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Environmental Monitoring at Hanford for 1985

K. R. Price, Editor

May 1986

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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Richland, Washington 99352

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PREFACE

Environmental monitoring at Hanford is conducted by the Battelle Memorial Institute, Pacific Northwest Division, as part of its contract to operate the Pacific Northwest Laboratory (PNL) for the Department of Energy (DOE). The data collected provide a historical record of the levels of radionuclides and radiation attributable to natural causes, worldwide fallout, and Hanford operations. Data are also collected to provide a record of the status of nonradioactive materials onsite and in the Columbia River. Included within this report are initial results from hazardous materials monitoring activities, which began in 1985.

This report represents a single, comprehensive source of environmental monitoring data collected in the offsite, onsite, and subsurface environments. Appendix A contains data and data summaries for results obtained during 1985 that include statistical estimates of errors. Information in Appendix A is intended for readers with a scientific interest or for those who wish to evaluate results in a manner not included here.

ACKNOWLEDGMENTS

Numerous PNL personnel were responsible for a productive environmental monitoring program during 1985. Important contributions were made by those people who collected samples, maintained equipment, provided laboratory analyses, managed data, evaluated results, and provided clerical support. Special thanks go to M. S. Trevathan for coordinating this report and to the many reviewers who provided valuable suggestions. Authors of this report include J. M. V. Carlile, C. S. Cline, R. L. Dirkes, P. A. Eddy, D. R. Fisher, M. J. Graham, R. E. Jaquish, L. S. Prater, L. A. Rathbun, J. R. Raymond, W. H. Rickard, J. T. Rieger, M. S. Trevathan, and R. K. Woodruff. Radiation dose assessments were provided by B. A. Napier, R. A. Peloquin, and J. K. Soldat. V. L. Brouns, L. K. Grove, K. R. Hanson, and M. E. Strong were responsible for technical editing.

SUMMARY

Environmental monitoring activities performed by the Pacific Northwest Laboratory for the Department of Energy on the Hanford Site for 1985 are discussed in this report. Samples of environmental media were collected to estimate radionuclide and chemical concentrations in the Hanford environment. Radiological impacts during 1985 in terms of radiation dose equivalents as a result of Hanford operations are also discussed. Applicable standards and concentration guides are given in Appendix C. As an aid to the reader, a glossary and conversion tables are given in Appendix B. The results provided in this report are summarized in the following sections.

RADIOLOGICAL IMPACT FROM 1985 HANFORD OPERATIONS

Measured and calculated radiation doses to the public from Hanford operations were well below applicable regulatory limits throughout 1985. The calculated 50-year, whole-body dose potentially received by a hypothetical maximally exposed individual was about 3 mrem during 1985. This is an increase of 1 mrem over the potential whole-body dose reported in 1984 and was attributed primarily to increased ^{90}Sr releases from N Reactor to the Columbia River. The calculated 50-year whole-body dose to the population living within 80 km of the Site was 7 man-rem as compared to 5 man-rem in 1984. These doses are much less than doses potentially received from other common sources of radiation. They can also be compared to the approximate 100 mrem and 34,000 man-rem received annually by an average individual and the surrounding population, respectively, as a result of naturally occurring and worldwide fallout radiation in the Hanford environs. The calculated effective dose equivalent using the new DOE Radiation Standards for Protection of the Public was 0.1 mrem, compared to the new limits of 100 mrem/yr for prolonged exposure and 500 mrem/yr for occasional annual exposures to a maximally exposed individual. (See "Radiological Impacts from Hanford Operations.")

RADIOLOGICAL MONITORING RESULTS

Air—Radioactive materials in air were sampled continuously on the Hanford Site, at the Site perimeter, and in nearby and distant communities in the Columbia Basin at a total of 48 locations. Air was sampled and analyzed for several gaseous radionuclides at selected locations. Dust particles filtered from the air at all locations were analyzed for radionuclides in solid form. No sample collected at the Site perimeter or in communities exceeded more than 0.3% of the applicable DOE Derived Concentration Guide.

The 1985 annual average Site perimeter concentrations of ^{85}Kr , ^{90}Sr , ^{129}I and $^{239,240}\text{Pu}$ and uranium were greater than concentrations measured at monitoring stations in distant Columbia Basin communities. Tritium (^3H), ^{14}C , ^{131}I , ^{137}Cs , and ^{238}Pu concentrations at the Site perimeter were similar to those in nearby communities, as well as distant communities where concentrations approached background levels. Increases in ^{85}Kr , ^{90}Sr , $^{239,240}\text{Pu}$, and uranium were observed at the Site perimeter compared to 1984.

Onsite measured concentrations of ^{85}Kr , ^{90}Sr , ^{129}I , $^{239,240}\text{Pu}$, ^3H , and ^{137}Cs were greater than levels at the distant monitoring stations. Tritium, ^{90}Sr , and uranium concentrations increased onsite compared to 1984. (See "Air Monitoring.")

Ground Water—During 1985, ground water was collected from wells that sample both the confined and unconfined aquifers beneath the Hanford Site. Radionuclides detected in various samples included ^3H , ^{60}Co , ^{90}Sr , ^{129}I , ^{137}Cs , uranium, gross alpha, and gross beta. The major ^3H plume continued to move eastward, resulting in seepage into the Columbia River. In addition, monitoring data from wells directly southeast of the 200E Area showed increasing tritium concentrations, reflecting current Hanford operations, specifically the restart of the PUREX Plant. The highest concentrations of ^{90}Sr , ^{60}Co , and ^{137}Cs were found in samples from the 100N Area. Concentrations of ^{129}I were elevated in samples collected from wells located in or adjacent to the 200 Areas, while the highest concentrations of

gross alpha, gross beta, and uranium were found in well water from the 100H Area. (See "Ground-water Monitoring.")

Surface Water—Very low levels of radionuclides were detected in samples of Columbia River water collected immediately upstream and downstream of the Hanford Site during 1985. Concentrations of all radionuclides observed in river water were well below applicable EPA and State of Washington drinking-water concentration guides. As in past years, radionuclides consistently observed in measurable quantities in the river water included ^3H , ^{90}Sr , ^{129}I , ^{137}Cs , uranium, and $^{239,240}\text{Pu}$. Tritium, ^{129}I , and uranium concentrations were consistently higher at the downstream sample site than at the upstream site. Strontium-90, ^{137}Cs , and $^{239,240}\text{Pu}$ concentrations were similar at the upstream and downstream sampling sites, indicating no measurable contribution as a result of Hanford operations. The major sources of radionuclides entering the river were from N Reactor liquid-disposal facilities and from the ground water moving beneath the Hanford Site and into the river.

Concentrations of radionuclides observed in samples of water from onsite ponds collected during 1985 were similar to those observed in previous years. (See "Surface Water Monitoring.")

Foodstuffs—Low levels of radionuclides attributable to worldwide fallout were observed in most foodstuff samples. In addition, ^{131}I was detected at very low levels in a small percentage (6%) of the individual milk samples. Foodstuffs irrigated with Columbia River water taken downstream of the Site were sampled in 1985 to determine if elevated concentrations of radionuclides were present. All results were similar to the low concentrations found in foodstuffs grown in other adjacent sampling areas, indicating no measurable impact as a result of Hanford operations. (See "Foodstuffs Monitoring.")

Wildlife—Samples of deer, rabbits, game birds, waterfowl, and fish were collected where the potential for radionuclide uptake was considered most likely, or at the nearest locations where wildlife samples were available. Game birds, waterfowl, fish, and deer showed low

levels of ^{137}Cs attributable to Hanford operations. Other radionuclide concentrations in wildlife were typical of levels attributable to worldwide fallout. (See "Wildlife Monitoring.")

Soil and Vegetation—Low concentrations of radionuclides were measured in onsite and offsite samples of soil and vegetation during 1985. Levels were similar to those observed in previous years. Evaluations of 1985 sample results provided no indication of any discernible increases in the concentrations of radionuclides that could be attributable to current Hanford operations. Results of a special study, however, noted the presence of Hanford-derived plutonium mixed with fallout plutonium in onsite and some offsite soil samples. (See "Soil and Vegetation Monitoring.")

Penetrating Radiation—Dose rates from external penetrating radiation measured in the vicinity of local residential areas were similar to those observed in previous years, and no contribution from Hanford activities could be identified. Measurements made in the vicinity of onsite operating areas and along the Hanford reach of the Columbia River continued to indicate several locations where dose rates were somewhat higher than those attributable to background sources but still well below applicable DOE radiation protection standards. (See "Penetrating Radiation Monitoring.")

NONRADIOLOGICAL MONITORING RESULTS

Air Quality—Continuous monitoring of nitrogen dioxide by the Hanford Environmental Health Foundation (HEHF) at seven locations demonstrated that concentrations were generally higher than in 1984, but well below national and Washington State ambient air quality standards. (See "Air Quality Monitoring.")

Ground Water—Ground-water monitoring for chemical constituents included both routine sampling and a special new effort involving hazardous materials. Samples collected under the routine effort were analyzed for a variety of

nonradiological constituents. Chromium, sodium, and the water quality parameters of conductivity and total dissolved solids were found in elevated levels in samples collected in the 100H Area compared to the rest of the Site.

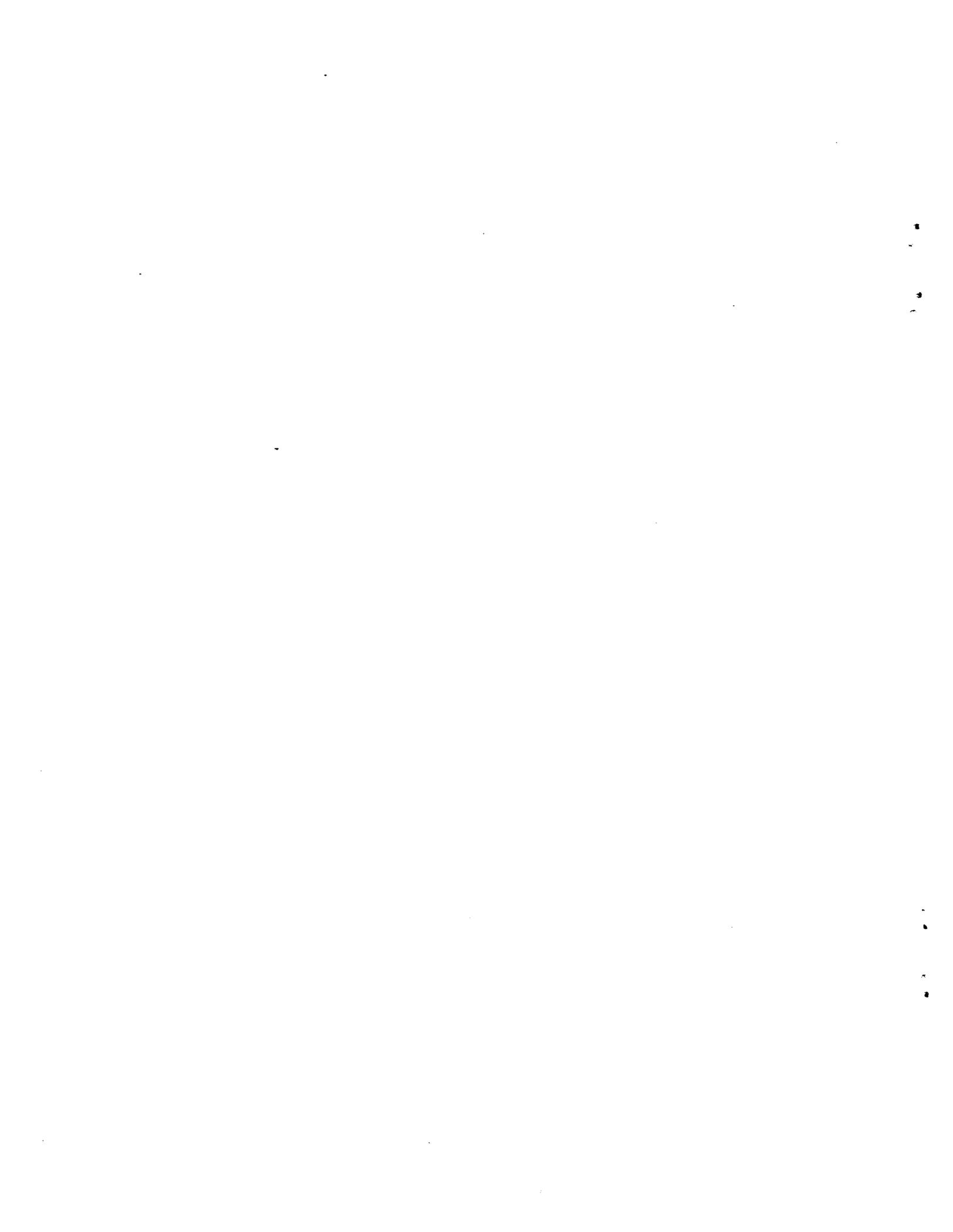
Monitoring for hazardous materials in the ground water consisted of an initial effort to collect a single set of samples from 75 wells. Samples were analyzed for 35 to 40 constituents. Constituents detected included several metals, anions, coliform bacteria, and total organic carbon. Low concentrations of many of the constituents detected would be expected in the natural ground water, and additional sampling is needed to determine any effects from Hanford operations. (See "Nonradiological Ground-Water Monitoring.")

Columbia River—Nonradiological water quality parameters for the Hanford reach of the Columbia River were within Washington State Water Quality Standards, with a few isolated exceptions in the case of pH and fecal coliform bacteria. Based on 1985 river-monitoring data (PNL

and USGS) and National Pollution Discharge Elimination System (NPDES) discharge reports, there was no apparent association of these deviations with Hanford operations, or any indication of reduced river water quality during 1985 as a result of Hanford operations. (See "Columbia River Water Quality Monitoring.")

QUALITY ASSURANCE

Comprehensive quality assurance programs were maintained to ensure that the data collected were representative of actual concentrations in the environment. These programs covered surface monitoring, hazardous materials monitoring, and ground-water monitoring. Standard quality assurance-quality control techniques were employed in conduct of the sample collection, laboratory analysis, data management, and dose calculation activities. (See "Quality Assurance.")



CONTENTS

PREFACE	iii
ACKNOWLEDGMENTS	iv
SUMMARY	v
Radiological Impact From 1985 Hanford Operations	v
Radiological Monitoring Results	v
Nonradiological Monitoring Results	vi
Quality Assurance	vii
INTRODUCTION	Intro.-1
I. BACKGROUND INFORMATION	I.1
Description of the Hanford Site	I.1
Surface Characteristics of the Site	I.1
Subsurface Characteristics of the Site	I.2
Major Activities	I.4
Environmental Monitoring	I.7
Scope	I.7
Objectives	I.7
Criteria	I.7
Environmental Protection Standards and Permits	I.9
Program Description	I.9
Related Programs and Special Studies	I.10
II. RADIOLOGICAL IMPACTS AND DOSE CALCULATIONS	II.1
Effluents, Waste Disposal, and Unusual Occurrences	II.1
Effluents and Waste Disposal	II.1
Environmentally Related Unusual Occurrences	II.2
Radiological Impact From 1985 Hanford Operations	II.4
Maximum "Fence-Post" Dose Rate	II.5
Maximally Exposed Individual Dose	II.5
Population Dose	II.7
Radiological Impact from Past Operations	II.10
Radiological Impact from PUREX Plant Operations	II.9
Radiological Impact on Drinking Water from Wells	II.10
Revised DOE Guidance for Dose Calculations	II.11
III. RADIOLOGICAL MONITORING RESULTS	III.1
Air Monitoring	III.1
Sample Collection and Analysis	III.1
Results	III.4
Ground-Water Monitoring	III.12
Sample Collection and Analysis	III.12
Results	III.14
Surface-Water Monitoring	III.20
Columbia River	III.20
Onsite Ponds	III.25

Foodstuffs Monitoring	III.29
Milk	III.29
Leafy Vegetables	III.29
Fruit	III.30
Wheat and Alfalfa	III.31
Beef, Poultry, and Eggs	III.31
Special Riverview Foodstuff Sampling	III.32
Wildlife Monitoring	III.33
Deer	III.33
Fish	III.33
Upland Game Birds	III.34
Waterfowl	III.36
Rabbits	III.36
Soil and Vegetation Monitoring	III.38
Sample Collection and Analysis	III.38
Soil Results	III.38
Isotopic Composition of Plutonium in Soil Samples	III.40
Vegetation Results	III.42
Tritium in Hanford Site Trees	III.42
Penetrating Radiation Monitoring	III.44
Penetrating Radiation Measurements	III.44
Radiation Surveys	III.48
Comparison of Measured and Calculated Results	III.51
IV. NONRADIOLOGICAL MONITORING RESULTS	IV.1
Air Quality Monitoring	IV.1
Sample Collection and Analysis	IV.1
Results	IV.1
Nonradiological Ground-Water Monitoring	IV.3
Routine Sample Collection and Analysis	IV.3
Results of Routine Sampling	IV.3
Sample Collection and Analysis for Hazardous Materials	IV.4
Results of Hazardous Materials Monitoring	IV.5
Columbia River Water Quality Monitoring	IV.10
Sample Collection and Analysis	IV.10
Results	IV.10
V. QUALITY ASSURANCE	V.1
Quality Assurance	V.1
Sample Collection Quality Assurance	V.1
Analytical Laboratory Quality Assurance	V.1
Dose Calculations Quality Assurance	V.5
REFERENCES	Ref.1
BIBLIOGRAPHY	Bib.1

APPENDICES

Appendix A — Monitoring Results For 1985

Appendix B — Reference Guide

Glossary	B.2
Acronyms and Abbreviations	B.6
Miscellaneous Abbreviations	B.7
Conversion Table	B.8
Table of Unit Prefixes	B.8

Appendix C — Applicable Standards and Permits

Appendix D — Analytical Procedures and Sampling Summary

Appendix E — Data Analysis

Appendix F — Dose Calculations and Effluent Data

APPENDIX REFERENCES

DISTRIBUTION

FIGURES

1	DOE's Hanford Site	I.1
2	Geologic Cross Section of the Site	I.3
3	Water Table Elevations	I.5
4	Potential Radiological Dose Pathways	I.8
5	Calculated Whole-Body Doses to the Maximally Exposed Individual, 1980 to 1985	II.7
6	Calculated 80-km Whole-Body Population Dose	II.9
7	Annual Radiation Doses from Various Sources	II.9
8	Air Sampling Locations	III.2
9	Monthly Average Gross Beta Radioactivity in Airborne Particulate Samples, 1975 to 1985 ..	III.4
10	⁸⁵ Kr Air Concentrations at Selected Locations	III.6
11	Annual Average ⁸⁵ Kr Concentrations (pCi/m ³) in Air and the 200 Area Windrose (showing direction from which wind blew) for 1985	III.6
12	Annual Average ⁹⁰ Sr Air Concentrations in the Hanford Environs Compared to Other U.S. Locations	III.7
13	Iodine-129 Concentrations (aCi/m ³) in Air in the Hanford Environs for 1985	III.8
14	Annual Average Tritium Concentrations (pCi/ℓ of water) in Atmospheric Water Vapor	III.9
15	Plutonium-239,240 Concentrations (aCi/m ³) in Air in the Hanford Environs for 1985	III.10
16	Annual Average Plutonium-239,240 Air Concentrations in the Northwest and Hanford Environs for 1980 through 1985	III.11
17	Locations of Sampled Wells	III.13
18	Tritium Plume for 1985	III.15
19	Tritium Concentrations for Well 699-41-23	III.16
20	Tritium Concentrations for Well 699-40-1	III.16
21	Tritium Concentrations for Well 699-34-42	III.17
22	Tritium Concentrations for Well 699-33-42	III.17
23	Columbia River Water Sampling and Onsite Pond Locations	III.21
24	Tritium Concentrations Measured in Columbia River Water During 1985	III.22
25	Annual Average Tritium Strontium-90 and Uranium Concentrations Measured in the Columbia River, 1981 to 1985	III.23
26	⁹⁰ Sr Concentrations Measured in Columbia River Water During 1985	III.24
27	Uranium Concentrations Measured in Columbia River Water During 1985	III.24
28	Iodine-129 Concentrations Measured in Columbia River Water, 1980 to 1985	III.25
29	Annual Average Gross Alpha and Gross Beta Concentrations Measured in Onsite Ponds, 1980 to 1985	III.27
30	Annual Average Tritium Concentrations Measured in Onsite Ponds, 1983 to 1985	III.27
31	Annual Average ⁹⁰ Sr Concentrations Measured in B Pond Water, 1980 to 1985	III.27
32	Annual Average ¹³⁷ Cs Concentrations Measured in B Pond Water, 1980 to 1985	III.27
33	Annual Average ⁹⁰ Sr Concentrations Measured in Gable Pond Water, 1980 to 1985	III.28
34	Annual Average ¹³⁷ Cs Concentrations Measured in Gable Pond Water, 1980 to 1985	III.28
35	Foodstuffs Sampling Areas	III.30
36	Annual Average ¹³⁷ Cs and ⁹⁰ Sr Concentrations Measured in Milk, 1980 to 1985	III.31
37	Annual Average ¹³⁷ Cs and ⁹⁰ Sr Concentrations Measured in Leafy Vegetables, 1980 to 1985	III.31
38	Annual Average ¹³⁷ Cs and ⁹⁰ Sr Concentrations Measured in Beef, 1980 to 1985	III.32
39	Wildlife Sampling Areas	III.34
40	Median Concentrations of ¹³⁷ Cs and ^{239,240} Pu Measured in Deer Muscle and Liver, 1980 to 1985	III.35
41	Median Concentrations of ⁶⁰ Co and ¹³⁷ Cs Measured in Whitefish and Bass, 1980 to 1985 ..	III.35
42	Median Concentrations of ¹³⁷ Cs Measured in Game Birds from the 100 and 200 Areas, 1980 to 1985	III.35

43	Median Concentrations of ¹³⁷ Cs Measured in Mallard Ducks from 1980 to 1985	III.36
44	Median Concentrations of ¹³⁷ Cs Measured in Muscle and ⁹⁰ Sr Measured in Bone of Cottontail Rabbits in the 100 Area, 1980 to 1985	III.37
45	Median Concentrations of ¹³⁷ Cs Measured in Muscle and ⁹⁰ Sr Measured in Bone of Jack Rabbits in the 200 Areas, 1980 to 1985	III.37
46	Soil and Vegetation Samples Collected at Onsite and Offsite Locations	III.39
47	Median ⁹⁰ Sr, ¹³⁷ Cs, ^{239,240} Pu, and Uranium Concentrations Measured in Soil at all Onsite and Offsite Locations, 1980 to 1985	III.40
48	Calculated Percentage of Plutonium Attributable to Hanford Activities at Each Sampling Location	III.41
49	Median ⁹⁰ Sr, ¹³⁷ Cs, ^{239,240} Pu, and Uranium Concentrations Measured in Vegetation at all Onsite and Offsite Locations, 1980 to 1985	III.42
50	Tritium in Hanford Site Trees	III.43
51	Environmental Dosimeter Locations at the Site Perimeter, Nearby Communities, and Distant Communities	III.45
52	Annual Average External Dose Rates Measured at Perimeter and Distant Locations, 1980 to 1985	III.46
53	Environmental Dosimeter Locations Along the Hanford Reach of the Columbia River	III.46
54	Environmental Dosimeter Locations at Publicly Accessible Onsite Locations	III.47
55	Environmental Dosimeter Locations on the Hanford Site	III.49
56	Road and Railroad Survey Routes	III.50
57	Nitrogen Dioxide Air Sampling Locations	IV.1
58	Hazardous Materials Sampling Locations	IV.4
59	Network Wells Receiving Screening Analysis	IV.6
60	Histograms for Selected Hazardous Materials Constituents Measured in 1985	IV.7
61	Columbia River Water Quality Measurements, 1980 to 1985	IV.11
62	Columbia River Temperature and Flow Rates Measured in 1985	IV.12
63	Laboratory Intercomparison Results for Nitrate	V.5
64	Laboratory Intercomparison Results for Sulfate	V.6
65	Laboratory Intercomparison Results for Chloride	V.6

TABLES

1	Radionuclide Nomenclature	Intro.1
2	Geographical Distribution of Environmental Sample and Measurement Locations	I.10
3	Calculated Doses to the Hypothetical Maximally Exposed Individual from 1985 Hanford Operations	II.6
4	Calculated Doses to the Hypothetical Maximally Exposed Individual from Hanford Operations, 1980 to 1985	II.8
5	Calculated Doses to the 80-km Population from 1985 Hanford Operations	II.8
6	Calculated Doses to the 80-km Population from Hanford Operations, 1980 to 1985	III.8
7	Calculated 50-Year Cumulative Doses from ^{239,240} Pu Released to the Atmosphere from the PUREX Plant in 1985	II.11
8	Calculated Committed Dose Equivalents and the Effective Dose Equivalent to the Hypothetical Maximally Exposed Individual from 1985 Hanford Operations	II.13
9	Calculated Committed Dose Equivalent and the Effective Dose Equivalent for the 80-km Population from 1985 Hanford Operations	II.13
10	Number of Locations by Air Sample Types	III.2
11	Numbers of Wells Sampled, Samples Taken, and Analyses Performed for Ground-Water Monitoring in 1985	III.14
12	Measured and Calculated 1985 Annual Average Concentrations of Selected Radionuclides in the Columbia River (pCi/ℓ)	III.52
13	Measured and Calculated 1985 Annual Average Air Concentrations of Selected Radionuclides (pCi/m ³)	III.52
14	Ambient Nitrogen Dioxide (NO ₂) Concentrations in the Hanford Environs for 1985	IV.2
15	Hazardous Material Constituents Selected for Analysis in 1985	IV.6
16	Measurements for NPDES-Permitted Discharges at Hanford	IV.11
17	U.S. Testing Laboratory Performance on DOE Quality Assessment Program Samples	V.3
18	U.S. Testing Laboratory Performance on EPA Laboratory Intercomparison Program Samples	V.3
19	PNL Performance on DOE Quality Assessment Program Samples	V.4

Appendix A — Monitoring Results for 1985

A.1	Air Sampling Locations and Sample Composite Groups	A.2
A.2	Concentrations of Gross Beta and Gross Alpha Activity Measured in Air in the Hanford Environs for 1985	A.3
A.3	Concentrations of Radionuclides Measured in Air in the Hanford Environs for 1985	A.6
A.4	Concentrations of Radionuclides Measured in Air Near the 100 Areas	A.7
A.5	Concentrations of Radionuclides Measured in Air Near the 200E Area	A.8
A.6	Concentrations of Radionuclides Measured in Air Near the 200W Area	A.9
A.7	Concentrations of Radionuclides Measured in Air North of the 200 Areas	A.9
A.8	Concentrations of Radionuclides Measured in Air Near the 300 Area	A.10
A.9	Concentrations of Radionuclides Measured in Air Near the 400 Area	A.10
A.10	Concentrations of Radionuclides Measured in Air in the 600 Area	A.11
A.11	Average, Minimum and Maximum Tritium Concentrations in the Ground Water	A.12
A.12	Iodine-129 Concentrations in Wells Sampled in 1985	A.17
A.13	Radionuclide Concentrations Measured in Columbia River Water Upstream from Hanford Operations in 1985	A.18
A.14	Radionuclide Concentrations Measured in Columbia River Water Downstream from Hanford Operations in 1985	A.19
A.15	Radionuclide Concentrations in Onsite Ponds in 1985	A.20
A.16	Radionuclides in Milk Samples	A.21

A.17	Radionuclides in Leafy Vegetables	A.21
A.18	Radionuclides in Fruit	A.22
A.19	Radionuclides in Wheat and Alfalfa	A.22
A.20	Radionuclides in Beef, Chickens, and Eggs	A.23
A.21	Special Riverview Foodstuff Sampling Results	A.23
A.22	Cesium-137 in Deer Muscle and Plutonium-239,240 in Deer Liver	A.24
A.23	Radionuclides in Columbia River Fish	A.24
A.24	Cobalt-60 and Cesium-137 in Muscle Tissue of Upland Gamebirds	A.24
A.25	Cesium-137 in Muscle Tissue of Mallard Ducks	A.25
A.26	Strontium-90 and Cesium-137 in Bone and Muscle Tissue of Rabbits	A.25
A.27	⁹⁰ Sr Concentrations in Soil (pCi/g, dry weight)	A.26
A.28	¹³⁷ Cs Concentrations in Soil (pCi/g, dry weight)	A.27
A.29	^{239,240} Pu Concentrations in Soil (pCi/g, dry weight)	A.28
A.30	U Concentrations in Soil (pCi/g, dry weight)	A.29
A.31	²⁴⁰ Pu to ²³⁹ Pu Ratios for Soil Samples Collected on and Around the Hanford Area in 1978, 1982, 1983, and 1984, in Ascending Order	A.30
A.32	⁹⁰ Sr Concentrations in Vegetation (pCi/g, dry weight)	A.31
A.33	¹³⁷ Cs Concentrations in Vegetation (pCi/g, dry weight)	A.32
A.34	^{239,240} Pu Concentrations in Vegetation (pCi/g, dry weight)	A.33
A.35	U Concentrations in Vegetation (pCi/g, dry weight)	A.34
A.36	Environmental Dosimeter Measurements - Perimeter and Community Locations	A.35
A.37	Immersion Dose Rates Measured in the Columbia River,	A.36
A.38	Environmental Dosimeter Measurements of Publicly Accessible Onsite Locations,	A.36
A.39	Environmental Dosimeter Measurements Along the Hanford Reach of the Columbia River	A.37
A.40	Onsite External Penetrating Dose Measurements	A.38
A.41	Water Quality Parameters Analyzed by HEHF, 1985	A.39
A.42	Constituents Detected in Sampling of 75 Wells in the Site-Wide Network	A.40
A.43	Constituents Detected in Sampling of Two Wells at the 100B Area	A.41
A.44	Constituents Detected in Sampling of Two Wells at the 100D Area	A.42
A.45	Constituents Detected in Sampling of Three Wells at the 100F Area	A.43
A.46	Constituents Detected in Sampling of Two Wells at the 100K Area	A.44
A.47	Constituents Detected in Sampling of Six Wells at the 100N Area	A.45
A.48	Constituents Detected in Sampling of 26 Wells in or Near the 200 Areas	A.47
A.49	Constituents Detected in Sampling of 34 Wells in the 600 Area	A.47
A.50	Columbia River Water Quality Data	A.48
A.51	Estimates of Total Precision Based on 1985 Replicate Sampling and Analysis	A.49
A.52	U.S. Testing Analysis of National Bureau of Standards Standard Reference Soil	A.49
A.53	U.S. Testing ⁹⁰ Sr Analysis of Environmental Measurements Laboratory Vegetation Samples	A.50
A.54	⁸⁵ Kr Analysis of Compressed Air Sample Split With REECO	A.50
A.55	Comparison of TLD Results With Known Exposures	A.51
A.56	Radiation Response of PNL and State of Washington DSHS Environmental Dosimeters	A.51
A.57	Washington State-DSHS and PNL Shared TLD Stations	A.52
A.58	Results of Split Samples Analyzed by State of Washington, State of Oregon and Department of Energy - Pacific Northwest Laboratory	A.53
A.59	Results of Duplicate Samples Analyzed for Tritium, 1985	A.54

Appendix C — Applicable Standards and Permits

C.1	Washington State Water Quality Standards for the Hanford Reach of the Columbia River	C.1
-----	--	-----

C.2	Drinking Water Standards: Environmental Protection Agency, National Interim Primary Drinking Water Regulations and State of Washington	C.2
C.3	DOE Radiation Protection Standards for External and Internal Exposure Prior to September 1, 1985	C.3
C.4	Radiation Standards for Protection of the Public in the Vicinity of DOE Facilities	C.3
C.5	Proposed Derived Concentration Guides (DCG)	C.4
C.6	Environmental Permits	C.4

Appendix D — Analytical Procedures and Sampling Summary

D.1	Radiological Monitoring Sampling Summary	D.2
D.2	List of Parameters and Analytical Methods for Ground-Water Hazardous Materials Monitoring	D.8

Appendix F — Dose Calculations and Effluent Data

F.1	Distribution of Population in 80-km Radius of the N Reactor by Population Grid Sector	F.4
F.2	Distribution of Population in 80-km Radius of 200 Area Hanford Meteorological Tower by Population Grid Sector	F.4
F.3	Distribution of Population in 80-km Radius of the FFTF by Population Grid Sector	F.4
F.4	Distribution of Population in 80-km Radius of 300 Area by Population Grid Sector	F.4
F.5	Annual Average Atmospheric Dispersion (\bar{X}/Q') Around the 100N Area During 1985 for an 89-m Release Height	F.5
F.6	Annual Average Atmospheric Dispersion (\bar{X}/Q') Around the 200 Areas During 1985 for an 89-m Release Height	F.5
F.7	Annual Average Atmospheric Dispersion (\bar{X}/Q') Around the 300 Area During 1985 for a Ground-Level Release Height	F.6
F.8	Annual Average Atmospheric Dispersion (\bar{X}/Q') Around the 400 Area During 1985 for a Ground-Level Release Height	F.6
F.9	Pathway Parameters Used in 1985 Dose Calculations	F.7
F.10	Dietary Parameters	F.8
F.11	Residency Parameters	F.8
F.12	Recreational Activities	F.8
F.13	Documentation of 100 Area Airborne Release Dose Calculation	F.9
F.14	Documentation of 100 Area Liquid Release Dose Calculation	F.10
F.15	Documentation of 200 Area Airborne Release Dose Calculation	F.11
F.16	Documentation of 300 Area Airborne Release Dose Calculation	F.12
F.17	Documentation of 400 Area Airborne Release Dose Calculation	F.13
F.18	Radionuclides in Gaseous Effluents Discharged to the Atmosphere	F.14
F.19	Nonradioactive Constituents in Gaseous Effluents Discharged to the Atmosphere in 1985	F.15
F.20	Radionuclides in Liquid Effluents Discharged to Ground Disposal Facilities in 1985	F.16
F.21	Nonradioactive Constituents in Liquid Discharged to Ground Disposal Facilities in 1985	F.17
F.22	Quantities of Materials Discharged to the 183-H Evaporation Basins in 1985	F.17
F.23	Radionuclides in Liquid Effluents Discharged to the Columbia River in 1985	F.17
F.24	Composition of Solid Waste Buried Onsite During 1985	F.17

INTRODUCTION

A variety of nuclear and non-nuclear activities have been conducted at the Hanford Site since 1943. The most environmentally significant activities have been the production of nuclear materials for national defense and the associated chemical processing and management of waste products. The U.S. Department of Energy (DOE) conducts effluent control, effluent monitoring, and environmental monitoring at the Hanford Site through contractor organizations to ensure compliance with applicable rules and regulations. An environmental monitoring program has been conducted at the Hanford Site for the past 42 years. Environmental monitoring has been conducted since 1965 by the Pacific Northwest Laboratory (PNL), which is operated for the DOE by the Battelle Memorial Institute.

Environmental monitoring activities provided for the measurement, interpretation, and evaluation of samples and other types of measurements to assess current onsite and offsite environmental impact, to determine compliance with pertinent regulations, and to evaluate the adequacy of onsite waste management practices. Results were not intended to characterize the Hanford environs. Monitoring data were aimed at assessing the radiation exposures from current effluent releases in terms of potential radiation dose and at determining compliance with state and federal regulations. Pathways of potential environmental impact were evaluated, with emphasis on the most important pathways.

The monitoring results have been recorded since 1946 in quarterly reports. Since 1958, the results have been publicly available as annual reports. Results in recent years have been published as separate reports under the titles:

- Environmental Surveillance at Hanford for CY (monitoring results for the offsite environs)
- Environmental Status of the Hanford Site for CY (monitoring results for the onsite environs)
- Ground-Water Monitoring at the Hanford Site (monitoring results for the onsite subsurface environs).

These three reports were combined into this report to summarize the data collected for calendar year 1985. This report includes information on all samples and measurements made in the offsite, onsite, and subsurface environment. A brief description of the Hanford Site and ongoing operations, the nature of environmental

monitoring activities, and the results and interpretation of environmental monitoring data for 1985 are included. The radiological impact of Hanford operations was assessed by calculating the potential radiation dose to people living in the vicinity of the Hanford Site.

This report emphasizes the radiological status of the Hanford environment and vicinity. In general, the data were compared to both background or control measurements taken at distant locations during 1985 and to data obtained during the past five years. The "Radiological Impact from Hanford Operations" section discusses an assessment of radiological impacts at the Hanford Site and on the surrounding environment. Potential doses are calculated for a hypothetical maximally exposed individual and for the local population. The dose rates at publicly accessible areas are also discussed.

Radionuclide data are expressed in terms of curies, picocuries, or attocuries. The curie (Ci) is the fundamental unit used to express radioactivity and defines the amount of a substance present based on its rate of radioactive disintegration. A microcurie (μCi) is one millionth (10^{-6}) of a curie. A picocurie (pCi) is one millionth-millionth (10^{-12}) of a curie. An attocurie (aCi) is one millionth-millionth-millionth (10^{-18}) of a curie. Environmental monitoring results are often very small numbers that are best expressed as picocuries or attocuries. As an additional aid in expressing small and variable environmental results, data are graphed using either linear or logarithmic (compressed) scales.

The radionuclides and corresponding symbols commonly used in this report are listed in Table 1. The radionuclides addressed by environmental monitoring are listed in Tables F.18 and F.20, Appendix F. Gross alpha and gross beta results are from screening-type analyses that measure all alpha or beta radiations in the sample, regardless of the radionuclide present.

Chemical data are expressed as parts per billion (ppb) or the equivalent measure, micrograms per liter ($\mu\text{g}/\ell$). Occasionally, they are expressed in parts per million (ppm) or the equivalent milligrams per liter (mg/ℓ). Because concentrations of chemicals in environmental media are often very small numbers, they are best expressed in these units.

Environmental monitoring data for 1985 are listed in Appendix A, and a glossary and list of acronyms and abbreviations are presented in Appendix B. Applicable standards and special permits are presented in Appendix C. Sample analysis procedures are described in Appendix D, and data analysis methods are summarized in Appendix E. Dose calculation methods and details including effluent data used in the calculations for 1985 are given in Appendix F.

TABLE 1. Radionuclide Nomenclature

<u>Radionuclide</u>	<u>Symbol</u>
Tritium	^3H
Carbon-14	^{14}C
Cobalt-60	^{60}Co
Krypton-85	^{85}Kr
Strontium-90	^{90}Sr
Technetium-99	^{99}Tc
Ruthenium-106	^{106}Ru
Iodine-129	^{129}I
Cesium-137	^{137}Cs
Plutonium-238	^{238}Pu
Plutonium-239,240	$^{239,240}\text{Pu}$
Uranium (total)	U or uranium

I. BACKGROUND INFORMATION

DESCRIPTION OF THE HANFORD SITE

The U.S. Department of Energy's Hanford Site is located in a rural region of southeastern Washington and occupies an area of 1,500 km². The Site, shown in Figure 1, lies about 320 km northeast of Portland, Oregon, 270 km southeast of Seattle, Washington, and 200 km southwest of Spokane, Washington. The Columbia River flows through the northern edge of the Hanford Site and forms part of its eastern boundary.

SURFACE CHARACTERISTICS OF THE SITE

The semiarid land on which the Hanford Site is located has a sparse covering of desert shrubs and drought-resistant grasses. The most broadly distributed type of vegetation on the site is the sagebrush/cheatgrass/bluegrass community. The most abundant mammal is the Great Basin pocket mouse. The mule deer is the most abundant big-game animal on the Site, and the most prolific small-game animal is the cottontail rabbit. The coyote is the most abundant furbearing animal. The bald eagle is a regular winter

visitor to the relatively large areas of uninhabited land comprising the Hanford Site.

The Hanford reach of the Columbia River extends from Priest Rapids Dam to the head of Lake Wallula, which is created by McNary Dam downstream of the Site. It is the last free-flowing reach of the Columbia River in eastern Washington. Water quality for the Hanford reach is designated as Class A by the State of Washington. This means the water is suitable for all uses, including raw drinking water, recreation, and wildlife. Monthly average river-water temperatures

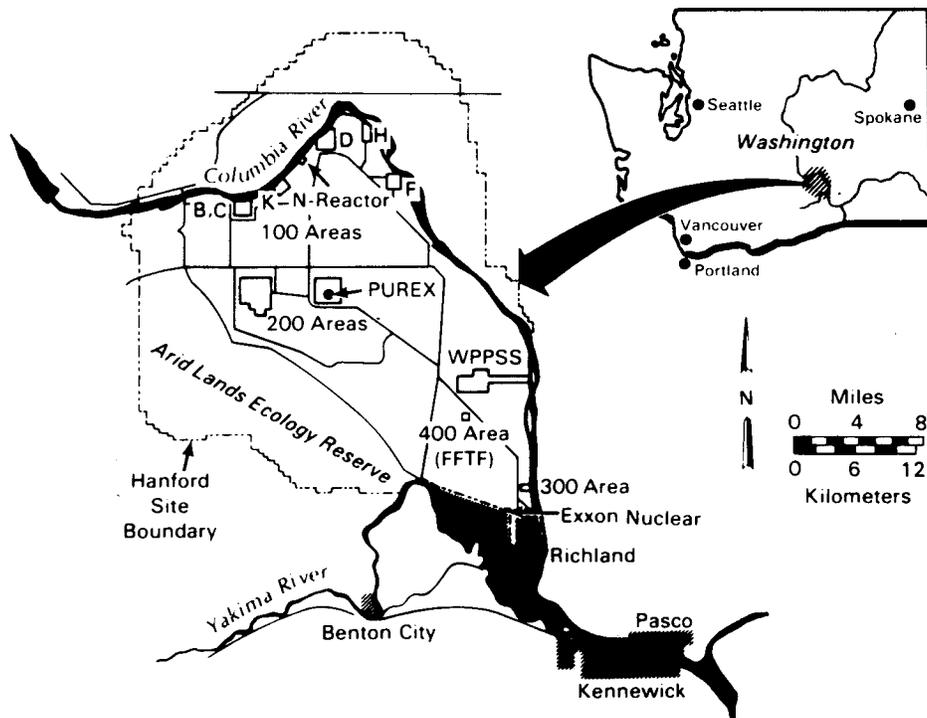


FIGURE 1. DOE's Hanford Site

range from about 3°C (37°F) in February to 19°C (67°F) in August. Other surface water on the Site consists of West Lake (a small, natural pond), a number of ditches, and three artificial ponds created for routine disposal of cooling water.

Hanford's climate is dry and mild; the area receives approximately 16 cm of precipitation annually. About 40% of the total precipitation occurs during November, December, and January; only 10% falls in July, August, and September. Approximately 45% of all precipitation from December through February is snow. The average maximum and minimum temperatures in July are 32°C (90°F) and 16°C (61°F). For January, the averages are 3°C (37°F) and -6°C (22°F).

Monthly average wind speeds range from about 10 km/h in the summer to 14 km/h in the winter. The prevailing regional winds are from the northwest, with occasional strong drainage and crosswinds. The region is a typical desert area with frequent strong inversions that occur at night and break during the day, resulting in unstable and turbulent conditions.

Land near the Hanford Site is principally used for agriculture and for livestock grazing. Agricultural lands occur north and east of the Columbia River and south of the Yakima River and include orchards, vineyards, and fields of alfalfa, wheat, and vegetables. Use of the Hanford Site north of the Columbia River is shared between a state wildlife management area and a federal wildlife refuge. The northeast slope of the Rattlesnake Hills is designated as the Arid Lands Ecology Reserve and is used for ecological research by DOE.

The major population center nearest to the Hanford Site is the Tri-Cities area (Richland, Pasco, and Kennewick), which is situated on the Columbia River downstream from the Site and has a population of approximately 90,000. Approximately 340,000 people live within an 80-km radius of the Hanford Site in the Tri-Cities, the Yakima area, several small communities, and the surrounding agricultural area. Considerably more detail on site characteristics and activities is available in the *Final Environmental Statement, Waste Management Operations, Hanford Reservation* (ERDA 1975).

SUBSURFACE CHARACTERISTICS OF THE SITE

The DOE operations onsite have resulted in the production of large volumes of waste water, which have historically been discharged to the ground through cribs, ditches, and ponds. Over 10 billion gallons of liquid effluent were disposed in the ground in 1985, including process cooling water and water containing low-level radioactive wastes. The discharge of waste water to the ground at the Hanford Site began in the mid-forties and reached a peak in 1955. After 1955, discharge to cribs declined because of improved treatment of waste streams and the deactivation of various facilities (Graham et al. 1981). Since the restart of the PUREX Plant and related facilities in late 1983, discharge of PUREX-related effluents has resumed.

Subsurface structures, such as cribs, have been used for the disposal of water containing radioactive wastes, while surface ponds and ditches have been used for the disposal of uncontaminated cooling water (Graham et al. 1981). Liquid disposal facilities occur at each of the operating areas (100, 200, 300, 400) shown in Figure 1. The majority of the waste water has been released in the 200 Areas located on a plateau near the center of the Site. Smaller amounts of waste water have been released through disposal facilities in the 100 and 300 Areas, while discharges of waste water in the 400 Area have been minimal.

Geologic and hydrologic properties of the Site's subsurface, including stratigraphy and physical and chemical properties of the host rock all influence the movement of the liquid effluents. Generally, ground-water movement has been in a west-to-east direction toward the Columbia River. The geology and hydrology of the Site's subsurface and the physical nature of liquid effluent movement are described in more detail in the following sections.

Geology

The main geologic units beneath the Hanford Site include, in ascending order, the Columbia River Basalt Group, the Ringold Formation, and a series of glaciofluvial sediments. A generalized geologic cross section of the Site is shown in Figure 2.

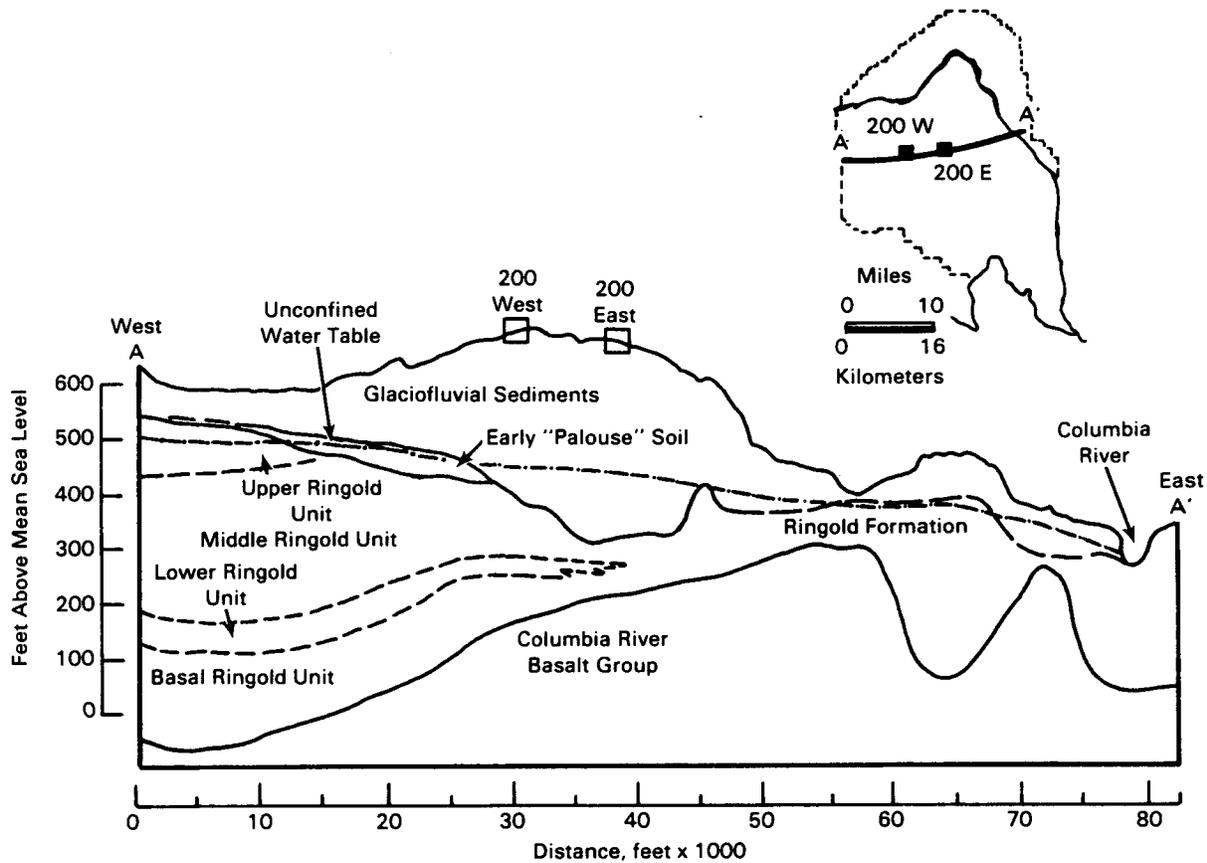


FIGURE 2. Geologic Cross Section of the Site (from Tallman et al. 1979)

The Columbia River Basalt Group is a thick series of lava flows that were extruded from fissures. The basalts have been warped and folded, producing anticlines that, in some places, crop out at the land surface. The Ringold Formation overlies the basalts except in some localized areas. This formation, consisting of fluvial and lacustrine sediments, is separated into four lithologic units: basal, lower, middle, and upper. The basal and middle units consist mostly of semiconsolidated gravels and sands, whereas the lower and upper units consist mainly of bedded silts and sands. Beneath the 200 West (200W) Area, sediments of the upper Ringold Formation have been reworked by the wind and redeposited as a silt layer called the Palouse soil. The glaciofluvial sediments rest atop the Ringold Formation or Palouse soil, and, in places where the Ringold has been removed, the basalts. These sediments were deposited by

the ancestral Columbia River when it was swollen by glacial meltwater. The glaciofluvial sediments are composed primarily of gravels, sands, and some silts (Newcomb, Strand and Frank 1972).

Hydrology

Both confined and unconfined aquifers are present beneath the Hanford Site. The confined aquifers, in which the ground water is under pressure greater than that of the atmosphere, are found primarily within the Columbia River basalts. In general, the unconfined or water-table aquifer consists of the Ringold Formation and glaciofluvial sediments, as well as some more recent alluvial sediments in areas adjacent to the Columbia River (Gephart et al. 1979). This relatively shallow aquifer has been affected more than the uppermost confined aquifer by

waste-water disposal at Hanford. Therefore, the unconfined aquifer is the most thoroughly monitored aquifer beneath the Site.

