevated concentrations are consistent with historical trends.

One exception was a sediment sample from White Bluffs Slough, in which case both DOH and the DOE contractor reported a Cs-137 concentration approximately twice as high as that typically seen in sediment samples.

Tritium concentrations in 100K Area groundwater wells had displayed large fluctuations during the time period from 2004 to 2005. Concentrations appear to have steadied during the last two years. 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, collocated, 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 annual results of environmental radiation measurements made by the Washington State Department of Health's Hanford Environmental Oversight Program.

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 lists the full element names of the radionuclides discussed in this report; i.e., H-3 is Hydrogen-3.

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. Samples are either split or collocated with DOE contractors. Typically, DOE contractors include Pacific Northwest National Laboratory (PNNL), Duratek, Fluor, and Waste Management Federal Services (WMFS).

Split samples are prepared by dividing a sample into two parts. Collocated 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 laboratory 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 the 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

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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 collocated 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 collocated 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 are 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 collocated 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 $\pm$ 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 collocated 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, drinking 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   Ambient Air Monitoring

Major Findings:

- The DOH and DOE contractor collocated biweekly gross beta results are in fair agreement. The data follow the same trends, but there is a small systematic discrepancy between the data sets. Different sampling frequencies and differences in sampling equipment between DOH and DOE contractors likely contribute to differences in results.
- The DOH and DOE contractor collocated quarterly and semiannual composite air sample results are in good agreement for all radionuclides, except for isotopes of uranium in which case the DOE contractor typically reports concentrations less than those reported by DOH.
- The gross beta results are consistent with background air concentrations.
- The DOH quarterly and semiannual composite air concentrations are below detection limits for most radionuclides. However, uranium was detected in composite air samples at concentrations consistent with historical results. Cesium-137 and Plutonium-239/240 were detected in a few samples, at concentrations slightly above detection limits.

3.1.1   Purpose and General Discussion

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

Sources of Hanford-specific airborne emissions include resuspension of contaminated soil (caused by wind or cleanup activities, for example) and escape of radioactive particulates and gasses from facilities and operations. Sources of natural airborne radioactivity include natural radon gas and its decay products, resuspension of soil containing natural radionuclides such as U-234, U-238, and K-40, and radioactive atoms such as Be-7 and H-3 (tritium) that are generated in the atmosphere by interactions with cosmic radiation. Other sources of man-made airborne radioactivity include resuspension of fallout from historical atmospheric testing of nuclear weapons, including Cs-137 and Pu-239/240. Appendix D lists the full element names for these radionuclides.

3.1.2   Monitoring Locations

Ambient air monitoring locations fall into two categories: (1) Near Facilities and Operations; and (2) Site-Wide and Offsite. For the Near Facilities program, most air samplers are located within 500 meters, and in the prevailing downwind direction from

sites having the potential for environmental releases. Duratek was the DOE contractor for this program. For the Site-Wide and Offsite program, samplers are located throughout the Hanford Site, along the Hanford perimeter, in nearby communities, and in distant communities. PNNL was the DOE contractor for this program. The two programs use different laboratories for analysis of the air samples, so each program is discussed separately in this report.

DOH collected air samples collocated with the Near Facilities and Operations program (Duratek) at five locations, four of which are near 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), the K East Area fuel storage basins (100K East Basin), and the Integrated Disposal Facility in the 200 Area (IDF). The fifth collocated site, which is not near any facility, is at the Wye Barricade.

DOH collected air samples collocated with the Site-Wide and Offsite program (PNNL) at five locations. These locations include Wye Barricade, Prosser Barricade, and Yakima Barricade, which are located throughout the Hanford Site; Station 8, which is located along the Hanford perimeter; and Battelle Complex, which is located in the nearby community of Richland. Note that Yakima Barricade is in the prevailing upwind direction of potential sources of airborne radioactivity.

The DOH collocated 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 collocated filters every other week (biweekly). 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 biweekly) filter samples for a three or six-month period are dissolved and combined into quarterly or semiannual composite samples. The composite samples are analyzed for gamma emitting radionuclides and isotopes of uranium and plutonium. A summary of the collocated monitoring program is presented in Table 3.1.1.

Type of Air Sample	DOH/PNNL	DOH/Duratek
Weekly (or Biweekly) 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/Biweekly Results

The DOH and PNNL gross beta concentrations in biweekly collocated 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 Wye Barricade are shown in Figure 3.1.2.

The scatter plots for 2007 and historical DOH and PNNL gross beta concentrations are shown in Figures 3.1.3 and 3.1.4, respectively. These plots show the data from all sites that are collocated with PNNL. The DOH and PNNL data follow the same general trend. However, there is significant scatter about the theoretical line in which 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 of historical data 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 mid and upper range.

The DOH and Duratek gross beta concentrations in biweekly collocated 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 100K East Basin are shown in Figure 3.1.5.

The scatter plots for 2007 and historical DOH and Duratek gross beta concentrations are shown in Figures 3.1.6 and 3.1.7. These plots show the data from all sites that are collocated with Duratek. The DOH and Duratek data follow the same general trend. However, there is significant scatter about the theoretical line where the DOH and Duratek 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 Duratek results. The regression analysis of historical data indicates that Duratek on average reports slightly higher concentrations at the lower range of results, while DOH on average reports slightly higher concentrations at the mid and upper range.

In general, the DOH and DOE contractor data sets are not expected to match identically because the sampling frequencies and equipment are different, and therefore the results correspond to an averaging of the air concentration over different time periods.

Quarterly Composite Results

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

The DOH and PNNL airborne concentrations are in good agreement for the gamma emitting isotopes of Co-60, Cs-134, and Cs-137, with all results below the detection limits listed in Appendix B. In addition, neither DOH nor PNNL reported measurable concentrations of any other gamma emitting radionuclides, including Eu-152, Eu-154, Eu-155, Ru-106, and Sb-125.

The isotopic uranium concentrations are mostly in good agreement, although most results are below the detection limits. Figure 3.1.8 shows the quarterly U-238 concentrations at Station 8 and Wye Barricade. Historically, the agreement is only fair, as the PNNL concentrations are systematically less than those reported by DOH when the DOH result is above the detection limit. The reason for the bias is under investigation (see Section 4 for a detailed discussion). The results for U-234 are similar. The U-235 concentrations are in agreement, although all the results are below the detection limit.

The historical DOH and PNNL quarterly composite U-238 concentrations for the years 1999 through 2007 are shown in the scatter plot of Figure 3.1.9. The discrepancy appears primarily 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. It should be noted, however, that the concentrations are very small, typically near the detection limit, and the differences between DOH and PNNL concentrations are also very small.

The PNNL samples were also analyzed to determine concentrations of Sr-90, Pu-238, and Pu-239/240. All results were below the PNNL detection limits. DOH did not analyze for these radionuclides in the quarterly composite air samples.

Semi-Annual Composite Results

DOH and Duratek analyzed collocated semiannual composite air samples for Co-60, Cs-134, Cs-137, Pu-238, Pu-239/240, and isotopes of uranium at 100K East Basin, C Farm, ERDF-SE, and IDF.

The DOH and Duratek airborne concentrations are in good agreement for the gamma emitting isotopes of Co-60, Cs-134, and Cs-137. Most results are below detection limits, although very low concentrations of Cs-137 were detected in air at C Farm, as shown in Figure 3.1.10. Cesium-137 concentrations slightly above the detection limit have been observed at C Farm for the last several years. In addition, neither DOH nor PNNL reported measurable concentrations of any other gamma emitting radionuclides, including Eu-152, Eu-154, Eu-155, Ru-106, and Sb-125.

Close inspection of historical data in semiannual composite air samples indicates that when DOH detects Cs-137 above the detection limit (0.0005 pCi/m^3), Duratek reports concentrations approximately 60% of those reported by DOH. This phenomenon is shown in Figure 3.1.11. This discrepancy will be investigated and discussed in future reports.

The DOH and Duratek Pu-238 and Pu-239/240 airborne concentrations are also in good agreement, and most results are below detection limits. One result at 100K East Basin was slightly above the detection limit of 0.000005 pCi/m^3. See Section 3.1.5 below for a discussion of the concentrations considered detectable. Historically, Duratek occasionally reports a Pu-239/240 concentration several times higher than DOH, although this was not the case in 2007.

The isotopic uranium concentrations are only in fair agreement, as several of the Duratek concentrations are less than those reported by DOH. The reason for the bias is under investigation (see Section 4 for a detailed discussion). The DOH and Duratek U-238 data for 2007 are shown in Figure 3.1.12, and the historical data are shown in the scatter plot of Figure 3.1.13. The historical scatter plot indicates that Duratek consistently reports uranium concentrations less than those reported by DOH when the DOH result is above the detection limit (see discussion of Quarterly Composite Results above). The U-234 results are similar. All of the U-235 results are below the detection limit.

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 3.1.14, which shows gross beta activity at Wye Barricade over the last decade from 1998 through 2007.

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 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, 100K East Basin, and IDF).

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. The standard deviation in gross beta air concentrations is approximately 0.015 pCi/m^3 for all sites.

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Site	Average DOH Gross Beta Concentration (pCi/m^3)
100K East Basin	0.020
Battelle Complex	0.022
C Farm	0.023
ERDF-SE	0.020
IDF	0.021
Prosser Barricade	0.023
Station 8	0.015
Wye Barricade	0.021
Yakima Barricade	0.020

Table 3.1.2   Summary Statistics for Gross Beta Concentrations in Air

Most 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). One exception is Cs-137 at C Farm, where concentrations slightly above the detection limit have been detected for the last several years. Historical Cs-137 concentrations in air samples at C Farm are shown in Figure 3.1.15.

Uranium-234 and U-238 were detected in most air samples, with concentrations ranging from below the detection limit to 0.00007 pCi/m^3. These uranium concentrations are consistent with historical results, and most likely originate from natural uranium in the soil.

Plutonium-239/240 was detected at KE Basin, at a concentration of 0.00001 pCi/m^3. Historical Pu-239/240 concentrations in air samples at 100K East Basin are shown in Figure 3.1.16. The levels of plutonium detected in Hanford air samples are very low, and are near the laboratory's capability for detection. Pu-238 is usually not detected in composite air samples.

DOH is looking at two solutions to improve the data related to plutonium in composite air samples. The first solution is a review and revision of laboratory procedures to improve recovery of plutonium. Plutonium in the environment is found in two forms: a non-soluble high fired oxide that tightly absorbs to soil, sediment, and air particulates; and a more soluble form. Historically, DOH used an acid leach procedure to separate plutonium from the particulates on the air filter. This procedure does not effectively separate the tightly bound, high fired oxide form of plutonium and make it available for quantification. Beginning in 2008, DOH changed the initial sample preparation from acid leaching to total dissolution of air filters in order to capture the high fired oxide form of plutonium.

The second solution is a review and revision of statistical parameters that are used to describe whether or not an analyte is present in a particular sample. DOH intends to measure to the lowest concentration practical and minimize the error of reporting a non-detectable analyte concentration when an analyte is actually present.

DOH has traditionally used the measured concentration, uncertainty, and minimum detectable activity (MDA) values to indicate if an analyte is present. The MDA represents the balance point between the probability functions that describe the likelihood of false-detection and false-rejection; it is not the point above which calculated activity can be considered to be positively detected.

One additional statistical term that applies to data interpretation where the results are at the limit of detection is the critical level. This key concept describes the minimum significant concentration that can be discriminated from the concentration observed for a blank sample, thus allowing a decision to be made that the radionuclide was detected or not. DOH is revising data interpretation procedures to include evaluation of the critical level when samples are at the edge of detection capabilities, such as with plutonium in air composite samples.

The maximum radionuclide concentrations detected in DOH quarterly and semiannual 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).
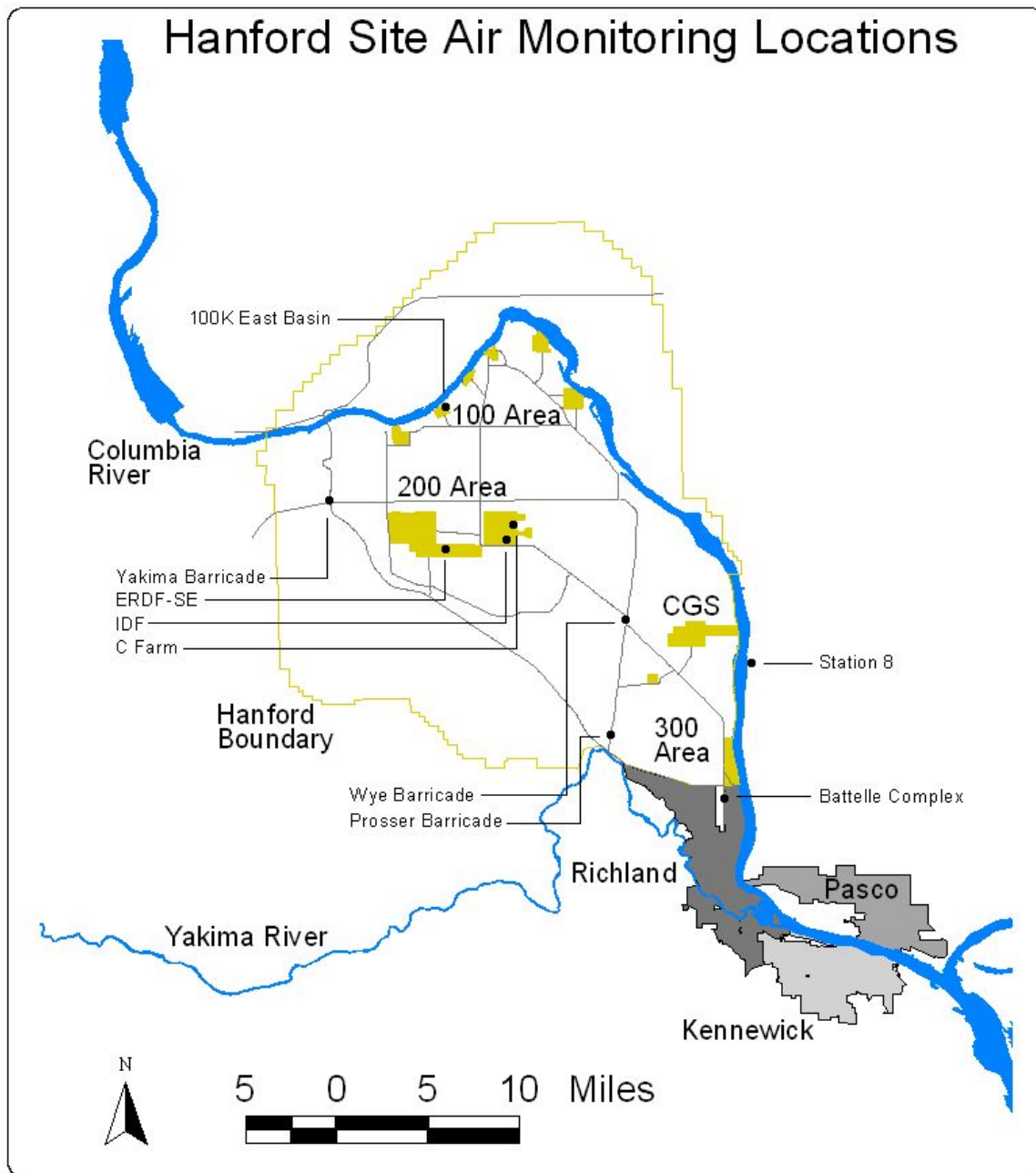
Figure 3.1.1   Air Monitoring Locations
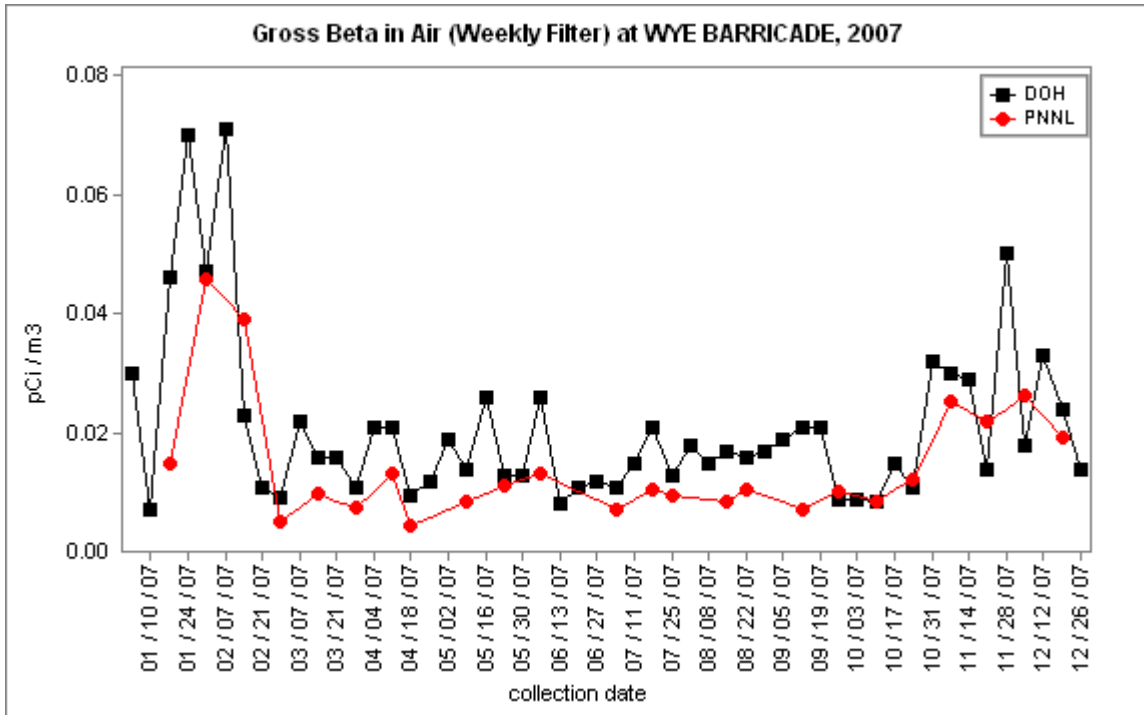
Figure 3.1.2   DOH and PNNL Gross Beta Concentrations in Air at Wye Barricade
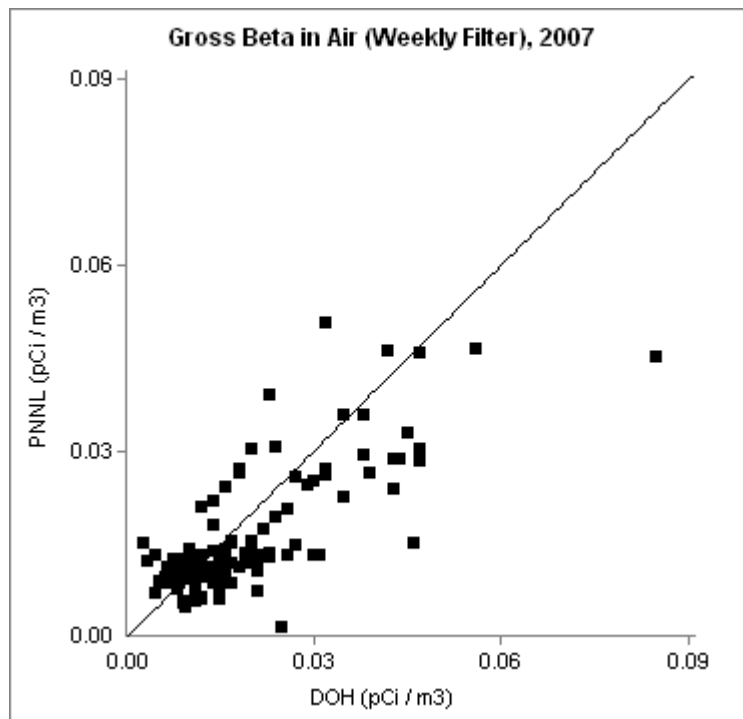
Figure 3.1.3   DOH and PNNL Scatter Plot for Gross Beta Concentrations in Air (2007)