The unconfined aquifer is bounded below by either the basalt surface or, in places, the relatively impervious clays and silts of the lower unit of the Ringold Formation. Laterally, the unconfined aquifer is bounded by the anticlinal basalt ridges that ring the basin, and by the Columbia River, where it eventually discharges. The saturated portion of the unconfined aquifer reaches a thickness of over 61 m in some areas and pinches out along the flanks of the basalt anticlines. With their low permeability, the basalt ridges above the water table act as a barrier to lateral flow of the ground water (Gephart et al. 1979). On the Hanford Site, the depth from the surface to the water table ranges from less than 0.3 m near the Columbia River to over 106 m in the center of the Site (Figure 3).

Recharge to the unconfined system comes from several sources. Natural recharge from precipitation and runoff occurs principally to the west from the Cold Creek and Dry Creek areas. The Yakima River recharges the unconfined aquifer as it flows along the southwest boundary of the Hanford Site. The Columbia River recharges the unconfined aquifer during its high stages when river water is transferred to bank storage. The unconfined system receives little, if any, recharge from precipitation within the perimeters of the Hanford Site, although present studies, such as those described by Gee and Heller (1985), suggest that precipitation may contribute more recharge to the ground water than was originally thought.

Artificial recharge occurs predominantly from liquid-waste disposal operations in or adjacent to the 200W and 200E Areas. It has been estimated that recharge to the ground water from the Separations Area (which includes B Pond and Gable Mountain Pond, as well as the various cribs and trenches in the 200W and 200E Areas) adds ten times as great an annual volume of water to the unconfined aquifer as is contributed by natural inflow to the area from precipitation and irrigation waters to the west (Graham et al. 1981). The discharge of water has created ground-water mounds near each of the major waste-water disposal facilities in the Separations Area, and the 100 and 300 Areas (Figure

3). These mounds alter the general flow pattern in the aquifer, from the recharge areas in the west to the discharge areas (primarily the Columbia River) in the east. Ground-water levels have changed continuously over the years because of variations in the volume of waste water discharged. Consequently, the movement of the ground water and its associated constituents has also changed with time. Although ground-water mounding occurs in the 100 and 300 Areas, the volume of liquid discharged to the ground is less. The mounding is also affected by the proximity of these areas to the Columbia River, where river stage may play a part. Therefore, ground-water mounding in these areas may not be as significant as in the Separations Area. The effect on the quality of the ground water that enters the Columbia River from the 100 and 300 Areas may be more pronounced because of the short travel times involved, compared to the longer travel times required to move possible contaminants from the 200 Areas.

Liquid Effluent Movement

Liquid effluents discharged to the ground at the Hanford Site waste disposal facilities percolate downward through the soil and may reach the water table. As the wastes move through the soil, adsorption, chemical precipitation, and ion exchange may delay the movement of some radionuclides, such as ^{90}Sr , ^{137}Cs , and $^{239,240}\text{Pu}$. Other materials, including nitrate and such radionuclides as ^3H , ^{129}I , and ^{99}Tc , are not retained by the soil as readily because of their chemical form. These soluble chemicals move through the soil column at varying rates and eventually enter the ground water. Subsequently, they move down-gradient in the same direction as and at a rate nearly or often equal to the flow of ground water. As the waste materials move with the ground water, concentrations are reduced by radioactive decay, dilution, molecular diffusion, and mechanical dispersion.

MAJOR ACTIVITIES

Established in 1943, the Hanford project was originally designed, built, and operated to produce plutonium for nuclear weapons. At one

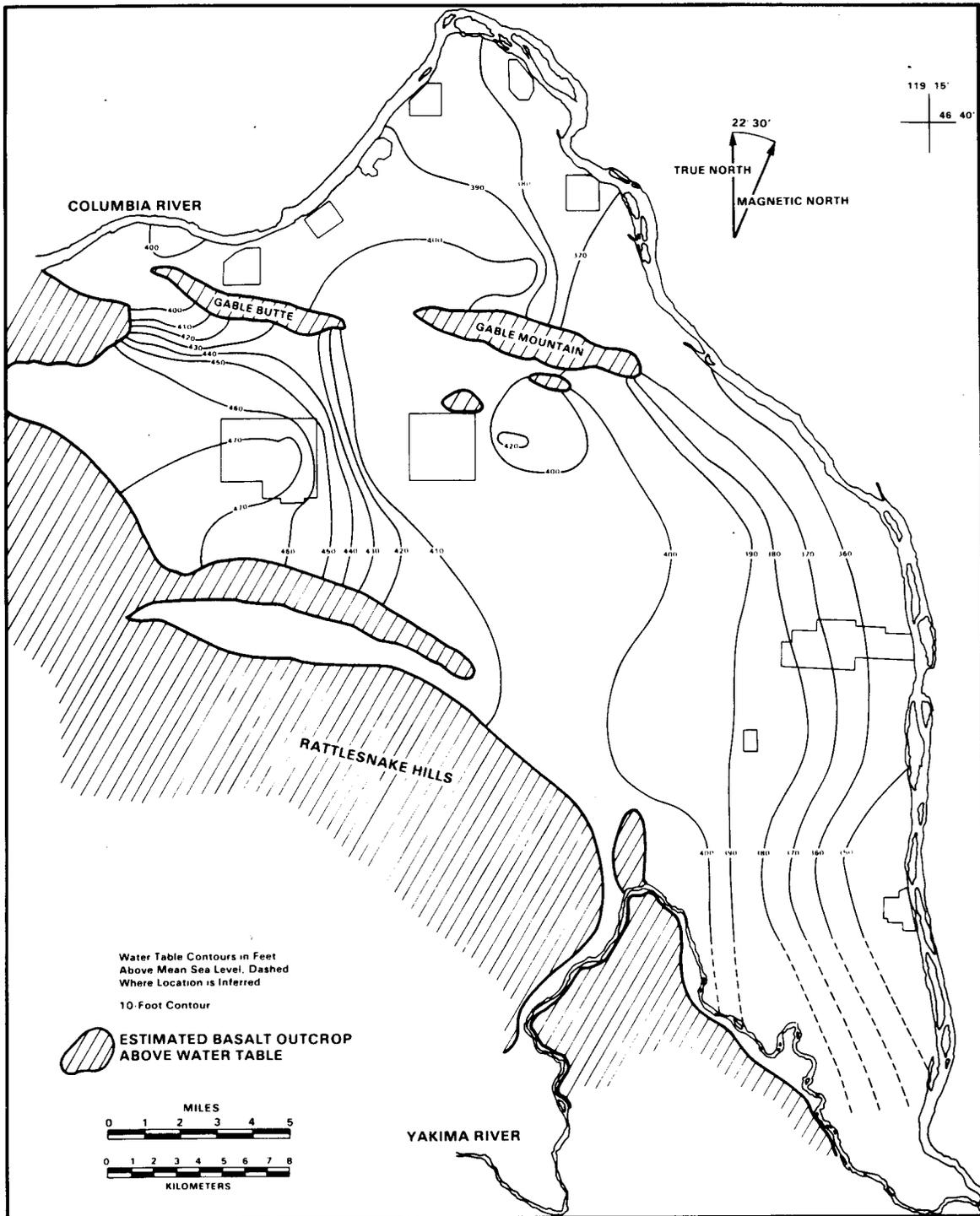


FIGURE 3. Water Table Elevations (December 1985)

time, nine production reactors were in operation, including eight with once-through cooling by treated river water. Between December 1964 and January 1971, all eight reactors with once-through cooling were deactivated. The N Reactor, the production reactor remaining in operation, has a closed primary cooling loop.

Four major DOE operating areas exist at the Hanford Site (see Figure 1). The 100 Areas include facilities for the N Reactor and the eight deactivated production reactors along the Columbia River. The reactor fuel reprocessing plant (PUREX Plant), Plutonium Finishing Plant (Z Plant), and waste-management facilities are on a plateau about 11.3 km from the river, in the 200 Areas. The 300 Area, just north of the city of Richland, contains the reactor fuel manufacturing facilities and research and development laboratories. The Fast Flux Test Facility (FFTF) is located in the 400 Area, approximately 8.8 km northwest of the 300 Area.

Privately owned facilities located within the Hanford Site boundaries include the Washington Public Power Supply System (WPPSS) generating station adjacent to N Reactor, the WPPSS power reactor and office buildings, and a low-level radioactive-waste burial site operated by U.S. Ecology. The Exxon fuel fabrication facility is immediately adjacent to the Hanford Site.

Principal DOE operating contractors at Hanford during 1985 were:

Rockwell Hanford Operations (Rockwell)—responsible for fuel reprocessing, waste management, and site support services such as plant security, fire protection, central stores, and electrical power distribution.

Battelle Memorial Institute—responsible for operating Pacific Northwest Laboratory (PNL) for the Department of Energy (DOE). This includes research and development in the physical, life, and environmental sciences, chemistry, and advanced methods of nuclear-waste management. Environmental monitoring also is a part of PNL activities.

UNC Nuclear Industries (UNC)—responsible for fabricating N Reactor fuel, operating the N Reactor, and decommissioning formerly used DOE facilities, including deactivated production reactors.

Westinghouse Hanford Company (WHC)—responsible for operating the Hanford Engineering Development Laboratory (HEDL), including advanced reactor developments and the FFTF test reactor.

Hanford Environmental Health Foundation (HEHF)—responsible for occupational medicine and environmental health support services.

Operational Highlights

Highlights of operational activities at Hanford during 1985 were:

- The N Reactor operated for 164 days, during which time it supplied steam used by WPPSS to generate 860 megawatts of electrical power. Since its startup, the N Reactor has supplied steam for the production of over 50 billion kilowatt-hours of electric power, which has been supplied to the Bonneville Power Administration grid covering the Pacific Northwest.
- The PUREX Plant fuel reprocessing facility in 200E Area completed a second year of operation since restart of operations in 1983. The uranium processing facility (UO₃ Plant) operated as needed through 1985. The Plutonium Reclamation Facility at Z Plant operated throughout the year as well.
- The FFTF completed two 100-day full-power operating campaigns and achieved a 71% annual capacity factor. An FFTF fuel assembly achieved an exposure of 152,000 megawatt days per metric ton of metal, the highest exposure of an oxide fuel assembly to date.
- Various 100 Area retired facilities underwent initial stages of decommissioning. The 108B Tritium Facility was dismantled and water was removed from the 105B, C, D, and DR fuel storage basins.

Work at Hanford during 1985 also included Hanford National Environmental Research Park studies, Arid Land Ecology studies, and Basalt Waste Isolation Project activities, as well as continued operation of a variety of national research and laboratory facilities.

ENVIRONMENTAL MONITORING

All DOE sites are required to conduct environmental monitoring and to report results on an annual basis according to DOE Order 5480.1A. The policy of the DOE is to ensure that radiation doses to members of the public are maintained as low as reasonably achievable (ALARA) consistent with technology and associated cost and applicable dose standards. A primary purpose of environmental monitoring is to estimate and assess radiation doses to individuals and groups of individuals (a population) that have a potential for being exposed to radioactive materials and radiation in the environment from present and past operations of Hanford facilities. The risk to people is evaluated by comparing calculated potential doses received from Hanford sources to established standards and to doses received from natural background and fallout radiation. Another purpose is to determine concentrations and to assess potential impacts of nonradiological materials in the Hanford environment. A third purpose is to detect and clarify any increasing trends in environmental radiation dose rates and in radioactive and nonradioactive material concentrations found in various kinds of environmental samples that may result from Hanford operations. The final purpose is to inform the public as well as federal, state, and local regulatory agencies of changes in the radiological and nonradiological status of the environment.

SCOPE

The scope of environmental monitoring activities encompasses all potential effluents, with emphasis on radioactive materials. Activities are selected to be responsive to both routine and potential releases of effluents according to the severity of possible impact. Activities also provide a feedback system to evaluate the adequacy and effectiveness of containment and effluent control systems. The appropriate facility manager is notified if off-standard conditions or adverse trends are detected in the environment near operating areas.

OBJECTIVES

The objectives of the program include:

- assessing dose impacts to the offsite public from Hanford Site operations
- verifying in-plant controls for the containment of radioactive and non-radioactive materials within controlled areas (onsite)
- monitoring to determine buildup of long-lived radionuclides in uncontrolled areas (offsite)
- providing reassurance to the public that the program is capable of adequately assessing

impacts and identifying noteworthy changes in the radiological and nonradiological status of the environment.

CRITERIA

The criteria for environmental monitoring derived from requirements set forth in applicable federal, state, and local regulations and recommendations are given in the monitoring guide published for use at DOE sites (Corley et al. 1981). These criteria have been applied through the identification of critical radionuclides, exposure pathways, and exposure rates. Experience gained from environmental monitoring activities conducted at the Hanford Site for over 40 years also has provided significant support for program planning and data evaluation.

The primary pathways available for the movement of significant quantities of radioactive material from Hanford operations to the public are the atmosphere, surface water, and ground water. Figure 4 illustrates these potential routes and the subsequent network of possible exposure pathways to man. The significance of each pathway is determined from data and models estimating the amount of radioactive material potentially available to be transported along the pathway and its resultant radiation dose. To ensure that radiological analyses of samples are

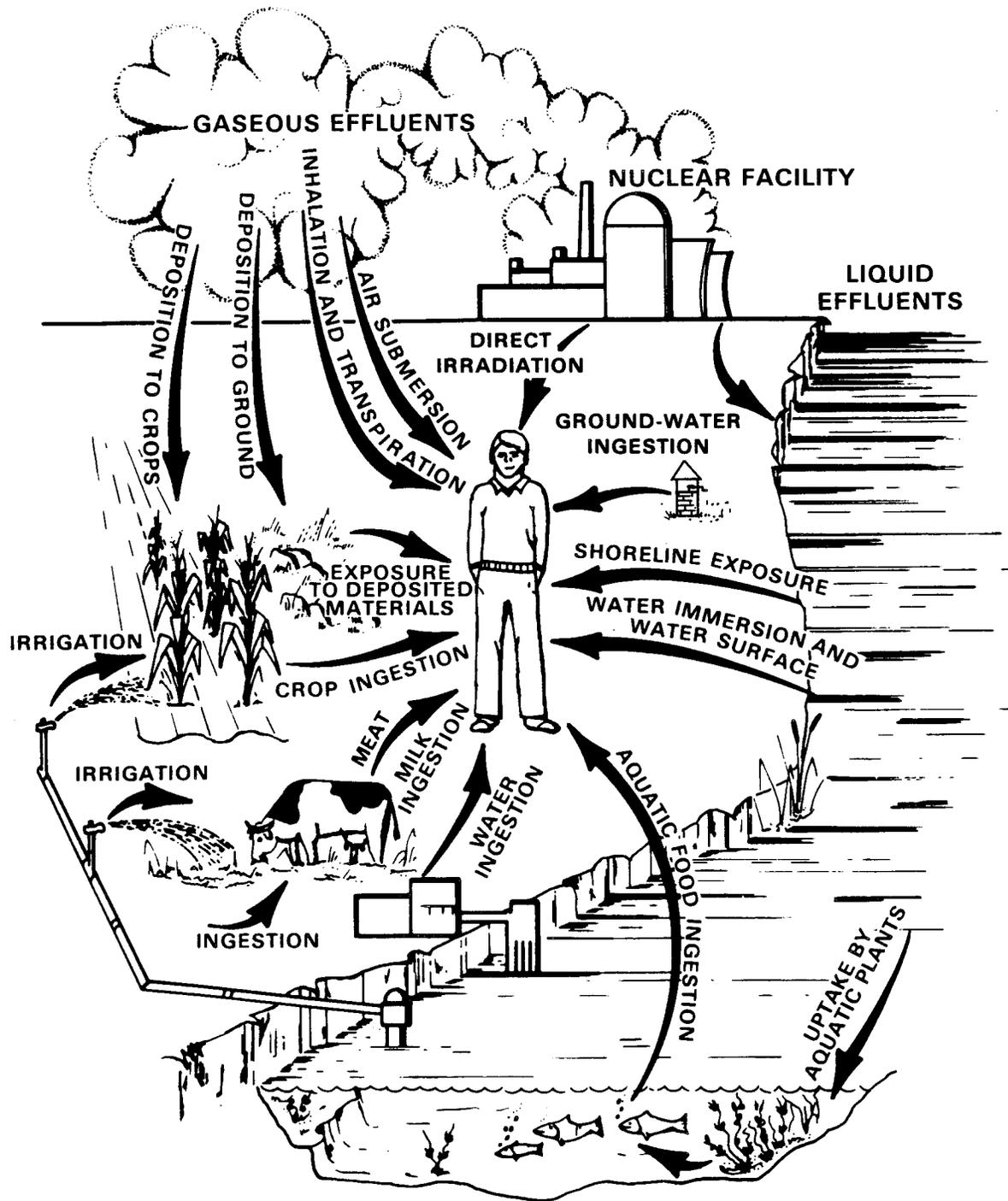


FIGURE 4. Potential Radiological Dose Pathways

sufficiently sensitive, minimum detectable concentrations of critical radionuclides in air, water, and food have been calculated and are given in Table D.1, Appendix D. The minimum detectable concentrations for other types of samples also are listed in the table.

ENVIRONMENTAL PROTECTION STANDARDS AND PERMITS

Operations at the Hanford Site are controlled to conform to a variety of federal and state standards and permits. Radiological releases are regulated by DOE orders pursuant to the Atomic Energy Act and the Clean Air Act. Nonradiological releases at the Site are subject to the same state and federal laws and regulations as at any civilian facility.

Environmental radiation protection standards are published in DOE ORDER 5480.1A "*Environmental Protection, Safety, and Health Protection Program of DOE Operations*" (USDOE 1981a). In 1985 DOE issued a revision to this order that incorporates a system for evaluating and controlling radiation exposures to members of the public in uncontrolled areas. The revision is based on recommendations of the International Commission on Radiation Protection (ICRP 1977, 1979-1982). These revisions are contained in a DOE directive, "Radiation Standards for Protection of the Public in the Vicinity of DOE Facilities," Revision 1, September 3, 1985. (See Table C.4, Appendix C.) The standards limit exposure to members of the public to 100 mrem per year for prolonged periods of exposure, and to 500 mrem per year for maximum occasional exposure. They also limit whole-body dose to 25 mrem per year for air pathways, in compliance with 40 CFR 61, Subpart H. Dose calculations reflecting the revised standards are now to be performed with a table of 50-year Committed Dose Equivalent Factors. The radionuclide concentration guides for air and water in DOE ORDER 5480.1A are no longer current. Instead, DOE has prepared draft tables of Derived Concentration Guides (DCG) that are similar in form to the tables in DOE ORDER 5480.1A but reflect the new standard.

Water quality standards for the Columbia River are implemented by the State of Washington

(WDOE 1982). Of importance to Hanford operations is the designation of the Hanford reach of the Columbia River as Class A Excellent. This designation requires that the water be usable for substantially all needs, including raw drinking water, recreation, and wildlife. Class A water standards are summarized in Appendix C. The Clean Water Act requires the issuance of permits for liquid discharges to the Columbia River under the National Pollutant Discharge Elimination System (NPDES). Eight Hanford discharge points were covered under an NPDES permit issued to DOE by EPA. This permit controls the release of nonradiological liquid discharges to the river and requires sampling, monitoring, and reporting each discharge.

Applicable ambient air quality standards are enforced by the Benton-Franklin-Walla Walla Counties Air Pollution Control Authority. The Clean Air Act of 1977 requires facilities emitting pollutants that may affect air quality to have Prevention of Significant Deterioration (PSD) permits. A PSD permit was issued to Rockwell by EPA in 1980 and legally limits the amount of NO_x released annually from the PUREX Plant and the UO₃ Plant.

PROGRAM DESCRIPTION

Environmental monitoring provides for the measurement and interpretation of the impact of Hanford operations on the public and on both the onsite and the offsite environment. The concentrations of measured radioactive materials are compared to applicable standards, concentration guides, and natural levels of radiation and radioactive materials (including worldwide fallout). The program is designed to examine all significant exposure pathways including direct radiation exposure from operating facilities. Radiological impacts are expressed in terms of radiation exposures. Numerous samples were collected and analyzed according to a published schedule (Blumer et al. 1984).

In response to increasing DOE and public interest in hazardous materials, a new project was initiated in 1985 to assess the potential environmental impacts from the release of hazardous materials from operations at the Hanford Site. Monitoring of some materials has been

conducted since 1983 in conjunction with ground-water monitoring. Ground-water sampling for hazardous materials was expanded in 1985 to identify locations onsite that needed further study.

Table 2 summarizes the geographic distribution of environmental sampling and measurement locations. Schedules, records, and data were maintained in a computer system. Unscheduled work also was conducted in response to specific needs (see "Public Information Activities.")

Analyses for radioactivity and hazardous materials were conducted by U.S. Testing Company, Inc. (UST), Richland, Washington. Analyses of environmental dosimeters for penetrating radiation were performed by PNL. Ground-water analyses were performed by PNL's analytical laboratories and the Hanford Environmental Health Foundation (HEHF). Water quality measurements, temperature, and flow rates for the Columbia River were taken by the U.S. Geological Survey (USGS). Quality assurance (QA) was an integral part of the program. Details

on sampling, analysis, measurement, dose assessments, and QA are discussed in the sections that follow.

RELATED PROGRAMS AND SPECIAL STUDIES

There are a number of other programs and special studies related to sitewide environmental monitoring.

Operating Areas Monitoring

Each of the major contractors (i.e., UNC, Rockwell, WHC, and PNL) measure and record the amounts of liquids, gases, and solids released to the environment. Effluent releases reported by the operating contractors are summarized in Appendix F. Operating contractors take environmental measurements near their facilities to audit the control of environmental releases and the general conditions of the local environment around their operations. These measurements supplement the extensive onsite and offsite monitoring done by PNL for DOE. Annual environmental reports are published by UNC and Rockwell.

TABLE 2. Geographical Distribution of Environmental Sample and Measurement Locations

Sample Types	Sample Locations				
	Total Number	Onsite	Perimeter	Communities	Distant
Air	48	23	15	5	5
Ground Water	339	339	-	-	-
Columbia River	3	-	2	1	-
Ponds	4	4	-	-	-
Foodstuffs	7	-	4	1	2
Wildlife	11	11	-	-	-
Soil & Vegetation	33	16	13	1	3
Dose Rate	79	26	43	5	5
Waste Site Surveys	72	72	-	-	-
Roadway Surveys	16	16	-	-	-
Shoreline Survey	11	-	11	-	-
Hazardous Materials	75	75	-	-	-

Drinking-Water Monitoring

Drinking water was supplied to DOE-operated facilities on the Hanford Site during 1985 by seventeen separate systems. Twelve of the systems used Columbia River water as a raw water source, four systems used ground water, and one system (Richland municipal) used a combination of the two. Monitoring of the drinking water on the Hanford Site was a joint effort between HEHF and PNL, with HEHF specializing in the areas of chemical and microbiological quality and PNL focusing on radiological quality. The primary purpose for the surveillance of Hanford Site drinking water was to ensure that the quality of the water complied with federal and state drinking-water standards. The 400 Area (FFTF) drinking-water supply is discussed briefly in this report in the "Radiological Impact from Hanford Operations" section. The results of the drinking-water surveillance program are reported annually by HEHF with contributions from PNL (Maas 1986).

Resource Conservation and Recovery Act (RCRA) Monitoring

Established by the U.S. Congress in 1976, RCRA is a comprehensive program to regulate and monitor the movement of hazardous wastes from generation to final disposal. One aspect of RCRA involves ground-water monitoring at hazardous-waste facilities. During 1985, ground-water monitoring efforts were initiated at the 183H solar evaporation basins and the 300-Area process trenches, to address RCRA concerns.

Nonradiological Air Monitoring

Nonradiological pollutants in atmospheric releases from chemical-processing plants and fossil-fueled steam plants at Hanford consisted primarily of the oxides of nitrogen (NO_x). The Hanford Environmental Health Foundation operated a seven-station network to sample ambient air nitrogen dioxide (NO_2) in 1985. Those results are summarized in the "Air Quality Monitoring" section.

Wildlife Census

The purpose of the wildlife census was to determine the population status of a few key wildlife and fish species that inhabit the Hanford Site. Information on changing populations of spawning chinook salmon and nesting Canada geese has been obtained for thirty consecutive years. The American bald eagle is a "threatened" species in the State of Washington (Fish and Wildlife Service 1986). Aerial censuses of bald eagles have been obtained since the 1960s. In recent years, the status of nesting hawks, long-billed curlews, and great blue herons has been added to the wildlife census. In general, the conservative use of the land and water resources of the Hanford Site has benefited indigenous wildlife species. Results of the wildlife census were reported in a scientific journal (Rickard and Watson 1985).

Public Information Activities

Environmental monitoring personnel participated in several public meetings throughout Washington and Oregon in 1985 to provide an overview of the program and to discuss results from the previous year's environmental monitoring effort. Meetings were held with a variety of public interest groups. Special concerns of the public were identified and plans for nonroutine sampling were established.

A cooperative effort among the DOE, the states of Washington and Oregon, and Greenpeace Northwest was established to collect and analyze water samples from the Columbia River and riverbank springs. A sufficient quantity of water was collected from each location to provide an aliquot each to Greenpeace, PNL (for the DOE), the Washington Department of Social and Health Services, and the Oregon Department of Human Resources. Results from this special sampling effort are discussed in the "Quality Assurance" section.

A public meeting in the fall of 1985 for people living downwind of the Hanford Site resulted in local residents being given the opportunity to have the current levels of radionuclides in their bodies evaluated by the use of bioassay techniques. A total of 89 persons were provided whole-body counts, and 32 individuals submitted samples for urine analyses. The bioassay measurements gave no evidence of the presence of radioactivity of potential Hanford origin in any individual (Sula and Bihl 1986).

A request was received from the White Bluffs Water Association in Franklin County to sample wells that supplied drinking water and to analyze the water for the presence of radionuclides. The results showed that no Hanford-derived radioactive materials were present, and the wells met all applicable State of Washington drinking-water standards.

II. RADIOLOGICAL IMPACTS AND DOSE CALCULATIONS

EFFLUENTS, WASTE DISPOSAL, AND UNUSUAL OCCURRENCES

The operating contractors at Hanford have the responsibility to control, monitor, sample, and report effluents released into the environment from their facilities. This section briefly summarizes the planned and unplanned releases of effluents that occurred at Hanford during 1985 as reported by the contractors.

EFFLUENTS AND WASTE DISPOSAL

Radioactive and nonradioactive materials were released to the environment during operations at Hanford. These releases consisted of airborne effluents (gases or particles), liquid effluents, and solid wastes. Both anticipated and unanticipated releases occurred. The formal reporting of effluent release data was the responsibility of the operating contractors. Radioactive discharges to the environment were reported to the DOE. Nonradioactive discharges to the Columbia River were reported to EPA through the National Pollutant Discharge Elimination System (NPDES).

Airborne Releases

Radioactive and nonradioactive effluents discharged to the atmosphere during 1985 are summarized in Tables F.18 and F.19, Appendix F. These tables are subdivided according to the major operating areas and include all releases reported by the contractors. Radioactive materials discharged to the atmosphere consisted mainly of fission and activation products, uranium, and some transuranics normally associated with Hanford operations. Nonradioactive airborne releases consisted primarily of emissions from fossil-fueled steam plants, organic liquids evaporated from scientific laboratories, and nitrogen oxides released from the fuel-fabrication plant, the UO₃ Plant, and the PUREX Plant.

Liquid Releases

Liquid wastes generated at Hanford were handled in several ways. They were stored, converted to solids, discharged to the ground

through cribs, ditches, ponds, or septic systems, or discharged directly into the Columbia River. Radioactive and nonradioactive effluents (except sanitary wastes) discharged to ground disposal facilities during 1985 are summarized in Tables F.20 and F.21, Appendix F.

Radioactive liquids discharged into the Columbia River from operating facilities during 1985 are listed in Table F.22, Appendix F. The reported discharges are from liquid effluent systems in the 100 Area and include seepage into the river from the 1301N/1325N Liquid Waste Disposal Facilities. The ³H and ¹²⁹I that may have entered the Columbia River through springs from the unconfined aquifer are not included in the releases listed in Table F.22. Nonradioactive liquids released to the Columbia River were monitored according to the individual requirements of each NPDES-permitted discharge point.

Solid-Waste Burial

Solid radioactive wastes were buried in trenches or special retrievable storage facilities within the 200 Area. Radioactive materials in solid wastes included fission and activation products, uranium, and transuranics. Solid wastes containing ²³³U or transuranic radionuclides were packaged and buried separately from other wastes for planned retrieval at a future date. Table F.23, Appendix F, lists the quantities of radionuclides buried during 1985.

Nonradioactive solid wastes were buried in a sanitary landfill, and chemicals were buried in a separate nonradioactive dangerous waste landfill. The buried waste included general refuse,

asbestos, and waste chemicals. These burial sites were located near the 200 Area. The quantities of nonradioactive solid wastes buried during 1985 are also included in Table F.23, Appendix F.

ENVIRONMENTALLY RELATED UNUSUAL OCCURRENCES

Unusual occurrences were reported to DOE during 1985 by onsite contractors. Several of these occurrences involved the inadvertent release of radioactive or nonradioactive pollutants to the environment. Generally, the pollutants were dispersed naturally, stabilized in existing waste disposal sites, or controlled and cleaned up with no permanent environmental impact noted. In some cases, particularly where the contaminants may have reached the ground water, the environmental impact is under continuing observation and evaluation. Complete summaries, including event descriptions and corrective actions, are available for review in the Public Reading Room at the Hanford Science Center, Richland, Washington. The occurrences with the most significant environmental impacts are summarized below.

Release from Diversion Box in 200E-Area C Tank Farm (UOR No. RHO-85-02)^(a)

An atmospheric release was detected on January 11, 1985, from a diversion box (liquid transfer system) in the 200E-Area C Tank Farm. Air sampling and ground-contamination surveys were performed by PNL and Rockwell during and after the time that efforts were made to control and contain the release.

The PNL response included field surveys of air filters and ground contamination in the immediate area outside of the 200E-Area fence and rapid analyses of filter and snow samples. Air filters and snow samples were provided to the Washington State Environmental Radiation and Emergency Response Unit of the Department of Social and Health Services for their independent analysis.

PNL's air sampling results showed elevated levels of ⁹⁰Sr, relative to typical environmental levels, and barely detectable levels of ¹³⁷Cs. For the filters collected and analyzed during the release period from locations immediately surrounding the 200E Area, ⁹⁰Sr concentrations ranged from 0.015 pCi/m³ to 0.287 pCi/m³. The wind shifted and carried the release in two predominant directions: southeast and northwest. This effect was seen in the ⁹⁰Sr data for the first calendar quarter, which showed ⁹⁰Sr levels above the typical range of environmental concentrations for the areas southeast and northwest of the 200E Area.

Consistent with this pattern, the highest annual average ⁹⁰Sr concentration (0.00079 pCi/m³) along the Site perimeter was measured in the northwest composite sample. This annual average value is the appropriate quantity to compare to the applicable DOE Derived Concentration Guide, and it represents only 0.01% of the guide value.

Uranium Contamination of Ground Water (UOR No. RHO-85-17)

A ground-water sample taken on January 23, 1985, from a well near the inactive 216-U-1 and U-2 cribs in the 200W Area showed an abrupt increase in uranium concentration. Water flow to the nearby 216-U-16 crib was stopped, and existing wells near the U-1 and U-2 cribs were grouted to preclude direct pathways between the contaminated sediments and the ground water. It was determined that a virtually impervious, thin sediment layer located above the water table in the vicinity of the cribs had caused a zone of perched water to build up beneath the U-16 crib, resulting in the horizontal movement of the perched water toward the U-1 and U-2 cribs. Exploratory drilling confirmed that the perched water beneath the U-1 and U-2 cribs was contaminated with uranium. Efforts to remove the uranium by pumping the contaminated ground water through an ion exchange system were initiated. Pumping began in June

(a) Unusual Occurrence Report Number.

1985 and continued until November 1985. Eight million gallons of ground water were pumped and treated in the ion exchange system. Uranium concentrations in the samples taken during the pumping operations decreased from $0.085 \mu\text{Ci}/\ell$ to less than $0.020 \mu\text{Ci}/\ell$. Isotopic analysis showed the contamination to consist of depleted uranium. Follow-up sampling is continuing, and further remedial action will be determined by the findings of detailed evaluations of hydrogeological data.

Leak from Underground Radioactive Drain Line (UOR No. UNC-85-11)

Data from routine well samples collected by UNC personnel on April 29, 1985, indicated that on or shortly before that date, primary coolant water from the N Reactor had leaked to the ground between the reactor building and the Columbia River shoreline. An investigation discovered the source of the leak to be a 25-cm drain line carrying radioactive liquid. A small hole had developed in the line from external corrosion caused by a leaking raw water line located above the drain line. The lines were repaired. No detectable radioactivity was measured in Columbia River water samples taken near the shoreline in the vicinity of the leak. Analysis of river samples routinely collected downstream of the Site for environmental monitoring also showed no increased concentrations of radioactivity.

Release of ^{106}Ru in Flakes from the PUREX Plant (UOR No. RHO-85-11 and RHO-85-36)

On four occasions during 1985, small amounts of ammonium nitrate particles contaminated with ^{106}Ru were released from the PUREX facility's main stack. The first release occurred on February 17, 1985, followed by similar discharges on April 16, April 25, and May 30, 1985. In all cases, ground contamination was limited to an area within the PUREX facility boundary. Following each release, the PUREX stack was flushed with water to remove the buildup of water-soluble ammonium nitrate- ^{106}Ru . Environmental monitoring conducted downwind of the PUREX Plant indicated that no measurable radioactivity was released to the environment as a result of the stack flush. Monitoring teams from PNL performed radioactive particle surveys around the 200 Area. No ^{106}Ru -contaminated particles were found outside of the operating area. All routine air monitoring results were checked to determine if low-levels of ^{106}Ru were present; none were observed.

RADIOLOGICAL IMPACT FROM 1985 HANFORD OPERATIONS

An assessment of potential radiological impact from Hanford operations during 1985 indicated that radiation doses to the public were well below all applicable regulatory limits and were substantially less than doses normally received from common sources of background radiation. The calculated 50-year whole-body cumulative dose received by a hypothetical maximally exposed individual was about 3 mrem. This was an increase of 1 mrem over the potential whole-body dose reported in 1984 and was attributed primarily to increased releases of ^{90}Sr to the Columbia River. The calculated 50-year whole-body cumulative dose to the surrounding population was about 7 man-rem, compared with 5 man-rem in 1984. This was attributed to increased releases of several radionuclides in both air and water effluents. The average per capita whole-body dose was estimated to be 0.02 mrem. For comparison, the average resident of the Tri-Cities received about 100 mrem of radiation exposure during 1985 from natural background and worldwide fallout sources. For the population within 80 km of the Hanford Site, total exposure to natural background and fallout radiation was about 34,000 man-rem. Thus, the Hanford operations contributed only a small fraction of the total radiation dose to the surrounding population. Assessments of potential radiation doses from radionuclides present in the Columbia River as a result of past Hanford operations and potential doses from 1985 operations at the PUREX plant also showed no significant impacts on the public. The calculated effective dose equivalent using the new DOE Radiation Standards for Protection of the Public was 0.1 mrem, compared to the new limits of 100 mrem/yr for prolonged exposure and 500 mrem/yr for occasional annual exposures to a maximally exposed individual. All measured and calculated radiation doses were well below the applicable standards for radiation protection.

Radioactive materials were released into the environment as air and water effluents from Hanford operations during 1985. The radiological impacts of these releases were evaluated in detail, as required by *DOE Order 5484.1* (USDOE 1981b), to determine compliance with pertinent regulations and standards.

The potential radiological impacts of 1985 Hanford operations were assessed in terms of the following:

- the maximum dose rate at a publicly accessible location on or within the Site boundary (this quantity is also termed the "fence-post" dose rate)
- the dose to a hypothetical, maximally exposed individual at an offsite location, expressed as the cumulative 50-year dose equivalent^(a) and, beginning in 1985, the 50-year "effective dose equivalent"

- the 50-year cumulative dose equivalent and, beginning this year, the 50-year "effective dose equivalent" to the population residing within an 80-km radius of one or more of the onsite operating areas.

To the extent possible, these radiological impact assessments were based on direct measurements of dose rates or radionuclide concentrations in the surrounding environment. However, the amounts of radioactive materials released during 1985 operations were usually too small to be measured directly once they were dispersed in the offsite environment. For most radionuclides in environmental media, it was not possible to distinguish between concentrations contributed by either worldwide fallout or effluent releases during 1985 Hanford operations. Some radionuclides could be detected in the Columbia River and in the air at sampling locations on the Site perimeter. In

(a) In accordance with common practice, the term "dose," when applied to individuals and populations, is used in this report instead of the more precise term "dose equivalent" as defined by the International Commission on Radiation Units and Measurements (ICRU).

most cases, the potential offsite radiation doses were estimated using computer models that predicted concentrations of radioactive materials in the environment from effluent releases. These models are described in Appendix F, and the reported Hanford effluents for 1985 are shown in Tables F.18 through F.23. The measured and estimated concentrations of selected radionuclides are compared in the "Comparison of Measured and Calculated Results" section.

The estimated potential offsite radiation doses to the public were very small and well below the sensitivity of direct measurement using modern measurement techniques. Although the uncertainty associated with the computer calculations is not specified, it could be relatively large because maximum values for uptake and consumption factors were selected for use in the models. Thus, the doses calculated using these models should be viewed as overestimates of the potential doses resulting from 1985 Hanford operations.

MAXIMUM "FENCE-POST" DOSE RATE

The "fence-post" dose rate is a measure of the maximum potential external radiation dose rate to publicly accessible locations on or near the Site during 1985. The "fence-post" dose rate was determined from radiation measurements using fixed environmental dosimeters placed at locations of expected maximum dose rates. It does not represent the dose actually received by any member of the public. The reporting of maximum "fence-post" dose rates is required by *DOE Order 5484.1*.

"Fence-post" dose rates were measured in the vicinity of the 100N, 300, and 400 (FFTF) operating areas, as described in the "Penetrating Radiation Monitoring" section of this report. The 200 Area was not included because it was not accessible to the general public.

The Columbia River provides public access to an area within a few hundred meters of the 100-Area N Reactor and supporting facilities. Measurements made at the 100N Area shoreline (Table A.38, Appendix A) were consistently above background. The highest average dose

rate observed along the shoreline during 1985 was 0.025 mrem/h, or about four times the dose rate normally observed at offsite locations (0.007 mrem/h).

The FFTF Reactor Visitors Information Center, located southeast of the FFTF Reactor building, provides public access to the 400 Area. Dose rate measurements during 1985 at this location (Table A.38, Appendix A) showed only normal background radiation levels (0.007 mrem/hr).

Dose rates along the perimeter of the 300 Area were above background at some locations accessible to the general public. The highest average dose rate measured was 0.017 mrem/h. The average dose rate for all other 300 Area perimeter locations accessible to the public was 0.012 mrem/h.

The environmental impact of reported "fence-post" dose rates was negligible. Measured dose rates should not be interpreted as actual exposure rates to any member of the general public because there is no basis for assuming that any member of the public frequented these "fence-post" locations for sufficient periods of time to have received anything but negligible doses.

MAXIMALLY EXPOSED INDIVIDUAL DOSE

The maximally exposed individual is a hypothetical person who receives the maximum calculated radiation exposure using the most conservative (i.e., worst-case) assumptions with regard to location, inhalation of radioactive effluents, consumption of contaminated foods and water, and direct exposure to contaminants. This individual's characteristics were chosen to maximize the potential combined doses from all realistic, available exposure pathways from environmental releases at Hanford. The particular characteristics of the maximally exposed individual were based on factors such as the total amount and composition of effluents and the dispersion of effluents released to the air or the Columbia River.

Based on 1985 environmental data, the following exposure pathways were included in the calculation of the hypothetical maximally exposed individual: inhalation and submersion in airborne

effluents, consumption of foods contaminated by effluents deposited on the ground from airborne materials and by irrigation with Columbia River water, direct exposure to radionuclides deposited on the ground, use of drinking water obtained from the Columbia River, consumption of fish taken from the Columbia River, and direct exposure to radionuclides while using the Columbia River for recreation. The hypothetical maximally exposed individual for 1985 was postulated to be an individual who

- was a long-term resident in an area approximately 13 km south-southeast of the 300 Area
- consumed foodstuffs grown in the northwestern part of the Riverview district using Columbia River water for irrigation
- ingested drinking water obtained from the Columbia River
- used the Columbia River extensively for boating, swimming, and fishing, and consumed the fish that were caught.

The doses to the hypothetical maximally exposed individual were calculated using the effluents shown in Tables F.18 and F.22, Appendix F.

The maximally exposed individual was assumed to be a long-term resident because a small quantity of long-lived radionuclide effluents persists in the environment for many years. However, thyroid doses were calculated for a one-year-old infant as well as for an adult because the potential thyroid dose to an infant is known to be slightly higher than to an adult. Other organ doses were calculated only for an adult maximally exposed individual.

Calculated 50-year cumulative doses for the maximally exposed individual are summarized in Table 3. These values include the doses received from exposure to liquid and airborne effluents during 1985 as well as potential exposure beyond 1985 to that fraction of the 1985 effluents estimated to be deposited on the ground from airborne deposition and irrigation with Columbia River water. For parent/daughter radionuclide combinations, it was assumed that the activity stated was for the parent, and that the radioactive daughter grew into radioactive equilibrium with time. Appendix F provides detailed information about the computer models and parameters used to calculate the doses given in Table 3.

TABLE 3. Calculated Doses to the Hypothetical Maximally Exposed Individual from 1985 Hanford Operations

Pathway	50-Year Cumulative Doses (mrem)					
	Whole Body	GI ^(a)	Bone	Lung	Thyroid	
					Adult	Infant
Direct Airborne ^(b)	< 0.01	< 0.01	0.03	0.03	0.01	0.01
Foodstuffs ^(c)	3	0.2	9	< 0.01	2	3
Drinking Water	0.01	< 0.01	0.05	< 0.01	0.06	0.2
River Recreation ^(d)	0.1	0.1	0.5	0.01	0.06	—
Total	3	0.3	10	0.04	2	3

(a) Gastrointestinal tract (lower large intestine)

(b) Includes inhalation, submersion, and direct exposure to ground deposition.

(c) Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition.

(d) Includes consumption of fish taken from the Columbia River. See Appendix F for additional description of exposure pathways.

All potential maximally exposed individual cumulative doses that were calculated for 1985 were well below the applicable Radiation Protection Standards in *DOE Order 5480.1A*. The organ receiving the largest fraction of the annual dose standard was the bone (10 mrem). The applicable radiation protection standard for bone was 1500 mrem. The calculated whole-body dose in 1985 was 3 mrem, as compared to 2 mrem in 1984 and 1 mrem in 1983. These levels are well below the DOE Radiation Protection Standard of 500 mrem per year. The whole-body and bone doses in 1985 were due almost entirely to the ^{90}Sr effluent released to the Columbia River at the 100N Area. The increase in the thyroid dose resulted from an increase in the gaseous emission of ^{129}I from the 200 Area.

A comparison of the cumulative whole-body dose for the maximally exposed individual from 1985 Hanford operations and estimates for the previous 5 years are shown in Figure 5. The calculated 50-year cumulative doses for whole body, gastrointestinal tract, bone, lung, and thyroid for 1985 and the previous 5 years are shown in Table 4.

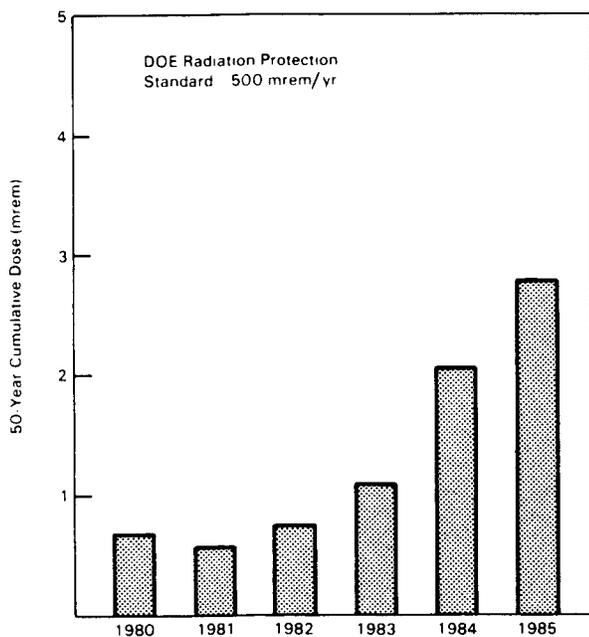


FIGURE 5. Calculated Whole-Body Doses to the Maximally Exposed Individual, 1980 to 1985

POPULATION DOSE

The regional dose impact from 1985 Hanford operations was estimated by calculating the collective radiation dose to the population residing within an 80-km radius of any of the onsite operating areas. Collective population doses are expressed in units of man-rem. Average individual doses for all radionuclide pathways to man were added together and multiplied by the number of people living in the area. The results are shown in Table 5. Site-specific population distribution characteristics, food pathway and dietary parameters, residency parameters, and recreational activity parameters assumed for these calculations are given in Appendix F, Tables F.1 to F.4 and F.9 to F.12.

A comparison of the 80-km population doses attributed to 1985 Hanford operations and estimated population doses for the five previous years are given in Table 6 and Figure 6.

The primary pathways contributing to the 1985 whole-body population dose were

- air immersion in the short-lived noble gases from the N Reactor
- consumption of foodstuffs irrigated with water obtained from the Columbia River.

The irrigation pathway for ^{90}Sr was the primary source of radiation dose to the bone. The population dose to the thyroid resulted primarily from the consumption of foods containing the long-lived radionuclide ^{129}I .

The average per capita whole-body cumulative dose from 1985 Hanford operations, based on the population of 340,000 within 80 km, was 0.02 mrem. This dose estimate may be compared with doses from other routinely encountered sources of radiation, such as natural terrestrial and cosmic background radiation, medical treatment and x-rays, natural internal body radioactivity, worldwide fallout, and a round-trip coast-to-coast airline trip.

The average radiation doses from these sources and the dose equivalent to the average and hypothetical maximally exposed individuals from Hanford emissions are compared in Figure 7. The potential radiation dose estimated for the maximally exposed individual is about 300 times greater than the estimated average per capita dose for individual members of the public

TABLE 4. Calculated Doses to the Hypothetical Maximally Exposed Individual from Hanford Operations, 1980 to 1985

Organ	50-Year Cumulative Doses (mrem) ^(a)					
	1980	1981	1982	1983	1984	1985
Whole Body	0.6	0.5	0.7	1	2	3
GI ^(b)	0.1	0.06	0.07	0.2	0.3	0.3
Bone	2	2	2	4	8	10
Lung	< 0.01	0.01	0.02	0.01	0.02	0.04
Thyroid	0.2	0.2	0.2	0.2 ^(c)	0.8	2

(a) Total dose to each organ from exposure to all available pathways.

(b) Gastrointestinal tract (lower large intestine).

(c) Reported as 0.09 mrem in Price et al. 1984a, corrected to 0.2 mrem in Price et al. 1984b.

TABLE 5. Calculated Doses to the 80-km Population from 1985 Hanford Operations

Pathway	50-Year Cumulative Doses (man-rem)				
	Whole Body	GI ^(a)	Bone	Lung	Thyroid
Direct Airborne ^(b)	4	3.5	8	8	5
Foodstuffs ^(c)	3	0.4	9	0.1	190
Drinking Water	0.6	0.1	2	< 0.01	3
River Recreation ^(d)	0.08	0.07	0.2	0.04	0.06
Total	7 ^(e)	4	19	8	200

(a) Gastrointestinal tract (lower large intestine).

(b) Includes inhalation, submersion, and direct exposure to ground deposition.

(c) Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition.

(d) Includes consumption of fish taken from the Columbia River.

(e) Total does not add correctly due to rounding error.

TABLE 6. Calculated Doses to the 80-km Population from Hanford Operations, 1980 to 1985

Organ	50-Year Cumulative Doses (man-rem) ^(a)					
	1980	1981	1982	1983	1984	1985
Whole Body	2	3	4	4	5	7
GI ^(b)	1	3	3	3	3	4
Bone	5	5	7	7	13	19
Lung	1	3	4	3	4	8
Thyroid	4	5	7	17 ^(c)	43	200

(a) Total dose to each organ from exposure to all available pathways.

(b) Gastrointestinal tract (lower large intestine).

(c) Reported as 7 man-rem in Price et al. 1984a; corrected to 17 man-rem in Price et al. 1984b.

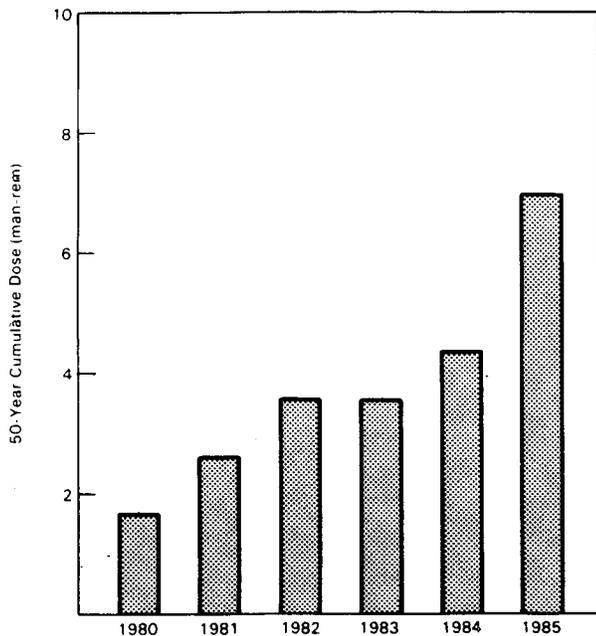


FIGURE 6. Calculated 80-km Whole-Body Population Dose

within an 80-km radius of the major operating areas (100N, 200, and 300 Areas). This potential "additional" radiation exposure is only a small fraction of the average per capita whole-body dose from natural background and medical sources of radiation (about 100 mrem/yr in the Tri-Cities area of Washington State).

RADIOLOGICAL IMPACT FROM PAST OPERATIONS

Columbia River

Measured levels of certain radionuclides in the Columbia River have been attributed to past operations at Hanford (see the "Surface Water Monitoring" section). The primary environmental impacts resulting from past operations were residual radionuclides deposited along the Columbia River shoreline in river sediments and the seepage of ground water into the river from the unconfined aquifer.