18
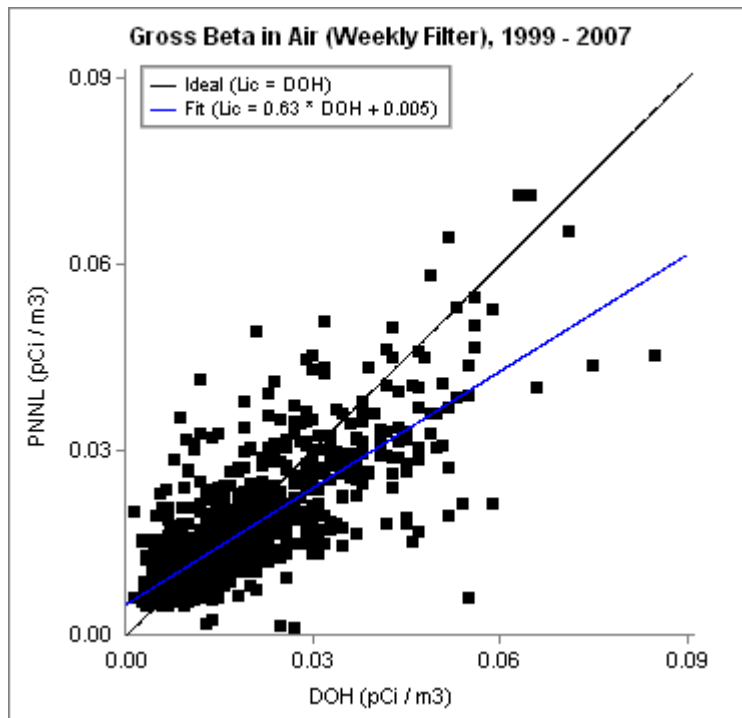
Figure 3.1.4   DOH and PNNL Scatter Plot for Historical Gross Beta Concentrations in Air
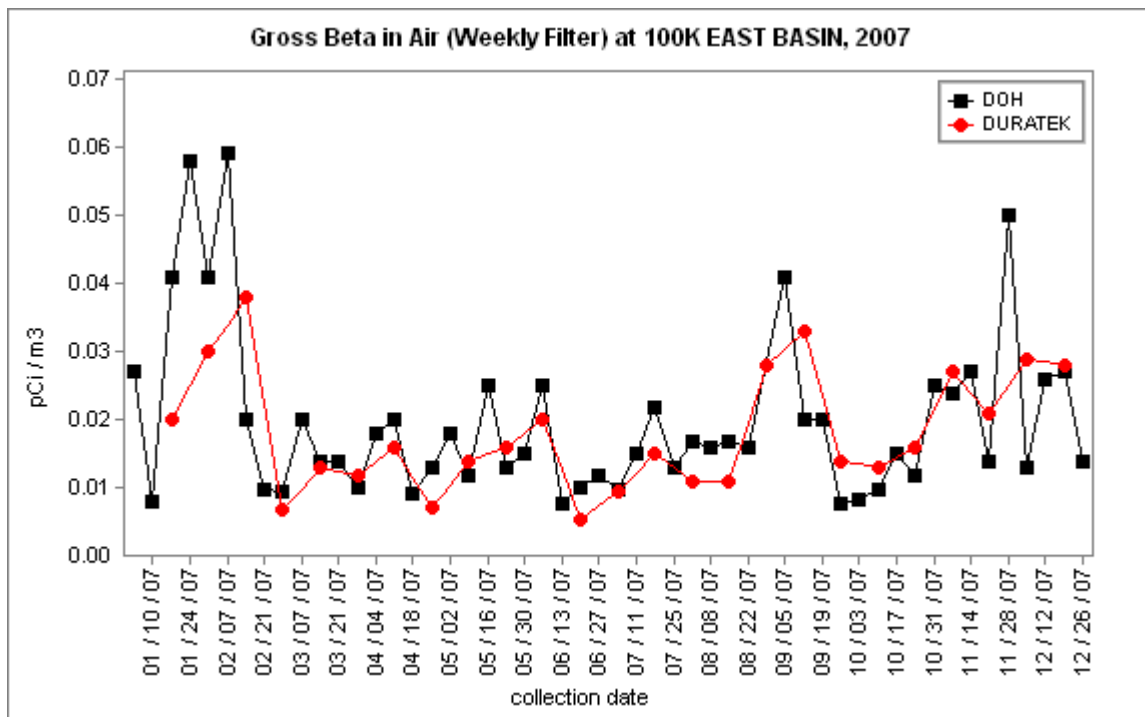
Figure 3.1.5   DOH and Duratek Gross Beta Concentrations in Air at 100K East Basin
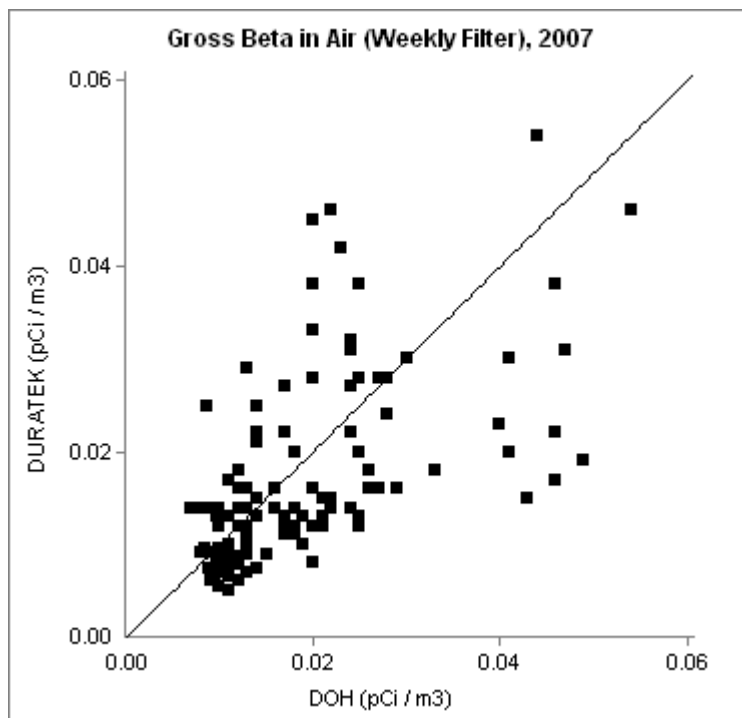
Figure 3.1.6   DOH and Duratek Scatter Plot for Gross Beta Concentrations in Air (2007)
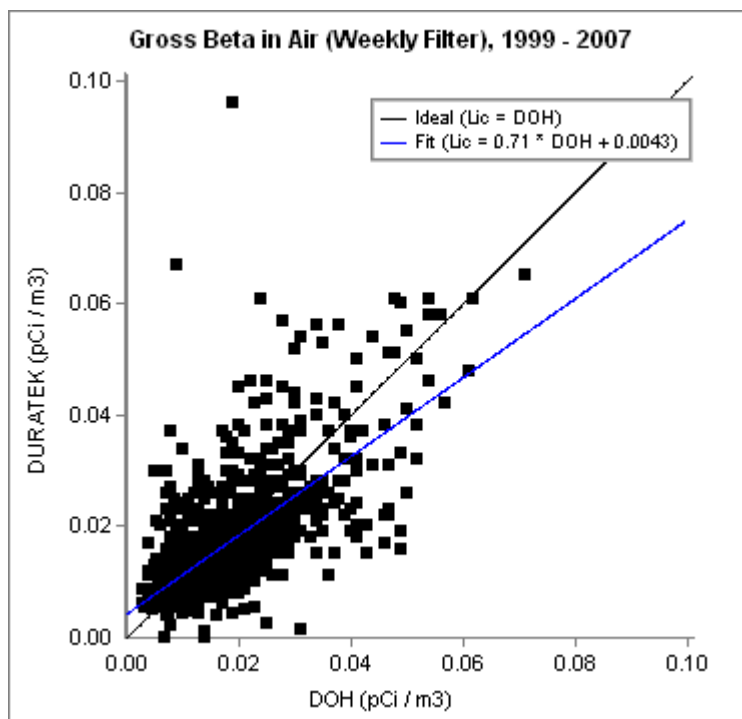
Figure 3.1.7   DOH and Duratek Scatter Plot for Historical Gross Beta Concentrations in Air
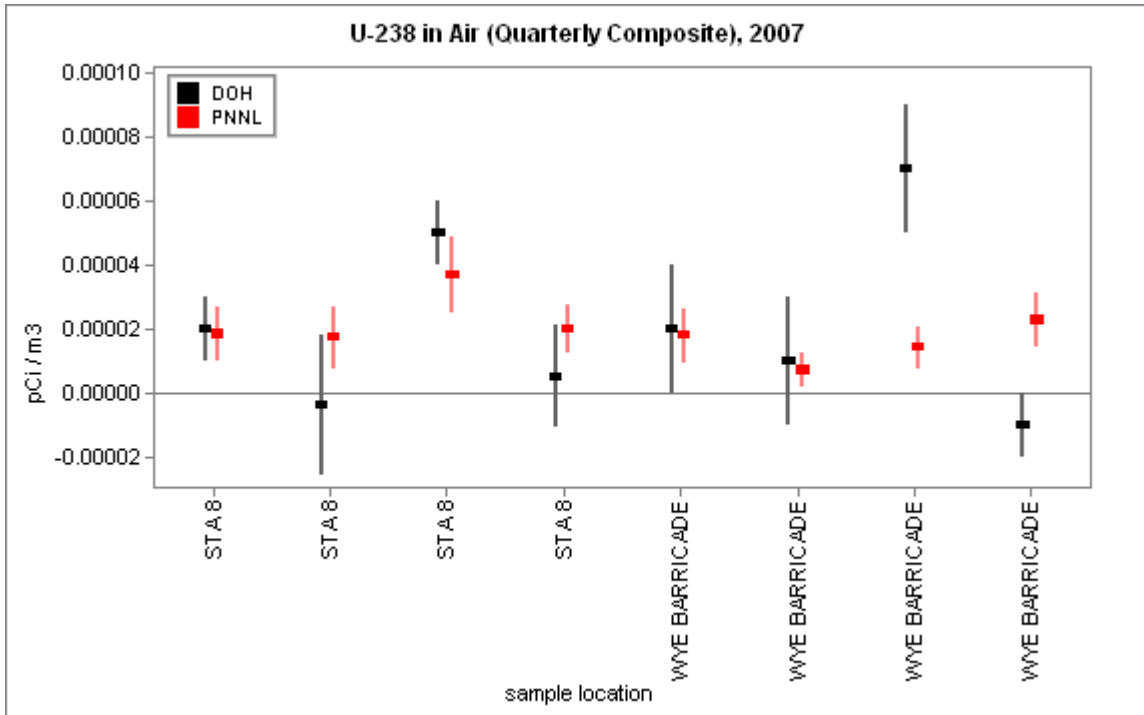
Figure 3.1.8   DOH and PNNL U-238 Concentrations in Air
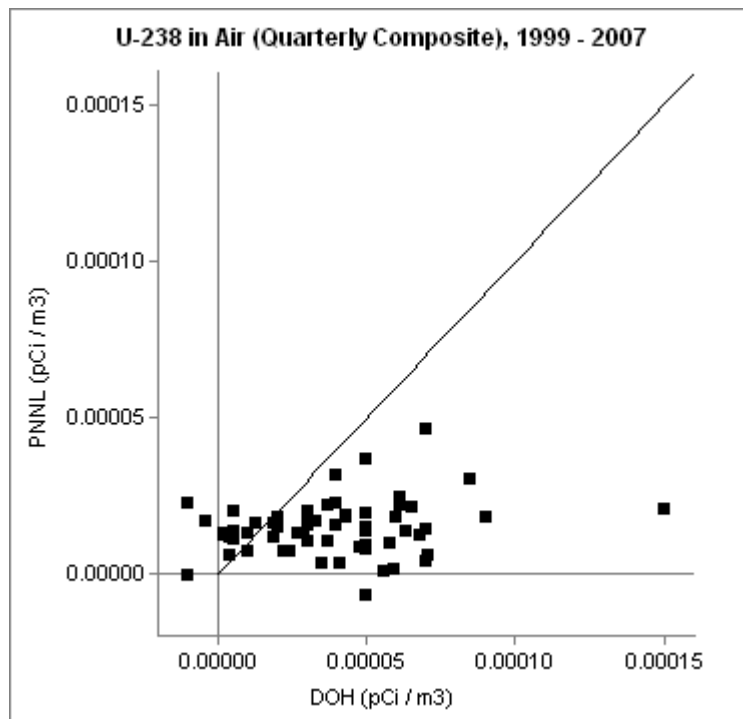
Figure 3.1.9   DOH and PNNL Scatter Plot for Historical U-238 Concentrations in Air

21
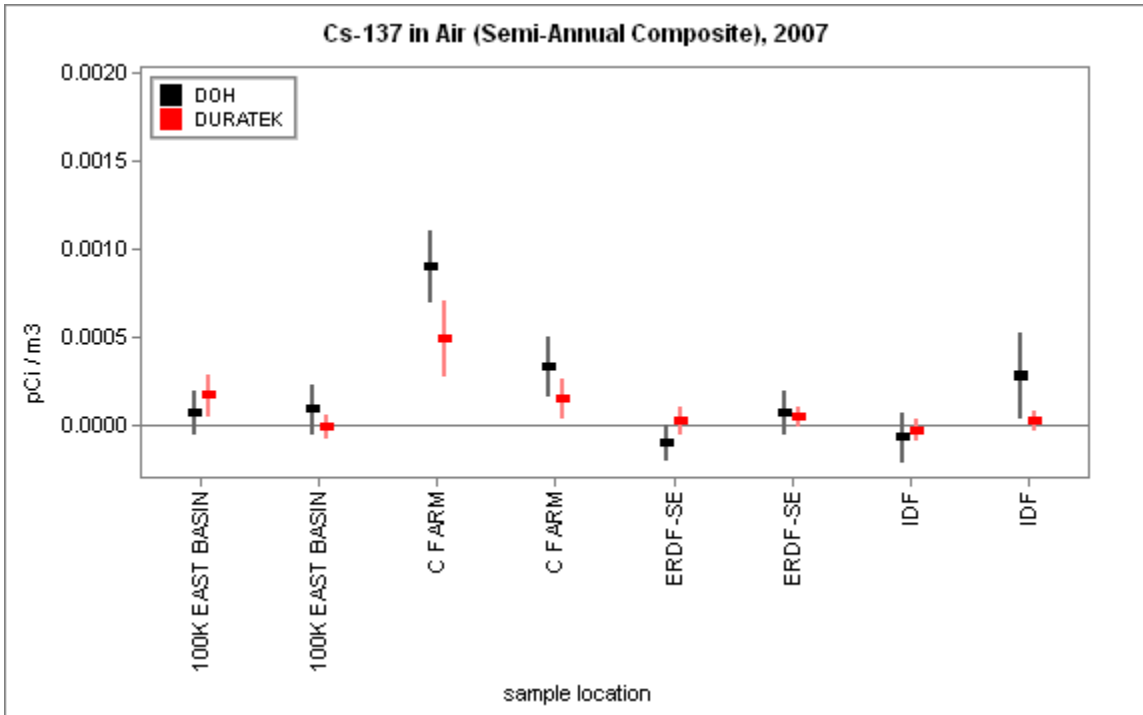
Figure 3.1.10   DOH and Duratek Cs-137 Concentrations in Air
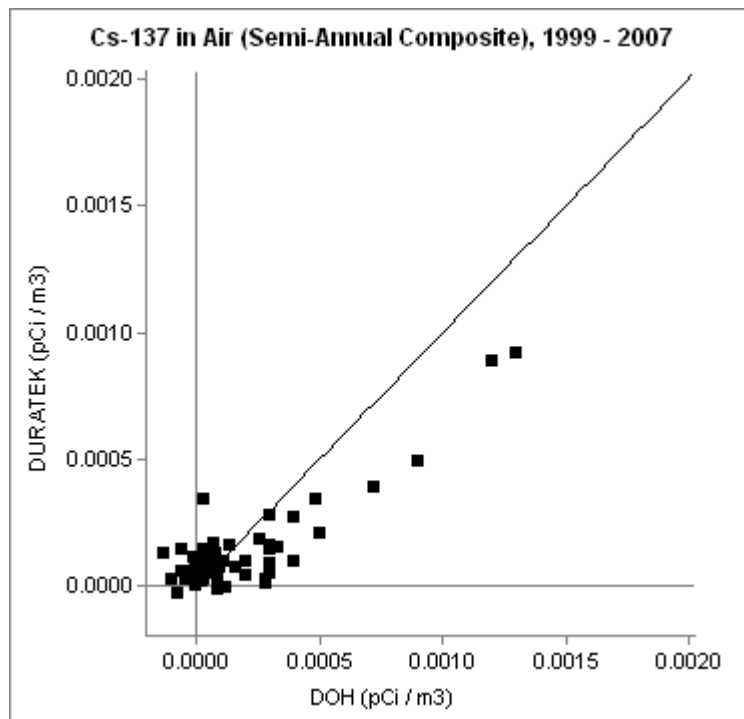
Figure 3.1.11   DOH and Duratek Scatter Plot for Historical Cs-137 Concentrations in Air

22
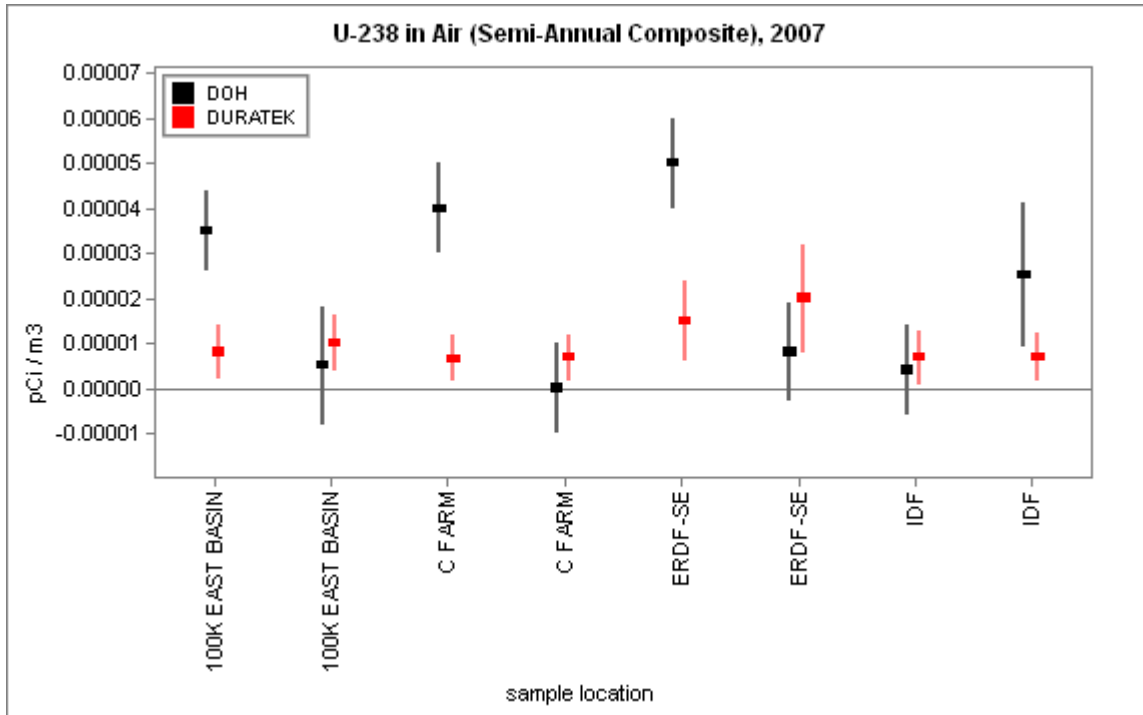
Figure 3.1.12   DOH and Duratek U-238 Concentrations in Air
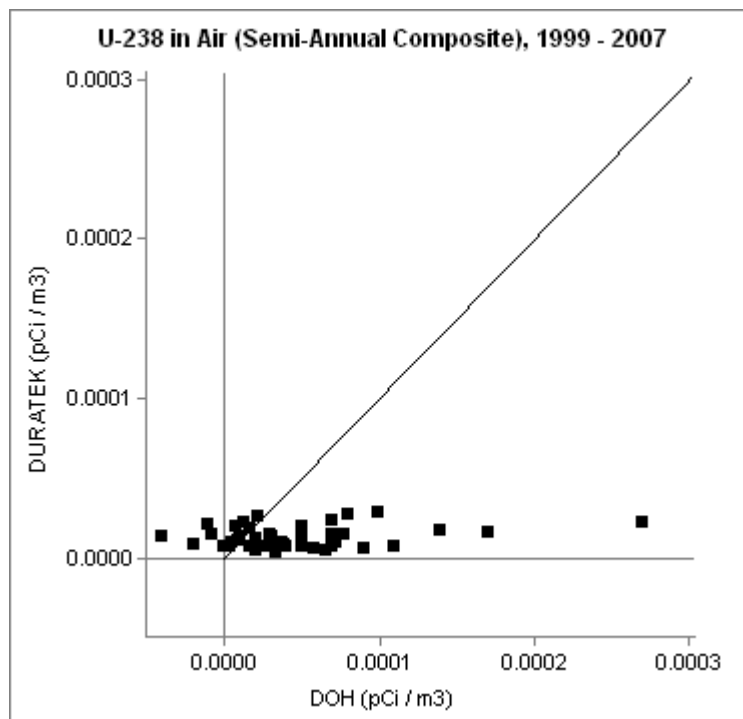
Figure 3.1.13   DOH and Duratek Scatter Plot for Historical U-238 Concentrations in Air

23
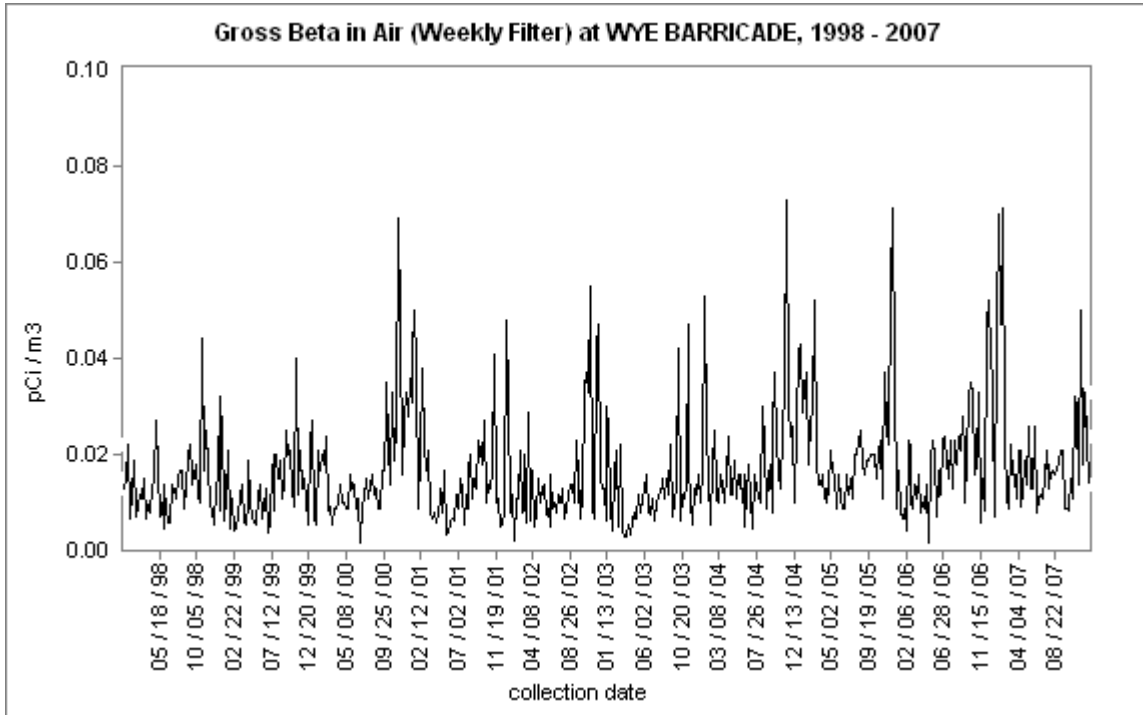
Figure 3.1.14   DOH Historical Gross Beta Concentrations in Air at Wye Barricade
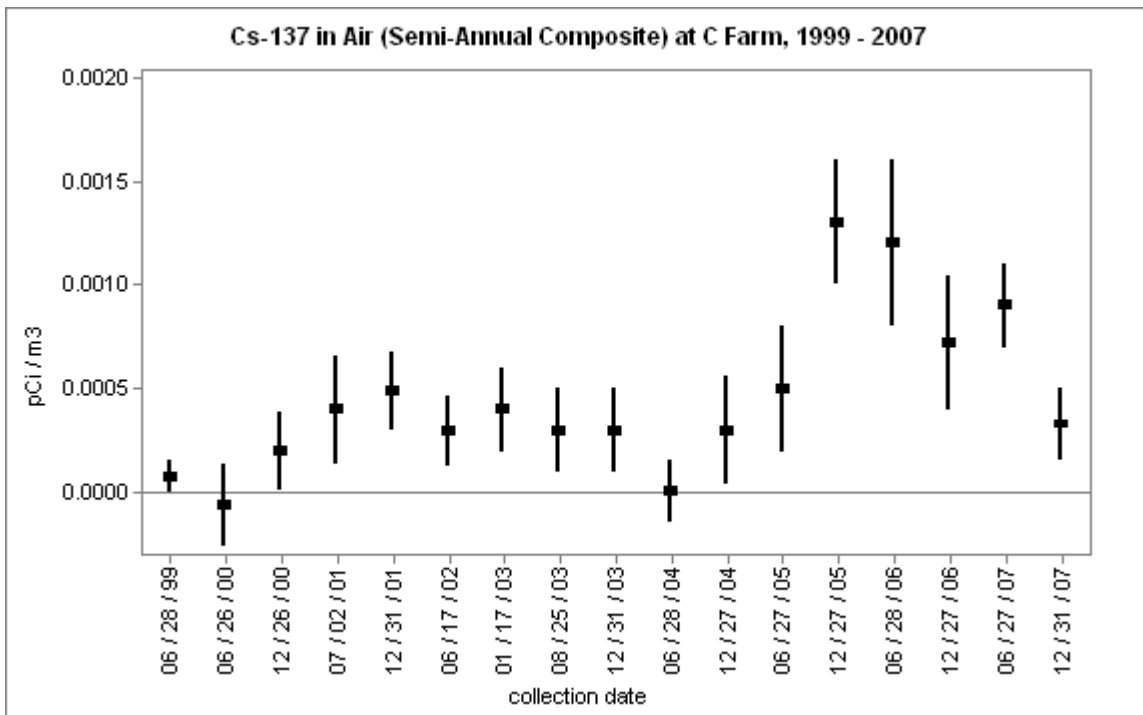
Figure 3.1.15   DOH Historical Cs-137 Concentrations in Air at C Farm

24
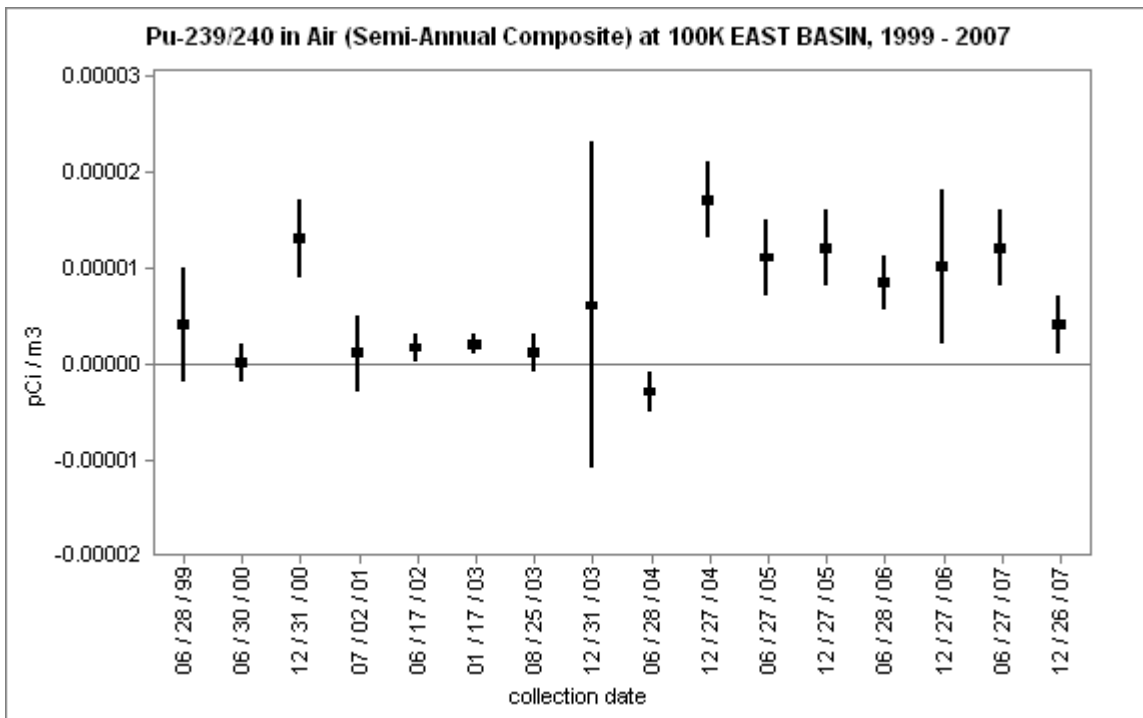
Figure 3.1.16   DOH Historical Pu-239/240 Concentrations in Air at KE Basin

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3.2   Groundwater, Riverbank Seep, and Surface Water Monitoring

Major Findings:

- The DOH and Fluor split water results are all in good agreement.
- Most DOH and PNNL split water results are in good agreement. There was an anomalous disagreement in one gross alpha and one H-3 result.
- The DOH and Duratek split effluent treatment discharge water result is in fair agreement, while the DOH WMFS split effluent treatment 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 C-14, H-3, I-129, Sr-90, Tc-99, and isotopes of uranium in some Hanford groundwater, seep water, and surface water samples. Most concentrations are consistent with historical trends.
- Radionuclide concentrations in drinking water samples analyzed by DOH 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 surface 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, effluent treatment discharge water, and drinking water samples with various DOE contractors. Monitoring is carried out to track contaminant plumes 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 assess impacts to the public.

3.2.2 Monitoring Locations

Water sample locations are shown in Figure 3.2.1.

Groundwater

DOH split 25 groundwater samples from 21 groundwater wells with Fluor. Most co-sampled well locations are on the Hanford Site, either within contaminated plumes, near waste sites, or along the Columbia River shoreline. A few of the co-sampled well locations are off the Hanford Site, located just south of Hanford in the northern part of Richland.

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 in radioactivity as spent nuclear fuel, shield water, and sludge are removed from the 100 KE Fuel Storage Basin. Eight samples were split from this area.

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, Sr-90, Tc-99, and isotopes of uranium. A primary objective of groundwater collection in the 200 Area is to track radioactive plume movement and monitor potential leaks from waste storage tanks. Two samples were split from this area.

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. Two samples were split from this area.

The 400 Area is the location of the Fast Flux Test Facility, a liquid sodium cooled test reactor that ceased operation in 1993. 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 part of Hanford. One sample was split from 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 radioactive plumes originating in the 200 Area that may be moving off-site. Twelve samples were split from this area.

Riverbank Seeps

DOH and PNNL split five Columbia River riverbank seep samples. 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 Town Site, and the 300 Area. Sample locations included the 100K and 100N areas, the Old Hanford Town Site (Spring 28.2), and the 300 Area.

Surface Water

DOH and PNNL split 20 surface water samples from 19 different locations. Eighteen of the samples were collected from the Columbia River - two from near Priest Rapids Dam located upstream of Hanford, four from the 100N Area, four from the Old Hanford Town Site, four from the 300 Area, and four from near the Richland drinking water pump house. 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 Yakima River irrigation pumping station.

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.

Discharge Water

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 split one discharge sample with Duratek and another with Waste Management Federal Services (WMFS).

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. For this year, one split sample from FFTF was collected. In addition to the split FFTF sample, DOH collected a drinking water sample from the Laser Interferometer Gravitational-Wave Observatory (LIGO) Facility and from the Edwin Markham elementary school in Pasco, of which both results are presented in this report.

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 those 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 C-14, I-129, Sr-90, 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 (Yakima River water) and Riverview (Columbia River water).

Samples were split in the field and analyzed unfiltered. All samples were analyzed for isotopes of uranium and for 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 (TEDF) were analyzed for gross alpha, gross beta, gamma emitting radionuclides, and H-3.

Drinking Water

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

Summary

A summary of the 2007 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, 137; Eu-152, 154, 155; gross alpha; gross beta; H-3; I-129; Ru-106; Sb-125; Sr-90; Tc-99; U-234, 235, 236, and 238	21	25
Riverbank Seep	Co-60; Cs-134, 137; Eu-152, 154, 155; gross alpha; gross beta; H-3; I-129; Ru-106; Sb-125; Sr-90; Tc-99; U-234, 235, 236, and 238	5	5
Surface Water	Co-60; Cs-134, 137; Eu-152, 154, 155; gross alpha; gross beta; H-3; Ru-106; Sb-125; Sr-90; Tc-99; U-234, 235, and 238	19	20
Discharge Water	Co-60, Cs-137, gross alpha, gross beta, H-3	1	2
Drinking Water	Gross alpha, H-3	1	1

Table 3.2.1   Summary of Water Samples

3.2.4   Comparison of DOH and DOE Contractor Data

DOH split groundwater samples with Fluor; and split surface water, riverbank seep water, and drinking water samples with PNNL. In addition, DOH split effluent treatment discharge water samples with Duratek and Waste Management Federal Services. The year 2007 is the first year that groundwater samples have been split with Fluor, so no historical data exists for comparing the current split results with historical trends. 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.

DOH / Fluor Results - 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, the term *gamma emitting radionuclide* refers to the fact that radioactivity concentrations were obtained by measuring gamma ray activity using gamma spectroscopy.

The DOH and Fluor concentrations of gamma emitting radionuclides in split groundwater samples are all in agreement, and all results are below detection limits. Eight split groundwater samples were analyzed for gamma emitting radionuclides. Radionuclides included in the gamma analysis include Co-60, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, I-129, Ru-106, and Sb-125.

DOH / Fluor Results - Gross Alpha and Gross Beta Activity

The DOH and Fluor gross alpha and gross beta concentrations in split groundwater samples are in good agreement. Eighteen split groundwater samples were analyzed for gross activity. Split gross alpha concentrations ranged from below the detection limit to 57 pCi/L, while split gross beta concentrations ranged from below the detection limit to 2,800 pCi/L.

DOH / Fluor Results - H-3, Sr-90, and Tc-99

The DOH and Fluor concentrations of H-3, Sr-90, and Tc-99 in split groundwater samples are all in good agreement. Twenty two split groundwater samples were analyzed for H-3, and concentrations ranged from below the detection limit to 252,000 pCi/L. Eight split groundwater samples were analyzed for Sr-90, and concentrations ranged from below the detection limit to 1,600 pCi/L. As an example of the agreement, the Sr-90 results are shown in Figure 3.2.2. Seven split groundwater samples were analyzed for Tc-99, and concentrations ranged from below the detection limit to 190 pCi/L.

DOH / Fluor Results - Uranium Isotopes

The DOH and Fluor concentrations of uranium isotopes in split groundwater samples are all in good agreement. Only a single groundwater sample, from the 400 Area, was analyzed for isotopes of uranium, and all results are below detection limits.

DOH / PNNL Results - Gamma Emitting Radionuclides

The DOH and PNNL concentrations of gamma emitting radionuclides in split water samples are all in agreement, and all results are below detection limits. Radionuclides included in the gamma analysis include Co-60, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, Ru-106, and Sb-125.

Historically, DOH and PNNL split water results are in good agreement for all gamma emitting radionuclides except I-129, in which case discrepancies have been observed. The majority of these historical split I-129 results came from groundwater well samples, as I-129 is not typically found in riverbank seep, surface water, or drinking water samples. Starting in 2007, DOH split groundwater samples with the contractor Fluor, and therefore there are no split I-129 results in groundwater with PNNL for this year's report. See Section 4 of this report for a further discussion of I-129.

DOH / PNNL Results - Gross Alpha and Gross Beta Activity

Most of the DOH and PNNL gross alpha and gross beta concentrations in water samples are in good agreement. The only exception is a split riverbank seep water sample from the 300 Area where DOH reported a concentration of 42 pCi/L and PNNL reported 14 pCi/L. Historically, not all gross alpha and gross beta results are in good agreement. Close inspection of historical data reveals a systematic bias, in which DOH

disproportionately reports higher concentrations than PNNL. Most of the bias occurred in samples with higher concentrations of gross activity, which in most cases were groundwater well samples. Starting in 2007, DOH does not split groundwater with PNNL, and therefore the higher gross activity samples are absent and the bias is not observed.

DOH / PNNL Results - H-3, Sr-90, and Tc-99

All of the DOH and PNNL tritium (H-3) concentrations in water samples are in good agreement. Historically, there is a small bias between the DOH and PNNL results for H-3 concentrations in water, especially for higher concentrations. Figure 3.2.3 shows 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 concentrations for Sr-90 and Tc-99 in water samples are in good agreement. Historically, the DOH and PNNL split results for Sr-90 and Tc-99 in water are in fair to good agreement. Scatter plots for historical Sr-90 and Tc-99 results are shown in Figures 3.2.4 and 3.2.5, in which most of the data fall near the line where DOH and PNNL concentrations are equal.

DOH / PNNL Results - Uranium Isotopes

The DOH and PNNL isotopic uranium concentrations for U-234, 235, and 238 in water samples are in good agreement. Historically, the DOH and PNNL split results for these uranium isotopes in water are in good agreement.

DOH / Duratek Results

DOH split a single effluent treatment discharge water sample with Duratek. The split sample was analyzed for gross beta activity. The current results, along with historical results, are shown in Figure 3.2.6. As can be seen in the figure, the agreement is fair, as the data follow the same trend. However, differences by a factor of two between DOH and Duratek are common.

DOH / WMFS Results

DOH split a single effluent treatment discharge water sample with Waste Management Federal Services. The split sample was analyzed for gross alpha and gross beta activity. The agreement between the DOH and WMFS data is good, as can be seen by the historical results shown in Figures 3.2.7 and 3.2.8.

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 and the Edwin Markham elementary school in Pasco. In addition, DOH independently analyzed many of the samples for

analytes not included as part of the oversight program split analysis. For example, Bi-214, C-14, Pb-214, Pu-238, Pu-239/240, Th-230, and U-236 were reported by DOH for numerous samples. Results from these additional DOH samples and analyses are included in the discussion below.