Environmental radiation dose rates resulting from residual radionuclides deposited along the Columbia River shoreline and islands were studied by Sula (1980). Dose rates along the river were found to be slightly above normal background levels except at a few locations where

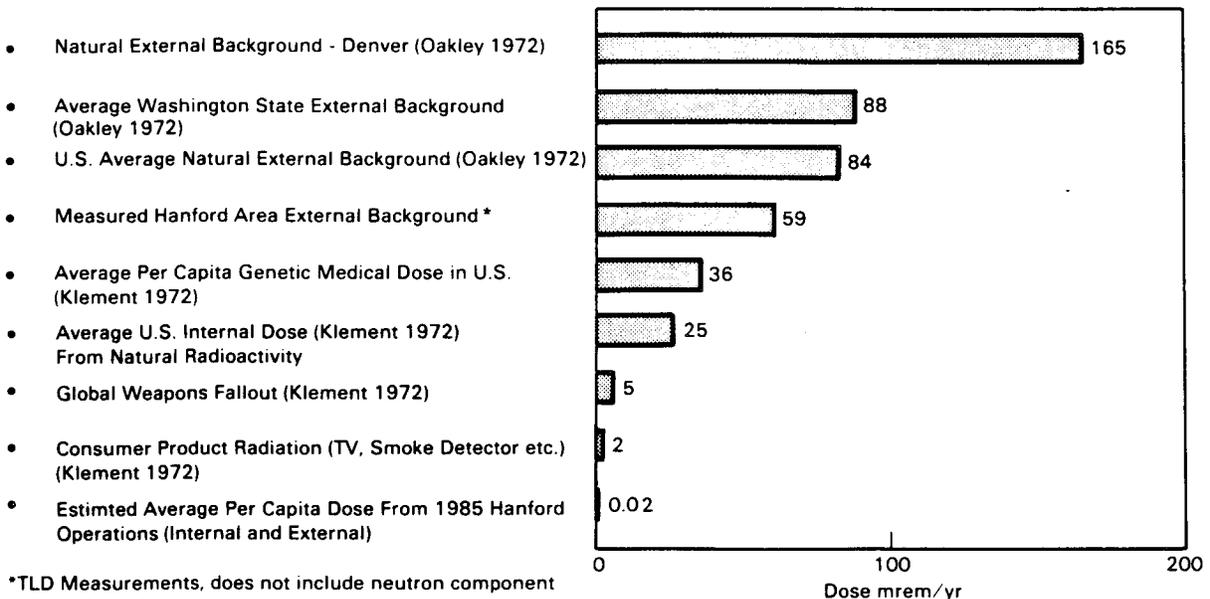


FIGURE 7. Annual Radiation Doses from Various Sources

dose rates were observed to be several times background levels (see the "Penetrating Radiation Monitoring" section).

For the purpose of evaluating the potential impact of these elevated dose rates on the regional population, a survey of Columbia River recreation was conducted during 1980. The survey area extended from the Vernita Bridge to Columbia Point at the confluence of the Yakima River. Through aerial and ground observations, the survey estimated annual man-hours spent in recreational activities along the Columbia River. By multiplying the shoreline man-hours per year by the measured net dose rates (in excess of background), an estimate of collective population whole-body annual dose was obtained. The potential population dose from exposure to residual radionuclides, derived by this method, was estimated to be approximately 1 man-rem/yr.

Concentrations of ^3H detected in the river in 1985 compared to 1984 were essentially unchanged. Iodine-129 was detected by using extremely sensitive sampling and analytical techniques, and concentrations were essentially unchanged from 1984. The dose impact from these nuclides entering the river, based on measured differences in river concentrations upstream and downstream of the Site for 1985 (see the "Surface Water Monitoring" section), was calculated to be only 0.014 mrem whole-body dose to a maximally exposed individual and 2.2 man-rem of bone dose to the population of 340,000 people within 80 km. The per capita bone dose was calculated to be 0.006 mrem.

Local Residents

A public meeting in the fall of 1985 for people living downwind of the Hanford Site resulted in local residents being given the opportunity to have the current levels of radionuclides in their bodies evaluated by the use of bioassay techniques. A total of 89 persons were provided whole-body counts, and 32 individuals submitted samples for urine analyses. The radioactive materials tested for included ^3H , ^{54}Mn , ^{60}Co , ^{65}Zn , ^{90}Sr , ^{106}Ru , ^{131}I , ^{137}Cs and $^{239,240}\text{Pu}$. These radionuclides were associated with 1985 effluent releases as well as historical operations at Hanford. The bioassay measurements gave no

evidence of the presence of radioactivity of potential Hanford origin in any individual (Sula and Bihl 1986).

RADIOLOGICAL IMPACT FROM PUREX PLANT OPERATIONS

The PUREX Plant restarted operations in November 1983 and continued operations throughout 1985. The major airborne emission from the PUREX Plant in 1985 was 700,000 Ci of ^{85}Kr . Krypton-85 is an inert gas and is not retained in environmental media or the human body. The dose from inhaling ^{85}Kr is small compared with doses from other radionuclides. Even though the curie quantity of this radionuclide was large, it was a minor contributor to the radiation dose. The average concentration of ^{85}Kr measured in 1985 at the perimeter monitoring stations was 150 pCi/m³, which was calculated to produce a potential whole-body dose of 0.003 mrem and a skin dose of 0.2 mrem to an individual who was at that location 100% of the time. In 1985, there was 0.01 Ci of $^{239,240}\text{Pu}$ in airborne emissions from the PUREX Plant. A summary of the maximally exposed individual and population doses from $^{239,240}\text{Pu}$ is shown in Table 7. Plutonium-239,240 was a minor contributor to the dose from 1985 Hanford operations, with a maximum potential cumulative dose to the whole-body of 0.0007 mrem and a bone dose of 0.02 mrem. There were also 0.001 Ci ^{238}Pu and 0.01 Ci of ^{241}Pu in the 1985 PUREX Plant emissions. These radionuclides contributed an additional 30% to the lung doses and 20% to the whole-body doses noted in Table 7 for $^{239,240}\text{Pu}$. The additional contribution to the bone doses was only 10% from these other Pu isotopes.

RADIOLOGICAL IMPACT ON DRINKING WATER FROM WELLS

During 1985, drinking water at the FFTF (well #499-S0-7 and #499-S0-8), the Yakima Barricade Guardhouse (well #699-49-100C), the Arid Land Ecology (ALE) site (spring and well #699-S18-51), and the Hanford Patrol Firing Range (well #699-S28-E0) was obtained from the unconfined aquifer, or in the case of the spring at the ALE site, the confined aquifer. The locations of these wells are identified in the section on "Ground-Water Monitoring." Drinking water samples

TABLE 7. Calculated 50-Year Cumulative Doses from ^{239,240}Pu Released to the Atmosphere from the PUREX Plant in 1985

Pathway	Maximally Exposed Individual Dose (mrem)		
	Whole Body	Lung	Bone
Inhalation	7×10^{-4}	1×10^{-2}	2×10^{-2}
Foodstuffs	2×10^{-6}	—	3×10^{-8}
Direct Exposure	2×10^{-8}	2×10^{-8}	2×10^{-8}
Total	0.0007	0.01	0.02

Pathway	80-km Population Dose (man-rem)		
	Whole Body	Lung	Bone
Inhalation	1×10^{-1}	2×10^0	3×10^0
Foodstuffs	2×10^{-4}	—	3×10^{-3}
Direct Exposure	2×10^{-6}	2×10^{-6}	2×10^{-6}
Total	1×10^{-1}	2×10^0	3×10^0
Per Capita Dose (mrem)	0.0003	0.006	0.009

were collected quarterly from taps at the various sites and analyzed to determine the concentrations of radioactive materials. Results for samples collected at the Patrol Firing Range, ALE, and the Yakima Barricade were at or below the detection limits. At the FFTF, only tritium was detected at concentrations that required a dose calculation. Tritium concentrations ranged from 19,900 to 23,600 pCi/l. Based on an occupational consumption of one l/d for 250 d/yr, at the average concentration of 21,900 pCi/l, the whole-body dose to the worker would be 0.34 mrem. This calculated dose is less than 9% of the Washington State Drinking Water Standard of 4 mrem/yr. Additional monitoring of all DOE drinking-water systems at Hanford was reported by HEHF (Maas 1986).

REVISED DOE GUIDANCE FOR DOSE CALCULATIONS

Beginning in 1985, the Department of Energy required estimates of radiation exposure to the general public be in terms of the "effective dose equivalent." The effective dose equivalent is based on a measure of the total risk of potential health effects from radiation exposure. The adoption and use of the effective dose equivalent was previously recommended by the International Commission on Radiological Protection (ICRP 1979-1982).

Estimated radiological impacts from DOE operations have previously been reported in terms of the "50-year cumulative dose equivalent" (or simply, radiation dose), which is a measure of the energy (rads) absorbed by tissue multiplied by a quality factor and any other necessary modifying factors. Under this system, standards for radiation protection were presented in terms of the critical organ dose limits and were expressed in rem. The dose equivalent is still used for controlling the exposure to individual organs and the whole body and for comparing the organ doses resulting from variable exposure conditions.

The new "effective dose equivalent" is the sum of individual committed organ dose equivalents multiplied by weighting factors that represent the proportion of the total random risk that each organ would receive from uniform irradiation of the whole body. The organ committed dose equivalent may result from irradiation by either internal or external sources, and the two are to be summed. The new effective dose equivalent is also expressed in rem. The reader should keep in mind that the older dose equivalent is a measure of potential radiation risk to individual organs, whereas the new effective dose equivalent is a measure of potential radiation risk to the individual as a whole.

In addition to implementing the effective dose equivalent requirement for offsite population dose calculations, the DOE has also adopted the revised biokinetic models and metabolic parameters for radionuclides given by the ICRP (1979-1982) for estimating radiological impacts.

The calculation of the new effective dose equivalent takes into account the long-term internal exposure from radionuclides taken into the body during the current year, but not the potential exposure from future intake of radionuclides remaining in the environment from the current year's release. For these reasons, the older 50-year cumulative dose and the newer 50-year effective dose equivalent represent different calculated estimates, and they cannot be compared directly. The effective dose equivalent is expressed in rem (or millirem), with the corresponding value in sievert (or millisievert) in parentheses.^(a)

Effective Dose Equivalent for the Maximally Exposed Individual

The 50-year effective dose equivalent was calculated for the maximally exposed individual. The same effluent release data, meteorology, and pathway parameters (as described in Appendix F) used to calculate the older 50-year cumulative dose were also used to calculate the new 50-year committed dose equivalents. The results are summarized in Table 8, which shows the pathway contributions, the 50-year committed dose equivalents, and the effective dose equivalents. The total 50-year effective dose equivalent for the hypothetical maximally exposed individual was calculated to be 0.1 mrem (0.001 mSv).

The effective dose equivalent limits for any member of the general public from all routine DOE operations are 500 mrem/yr (5 mSv/yr) for

occasional exposures and 100 mrem/yr (1 mSv) for prolonged exposure periods. The calculated effective dose equivalent for the hypothetical maximally exposed individual was 0.1% of the prolonged exposure limit. The annual dose equivalent limit for any individual organ is 5000 mrem/yr (50 mSv/yr). In the maximally exposed individual, the organ calculated to receive the highest annual dose equivalent was the thyroid (0.02% of the limit).

Additional limits for the air pathway are provided in 40 CFR 61, Subpart H of the Clean Air Act: 25 mrem/yr whole-body committed dose equivalent and 75 mrem/yr committed dose equivalent to any organ for any member of the public. The 1985 emissions resulted in doses of 0.2% of the whole-body dose equivalent limit and 0.9% of the organ dose limit. Thus, the calculated maximum hypothetical annual dose equivalents for 1985 Hanford releases were well below all applicable standards.

Collective Dose Equivalent for the Population

The 50-year effective dose equivalent was calculated for the population residing within an 80-km radius of any of the onsite operating areas. The effluent release data, meteorology and pathway parameters described in Appendix F were also used for this calculation. The results are summarized in Table 9, which shows the pathway contributions, 50-year committed dose equivalents, and effective dose equivalents. The 50-year collective effective dose equivalent for the population was calculated to be 9 man-rem (0.09 man-Sv). This corresponds to an average per capita effective dose equivalent commitment of 0.03 mrem (0.0003 mSv) for individuals living in the 80-km radius of Hanford.

(a) 1 rem (or 1000 mrem) = 0.01 Sv (or 10 mSv).

TABLE 8. Calculated Committed Dose Equivalents and the Effective Dose Equivalent to the Hypothetical Maximally Exposed Individual from 1985 Hanford Operations (mrem)

Pathway	50-Year Committed Dose Equivalent					Effective Dose Equivalent
	Red Marrow	Bone Surfaces	Lung	GI ^(a)	Thyroid	
Direct Airborne ^(b)	0.01	0.1	0.05	0.004	0.01	0.02
Foodstuffs ^(c)	0.2	0.4	0.003	0.01	0.8	0.06
Drinking Water	0.01	0.02	0.0002	0.003	0.06	0.004
River Recreation ^(d)	0.09	0.2	0.01	0.07	0.07	0.03
Total	0.3	0.7	0.07	0.09	1.0	0.1

(a) Gastrointestinal tract (lower large intestine).

(b) Includes inhalation, submersion, and direct exposure to ground deposition.

(c) Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition.

(d) Includes consumption of fish taken from the Columbia River.

TABLE 9. Calculated Committed Dose Equivalents and the Effective Dose Equivalent for the 80-km Population from 1985 Hanford Operations (man-rem)

Pathway	50-Year Committed Dose Equivalent					Effective Dose Equivalent
	Red Marrow	Bone Surfaces	Lung	GI ^(a)	Thyroid	
Direct Airborne ^(b)	5	29	13	3	4	6
Foodstuffs ^(c)	0.5	0.8	0.3	0.5	91	3
Drinking Water	0.4	0.9	0.009	0.1	3	0.2
River Recreation ^(d)	0.04	0.07	0.009	0.03	0.03	0.02
Total	6	31	13	4	98	9

(a) Gastrointestinal tract (lower large intestine).

(b) Includes inhalation, submersion, and direct exposure to ground deposition.

(c) Includes consumption of all foodstuffs contaminated via irrigation water and dry deposition.

(d) Includes consumption of fish taken from the Columbia River.

III. RADIOLOGICAL MONITORING RESULTS

AIR MONITORING

The transport of atmospheric releases from Hanford to the surrounding region by wind represents a direct pathway for human exposure. The radioactive materials in air were sampled continuously onsite, at the Site perimeter, and in nearby and distant communities for a total of 48 locations. Air was sampled and analyzed for selected gaseous radionuclides at selected locations. Particulates filtered from the air at all locations were analyzed for radionuclides in solid form.

Many of the radionuclides released to the environment at Hanford also are found worldwide from two other sources: natural nuclear processes and worldwide nuclear weapons testing fallout. The samples collected onsite contained contributions from all three sources. Those collected at distant community locations within the region essentially contained contributions from only natural and fallout sources, as evidenced by comparison with data obtained prior to restart of the PUREX Plant or comparison with locations outside the region. Therefore, an indicator of the influence of Hanford emissions on local radionuclide levels was the difference between concentrations measured at distant community locations within the region and concentrations measured closer to the Site. When comparable data were found, it was also useful to compare regional data with data from monitoring stations outside the region.

In 1985 the average Hanford Site perimeter and downwind perimeter concentrations of ^{85}Kr , ^{90}Sr , ^{129}I , $^{239, 240}\text{Pu}$, and uranium were numerically greater than levels measured at distant monitoring stations. These differences, however, were not statistically significant. Increases in ^{85}Kr , ^{90}Sr , $^{239, 240}\text{Pu}$, and uranium were observed at the perimeter compared to 1984. No single sample, however, exceeded 0.3% of the applicable DOE Derived Concentration Guide (DCG) for levels in areas permanently occupied by members of the public. Even this is an overestimate since the DCG applies to the annual average concentration rather than the maximum single sample. Moreover, the results reported here also contained contributions from natural sources and fallout that were not subtracted from the totals.

Onsite concentrations of ^{85}Kr , ^{90}Sr , ^{129}I , and $^{239, 240}\text{Pu}$, as well as ^3H and ^{137}Cs were greater than levels at distant locations. Tritium, ^{90}Sr , and uranium concentrations increased onsite from 1984.

SAMPLE COLLECTION AND ANALYSIS

Radioactivity in air was measured by a network of continuously operating air samplers at 23 locations on the Hanford Site, 15 near the Site perimeter, five in nearby communities, and five in relatively distant communities (see Figure 8 and Table A.1). Air samplers on the Hanford Site were located primarily around the major operating areas to characterize maximum concentrations in the air from Site operations. Site perimeter samplers were located in all directions, with emphasis in the prevailing downwind directions to the south and east of the Site, to characterize concentrations at the nearest locations where the public could reside. Continuous samplers located in Benton City, Richland, Pasco, Connell, and Othello allowed characterization of air concentrations at the locations

where the largest numbers of people were located. Samplers located in the distant communities of Sunnyside, Moses Lake, Washtucna, and Walla Walla and at McNary Dam provided data from relatively unaffected locations for comparison.

Samples were collected according to the documented schedule established prior to each monitoring year (Blumer et al. 1984). The distribution of sample types in 1985 is summarized in Table 10.

Radionuclides in airborne dust were sampled by continuously drawing air at a flow rate of 2.6 m^3/h through a 5-cm diameter high-efficiency fiber glass filter for 2 weeks^(a). (Airborne dust that is removed from the air by rain or dry

^(a) Measured efficiencies exceed 99% for DOP (dioctylphthalate) particles.

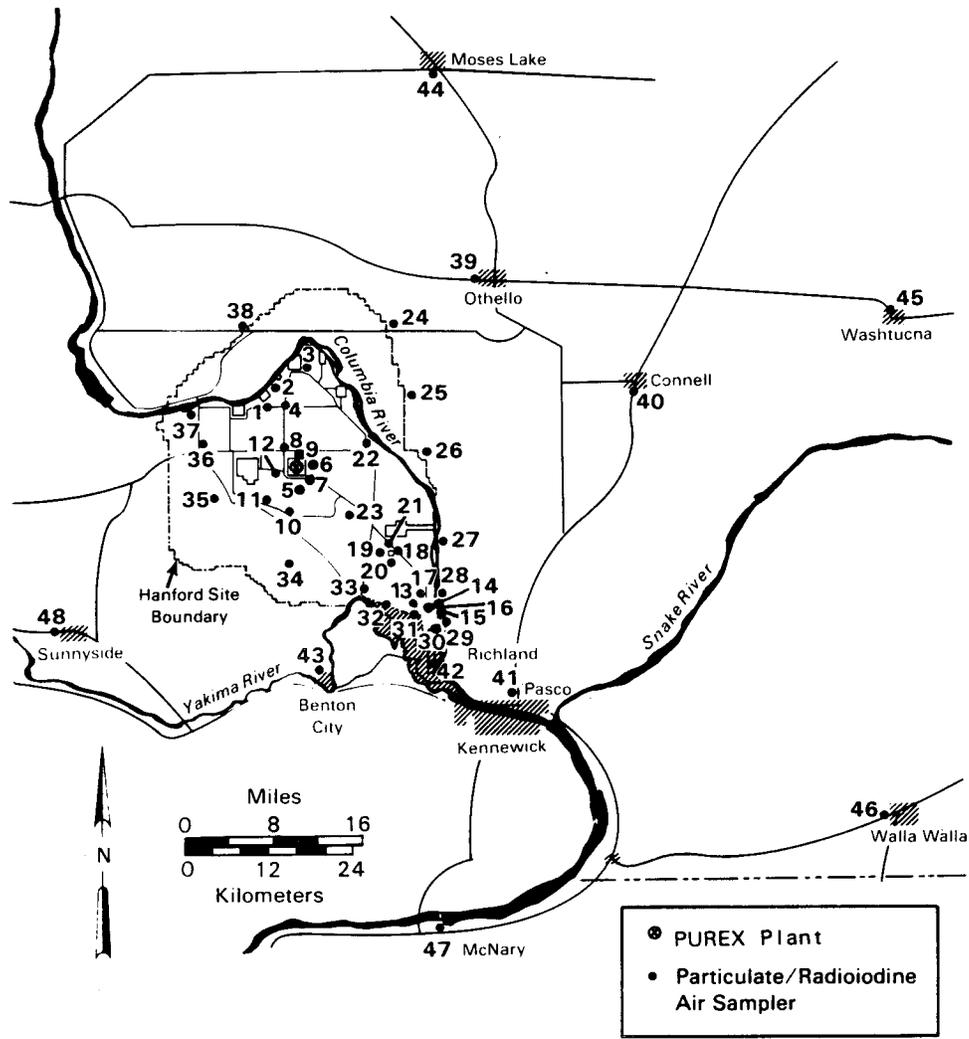


FIGURE 8. Air Sampling Locations (see Table A.1, Appendix A, for location key)

TABLE 10. Number of Locations by Air Sample Types

Locations	Particulates				Gases				
	Gross Beta	Gross Alpha	Gamma Scan ⁸⁹ Sr, ⁹⁰ Sr ²³⁸ Pu, ^{239,240} Pu	Uranium	¹³¹ I	¹²⁹ I	³ H	¹⁴ C	⁸⁵ Kr
Onsite	23	17	8/23 ^(a)	8/23 ^(a)	10/23 ^(b)	2	14	3	4
Perimeter	15	11	8/15	6/10	4/15	1	11	5	4
Nearby Communities	5	3	3/5	None	1/5	None	2	1	None
Distant Communities	5	3	3/5	1/1	1/5	1	2	1	1

(a) Number of composites/number of locations represented in the composites.

(b) Number of locations analyzed routinely/number of locations sampled routinely.

deposition to the soil or vegetation is sampled through soil and vegetation sampling, see "Soil and Vegetation Monitoring.") The filters were collected biweekly, held for seven days, and analyzed for gross beta radioactivity. The holding period was necessary to allow for the decay of short-lived naturally occurring radionuclides, which would otherwise obscure the detection of the lower levels of longer-lived radionuclides potentially present from Hanford emissions. The gross beta measurement provided a current indication of changes in environmental trends that could warrant special attention. In addition, filters from selected locations were analyzed for gross alpha radioactivity in a similar manner and for a similar purpose.

For most of the radionuclides of interest, the amount present in the atmosphere that could have been collected on a filter by continuously sampling for two weeks was too small to be measured with the accuracy desired. Since the accuracy of a sample analysis is increased when the sample contains more material, two biweekly samples were combined into monthly composite samples for each location. The monthly composites for a few prescribed nearby locations were then combined to form a geographical composite. (The 22 geographical composites used in 1985 are listed in Table A.1, Appendix A.) Each of the monthly composites was analyzed for gamma-emitting radionuclides, then combined into quarterly composites and analyzed for strontium and plutonium. Most quarterly composites also were analyzed for uranium.

Gaseous ^{131}I was sampled by drawing a $2.6\text{ m}^3/\text{h}$ air flow through a 6.3-cm diameter by 2.5-cm deep cartridge containing activated charcoal.^(a) These cartridges were placed downstream of the particle filter at each air sampling station. Charcoal cartridges from prescribed sampling locations were exchanged biweekly and analyzed

^(a) The coconut-shell activated carbon is impregnated with triethylene diAmine (TEDA). Retention efficiencies are 99% for both elemental and methyl-iodide.

for ^{131}I . The remaining cartridges were exchanged monthly to maintain fresh adsorption media, but were analyzed only if ^{131}I was identified in one of the routinely analyzed samples or if there was any other indication of an effluent release that could result in a detectable concentration. Iodine-129 was sampled using the same technique; however, a petroleum-based charcoal was used because of its lower background concentration, and samples were obtained once per quarter at four locations.

Atmospheric water vapor was collected for tritium analysis by continuously passing air through cartridges of silica gel at a flow rate of $0.014\text{ m}^3/\text{h}$ for 4 weeks. The collected moisture was removed from the silica gel and analyzed. The silica gel cartridges were exchanged every 4 weeks. Tritium data for other media, and historically for air moisture at Hanford, have been reported in terms of activity per liter of water. Therefore, the trend of concentrations since 1980 is shown in this section in terms of pCi/m^3 of atmospheric water. Because the DCG is stated in terms of activity per cubic meter of air, tritium results for 1985 are reported in pCi/m^3 of air in the tables of Appendix A. The comparability of the two measures was demonstrated in the 1984 annual report.

Atmospheric carbon dioxide was collected by continuously passing air through a soda-lime collection medium for 8 weeks at a flow rate of $0.28\text{ m}^3/\text{h}$. The trapped CO_2 was then analyzed for ^{14}C content and the atmospheric concentration calculated. Soda-lime cartridges were changed every 8 weeks.

Samples of air for ^{85}Kr analysis were collected using a small pump that continuously filled a collection bag with air at a low flow rate. About 0.3 m^3 of air was collected over 4-week sampling periods throughout the year. The entire sample of air was analyzed for ^{85}Kr .

Results

Results of gross beta and gross alpha radioactivity in airborne particulate samples collected in 1985 are given in Table A.2, Appendix A. Gross beta levels for 1985, as shown in Figure 9, peaked during unusually prolonged stagnant winter conditions similar to those of the previous winter. However, 1985 summer levels were not as low as in 1984, resulting in an annual average about 65% higher than in 1984. As shown in Table A.2, Appendix A, gross beta levels were about the same onsite, at the Site perimeter, and in nearby and distant communities. The elevated levels were apparently the result of natural radionuclides of terrestrial origin and worldwide fallout, because they were uniformly detected throughout the region. If Hanford operations had been an important source, concentrations would have shown a decrease with distance from the Hanford Site.

The gross alpha values shown in Table A.2, Appendix A, also were essentially the same at all distances, indicating that the observed levels were predominantly due to natural sources and worldwide fallout. Regional gross alpha levels also increased over 1984 levels, but not as much as the gross beta levels.

Onsite, perimeter, and nearby and distant community averages for specific detectable radionuclides, or others of special interest, are summarized in Table A.3, Appendix A. Fifty-five other radionuclides were also analyzed in the monthly composite gamma energy analyses, but only ^{137}Cs was detectable with any consistency. Annual average concentrations of ^{85}Kr , ^{90}Sr , ^{129}I , $^{239, 240}\text{Pu}$, and uranium appear higher at the site perimeter than offsite. Concentrations of

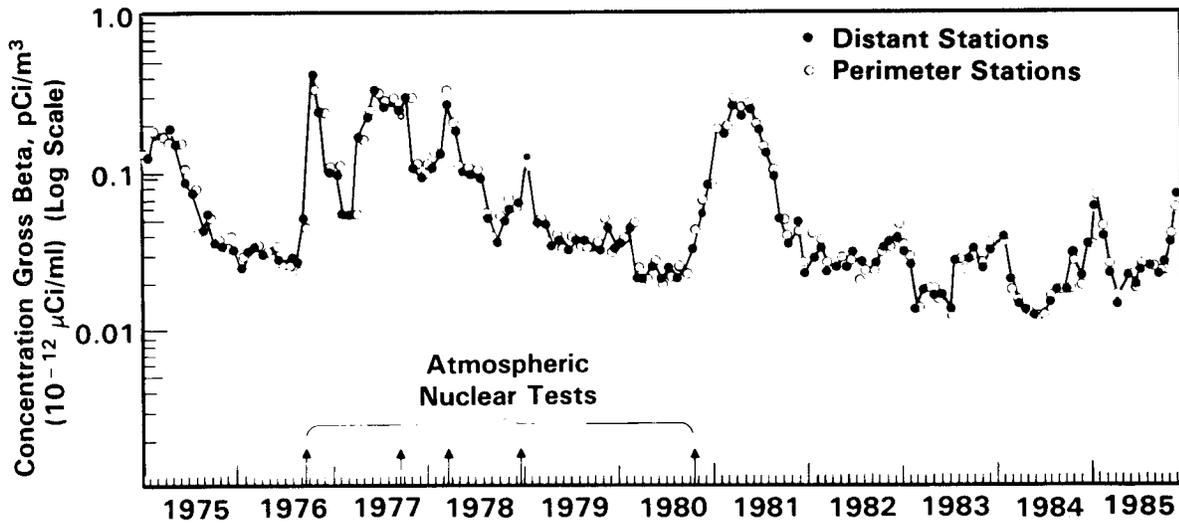


FIGURE 9. Monthly Average Gross Beta Radioactivity in Airborne Particulate Samples, 1975 to 1985

these radionuclides and tritium tended to increase onsite near the 200 Areas. The other radionuclides listed in Table A.3, Appendix A, were similar at the perimeter and offsite, indicating the predominant sources were worldwide fallout and natural sources. Onsite results from each sampling station near the major operating areas are summarized in Tables A.4 through A.10, Appendix A. All sample results were far below levels that would result in doses approaching applicable limits. The paragraphs that follow discuss the results for each radionuclide in more detail.

The comparisons discussed in the above and following paragraphs are based on the measured numerical results or averages without considering the variability in the results or averages. Statistical analysis of variance of differences of annual averages between the onsite, perimeter, downwind perimeter, and nearby and distant communities, for the radionuclides are listed in Table A.3, Appendix A. With the exception of ^{129}I , these tests did not indicate that average concentrations were statistically different at the 5% significance level. A different statistical analysis (nonparametric ranking) was applied to the ^{129}I data because these data were sampled intermittently during the year and indicated that the onsite, perimeter, and distant community ^{129}I concentrations were statistically different at the 5% significance level.

With the resumption of PUREX Plant operations in 1983, ambient air concentrations of ^{85}Kr increased at all sampling locations above the pre-operational levels of about 19 pCi/m^3 , as shown in Figure 10. The map in Figure 11 shows the average ^{85}Kr concentrations in 1985 at each sampling location. As expected, both figures show that concentrations were highest onsite near the source and decreased with distance offsite. The individual ^{85}Kr sample concentrations were quite variable, ranging from 40 to 3400 pCi/m^3 at the 200 ESE location (Figure 8, map location No. 7) and from 19 to 177 pCi/m^3 at Sunnyside, reflecting changing meteorology and source emissions. Concentrations in 1985 were higher than in 1984, with the average for perimeter stations

increasing about 100%. As in 1984, the measurements close to the PUREX Plant showed the effect of the prevailing northwest winds in the 200 Areas; and measurements along the perimeter indicate that much of the time the stack plume turns south toward Richland before it crosses the eastern site perimeter. This pattern is also demonstrated in the historical record (Healy et al. 1958).

Onsite, perimeter, and offsite average ^{90}Sr levels in 1985, as shown in Table A.3, Appendix A, were higher than 1984 levels by two to four times. Figure 12 shows the variation over the 5 years prior to 1985 for the 200E Area sample composite, for a sample composite made up of samples from stations along the southeast perimeter of the Site and the Tri-Cities, and for a sample composite from distant communities. Also shown are the measurements for two other U.S. locations in northern latitudes most recently reported by the DOE Environmental Measurements Laboratory (EML) as part of its international fallout monitoring program (Feely et al. 1985). Environmental Measurements Laboratory data for 1984 and 1985 have not yet been published. Most of the increase noted in Figure 12 for the 200E Area composite sample is the result of an inadvertent airborne release from a liquid-waste diversion box in the C-Tank Farm that occurred in January (see "Effluents, Waste Disposal, and Unusual Occurrences" section). The maximum annual average concentration measured at the Site perimeter occurred northwest of the Site, where the ^{90}Sr concentration was measured to be 0.00079 pCi/m^3 . This concentration was far below the applicable DCG of 9.0 pCi/m^3 . A comparison of the southeast perimeter composite and distant composite data on a year-to-year basis, shown in Figure 12, suggests that, with the exception of the 200E Area and the northwest perimeter, the 1985 levels were not greatly different from recent years, although the 1981 levels undoubtedly include effects of Chinese weapons testing in late 1980.

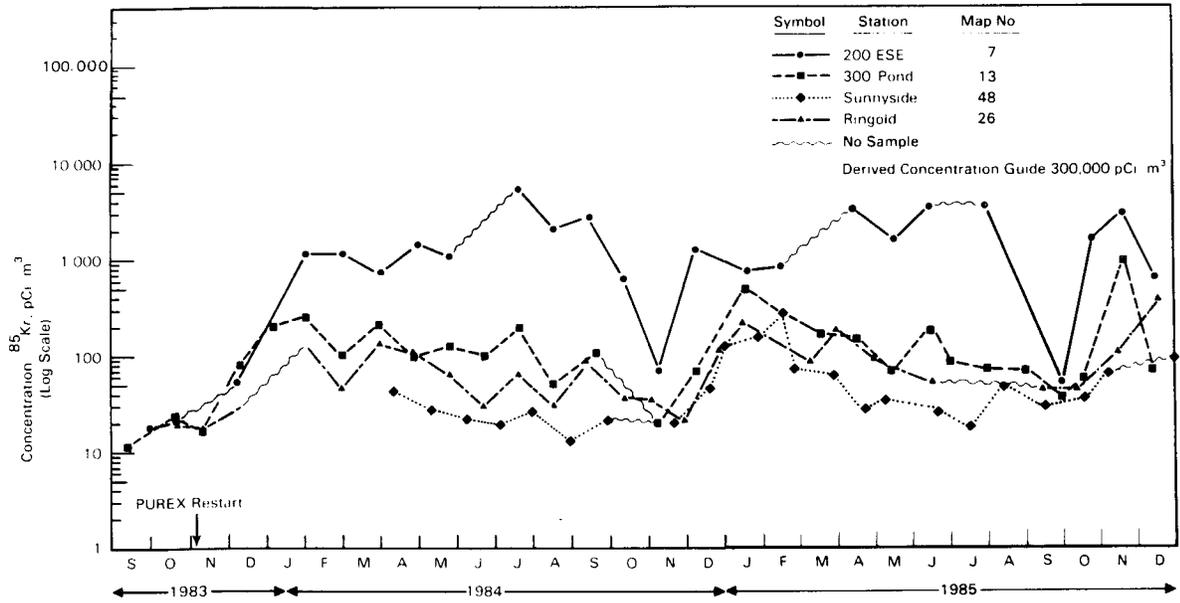


FIGURE 10. ⁸⁵Kr Air Concentrations at Selected Locations

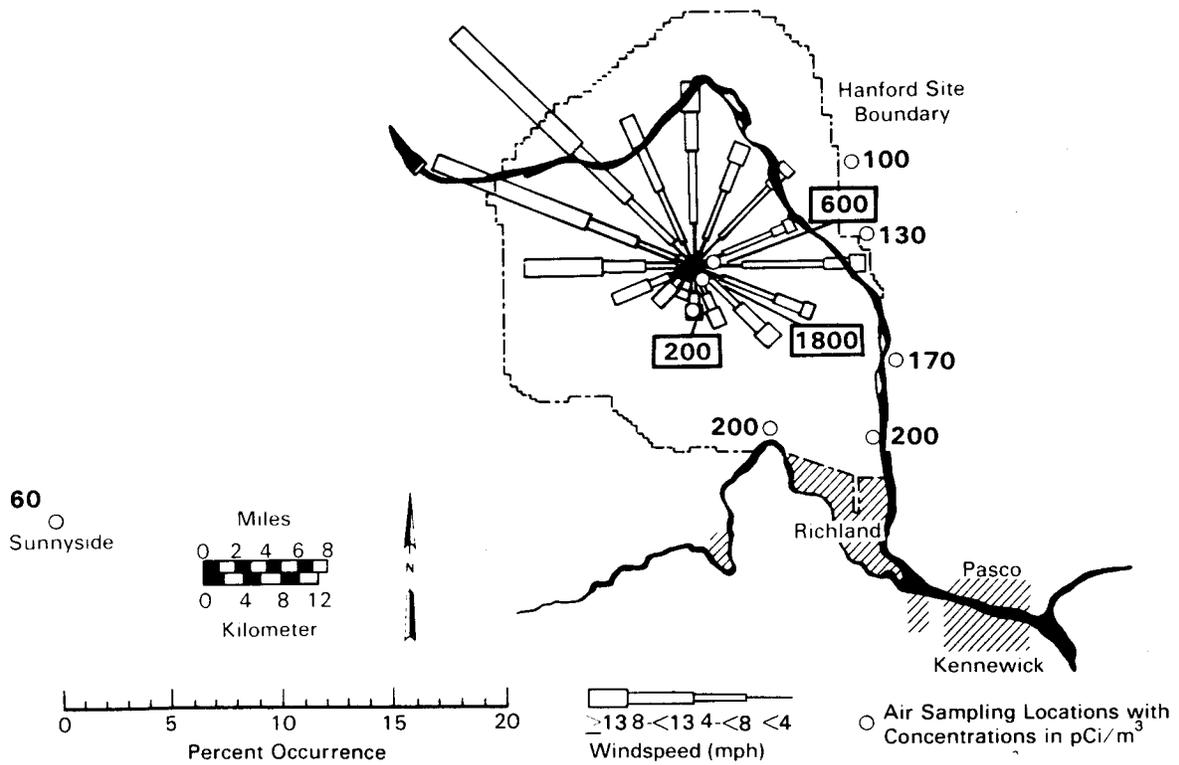


FIGURE 11. Annual Average ⁸⁵Kr Concentrations (pCi/m³) in Air and the 200 Area Windrose (showing direction from which wind blew) for 1985

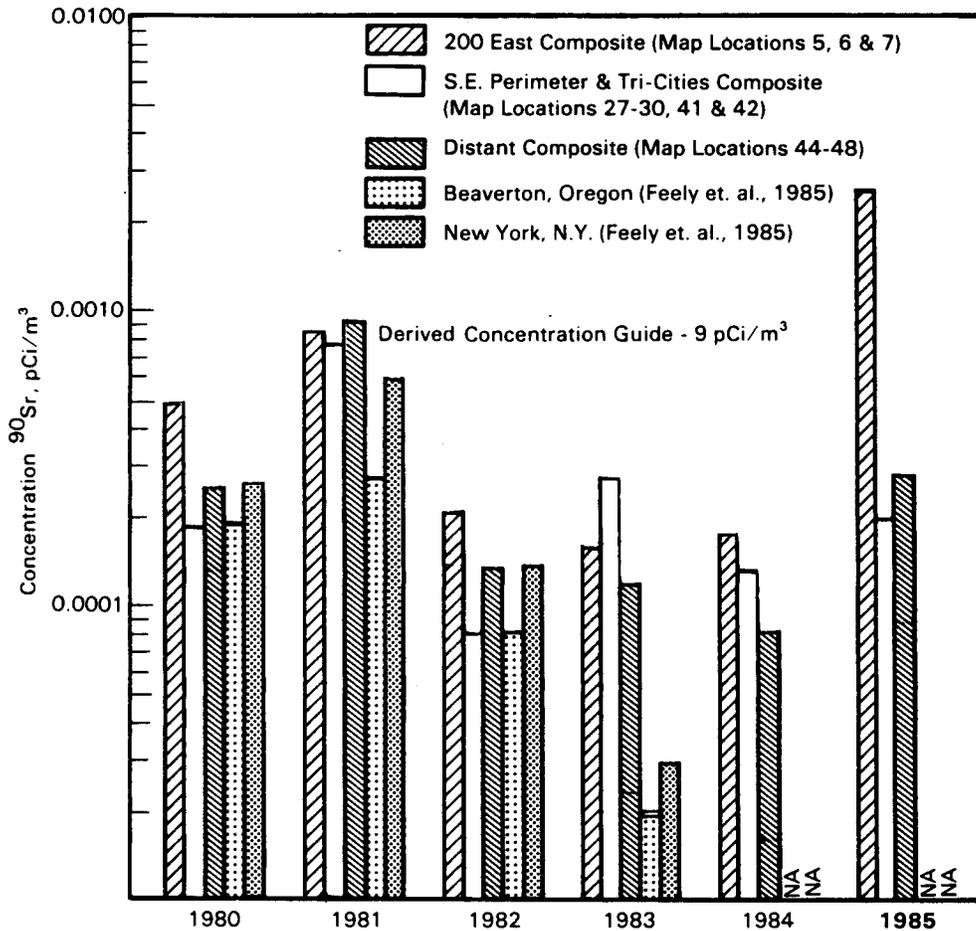


FIGURE 12. Annual Average ⁹⁰Sr Air Concentrations in the Hanford Environs Compared to Other U. S. Locations

Quarterly air sampling for ¹²⁹I began in July 1984 at the locations identified in Figure 13. Sampling was conducted for 2 weeks per quarter as an indicator of general environmental levels. Iodine-129 was detected at all locations where samples were collected in 1985. Average concentrations onsite were statistically larger than those observed at offsite locations, as shown in Figure 13 and Table A.3, Appendix A. Concentrations were quite variable and ranged from 1.4 to 613 aCi/m³ at the 200 ESE location, and from 0.02 to 18.7 aCi/m³ at Sunnyside. The average onsite and perimeter concentrations appeared to have decreased somewhat from 1984 to 1985, while

the distant measurement at Sunnyside appeared to increase. It is not possible, however, to conclude that changes actually occurred because data were obtained for only two quarters in 1984, and sampling was conducted for only 2 weeks in each quarter. All ¹²⁹I concentrations, however, were far below the DCG of 70 pCi/m³ (70,000,000 aCi/m³).

Average tritium concentrations, expressed in pCi/m³, measured at the Site perimeter and off-site were similar, as shown in Table A.3, Appendix A. Onsite concentrations were highest at the sampling locations immediately downwind

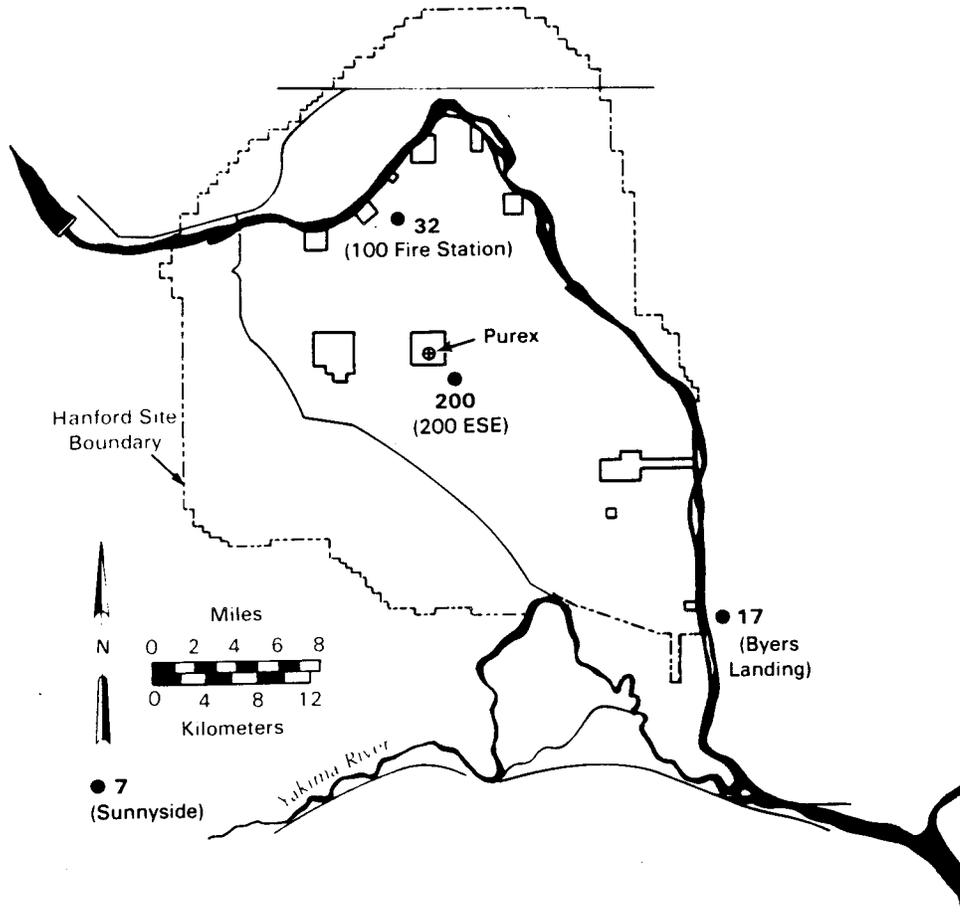


FIGURE 13. Iodine-129 Concentrations (aCi/m^3) in Air in the Hanford Environs for 1985 (Concentration Guide $70,000,000 \text{ aCi}/\text{m}^3$)

of the PUREX Plant, and the onsite average concentration was higher than the offsite average. Figure 14 traces the annual trend of ^3H concentration in atmospheric water vapor, in terms of pCi/ℓ of atmospheric water, for three individual locations and the average of two distant community locations. The effect of the restart of the PUREX Plant on air ^3H concentrations from 1983 to 1985 is clear at the 200 ESE sampling location. There appears to be no effect in either the distant communities or Richland. The Fir Road location on the southeast perimeter shows a numerical increase from 1984 to 1985. All perimeter and offsite concentrations were far below the applicable DCG of $200,000 \text{ pCi}/\text{m}^3$.

The annual average concentrations of $^{239,240}\text{Pu}$ in air for each perimeter and offsite sample composite and the maximum onsite sample composite are shown in the map in Figure 15. Values from the southern and eastern perimeter were numerically elevated relative to the more distant values, which were more typical of national levels. Concentrations increased onsite to a maximum of $18 \text{ aCi}/\text{m}^3$ immediately downwind of the 200E Area. The annual averages of all onsite, perimeter and near and distant community samples are shown in Table A.3, Appendix A. All of the results were far less than the applicable DCG for $^{239,240}\text{Pu}$ of $20,000 \text{ aCi}/\text{m}^3$.

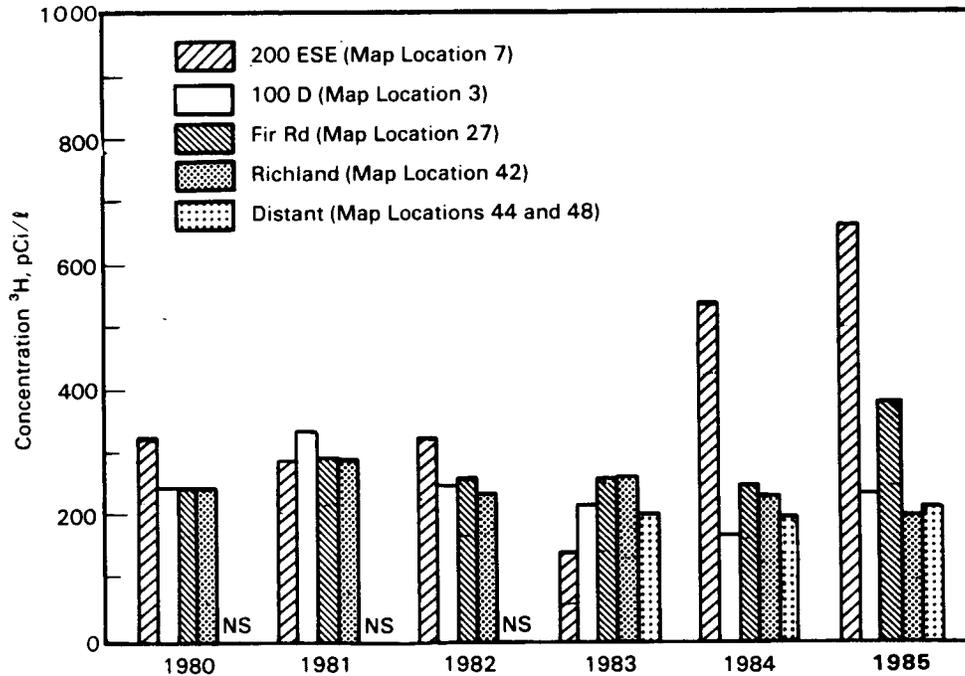


FIGURE 14. Annual Average Tritium Concentrations (pCi/l of water) in Atmospheric Water Vapor (NS: distant locations not sampled in these years)

The most recent data for $^{239}, ^{240}\text{Pu}$ reported by the EPA for Seattle, Spokane, and Portland for 1980 through 1983 (U.S. EPA 1980-1985) are compared in Figure 16 with measurements from two separate efforts at the Hanford Site. The Hanford southeast perimeter and Tri-Cities composite data were obtained from the routine monitoring program described in this report. The 300-Area sampler has been operated independently since 1961 to collect high-volume measurements of worldwide fallout radionuclides. Comparison of the 300 Area high-volume sampler data with the EPA data for Seattle, Spokane, and Portland indicates that levels from all four sites for 1980 through 1983 (the last year for which EPA data were reported) were very similar. The routine monitoring program recorded data that were higher in 1980 through 1983, but these data, as discussed in last year's annual report, were biased high because the analytical technique used was less sensitive. In 1984, a more sensitive analytical technique was

initiated, resulting in a better comparison between the routine and high-volume sampling results in 1984 and 1985 (high-volume data from the 300 Area are available for only the first quarter of 1985).

Uranium concentrations in airborne particulate matter at the perimeter were slightly elevated relative to distant samples in 1985, as shown in Table A.3, Appendix A. Perimeter and onsite concentrations increased over 1984 levels, while the distant composite concentration decreased. Even the highest single concentration measured, either onsite or offsite, was a very small portion of the applicable DCG of 0.1 pCi/m^3 .

Ruthenium-106 was routinely monitored through the biweekly gross beta analyses and the monthly composite gamma energy analyses but was rarely detected. As described in the section "Effluents, Waste Disposal, and Unusual Occurrences," ^{106}Ru was detected in large particles at the base of the PUREX Plant exhaust stack.

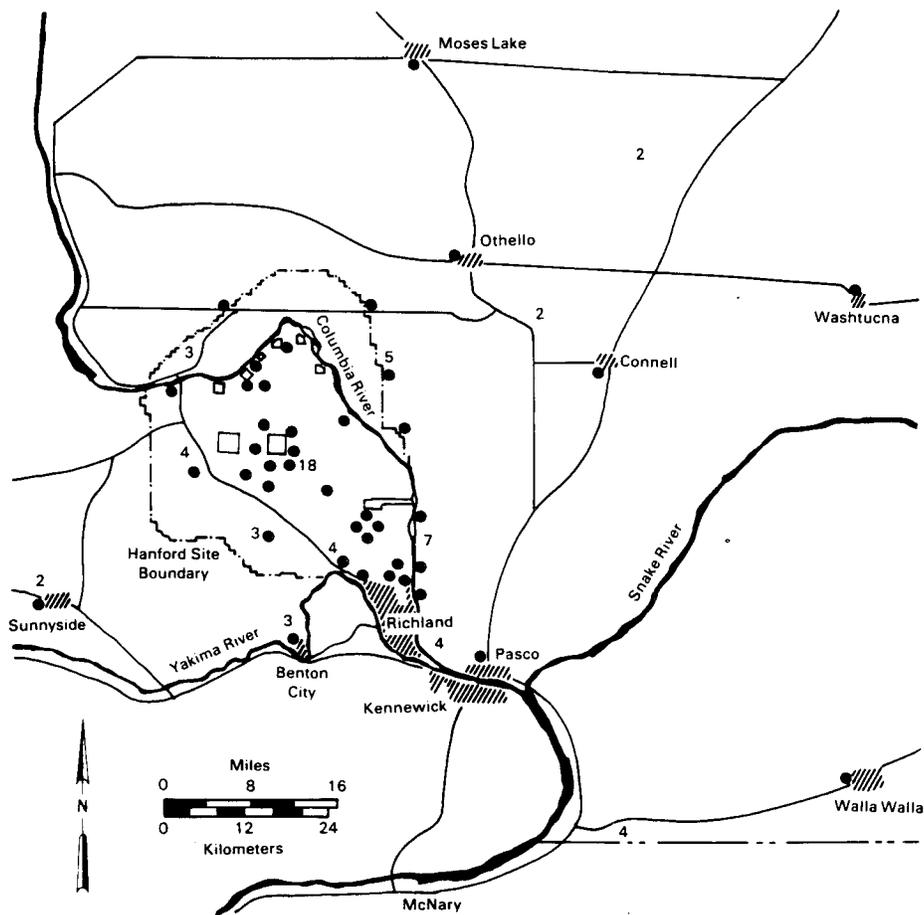


FIGURE 15. Plutonium-239,240 Concentrations (aCi/m^3) in Air in the Hanford Environs for 1985 (Derived Concentration Guide 20,000 aCi/m^3)

Therefore, the results obtained for ^{106}Ru in 1985 are included in Tables A.3 and A.5 through A.7, Appendix A. These results indicate that there was no significant onsite or offsite release of widely dispersed fine particles.