Concentrations of gamma emitting radionuclides in all water samples analyzed by DOH were below detection limits, except for one Co-60 result of 3.7 pCi/L and one I-129 result of 32 pCi/L, both from groundwater well 299-W14-13. 2007 was the first year DOH analyzed a sample from this well. Gamma emitting radionuclides include Co-60, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, I-129, Ru-106, and Sb-125. Detection limits are listed in Appendix B. Most of the DOH results for gamma emitting radionuclides in water samples are similar to historical data. The Co-60 detection at well 299-W14-13 is anomalous since DOH does not typically detect this radionuclide in water samples.

Iodine-129 is often detected in groundwater well 699-35-70, with historical concentrations ranging from 5 to 35 pCi/L. However, for this year's analysis, there was an insufficient quantity of sample from this well for the DOH laboratory to carry out an I-129 analysis.

DOH routinely detects H-3, Sr-90, Tc-99, isotopes of uranium, gross alpha activity, and gross beta activity 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. Most concentrations currently 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 1,290,000 pCi/L (well 299-W14-13). Concentrations above the 20,000 pCi/L EPA drinking water standard were detected in wells 199-N-14, 299-W14-13, 699-26-33, 699-35-70, 699-41-1A, and 699-60-60. Tritium (H-3) concentrations in most wells historically sampled by DOH continue to steadily decrease with time. Groundwater wells 199-K-109A and 199-K-27, at the 100K Area, had sharp increases in H-3 concentrations in 2003; however, the concentrations have since decreased to levels below the drinking water standard.

DOH detected H-3 in all riverbank seep water samples, with concentrations ranging from 300 to 31,000 pCi/L. The highest concentration, 31,000 pCi/L at a Hanford Townsite seep, is the only result above the EPA drinking water standard of 20,000 pCi/L. Tritium was also detected at low levels (most results less than 200 pCi/L) in several of the Columbia River surface water samples, with a maximum concentration of 1,100 pCi/L adjacent to the 300 Area. Tritium was detected in TEDF discharge water at 340 pCi/L, and in FFTF drinking water at 2,700 pCi/L (both below the EPA drinking water standard of 20,000 pCi/L). Tritium was detected at very low levels in the LIGO and Edwin Markham drinking water samples (both at 40 pCi/L).

DOH detected Sr-90 in groundwater wells at concentrations ranging from below the detection limit to 1,400 pCi/L (wells 199-K-109A and 199-N-14). Concentrations above the 8 pCi/L EPA drinking water standard were detected at wells from the 100K and 100N Areas, where the results are consistent with historical concentrations at these locations.

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DOH did not report concentrations of Sr-90 in riverbank seep water for the current reporting period. Strontium-90 was not detected in any Columbia River surface water samples, although DOH did not report Sr-90 for samples adjacent to the 100N Area where Sr-90 is typically detected. Strontium-90 was not detected in the Edwin Markham drinking water sample. These concentrations are consistent with historical results.

DOH detected Tc-99 in groundwater wells at concentrations ranging from below the detection limit to 5,200 pCi/L (high result at well 299-W14-13). Technetium-99 was detected in Old Hanford Townsite seep water at 30 pCi/L, and was not detected in any of the Columbia River surface water samples. These Tc-99 concentrations are consistent with historical results, and other than the result at 299-W14-13, all concentrations were far below the EPA drinking water standard of 900 pCi/L.

DOH detected total uranium (the sum of all uranium isotopes) concentrations of 55 pCi/L in groundwater well 399-1-17A in the 300 Area and 57 pCi/L in a 300 Area riverbank seep. Both these results are above the EPA drinking water standard for total uranium of 21 pCi/L. These concentrations are consistent with historical results.

Isotopic uranium results are typically reported for U-234, U-235, and U-238. Uranium-236 is another isotope of uranium, one that does not occur in nature, but rather is a byproduct of Hanford reactor operations. Uranium-236 is occasionally detected in Columbia River sediments and in water samples. DOH detected U-236 in groundwater samples from the 100H and 300 Areas, and in a riverbank seep from the 300 Area. Concentrations ranged from 0.03 to 0.7 pCi/L, and these concentrations are consistent with historical results.

Uranium-234 and uranium-238 concentrations in water samples ranged from below the detection limit to 28 pCi/L at a 300 Area groundwater well and riverbank seep. Uranium-235 concentrations ranged from below the detection limit to 1.4 pCi/L, again at a groundwater well and riverbank seep in the 300 Area. These isotopic uranium concentrations are consistent with 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).

DOH detected Bi-214 in several groundwater samples, with concentrations ranging from 16 to 91 pCi/L. DOH detected Pb-214 in several groundwater wells, with concentrations ranging from 14 to 110 pCi/L. One groundwater sample from the 600 Area was analyzed for Pu-239, Pu-239/240, and Th-230, with all results below the detection limits.

DOH detected C-14 in groundwater well 199-K-27. DOE contractors did not report C-14 results for this split sample. This well is in the vicinity of a known C-14 groundwater

plume at the 100K Area. Carbon-14 has been detected in well 199-K-27 for the past several years at concentrations ranging from 62 to 1,600 pCi/L. The EPA drinking water standard for this radionuclide is 2,000 pCi/L.

Summary

Radionuclides detected in groundwater wells include Bi-214, C-14, Co-60, H-3, I-129, Pb-214, Sr-90, Tc-99, and isotopes of uranium. Most radionuclide concentrations were similar to historical data, and were detected in the vicinity of known groundwater plumes. The single Co-60 detection at well 299-W14-13 is an anomaly, as DOH does not typically detect this radionuclide in water samples. However, this was the first reporting period in which a sample from this well was analyzed by DOH. In addition, this is the first reporting period in which water samples were analyzed for Bi-214 and Pb-214.

Radionuclides detected in riverbank seep water include H-3, Tc-99, and isotopes of uranium. Most radionuclide concentrations were similar to historical data, and were detected in the vicinity of where groundwater plumes are known to be entering the Columbia River. Typically, Sr-90 is also detected in riverbank seep samples, particularly from the 100N Area.   However, for this reporting period, DOH did not report Sr-90 results in seep samples.

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 and the 300 Area. Strontium-90 is often detected in surface water samples by DOH, but this was not the case for this reporting period.

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.
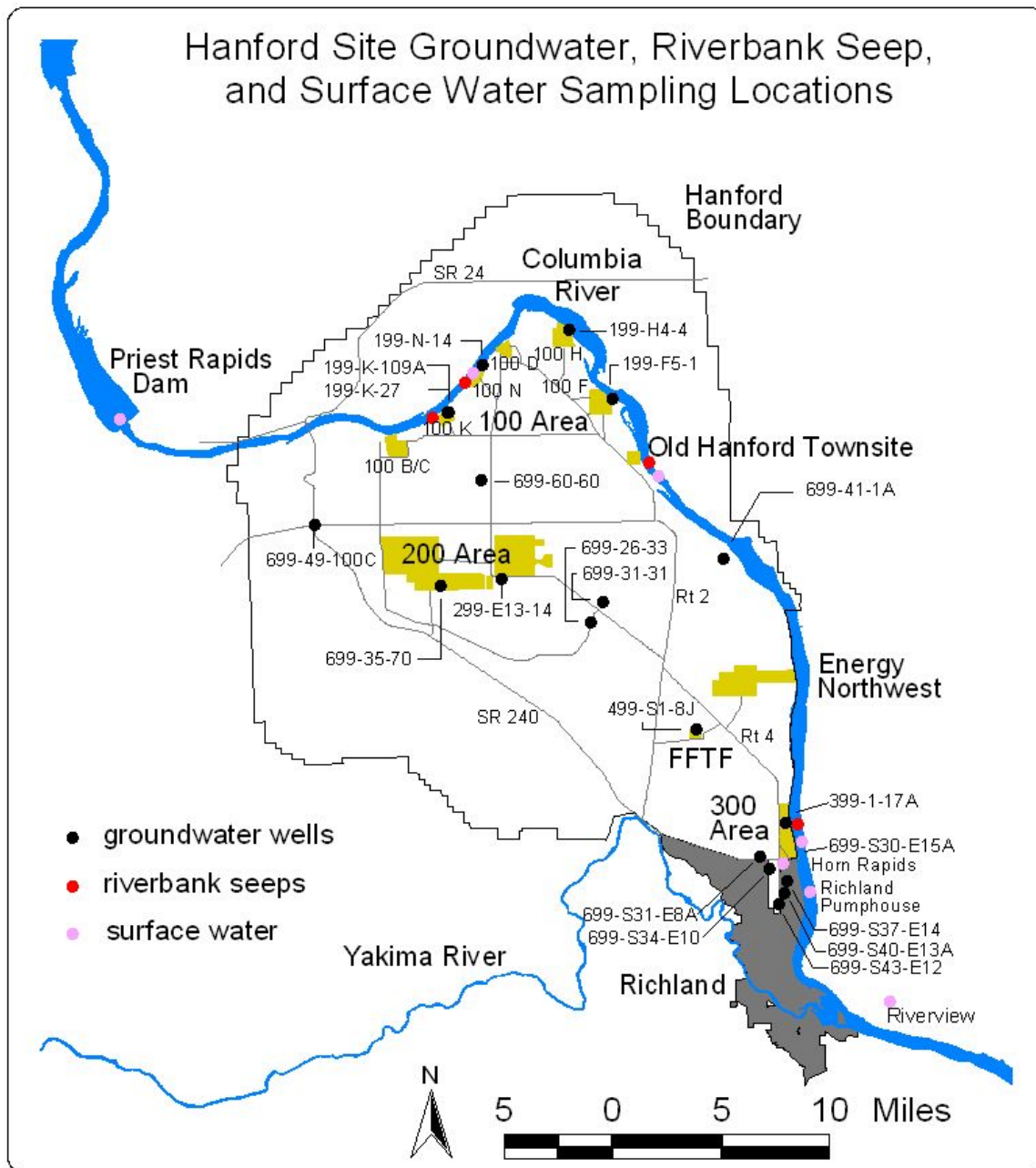
Figure 3.2.1   Water Monitoring Locations
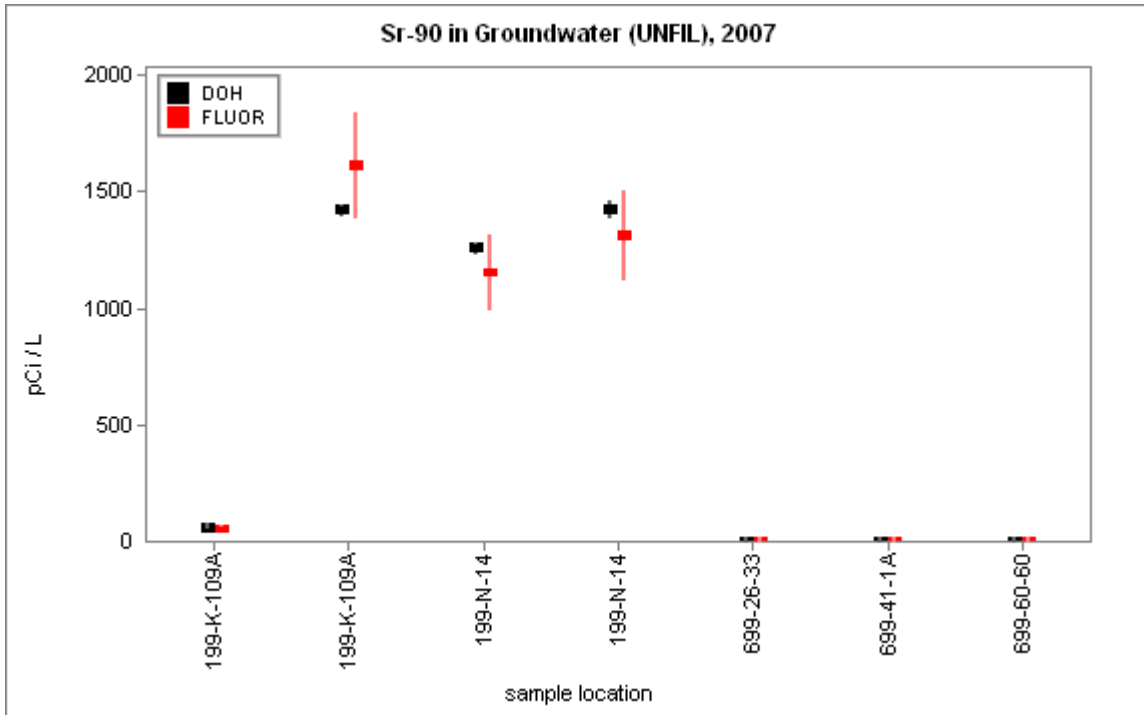
Figure 3.2.2   DOH and Fluor Sr-90 Concentrations in Groundwater Samples
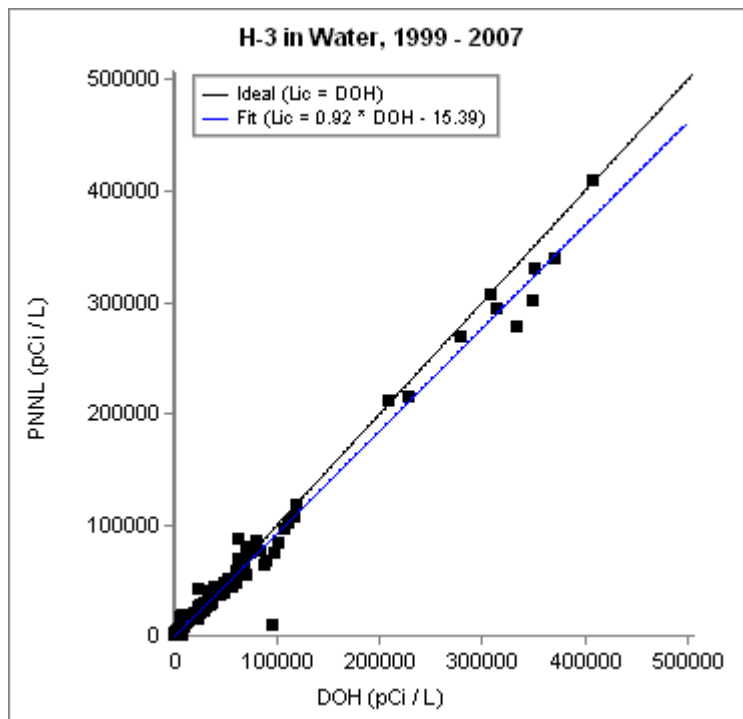
Figure 3.2.3   DOH and PNNL Scatter Plot for Historical H-3 Concentrations in Water Samples
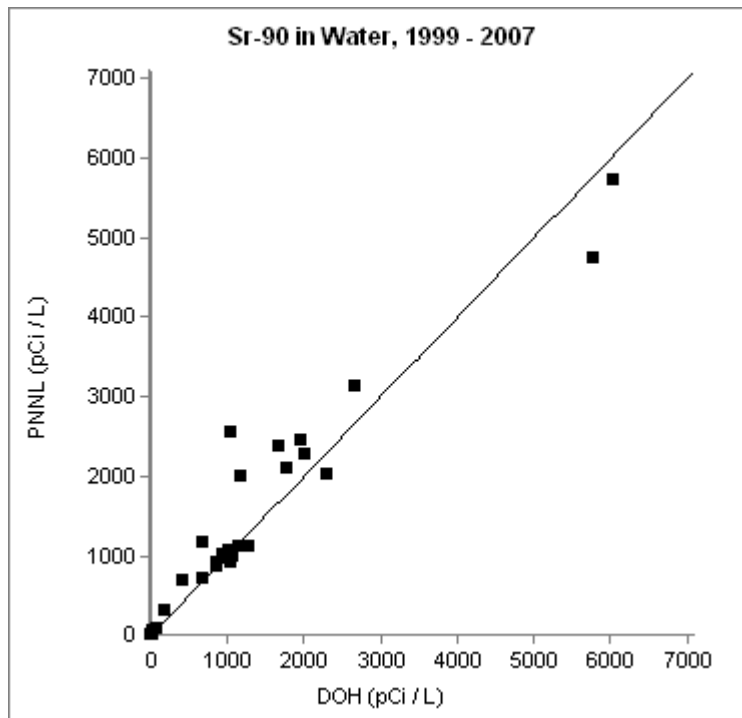
Figure 3.2.4   DOH and PNNL Scatter Plot for Historical Sr-90 Concentrations in Water Samples
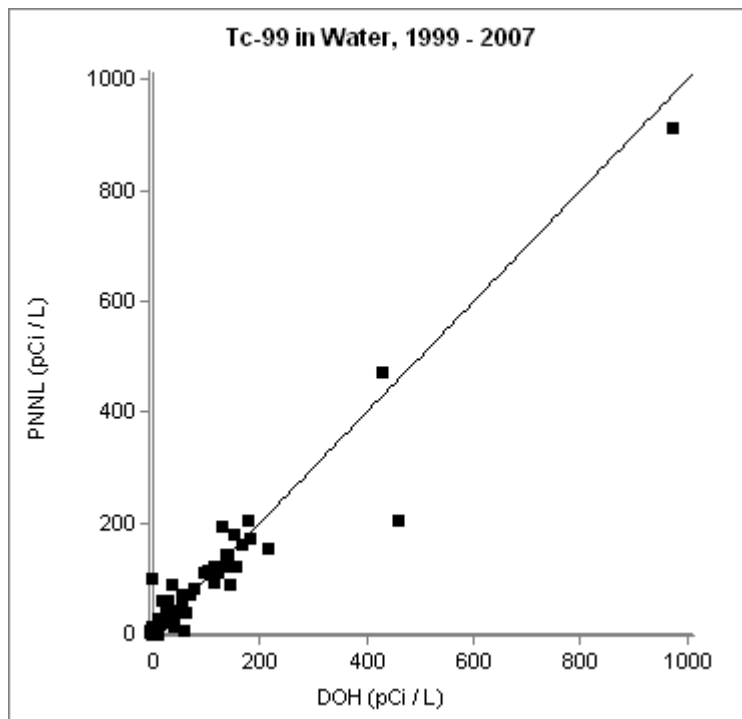
Figure 3.2.5   DOH and PNNL Scatter Plot for Historical Tc-99 Concentrations in Water Samples
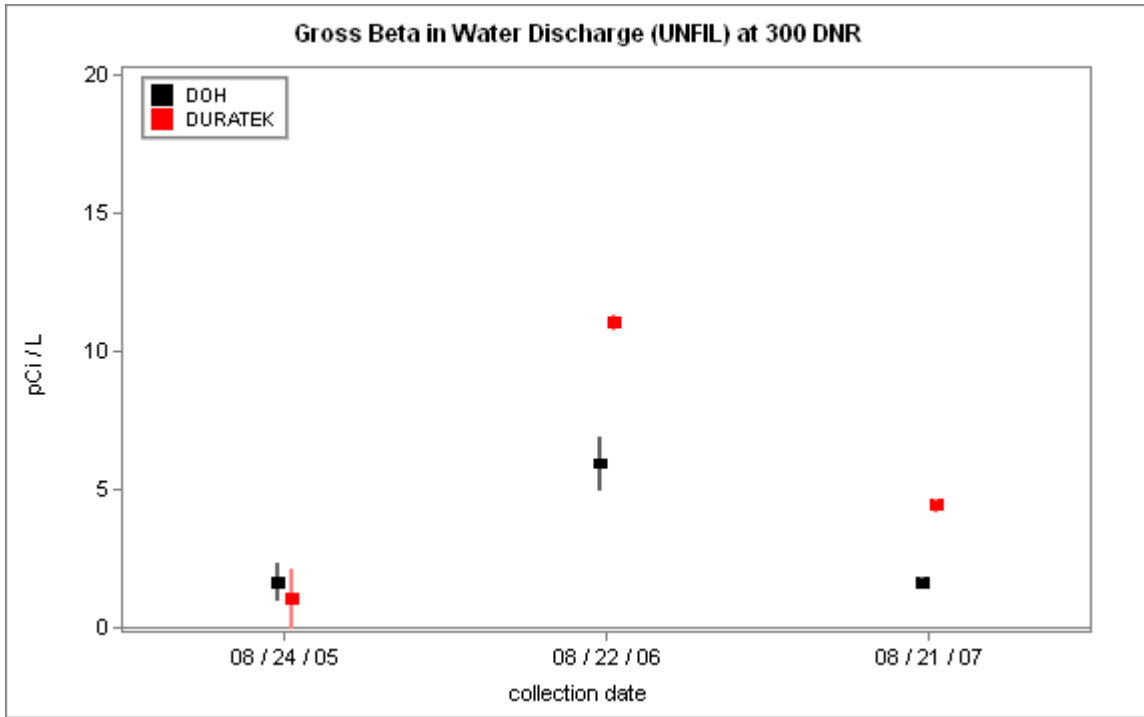
Figure 3.2.6   DOH and Duratek Gross Beta Concentrations in Effluent Treatment Discharge Water
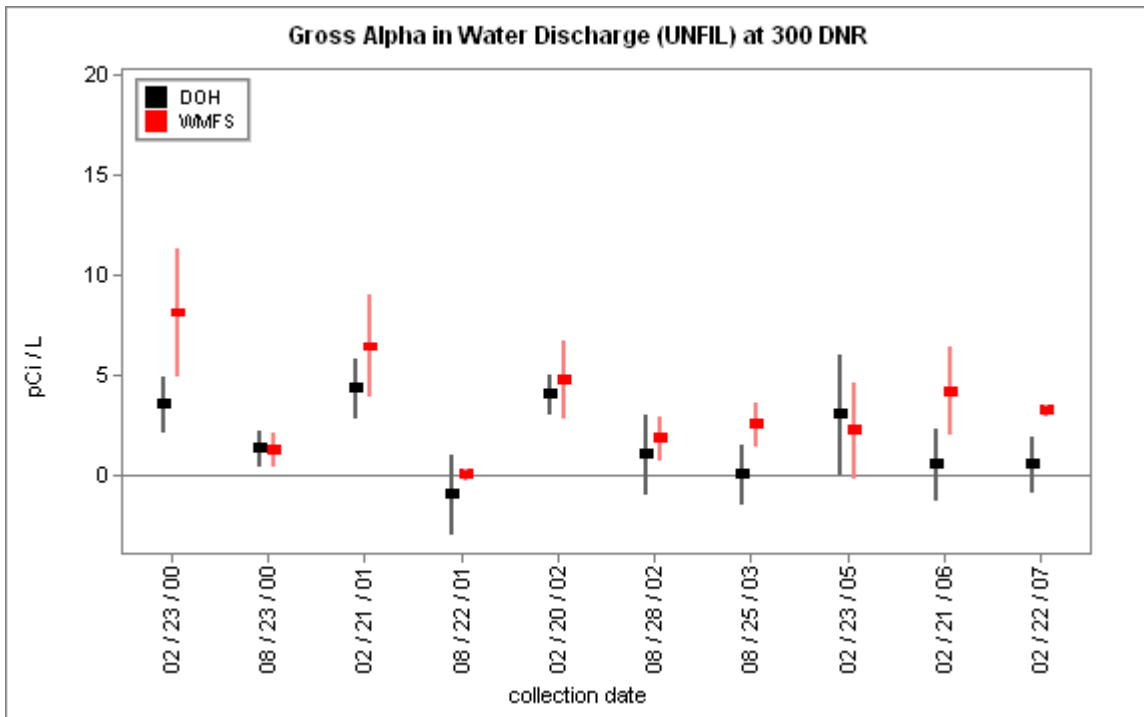
Figure 3.2.7   DOH and WMFS Gross Alpha Concentrations in Effluent Treatment Discharge Water
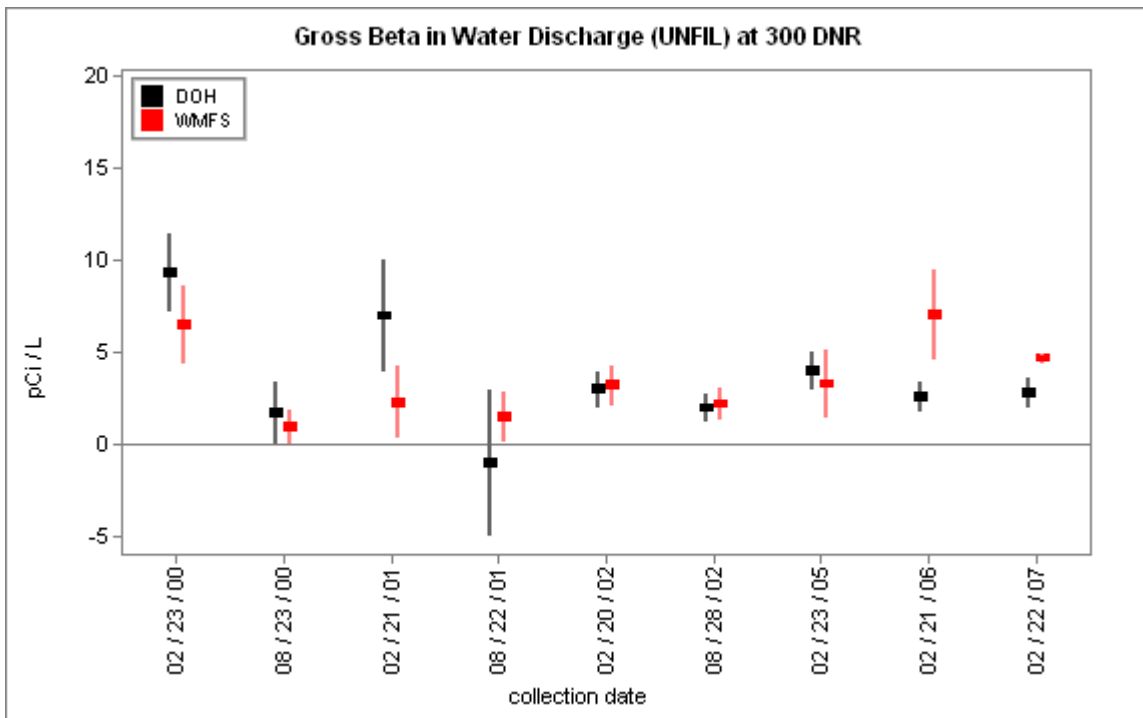
Figure 3.2.8   DOH and WMFS Gross Beta Concentrations in Effluent Treatment Discharge Water

3.3 External Gamma Radiation Monitoring

Major Findings:

- The DOH and DOE contractor external radiation rates are in good agreement.
- Radiation exposure rates at most DOH TLD locations on the Hanford Site are consistent with historical results and are similar to rates at locations along the Hanford perimeter and distant from the Hanford Site.
- Exposure rates along the Columbia River were consistent with background.
- Exposure rates near the 100K East Basin at Hanford's 100K East Area were anomalously high in 2007 due to temporary outdoor storage of radioactive materials.

3.3.1 Purpose and General Discussion

The Department of Health and DOE contractors monitor external radiation levels with thermoluminescent dosimeters (TLDs). TLDs measure the time-integrated exposure to external radiation at their location. Sources of background external 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 external 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.

External radiation levels can vary by up to 25% over the course of a year at any one location. This variation is primarily due to changes in soil moisture and snow cover, both of which affect shielding of natural radiation from the earth's crust.

DOH has historically maintained TLD monitoring sites collocated with the Near-facility monitoring program, historically run by Duratek; and the site-wide and off-site locations monitoring program, historically run by PNNL. In 2006, the site-wide and off-site TLD program was dropped by DOE. In response, DOH added 26 new TLD locations along the Columbia River to monitor locations that were previously monitored by PNNL. In addition, DOH will continue to maintain its original TLD sites that were collocated with PNNL. Therefore, from 2006 forward, the TLD section of this report will cover the sites collocated with the Near-facility program, as well as the sites operated independently by DOH.

3.3.2 Monitoring Locations

DOH operated 49 external radiation monitoring sites (TLD sites) that are relevant to the Hanford Site. Forty of these sites are operated under the Hanford Environmental Oversight Program, in which five sites are collocated with the Near-facility program currently run by Duratek, and thirty-five sites are independently monitored by DOH.

The remaining nine sites are part of the Columbia Generating Station Oversight Program, and they are included in this report because the sites are located along the Hanford perimeter.

The DOH TLD site locations are shown in Figure 3.3.1. Nine of the sites are near Hanford facilities with known, suspected, or potential radiation sources. Three sites (Yakima and Wye Barricades, and LIGO Facility) are located on the Hanford Site, but away from radiation sources. Twenty-five sites are along the Columbia River shoreline from the Vernita Bridge to downstream of Bateman Island at the mouth of the Yakima River. Ten sites are located around the Hanford Site perimeter. The remaining two sites (Othello and Yakima Airport) are significantly distant from the Hanford Site. The distant site at Toppenish was discontinued in 2006. Many of the TLD sites are collocated with air monitoring sites.

3.3.3 Monitoring Procedures

Collocated TLDs are deployed on a quarterly basis at each monitoring location, 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 external 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, new TLDs are placed at each site.

3.3.4 Comparison of DOH and Contractor Data

The DOH and DOE Near-facility program (Duratek) TLD results for the five collocated sites are shown in Figure 3.3.2. This figure shows the first, second, third, and fourth quarter results at 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 figure indicates that the Duratek dose rates are typically slightly higher than those reported by DOH.

A scatter plot of historical DOH/Duratek TLD data for all the collocated sites is shown in Figure 3.3.3. The small discrepancy between DOH and Duratek results is seen 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. The solid black line represents where data would lie if there was perfect agreement between DOH and the DOE contactor. This discrepancy is small, and is not considered significant.

Further inspection of the data indicates that the first and fourth quarter results are in good agreement, as shown by the historical data scatter plot in Figure 3.3.4. On the other hand, the third quarter results are only in fair agreement, as they follow the same trend, but the Duratek results are always slightly greater than those reported by DOH, as shown by the historical data scatter plot in Figure 3.3.5. This phenomenon is observed to a smaller degree in the second quarter results also. Analysis of historical results collocated with the site-wide and off-site monitoring program operated by PNNL show a similar pattern

where the third quarter data are in disagreement. DOH is currently investigating the source of this discrepancy.

3.3.5   Discussion of DOH Results

The DOH TLD sites are categorized by their location type. These categories include: (1) onsite near operational or contaminated areas; (2) onsite but away from operational or contaminated areas; (3) along the Columbia River [broken down further by 100 Area, 300 Area, Columbia Generating Station (CGS), Hanford Townsite (HTS), and offsite]; (4) along the Hanford perimeter; and (5) distant from the Hanford Site.

The average and standard deviation of the exposure rates for the sites at these location types are shown in Figure 3.3.6 and in Table 3.3.1.

Location Category	Average Exposure Rate (mR/day)	Standard Deviation (mR/day)
Near operational or contaminated areas	0.23	0.064
Away from operational or contaminated areas	0.22	0.024
Along the Columbia River - 100 Area	0.20	0.036
Along the Columbia River - 300 Area	0.22	0.026
Along the Columbia River - CGS	0.22	0.012
Along the Columbia River - HTS	0.23	0.030
Along the Columbia River - offsite	0.21	0.031
Along the Hanford perimeter	0.22	0.027
Distant from Hanford	0.18	0.019

Table 3.3.1   Average External Exposure Rates for Each Location Category

The average exposure rate from sites near potential radiation sources is 0.23 mR/day, which is similar to the value of 0.22 mR/day from sites at Hanford but away from contaminated facilities and sites around the Hanford perimeter. The data indicate that areas monitored on-site do not contribute additional exposure rates above background.

The average exposure rates at sub-locations along the Columbia River range from 0.20 to 0.23 mR/day, which are similar to the exposure rates measured on-site. The average exposure rate of 0.18 mR/day for sites distant from Hanford is slightly lower than the average exposure rates at other location types. Along the Columbia River, lower exposure rates are expected due to shielding of natural terrestrial radiation by water in the Columbia River. The distant sites are located in areas covered by concrete or gravel, whereas most other sites are located directly over soil. For example, the Yakima Airport site is on a concrete tarmac. Concrete and gravel, like water in the river, shield the terrestrial component of natural radiation. Therefore, lower exposure rates are expected at these sites.

Historically, DOH has measured elevated exposure rates at site 100N Spr, which is within Hanford's 100N Area (see Figure 3.3.7). The exposure rate at this site has steadily been decreasing with time due to the natural decay of Co-60 surface contamination. With the recent cleanup of contaminated surface soil, exposure rates over the past several years now appear constant, at rates similar to those at perimeter locations. In 2007, the average exposure rate at this site was 0.20 mR/day.

Elevated exposure rates have been seen at location 100K East Basin, within Hanford's 100K East Area, since 2005. Figure 3.3.8 shows historical TLD data at this location. Radioactive material has been temporarily stored outside of the KE Basin facility since 2005. The TLD detected increased radiation exposure rates due to this material. The storage area was properly posted and access was restricted. Measurements along the Columbia River at the 100K Area, the closest public access point, did not detect elevated exposure rates. In 2007, the average exposure rate at this site was 0.39 mR/day, about twice that of exposure rates at other locations.