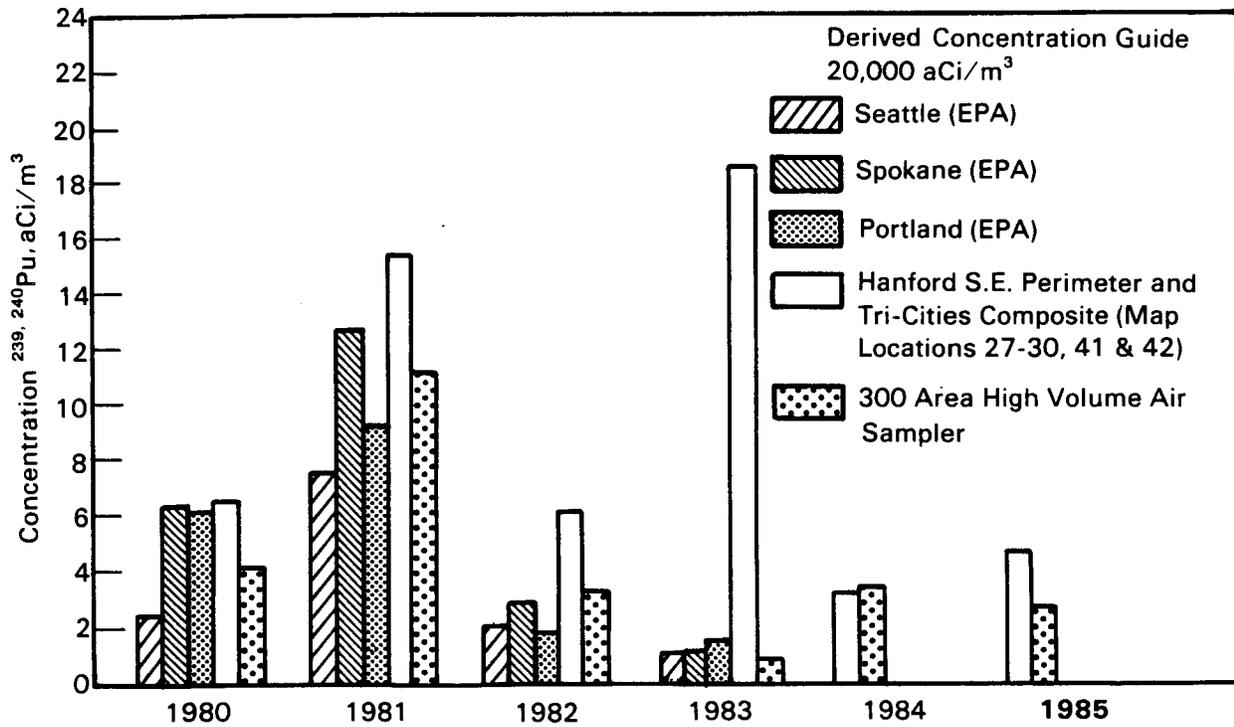


FIGURE 16. Annual Average Plutonium-239,240 Air Concentrations in the Northwest and Hanford Environs for 1980 through 1985

GROUND-WATER MONITORING

Ground water was sampled at over 300 locations on the Hanford Site during 1985. In addition, special studies were conducted to provide additional information to further characterize the ground-water system, refine the hydrologic models, and determine the impact of site operations on the environment. Results for 1985 indicated that the tritium from releases prior to 1983 continued to move slowly toward the Columbia River and a new plume has developed near the 200 Area. Tritium concentrations ranged from the detection limit (300 pCi/ℓ) to a high of 9,400,000 pCi/ℓ near or within the 200 Areas. A high of 580,000 pCi/ℓ was measured in the center of the tritium plume.

Radionuclides have also been observed in measurable quantities in Columbia River water (see "Surface Water Monitoring"). The presence of some radionuclides in the river was partially attributed to the flow of riverbank springs moving ground water into the river. Tritium, ¹²⁹I, and uranium in the ground water contributed to the concentrations of these naturally occurring radionuclides as measured in the Columbia River.

SAMPLE COLLECTION AND ANALYSIS

Samples were collected in 1985 from 339 wells in the unconfined and confined aquifers. Locations of these sampling wells are shown in Figure 17. Wells sampled during 1985 that sample the confined aquifer are noted in Table A.11, Appendix A. Most wells are either 15 or 20 cm in diameter and constructed of steel casings, with screens or perforated casing in the water intake portion.

During 1985, about 1,500 samples were collected, and more than 4,000 analyses were performed. Table 11 summarizes the number of samples collected from each of the major operating areas onsite. Samples were collected for Rockwell and UNC for special operational purposes. Most routine samples were collected on a quarterly basis; others were obtained monthly, semiannually, or annually. The method of sample collection varied, but the majority of the samples were obtained from monitoring wells that contain permanently mounted submersible pumps. Bailers were used to dip water samples from wells incapable of producing water by pumping, and the airlift method was used to collect samples from wells too narrow to allow placement of submersible pumps. Samples were collected just below the water table because that has been demonstrated to be the

location of maximum concentration for most contaminants found in the ground water at Hanford (Eddy, Myers, and Raymond 1978). To ensure that the water sample was representative of the aquifer, samples were collected after water was pumped a sufficient length of time to allow equilibration of key constituents (Scharnhorst 1982).

Samples collected during routine monitoring were analyzed for a number of radioactive and nonradioactive constituents, with tritium analyzed most frequently. Samples from selected wells were also analyzed for ⁹⁰Sr, ⁶⁰Co, ¹⁰⁶Ru, ¹²⁹I, ¹³⁷Cs, and uranium. Gross beta activity was measured in well water from the 300 Area and from selected wells in the 100 and 400 Areas, while gross alpha was monitored in a few wells in the 200 Areas. When elevated levels of radionuclides were found, special analyses were performed (i.e., for ⁹⁹Tc, ²²Na, and ⁶⁵Zn) (Eddy 1981).

Most of the analyses were performed by PNL's Radiological and Inorganic Chemistry Section. Iodine-129 samples were analyzed by PNL's Analytical and Nuclear Research Section. Standard radiometric methods were used to analyze the ground-water samples. These methods are described briefly in Appendix D.

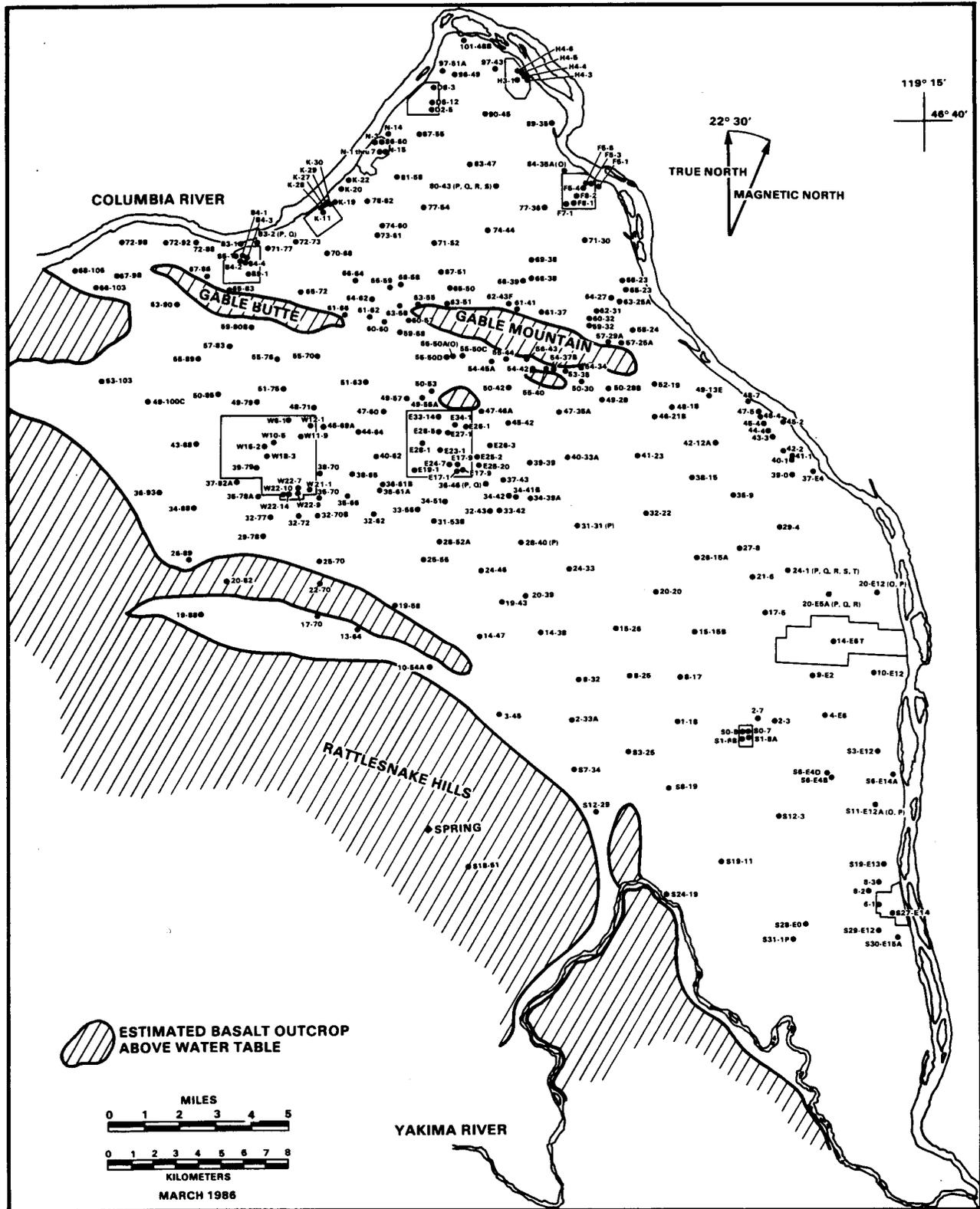


TABLE 11. Numbers of Wells Sampled, Samples Taken, and Analyses Performed for Ground-Water Monitoring in 1985

Area	Number of Wells Sampled	Number of Samples Taken	Number of Analyses Performed
100	59	282	732
200	22	96	264
300	28	112	696
400	6	24	72
600 ^(a)	224	973	2077
Totals	339	1487	3841

(a) The 600 Area encompasses all of the Hanford Site not included in the operating areas (100, 200, 300, and 400 Areas.)

RESULTS

Tritium (^3H) has been present in many of the liquid wastes discharged to the ground on the Hanford Site. Currently the main source for these wastes is the PUREX Plant in the 200E Area (USDOE 1983). Because tritium is transported in the form of tritiated water molecules, the distribution of tritium in the ground water serves as an indicator of the movement of liquid wastes discharged from current and past waste-management operations.

Figure 18 illustrates the distribution of tritium in the unconfined aquifer for 1985. This map was produced by contouring the average tritium concentrations in well samples collected in 1985. The map depicts the positions of the tritium plumes in the ground water.

As shown in Figure 18, the tritium from the 200E Area disposal sites has migrated along ground-water flow paths in a southeasterly direction to the Columbia River. Migration of the tritium also can be observed at individual monitoring wells over time. Figure 19 illustrates the tritium data measured for well 699-41-23, located approximately half way between the 200E Area and the Columbia River. The tritium concentration in this well over time reflects the migration of tritium toward the well in the early 1960s, illustrated by increasing concentrations, followed by decreasing concentrations after the PUREX facilities were placed on standby in 1972.

Figure 20 illustrates the tritium data measured over time for well 699-40-1, located along the Columbia River near the Hanford townsite. The increasing concentrations in this well indicate that the existing tritium plume is migrating toward the Columbia River. Ground water from the unconfined aquifer enters the Columbia River through subsurface flow and springs that emanate from the riverbank (McCormack and Carlile 1984). Tritium concentrations measured in wells near the springs ranged from 19,000 to 250,000 pCi/l and averaged 176,000 pCi/l over 1985. Except for some small zones around the 100 Areas, ground water from the Hanford townsite represented the highest probable tritium concentrations entering the Columbia River.

Although most of the contamination in the ground water was from past operations, there was evidence that contamination from the restart of the PUREX Plant in 1983 had reached the ground water. Wells approximately one mile southeast of the 200E Area showed an increase in tritium concentrations. Figure 21 illustrates tritium data measured over time for well 699-34-42, and Figure 22 illustrates the tritium data measured over time for well 699-33-42. Increases in tritium concentrations in wells located down-gradient from PUREX Plant liquid-waste disposal sites were the result of resumed PUREX Plant operations. The tritium plume map (Figure 18) is not detailed enough to show the new plume developing since the restart of the PUREX Plant.

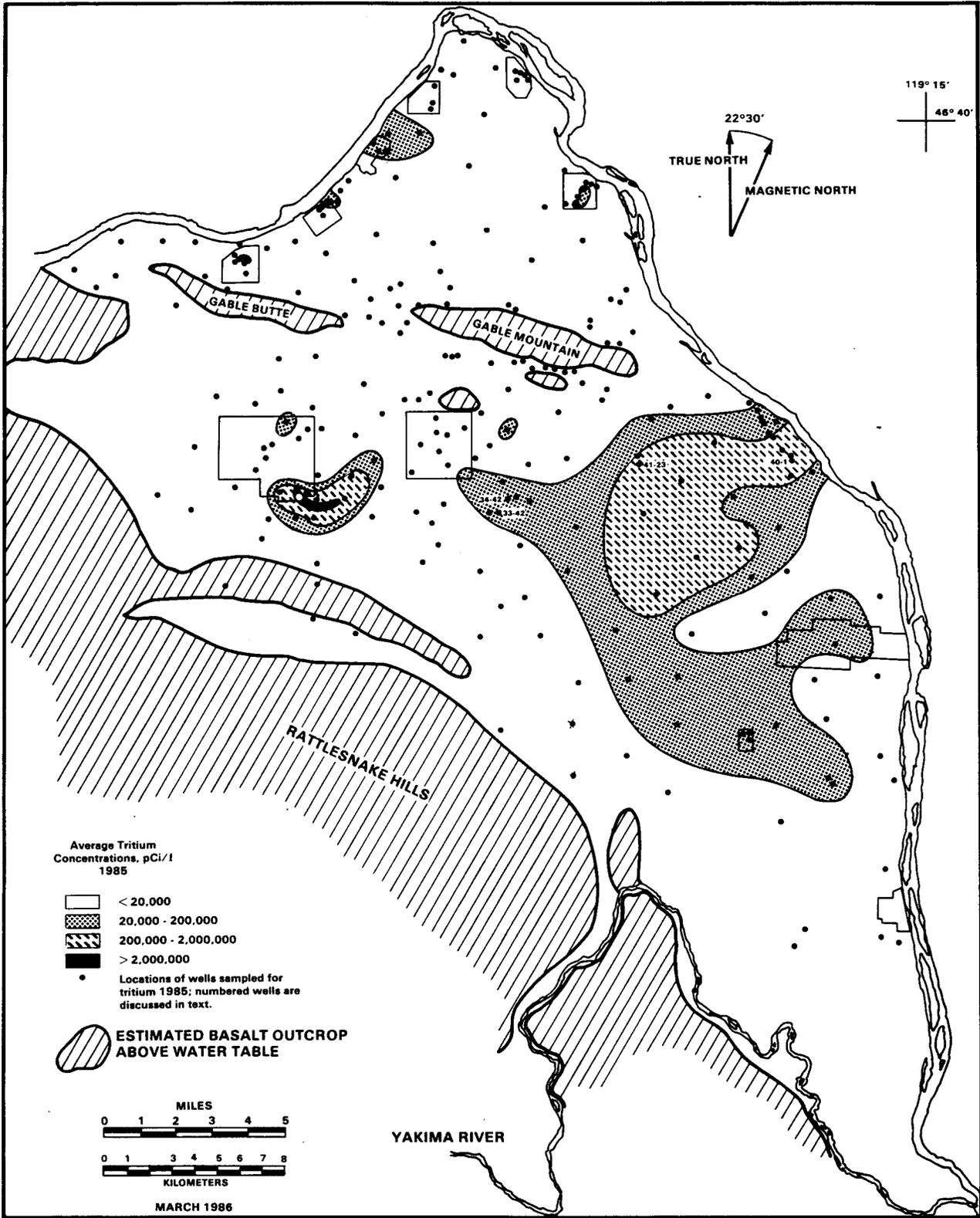


FIGURE 18. Tritium Plume for 1985

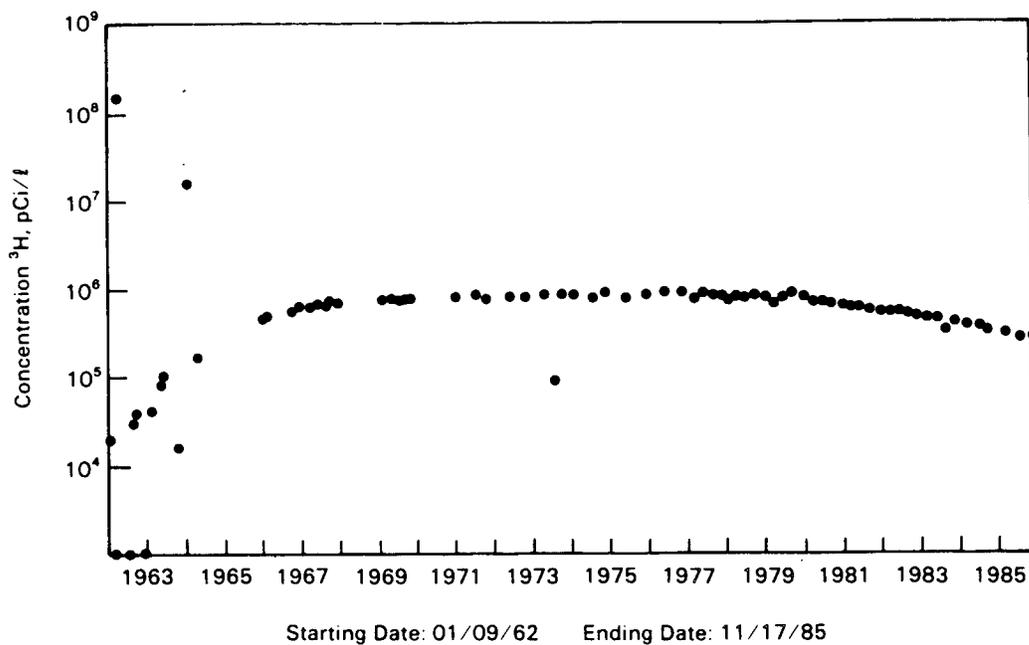


FIGURE 19. Tritium Concentrations for Well 699-41-23 (For location, see Figure 18)

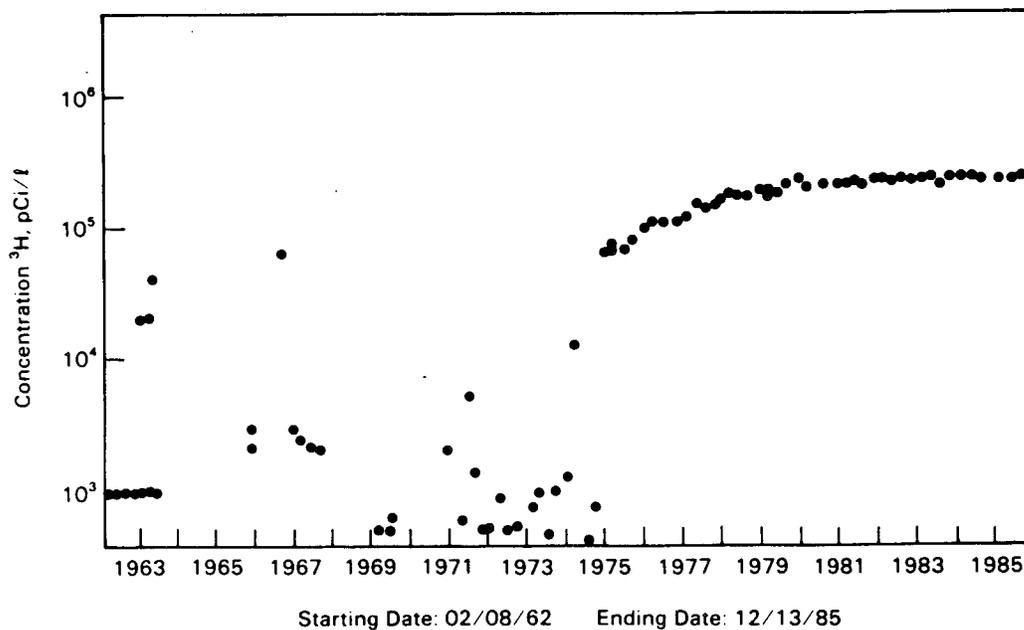


FIGURE 20. Tritium Concentrations for Well 699-40-1 (For location, see Figure 18)

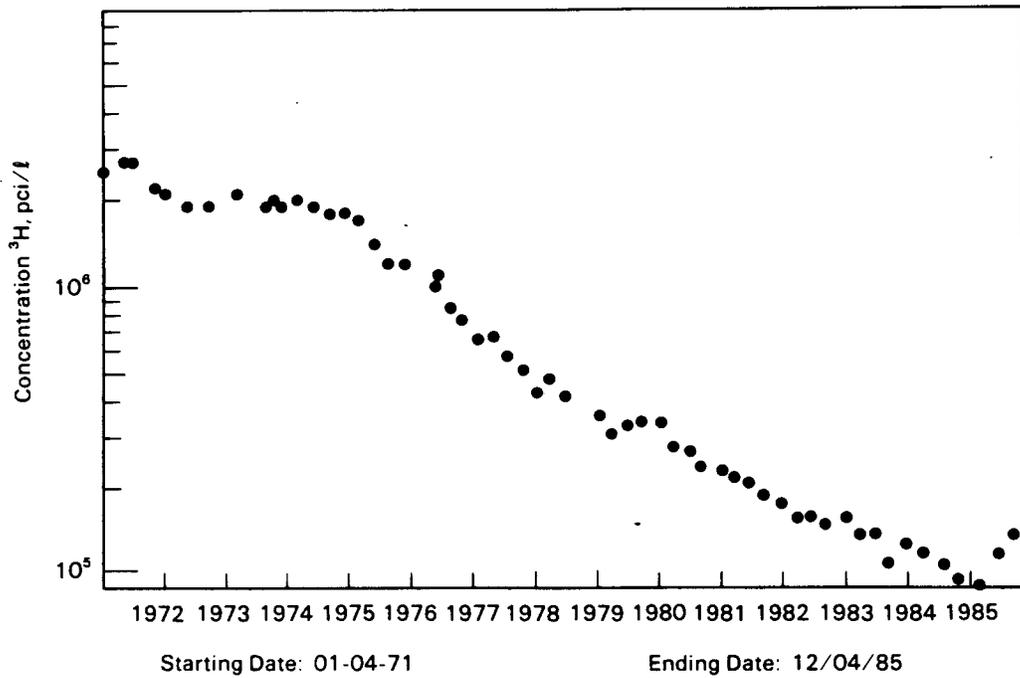


FIGURE 21. Tritium Concentrations for Well 699-34-42 (For location, see Figure 18)

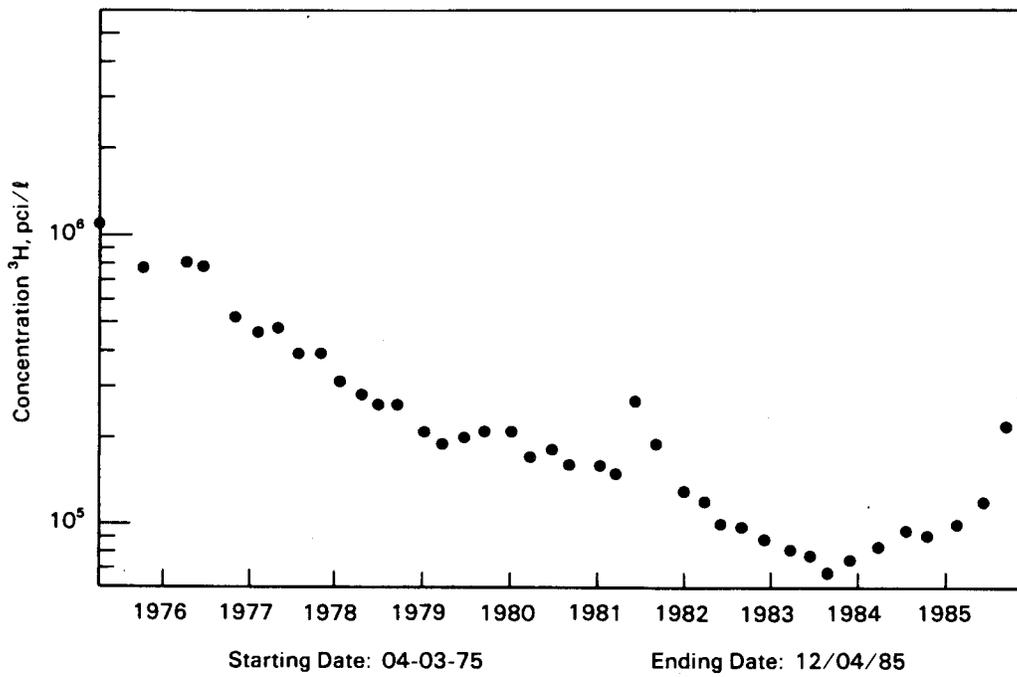


FIGURE 22. Tritium Concentrations for Well 699-33-42 (For location, see Figure 18)

Concentrations of tritium from the ground-water monitoring network over the entire Hanford Site ranged from the detection limit (300 pCi/l) to a maximum of 9,400,000 pCi/l. The maximum concentrations were found in the 200 Area. Other high values were in the center of the main plume (Figure 18). The highest tritium concentration was collected from a well located close to inactive disposal facilities in the 200 Areas. The results of samples analyzed for tritium in 1985 are summarized in Table A.11, Appendix A.

Alpha and beta radiations were measured in samples from various areas as a screening method. If high alpha or beta activity was measured in a sample, it was analyzed further to determine the probable source of this activity. In the past, ^{106}Ru has been a major contributor of beta radiation. However, since the half-life of ruthenium-106 is approximately one year, it has essentially disappeared from the ground water in the areas distant from the 200 Areas.

Cesium-137, ^{90}Sr , and ^{60}Co , however, also emit beta radiation and were specifically measured when beta results were positive. Cesium-137 and ^{60}Co also emit gamma radiation and can be detected by the gamma spectrometry method. The methods of analysis are described in Appendix D. During 1985, beta activity in well water ranged from the detection limit (16 pCi/l) to 530 pCi/l, while the gamma activity ranged from the detection limit (30 pCi/l) to 440 pCi/l.

The alpha analysis was used to determine the presence of uranium or plutonium in the water samples. When the gross alpha levels increased, the samples were further analyzed for uranium, ^{238}Pu , and $^{239,240}\text{Pu}$. During 1985, alpha radioactivity ranged from the detection limit (4 pCi/l) to 310 pCi/l in the ground-water samples analyzed.

Strontium-90 is a fission product monitored in the ground water at various locations on the Hanford Site. Operations in the 100N Area and past operations in the 200E Area are probable sources of ^{90}Sr found in the ground water. Average concentrations ranging from 1.5 to 4060 pCi/l were found in environmental well-water samples collected adjacent to the 100N Area in

1985. The 100N Area springs contributed approximately 8.7 Ci of ^{90}Sr to the Columbia River. The ^{90}Sr concentration in the Columbia River water adjacent to these springs was approximately 0.09 pCi/l, as stated in the "Comparison of Measured and Calculated Results" section of this report. The "Surface-Water Monitoring" section discusses results from monitoring the Columbia River.

The presence of iodine-129 in ground water is significant primarily because of its relatively long half-life of 16 million years and the potential for accumulation in the environment from long-term, chronic releases from nuclear fuel reprocessing facilities (Soldat 1976). On the Hanford Site, the main contributor of ^{129}I to the ground water has been liquid discharges to cribs in the 200 Area. A study conducted in 1981 and 1982 indicated that N-Reactor discharges did not contribute detectable amounts of ^{129}I to the river. Most of the ^{129}I was entering the river from the 200 Area ground-water plume at the Hanford Townsite (McCormack and Carlile 1984). The "Surface-Water Monitoring" section discusses results from monitoring the Columbia River.

Iodine-129 was sampled in ground water more systematically in 1985 than in previous years. Samples were collected in wells adjacent to the Columbia River near the Hanford Townsite and in wells located within or close to the 200 Areas. Table A.12, Appendix A, lists the wells sampled during 1985 and the corresponding ^{129}I results. Concentrations ranged from 0.000008 to 67 pCi/l.

Cesium-137 and $^{239,240}\text{Pu}$ are considered to be immobile in soil and ground water. Because of their immobility, these radionuclides are monitored in ground water predominantly near operating or decommissioned facilities in the 100, 200, and 300 Areas. Cesium-137 concentrations in the ground water ranged from the detection limit (30 pCi/l) to 110 pCi/l. Plutonium was not detected in the ground water sampled in 1985.

Cobalt-60 was monitored in the ground water at various locations on the Hanford Site. Concentrations in the ground water on the Hanford Site ranged from the detection limit (20 pCi/l) to 440 pCi/l.

Uranium occurs naturally in the environment and in all types of soils, rock, ground water, and surface water (Fairbridge 1972). The sources of processed uranium found in the ground water at the Hanford Site were liquid disposal cribs in the 200 Areas and liquid disposal trenches in the 300 Area (USERDA 1975). The uranium detected in Columbia River water is from natural sources, disposal to trenches in the 300 Area, and contaminated ground water in the 100H Area. Uranium concentrations in wells located adjacent to

the 100H solar evaporation basins ranged from less than detectable to 390 pCi/ℓ. Results from wells located within the 300 Area ranged from the detection limit (0.5 pCi/ℓ) to 120 pCi/ℓ.

Other radionuclides such as ⁹⁹Tc and ¹⁴C have been detected in the ground water beneath the Hanford Site. Because these radionuclides have been found in such small quantities outside of the disposal areas, they were not routinely monitored during 1985.

SURFACE-WATER MONITORING

The Columbia River constituted the primary environmental exposure pathway to the public for radioactivity in liquid effluents. Radionuclides in the river have decreased significantly since the shutdown of the plutonium production reactors with single-pass cooling systems and the installation of improved liquid effluent control systems at the N Reactor. However, radionuclides associated with Hanford operations continued to be routinely identified in the river water during 1985.

In addition to the river, four onsite ponds were sampled periodically to determine radionuclide concentrations. These ponds were accessible to migratory water fowl as well as other animals residing on the Site. As a result, a potential biological pathway existed for the removal and dispersal of any contaminants that may have been present in the pond water and sediments.

COLUMBIA RIVER

The Columbia River is used as a source of drinking water onsite as well as at communities downstream of the Hanford Site. As a result, the Environmental Protection Agency and the State of Washington drinking-water regulations are applicable (Appendix C). In addition, the river is also used extensively for crop irrigation and recreational activities such as fishing, hunting, boating, water skiing, and swimming. In view of this, the river water continued to be closely monitored for radionuclides of potential Hanford origin. Samples taken upstream and downstream of the Site are analyzed for selected radionuclides at frequencies commensurate with their half-lives and their importance as either verifiers of waste containment or indicators of potential environmental impacts. Radionuclides of primary significance in the river are ^3H , ^{60}Co , ^{89}Sr , ^{90}Sr , ^{131}I , ^{129}I , ^{137}Cs , $^{239,240}\text{Pu}$, and uranium (U).

Sample Collection and Analysis

Samples of Columbia River water were collected throughout 1985 at the upstream and downstream locations shown in Figure 23. The upstream sampler was located approximately mid-stream within Priest Rapids Dam and collected samples as water passed through the dam. Priest Rapids Dam is located approximately 5 miles upstream of the Hanford Site boundary. The downstream samples were collected at the 300 Area and City of Richland water-supply intakes. The 300 Area sampling location was near the southern boundary of the Site and collected water from the intake forebay along

the shoreline. The Richland sampler, located about 2 miles downstream of the site boundary, collected water from a point approximately 30 feet into the river from the shoreline.

Two types of samplers were used in most instances: a cumulative system that collected a fixed volume of water at set intervals during each sample period and a specially designed system that continuously collected waterborne radionuclides from the river water on a series of filters and ion-exchange resins. Grab samples were used in a few special cases when routine equipment was inoperable.

The cumulative samplers consisted of a timer-activated solenoid valve that periodically diverted a continuously flowing substream of Columbia River water into a 10 l container. This cycle repeated itself throughout the 1-week sample period such that approximately 30 ml of water were collected every 30 minutes. The 10-l sample container was changed every week, and the sample was taken to the laboratory, where the water from a single location was composited over a 4-week period prior to analysis, resulting in a total sample size of approximately 40 l. Tritium, ^{89}Sr , ^{90}Sr and uranium were the radionuclides of interest in the samples collected with the cumulative sampling system.

A special system was used to separate the radionuclides from river water prior to analysis. A large volume of water was required to allow the extremely small concentrations of certain radionuclides in the river water to be detected.

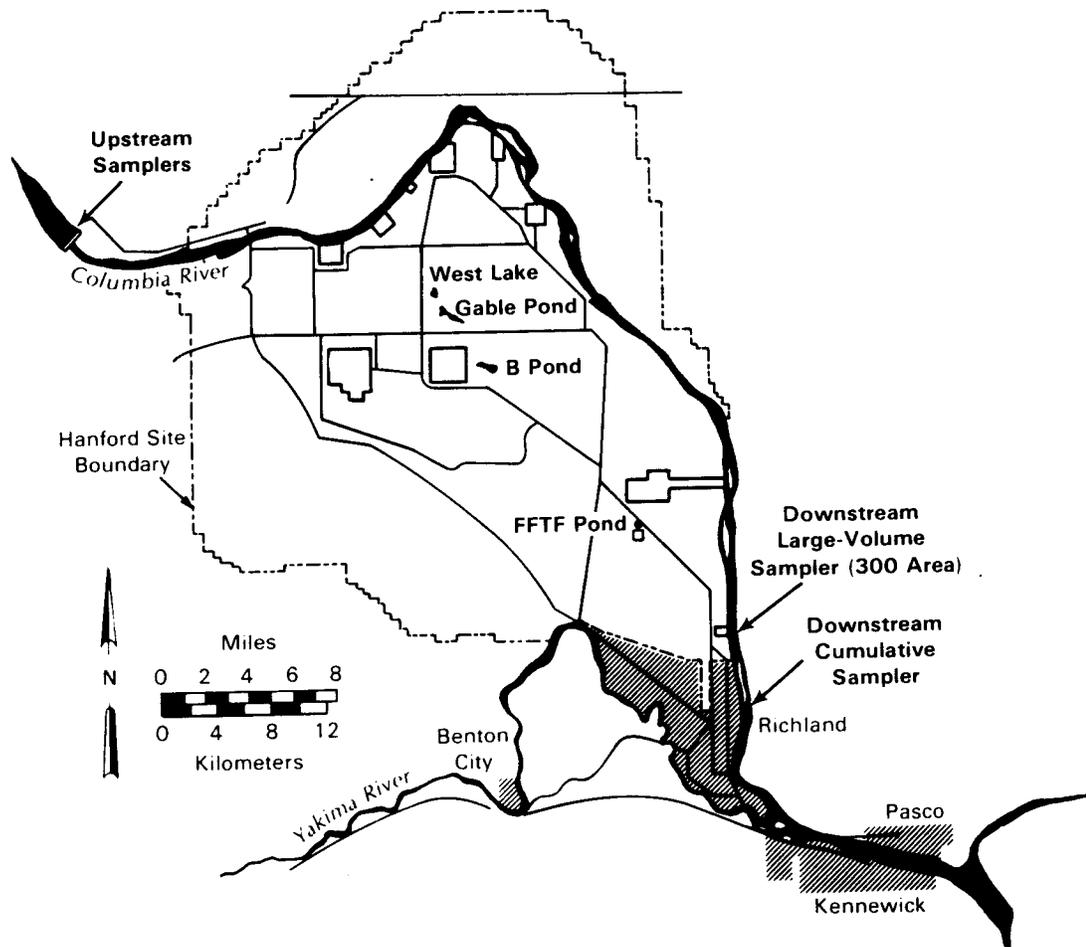


FIGURE 23. Columbia River Water Sampling and Onsite Pond Locations

River water flowed through the collection system at a rate of approximately 50 mL/min, resulting in a total volume of about 1000 L sampled during each 2-week sample period. Suspended particulates greater than 0.45 μm in diameter were removed from the water on a series of filters, and soluble radionuclides, except tritium, were collected on a mixed-bed, ion-exchange resin column. The filters and ion-exchange resin were exchanged every 2 weeks and analyzed for gamma-emitting radionuclides. The filters and resin from each location were then composited separately for quarterly analyses of ^{129}I , ^{238}Pu , and $^{239,240}\text{Pu}$.

Results

The results of the analysis of Columbia River water samples collected during 1985 are summarized in Tables A.13 and A.14, Appendix A. Significant results are discussed and illustrated below, with comparisons to previous years' results provided as well. Radionuclides consistently observed in measurable quantities in river water during 1985 were ^3H , ^{90}Sr , U , ^{129}I , ^{137}Cs , and $^{239,240}\text{Pu}$. All of these are reportedly present in effluents from Hanford facilities and exist in worldwide fallout as well. In addition, ^3H and U occur naturally in the environment.

Annual average concentrations of tritium measured upstream and downstream of the Hanford

Site during 1985 were 110 pCi/l and 150 pCi/l, respectively. Figure 24 provides a comparison of monthly tritium concentrations observed in river water, showing that concentrations downstream were generally higher than those upstream during the year. Statistical tests indicated that the difference between the downstream and upstream concentrations was significant.^(a) Sources of tritium entering the river were effluent releases from N Reactor and ground water entering the river along the Site (see "Effluents, Waste Disposal, and Unusual Occurrences" and "Ground-Water Monitoring"). The concentrations of tritium observed in the river during 1985 were similar to those observed during recent years and were comparable to measurements made on Columbia River water by State of Washington personnel (DSHS 1985). Figure 25 provides a comparison of the annual average concentrations of ³H, ⁹⁰Sr, and U for the period

1981 through 1985. All observed tritium concentrations were well below the State of Washington and EPA screening level of 20,000 pCi/l for drinking water.

The ⁹⁰Sr concentrations measured upstream and downstream during 1985 were essentially the same (0.15 pCi/l and 0.16 pCi/l, respectively). Figure 25 shows the annual average ⁹⁰Sr concentration to be slightly higher at the downstream location, consistent with observations made in past years. However, differences observed since 1981 have been very slight, especially when the uncertainty associated with the averages is considered. Figure 26 presents the monthly ⁹⁰Sr concentrations observed during the year at both the upstream and downstream locations, demonstrating that downstream concentrations are not consistently higher than the upstream concentrations. Statistical tests also indicated that the difference between upstream

(a) Paired sample comparison, t-test of differences (Snedecor and Cochran 1976).

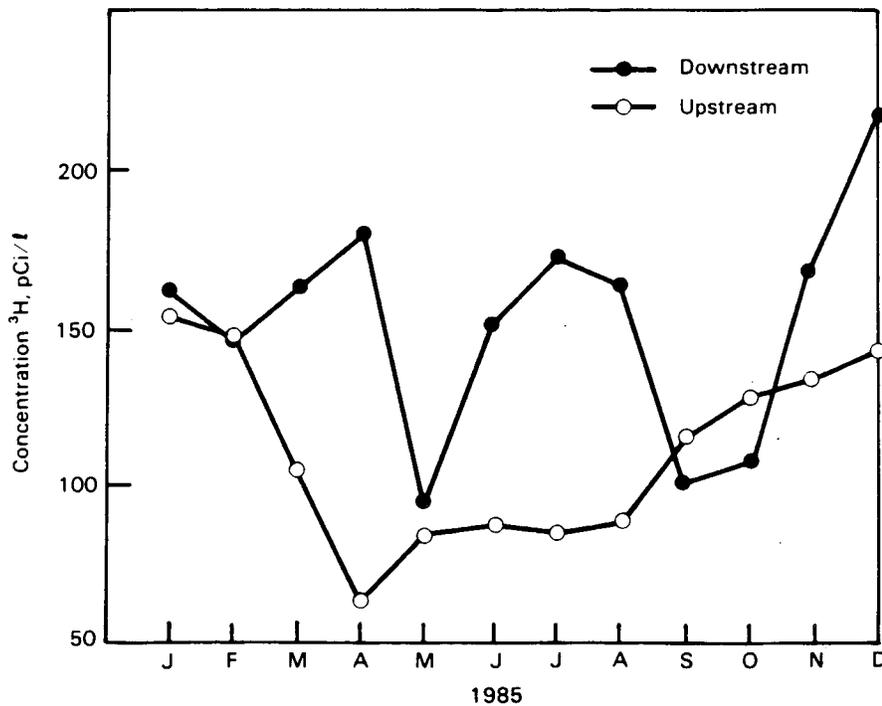


FIGURE 24. Tritium Concentrations Measured in Columbia River Water During 1985

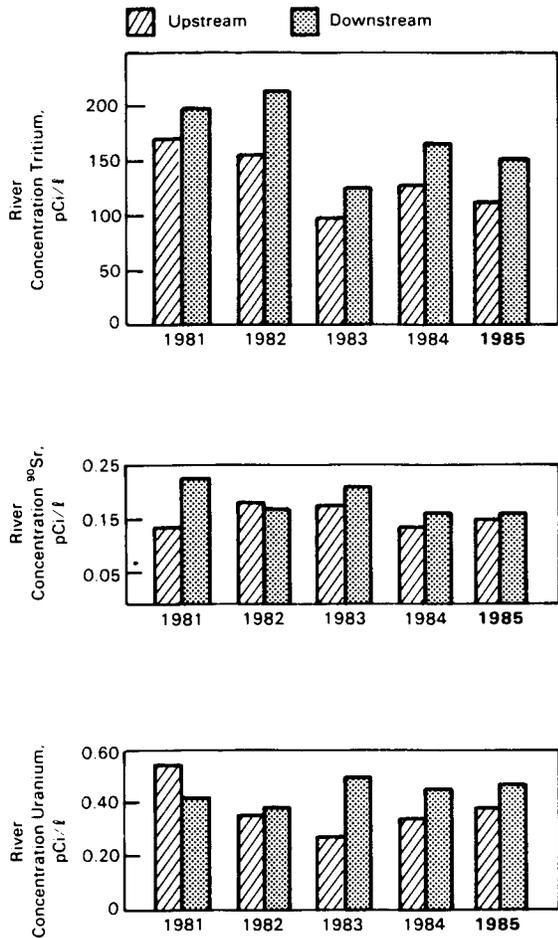


FIGURE 25. Annual Average Tritium, Strontium-90 and Uranium Concentrations Measured in the Columbia River, 1981 to 1985

and downstream concentrations was insignificant. The only known source of ⁹⁰Sr entering the Columbia River was from the 100N liquid-waste disposal facility, which reportedly discharged 8.7 Ci to the river during 1985. All ⁹⁰Sr concentrations observed during 1985 in the Columbia River water were well below the State of Washington and EPA screening level of 8 pCi/l for drinking water.

Strontium-89 concentrations in Columbia River water collected upstream and downstream of Hanford were generally below the detection level during 1985. As in past years, average concentrations of ⁸⁹Sr were essentially the same upstream and downstream of the Site (0.087 pCi/l and 0.100 pCi/l, respectively).

Uranium concentrations in 1985 continued to be slightly higher in samples of Columbia River water collected downstream of Hanford than in those collected upstream, as shown in Figure 25. While the difference in the annual averages upstream versus downstream (0.38 pCi/l and 0.48 pCi/l, respectively) is very slight, monthly values observed during the year were generally higher at the downstream location, as Figure 27 shows. All uranium concentrations observed during 1985 correspond with doses well below the State of Washington and EPA standard of 4 mrem/yr for drinking water. Although there is no direct discharge of uranium to the river, it is known to be a primary constituent of the ground water beneath the 300 Area (see "Ground-Water Monitoring" section) and has been detected at elevated levels in riverbank springs entering the river in this area (McCormack and Carlile 1984).

As in the past several years, ¹²⁹I concentrations continue to be higher in downstream river water than upstream. The average upstream and downstream concentrations in river water during 1985 were 9 aCi/l and 88 aCi/l, respectively. Iodine-129 in the river is attributable to the flow of ground water, which is known to contain ¹²⁹I, from the unconfined aquifer into the river (see "Ground-Water Monitoring" section). Figure 28 provides the quarterly ¹²⁹I results for the upstream and downstream locations and also shows the average quarterly flow rate of the Columbia River for 1985 and the previous 5 years. As the figure shows, the differences observed during 1985 between the upstream and downstream concentrations were similar to the differences observed in past years. The figure also illustrates the influence of the river flow rate on the downstream ¹²⁹I concentrations, as higher flow rates are associated with reduced concentrations, and vice versa. As has been the case for other radionuclides, the concentrations of ¹²⁹I observed in the Columbia River water during 1985 were well below those concentrations which would result in doses exceeding the State of Washington and EPA Standard for drinking water, 4 mrem/yr.

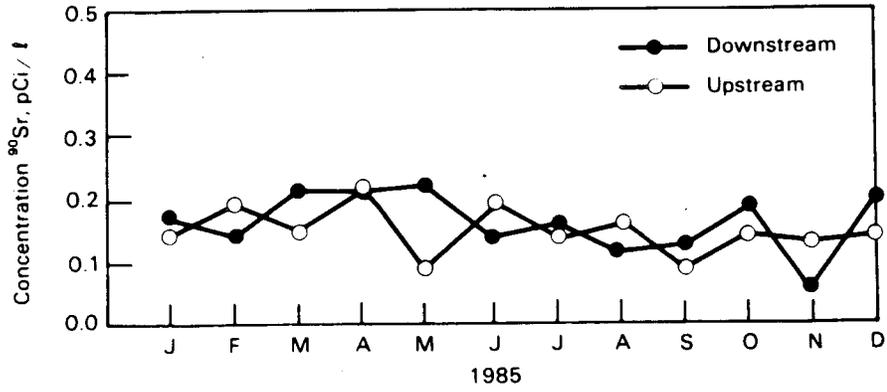


FIGURE 26. ⁹⁰Sr Concentrations Measured in Columbia River Water During 1985

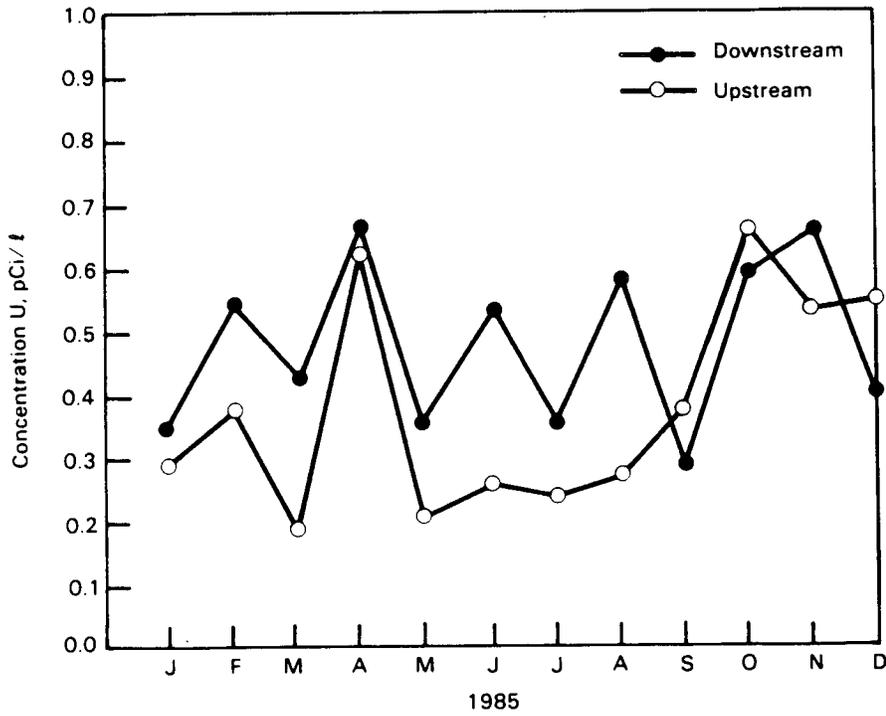


FIGURE 27. Uranium Concentrations Measured in Columbia River Water During 1985

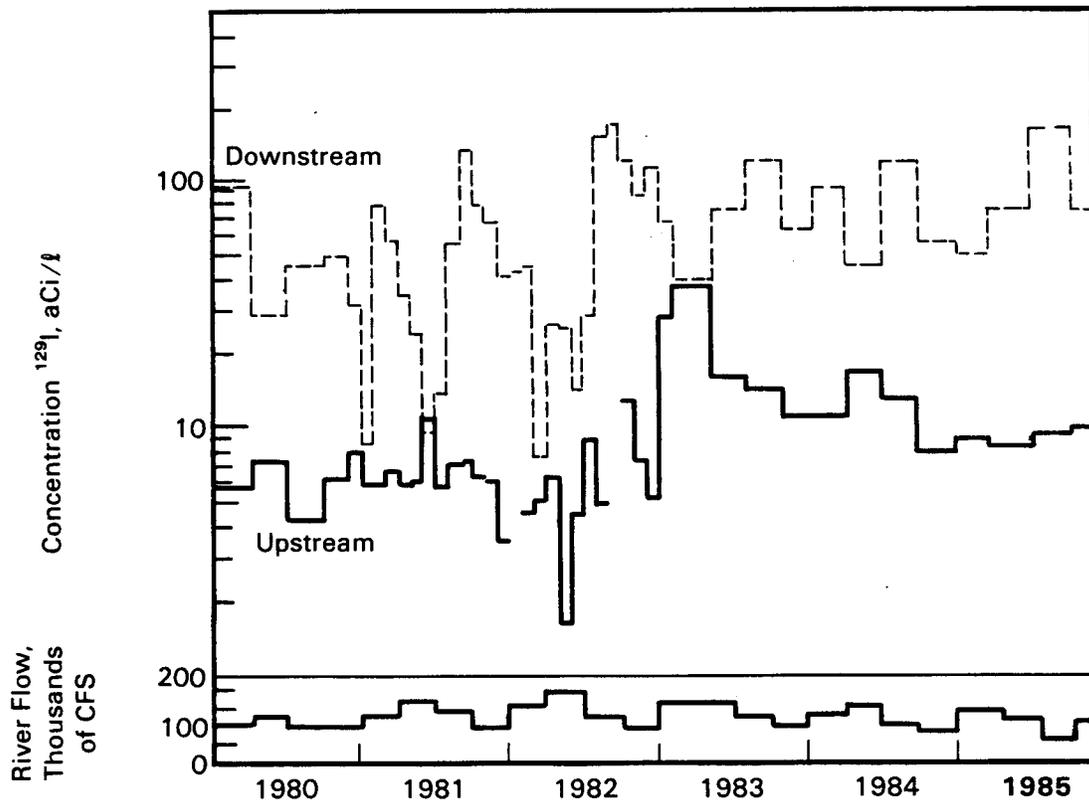


FIGURE 28. Iodine-129 Concentrations Measured in Columbia River Water, 1980 to 1985

Iodine-131 was observed at very low concentrations in the Columbia River periodically during 1985. While the concentrations of ^{131}I were generally at less than detectable levels at the upstream location, the average concentration of ^{131}I downstream of Hanford was 0.019 pCi/l. The average ^{131}I concentration observed during 1985 was similar to those of the past and remained well below that concentration which would result in doses exceeding the State of Washington and EPA Standard of 4 mrem/yr for drinking water. Iodine-131 periodically enters the river as a result of 100N Reactor operational upsets.