All other sites monitored by DOH in 2007 had TLD results consistent with historical data.
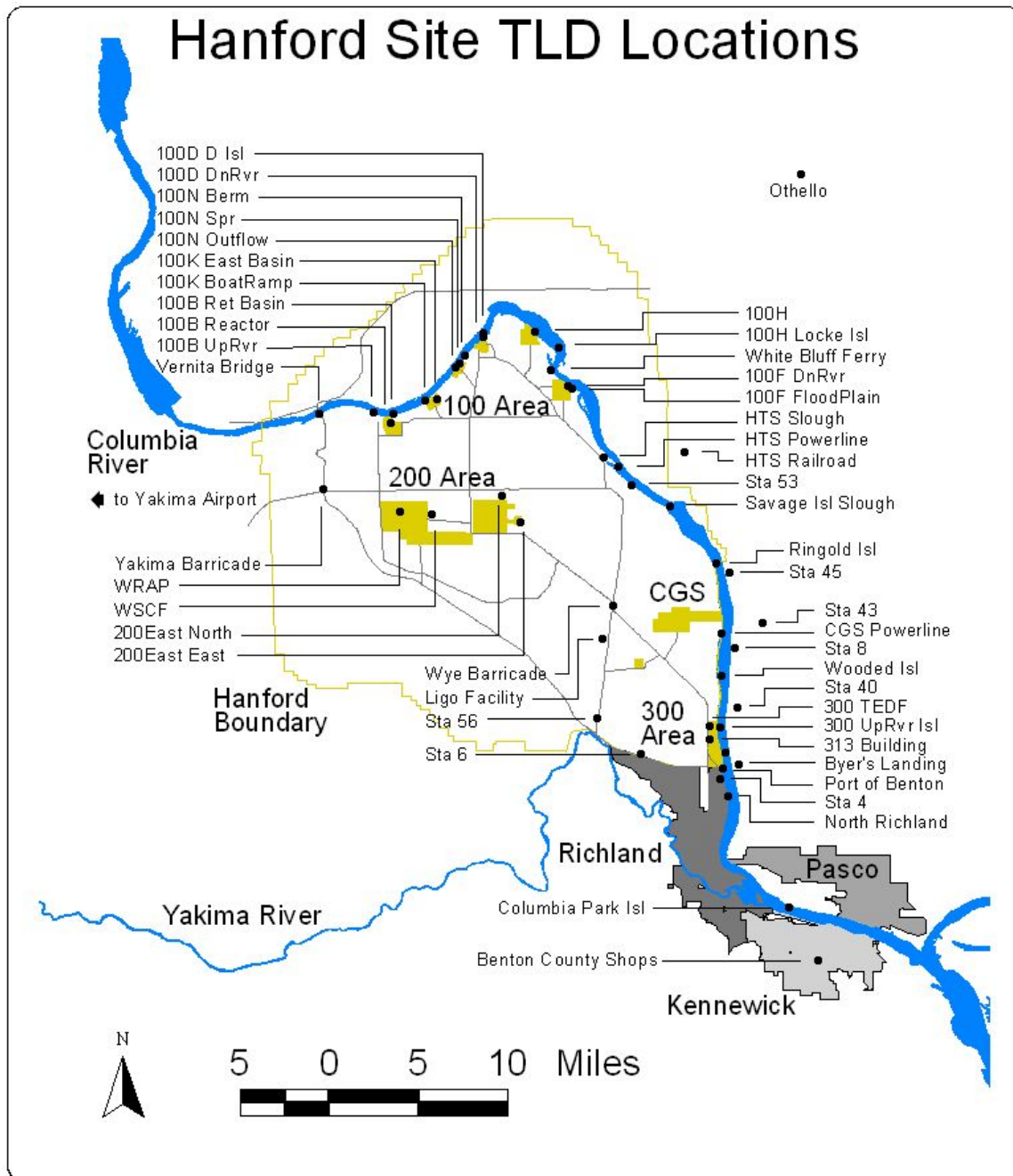
Figure 3.3.1   External Radiation Monitoring (TLD) Locations
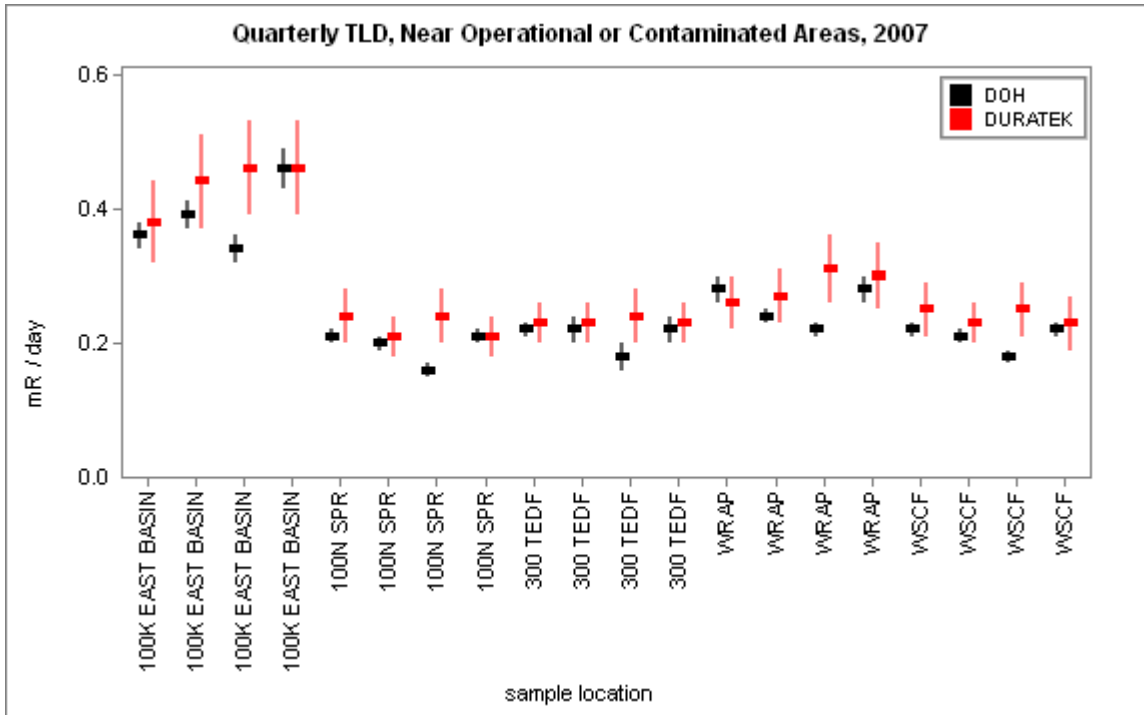
Figure 3.3.2   DOH and Duratek Quarterly TLD Results at Sites Near
Operational or Contaminated Facilities
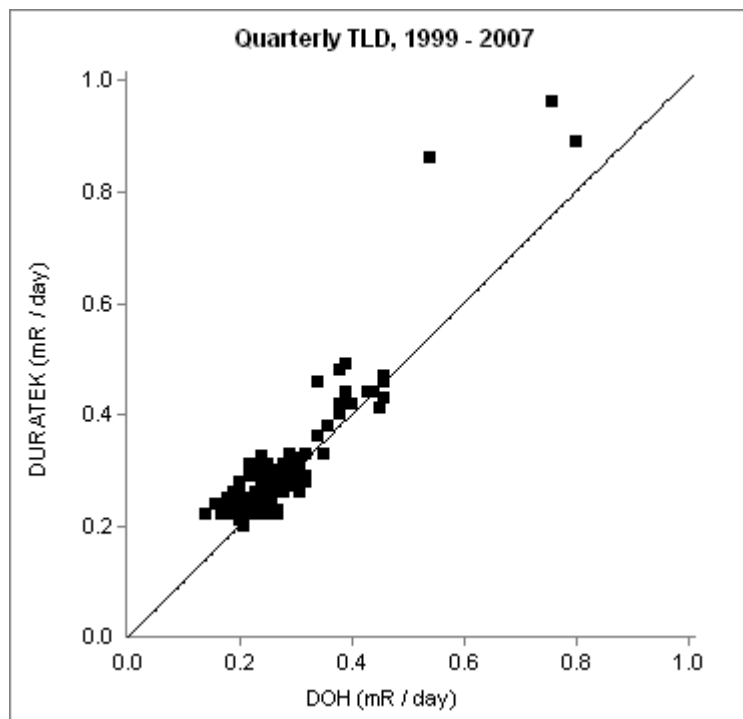
Figure 3.3.3   DOH and Duratek Scatter Plot for Historical TLD Results
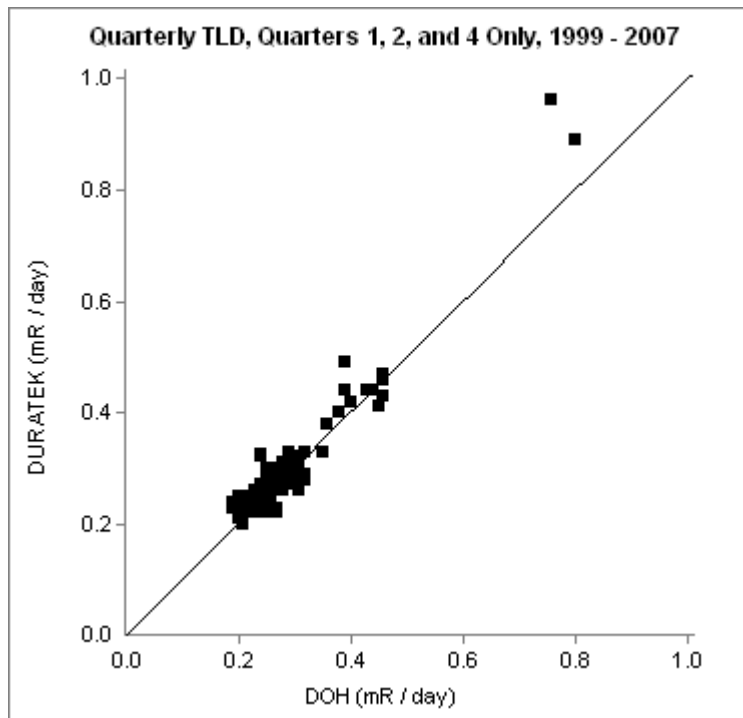
Figure 3.3.4   DOH and Duratek Scatter Plot for Historical TLD Results for the
First, Second, and Fourth Quarters Only
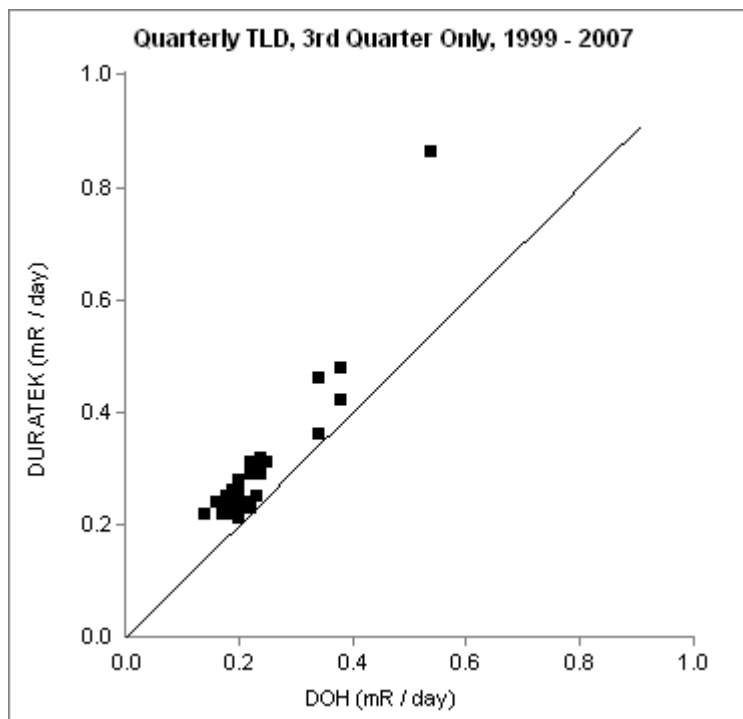
Figure 3.3.5   DOH and Duratek Scatter Plot for Historical TLD Results for the Third Quarter Only
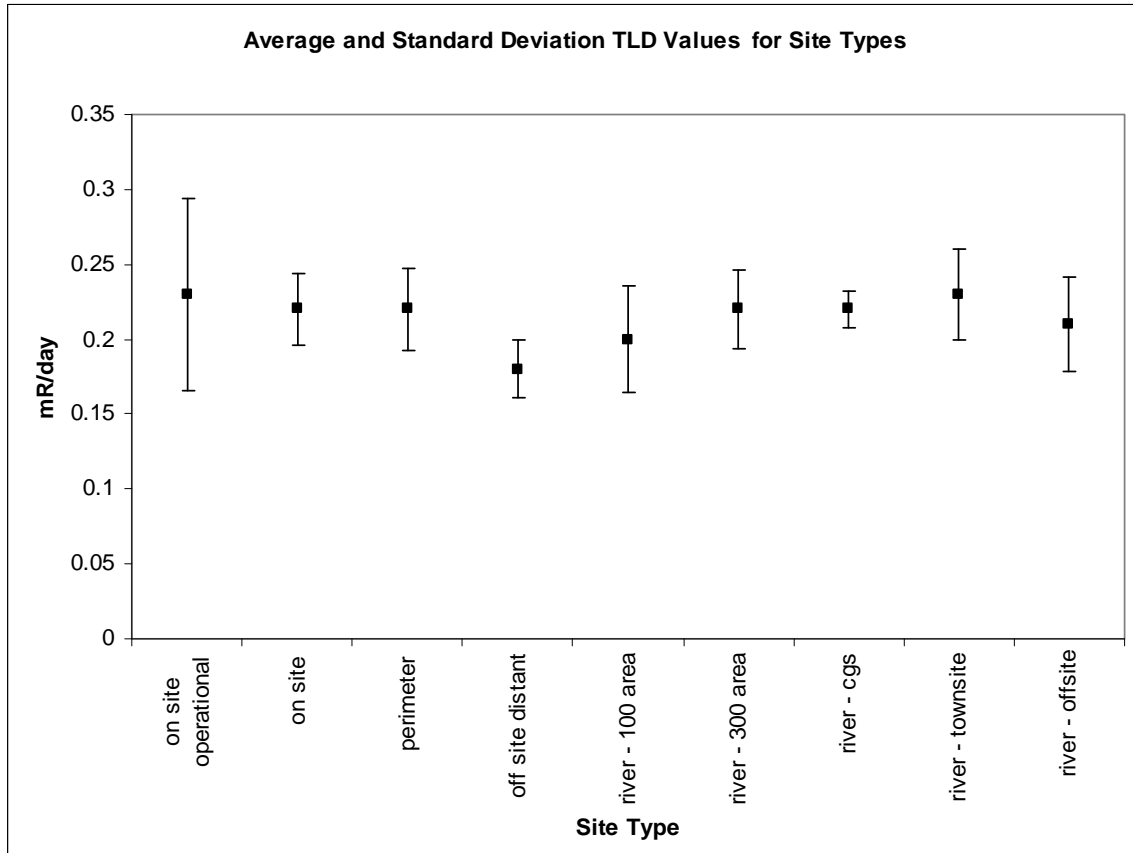
Figure 3.3.6   Statistical TLD Values for the Different DOH Site Location Types
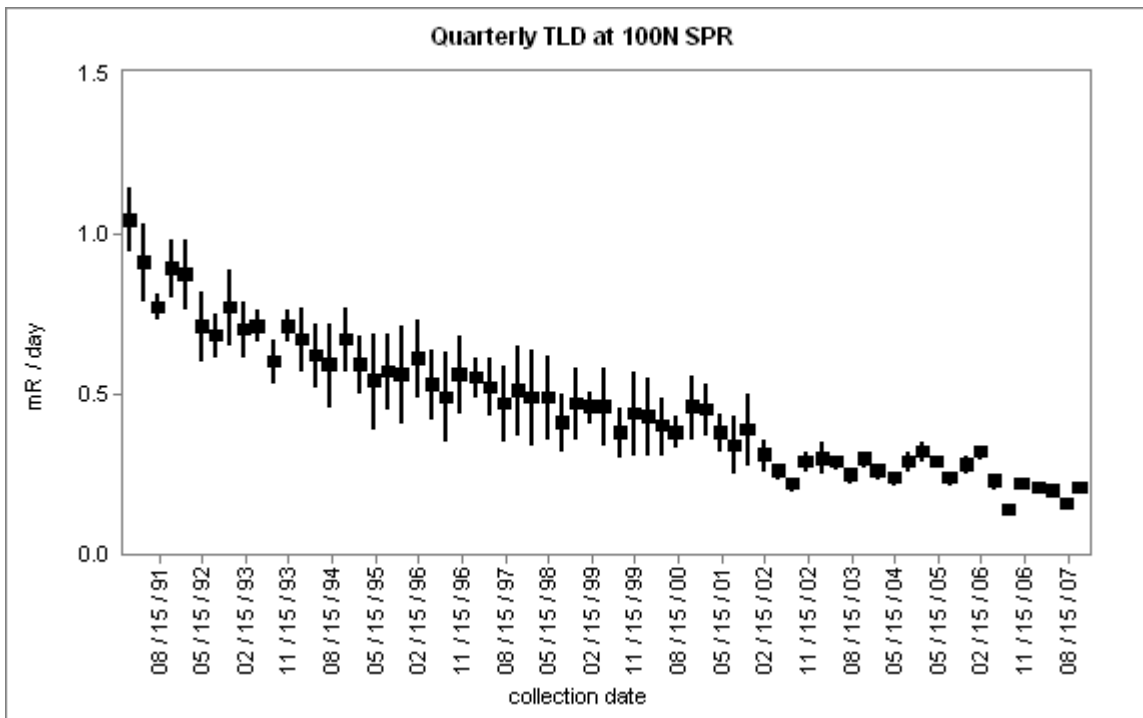
Figure 3.3.7   DOH Historical TLD Results at Location 100N SPR in the 100N Area
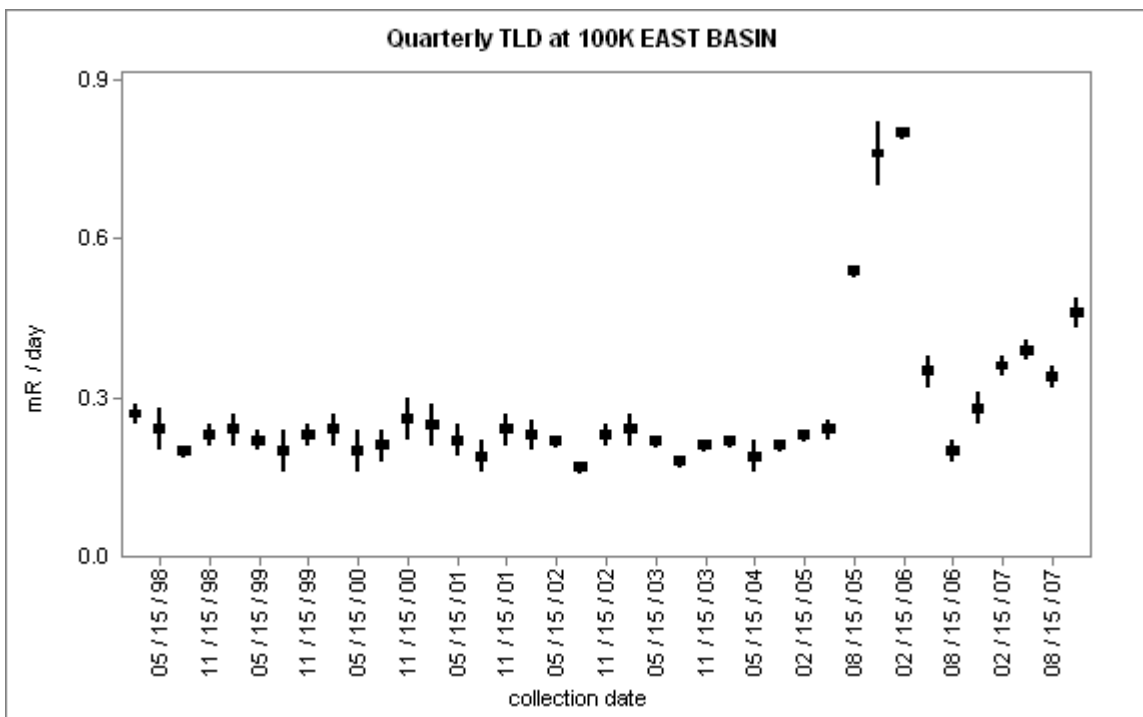
Figure 3.3.8   DOH Historical TLD Results at Location 100K East Basin, at 100K Area

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3.4   Soil and Sediment Monitoring

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Major Findings:

- DOH and PNNL results in sediment samples are in good agreement for all radionuclides, except for isotopes of uranium. The discrepancy in uranium originates from a difference in DOH and PNNL laboratory analytical methods.
- Concentrations of most radionuclides in sediment samples from locations adjacent to or downriver from Hanford are consistent with those at locations upriver from Hanford. Europium-152 was detected at locations adjacent to and downriver from Hanford, but not at the location upriver from Hanford. The Eu-152 results are consistent with historical results.

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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 because they exist in world-wide 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

Nine sediment samples from the Columbia River and one sediment sample from West Lake were split with PNNL. No split soil samples were collected in 2007. The Columbia River sediment samples were collected upriver from Hanford at Priest Rapids Dam; along the Hanford Site at the 100F and 100K Areas, the White Bluff Slough, the Old Hanford Townsite, and the 300 Area; and downriver from Hanford at McNary Dam. West Lake is located on the Hanford Site in between the 100 and 200 Areas.

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.

3.4.3 Monitoring Procedures

Split soil samples were not collected in 2007, but the monitoring procedures are discussed here for reference. Soil samples are collected by compositing four one-square foot areas, each excavated to a depth of one inch. The composited samples are split, and then dried prior to radiochemical analysis. Samples are analyzed for radionuclides that are most likely present in the area sampled, which at Hanford typically include gamma emitting radionuclides, Sr-90, isotopic uranium, and isotopic plutonium.

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

3.4.4 Comparison of DOH and Contractor Data

The DOH and PNNL split sediment sample concentrations for the gamma emitting radionuclides, which include Co-60, Cs-137, Eu-152, Eu-154, and Eu-155 are in good agreement. Except for Cs-137 and Eu-152, most of the results are below detection limits. The split Cs-137 and Eu-152 results are shown in Figures 3.4.1 and 3.4.2.

Most of the split Sr-90 results, shown in Figure 3.4.3, are in good agreement. The exception lies with the sample from West Lake, in which DOH reported a Sr-90 concentration of 0.35 pCi/g, about ten times greater than the value reported by PNNL. This is the first split sample collected from West Lake, so there are no prior data at this site for comparison. Historically, most DOH and PNNL results for Sr-90 in soil and sediment are in good agreement, so the difference in the split result for West Lake appears to be an anomaly. A split sample at West Lake was collected in 2008, and the results will be reported in next year's report.

All of the split results for the alpha emitting radionuclides Pu-238 and Pu-239/240 are in good agreement. Most of the results are either below detection limits or slightly above detection limits.

There is a significant difference in detection limits for Pu-238 between DOH and PNNL, as is reflected in the size of the error bars for the data shown in Figure 3.4.4. All of the DOH concentrations are less than the DOH detection limit of 0.005 pCi/g. PNNL has a much lower detection limit, and their result at McNary Oregon is considered detected, even though the concentration is less than the DOH detection limit. Despite the difference in detection limits or the related difference in detection status, the DOH and PNNL data are considered in agreement because the range of the uncertainty bars overlap. The split Pu-239/240 results are shown in Figure 3.4.5.

The DOH and PNNL split sediment results for isotopes of uranium are in fair agreement. The split U-238 results are shown in Figure 3.4.6. In addition, the historical U-238 results for both soil and sediment are shown in a scatter plot in Figure 3.4.7. 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).

The sample at West Lake was also analyzed for Tc-99, and both DOH and PNNL reported a result below the detection limit (DOH detection limit of 0.2 pCi/g).

3.4.5   Discussion of DOH Results

Radionuclides consistently identified by DOH in soil and sediment samples include Cs-137, Pu-239/240, U-234, U-235, and U-238. Uranium-233 (lower limit of detection approximately 0.1 pCi/g) has not been detected by DOH in any sediment samples. Cesium-137 and plutonium isotopes exist in world-wide fallout as a result of nuclear weapons testing and may also exist in effluent from the Hanford Site. Uranium isotopes occur naturally in the environment and may also be present in Hanford Site effluent.

Most concentrations of Cs-137 in sediment ranged from 0.09 to 0.4 pCi/g, which is consistent with historical results. The concentrations at most sites adjacent to and downriver from Hanford are not significantly different than those at the background location at Priest Rapids Dam (see Figure 3.4.1), indicating the source of the Cs-137 is most likely world-wide fallout.

The Cs-137 result of 0.7 pCi/g at White Bluff Slough is approximately twice the average concentration typically seen in sediment samples. DOH collected a sediment sample from this area in 1996, with a Cs-137 concentration of 0.55 pCi/g, also higher than typical Hanford sediment results. This data suggests the possibility that Hanford related Cs-137 has migrated to this area.

Concentrations of Pu-239/240 in sediment ranged from below the detection limit of 0.005 pCi/g to 0.014 pCi/g, which is consistent with historical results. There is no significant difference in historical Pu-239/240 concentrations in sediment from sampling locations upstream (Priest Rapids Dam) and downstream (McNary Dam) of Hanford, as the historical average at both locations is approximately 0.009 pCi/g. This indicates the most likely source of Pu-239/240 in sediment is world-wide fallout.

Most of the sediment samples, including the background location near Priest Rapids Dam, had U-234 and U-238 concentrations near 1 pCi/g, while concentrations of U-235 were near 0.04 pCi/g. These concentrations are consistent with historical results.

Sediment samples from the 300 Area typically have slightly higher concentrations, but no samples from this area were split in 2007.