Like ^{131}I , ^{60}Co was observed in more downstream river water samples than upstream samples, and the average concentrations were comparable to past years. The annual average ^{60}Co concentration downstream of the Hanford Site was 0.012 pCi/l during 1985. Potential sources of ^{60}Co in the river included N-Reactor effluents and possible resuspension of ^{60}Co known to be deposited in the river bed as a result of past operations (Sula 1980).

There were no measurable differences in the concentrations of ^{137}Cs or $^{239,240}\text{Pu}$ in Columbia River water collected upstream and downstream of the Hanford Site. The annual average concentration of ^{137}Cs was slightly lower than that observed during 1984, while the $^{239,240}\text{Pu}$ concentration was similar to those observed during previous years.

ONSITE PONDS

Four onsite ponds were located near operating areas as shown in Figure 23. Two of the ponds, Gable Mountain Pond (also referred to as Gable Pond) and B Pond near the 200E Area, were excavated in the mid-1950s for disposal of process cooling water and wastes occasionally containing low levels of radioactive contamination. During 1985, Gable Pond was significantly reduced in size as a result of decommissioning efforts, and B Pond was expanded considerably in anticipation of receiving waste water previously routed to Gable Pond. The FFTF Pond,

excavated in 1978, received cooling water from various facilities within the 400 Area that did not routinely contain radioactive wastes. The fourth pond, West Lake, was a natural lake interconnected with the ground water and did not receive direct effluent discharges from site facilities. Operating contractors were responsible for monitoring effluents discharged to the ponds and operational aspects of the ponds. Although the ponds were inaccessible to the public and did not constitute a direct offsite environmental impact, they were accessible to migratory waterfowl, creating a potential biological pathway for the dispersion of contaminants. Periodic sampling also provided a secondary check on effluent control systems.

Sample Collection and Analysis

During 1985, quarterly grab samples consisting of 10L of water were collected from each of the ponds. Special care was taken to avoid the resuspension and inadvertent collection of bottom sediments during the sampling process. Unfiltered aliquots of the samples were analyzed for gross alpha and gross beta activities, gamma-emitting radionuclides, ^3H , and ^{90}Sr . The FFTF pond samples were analyzed for ^{22}Na instead of ^{90}Sr .

Results

Results from pond samples for 1985 are summarized in Table A.15, Appendix A. Maximum, minimum, and mean values are provided for the various radionuclides measured. Further discussion of individual constituents and comparisons with results observed during previous years are provided below.

Figure 29 illustrates gross alpha and gross beta results for 1980 through 1985 for Gable Pond, B Pond, FFTF Pond, and West Lake. Concentrations of gross alpha and gross beta during 1985 were consistent with previous years' results. Gross alpha concentrations in the FFTF Pond were generally less than detectable and were therefore omitted from the figure. As in past years, the highest gross alpha and gross beta concentrations were observed at West Lake, which is constantly recharged from the ground water (Gephart et al. 1976). Special water samples collected and analyzed in 1975 indicated

that the gross alpha and gross beta radioactivity in the pond came primarily from naturally occurring uranium (Speer, Fix and Blumer 1976). Therefore, the elevated gross alpha and gross beta concentrations observed during 1985 and previous years were most probably the result of naturally occurring radionuclides in the pond recharge that have been concentrated by evaporation over the years.

Tritium analysis of all pond water samples was initiated in 1983. Figure 30 displays the annual average tritium concentrations for each of the onsite ponds for the past 3 years. The tritium levels in the ponds have remained relatively stable during this time period. The elevated average concentrations of tritium in the FFTF pond were similar to those observed in the ground water beneath this site, which is the source of the 400 Area water supply. Tritium concentrations observed in West Lake were similar to those known to occur in the local ground water as well. Although tritium concentrations in B Pond appear to be widely variable, the elevated average concentration observed during 1984 was attributable to a single elevated sample result, which influenced the average accordingly. With this exception, individual ^3H results observed in B Pond water were similar throughout this time period.

Concentrations of ^{90}Sr and ^{137}Cs observed in B Pond water during 1985 were similar to those observed during recent years, as shown in Figures 31 and 32, respectively. Similarly, Figures 33 and 34 provide annual average ^{90}Sr and ^{137}Cs concentrations in Gable Pond.

Although no radionuclides are routinely discharged to FFTF Pond, the potential for an accidental release has been identified. Therefore, samples from this pond are routinely analyzed for ^{22}Na as an indicator of process failure. As in past years, the annual average concentration of ^{22}Na in FFTF Pond water was less than the uncertainty associated with the calculated mean and provided no indication of an inadvertent release during the year.

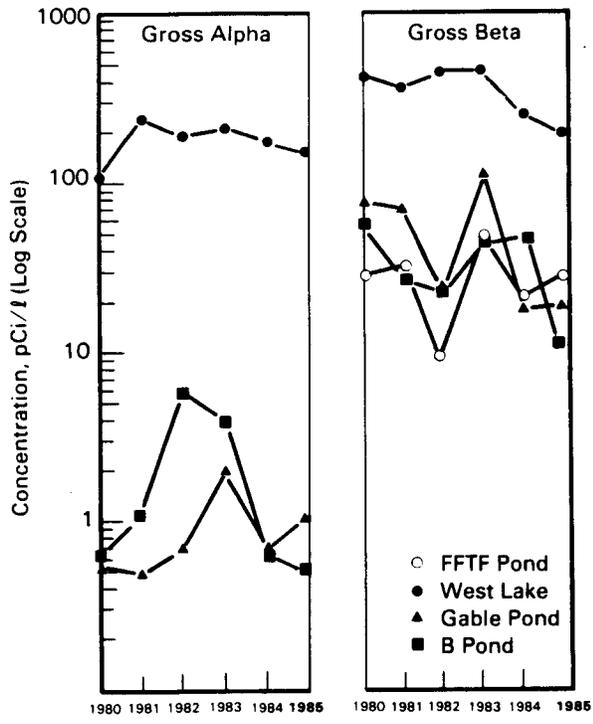


FIGURE 29. Annual Average Gross Alpha and Gross Beta Concentrations Measured in Onsite Ponds, 1980 to 1985

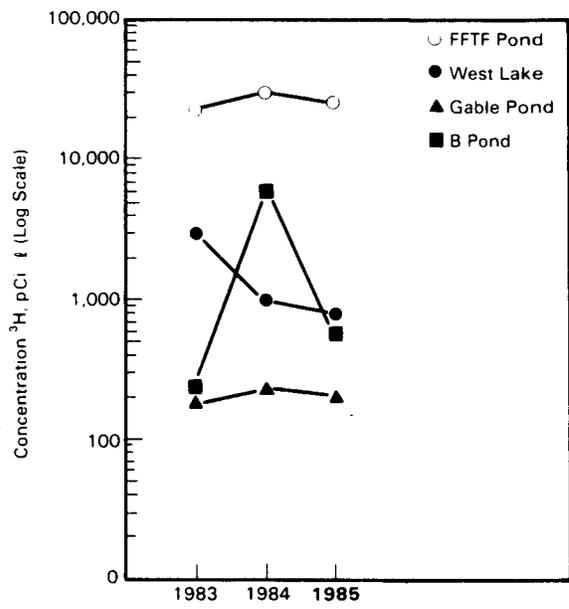


FIGURE 30. Annual Average Tritium Concentrations Measured in Onsite Ponds, 1983 to 1985

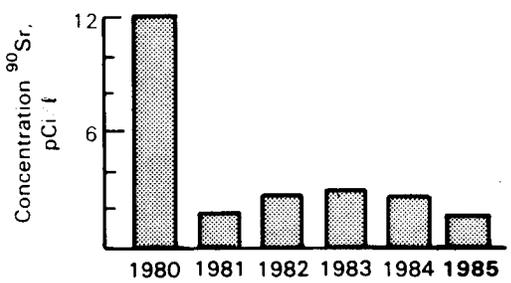


FIGURE 31. Annual Average ⁹⁰Sr Concentrations Measured in B Pond Water, 1980 to 1985

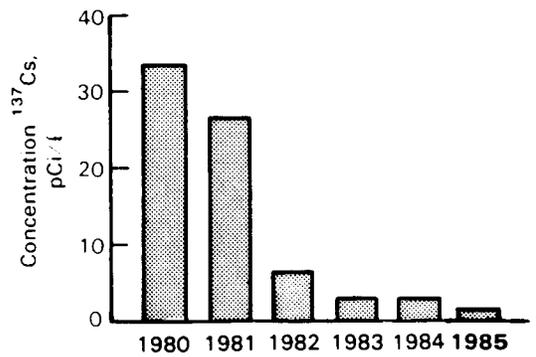


FIGURE 32. Annual Average ¹³⁷Cs Concentrations Measured in B Pond Water, 1980 to 1985

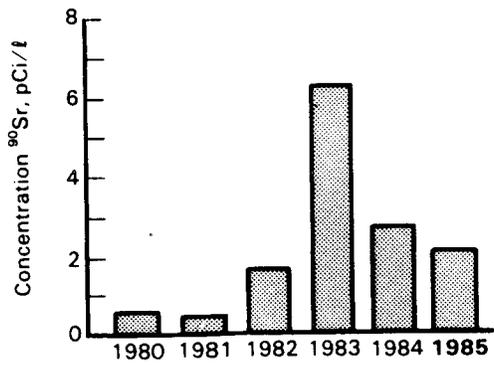


FIGURE 33. Annual Average ^{90}Sr Concentrations Measured in Gable Pond Water, 1980 to 1985

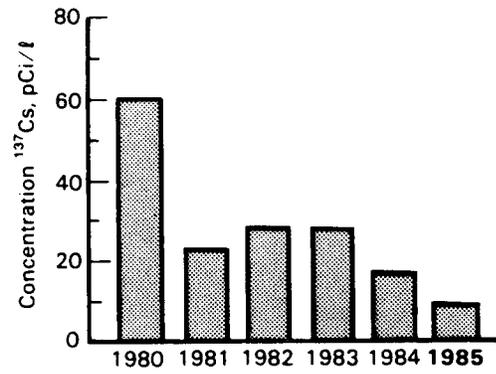


FIGURE 34. Annual Average ^{137}Cs Concentrations Measured in Gable Pond Water, 1980 to 1985

FOODSTUFFS MONITORING

Alfalfa and several types of foodstuffs, including milk, leafy vegetables, fruits, beef, chickens, eggs, and wheat, were collected at several locations in the Hanford Site environs during 1985 (Figure 35). Samples were collected primarily from locations in the prevalent downwind directions (i.e., to the south and east of the Site). Samples were also collected in generally upwind directions somewhat distant from the Site to provide information on radioactivity levels that could be attributed to worldwide fallout. Foodstuffs collected in the Riverview Area (see Figure 35) had been irrigated with Columbia River water collected from downstream of the Site. All samples were analyzed for ^{90}Sr and ^{137}Cs . Milk samples also were analyzed for ^{129}I , ^{131}I , ^{89}Sr , and tritium. Fruit samples were analyzed for ^3H , ^{90}Sr , and ^{137}Cs .

Low levels of tritium, ^{90}Sr , and ^{137}Cs were found in a number of foodstuff samples collected during 1985; however, the concentrations measured in samples collected near the Hanford Site were similar to those measured in samples collected away from the Site. In addition, ^{131}I was detected at very low levels in a small percentage (6%) of the individual milk samples. However, the annual average concentrations of ^{131}I were less than the uncertainty associated with the calculated average in all sampling areas. There are no radionuclide concentration limits for foodstuffs. Impact was assessed by predicting radiation dose from food consumption (as discussed in the "Radiological Impact from Hanford Operations" section).

MILK

Samples of raw, whole milk were collected from several dairy farms near the Site perimeter and in the prevalent downwind directions to evaluate possible Hanford impacts. Samples also were collected from dairy farms near Sunnyside and Moses Lake to provide indications of the general concentrations of radionuclides in milk attributable to worldwide fallout. The sampling locations are shown in Figure 35 and listed in Table A.16, Appendix A. Samples were collected every other week throughout the year from the Sagemoor and Sunnyside areas. Samples from the other areas were collected monthly during the year.

Iodine-131 was detected in six individual milk samples (6% of total) collected during different times of the year in the Sagemoor, Wahluke, Riverview, Sunnyside, and Moses Lake areas. All concentrations were just above the detection level and annual average concentrations of ^{131}I in milk were less than the uncertainty associated with the average.

Cesium-137 was identified in about 14% of the samples. Concentrations in all cases were low

and within the range attributable to worldwide fallout (USEPA 1985a).

A portion of each milk sample was analyzed for ^{89}Sr and ^{90}Sr . Strontium-89 was not regularly detected in the milk; however, ^{90}Sr was observed in most samples analyzed. Maximum and average concentrations were similar at all locations, both near and distant, and were comparable to concentrations observed in recent years. Average ^{137}Cs and ^{90}Sr concentrations in milk for 1985 and the previous five years are shown in Figure 36. The effects of atmospheric nuclear testing are reflected in the somewhat higher ^{137}Cs values for 1980, while the ^{90}Sr data have been consistently low for the past several years.

Analyses for ^3H and ^{129}I were performed on selected milk samples in 1985. Tritium was identified in half of the samples, and ^{129}I in all of the samples. Concentrations, however, were low, and no differences were apparent between near-site and distant sampling locations.

LEAFY VEGETABLES

Samples of leafy vegetables (i.e., spinach, leaf lettuce, or cabbage) were obtained once during

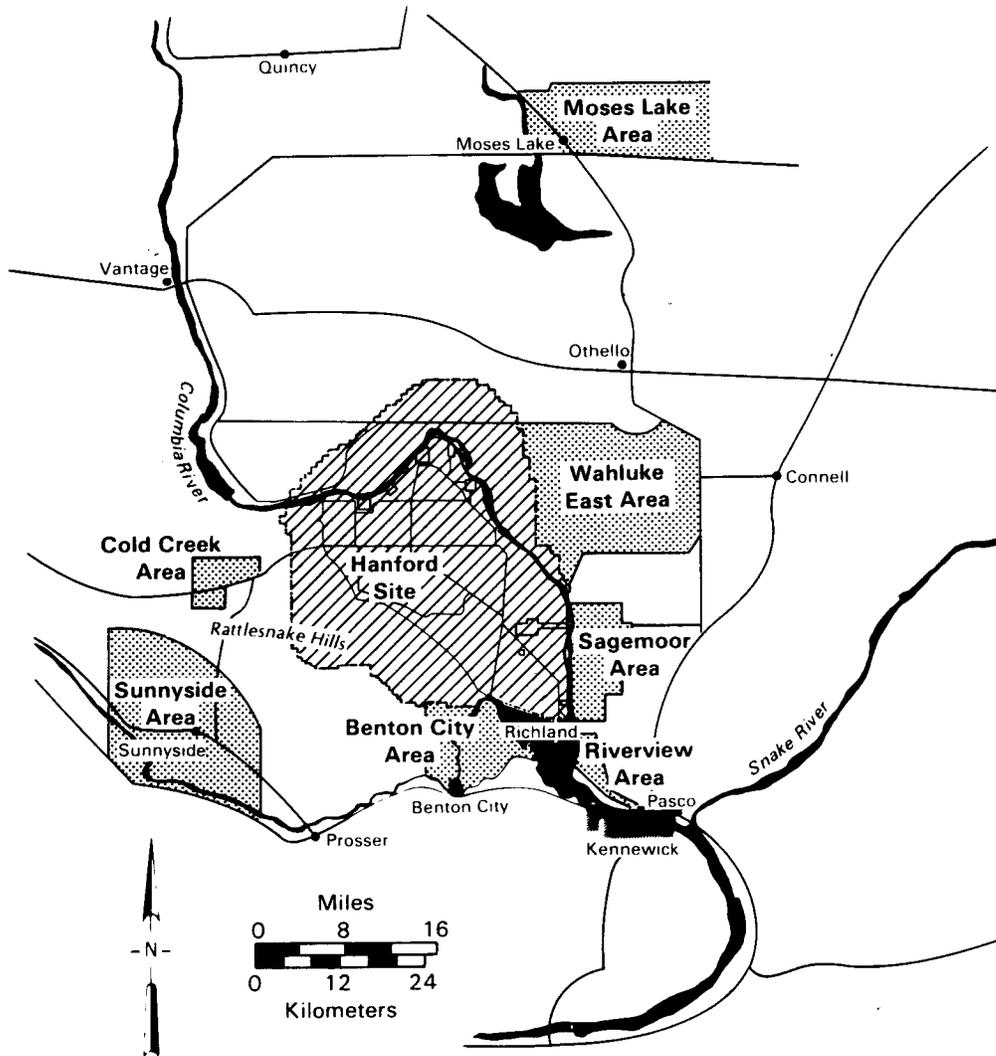


FIGURE 35. Foodstuffs Sampling Areas

the summer from gardens located within the sampling areas listed in Table A.17, Appendix A. The leafy vegetables provided an indication of radionuclides present in locally grown produce. Three replicate samples, each composed of mixtures of the edible portions of the various leafy vegetables grown at the sampling locations, were obtained. Samples were analyzed for ^{90}Sr and ^{137}Cs , and results are provided in Table A.17, Appendix A. Strontium-90 was identified in most samples but with no apparent difference between distant and nearby locations. Cesium-137 was identified in about 22% of the samples, without any indication of a difference between locations. There were no significant changes in

^{90}Sr and ^{137}Cs concentrations when compared to recent years, as shown in Figure 37.

FRUIT

Samples of apples, cherries, and grapes were collected during harvest from the areas listed in Table A.18, Appendix A. Three replicate samples were collected at each sampling location, and the edible portions were analyzed for ^3H , ^{90}Sr , and ^{137}Cs . Results are provided in Table A.18.

Tritium was identified in about one-third of the samples analyzed, and ^{90}Sr in about 85% of the samples. Grapes had slightly higher ^3H concentrations than the other fruits, but otherwise

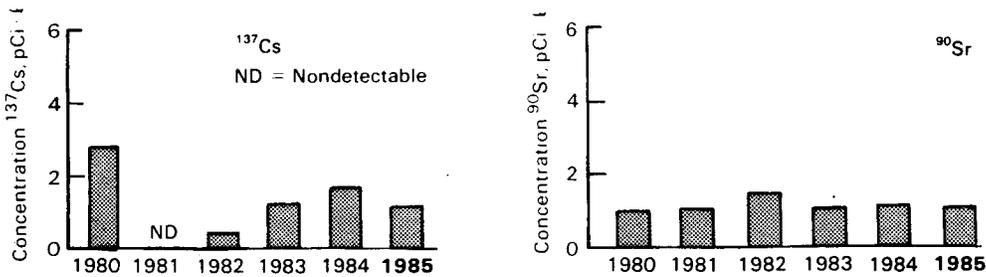


FIGURE 36. Annual Average ¹³⁷Cs and ⁹⁰Sr Concentrations Measured in Milk, 1980 to 1985

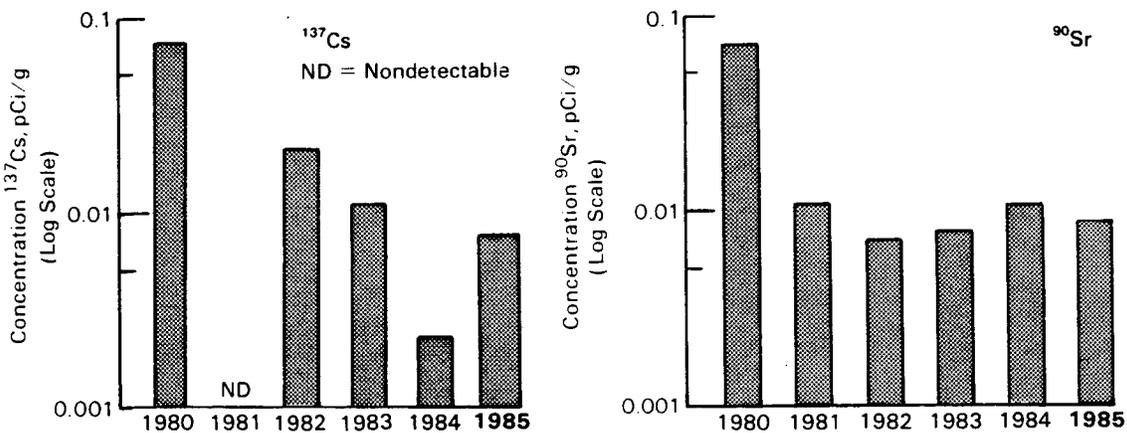


FIGURE 37. Annual Average ¹³⁷Cs and ⁹⁰Sr Concentrations Measured in Leafy Vegetables, 1980 to 1985

there were no apparent differences between fruit types or sampling locations. As in recent years, ¹³⁷Cs was generally not detectable in fruit samples.

WHEAT AND ALFALFA

Samples of ripened wheat and mature alfalfa were collected from the areas listed in Table A.19, Appendix A. Three replicate samples, each of wheat and alfalfa, were collected at each location and analyzed for ⁹⁰Sr and ¹³⁷Cs. Results of the analysis are shown in Table A.19, Appendix A.

When sampling of wheat and alfalfa began in 1982, variable moisture content in the samples from different locations may have contributed

to the variability in the 1982 results. Beginning in 1983, samples were reported on a dry weight basis, eliminating variability caused by different moisture contents. In 1985, as in 1984, ⁹⁰Sr was identified in nearly all of the samples, and ¹³⁷Cs was identified in very few samples. No distinct difference in radionuclide concentrations was apparent between samples collected near the Site and those collected far from the Site.

BEEF, POULTRY, AND EGGS

Samples of locally produced chickens, eggs, and beef were collected from the areas listed in Table A.20, Appendix A. Table A.20 provides results of analysis of the samples for ¹³⁷Cs and ⁹⁰Sr.

Results were all very low and generally near detection levels. Cesium-137 and ⁹⁰Sr concentrations in beef for 1985 and the previous 5 years are shown in Figure 38.

SPECIAL RIVERVIEW FOODSTUFF SAMPLING

The potential radiation dose to the hypothetical maximally exposed individual was calculated for an individual who was a long-term resident of the Riverview area (see "Radiological Impact from Hanford Operations" section). A major contributor to the estimated dose was ⁹⁰Sr from Columbia River water that was used to irrigate foodstuffs grown in the Riverview area. A special

effort was made in 1985 to collect samples consisting of a variety of fruit and vegetables from the Riverview area. Potatoes, carrots, beets, tomatoes, beans, corn, apples, and grapes were collected from farms and analyzed for ⁹⁰Sr, ³H, and gamma-emitting radionuclides. All results were similar to concentrations found in foodstuffs from other sampling areas, and no measurable effect from the use of Columbia River water for irrigation was detected. Results are shown in Table A.21, Appendix A.

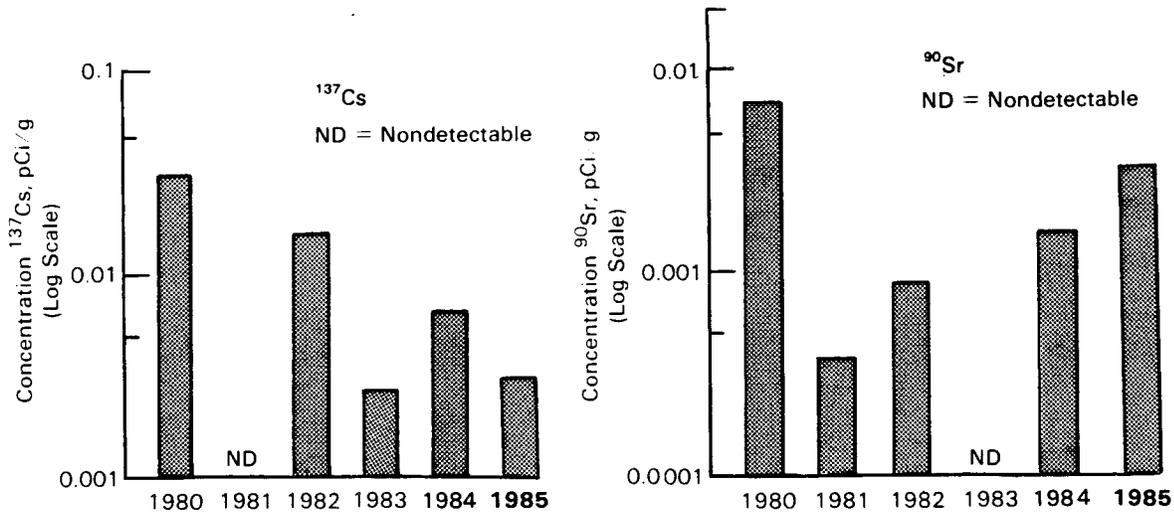


FIGURE 38. Annual Average ¹³⁷Cs and ⁹⁰Sr Concentrations Measured in Beef, 1980 to 1985

WILDLIFE MONITORING

The Hanford Site serves as a refuge for waterfowl, upland game birds, and a variety of other animals. Wildlife have access to several areas near site facilities that contain low levels of radionuclides attributable to site operations (e.g., waste-water ponds). Sampling was performed in areas where the potential existed for wildlife to take in radionuclides (see Figure 39). The number of animals that visited these areas was small compared to the total wildlife population in the region, and, as a result, human consumption of animals from the sampling locations was unlikely. Nevertheless, these samples helped provide an estimate of the potential dose impact if onsite game animals were consumed.

Fish were collected from the Hanford reach of the Columbia River. Results provided an indication of the radionuclide concentrations in local fish so that the potential dose to humans from this pathway could be evaluated. Fish collected from the Hanford reach of the Columbia River showed no important difference in radionuclide concentration compared to upstream samples. Analytical results of terrestrial wildlife samples collected during 1985 were similar to those observed in recent years. The dose that could have been received by consuming any of the sampled wildlife at the maximum radionuclide concentrations measured in 1985 was well below applicable DOE dose standards.

DEER

Samples taken from road-killed deer (Figure 39) were used to provide an indication of the general levels of radionuclides in Hanford Site deer. Four deer were sampled and analyzed for ^{137}Cs in muscle and $^{239,240}\text{Pu}$ in liver. Results indicated the presence of detectable levels of ^{137}Cs (0.02 pCi/g) in only one deer. The liver of one animal contained detectable quantities of $^{239,240}\text{Pu}$ at 0.0002 pCi/g. The concentrations were in the range generally attributed to worldwide fallout, and the median values were consistent with those observed in previous years, as shown in Figure 40. Individual results for 1985 are shown in Table A.22, Appendix A.

In addition, a specially selected deer was collected in the vicinity of B Pond near the 200 Area (Figure 39). This animal was part of a group studied during 1981-1982 to determine the probable maximum ^{137}Cs concentration in muscle tissue of deer residing on the Hanford Site (Eberhardt, Hanson, and Cadwell 1982). As part of the study, deer were captured and fitted with radio-transmitting collars to track their movements. Although this deer was no longer tracked by radio, it was reasonable to assume that it continued to reside in the vicinity of B Pond during 1985, based on tracking results during the study.

Analytical results showed a slightly higher ^{135}Cs concentration (0.52 pCi/g) in muscle tissue compared with the road-killed deer. The $^{239,240}\text{Pu}$ concentration in the liver sample was undetectable.

FISH

Fish were collected at various locations along the Columbia River (see Figure 39), and boneless fillets were analyzed for ^{60}Co , ^{90}Sr , and ^{137}Cs . Median concentrations for ^{60}Co and ^{137}Cs in whitefish and bass in recent years are shown in Figure 41. Whitefish were collected both upstream of Hanford near Priest Rapids Dam and within the Site near the 100D Area. Bass were collected near the 100F Area. Individual results for ^{60}Co , ^{90}Sr , and ^{137}Cs for 1985 are shown in Table A.23, Appendix A.

Cesium-137 was identified more frequently in whitefish samples collected along the Hanford reach of the river near the 100D Area than in samples collected upstream of the Site, but the concentrations were not quantifiably different. The maximum and average concentrations of ^{90}Sr in whitefish fillets from samples collected near the 100D Area were slightly higher than those collected near Priest Rapids Dam. On the other hand, ^{60}Co was detected more frequently in whitefish samples collected near Priest

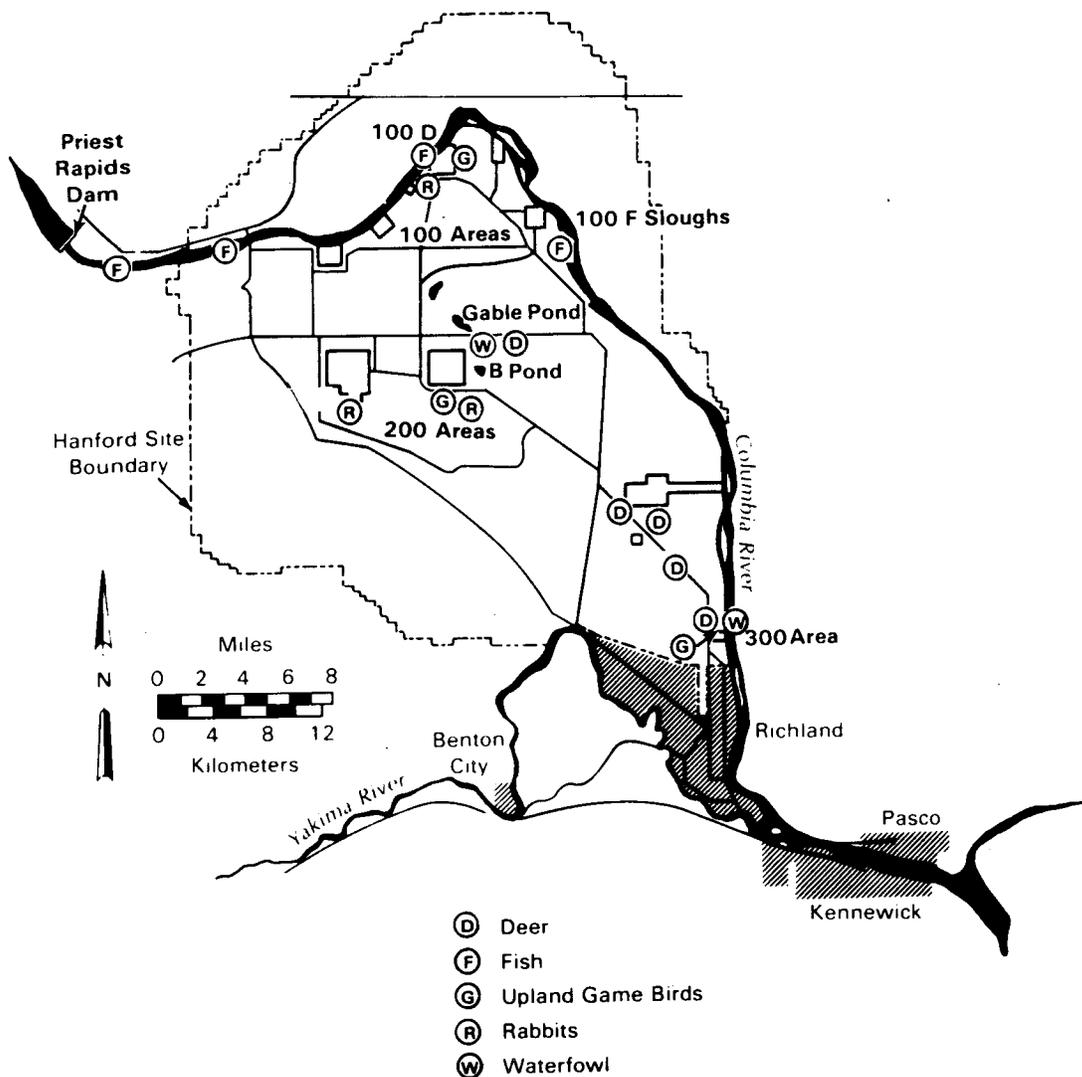


FIGURE 39. Wildlife Sampling Areas

Rapids Dam than in samples collected near the 100D Area.

The presence of ^{90}Sr in whitefish at both sample collection areas is accounted for by the migratory pattern of whitefish along the Hanford reach of the Columbia River. The whitefish population in the Columbia River near the Hanford Site migrates upstream toward Priest Rapids Dam in the fall and winter to spawn. Therefore, the whitefish population upstream probably includes fish that have resided near or below reactor areas. The presence of ^{60}Co in the fish collected upstream may thus be associated with

residual radioactivity in sediments of the Columbia River from past operations or effluent releases from the N Reactor.

UPLAND GAME BIRDS

Upland game birds, primarily pheasant and chukar, were collected from the 100, 200, and 300 Areas (Figure 39). Samples of breast meat from each bird were analyzed for ^{60}Co and ^{137}Cs . A slightly higher percentage of the birds showed detectable concentrations of ^{137}Cs than of ^{60}Co . The median concentrations for ^{137}Cs in the 100 and 200 Areas are shown in Figure 42 and are

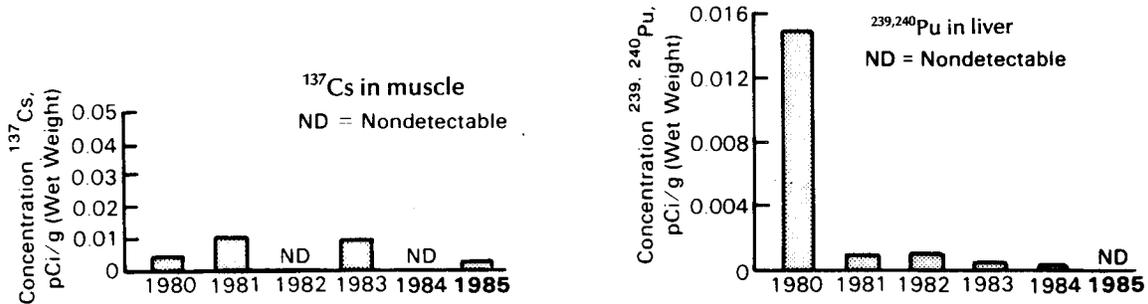


FIGURE 40. Median Concentrations of ¹³⁷Cs and ^{239,240}Pu Measured in Deer Muscle and Liver, 1980 to 1985

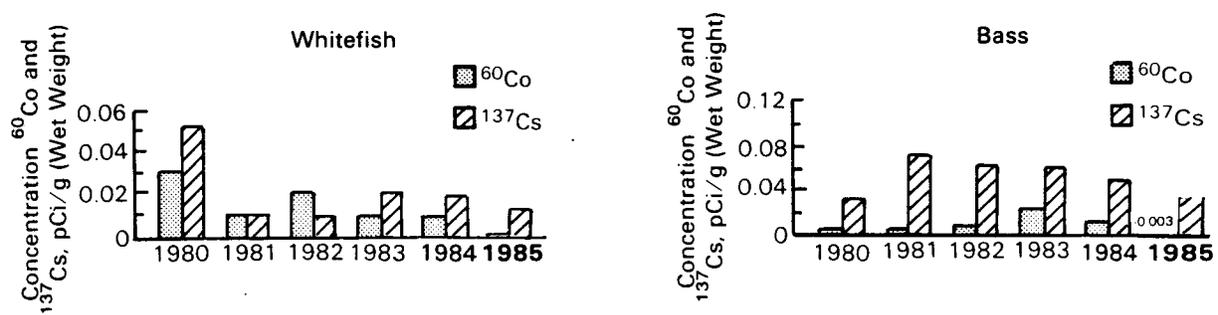


FIGURE 41. Median Concentrations of ⁶⁰Co and ¹³⁷Cs Measured in Whitefish and Bass, 1980 to 1985

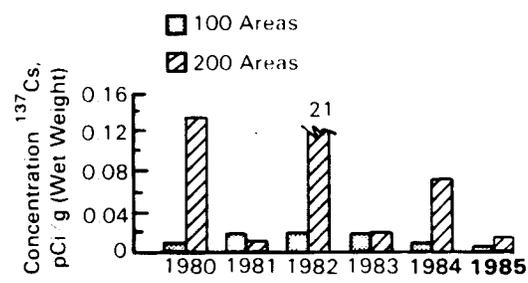


FIGURE 42. Median Concentrations of ¹³⁷Cs Measured in Game Birds from the 100 and 200 Areas, 1980 to 1985

within the ranges observed during previous years. Median ^{137}Cs concentrations in the 300 Area were lower than in the other areas. Cobalt-60 concentrations were near minimum detectable levels, with the maximum sample at 0.02 pCi/g. Maximum and average concentrations for 1985 for both nuclides are shown in Table A.24, Appendix A.

WATERFOWL

Waterfowl samples (mallard ducks) were collected from B Pond in the 200 Area and the 300 Area Trench (Figure 39). An approximately 0.5-kg sample of breast meat from each bird was analyzed for ^{137}Cs . The results illustrated in Figure 43 show decreasing concentrations in ducks collected from B Pond over the last several years. Concentrations in samples collected from the 300 Area Trench in 1985 were about one fifth those in the 200 Area, as shown in Table A.25,

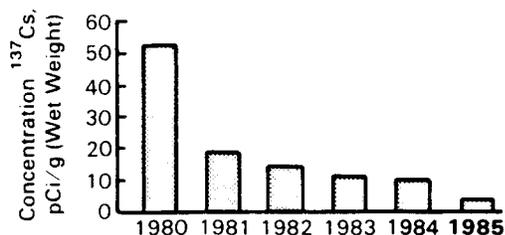


FIGURE 43. Median Concentrations of ^{137}Cs Measured in Mallard Ducks from 1980 to 1985

Appendix A. Samples have been taken in previous years from other operating areas, from along the Columbia River, and from Gable Pond and U Pond, and these are reported in earlier annual reports. Gable Pond was being decommissioned in 1985 and ducks were not readily available. U Pond was decommissioned in 1984.

RABBITS

Cottontail and black-tailed jack rabbits were collected from near the 100 and 200 Areas during 1985. The samples were analyzed for gamma-emitting radionuclides in muscle, ^{90}Sr in bone, and plutonium in liver. Median concentrations for ^{90}Sr in bone and ^{137}Cs in muscle for the last several years are shown in Figures 44 and 45. Median concentrations in 1985 were within the range of previous years. Maximum and average concentrations for 1985 are shown in Table A.26, Appendix A.

No other gamma-emitting radionuclides of possible Hanford origin were detected in any samples at levels greater than expected from worldwide fallout. Concentrations of $^{239,240}\text{Pu}$ in liver samples ranged from less than detectable to values near the detection limit (0.0006 pCi/g), with only one sample, at 0.003 pCi/g, significantly above the detection limit.

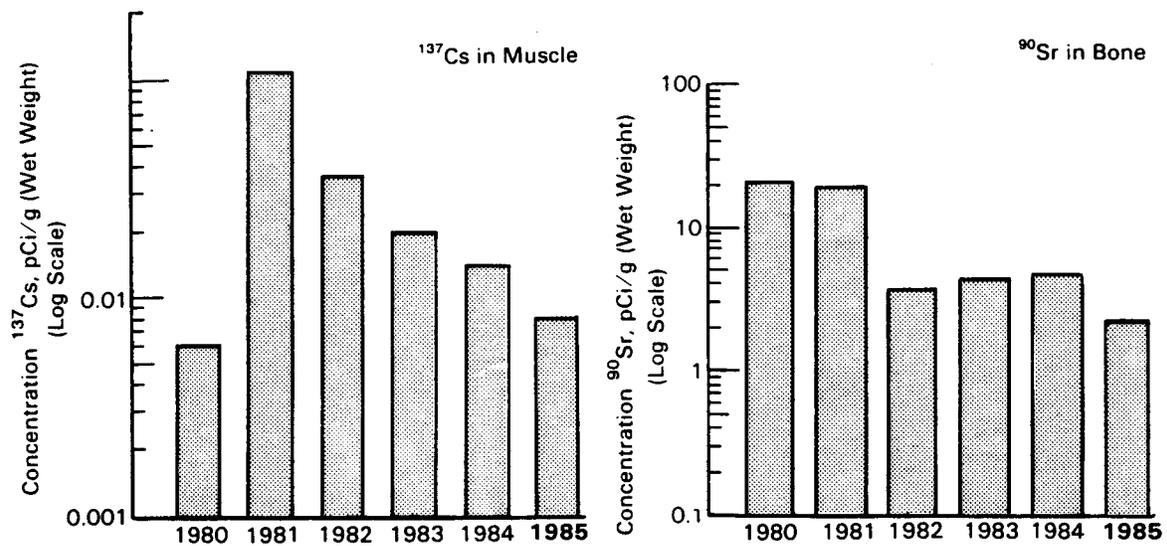


FIGURE 44. Median Concentrations of ^{137}Cs Measured in Muscle and ^{90}Sr Measured in Bone of Cottontail Rabbits in the 100 Area, 1980 to 1985

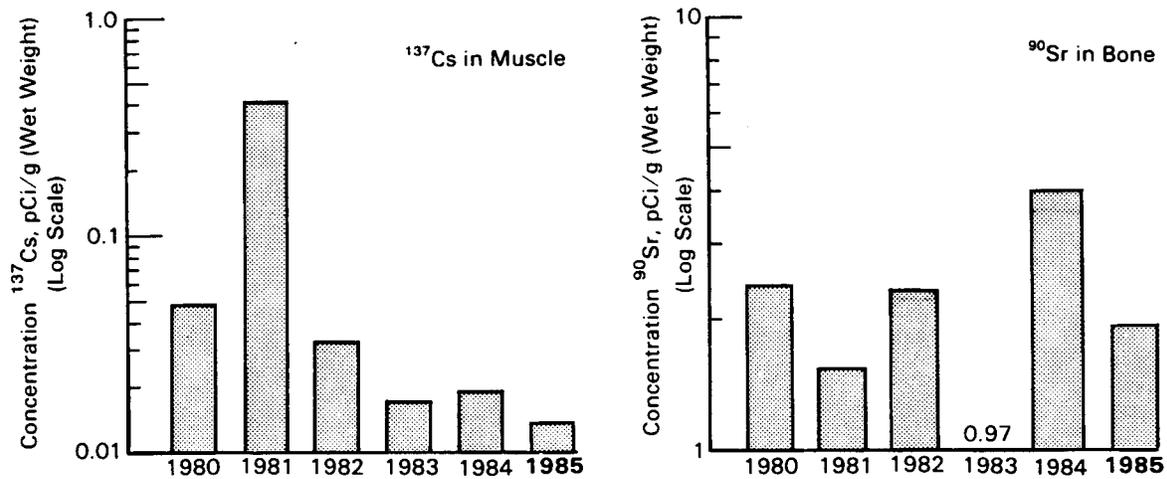


FIGURE 45. Median Concentrations of ^{137}Cs Measured in Muscle and ^{90}Sr Measured in Bone of Jack Rabbits in the 200 Areas, 1980 to 1985

SOIL AND VEGETATION MONITORING

Surface soil and rangeland vegetation samples were collected at a number of locations during 1985, both onsite and offsite. The purpose of sampling was to detect the buildup of radionuclides from the deposition of airborne effluents released from Hanford facilities. Samples were collected at non-agricultural, undisturbed sites so that natural deposition and buildup processes would be represented. Because the radionuclides of interest were present in worldwide fallout or occurred naturally as well as in Hanford effluents, their presence was expected, to some extent, in all samples.

An assessment of radionuclide contribution from Hanford operations was made by comparing the results of samples collected onsite with those collected offsite, the results of samples collected around the Site perimeter with those collected at distant locations, and the results of samples collected downwind (primarily east and south of the Site) with those collected from generally upwind and distant locations. In addition, sample results obtained from a specific location in 1985 were compared to results obtained from the same location during previous years. Evaluations of 1985 sample results provided no indication of significant trends or important increases in the concentrations of radionuclides in the offsite environment that could be attributable to Hanford operations. Results of a special study noted the presence of Hanford-derived plutonium in some offsite soil samples. Another special study investigated ^3H in native trees growing on the Hanford Site.

SAMPLE COLLECTION AND ANALYSIS

Soil and vegetation samples were collected at the 15 onsite and 16 offsite locations shown in Figure 46, with one exception. Vegetation was not available at one onsite location as a result of the 1984 fire. In addition, two new soil sampling sites were established during 1985, one at McNary Dam and one near Walla Walla. Most of the onsite sampling locations were adjacent to major operating areas where the contribution of radionuclides from operations could be readily assessed. The majority of the offsite samples were collected in a generally downwind direction of the Site, where any Hanford contribution to radionuclide levels in soil and vegetation would be expected to be most easily detected. Samples were also collected in a generally upwind direction for comparison.

Single composited samples of surface soil were collected at each of the locations. Each sample was made up of five "plugs" of soil, approximately 2.5-cm deep and 10-cm in diameter, obtained within a 100-m² area at the sampling site. The samples were dried, sieved through a 2-mm screen, and thoroughly mixed. Aliquots of this well-mixed composite sample were analyzed for gamma-emitting radionuclides, ^{90}Sr , plutonium, and uranium.

Samples of perennial vegetation were collected in the immediate vicinity of the soil sample locations when soil samples were collected. Vegetation samples included a mixture of rabbitbrush, sagebrush, and bitterbrush in roughly the same proportions as occurred naturally at the specific sample site. The vegetation samples were collected by cutting a small amount of recent growth from a sufficient number of plants in the area to make up a sample weighing approximately 1 kg. The sample was then dried and ground, and aliquots were taken for analysis. Vegetation samples were analyzed for gamma-emitting radionuclides, ^{90}Sr , plutonium, and uranium.

SOIL RESULTS

Analytical results from soil samples collected onsite and offsite during 1985 are reported in Table A.27 through Table A.30, Appendix A. Also included in these tables for each specific location are the individual results observed during the previous 5 years and the mean of the results from each location for this time period. For comparative purposes, the means of the results from all onsite locations and all offsite locations are provided as well. Several new sample locations

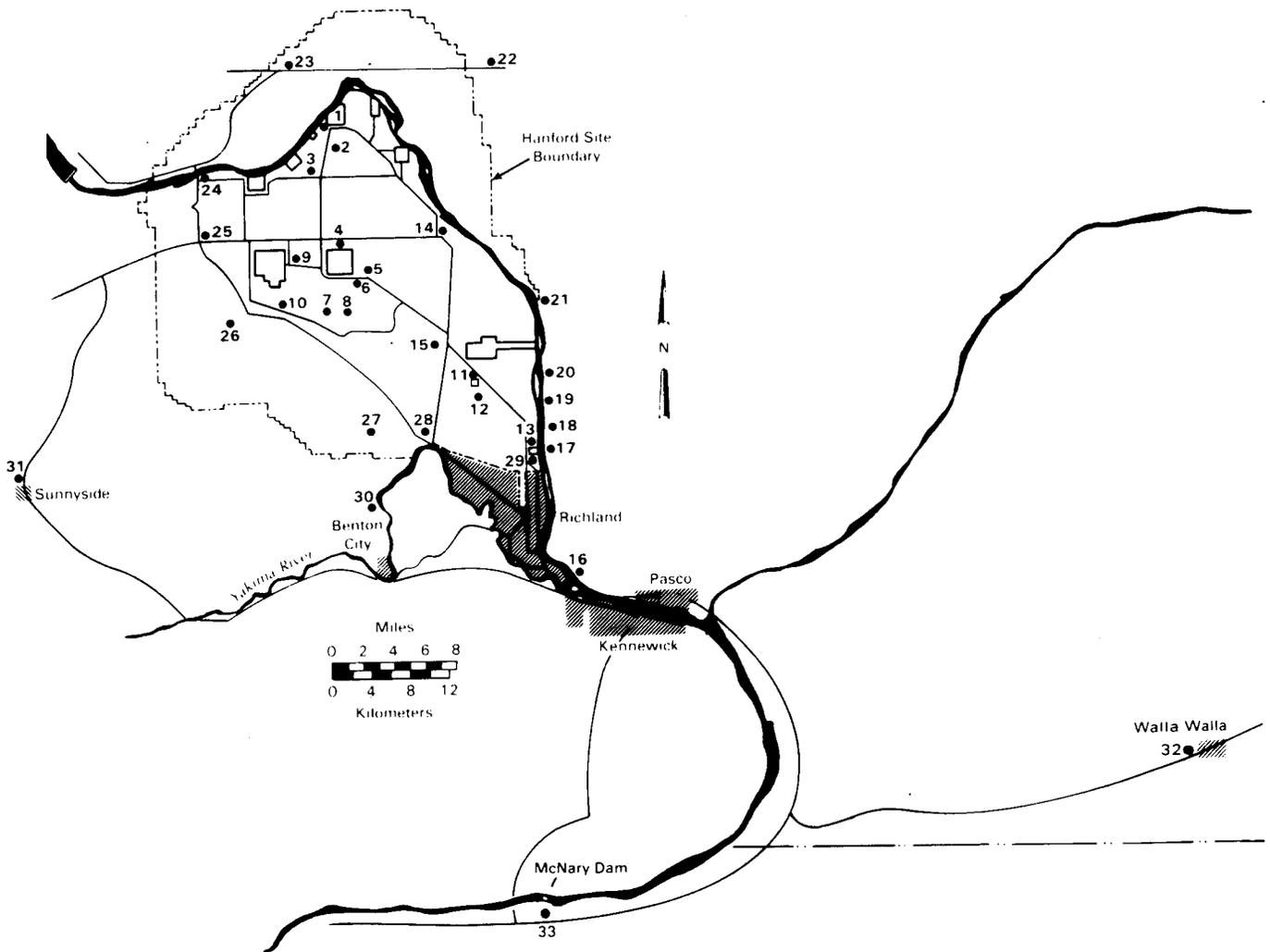


FIGURE 46. Soil and Vegetation Samples Collected at Onsite and Offsite Locations

were established during 1982 as a result of program revisions and expansions; therefore, there are gaps in the data tables for years before 1982.

Radionuclide concentrations observed in individual onsite soil samples during 1985 were similar to those observed in previous years. Although some variability was evident between sampling locations, the means of onsite soil sample results for specific radionuclides were similar to those observed during previous years. As expected, locations near operating areas, the

200 Area in particular, continue to show slightly elevated concentrations for a few radionuclides. Specifically, the 200 ENC (Figure 46, Number 4) sample showed elevated levels of ^{90}Sr and ^{137}Cs , and the E of 200W (Figure 46, Number 9) sample exhibited elevated levels of $^{239,240}\text{Pu}$, as had been the case during previous years.

The offsite soil sample results were similar to those collected during the past several years, as reflected in both the individual sample results and the mean of all offsite sample results. The histograms in Figure 47 display ^{90}Sr , ^{137}Cs ,

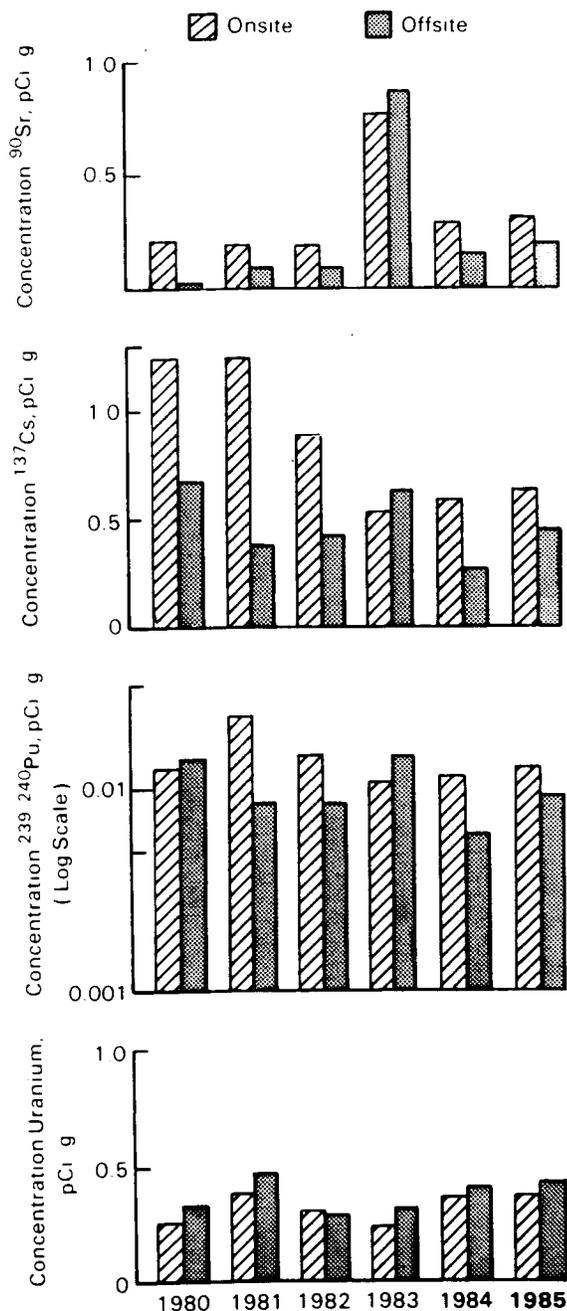


FIGURE 47. Median ⁹⁰Sr, ¹³⁷Cs, ^{239,240}Pu, and Uranium Concentrations Measured in Soil at all Onsite and Offsite Locations, 1980 to 1985

^{239,240}Pu, and uranium median values for all samples collected at the onsite and offsite locations during 1985. The median values rather than the means are plotted because of the small number of samples and the high degree of variability in the results. As these illustrate, radionuclide concentrations tend to be slightly elevated at onsite locations compared with offsite locations, with the exception of uranium. As has been the case in previous years, the offsite uranium concentrations in soil were slightly higher than those observed onsite. Uranium is thought to occur naturally in the soil at several offsite sampling locations.

Further evaluation of the offsite sample results indicates that, with the exception of uranium, the radionuclide concentrations in soil collected at locations near the Hanford Site are similar to those collected at distant locations. Similarly, sample results from generally downwind offsite locations are in agreement with those from generally upwind sites. As has been observed in the past, radionuclide concentrations in soil are quite low and are in agreement with concentrations observed at other locations, although they do appear to be highly variable over time at a single location.

Isotopic Composition of Plutonium in Soil Samples

A special task was conducted to evaluate the plutonium measured in soil samples routinely collected for radionuclide analyses. The purpose was to estimate the amount of plutonium that may have accumulated in soil over past years of Hanford operations. The unique analytical method involved the determination of individual plutonium isotopes using a mass spectrograph technique.

Results are tabulated in Table A.31, Appendix A in the form of the ratio of ²⁴⁰Pu to ²³⁹Pu. The average ²⁴⁰Pu/²³⁹Pu value for worldwide fallout has been reported as 0.176 ± 0.014 (Krey et al. 1976). The average ²⁴⁰Pu/²³⁹Pu value for Hanford-derived plutonium is estimated to be 0.0676, based on measurements from samples of high-level waste (USERDA 1977). The formula given by Beasley (1981) was used to estimate the percentage of Hanford-derived ^{239,240}Pu from the

median ratio calculated for each sampling location. The percentage of Hanford-derived plutonium in soil samples collected from various onsite, onsite perimeter, and offsite locations is plotted in Figure 48. Data are arranged by sampling location in descending order from highest percentage to lowest percentage. This sensitive technique indicates that Hanford-derived plutonium historically has been added to the total amount of plutonium that has been detected in samples of soil collected from the local environment. The maximum amount of Hanford-derived plutonium detected onsite was from samples collected near the 200W Area (E of 200W

location). The calculated percentage shown in Figure 48 is greater than 100% because the plutonium in soil at that location is lower in the ^{240}Pu isotope (3.9%) than the average (6.0%) for plutonium produced at Hanford over the years. The maximum amount of Hanford-derived plutonium detected in samples collected offsite was about 17% for the Benton City area. Soil from the Sunnyside area contained virtually no Hanford-derived plutonium. The Hanford-derived plutonium probably has accumulated gradually over a number of years because the data given in Table A.31 for sites sampled in 1978, 1982, 1983, and 1984 do not show a sudden increase for any one year.

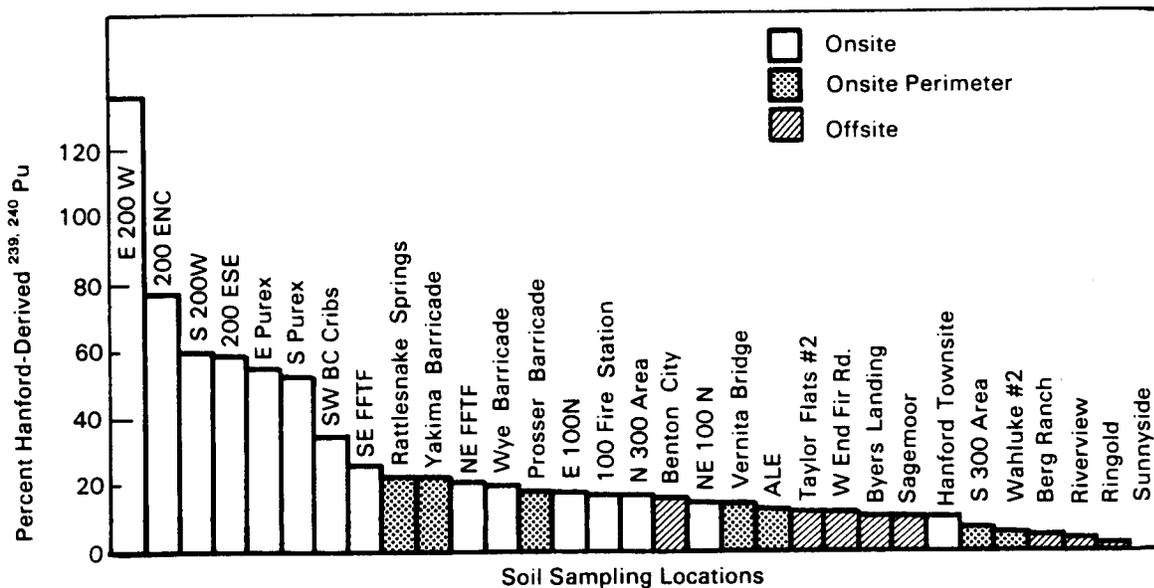


FIGURE 48. Calculated Percentage of $^{239,240}\text{Pu}$ Attributable to Hanford Activities at Each Sampling Location

VEGETATION RESULTS

Analytical results from samples of mature, perennial vegetation collected during 1985 are provided in Tables A.32 through A.35, Appendix A. As in the case of soil sample results, individual results observed during the previous five years at each location are shown along with the mean of the results for the same time period. The means of onsite and offsite sample results are also included for comparative purposes. The apparent gaps in the data prior to 1982 are due to expansions and revisions of the program during 1982.

Radionuclide concentrations observed in perennial vegetation samples collected onsite and offsite during 1985 were similar to those observed at the same locations during previous years. Figure 49 provides histograms illustrating the ^{90}Sr , ^{137}Cs , $^{239,240}\text{Pu}$, and uranium median values for samples collected at onsite and offsite locations. The median values are plotted rather than the means due to the small number of samples and the wide range of concentrations measured. As with the soil data, concentrations of radionuclides in onsite vegetation were slightly elevated when compared with offsite concentrations with the exception of uranium. Uranium concentrations in vegetation were slightly higher at offsite locations than at onsite locations.

Tritium in Hanford Site Trees

Ground water containing ^3H is widely dispersed in the unconfined aquifer beneath the Hanford Site (see "Ground Water Monitoring" section). In most instances, ground water is too deep to expect contact by plant roots. Trees are scarce on the Site. Only a few native trees are located near the river and some scattered trees grow near abandoned homesites. After more than 40 years without irrigation, the longevity of the surviving trees near the homesites suggests that their roots have access to ground water. A study was conducted during 1985 to determine if Hanford trees had access to ^3H in ground water and, if so, whether the trees could be useful as biological indicators of the presence of ^3H in ground water and so serve as an adjunct to environmental monitoring.

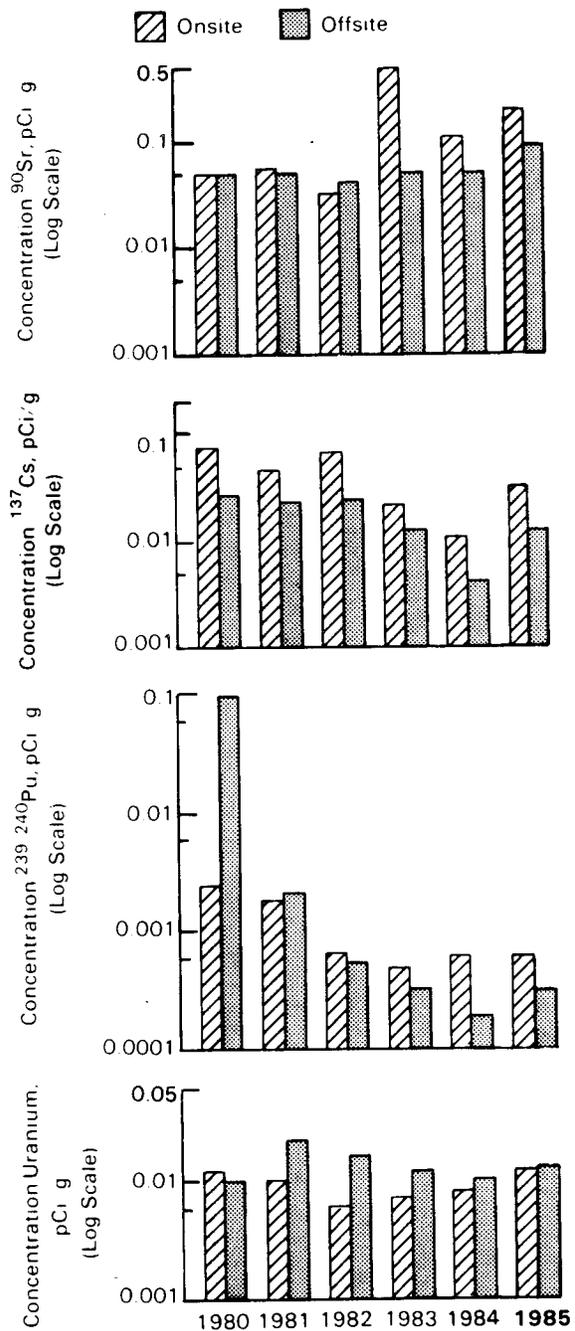


FIGURE 49. Median ^{90}Sr , ^{137}Cs , $^{239,240}\text{Pu}$, and Uranium Concentrations Measured in Vegetation at All Onsite and Offsite Locations, 1980 to 1985

Results shown in Figure 50 confirmed that a few trees on the site have access to tritiated ground water. The moisture in the leaves of these trees had concentrations ranging from 1000 to 14,000 pCi/l compared to background concentrations of less than 500 pCi/l.

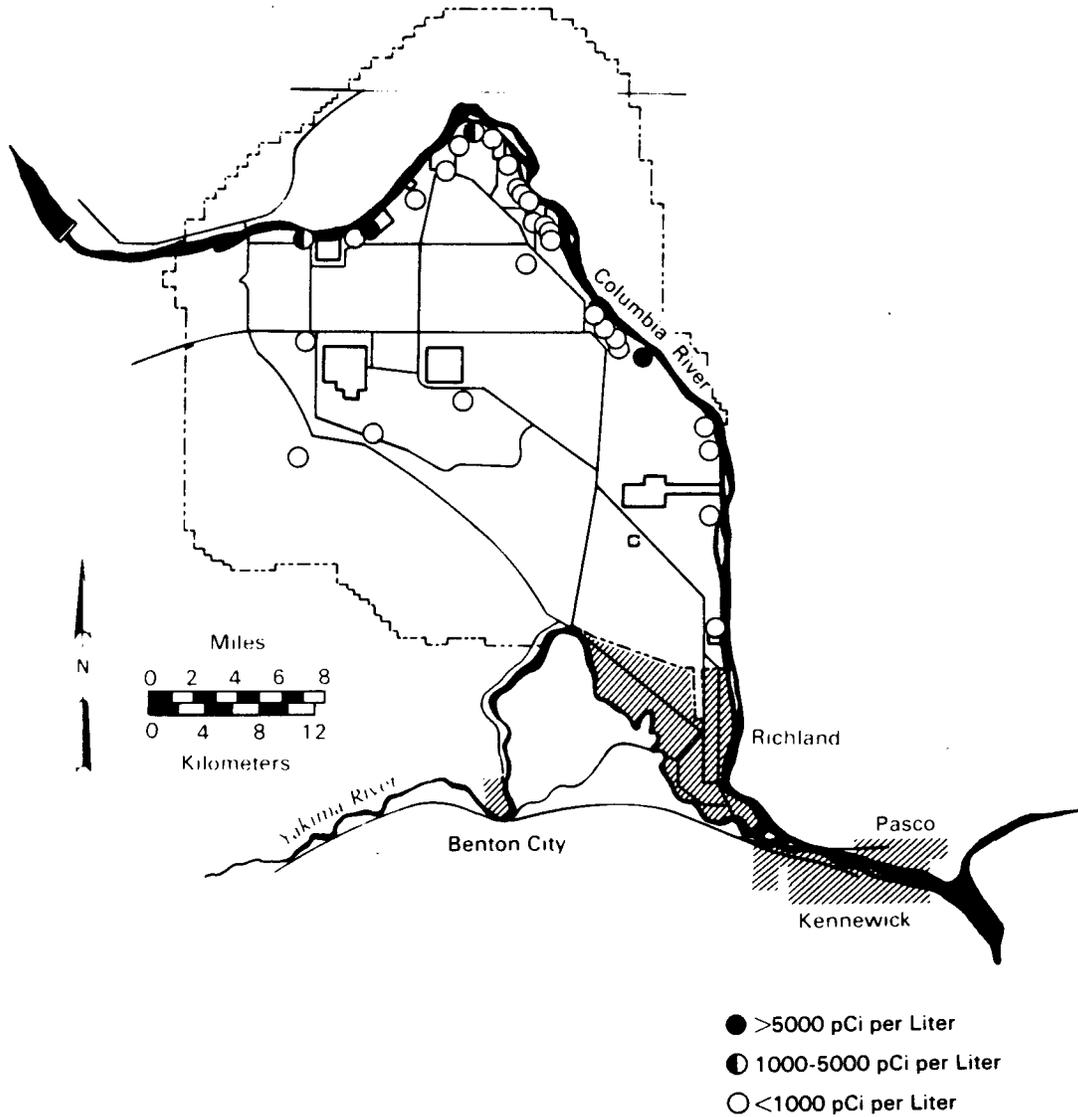


FIGURE 50. Tritium in Hanford Site Trees

PENETRATING RADIATION MONITORING

Dose rates from penetrating radiations (primarily gamma-rays) were measured at a number of locations in the Hanford environs during 1985. The measurements were made using thermoluminescent dosimeters (TLDs) to provide estimates of the dose rates from external radiation sources. Naturally occurring sources, including cosmic radiations and natural radioactive materials in the air and ground, as well as from worldwide fallout, resulted in a certain amount of penetrating radiation being recorded at all dosimeter locations. The dosimeters also measured dose rates from exposure to radioactive materials associated with activities at Hanford. Measurements made onsite and offsite were similar to past years. As expected, dose rates near operating facilities were somewhat higher than natural background rates.

Radiation surveys were conducted at numerous locations on the Hanford Site. Onsite roads, railroads, and retired waste-disposal sites located outside of operating areas were routinely surveyed during 1985. These surveys were designed to confirm the continued integrity of containment facilities and to identify areas where abnormal levels of radioactivity may have existed. Survey results for 1985 were comparable to past years. No unexpected or abnormal conditions were observed on the Site highways or railroads.

PENETRATING RADIATION MEASUREMENTS

External radiation measurements were made using environmental TLDs at numerous locations onsite, around the perimeter of the Site, in nearby and distant communities, and along the shoreline of the Columbia River. Environmental radiation dosimeters consisted of five $\text{CaF}_2:\text{Mn}$ thermoluminescent chips encased in a plastic capsule. The capsule contained a lead/tantalum filter to provide uniform dose response characteristics for penetrating radiations above 60 keV (Fix and Miller 1978). The dosimeters were mounted one meter above ground level and were exchanged every four weeks, with the exception of the shoreline TLDs, which were exchanged quarterly. Measured doses are reported in dose equivalent units (mrem) to allow comparison to dose standards and dose equivalents reported elsewhere in this document. The TLDs record radiation exposure from natural and fallout sources as well as any local contribution (NCRP 1975).

Dosimeters were placed at numerous locations in the vicinity of the Hanford Site and at several locations more distant from the Site, as shown in Figure 51. The dose rates measured at each location during 1985 are given in Table A.36, Appendix A. Offsite dosimeter locations were

chosen to represent areas that could have been inhabited continuously. Dose measurements at these locations are reported in units of mrem/yr. Results were similar to those observed in previous years for the same locations. The background dose rate, calculated from the annual average dose rates observed at distant locations, was slightly lower than in past years, at 59 mrem/yr (0.007 mrem/h). Dose rates measured in 1983 by the Washington State Department of Ecology at Seattle and Spokane were 58 mrem/yr and 97 mrem/yr, respectively (DSHS 1985). Figure 52 shows average annual dose rates measured at perimeter and distant locations during 1985 and the previous 5 years. The figure illustrates the natural year-to-year variability of penetrating radiations in the environs at both near and distant locations. The figure also demonstrates that dose rates at perimeter stations generally averaged several mrem/yr higher than the distant locations. The possibility that a release of radioactive material prior to 1974 might be a cause for the observed differences in dose rate is not substantiated by the soil and vegetation sampling data provided in this and previous annual reports. The differences may be due to natural geographic variations in terrestrial radiation.

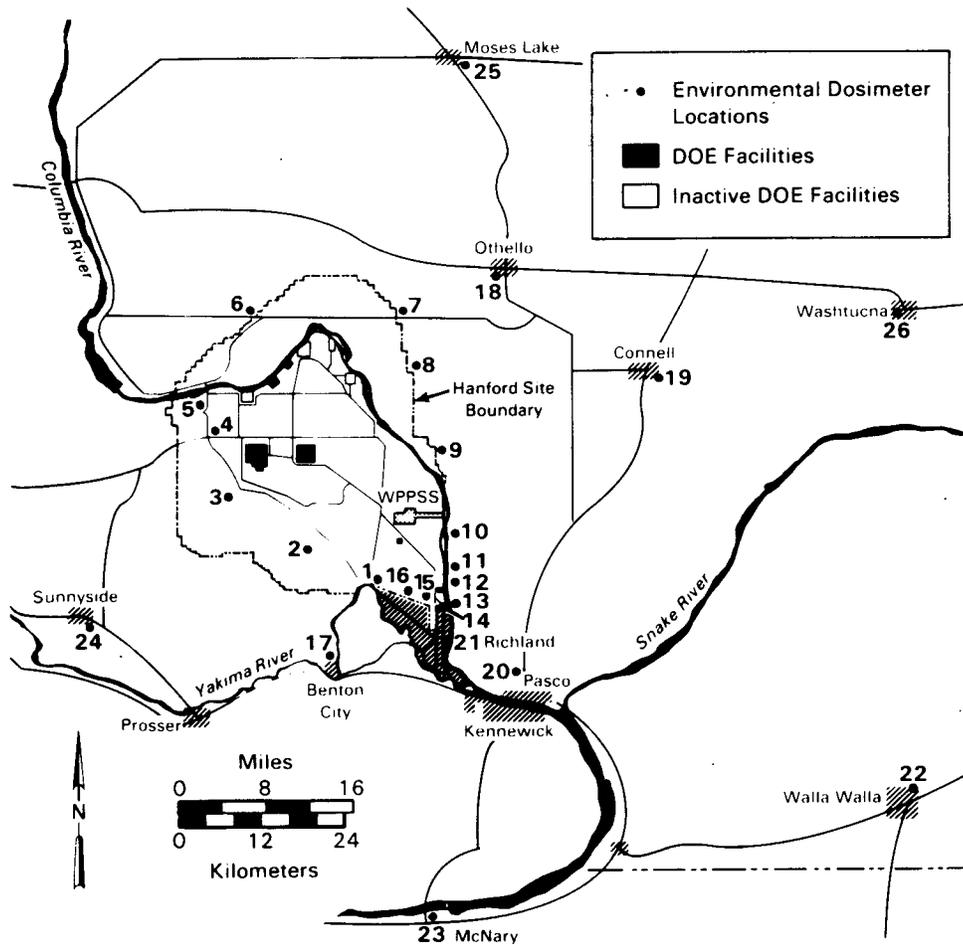


FIGURE 51. Environmental Dosimeter Locations at the Site Perimeter, Nearby Communities, and Distant Communities (see Table A.36, Appendix A for location number key)

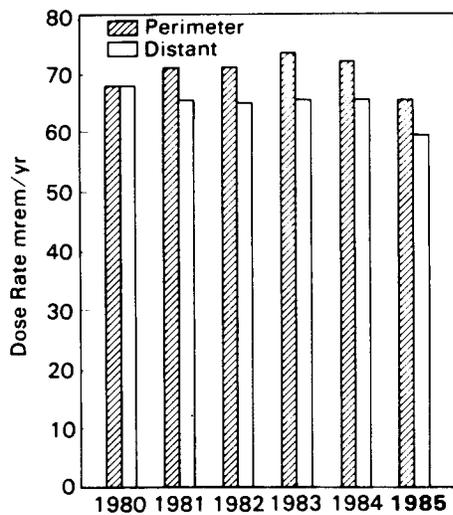


FIGURE 52. Annual Average External Dose Rates Measured at Perimeter and Distant Locations, 1980 to 1985

Dosimeters were submerged in the Columbia River at Coyote Rapids and at the Richland pumphouse (Figure 53) to provide an estimate of penetrating dose rates that could be received by a person immersed in the river. Results of the measurements, shown in Table A.37, Appendix A, were less than the background dose rate of 0.007 mrem/h measured on land. The average dose rates at the Coyote Rapids and Richland pumphouse locations were 0.004 mrem/h and 0.003 mrem/h, respectively, during 1985. As expected, these dose rates have remained low and relatively constant over the years.

Dosimeters were placed at several publicly accessible locations near the perimeter of operating areas on the Hanford Site as shown in Figure 54. These locations included the shoreline of the Columbia River near the 100N Area, parking lots near the west perimeter of the 300 Area, and the parking lot near the visitors center at the 400 Area (FFTF). Results of these measurements for

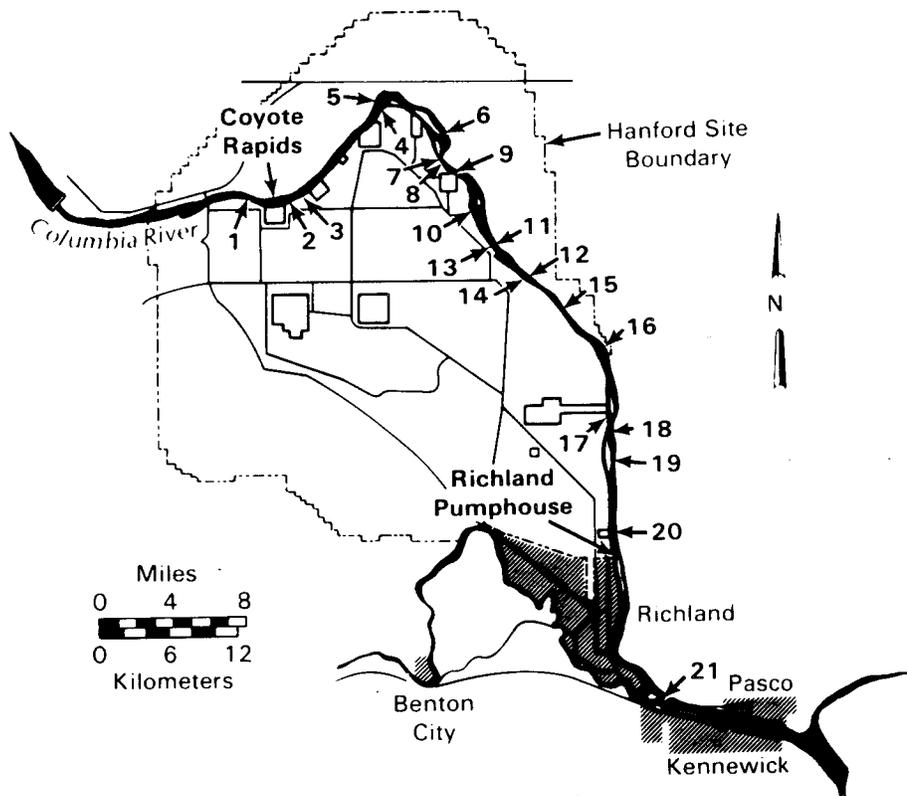


FIGURE 53. Environmental Dosimeter Locations Along the Hanford Reach of the Columbia River (see Table A.39, Appendix A, for location number key)

Figure removed as per DOE guidance.

FIGURE 54. Environmental Dosimeter Locations at Publicly Accessible Onsite Locations
(see Table A.38, Appendix A, for location number key)

1985 are shown in Table A.38, Appendix A. Results are reported as mrem/h (instead of mrem/yr) because the locations are not continuously occupied by the same person. Dose rates near the 100N Area on the river shoreline were slightly elevated but similar to those observed in previous years. The maximum dose rate recorded near 100N was 0.043 mrem/h, while the average varied between 0.007 and 0.025 mrem/h. Dose rates in this vicinity were attributed to waste-management activities within the 100N Area. Dose rates at publicly accessible locations along the west perimeter of the 300 Area were elevated slightly compared to normal background levels of 0.007 mrem/h. The highest dose rate measured along the west perimeter of the 300 Area was 0.028 mrem/h, recorded at a location near a research facility housing a radioactive steam generator currently under study. The average dose rate at the other 300 Area perimeter location near a publicly accessible area was also elevated (0.012 mrem/h). Dose rates near the visitors center at the 400 Area (FFTF) were at background levels, indicating no additional penetrating dose rate at this location could be attributed to FFTF activities during 1985.

Low levels of residual radioactivity (primarily ^{60}Co and ^{154}Eu) from past reactor operations in the 100 Areas can still be measured at several locations along the shorelines and on islands in the Hanford reach of the Columbia River. Radiation dose rates from these radionuclides were the subject of an extensive radiological survey in 1979 (Sula 1980). In 1980, based upon findings of the survey, dosimeters were placed in areas along the river (see Figure 53) where dose rates were determined to be slightly elevated with respect to background levels. Table A.39, Appendix A, provides results of measurements at these locations during 1985. Dose rates measured during 1985 were similar to those observed in recent years.

Onsite external penetrating radiation was measured at the locations shown in Figure 55. The results of these measurements are given in Table A.40, Appendix A. Dose rates above background were observed at several locations onsite during 1985. The elevated levels observed near the 100N

Area were attributed to short-lived, airborne noble gases and direct radiations from reactor operations and waste-handling and storage facilities. Dose rates at two of the 300 Area locations (locations #15 and #16 of Figure 55) were slightly elevated during 1985. These locations were near the facility where the steam generator was being examined, which accounted for the elevated levels. Dose rates around the 200 and 400 Areas were within the expected background levels.

RADIATION SURVEYS

Onsite roads, railroads, and inactive radioactive-waste disposal sites located outside of operating areas were routinely surveyed during 1985 to detect abnormal levels of radioactivity. The frequency of the surveys on specific routes for roads and railroads was based on their use and the potential for their contamination. The majority of the waste sites were surveyed on a semiannual basis during 1985. Specific routes and frequencies for surveys conducted during 1985 were defined in the master schedule (Blumer et al. 1984).

Roads, shown in Figure 56, were surveyed routinely using four scintillation detectors positioned approximately 0.5 m above the ground, evenly spaced across the width of a vehicle. No abnormal conditions were observed on the Site roadways surveyed during 1985.

Railroad routes, also shown in Figure 56, were surveyed using a small railcar with two scintillation detectors mounted approximately 0.3 m directly above the tracks. Railroad surveys conducted during 1985 did not reveal any abnormal conditions on the Site railways.

Inactive waste-disposal sites outside of the operating-area perimeter fences were surveyed during 1985 with portable instruments to detect changes in levels of external radioactivity. Sites also were visually inspected with respect to general physical conditions. In general, radiation surveys conducted during 1985 showed levels comparable to those observed in the past. Problems with respect to housekeeping or the maintenance of the integrity of the site were promptly reported to the responsible contractor for appropriate corrective action.

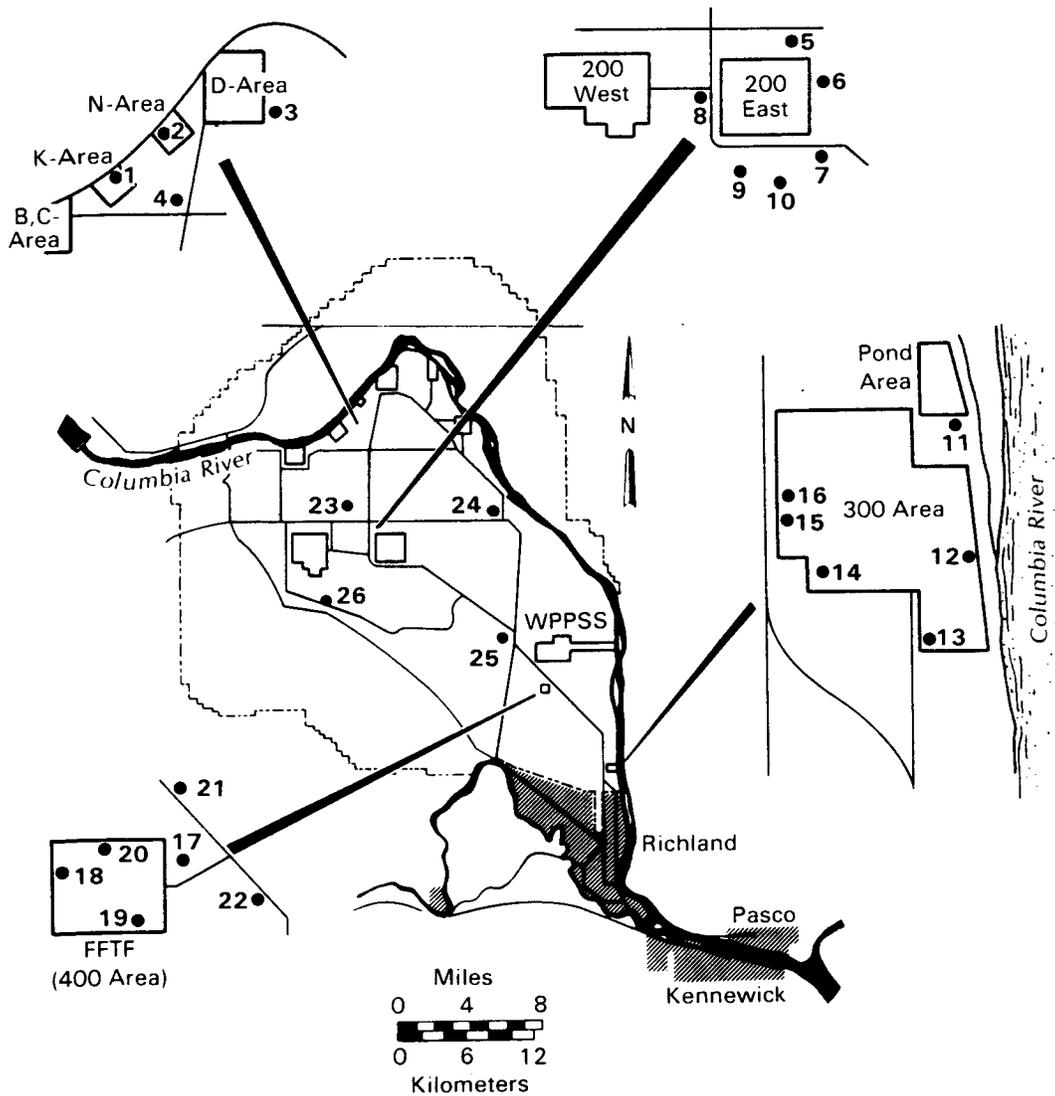


FIGURE 55. Environmental Dosimeter Locations on the Hanford Site (see Table A.40, Appendix A, for location number Key)

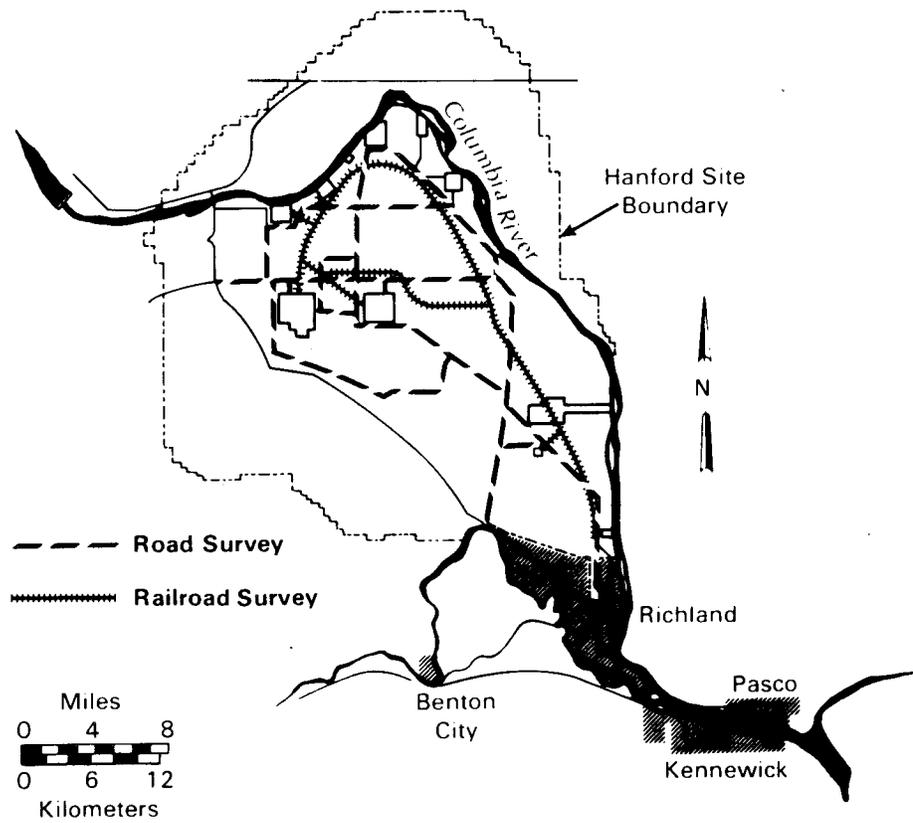


FIGURE 56. Road and Railroad Survey Routes

COMPARISON OF MEASURED AND CALCULATED RESULTS

Measurements of radiation levels and radionuclide concentrations in the environment were used to estimate the radiological impact of Hanford operations. However, the quantities of radionuclides released to the environment were usually small, and frequently it was not possible to measure radioactivity attributable to Hanford operations. For dose calculation purposes, environmental concentration of radionuclides in air, water, and other media were calculated based on the quantities released in various effluents. To verify that the calculated environmental concentrations used in the dose models were reasonable, the concentrations of radionuclides that could be measured in air and water were compared with calculated values. The calculated concentrations used for radiological dose assessment were verified as reasonable estimates.

Table 12 lists the major nuclides contributing to the radiological dose impact from Hanford operations liquid effluents in the Columbia River and compares the calculated concentrations to the concentrations measured upstream and downstream. The difference between upstream and downstream was used as an estimate of the contribution from the Hanford operations. There is considerable uncertainty in estimating the concentration due to Hanford operations as the difference between upstream and downstream concentrations because the measured concentrations are very low and near the minimum detectable concentrations. Results near the minimum detectable concentrations are typically associated with large uncertainties. For $^{239,240}\text{Pu}$ and ^{137}Cs , the upstream and downstream concentrations were very low and nearly equal. This corresponds well with the calculated added concentrations, which are very small and would not be detected within the precision of the measurements. For ^{60}Co , ^{131}I , and ^{89}Sr , there was close agreement between measured and calculated results. The measured ^{90}Sr concentrations were higher downstream but not as high as the calculated concentrations. The calculated concentration of ^3H from releases in the 100N Area was much less than the monitored downstream concentration, indicating that ^3H was added to the river from another source, presumably ground water. Uranium and ^{129}I were not reported as effluents, and the source of the measured concentrations in the river was assumed to be from natural sources, worldwide fallout, and ground-water seepage (see "Ground-Water Monitoring" section).

The comparison of airborne radionuclides was made by calculating the concentrations for the offsite monitoring location nearest to the PUREX Plant stack (Ringold) and comparing these values with the concentrations measured. The 1985 average dispersion (X/Q) values were used for these calculations (see Tables F.5 to F.8, Appendix F). The comparisons are shown in Table 13. The six major radionuclides emitted from the 200 Area listed in Table 13 also could be present in the environment from worldwide fallout. For all radionuclides except ^{85}Kr and $^{239,240}\text{Pu}$, the contributions for Hanford effluents were indistinguishable from fallout within the precision of the monitoring measurements. This agrees with the calculations, which show that the added concentrations from the 200 Area were very small, below the capability of analytical measurements to distinguish from the higher concentrations resulting from worldwide fallout. The calculated ^{85}Kr perimeter concentration of 170 pCi/m^3 agrees well with the average perimeter measured value of 150 pCi/m^3 . The average measured $^{239,240}\text{Pu}$ perimeter concentration was 4.1 aCi/m^3 , which included the worldwide fallout contribution of $1 \text{ to } 2 \text{ aCi/m}^3$. This compares well with the calculated concentration of 2.5 aCi/m^3 .

In general, the measured and calculated concentrations of radionuclides in air and water compared well. The measurements confirmed that the calculated concentrations used for the dose calculations were reasonable estimates of the radionuclide concentrations in the environment attributable to Hanford operations.

TABLE 12. Measured and Calculated 1985 Annual Average Concentrations of Selected Radionuclides in the Columbia River (pCi/ℓ)

Radionuclide	100 Area Releases, Ci ^(a)	Calculated Conc. Added Downstream	Measured Concentration ^(b)		
			Upstream	Downstream	Difference
³ H	270	2.8	110	150	40 ^(c)
⁶⁰ Co	2	0.02	- 0.0003	0.0076	0.008
⁸⁹ Sr	1.4	0.01	0.088	0.10	0.01
⁹⁰ Sr	8.7	0.09	0.15	0.16	0.01
¹³¹ I	5.7	0.06	<0.0034	0.019	0.02
¹³⁷ Cs	0.3	0.003	0.018	0.016	- 0.002
^{239,240} Pu	0.001	0.00001	0.00035	0.00028	- 0.00007

(a) From Table F.23, Appendix F.

(b) From Tables A.13 and A.14, Appendix A.

(c) Measured downstream difference due to seepage from ground water (see text).

TABLE 13. Measured and Calculated 1985 Annual Average Air Concentrations of Selected Radionuclides (pCi/m³)

Radionuclide	200 Area Releases, Ci ^(a)	Calculated Perimeter Concentration	Measured Concentration ^(b)		
			Perimeter	Distant	Onsite
³ H	200	0.05	1.7	1.8	3.1
⁸⁵ Kr	700,000	170	150	58	710
⁹⁰ Sr	0.0085	0.000018	0.00031	0.00028	0.00085
¹³¹ I	0.2	0.000049	0.0001	- 0.0006	0.0002
¹³⁷ Cs	0.01	0.000025	0.0001	0.0	0.000
^{239,240} Pu	0.01	0.000025	0.000041	0.000029	0.000072

(a) From Table F.18, Appendix F.

(b) From Tables A.3, Appendix A.

IV. NONRADIOLOGICAL MONITORING RESULTS

AIR QUALITY MONITORING

Oxides of nitrogen (NO_x) were routinely released onsite from fossil-fueled steam plants and chemical processing plants, most notably the PUREX Plant located in the 200E Area. For this reason, the Hanford Environmental Health Foundation (HEHF) operated an air-sampling network to determine ambient levels of nitrogen dioxide (NO_2) in the Hanford environs. Results from this seven-station network revealed that NO_2 concentrations were generally higher in 1985 than in 1984, but still were well below U.S. Environmental Protection Agency and local ambient air quality standards.

SAMPLE COLLECTION AND ANALYSIS

The NO_2 sampling locations were selected in an effort to adequately assess onsite and potential offsite nitrogen oxide impacts, primarily in relation to PUREX Plant emissions. The sample locations are depicted on the map in Figure 57 and identified in Table 14.

The NO_2 sampling was performed in accordance with EPA Designated Equivalent Method EQN-1277-028 (TGS-ANSA Method). The NO_2 sampling unit consisted of a bubbler assembly with absorbing solution, operated by a sequential sampling pump. The pumps were set to sequence on a 24-h basis; thus, all sample results are midnight-to-midnight, 24-h integrated averages.

RESULTS

As shown in Table 14, NO_2 data collected by the network in 1985 indicated that the highest annual average result (0.009 ppm) was from the Wye Barricade, which also was the location of the highest average in 1984. The applicable national and Washington State annual average ambient air standard for NO_2 is 0.05 ppm.

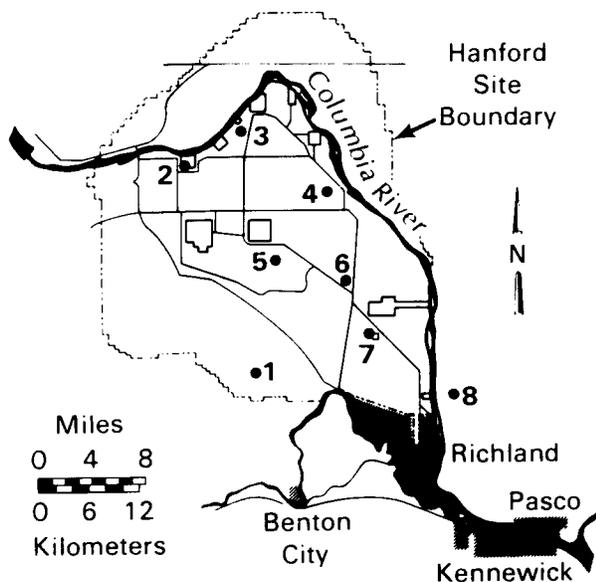


FIGURE 57. Nitrogen Dioxide Air Sampling Locations (see Table 14 for location number key)

TABLE 14. Ambient Nitrogen Dioxide (NO₂) Concentrations in the Hanford Environs for 1985

Location	Map Location ^(a)	Number of 24-hour Samples	Annual Average ^(b) (ppm NO ₂)	% Samples Less Than Detection Limit (0.003 ppm NO ₂)	Maximum Sample (ppm NO ₂)
ALE	1	268	0.006 ± 0.0003	4.5	0.018
100B	2	282	0.006 ± 0.0003	2.8	0.016
100D	3	286	0.006 ± 0.0004	5.2	0.017
Hanford Townsite	4	289	0.007 ± 0.0003	1.0	0.015
200 ESE	5	265	0.007 ± 0.0004	2.6	0.021
Wye Barricade	6	193	0.009 ± 0.0006	0.5	0.039
400 Area ^(c)	7	62	0.007 ± 0.0008	0.0	0.016
Sullivan Barn	8	278	0.008 ± 0.0004	0.0	0.020

(a) Locations are identified in Figure 57.

(b) Annual averages ± two standard error of the mean. Samples less than detectable daily concentrations were assumed equal to the 24-hour detection limit (0.003 ppm).

(c) Based on data for March, April, and May only because of electrical maintenance work.

NONRADIOLOGICAL GROUND-WATER MONITORING

Ground-water monitoring for chemical constituents in 1985 included both routine sampling and a special effort concerned with hazardous materials. Nearly 1,500 samples were collected during routine ground-water monitoring activities in 1985. Nearly all were analyzed for some inorganic constituent, primarily nitrate ion, and also for chromium and fluoride. In addition, about 40 well samples were analyzed by HEHF once during the year for water-quality parameters, which included pH, conductance, calcium (Ca), magnesium (Mg), sodium (Na), carbonate (CO₃), bicarbonate (HCO₃), potassium (K), boron (B), NO₃-nitrogen, chloride (Cl), SO₄-sulfur, and dissolved solids. The nitrate results for 1985 indicated that concentrations were inconsistent with past results. A review of the laboratory analytical procedures that used the specific ion probe showed a consistent increase in the analytical results during the last two months of the year. This increase distorted the average concentrations of nitrate available to plot the plume map, resulting in a map that showed little similarity to past results. Therefore, because of the anomalous data, nitrate results will not be discussed in this report. A special report on nitrate results will be released at a later date. Chromium (Cr⁺⁶) and fluoride (F) were monitored adjacent to and within the 300 and 100H Areas. In 1985, chromium and fluoride concentrations ranged from less than detectable (0.003 mg/l) to 1.2 mg/l, and 0.088 to 9.6 mg/l, respectively. Results of water-quality sampling indicate that Na, total dissolved solids, and conductivity were highest near the 100H Area.

Monitoring of hazardous materials for 1985 consisted of a one-time sampling of 75 of the 90 wells identified in a sitewide network. Each sample was analyzed for 35 to 40 constituents. Many of the constituents (including pesticides, herbicides, total organic halogen, and some metals) were below detection limits. Constituents that were detected included several metals, anions, coliform bacteria, radionuclides, and total organic carbon. Low concentrations of many of these constituents are expected in the natural ground water, and additional sampling is needed to determine the effects of Hanford operations.

ROUTINE SAMPLE COLLECTION AND ANALYSIS

Ground-water samples were collected in the same manner as described in the radiological "Ground-Water Monitoring" section. Most routine samples were collected on a quarterly basis; others were obtained monthly, semiannually, or annually. Nonradioactive constituents monitored included Cr⁺⁶, F, and the water-quality parameters Ca, Mg, Na, CO₃, HCO₃, K, B, Cl, SO₄, NO₃-nitrogen, pH, conductance, and dissolved solids. The values reported here for Cr⁺⁶ and F were analyzed by PNL's Radiological and Inorganic Chemistry Section. The water-quality analyses were performed by the Hanford Environmental Health Foundation (HEHF). Standard chemical methods described in Appendix D were used to determine the concentrations of the various constituents in ground-water samples.

RESULTS OF ROUTINE SAMPLING

Chromium and F were monitored in the vicinity of the 100H Area because of the quantity and nature of materials that have been disposed to the 183H solar-evaporation basins in the past. Disposal of material to these basins was discontinued in November 1985. Table F.22, Appendix F, is a list of the constituents and the quantities disposed to these basins during 1985. Chromium and F were also monitored in the 300 and 400 Areas, and in wells adjacent to the 300 Area. Both Cr⁺⁶ and F are constituents involved in the fuel fabrication process conducted in the 300 Area. Concentrations ranged from less than detectable (0.003 mg/l) to 1.2 mg/l for Cr⁺⁶ and 0.088 to 9.6 mg/l for F. The wells with the highest concentration of Cr⁺⁶ were located in the 100H Area. Well 699-S18-51 (see Figure 17, Section III, "Ground-Water Monitoring") contained the highest concentration of F.

The water-quality parameters (Table A.41, Appendix A), as analyzed by HEHF, indicated

higher levels of NO₃-nitrogen, Na, total dissolved solids, and conductivity near the 100H Area. Nitrogen as nitrate ranged from less than detectable (0.1 mg/l) to 210 mg/l in well 199-H4-3. Sodium ranged from 3.6 mg/l in well 699-81-58 to 336 mg/l in well 199-H4-3. Total dissolved solids and conductivity also were highest in well 199-H4-3, with concentrations of 1520 mg/l and 2150 μmho/cm, respectively. Well 699-2-7 was high in conductivity as well as in HCO₃, SO₄, Ca, Mg, and K. Figure 17 shows the location of these wells.