Other radionuclides identified in some sediment samples include Eu-152 and Sr-90. DOH detected Eu-152 in all of the sediment samples, with concentrations ranging from 0.04 to 0.17 pCi/g (see Figure 3.4.2). These concentrations are consistent with historical results. Europium-152 is historically detected in sediment at McNary Dam, downriver from Hanford. Europium-152 has not been detected by DOH at the Priest Rapids Dam background location. Note in Figure 3.4.2 that there are no DOH data points for Eu-152 at the Priest Rapids Dam locations. This is because none of the europium isotopes were identified by the gamma scan, and therefore no results were reported.

Strontium-90 concentrations in sediment samples ranged from below the detection limit of 0.002 pCi/g to 0.35 pCi/g (see Figure 3.4.3). Strontium-90, which is found in the environment from world-wide fallout of nuclear weapons testing, has been historically detected in sediment samples from both Priest Rapids Dam (upriver of Hanford) and McNary Dam (downriver of Hanford). There is no significant difference in historical Sr-90 concentrations between the upstream and downstream locations, as they both average approximately 0.017 pCi/g.

The Sr-90 result at West Lake is anomalous, as the result is about twenty times higher than concentrations typically found in sediment. Another sample was collected in 2008 from this location, and the result will be discussed in next years report.
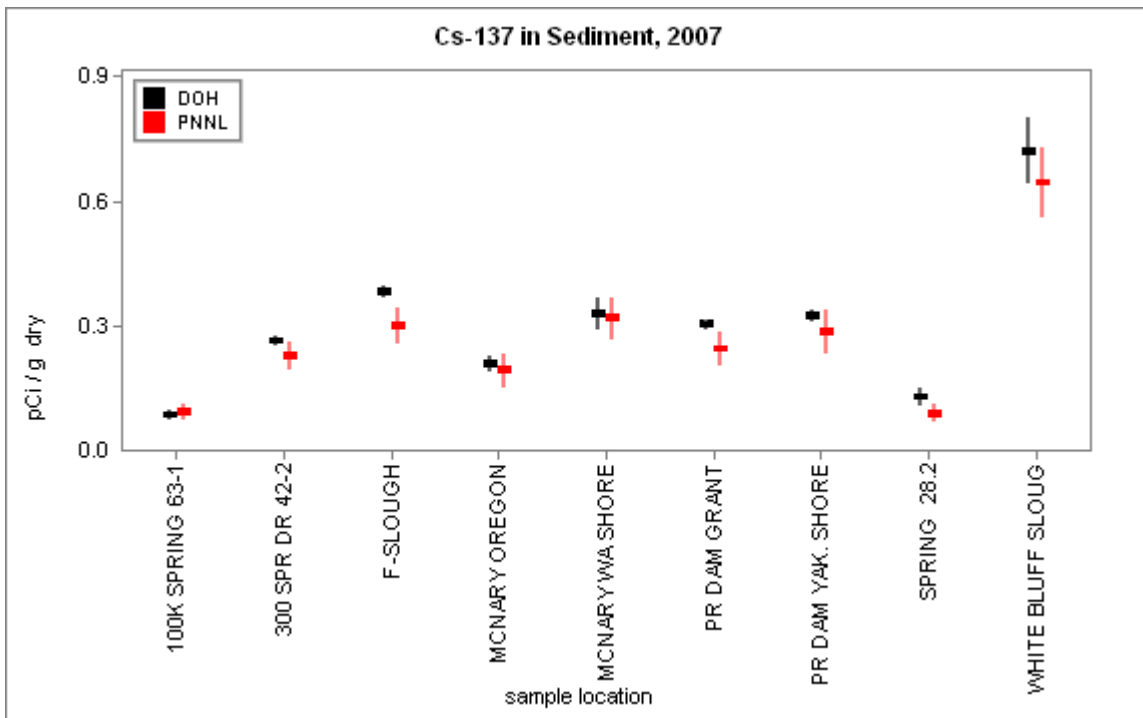
Figure 3.4.1   DOH and PNNL Cs-137 Concentrations in Columbia River Sediment
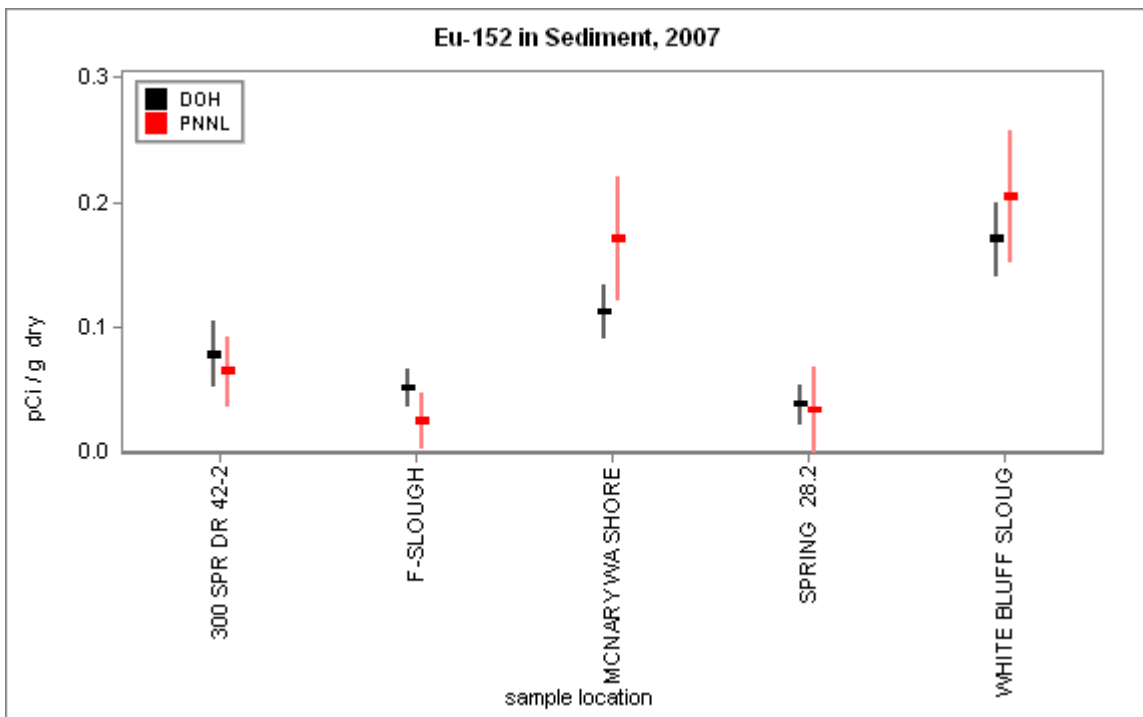
Figure 3.4.2   DOH and PNNL Eu-152 Concentrations in Columbia River Sediment

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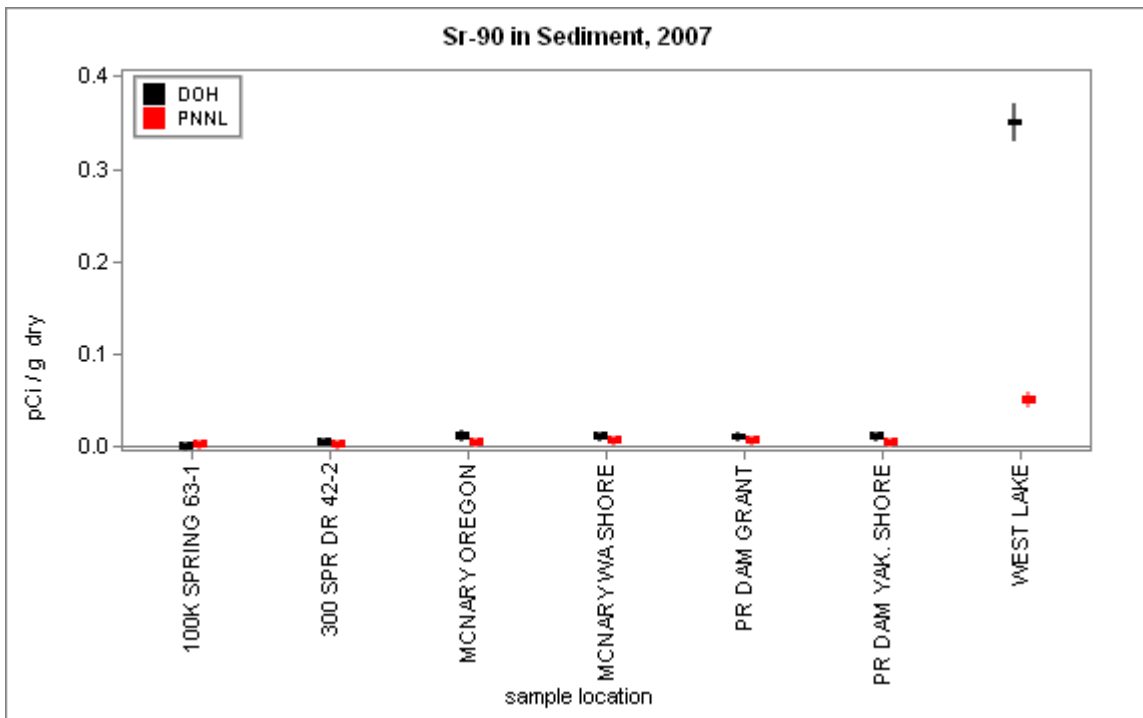
Figure 3.4.3   DOH and PNNL Sr-90 Concentrations in Columbia River Sediment
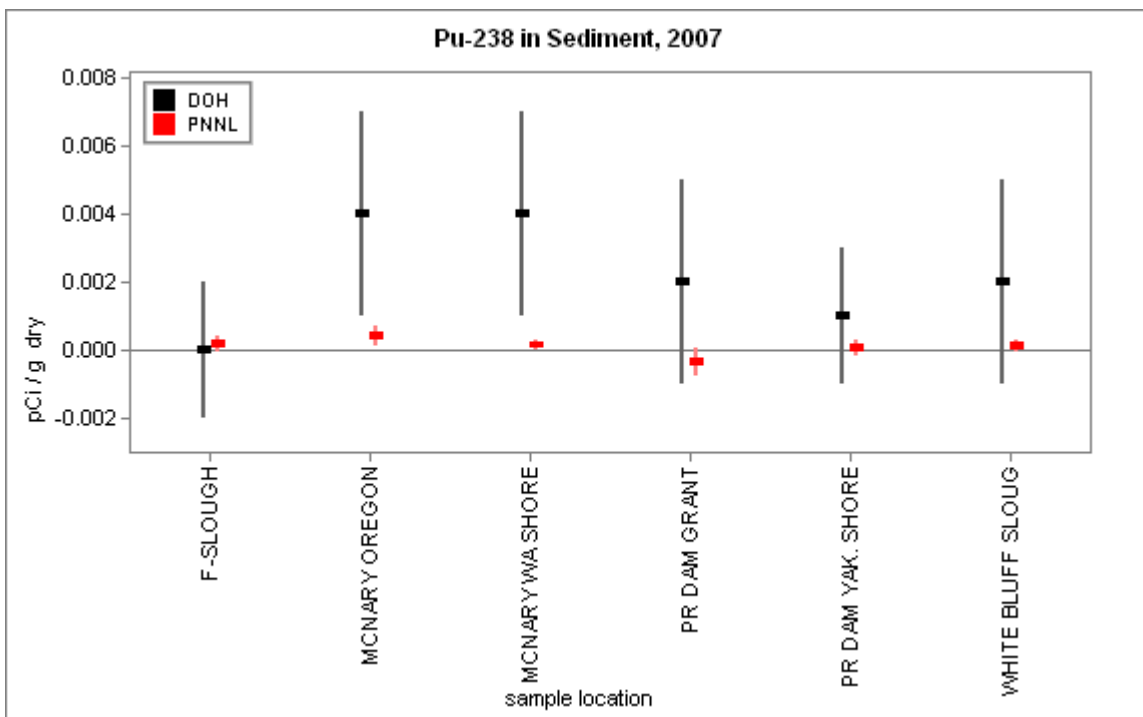
Figure 3.4.4   DOH and PNNL Pu-238 Concentrations in Columbia River Sediment
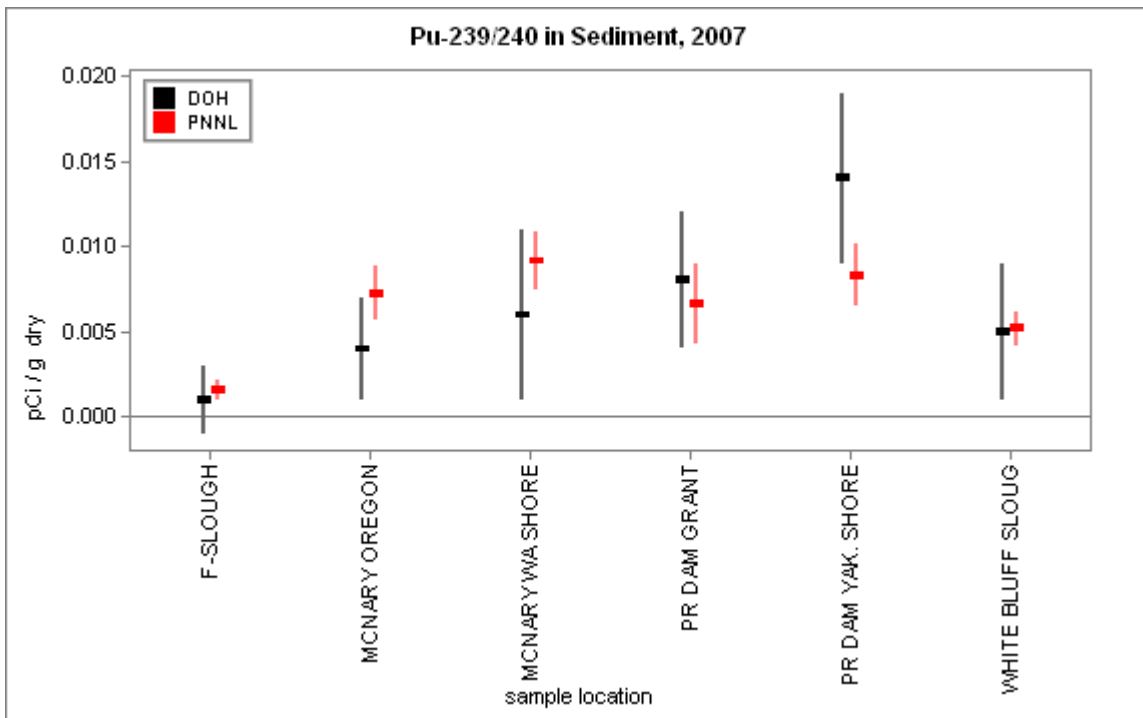
Figure 3.4.5   DOH and PNNL Pu-239/240 Concentrations in Columbia River Sediment
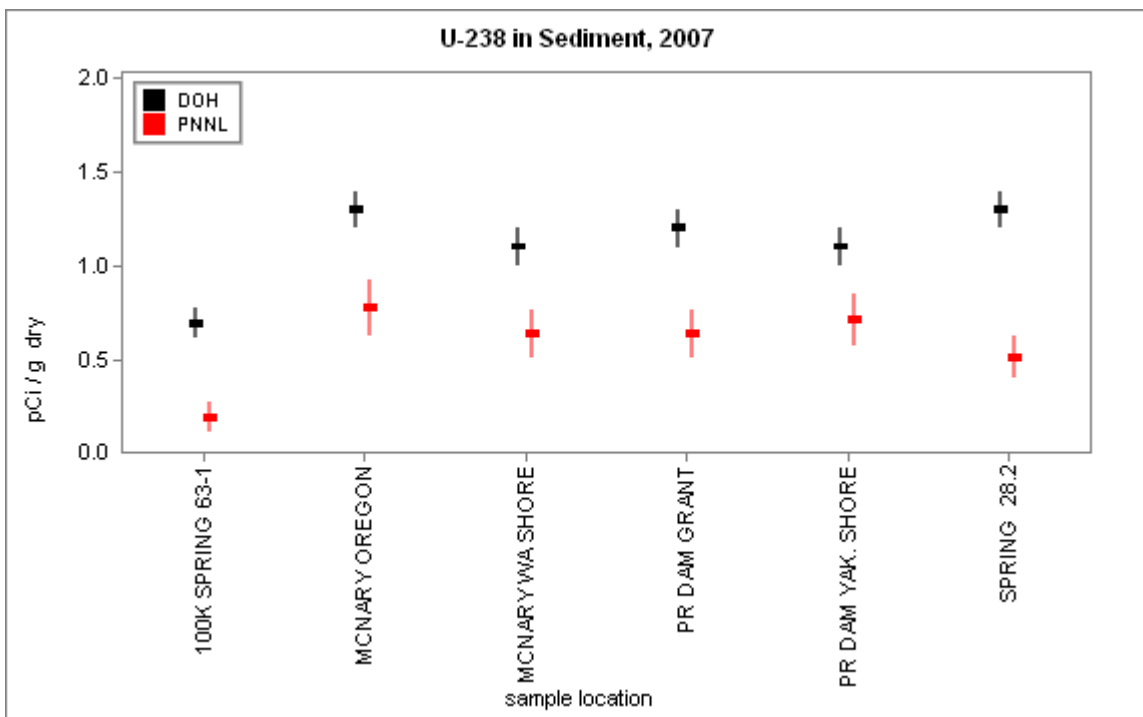
Figure 3.4.6   DOH and PNNL U-238 Concentrations in Columbia River Sediment
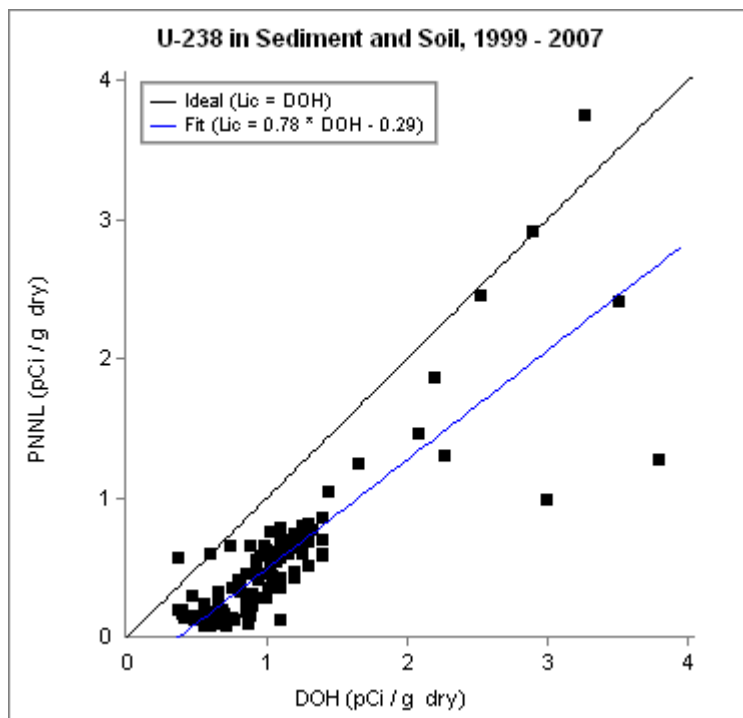
Figure 3.4.7   DOH and PNNL Scatter Plot for Historical U-238 Concentrations in Sediment and Soil

3.5   Farm Products Monitoring

Major Findings:

- All DOH and DOE contractor concentrations in split farm product samples are in good agreement.
- All radioactivity concentrations measured by DOH are below detection limits.

3.5.1   Purpose and General Discussion

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

Farm Product	Analyte	Number of Samples
Grapes	Co-60, Cs-137	2
Potatoes	Co-60, Cs-137	1
Wine	Co-60, Cs-137	6

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 are generally collected from farms located in the areas of Riverview, Sagemoor, Horn Rapids, East Wahluke, Ringold, Mattawa, Sunnyside, Yakima Valley, and the Columbia Valley.