SAMPLE COLLECTION AND ANALYSIS FOR HAZARDOUS MATERIALS

Efforts in 1985 involved identifying areas onsite for future ground-water sampling. Of the 90 wells chosen sitewide for initial sampling (Figure 58), 75 were sampled once during 1985 for hazardous materials. The remaining wells will be sampled in 1986. Samples were collected near the major operating areas, within the radionuclide plumes, and far removed from site operations. The sampling network did not include wells within the 100H Area or the 300 Area because extensive sampling was being conducted in those areas under a related project.

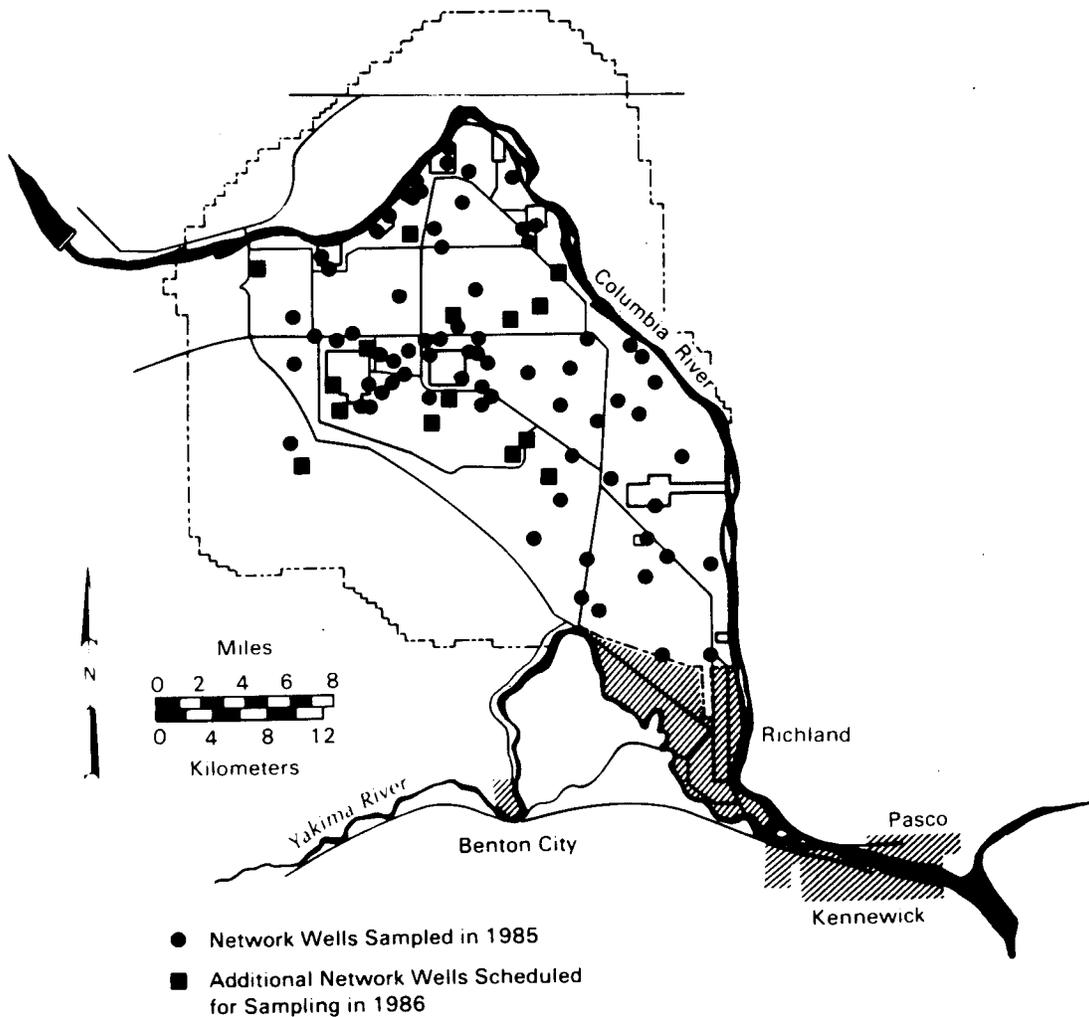


FIGURE 58. Hazardous Materials Sampling Locations

Table 15 itemizes the constituents that were selected for analysis. This list includes the parameters from the EPA list used in RCRA monitoring programs (USEPA 1984), as well as additional materials known to have been used in Hanford operations. Three radiological measurements (i.e., radium, gross alpha, and gross beta) were included because they are part of EPA's list for RCRA monitoring programs. In addition, to ensure that no chemicals were overlooked, samples from five wells in the network were selected for an extensive screening analysis that involved over 375 hazardous chemicals (WDOE 1984). Locations of the five wells included in this screening are shown in Figure 59.

Most of the samples were collected using submersible pumps and followed established hazardous materials sampling procedures. Samples to be analyzed for chemicals prone to volatilization or absorption were collected using a Teflon bailer. Samples were sealed to prevent tampering, transported to the laboratory on ice, and tracked using chain-of-custody procedures.

Analyses were performed by UST using EPA-approved procedures or other standard methods. In a few cases where standard methods were not available, an in-house method was developed, documented, and used by the laboratory. Specific conductance and pH measurements were performed in the field at the time of collection. Further details on analyses and quality control are found in Appendix D and the "Quality Assurance" section.

RESULTS OF HAZARDOUS MATERIALS MONITORING

Results from single samples are useful only to give a general indication of the status of the ground water and to guide future sampling efforts. Therefore, the following discussion is a qualitative description of the results obtained.

Results for the sitewide network and for each of the individual areas sampled are summarized in Tables A.42 through A.49, Appendix A. Only those constituents whose measured values were above detection limits in one or more wells are included. Comparing these tables with the list of analyses shows that many of the constituents (e.g., pesticides, herbicides, total organic halogen, and some of the metals) were not detected in any of the wells. Results of the extensive screening analyses mentioned previously have not yet been received.

Constituents that were detected included a number of metals, several anions, coliform bacteria, beta and alpha emitters, and total organic carbon. Histograms for 10 of the detected constituents and for pH and specific conductivity are shown in Figure 60. The constituents detected most commonly were B, Na, vanadium (V), K, nitrate, sulfate, chloride, and gross beta. These constituents were found in nearly all of the 75 wells in the network. Similar types of constituents were detected in ground-water samples collected at the 100H Area and 300 Area under a related project. Low concentrations of many of the constituents detected would be expected in the natural ground water, and additional sampling is needed to determine the effects of Hanford operations.

TABLE 15. Hazardous Material Constituents Selected for Analysis in 1985.

Primary Drinking-Water Constituents	Ground-Water Quality Parameters	Ground-Water Contamination Indicators	Additional Metals	Additional Inorganic Ions	Site-Specific Parameters ^(a)
Arsenic	Chloride	pH	Nickel	Phosphate	Ammonium
Barium	Iron	Specific conductance	Vanadium		Carbon tetrachloride
Cadmium	Manganese	Total organic halogen (TOX)	Copper		Trichloroethylene
Chromium	Sodium	Total organic carbon (TOC)	Aluminum		Polychlorinated biphenyls (PCBs)
Fluoride	Sulfate		Antimony		Xylene
Lead			Potassium		Hydrazine
Mercury					
Nitrate					
Selenium					
Silver					
Endrin					
Lindane					
Methoxychlor					
Toxaphene					
2,4-D					
2,4,5-TP Silvex					
Radium					
Gross Alpha					
Gross Beta					
Coliform					

(a) Only selected samples taken near operating areas were analyzed for these parameters.

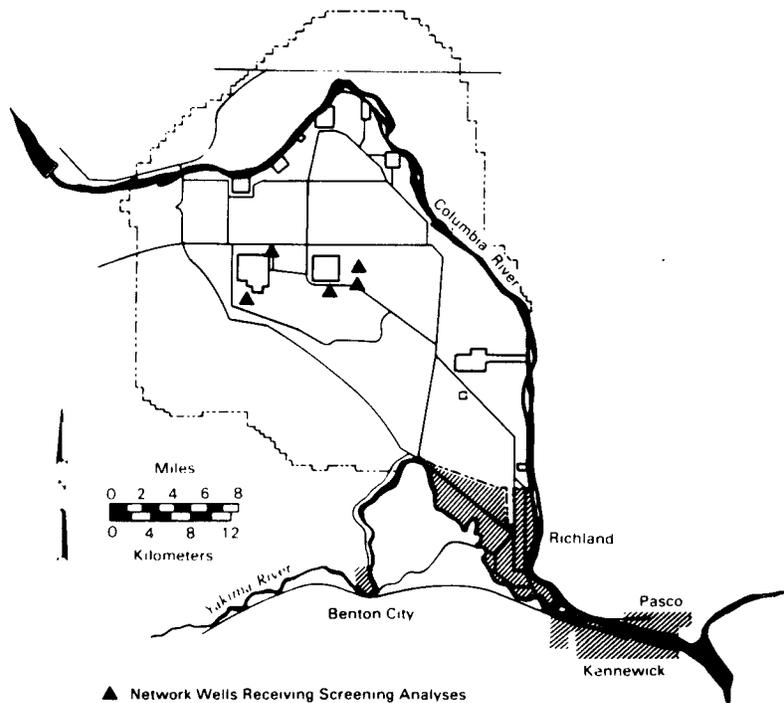
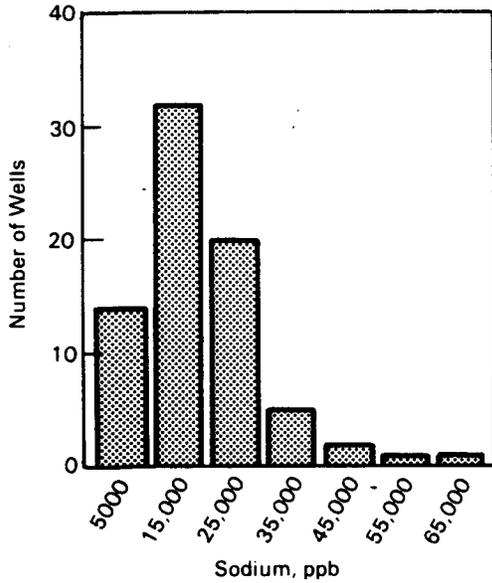
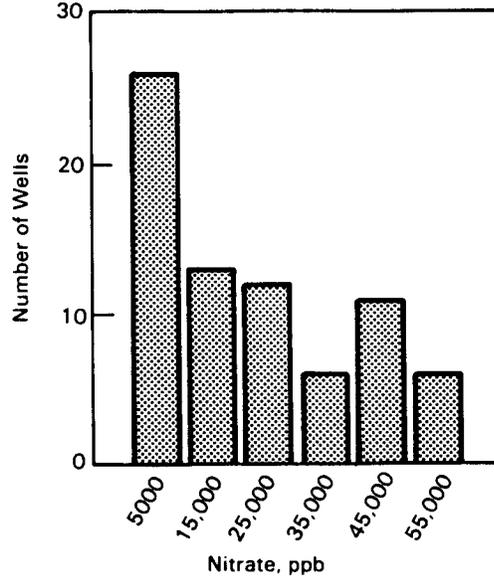


FIGURE 59. Network Wells Receiving Screening Analysis

No Wells Were Below Detection Limit of 100 ppb

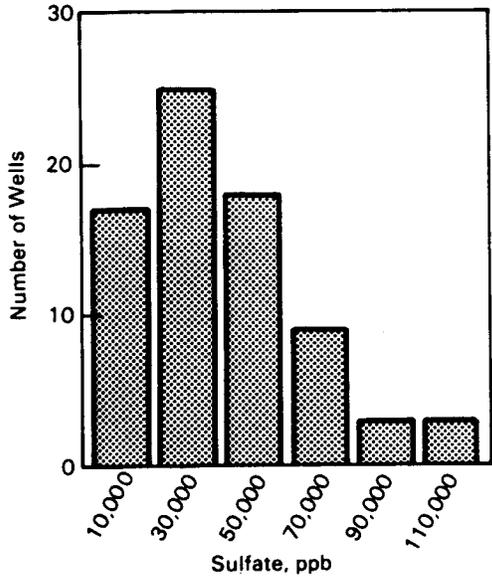


1 Well Was Below Detection Limit of 500 ppb



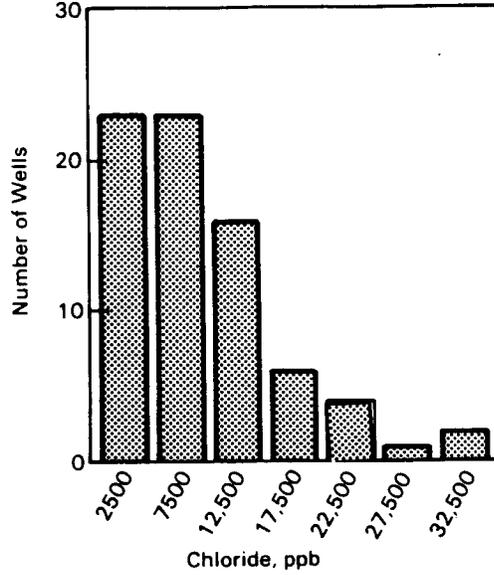
The following are not included in this histogram
 159,000 ppb 141,00 ppb 234,000 ppb 114,000 ppb

No Wells Were Below Detection Limit of 500 ppb



The following are not included in this histogram
 176,000 ppb

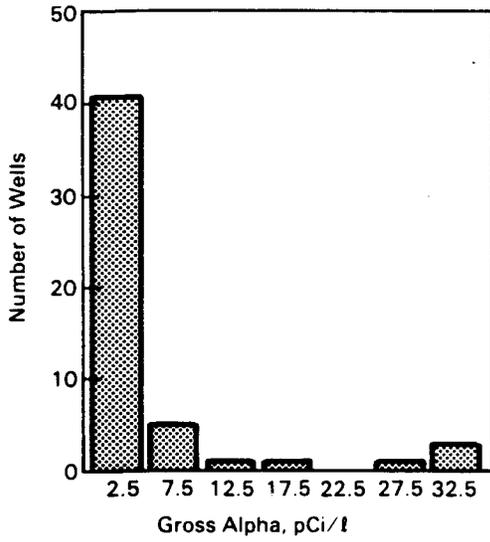
No Wells Were Below Detection Limit of 500 ppb



The following are not included in this histogram
 66,600 ppb

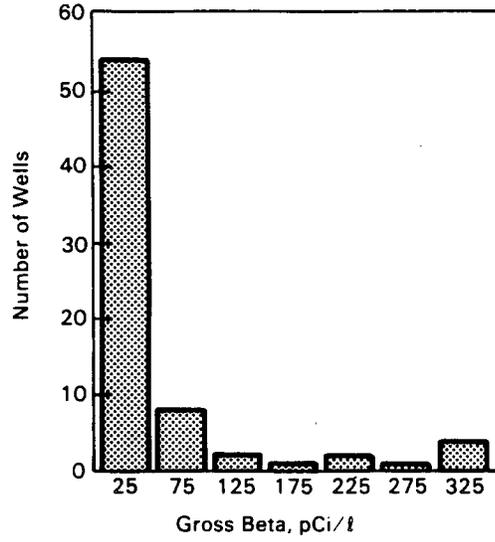
FIGURE 60. Histograms for Selected Hazardous Materials Constituents Measured in 1985

23 Wells Were Below Detection Limit of 4 pCi/ l



The following is not included in this histogram
171 pCi/l

3 Wells Were Below Detection Limit of 8 pCi/ l



The following values are not included in this histogram
1850 pCi/l, 2290 pCi/l, 518 pCi/l

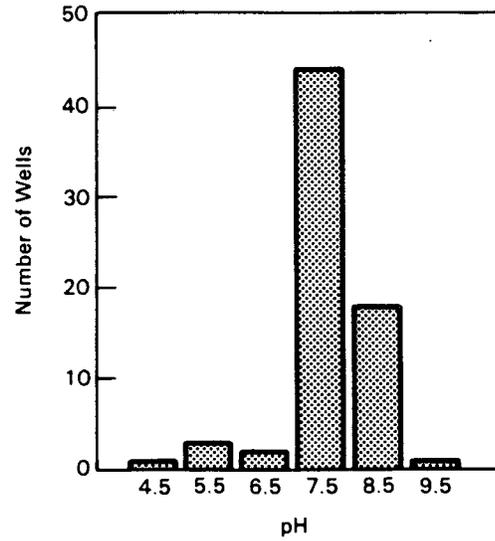
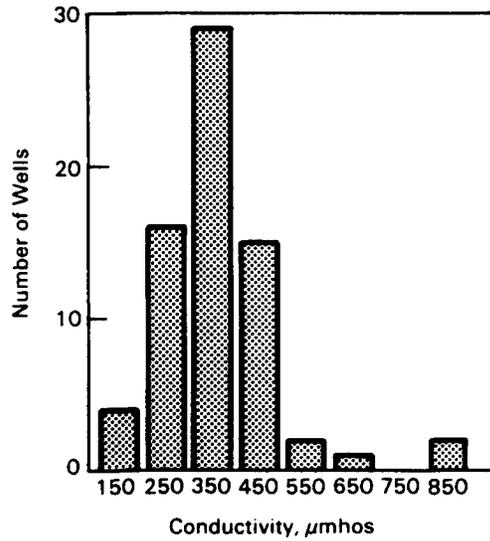
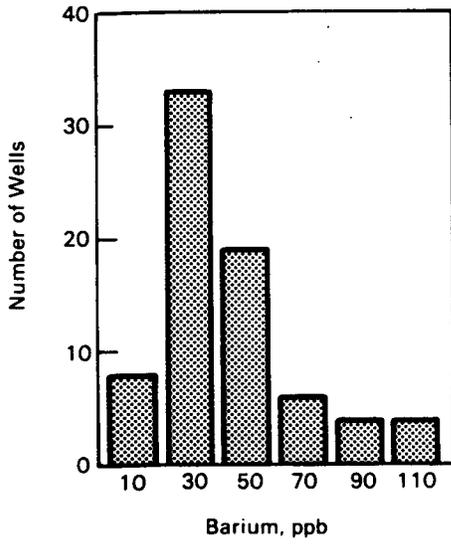


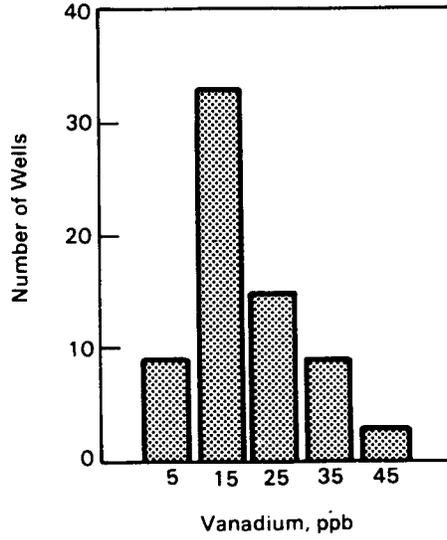
FIGURE 60. (contd)

1 Well Was Below Detection Limit of 6 ppb



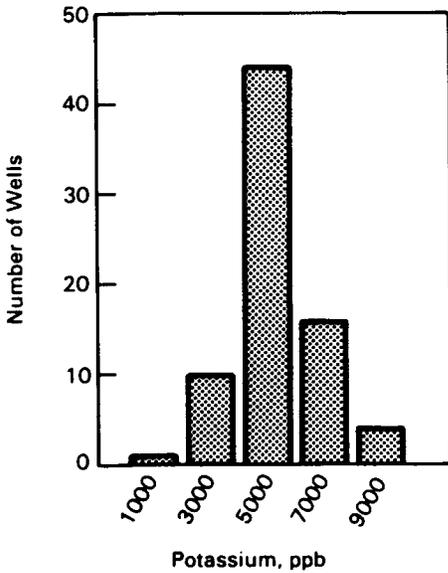
The following values are not included in this histogram
627 ppb 1530 ppb

6 Wells Were Below Detection Limit of 5 ppb



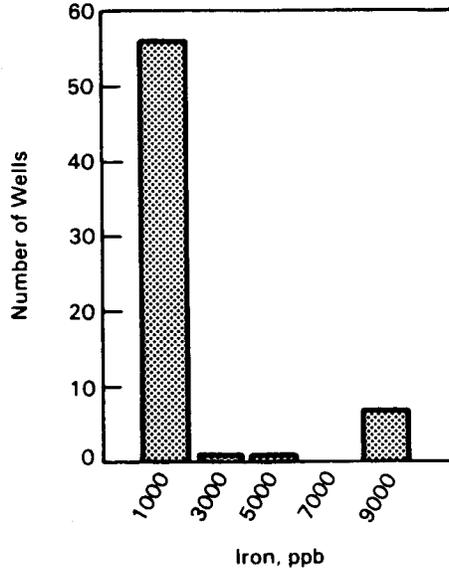
The following values are not included in this histogram
672 ppb 284 ppb

No Wells Were Below Detection Limit of 100 ppb



The following values are not included in this histogram
42,000 ppb 18,600 ppb

10 Wells Were Below Detection Limit of 50 ppb



The following values are not included in this histogram
397,000 ppb, 161,000 ppb, 55,700 ppb,
24,100 ppb, 21,100 ppb

FIGURE 60. (contd)

COLUMBIA RIVER WATER QUALITY MONITORING

Nonradioactive waste water is discharged at eight points along the Hanford reach of the Columbia River. These discharges consist of backwash water from water intake screens, cooling water, water storage tank overflow, and fish laboratory waste water. Each direct discharge point is identified in a National Pollutant Discharge Elimination System (NPDES) permit issued by the EPA. Effluents from each of these outfalls were routinely monitored and reported by the operating contractors.

The water quality of the Columbia River was monitored routinely during 1985 both upstream and downstream of the Hanford Site. The purpose of monitoring was to identify any characteristics of the river that could be attributed to Hanford discharges and to determine compliance with the Class A designation requirements.

SAMPLE COLLECTION AND ANALYSIS

Grab samples of Columbia River water were collected monthly at the Vernita Bridge (upstream of Hanford) and at Richland (downstream) as shown in Figure 23. Samples were analyzed to identify changes in general water quality along the Hanford reach of the river. Samples were delivered to HEHF for analyses that included biological oxygen demand (BOD), coliform bacteria, pH, and nitrate.

Water-quality measurements of the Columbia River were also performed by the U.S. Geological Survey (USGS) at similar upstream and downstream locations. The USGS samples consisted of river cross-section composites collected bi-monthly at the Vernita Bridge and quarterly at Richland. Analyses for numerous physical, biological, and chemical constituents were performed at the USGS laboratory in Denver, Colorado. The USGS also provided continuous temperature monitoring of the river upstream and downstream and flow-rate measurements upstream of the site. Routine discharges to the Columbia River were monitored through the NPDES system. The NPDES-permitted discharge locations and the parameters routinely measured are indicated in Table 16.

RESULTS

Figure 61 illustrates sampling results for constituents included in existing Washington State water-quality regulations. With four exceptions (two upstream and the two downstream), pH values taken upstream and downstream agreed

closely and were within the acceptable range during 1985. The median fecal coliform concentration during 1985 was slightly higher at the downstream location, but both upstream and downstream concentrations were well below the standard. Average turbidity values were similar upstream and downstream, were consistent with previous years' data, and did not exceed the standard.

Average monthly flow rates for the Columbia River and periods when the N Reactor was operating are shown in Figure 62. No substantial difference existed between upstream and downstream temperatures, and monthly averages remained within the standard during 1985. While the highest downstream temperatures coincided with periods of low river flow and periods when the N Reactor was in operation, upstream temperatures were also highest then. This suggests that heat contributed by N-Reactor effluents was, at most, a small fraction of the temperature increases observed. Natural heating by the sun, therefore, appeared to be the major cause of increased water temperatures along the Hanford reach.

Data collected by both PNL and the USGS are summarized in Table A.50, Appendix A. These data include a number of variables for which state standards do not exist. Results of USGS analyses and duplicate analyses performed on-site were in general agreement. None of the analytical results indicated significant deterioration of water quality at the downstream sampling location.

TABLE 16. Measurements for NPDES-Permitted Discharges at Hanford^(a)

Measurement	Location		
	100 K Area (2 Discharges)	100 N Area (5 Discharges)	300 Area (1 Discharge)
Flow Rate	X	X	X
Suspended Solids	X	X	X
Temperature	X	X	---
pH	X	X	X
Chlorine	X	X	---
Oil and Grease	---(b)	X	---
Heat Discharged	---	X	---
Settleable Solids	---	---	X
Iron	---	X	---
Ammonia	---	X	---
Chromium	---	X	---

(a) NPDES Permit No. WA-000374-3 (USEPA 1983b).

(b) Dashed line indicates no measurement required.

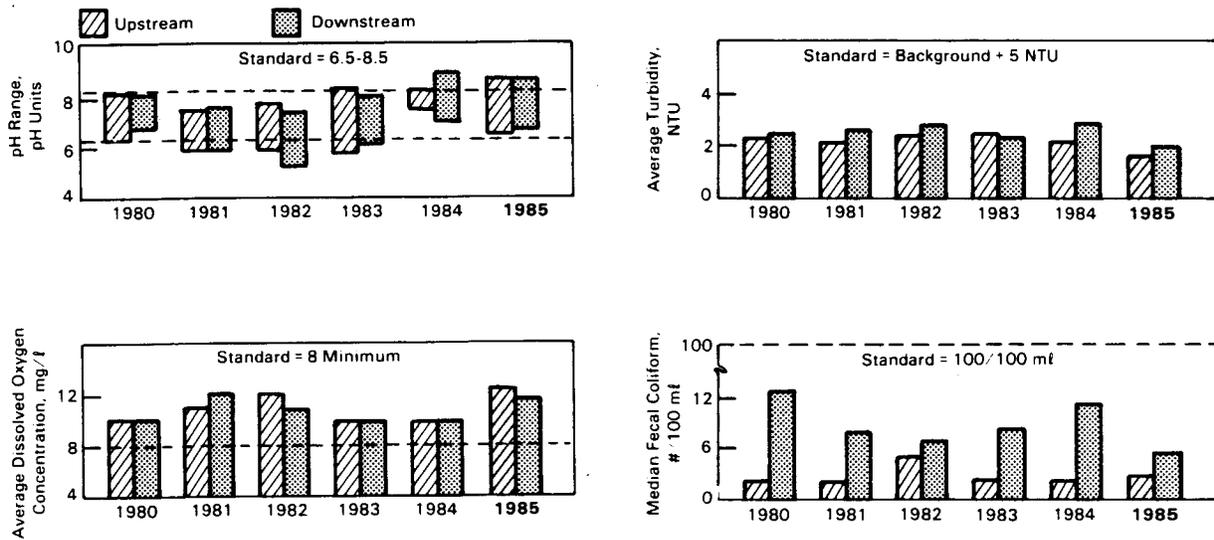


FIGURE 61. Columbia River Water Quality Measurements, 1980 to 1985

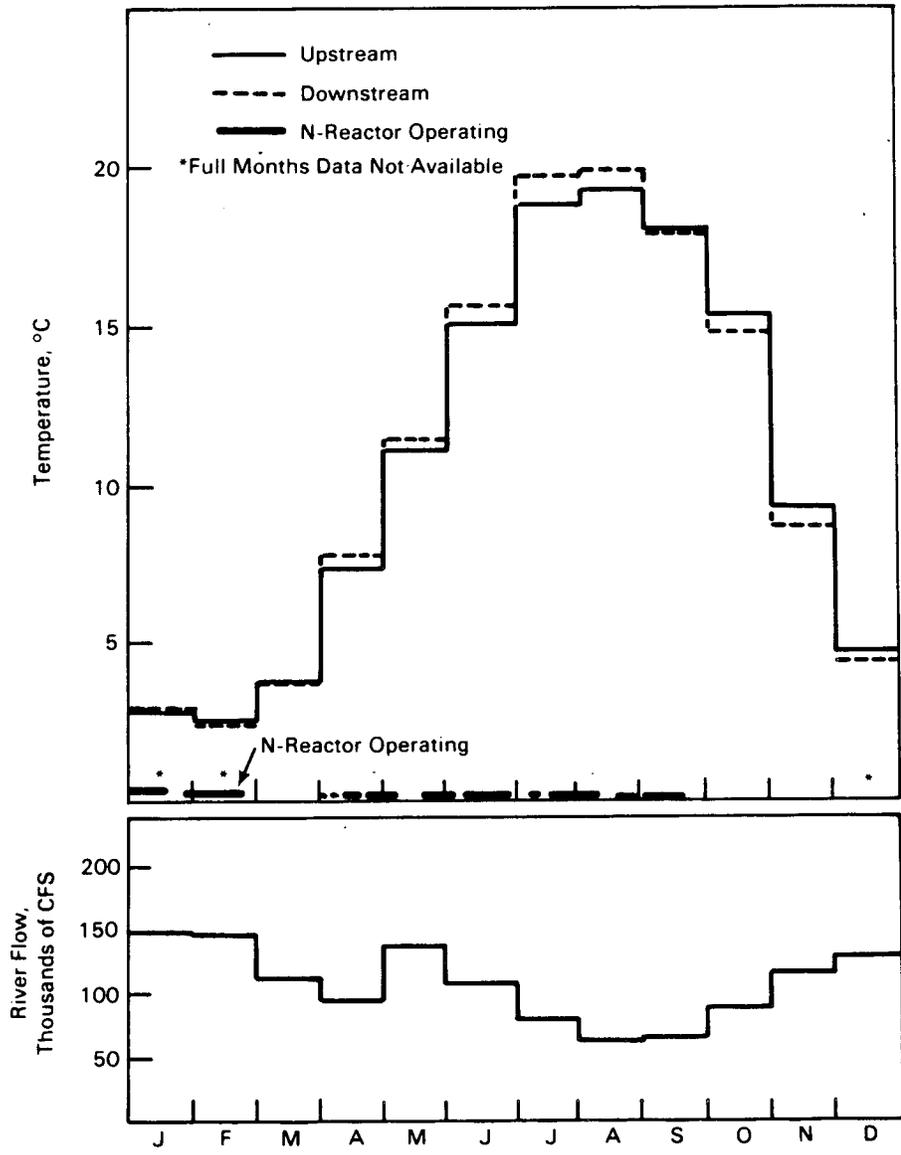


FIGURE 62. Columbia River Temperature and Flow Rates Measured in 1985

V. QUALITY ASSURANCE

QUALITY ASSURANCE

Comprehensive quality assurance programs were maintained to ensure that the data collected were representative of actual concentrations in the environment. These programs covered surface and ground-water monitoring for radioactive, nonradioactive, and hazardous materials. First, extensive environmental data were obtained to eliminate an unrealistic reliance on only a few results. Second, newly collected data were compared with both recent results and historical data for each location and each environmental medium to ensure that deviations from previous conditions were identified and promptly evaluated. Third, samples at all locations were collected using well-established and documented procedures to ensure consistency in sample collection. Fourth, samples were analyzed by documented standard analytical procedures. Fifth, the quality of the data was verified by a continuing program of analytical laboratory quality control, participation in interlaboratory cross-checks, replicate sampling and analysis, and splitting samples with other recognized laboratories. In addition, the ground-water monitoring program included 1) documentation of instrument calibrations and procedures used in the field and the laboratory, 2) scheduled maintenance of wells to ensure their integrity, 3) inspection of wells using downhole TV cameras and other devices, and 4) use of dedicated sampling pumps to avoid cross-contamination. These programs help ensure that the monitoring data can be used to evaluate accurately the environmental impacts from Hanford operations.

SAMPLE COLLECTION QUALITY ASSURANCE

Environmental samples were collected by trained Radiation Protection Technologists using written procedures documented in "Environmental Monitoring Procedures" (PNL-MA-580). The continuity of sampling locations is maintained year after year by documentation in "Environmental Sampling Locations Manual" (PNL-MA-514). To check the precision of sampling and analysis, replicate samples are routinely collected. The replicate data provided an estimate of the variability that can be expected from the total sampling and analysis process. The summary of the calculated precision based on replicate sampling is shown in Table A.51, Appendix A. The results indicated the precision (or reproducibility) of results in terms of coefficient of variation was in the range of 20-50%. The expected analytical precision for samples above the minimum detectable concentration is in the range of 10%, indicating there is uncertainty added during the sampling processes. The total precision values were within the expected range and were acceptable to assess the concentrations of radionuclides measured in the environment.

Sample collection for hazardous materials monitoring was performed according to specially developed written procedures. The samples were sealed with evidence tape to prevent tampering and were transported to the laboratory following the chain-of-custody procedures required by EPA for RCRA monitoring programs. Where possible, the analyses were conducted using EPA-approved procedures or other standard methods. In a few cases where standard methods were not available, an in-house method was developed, documented, and used by the laboratory.

ANALYTICAL LABORATORY QUALITY ASSURANCE

Most of the routine radiochemical analyses for the environmental monitoring program were performed under subcontract by UST. This laboratory maintained an internal quality assurance program that involved routine calibration of counting instruments, daily source and background counts, routine yield determinations of radiochemical procedures, replicate analyses to check precision, and analyses of reagents to ensure purity of chemicals. Calibration standards traceable to the National Bureau of Standards

were used for radiochemical calibrations when available. The laboratory continued participation in the DOE Quality Assessment Program (QAP) and the Environmental Protection Agency's (EPA) Laboratory Intercomparison Studies Program. These programs provide standard samples of various environmental media (water, milk, air filters, soil, foodstuffs, and tissue ash) containing one or more radionuclides in known amounts. After the samples were analyzed, the results were forwarded to DOE and EPA for comparison with known values and with the results from other laboratories. Both EPA and DOE have established criteria for evaluating the accuracy of results (Jarvis and Sui 1981; Sanderson 1985). These programs provided a regular means of evaluating the accuracy of the results and indications where corrective actions were needed. Summaries of the 1985 UST results in these two programs are provided in Tables 17 and 18. The results were within the acceptable range for nearly all samples.

The PNL analytical laboratories also participated in the DOE's Quality Assessment Program (QAP) operated by the Environment Measurements Laboratory. Table 19 summarizes recent performance results in relation to the QAP value and the 10% of the mean of results reported by the other laboratory participants.

Surface Monitoring

In addition to the DOE and EPA programs, there was a constant effort to evaluate the accuracy and precision of data provided by the analytical laboratories. All data were reviewed by a computerized anomalous-data system that checked each entry against established limits. Standard reference samples of soil, vegetation, and potato ash were submitted for blind analysis; the results are shown in Tables A.52 and A.53, Appendix A. The results of a compressed air sample split with Reynolds Electrical and Engineering Co. (REECO) and analyzed for ^{85}Kr are shown in Table A.54, Appendix A.

To evaluate the accuracy and precision of the environmental dosimeter measurements, three pairs of dosimeters were exposed to known levels of radiation each month and analyzed with the routine environmental dosimeters. A summary of the 1985 results is shown in Table A.55,

Appendix A. An average bias of approximately -2.1% was observed between the known and measured exposures.

A dosimeter intercomparison was conducted with the State of Washington Department of Social and Health Services (DSHS) to compare the responses of environmental dosimeters. Dosimeters from each organization were exposed to beta radiation, gamma radiation, and x-rays of various energies. The results of the study are shown in Table A.56, Appendix A. The dosimeters used by the two organizations are of different types. The environmental dosimeter in routine use at Hanford uses a very sensitive phosphor that is shielded to minimize the over-response to low-energy radiation. The DSHS dosimeter uses an unshielded, less sensitive phosphor that over-responds somewhat to low-energy radiation. The PNL dosimeter does not respond to beta radiation or to x-rays or gamma radiation below 60 keV. The test results indicated that agreement between dosimeters was good for photon energies above 60 keV.

In 1985, PNL and the State of Washington DSHS shared seven environmental dosimeter locations. The locations were on the Hanford Site, around the U.S. Ecology site and the Washington Public Power Supply System WNP-2 Plant. The PNL and DSHS dosimeters were put in place and collected at the same times. The field results from the two organizations are shown in Table A.57, Appendix A. The DSHS results averaged 13% higher than the PNL results. This was expected and was due to the different sensitivities of the two types of dosimeters, as described above.

There was a special quality assurance effort conducted in August 1985, involving sampling springs along the Columbia River. The study was conducted jointly by the State of Washington, the State of Oregon, PNL (for the DOE), and Greenpeace Northwest. The samples were shared among the participants and independently analyzed. Greenpeace Northwest prepared a blind sample for analysis by the participants. Each laboratory also analyzed a set of cross-check samples provided by EPA. The participants met in October 1985 to exchange results. The analytical results are given in Table A.58, Appendix A, and show good agreement among participants.

TABLE 17. U.S. Testing Laboratory Performance on DOE Quality Assessment Program Samples

Sample Media	Radionuclides	Number Analyzed	Number of Analyses Within Control Limits ^(a)
Air filters	⁷ Be, ⁵⁴ Mn, ⁶⁰ Co, ⁹⁰ Sr, ¹²⁵ Sb, ¹³⁷ Cs, ²³⁴ U, ²³⁸ U, ²³⁹ Pu, ²⁴¹ Am	15	14 ^(b)
Soil	⁴⁰ K, ⁶⁰ Co, ⁹⁰ Sr, ¹³⁷ Cs, ²²⁶ Ra, ²³⁸ Pu, ²³⁴ U, ²³⁸ U, ²³⁹ Pu	12	12
Vegetation	⁴⁰ K, ⁶⁰ Co, ⁹⁰ Sr, ¹³⁷ Cs, ²³⁹ Pu	10	10
Tissue	⁴⁰ K, ⁹⁰ Sr, ¹³⁷ Cs, ²³⁴ U, ²³⁸ U, ²²⁶ Ra, ²³⁹ Pu	13	13
Water	³ H, ⁵⁴ Mn, ⁶⁰ Co, ⁹⁰ Sr, ¹³⁷ Cs, ¹⁴⁴ Ce, ²³⁴ U, ²³⁸ U, U (total), ²³⁹ Pu, ²⁴¹ Pu	20	20

(a) Control limits from Sanderson (1985).

(b) One sample outside control limits was due to a data transcription error.

TABLE 18. U.S. Testing Laboratory Performance on EPA Laboratory Intercomparison Program Samples

Sample Media	Radionuclides	Number Analyzed	Number of Analyses Within Control Limits ^(a)
Water	Gross Alpha, Gross Beta, ⁵¹ Cr, ⁶⁵ Zn, ⁶⁰ Co, ¹⁰⁶ Ru, ¹³¹ I, ¹³⁴ Cs, ¹³⁷ Cs	33	33
Water	²²⁶ Ra, ²³⁹ Pu, ²³⁸ U	8	8
Water	⁸⁹ Sr, ⁹⁰ Sr	6	6
Water	³ H	5	5
Milk	⁸⁹ Sr, ⁹⁰ Sr, ¹³¹ I, ¹³⁷ Cs	9	8
Food	⁸⁹ Sr, ⁹⁰ Sr, ¹³¹ I, ¹³⁷ Cs	8	6
Air Filters	Gross Alpha, Gross Beta, ⁹⁰ Sr, ¹³⁷ Cs	8	8

(a) Control limits from Jarvis and Siu (1981).

TABLE 19. PNL Performance on DOE Quality Assessment Program Samples

Sample Media	Radionuclides	Number Analyzed	Number of Analyses Within Control Limits ^(a)
Water	³ H, ⁴⁰ Sr, ²³⁹ Pu	5	5
Soil	⁴⁰ K, ¹³⁷ Cs	2	2
Tissue	⁴⁰ K, ¹³⁷ Cs	2	2
Vegetation	⁶⁰ Co, ¹³⁷ Cs	2	2

(a) Control limits from Sanderson (1985).

Ground-Water Monitoring

One method PNL uses to demonstrate the quality of the ground-water monitoring data is to periodically submit duplicate field samples for analysis by the analytical laboratory. The duplicate samples consist of a record sample and a blind duplicate sample. The record sample is labelled with the actual well number and the blind sample is labelled with a fictitious well number. Analytical results for the duplicate samples analyzed for tritium in 1985 are given in Table A.59, Appendix A. The last column in this table presents the coefficient of variation for each pair of duplicate samples, and an indication of the variability of the two sample results relative to their average value. Except for pairs of duplicates with low results, and therefore large coefficients of variation, the coefficients of variation were acceptable in the range of 1 to 7%.

Hazardous Materials Monitoring

The quality assurance effort for hazardous materials monitoring included routine internal checks performed by the laboratory as well as external checks conducted by the program to evaluate laboratory performance. Internal checks for both inorganic and organic analyses included extensive use of analytical standards, blank samples, and spiked samples.

External quality assurance checks included interlaboratory comparisons conducted using field samples. Replicate samples were collected from selected wells in the network and distributed to the participating laboratories for analysis. Participating laboratories included: UST, which was the primary laboratory, HEHF, WHC, and PNL. Results of one set of anion comparisons are shown in Figures 63 through 65. The agreement between the three participating laboratories (UST, WHC, and HEHF) was considered adequate although in some cases they did show statistically significant differences. For the two sets of anion analyses evaluated, the maximum difference between laboratories was 24%. Further evaluation of the observed differences will be conducted upon receipt of information from the American Society for Testing and Materials (ASTM).

Evaluation of comparisons of volatile organic chemicals focused on chloroform. Two laboratories (PNL and UST) participated in this comparison. The results from PNL were generally 20 to 50% higher than the UST results. Information provided by the EPA (USEPA 1985b) indicated that, for low concentrations of volatile organic chemicals, differences of up to 40% were acceptable. Four of the 14 chloroform comparisons showed differences outside of this range. These differences may be partially due to the use of different analytical equipment.

DOSE CALCULATIONS QUALITY ASSURANCE

Assurance of the quality of the radiation dose calculations was provided in several ways. First, comparisons were made against past calculated doses and significant differences were verified. Second, all computed doses were double checked by the originator and by an independent third party who also checked all input data and assumptions used in the calculation. Third, information necessary to perform all of the calculations was fully documented (see Appendix F, "Dose Calculations and Effluents").

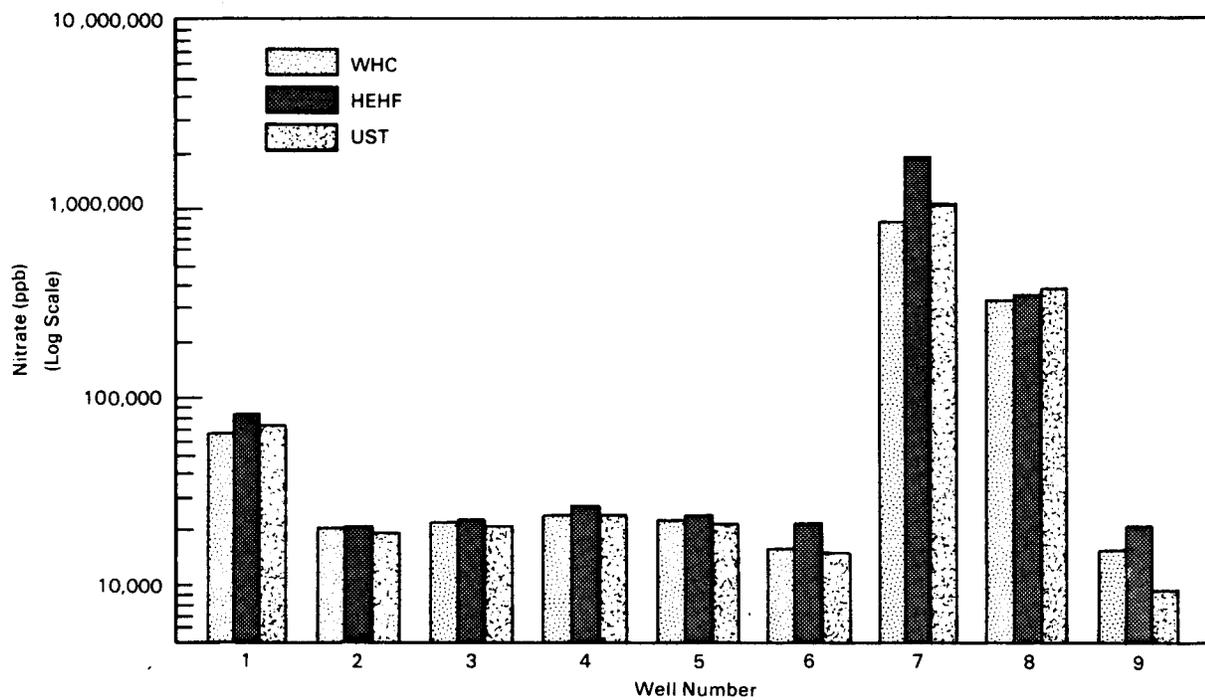


FIGURE 63. Laboratory Intercomparison Results for Nitrate

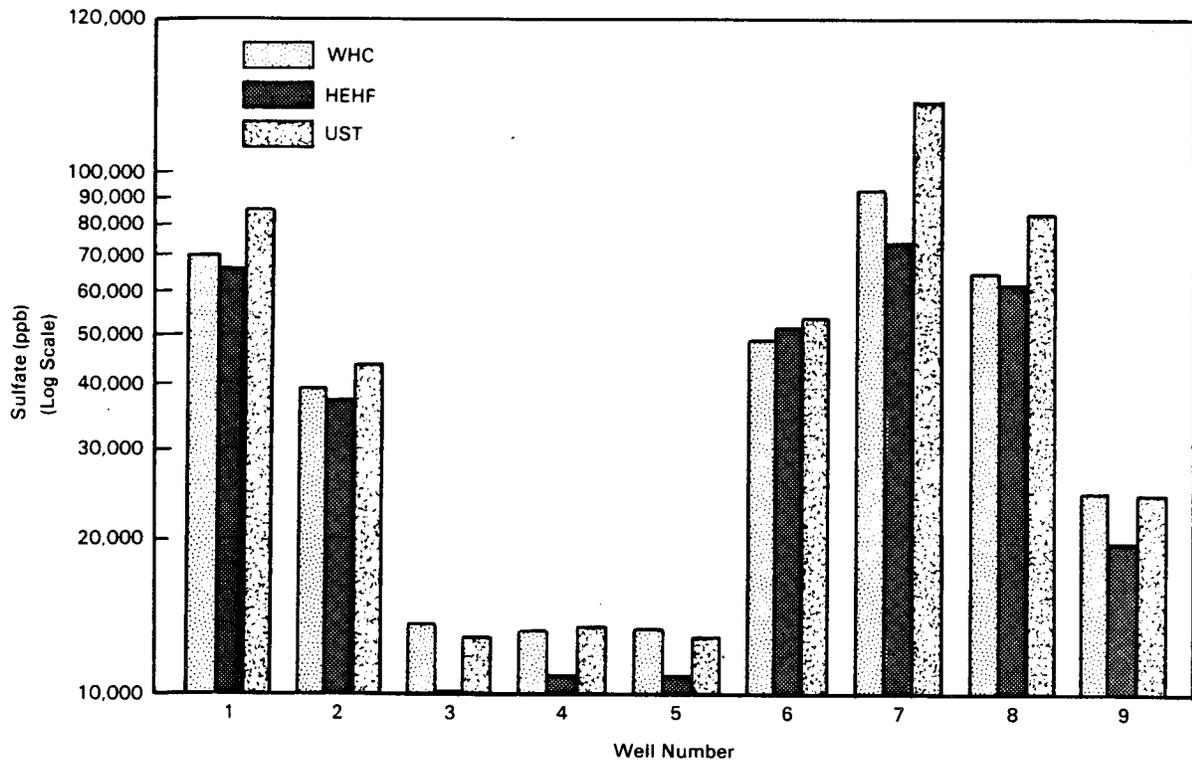


FIGURE 64. Laboratory Intercomparison Results for Sulfate

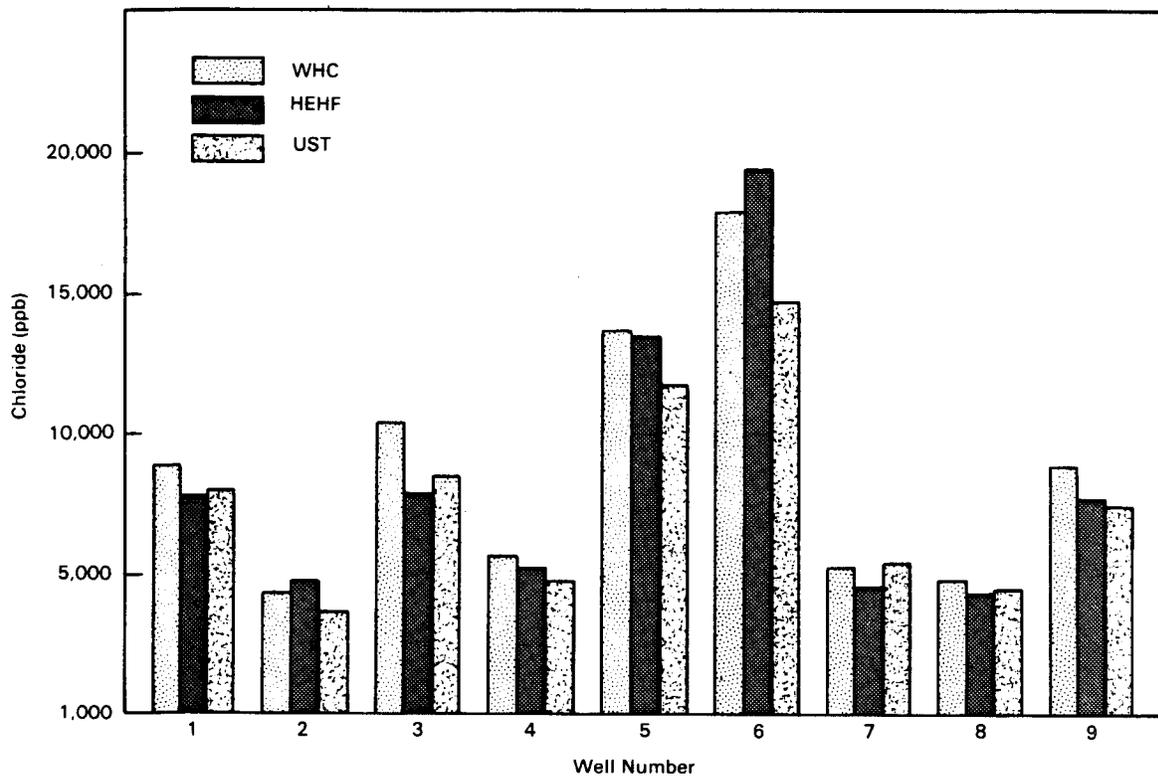


FIGURE 65. Laboratory Intercomparison Results for Chloride

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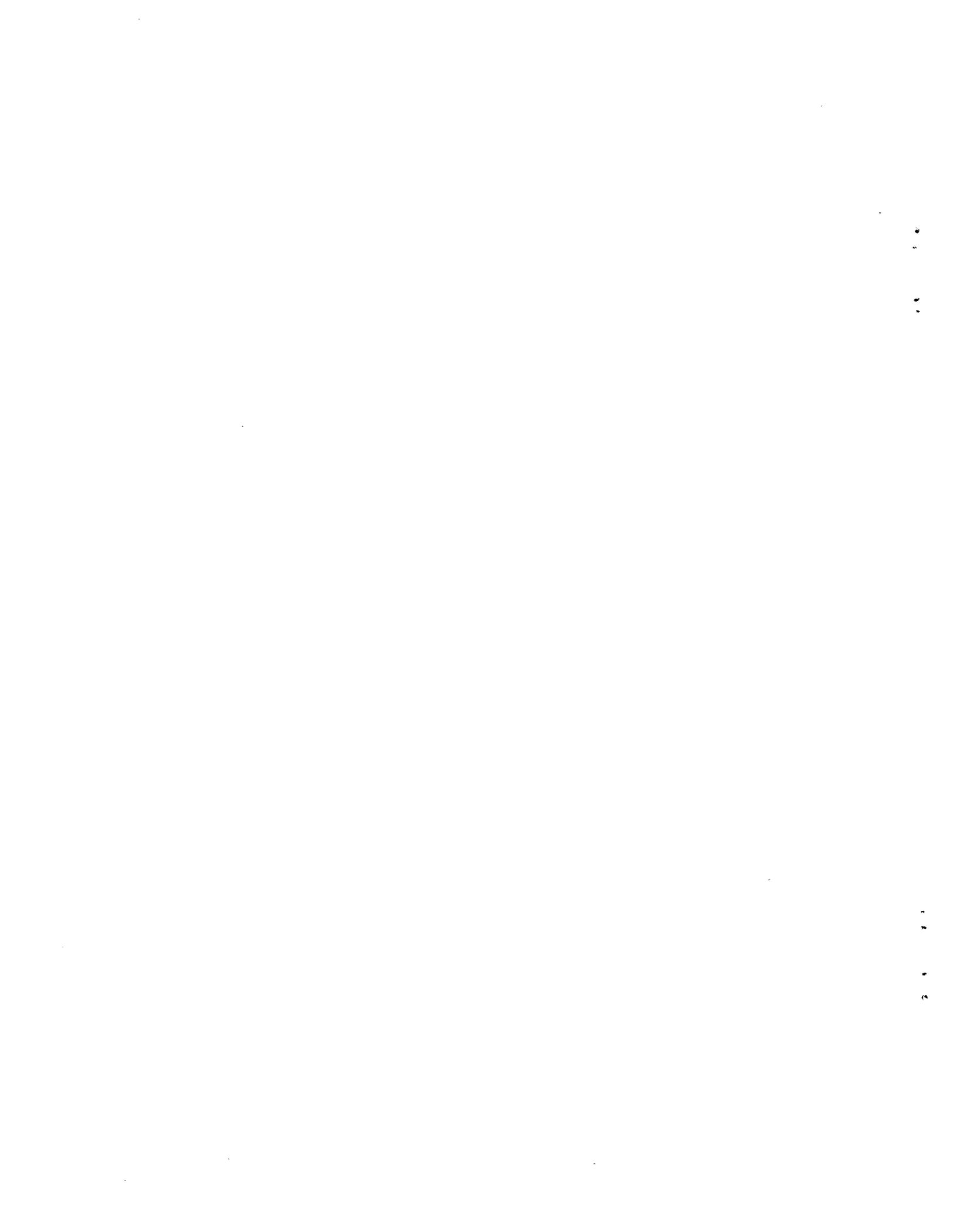
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APPENDIX A
MONITORING RESULTS FOR 1985



APPENDIX A

MONITORING RESULTS FOR 1985

Appendix A provides tables of environmental data for the reader who has a comprehensive interest in the individual results from the 1985 sampling effort. The tables present summaries of the data used in compiling this report. The tables contain some or all of the following information:

- the constituent measured
- the sampling location
- the number of samples collected at that location during the year
- the minimum (lowest) sample value observed
- the maximum (highest) sample value observed
- the mean (arithmetic average) of all the sample values

The minimum and maximum values are used to represent the range of values observed at a location, while the mean represents an average observed value at the location. In some cases the median (central value) is used where only a few high variable results are available. Further details on data presentation are given in Appendix E.