3.5.3   Monitoring Procedures

Farm product samples are 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.

Typically, wine samples are analyzed for Co-60, Cs-137, Sr-90, and H-3 activity. However, the Washington State Public Health Laboratory's procedure for tritium (H-3) analysis in wine is currently under review. Therefore, split H-3 results are not reported for the current samples, and the results of the review will be discussed in a future report. In addition, split Sr-90 results were not reported for the current samples.

3.5.4 Comparison of DOH and Contractor Data

All of the DOH and PNNL radionuclide concentrations reported for split food and wine samples are in good agreement, and all concentrations are below detection limits. Historically, most DOH and PNNL concentrations in split food and wine samples are in good agreement.

3.5.5 Discussion of DOH Results

All DOH reported concentrations of Co-60 and Cs-137 in farm product samples are below the detection limits listed in Appendix B. No other gamma emitting radionuclides were detected by DOH. Historically, DOH occasionally detects small concentrations of Sr-90 in farm produce around the Hanford Site, with concentrations ranging from 0.01 to 0.1 pCi/g. However, Sr-90 was not reported for the current samples.

3.6   Fish and Wildlife Monitoring

Major Findings:

- DOH and DOE contractor concentrations of gamma emitting radionuclides in the single fish sample are in good agreement.
- All of the DOH concentrations for gamma emitting radionuclides are below detection limits.

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. For this current report, DOH split a single fish sample. No wildlife samples were split. The type of samples, radionuclides analyzed, and number of samples are listed in Table 3.6.1.

Sample Type	Analyte	Number of Samples
Whitefish Meat	Co-60, Cs-137	1

Table 3.6.1   Radionuclides Analyzed in Fish and Wildlife

3.6.2   Monitoring Locations

The fish sample was collected from a background location near the Wanapum Dam area, upstream of the Hanford Site.

3.6.3   Monitoring Procedures

Fish and wildlife samples are collected by PNNL and then split with DOH. DOH and PNNL independently analyze the samples and then compare results. Carcass and bone samples are analyzed for Sr-90, as this radionuclide accumulates in the bone, not the meat. Meat samples are analyzed for gamma emitting radionuclides, which include Co-60, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, Ru-106, and Sb-125. DOH reports Co-60 and Cs-137 results whether they are detectable or not, whereas the remaining gamma emitting radionuclides are only reported if they are detectable. For this current report, only results in fish meat are reported (no bone or carcass results.)

3.6.4　　Comparison of DOH and Contractor Data

The DOH and PNNL gamma emitting radionuclide concentrations in the fish sample are in good agreement, and all results are below detection limits.

Split results for Sr-90 in carcass samples were not reported for this fish sample. Historically, the agreement between DOH and PNNL Sr-90 results in fish and wildlife range from good to fair to poor, as can be seen in the scatter plot of Figure 3.6.1. The points in the plot off the ideal fit line indicate disagreement between DOH and PNNL.

3.6.5　　Discussion of DOH Results

The DOH gamma emitting radionuclide concentrations in the fish sample are all below detection limits, including concentrations of Co-60, Cs-137, Eu-152, Eu-154, and Eu-155.
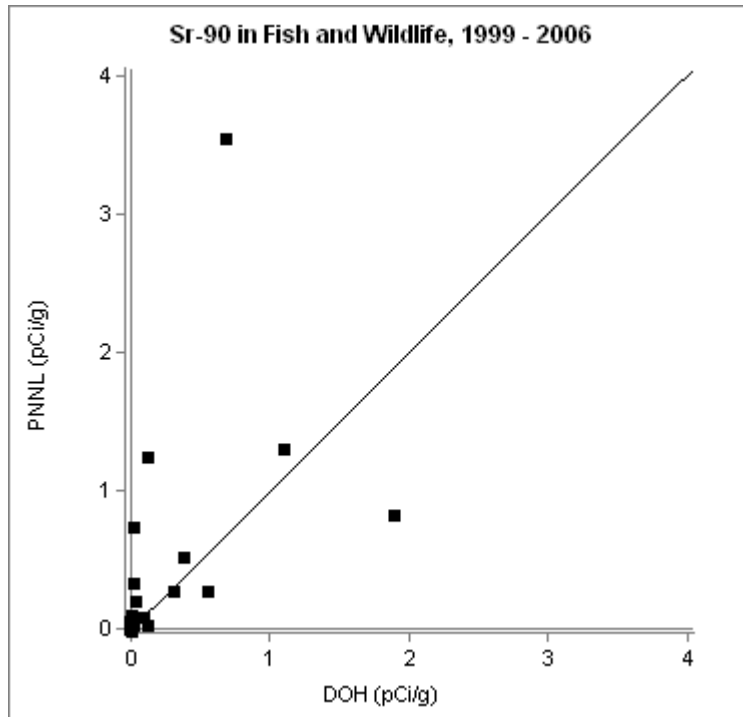
Figure 3.6.1   DOH and PNNL Scatter Plot for Historical Sr-90 Concentrations in Fish and Wildlife

3.7 Vegetation Monitoring

> Major Findings:
>
> - DOH and DOE contractor concentrations in split vegetation samples are in good agreement for gamma emitting isotopes and in fair agreement for Sr-90.
> - DOH did not detect gamma emitting radionuclides in any vegetation samples, while one vegetation sample contained a small concentration of Sr-90. It is common to detect small concentrations of Sr-90 in vegetation samples, and the source is most likely fallout from atmospheric weapons testing.

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 primarily arise from airborne deposition, soil to plant transfer, and water to plant transfer.

Since 2005, split vegetation sampling is monitored only in odd-numbered years. For this current report, two alfalfa samples were split with PNNL. The type of vegetation, radionuclides analyzed, and number of samples collected are listed in Table 3.7.1.

Type of Vegetation	Analyte	Number of Samples
Alfalfa	Co-60, Cs-137, Sr-90	2

Table 3.7.1   Radionuclides Analyzed in Vegetation

3.7.2 Monitoring Locations

Alfalfa samples were collected from a farm in the Horn Rapids area and from a farm in the Riverview area, which are to the southeast, and in the predominant downwind direction of the Hanford Site.

3.7.3 Monitoring Procedures

The vegetation samples were collected in the spring season, and split with PNNL. DOH and PNNL independently analyzed the samples. The measured radionuclide concentrations are reported in pCi/g.

3.7.4　　Comparison of DOH and Contractor Data

The DOH and PNNL split vegetation results are in good agreement for gamma emitting radionuclides, including Co-60 and Cs-137, and all results are below detection limits.

Of the two Sr-90 results, one is in good agreement and the other in fair agreement (Figure 3.7.1). Historically, the agreement between DOH and DOE contractor results for Sr-90 in vegetation samples ranges from good to fair, as the uncertainty intervals for DOH and DOE results do not always overlap. The disparity in agreement can be seen in the scatter plot of historical results for Sr-90 in vegetation, shown in Figure 3.7.2, where many of the data points lie off the line that represents perfect agreement. However, all historical concentrations are below 0.22 pCi/g, and therefore, the disagreements are very small.

3.7.5　　Discussion of DOH Results

The DOH concentrations of gamma emitting radionuclides (including Co-60, Cs-134, Cs-137, Eu-152, Eu-154, and Eu-155) are all below the detection limits listed in Appendix B. In addition to the split Co-60 and Cs-137 results discussed above, DOH did not detect any other gamma emitting radionuclides, including Cs-134, Eu-152, Eu-154, and Eu-155. DOH also independently analyzed the Horn Rapids sample for isotopes of uranium and plutonium, and all results were below detection limits. The radionuclide concentrations in these current samples are consistent with historical results.

DOH detected Sr-90, at 0.09 pCi/g, in the sample from Riverview, but the result at Horn Rapids was below the detection limit. The Sr-90 concentrations in these current samples are consistent with historical results, which range from below the detection limit to 0.2 pCi/g, with an average of 0.06 pCi/g. Strontium-90 in alfalfa likely originates from worldwide fallout from historical atmospheric weapons testing.
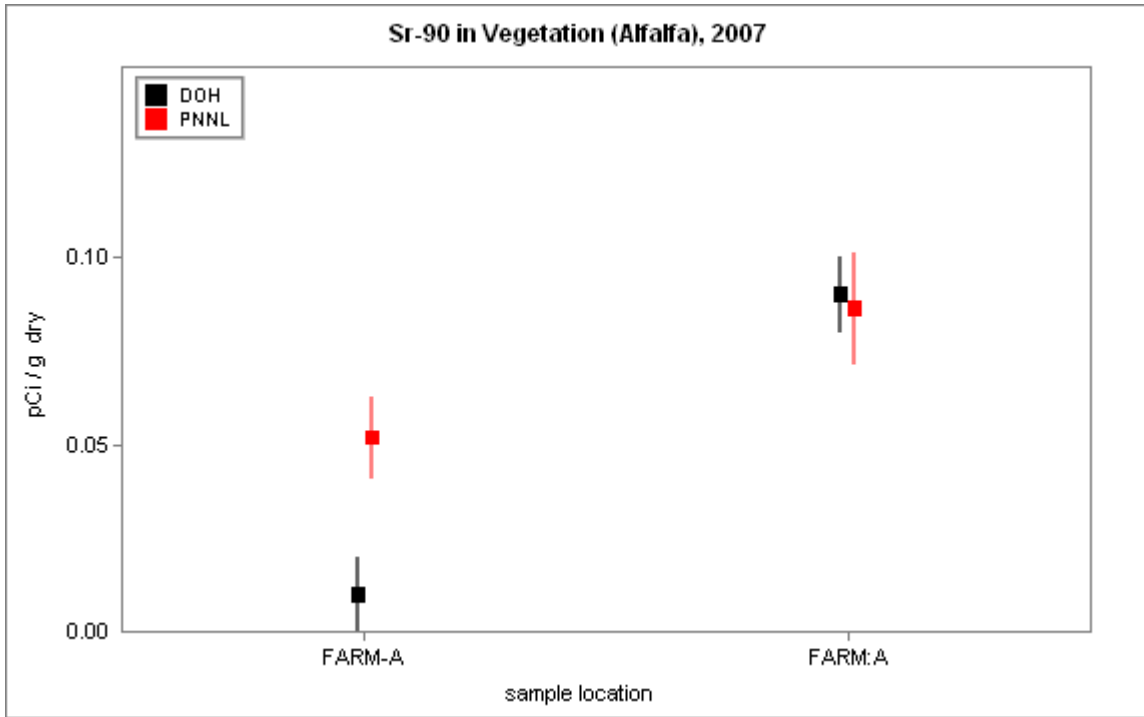
Figure 3.7.1   DOH and PNNL Sr-90 Concentrations in Alfalfa
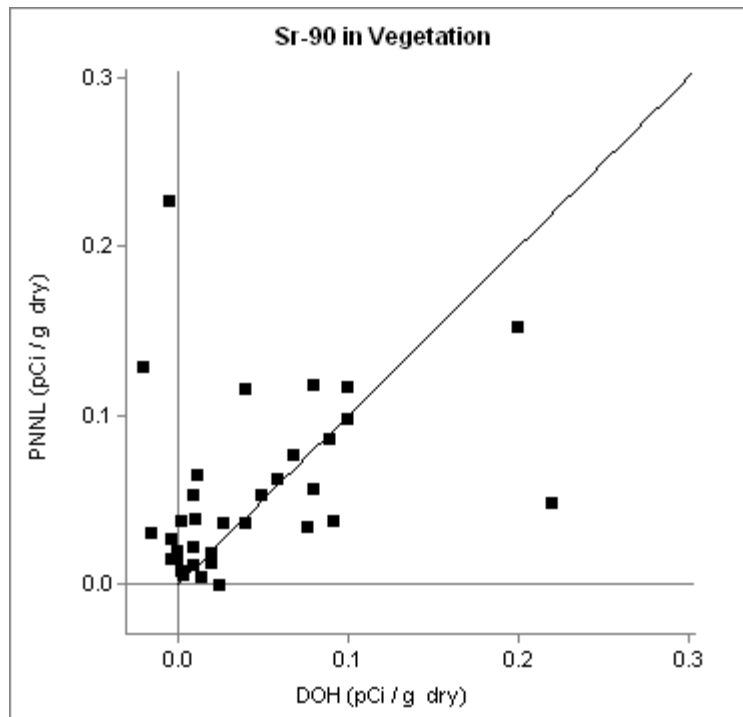
Figure 3.7.2 DOH and PNNL Scatter Plot for Historical Sr-90 Concentrations in Vegetation

4. Summary of Discrepancies Between DOH and DOE Contractor Results

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

The DOH and DOE contractor collocated biweekly gross beta results in air samples are in fair agreement. The DOH and DOE data follow the same trends; however, differences in concentration up to a factor of two are common, and 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 mid and 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 is observed in historical DOH and DOE results.

The DOH and DOE collocated composite uranium results in air samples, for both quarterly and semiannual composite samples, are in fair agreement. The data generally follow the same trends; however, the DOE contractor concentrations are significantly lower than the concentrations reported by DOH for cases in which the DOH result is above the detection limit. This discrepancy is currently under investigation, and the progress is discussed below.

First, DOH is evaluating laboratory procedures and sampling media to understand the discrepancy in uranium concentrations in air samples. Initial investigations indicate a difference in laboratory procedures between DOH and DOE contractors, that may contribute to the discrepancy. The final results of this investigation will be discussed in a future report.

Second, DOH is evaluating the sampling media. DOH and DOE contractors use different suppliers of filters for air particulate sampling. The preliminary results of blank samples show that the filters used by DOH give higher background counts than those used by DOE. To what extent using filters with higher background counts contributes to the observed bias is under investigation and will be discussed in a future report. Results of this investigation will be used to guide DOH in making appropriate changes in sampling media.

The DOH and DOE contractor results for Cs-137 in semiannual composite air samples are in good agreement; however, there is a systematic bias. Close inspection of historical data in semiannual composite air samples indicates that when DOH detects Cs-137 above the detection limit (0.0005 pCi/m^3), DOE reports concentrations approximately 60% of those reported by DOH. This discrepancy will be investigated and discussed in future reports.

Historically, a systematic discrepancy has been observed for DOH and PNNL split H-3 results in water samples. The data generally follow the same trends; however, for relatively high concentrations that often appear in groundwater samples, DOH generally reports concentrations approximately 8% higher than PNNL. This discrepancy was not

observed for this reporting period, most likely because DOH and PNNL did not split any samples with high concentrations of H-3.

Historically, the DOH and PNNL split I-129 results in water samples, most of which are groundwater, are in poor agreement. Three problems have been previously identified. First, for samples in which I-129 is detected, DOH typically reports concentrations significantly lower than those reported by PNNL. Second and perhaps related to the first problem, for samples in which I-129 is not detected, DOH reports a disproportionate number of negative results, more so than statistically expected. This suggests a negative bias in the DOH laboratory analysis method. Third, some PNNL results are reported at concentrations greater than the sample's minimum detectable activity (MDA), although the results are tagged as not detectable.

DOH is currently working on four steps to resolve these I-129 issues. The steps were initiated in 2006 and will continue until the issue is resolved. This section will continue to document the ongoing investigation into this issue.

The first step, which has been completed, was to review the DOH laboratory procedures. DOH identified potential sources of error with sample preparation, sample holding times, and detector calibration. The detector calibration has been investigated and while some bias cannot be ruled out, it would not be sufficient to account for the discrepancies observed in the split sample results. It is suspected that collectively, the laboratory sample preparation and processing protocols caused most of the DOH under-reported I-129 concentrations. To address these issues, new procedures which call for timely sample preparation and shorter holding times between sample collection and analysis have been implemented, starting with samples collected in 2008. These steps are expected to provide a more quantitative assessment of I-129 in the water samples.

For the second step, DOH reviewed sample collection practices and implemented a revised sample collection procedure in 2008 that more immediately addresses sample preparation. In this procedure, iodine is converted to a more stable chemical form as soon as possible after sample collection. Previously, the collection practice called for samples to be acidified in the field or upon receipt at the laboratory. At the laboratory, a portion of the sample was pH neutralized and the I-129 concentrated using an anion-exchange resin material with high specificity for I-129. This portion was taken after all other analyses were completed to ensure that sufficient sample was available for those tests. The problem with this collection practice is that the acid addition, which is good for keeping most radionuclides in solution, causes iodine to volatilize. Furthermore, iodine is strongly adsorbed by plastics, so that some quantity is likely lost to the walls of the container during holding. Converting the iodine to a more stable form and then trapping the iodine on resin as soon as the sample is collected eliminates these loss problems.

In 2008, DOH will conduct a set of experiments to evaluate the extent to which sample collection procedures and holding times contribute to reported result bias in historic samples. Results of this study will be used to guide interpretation of historical results.

The third step in resolving the I-129 question is to target several groundwater wells with historically elevated concentrations of I-129 for split sample collection and analysis. This will provide results over a wider range of activity with which to evaluate the changes in collection practices and laboratory procedures. In 2008, ten wells known to be associated with I-129 in groundwater will be sampled.

Fourth, DOH will review PNNL's laboratory procedures for I-129 analysis. Findings will be discussed in future reports.

The DOH and DOE contractor TLD results generally follow the same trend. The first and fourth quarter results are in good agreement. A systematic bias is observed for third quarter results, in which DOH reports concentrations slightly lower than those reported by DOE. The bias is also observed to a smaller degree for second quarter results. Inspection of the data suggests a seasonal influence on the DOH concentrations, which are lower in the heat of summer. DOH will initiate an investigation into this phenomenon and will discuss the results in future reports.

The DOH and DOE contractor split uranium results in sediment are in fair agreement. The data generally follow the same trends; however, for most samples, a systematic discrepancy is observed between the two data sets.

For cases in which the uranium concentrations are typical of natural background, DOE reports uranium concentrations that are approximately 75% of the values reported by DOH. This phenomenon is well understood, and results from different laboratory procedures, in which the DOE laboratory is less efficient in measuring the natural background component of uranium in a sample.

For cases in which uranium contamination is present, both DOH and DOE laboratories are equally efficient in measuring the contamination component of uranium in a sample. If the contamination is high compared to background, the DOH and DOE reported concentrations are in good agreement. Samples of this type are not typically encountered.

Historically, DOH and PNNL results for Sr-90 concentrations in farm products, fish and wildlife, and vegetation samples range from good to fair to poor agreement. This trend continued for the current reporting period, as there was disagreement for one of the vegetation samples.

All unaccounted 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	$\alpha\beta$ 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

	Nuclide	Volume (m^3)	Method	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	$\alpha\beta$ 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/ $\alpha\beta$ 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/ $\alpha\beta$ 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	$\alpha\beta$ Cntr	1.00E-01
	Ra-226(DA)	600	INGe	2.00E-02

				Standard (100 min.)
Alpha	Gross	0.1	$\alpha\beta$ 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	$\alpha\beta$ 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	$\alpha\beta$ Cntr	1.50E+00
	Sr-90	20	Nitric Acid/ $\alpha\beta$ 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)				Standard LLD	Standard LLD
---	Nuclide	Volume (L)	Method	(1000 min.)	(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	$\alpha\beta$ 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/ $\alpha\beta$ Cntr		7.00E-01
	Tc-99	0.5	3M/LS		4.00E+00
Gross	Alpha	0.1	$\alpha\beta$ Cntr		4.00E+00
	Beta	0.5	$\alpha\beta$ 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
  $\alpha\beta$ Cntr = Alpha, Beta Counter
  Alpha Spec = Alpha Spectrometry
  LS = Liquid Scintillation
  LEP = Low Energy Photon Detector

Formulas

A. **Random Uncertainty**

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

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 = $e^{-(\ln 2/T_{1/2})(t)}$
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 $(BKG/T_2)^{1/2}$)
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 analysis 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