TABLE A.1. Air Sampling Locations and Sample Composite Groups

Composite Group	Sampling Location	Map Location (a)
Onsite		
100 Area	100K	1
	100N	2
	100D	3
	Fire Station	4
200 East Area	South of 200E	5
	East of 200E	6
	200 ESE	7
North of 200 Areas	Rt. 11A, Mi. 9	8
	N of 200E	9
200 West Area	SW BC Cribs	10
	Army Loop Camp	11
	GTE Building	12
300 Area	300 Pond	13
	3614-A Bldg.	14
	300S Gate	15
	300SW Gate	16
	3705 Bldg.	17
400 Area	400E	18
	400W	19
	400S	20
	400N	21
Hanford Townsite	Hanford Townsite	22
Wye Barricade	Wye Barricade	23
Perimeter		
Northeast Perimeter	Berg Ranch	24
	Sagehill	25
	Ringold	26
East Perimeter	Fir Road	27
	Pettett	28
Southeast Perimeter	Byers Landing	29
	RRC #64	30
Horn Rapids Road	Horn Rapids Rd. Mi. 12	31
	Horn Rapids Rd. Substation	32
Prosser Barricade	Prosser Barricade	33
ALE	ALE	34
West Perimeter	Rattlesnake Springs	35
	Yakima Barricade	36
Northwest Perimeter	Vernita Bridge	37
	Wahluke Slope #2	38
Nearby Communities		
Northeast Communities	Othello	39
	Connell	40
Tri-Cities	Pasco	41
	Richland	42
Benton City	Benton City	43
Distant Communities		
Outer Northeast	Moses Lake	44
	Wash Tucna	45
Outer Southeast	Walla Walla	46
	McNary Dam	47
Outer Western	Sunnyside	48
	Sunnyside Duplicate	

(a) Locations are identified in Figure 8.

TABLE A.2. Concentrations of Gross Beta and Gross Alpha Activity Measured in Air in the Hanford Environs for 1985

Station No.	Location ^(b)	Gross Beta Concentrations ^(a) pCi/m ³ (10 ⁻¹² µCi/m ³)			
		No. Samp.	Maximum	Minimum	Mean
ONSITE GROSS BETA					
1	100K	25	0.081 ± 0.006	0.008 ± 0.004	0.029 ± 0.033
2	100N	25	0.14 ± 0.006	0.010 ± 0.004	0.034 ± 0.052
3	100D	26	0.12 ± 0.006	0.010 ± 0.004	0.035 ± 0.050
4	100 Fire Station	26	0.099 ± 0.010	0.008 ± 0.004	0.033 ± 0.040
5	S of 200E	21	0.073 ± 0.006	0.005 ± 0.004	0.030 ± 0.035
6	E of 200E	24	0.095 ± 0.005	0.018 ± 0.004	0.039 ± 0.043
7	200 ESE	26	0.13 ± 0.006	0.012 ± 0.004	0.041 ± 0.049
8	Rt. 11A, Mi. 9	25	0.052 ± 0.005	0.010 ± 0.004	0.024 ± 0.021
9	N of 200E	26	0.12 ± 0.006	0.013 ± 0.004	0.035 ± 0.053
10	SW of BC Cribs	23	0.11 ± 0.006	0.010 ± 0.004	0.031 ± 0.048
11	Army Loop Camp	25	0.27 ± 0.008	0.009 ± 0.004	0.046 ± 0.11
12	200 GTE	24	0.12 ± 0.006	0.012 ± 0.004	0.039 ± 0.058
13	300 Pond	23	0.084 ± 0.006	0.015 ± 0.004	0.034 ± 0.035
14	3614A Bldg	25	0.081 ± 0.006	0.016 ± 0.005	0.032 ± 0.037
15	300S Gate	24	0.11 ± 0.006	0.008 ± 0.004	0.036 ± 0.052
16	300SW Gate	25	0.11 ± 0.006	0.015 ± 0.004	0.036 ± 0.045
17	3705 Bldg	25	0.11 ± 0.006	0.014 ± 0.004	0.035 ± 0.043
18	400E	25	0.12 ± 0.007	0.014 ± 0.004	0.038 ± 0.050
19	400W	14	0.091 ± 0.006	0.015 ± 0.005	0.038 ± 0.048
20	400S	24	0.078 ± 0.006	0.013 ± 0.004	0.033 ± 0.039
21	400N	13	0.096 ± 0.006	0.018 ± 0.005	0.040 ± 0.051
22	Hanford Townsite	26	0.13 ± 0.006	0.009 ± 0.004	0.033 ± 0.045
23	Wye Barricade	26	0.096 ± 0.006	0.015 ± 0.004	0.032 ± 0.039
					0.035 ± 0.002
ONSITE GROSS ALPHA					
			Gross Alpha Concentrations ^(a) pCi/m ³ (10 ⁻¹² µCi/m ³)		
3	100D	26	0.0028 ± 0.0007	0.0005 ± 0.0003	0.0011 ± 0.0012
5	S of 200E	21	0.0023 ± 0.0007	0.0005 ± 0.0004	0.0010 ± 0.0010
6	E of 200E	24	0.0024 ± 0.0007	0.0006 ± 0.0004	0.0011 ± 0.0011
7	200 ESE	26	0.0020 ± 0.0006	0.0007 ± 0.0004	0.0011 ± 0.0008
8	Rt. 11A, Mi. 9	25	0.0020 ± 0.0008	0.0003 ± 0.0006	0.0009 ± 0.0008
9	N of 200E	26	0.0031 ± 0.0008	0.0006 ± 0.0004	0.0012 ± 0.0012
10	SW of BC Cribs	23	0.0020 ± 0.0006	0.0005 ± 0.0003	0.0010 ± 0.0010
11	Army Loop Camp	25	0.0030 ± 0.0008	0.0005 ± 0.0003	0.0011 ± 0.0012
12	200 GTE	24	0.0032 ± 0.0008	0.0005 ± 0.0003	0.0013 ± 0.0014
13	300 Pond	23	0.0035 ± 0.0008	0.0009 ± 0.0004	0.0018 ± 0.0015
15	300S Gate	24	0.0021 ± 0.0006	0.0004 ± 0.0003	0.0011 ± 0.0010
18	400E	25	0.0018 ± 0.0006	0.0005 ± 0.0003	0.0011 ± 0.0008
19	400W	14	0.0022 ± 0.0009	0.0006 ± 0.0004	0.0012 ± 0.0010
20	400S	24	0.0021 ± 0.0006	0.0007 ± 0.0004	0.0011 ± 0.0008
21	400N	13	0.0025 ± 0.0010	0.0005 ± 0.0003	0.0013 ± 0.0012
22	Hanford Townsite	26	0.0026 ± 0.0007	0.0005 ± 0.0003	0.0011 ± 0.0011
23	Wye Barricade	26	0.0018 ± 0.0006	0.0004 ± 0.0006	0.0011 ± 0.0009
					0.0011 ± 0.0001

TABLE A.2. contd

Station No.	Location (b)	No. Samp.	Maximum		Miniumum		Mean	
PERIMETER GROSS BETA								
24	Berg Ranch	25	0.11	± 0.006	0.009	± 0.004	0.034	± 0.048
25	Sagehill	26	0.10	± 0.006	0.008	± 0.004	0.032	± 0.044
26	Ringold	26	0.060	± 0.005	0.008	± 0.004	0.021	± 0.025
27	Fir Road	26	0.084	± 0.006	0.006	± 0.004	0.030	± 0.039
28	Pettett	24	0.091	± 0.006	0.019	± 0.004	0.034	± 0.034
29	Byers Landing	26	0.084	± 0.006	0.010	± 0.004	0.026	± 0.031
30	RRC #64	24	0.10	± 0.006	0.013	± 0.004	0.034	± 0.044
31	Horn Rapids Rd. Mi. 12	26	0.081	± 0.006	0.008	± 0.004	0.029	± 0.038
32	Horn Rapids Rd. Substation	24	0.060	± 0.005	0.012	± 0.004	0.026	± 0.021
33	Prosser Barricade	24	0.070	± 0.006	0.017	± 0.004	0.031	± 0.033
34	ERC	24	0.12	± 0.007	0.015	± 0.004	0.032	± 0.044
35	Rattlesnake Springs	26	0.24	± 0.008	0.012	± 0.004	0.042	± 0.095
36	Yakima Barricade	26	0.31	± 0.009	0.011	± 0.004	0.046	± 0.12
37	Vernita Bridge	24	0.22	± 0.008	0.008	± 0.004	0.041	± 0.093
38	Wahluke #2	25	0.15	± 0.007	0.010	± 0.004	0.036	± 0.059
							0.033	± 0.003
PERIMETER GROSS ALPHA								
24	Berg Ranch	25	0.0028	± 0.0007	0.0003	± 0.0003	0.0011	± 0.0012
25	Sagehill	9	0.0026	± 0.0007	0.0007	± 0.0004	0.0014	± 0.0014
26	Ringold	9	0.0022	± 0.0007	0.0003	± 0.0003	0.0010	± 0.0014
27	Fir Road	8	0.0016	± 0.0005	0.0008	± 0.0004	0.0012	± 0.0007
28	Pettett	24	0.0020	± 0.0007	0.0004	± 0.0004	0.0011	± 0.0009
29	Byers Landing	25	0.0020	± 0.0007	0.0004	± 0.0003	0.0011	± 0.0010
30	RRC #64	24	0.0020	± 0.0007	0.0005	± 0.0003	0.0011	± 0.0009
31	Horn Rapids Rd. Mi. 12	26	0.0021	± 0.0007	0.0003	± 0.0003	0.0010	± 0.0011
33	Prosser Barricade	24	0.0022	± 0.0007	0.0007	± 0.0004	0.0010	± 0.0008
36	Yakima Barricade	26	0.0027	± 0.0007	0.0004	± 0.0003	0.0011	± 0.0012
38	Wahluke #2	25	0.0029	± 0.0008	0.0006	± 0.0004	0.0012	± 0.0011
							0.0011	± 0.0001
NEARBY COMMUNITIES GROSS BETA								
39	Othello	25	0.13	± 0.006	0.011	± 0.004	0.034	± 0.050
40	Connell	25	0.15	± 0.007	0.009	± 0.004	0.037	± 0.062
41	Pasco	22	0.081	± 0.006	0.015	± 0.004	0.036	± 0.044
42	Richland	24	0.11	± 0.007	0.016	± 0.004	0.035	± 0.048
43	Benton City	25	0.15	± 0.007	0.006	± 0.004	0.029	± 0.055
							0.034	± 0.005

TABLE A.2. contd

Station No.	Location ^(b)	No. Samp.	Maximum	Minimum	Mean
NEARBY COMMUNITIES GROSS ALPHA					
40	Connell	25	0.0033 ± 0.0008	0.0003 ± 0.0003	0.0012 ± 0.0015
42	Richland	24	0.0025 ± 0.0007	0.0006 ± 0.0004	0.0012 ± 0.0010
43	Benton City	25	0.0044 ± 0.0009	0.0005 ± 0.0004	0.0012 ± 0.0017
					<u>0.0012 ± 0.0002</u>
DISTANT COMMUNITIES GROSS BETA					
44	Moses Lake	25	0.098 ± 0.007	0.012 ± 0.004	0.027 ± 0.039
45	Washtuchna	25	0.11 ± 0.007	0.015 ± 0.004	0.035 ± 0.044
46	Walla Walla	25	0.079 ± 0.006	0.014 ± 0.004	0.031 ± 0.039
47	McNary Dam	25	0.12 ± 0.006	0.012 ± 0.004	0.034 ± 0.044
48	Sunnyside	26	0.11 ± 0.009	0.015 ± 0.004	0.033 ± 0.049
					<u>0.032 ± 0.004</u>
DISTANT COMMUNITIES GROSS ALPHA					
44	Moses Lake	25	0.0027 ± 0.0007	0.0004 ± 0.0003	0.0010 ± 0.0011
46	Walla Walla	25	0.0024 ± 0.0008	0.0006 ± 0.0006	0.0011 ± 0.0009
48	Sunnyside	26	0.0042 ± 0.0009	0.0005 ± 0.0003	0.0012 ± 0.0016
					<u>0.0011 ± 0.0001</u>

- (a) Maximum and minimum values ±2 sigma counting error. Averages ±2 standard error of the calculated mean.
- (b) Locations are identified in Figure 8.

TABLE A.3. Concentrations of Radionuclides Measured in Air in the Hanford Environs for 1985

Radio-Nuclide	Composite Group ^(b)	Number of Samples	Concentration, pCi/m ³ ^(a) (10 ⁻¹² uCi/m ³)			Concentration Guide pCi/m ³ ^(c)
			Maximum	Minimum	Average	
³ H (HTO)	Onsite	177	32.0 ± 6.7	* ^(d) -1.0 ± 1.6	3.1 ± 0.6	200,000
	Perimeter	141	13.0 ± 7.8	*-1.3 ± 2.3	1.7 ± 0.4	
	Nearby Communities	25	5.3 ± 4.3	*-7.0 ± 2.0	1.5 ± 0.6	
	Distant Communities	26	8.6 ± 5.1	*-1.0 ± 1.6	1.8 ± 0.9	
¹⁴ C (CO ₂)	Onsite	18	1.6 ± 0.09	1.2 ± 0.1	1.4 ± 0.1	500,000
	Perimeter	31	1.6 ± 0.11	1.1 ± 0.1	1.3 ± 0.1	
	Nearby Communities	6	1.9 ± 0.07	1.3 ± 0.1	1.4 ± 0.2	
	Distant Communities	6	1.5 ± 0.13	1.1 ± 0.1	1.3 ± 0.3	
⁸⁵ Kr	Onsite	39	3400 ± 440	15 ± 8	710 ± 300	600
	Perimeter	41	910 ± 120	26 ± 6	150 ± 47	
	Nearby Communities ^(e)	0				
	Distant Communities	12	180 ± 24	19 ± 13	58 ± 28	
⁹⁰ Sr	Onsite	32	0.0098 ± 0.00025	*0.00002 ± 0.00002	0.00075 ± 0.00070	9
	Perimeter	31	0.0030 ± 0.00040	*0.00004 ± 0.00005	0.00029 ± 0.00020	
	Nearby Communities	12	0.00064 ± 0.00019	*0.00000 ± 0.00004	0.00020 ± 0.00013	
	Distant Communities	12	0.00064 ± 0.00010	*0.00004 ± 0.00005	0.00021 ± 0.00012	
¹⁰⁶ Ru	Onsite	96	0.013 ± 0.007	*-0.014 ± 0.016	0.001 ± 0.001	30
	Perimeter	96	0.012 ± 0.008	*-0.021 ± 0.016	0.000 ± 0.002	
	Nearby Communities	36	0.013 ± 0.008	*-0.020 ± 0.016	0.000 ± 0.003	
	Distant Communities	36	0.012 ± 0.007	*-0.023 ± 0.011	-0.001 ± 0.003	
¹²⁹ I	Onsite	7	0.00061 ± 0.000076	0.0000014 ± 0.0000022	0.00011 ± 0.00017	70
	Perimeter	3	0.000021 ± 0.0000029	0.0000099 ± 0.0000014	0.000017 ± 0.0000079	
	Nearby Communities ^(d)	0				
	Distant Communities	4	0.000019 ± 0.0000023	0.00000002 ± 0.00000001	0.0000072 ± 0.0000091	
¹³¹ I	Onsite	229	*0.023 ± 0.023	*-0.014 ± 0.0081	0.0002 ± 0.0007	400
	Perimeter	103	*0.0087 ± 0.0087	*-0.0110 ± 0.0064	0.0001 ± 0.0009	
	Nearby Communities	25	*0.0055 ± 0.0070	*-0.012 ± 0.0090	0.0003 ± 0.0018	
	Distant Communities	25	*0.0061 ± 0.0061	*-0.0092 ± 0.0106	-0.0006 ± 0.0020	
¹³⁷ Cs	Onsite	96	0.0031 ± 0.0015	*-0.0021 ± 0.0006	0.0003 ± 0.0002	400
	Perimeter	96	0.0028 ± 0.0026	*-0.0021 ± 0.0019	0.0001 ± 0.0002	
	Nearby Communities	36	0.0013 ± 0.0008	*-0.0019 ± 0.0018	0.0000 ± 0.0003	
	Distant Communities	36	0.0019 ± 0.0010	*-0.0013 ± 0.0012	0.0000 ± 0.0003	
U(total)	Onsite	32	0.0017 ± 0.00039	0.000008 ± 0.000005	0.000172 ± 0.000112	0.1
	Perimeter	24	0.00027 ± 0.000099	0.000042 ± 0.000018	0.000120 ± 0.000027	
	Nearby Communities ^(d)	0				
	Distant Communities	4	0.00013 ± 0.000051	0.000051 ± 0.000023	0.000077 ± 0.000040	
²³⁸ Pu	Onsite	32	0.0000095 ± 0.0000036	*-0.0000008 ± 0.0000021	0.0000020 ± 0.0000011	0.03
	Perimeter	31	0.0000088 ± 0.0000058	*-0.0000008 ± 0.0000007	0.0000014 ± 0.0000009	
	Nearby Communities	12	0.0000045 ± 0.0000027	* 0.0000000 ± 0.0000000	0.0000015 ± 0.0000011	
	Distant Communities	12	0.0000049 ± 0.0000031	*-0.0000007 ± 0.0000018	0.0000013 ± 0.0000012	
^{239,240} Pu	Onsite	32	0.000044 ± 0.0000084	* 0.0000000 ± 0.0000000	0.0000064 ± 0.0000030	0.02
	Perimeter	31	0.0000098 ± 0.0000065	* 0.0000003 ± 0.0000012	0.0000032 ± 0.0000010	
	Nearby Communities	12	0.000010 ± 0.0000042	*-0.0000012 ± 0.0000014	0.0000030 ± 0.0000020	
	Distant Communities	12	0.000013 ± 0.0000051	* 0.0000001 ± 0.0000008	0.0000029 ± 0.0000021	

(a) Maximum and minimum values ±2 sigma counting error. Averages ±2 standard error of calculated mean. Entries have been rounded for clarity.

(b) Onsite, perimeter, nearby communities, and distant sampling locations are identified in Table A.1 and Figure 8.

(c) From draft DOE Derived Concentration Guide (See Appendix C).

(d) The * indicates ±2 sigma counting error greater than result.

(e) No analysis was performed.

TABLE A.4. Concentrations of Radionuclides Measured in Air Near the 100 Areas

Radio-Nuclide	Sampling Location ^(b)	Number of Samples	Concentration, pCi/m ³ (a)			Average 1985 Distant ^(b)
			Maximum	Minimum	Average	
³ H (HTO)	K Area	13	12.0 ± 6.9	* ^(c) 0.5 ± 1.3	2.4 ± 1.8	1.8 ± 0.9
	N Area	13	7.2 ± 6.0	*0.3 ± 1.7	1.7 ± 1.2	
	D Area	13	3.7 ± 2.6	*0.1 ± 1.0	1.9 ± 1.0	
	Fire Station	12	3.0 ± 1.3	*0.3 ± 1.1	2.3 ± 1.6	
				2.1 ± 0.7		
¹⁴ C (CO ₂)	Fire Station	6	1.6 ± 0.1	1.2 ± 0.1	1.4 ± 0.3	1.3 ± 0.3
⁹⁰ Sr	Composite ^(d)	4	0.00048 ± 0.00005	0.00002 ± 0.00002	0.00018 ± 0.00023	0.00021 ± 0.00012
¹²⁹ I	Fire Station	4	0.000042 ± 0.000006	0.000022 ± 0.000003	0.000032 ± 0.000010	0.000007 ± 0.000009
¹³¹ I	N Area	25	*0.023 ± 0.023	*-0.004 ± 0.005	0.002 ± 0.003	-0.001 ± 0.002
	D Area	26	*0.008 ± 0.008	*-0.005 ± 0.004	0.001 ± 0.002	
¹³⁷ Cs	Composite	12	0.0004 ± 0.0003	*-0.0002 ± 0.0003	0.0002 ± 0.0002	0.0000 ± 0.0003
U(total)	Composite	4	0.00009 ± 0.00003	0.00004 ± 0.00002	0.00006 ± 0.00003	0.00008 ± 0.00004
²³⁸ Pu	Composite	4	0.0000012 ± 0.0000010	*0.0000002 ± 0.0000008	0.0000006 ± 0.0000007	0.0000013 ± 0.0000012
^{239,240} Pu	Composite	4	0.0000047 ± 0.0000019	*0.0000007 ± 0.0000015	0.0000027 ± 0.0000021	0.0000029 ± 0.0000021
Gross Beta	K Area	25	0.081 ± 0.006	0.008 ± 0.004	0.029 ± 0.007	0.032 ± 0.004
	N Area	25	0.14 ± 0.006	0.010 ± 0.004	0.034 ± 0.010	
	D Area	26	0.12 ± 0.006	0.010 ± 0.004	0.035 ± 0.010	
	Fire Station	26	0.099 ± 0.010	0.008 ± 0.004	0.033 ± 0.008	
					0.033 ± 0.004	
Gross Alpha	D Area	26	0.0028 ± 0.0007	0.0005 ± 0.0003	0.0011 ± 0.0002	0.0011 ± 0.0001

(a) Maximum and minimum concentrations ±2 sigma counting error. Averages ±2 standard error of the calculated mean. Entries have been rounded for clarity.

(b) Distant sampling locations are identified in Table A.1 and Figure 8.

(c) The * indicates ±2 sigma counting error greater than result.

(d) Composites of biweekly samples from the individual sampling locations in Table A.1.

TABLE A.5. Concentrations of Radionuclides Measured in Air Near the 200E Area

Radio-Nuclide	Sampling Location ^(b)	Number of Samples	Concentration, pCi/m ³ (a)			Average 1985 Distant ^(b)	
			Maximum	Minimum	Average		
³ H (HTO)	S of 200E	13	6.8 ± 6.3	0.5 ± 0.4	2.4 ± 1.4	1.8 ± 0.9	
	E of 200E	12	32 ± 6.7	3.7 ± 1.1	9.2 ± 4.4		
	200 ESE	13	16 ± 6.2	2.9 ± 2.1	5.9 ± 2.1		
			<u>5.7 ± 1.8</u>				
¹⁴ C (CO ₂)	200 ESE	6	1.6 ± 0.1	1.4 ± 0.2	1.5 ± 0.2		1.3 ± 0.3
⁸⁵ Kr	S of 200E	7	500 ± 120	15 ± 8	230 ± 140		58 ± 28
	E of 200E	9	1400 ± 180	21 ± 11	620 ± 310		
	200 ESE	10	3400 ± 440	49 ± 8	1800 ± 790		
			<u>970 ± 420</u>				
⁹⁰ Sr	Composite ^(c)	4	0.0098 ± 0.00025	0.00004 ± 0.00004	0.0026 ± 0.00047	0.00021 ± 0.00012	
¹⁰⁶ Ru	Composite	12	0.009 ± 0.005	* ^(d) -0.009 ± 0.012	0.000 ± 0.004	-0.001 ± 0.003	
¹²⁹ I	200 ESE	3	0.00061 ± 0.000076	0.0000014 ± 0.0000002	0.00021 ± 0.00042	0.0000072 ± 0.0000091	
¹³¹ I	S of 200E	26	*0.005 ± 0.005	*-0.013 ± 0.007	-0.001 ± 0.002	-0.001 ± 0.002	
	E of 200E	24	*0.012 ± 0.012	*-0.011 ± 0.012	0.001 ± 0.003		
	200 ESE	26	*0.009 ± 0.009	*-0.006 ± 0.007	0.001 ± 0.002		
¹³⁷ Cs	Composite	12	0.0012 ± 0.0007	*-0.0009 ± 0.0012	0.0002 ± 0.0004	0.0000 ± 0.0003	
U(total)	Composite	4	0.00011 ± 0.00004	0.00003 ± 0.00001	0.00006 ± 0.00004	0.00008 ± 0.00004	
²³⁸ Pu	Composite	4	0.0000035 ± 0.0000021	*0.0000000 ± 0.0000016	0.0000017 ± 0.0000019	0.0000013 ± 0.0000012	
^{239,240} Pu	Composite	4	0.000044 ± 0.0000084	*0.0000006 ± 0.0000008	0.000018 ± 0.000022	0.0000029 ± 0.0000021	
Gross Beta	S of 200E	21	0.073 ± 0.006	0.005 ± 0.004	0.030 ± 0.008	0.032 ± 0.004	
	E of 200E	24	0.095 ± 0.005	0.018 ± 0.004	0.039 ± 0.009		
	200 ESE	26	0.13 ± 0.006	0.012 ± 0.004	0.041 ± 0.010		
			<u>0.037 ± 0.005</u>				
Gross Alpha	S of 200E	21	0.0023 ± 0.0007	0.0005 ± 0.0004	0.0010 ± 0.0002		0.0011 ± 0.0001
	E of 200E	24	0.0024 ± 0.0007	0.0006 ± 0.0004	0.0011 ± 0.0002		
	200 ESE	26	0.0020 ± 0.0006	0.0007 ± 0.0004	0.0011 ± 0.0002		
			<u>0.0011 ± 0.0001</u>				

(a) Maximum and minimum concentrations ±2 sigma counting error. Averages ±2 standard error of the calculated mean. Entries have been rounded for clarity.

(b) Distant sampling locations are identified in Table A.1 and Figure 8.

(c) Composites of biweekly samples from the individual sampling locations in Table A.1.

(d) The * indicates ±2 sigma counting error greater than result.

TABLE A.6. Concentrations of Radionuclides Measured in Air Near the 200W Area

Radio-Nuclide	Sampling Location ^(b)	Number of Samples	Concentration, pCi/m ³ (a)			Average 1985 Distant ^(b)
			Maximum	Minimum	Average	
³ H (HTO)	SW BC Cribs GTE Bldg.	11	7.2 ± 1.5	*(c)0.2 ± 1.1	2.0 ± 1.3	1.8 ± 0.9
		12	8.7 ± 1.6	*0.3 ± 1.0	<u>2.0 ± 1.4</u> 2.0 ± 0.9	
⁹⁰ Sr	Composite ^(d)	4	0.0056 ± 0.00026	0.00008 ± 0.00005	0.0015 ± 0.00027	0.00021 ± 0.00012
¹⁰⁶ Ru	Composite	12	0.010 ± 0.006	*-0.002 ± 0.006	0.003 ± 0.003	-0.001 ± 0.003
¹³¹ I	All Locations ^(e)	0				
¹³⁷ Cs	Composite	12	0.0031 ± 0.0015	*-0.0014 ± 0.0007	0.0002 ± 0.0006	0.0000 ± 0.0003
U(total)	Composite	4	0.00011 ± 0.00003	0.00006 ± 0.00002	0.00008 ± 0.00003	0.00008 ± 0.00004
²³⁸ Pu	Composite	4	0.0000095 ± 0.0000036	*-0.0000004 ± 0.0000005	0.0000026 ± 0.0000049	0.0000013 ± 0.0000012
^{239,240} Pu	Composite	4	0.000010 ± 0.0000037	* 0.00 ± 0.00	0.0000047 ± 0.0000050	0.0000029 ± 0.0000021
Gross Beta	SW BC Cribs Army Loop Camp GTE Bldg.	23	0.11 ± 0.006	0.010 ± 0.004	0.031 ± 0.010	0.032 ± 0.004
		25	0.29 ± 0.008	0.009 ± 0.004	0.046 ± 0.021	
		24	0.12 ± 0.006	0.012 ± 0.004	<u>0.039 ± 0.012</u> 0.039 ± 0.009	
Gross Alpha	SW BC Cribs Army Loop Camp GTE Bldg.	23	0.0020 ± 0.0006	0.0005 ± 0.0003	0.0010 ± 0.0002	0.0011 ± 0.0001
		25	0.0030 ± 0.0008	0.0005 ± 0.0003	0.0011 ± 0.0002	
		24	0.0032 ± 0.0008	0.0005 ± 0.0003	<u>0.0013 ± 0.0003</u> 0.0011 ± 0.0001	

- (a) Maximum and minimum concentrations ±2 sigma counting error. Averages ±2 standard error of the calculated mean. Entries have been rounded for clarity.
 (b) Distant sampling locations are identified in Table A.1 and Figure 8.
 (c) The * indicates ±2 sigma counting error greater than result.
 (d) Composites of biweekly samples from the individual sampling locations in Table A.1.
 (e) Not routinely analyzed.

TABLE A.7. Concentrations of Radionuclides Measured in Air North of the 200 Area

Radio-Nuclide	Sampling Location ^(b)	Number of Samples	Concentration, pCi/m ³ (a)			Average 1985 Distant ^(b)
			Maximum	Minimum	Average	
³ H (HTO)	Rt. 11 A. Mi. 9 N of 200E	13	6.9 ± 1.8	*(c)1.0 ± 1.6	1.7 ± 1.1	1.8 ± 0.9
		13	12 ± 1.7	*0.8 ± 1.7	<u>3.8 ± 1.8</u> 2.8 ± 1.1	
⁹⁰ Sr	Composite ^(d)	4	0.0033 ± 0.00022	0.00007 ± 0.00005	0.00091 ± 0.00016	0.00021 ± 0.00012
¹⁰⁶ Ru	Composite	12	0.013 ± 0.007	*-0.010 ± 0.008	0.001 ± 0.004	-0.001 ± 0.003
¹³¹ I	All Locations ^(e)	0				
¹³⁷ Cs	Composite	12	0.0017 ± 0.0015	*-0.0005 ± 0.0012	0.0005 ± 0.0005	0.0000 ± 0.0003
U(total)	Composite	4	0.0017 ± 0.00039	0.00007 ± 0.00003	0.00051 ± 0.00080	0.00008 ± 0.00004
²³⁸ Pu	Composite	4	0.000006 ± 0.000005	*-0.000001 ± 0.000002	0.000002 ± 0.000003	0.0000013 ± 0.0000012
^{239,240} Pu	Composite	4	0.000013 ± 0.000005	* 0.000002 ± 0.000003	0.000008 ± 0.000006	0.000003 ± 0.000002
Gross Beta	Rt. 11 A. Mi. 9 N of 200E	25	0.052 ± 0.005	0.010 ± 0.004	0.024 ± 0.004	0.032 ± 0.004
		26	0.12 ± 0.006	0.013 ± 0.004	<u>0.035 ± 0.010</u> 0.030 ± 0.006	
Gross Alpha	Rt. 11 A. Mi. 9 N of 200E	25	0.0020 ± 0.0008	*0.0003 ± 0.0006	0.0009 ± 0.0002	0.0011 ± 0.0001
		26	0.0031 ± 0.0008	0.0006 ± 0.0004	<u>0.0012 ± 0.0000</u> 0.0010 ± 0.0001	

- (a) Maximum and minimum concentrations ±2 sigma counting error. Averages ±2 standard error of the calculated mean. Entries have been rounded for clarity.
 (b) Distant sampling locations are identified in Table A.1 and Figure 8.
 (c) The * indicates ±2 sigma counting error greater than result.
 (d) Composites of biweekly samples from the individual sampling locations in Table A.1.
 (e) Not routinely analyzed.

TABLE A.8. Concentrations of Radionuclides Measured in Air Near the 300 Area

Radio-Nuclide	Sampling Location ^(b)	Number of Samples	Concentration, pCi/m ³ (a)			Average 1985 Distant ^(b)
			Maximum	Minimum	Average	
⁸⁵ Kr	300 Pond	13	880 ± 110	31 ± 9	180 ± 130	58 ± 28
⁹⁰ Sr	Composite ^(c)	4	0.00041 ± 0.00006	0.00004 ± 0.00002	0.00016 ± 0.00018	0.00021 ± 0.00012
¹³¹ I	300 SW Gate	26	* ^(d) 0.012 ± 0.012	*-0.014 ± 0.008	-0.002 ± 0.002	-0.001 ± 0.002
¹³⁷ Cs	Composite	12	0.0009 ± 0.0004	*-0.0009 ± 0.0005	0.0002 ± 0.0003	0.0000 ± 0.0003
U(total)	Composite	4	0.00045 ± 0.00011	0.00004 ± 0.00002	0.00021 ± 0.00020	0.00008 ± 0.00004
²³⁸ Pu	Composite	4	0.0000012 ± 0.0000009	*0.0000003 ± 0.0000006	0.0000008 ± 0.0000006	0.0000013 ± 0.0000012
^{239,240} Pu	Composite	4	0.0000062 ± 0.0000020	*0.0000003 ± 0.0000006	0.0000026 ± 0.0000029	0.0000029 ± 0.0000021
Gross Beta	300 Pond	23	0.084 ± 0.006	0.015 ± 0.004	0.034 ± 0.007	
	3614-A Bldg.	25	0.081 ± 0.006	0.016 ± 0.005	0.032 ± 0.007	
	300 S Gate	24	0.11 ± 0.006	0.008 ± 0.004	0.036 ± 0.011	
	300 SW Gate	25	0.11 ± 0.006	0.015 ± 0.004	0.036 ± 0.009	
	3705 Bldg	25	0.11 ± 0.006	0.014 ± 0.004	0.035 ± 0.009	
					0.035 ± 0.004	0.032 ± 0.004
Gross Alpha	300 Pond	23	0.0035 ± 0.0008	0.0009 ± 0.0004	0.0018 ± 0.0003	
	300 S Gate	24	0.0021 ± 0.0006	0.0004 ± 0.0003	0.0011 ± 0.0002	
					0.0015 ± 0.0002	0.0011 ± 0.0001

- (a) Maximum and minimum concentrations ±2 sigma counting error. Averages ±2 standard error of the calculated mean. Entries have been rounded for clarity.
 (b) Distant sampling locations are identified in Table A.1 and Figure 8.
 (c) Composites of biweekly samples from the individual sampling locations in Table A.1.
 (d) The * indicates ±2 sigma counting error greater than result.

TABLE A.9. Concentrations of Radionuclides Measured in Air Near the 400 Area

Radio-Nuclide	Sampling Location ^(b)	Number of Samples	Concentration, pCi/m ³ (a)			Average 1985 Distant ^(b)
			Maximum	Minimum	Average	
³ H (HTO)	400E	13	21 ± 13	* ^(c) 0.1 ± 1.1	3.2 ± 3.3	1.8 ± 0.9
⁹⁰ Sr	Composite ^(d)	4	0.00079 ± 0.00007	0.00006 ± 0.00003	0.00032 ± 0.00036	0.00021 ± 0.00012
¹³¹ I	400E	26	*0.008 ± 0.008	*-0.009 ± 0.006	-0.001 ± 0.002	
	400W	13	*0.005 ± 0.005	*-0.003 ± 0.005	0.000 ± 0.002	-0.001 ± 0.002
	400S	24	*0.006 ± 0.006	*-0.008 ± 0.006	0.000 ± 0.002	
	400N	12	*0.009 ± 0.009	*-0.008 ± 0.007	0.001 ± 0.004	
¹³⁷ Cs	Composite	12	0.0017 ± 0.0009	*0.0010 ± 0.0006	0.0001 ± 0.0005	0.0000 ± 0.0003
U(total)	Composite	4	0.000149 ± 0.000054	0.000009 ± 0.000005	0.000075 ± 0.000070	0.00077 ± 0.000040
²³⁸ Pu	Composite	4	0.000002 ± 0.000001	*0.000000 ± 0.000002	0.000001 ± 0.000001	0.000001 ± 0.000001
^{239,240} Pu	Composite	4	0.000015 ± 0.000003	*0.000001 ± 0.000002	0.000007 ± 0.000018	0.000003 ± 0.000001
Gross Beta	400E	25	0.119 ± 0.007	0.014 ± 0.004	0.038 ± 0.010	
	400W	14	0.091 ± 0.006	0.015 ± 0.005	0.038 ± 0.013	
	400S	24	0.078 ± 0.006	0.013 ± 0.004	0.033 ± 0.008	
	400N	13	0.096 ± 0.006	0.018 ± 0.005	0.040 ± 0.014	
					0.037 ± 0.005	0.032 ± 0.004
Gross Alpha	400E	25	0.0018 ± 0.0006	0.0005 ± 0.0003	0.0011 ± 0.0002	
	400W	14	0.0022 ± 0.0009	0.0006 ± 0.0004	0.0012 ± 0.0003	
	400S	24	0.0021 ± 0.0006	0.0007 ± 0.0004	0.0011 ± 0.0002	
	400N	13	0.0025 ± 0.0010	0.0005 ± 0.0003	0.0013 ± 0.0003	
					0.0011 ± 0.0001	0.0011 ± 0.0001

- (a) Maximum and minimum concentrations ±2 sigma counting error. Averages ±2 standard error of the calculated mean. Entries have been rounded for clarity.
 (b) Distant sampling locations are identified in Table A.1 and Figure 8.
 (c) The * indicates ±2 sigma counting error greater than result.
 (d) Composites of biweekly samples from the individual sampling locations in Table A.1.

TABLE A.10. Concentrations of Radionuclides Measured in Air in the 600 Area

Radio-Nuclide	Sampling Location ^(b)	Number of Samples	Concentration, pCi/m ³ (a)			Average 1985 Distant ^(b)
			Maximum	Minimum	Average	
³ H (HTO)	Hanford Townsite	13	4.7 ± 1.9	*0.7 ± 1.0	2.2 ± 1.1	1.8 ± 0.9
	Wye Barricade	13	4.2 ± 3.7	*0.8 ± 0.9	2.7 ± 1.5	
¹⁴ C (CO ₂)	Wye Barricade	6	1.5 ± 0.06	1.3 ± 0.06	1.4 ± 0.18	1.3 ± 0.3
⁹⁰ Sr	Hanford Townsite	4	0.00020 ± 0.00019	* ^(c) 0.00009 ± 0.00012	0.00016 ± 0.00009	0.00021 ± 0.00012
	Wye Barricade	4	0.00061 ± 0.00013	0.00013 ± 0.00008	0.00027 ± 0.00024	
¹³¹ I	Hanford Townsite ^(d)	0				
	Wye Barricade ^(d)	0				
¹³⁷ Cs	Hanford Townsite	12	0.0016 ± 0.0014	*-0.0010 ± 0.0016	0.0006 ± 0.0010	0.0000 ± 0.0003
	Wye Barricade	12	0.0017 ± 0.0011	*-0.0020 ± 0.0017	0.0002 ± 0.0014	
U(total)	Hanford Townsite	4	0.00077 ± 0.00004	0.00006 ± 0.00004	0.00030 ± 0.00035	0.00008 ± 0.00004
	Wye Barricade	4	0.00017 ± 0.00007	0.00003 ± 0.00002	0.00009 ± 0.00014	
²³⁸ Pu	Hanford Townsite	4	0.000009 ± 0.000006	*0.000000 ± 0.000000	0.000004 ± 0.000005	0.000001 ± 0.000001
	Wye Barricade	4	0.000008 ± 0.000005	*0.000000 ± 0.000000	0.000004 ± 0.000004	
^{239,240} Pu	Hanford Townsite	4	0.000005 ± 0.000005	*0.000001 ± 0.000002	0.000003 ± 0.000003	0.000003 ± 0.000002
	Wye Barricade	4	0.000013 ± 0.000007	*0.000001 ± 0.000001	0.000006 ± 0.000006	
Gross Beta	Hanford Townsite	26	0.13 ± 0.006	0.009 ± 0.004	0.033 ± 0.009	0.032 ± 0.004
	Wye Barricade	26	0.096 ± 0.006	0.015 ± 0.004	0.032 ± 0.008	
Gross Alpha	Hanford Townsite	26	0.0026 ± 0.0007	0.0005 ± 0.0003	0.0011 ± 0.0002	0.0011 ± 0.0001
	Wye Barricade	26	0.0018 ± 0.0006	*0.0004 ± 0.0006	0.0011 ± 0.0002	

- (a) Maximum and minimum concentrations ±2 sigma counting error. Averages ±2 standard error of the calculated mean. Entries have been rounded for clarity.
- (b) Distant sampling locations are identified in Table A.1 and Figure 8.
- (c) The * indicates ±2 sigma counting error greater than result.
- (d) Not routinely analyzed.

TABLE A.11. Average, Minimum and Maximum Tritium Concentrations in the Ground Water

Well Name	No. of Samples	Concentration, pCi/g (a)		
		Minimum	Maximum	Average
1-B3-1	2	1800 ± 550	2000 ± 430	1900 ± 430
1-B3-2P(b)	1	670 ± 420	670 ± 420	670 ± 420
1-B3-20(b)	2	430 ± 410	1000 ± 540	715 ± 791
1-B4-1	4	8600 ± 560	67000 --- (c)	40900 ± 28400
1-B4-2	4	2300 ± 490	19000 ---	8950 ± 8120
1-B4-3	3	4900 ± 580	130000 ---	56000 ± 85400
1-B4-4	2	1600 ± 430	3600 ± 570	2600 ± 2530
1-B5-1	3	940 ± 420	1500 ± 550	1250 ± 474
1-B9-1	2	940 ± 420	1900 ± 550	1420 ± 1250
1-D2-5	2	1600 ± 490	2800 ± 560	2200 ± 1550
1-D5-12	4	2800 ± 460	4400 ± 580	3650 ± 818
1-D8-3	4	3200 ± 510	3800 ± 470	3450 ± 385
1-F5-1	4	-180 ± 410	510 ± 430	209 ± 410
1-F5-3	4	660 ± 470	1300 ± 560	1010 ± 391
1-F5-4	4	18000 ---	23000 ± 640	20300 ± 2440
1-F5-6	4	560 ± 430	930 ± 480	825 ± 298
1-F7-1	4	290 ± 420	1900 ± 550	1120 ± 817
1-F8-1	4	13000 ---	39000 ---	25000 ± 12600
1-F8-2	4	2200 ± 450	3400 ± 510	2930 ± 634
1-H3-1	5	2400 ± 490	4900 ± 600	3580 ± 990
1-H4-3	4	250 ± 470	1100 ± 540	568 ± 477
1-H4-4	3	-450 ± 460	620 ± 420	10 ± 774
1-H4-5	4	-510 ± 450	620 ± 420	128 ± 598
1-H4-6	4	910 ± 480	2700 ± 580	1600 ± 904
1-K-11	4	2200 ± 440	3500 ± 510	2780 ± 680
1-K-19	4	17000 ± 570	30000 ---	24300 ± 6320
1-K-20	4	1300 ± 440	4300 ± 520	2350 ± 1480
1-K-22	4	940 ± 480	1800 ± 550	1310 ± 480
1-K-27	4	1400 ± 430	2600 ± 580	1830 ± 632
1-K-28	4	2100 ± 430	4400 ± 520	3550 ± 1150
1-K-29	4	42000 ---	59000 ---	49300 ± 8260
1-K-30	4	360000 ---	490000 ---	420000 ± 63200
1-N-2	3	17000 ---	58000 ---	36000 ± 28000
1-N-3	4	33000 ---	56000 ± 870	45500 ± 11200
1-N-4	3	33000 ---	43000 ---	37300 ± 6820
1-N-5	2	34000 ---	40000 ---	37000 ± 7520
1-N-6	3	25000 ---	67000 ± 930	42000 ± 28700
1-N-7	3	30000 ---	46000 ---	35300 ± 10900
1-N-14	4	30000 ---	60000 ± 890	43500 ± 14600
1-N-15	3	25000 ---	35000 ---	29000 ± 6820
1-N-16	4	-390 ± 450	2100 ± 580	718 ± 1230
1-N-17	4	16000 ---	52000 ---	31800 ± 17500
1-N-18	3	15000 ---	51000 ---	30700 ± 24600
1-N-19	4	14000 ± 560	29000 ---	22000 ± 7290
1-N-20	4	9000 ± 510	23000 ---	17000 ± 6810
1-N-21	4	9300 ± ---	32000 ---	17300 ± 11000
1-N-22	4	2100 ± 560	6800 ± 470	4050 ± 2300
1-N-23	4	4200 ± 580	17000 ± 570	10600 ± 6230
1-N-24	1	4000 ± 500	4000 ± 500	4000 ± 500
1-N-25	1	190 ± 460	190 ± 460	190 ± 460
1-N-26	4	53 ± 410	790 ± 550	326 ± 427
1-N-27	3	35000 ---	62000 ---	45700 ± 18400
1-N-28	3	38000 ---	61000 ---	45700 ± 15700
1-N-29	3	33000 ---	64000 ---	48700 ± 21200
1-N-30	3	28000 ---	44000 ---	35700 ± 10900
1-N-31	4	25000 ---	54000 ---	36800 ± 14100

TABLE A.11. (contd)

Well Name	No. of Samples	Concentration, pCi/l ^(a)		
		Minimum	Maximum	Average
1-N-32	3	29000 ---	42000 ---	34700 ± 8870
1-N-33	4	29000 ---	52000 ---	42500 ± 11200
1-N-34	4	27000 ---	55000 ---	35800 ± 13600
2-E19-1	4	-440 ± 540	7900 ± 490	2080 ± 4060
2-E23-1	4	4800 ± 460	6700 ± 610	5650 ± 963
2-E24-7	4	4900 ± 630	6500 ± 610	5480 ± 825
2-E25-2	3	12000 ± 690	14000 ---	13000 ± 1400
2-E26-1	3	570 ± 550	1200 ± 420	850 ± 525
2-E26-3	4	4900 ± 480	21000 ---	10500 ± 7830
2-E27-1	3	8600 ± 560	14000 ---	10600 ± 3700
2-E28-1	4	7700 ± 660	9700 ± 510	8580 ± 1010
2-E28-5	4	2300 ± 500	9600 ± 520	5830 ± 3560
2-E33-14	3	370 ± 410	2400 ± 600	1150 ± 1420
2-W6-1	3	25000 ± ---	43000 ± 790	36700 ± 12300
2-W10-5	3	10000 ± 540	13000 ---	11300 ± 2060
2-W11-9	3	890 ± 560	8000 ± 510	3300 ± 4860
2-W12-1	3	1900 ± 490	2400 ± 570	2100 ± 449
2-W15-2	2	390 ± 470	850 ± 560	620 ± 683
2-W18-3	3	-350 ± 450	1600 ± 440	523 ± 1360
2-W21-1	3	180000 ---	230000 ---	200000 ± 34100
2-W22-7	3	470000 ---	540000 ---	507000 ± 47800
2-W22-9	3	8900000 ---	9400000 ---	9170000 ± 341000
2-W22-10	1	740000 ---	740000 ---	740000 ---
3-1-5	1	18 ± 420	18 ± 420	18 ± 420
4-S0-7	4	20000 ---	39000 ---	25800 ± 9230
4-S0-8	4	18000 ---	59000 ---	32000 ± 19900
4-S1-7B	4	63000 ---	74000 ---	67500 ± 5350
4-S1-7C	4	86000 ---	91000 ---	88300 ± 2430
4-S1-8A	4	96000 ---	100000 ---	98000 ± 1940
6-S3-25	4	-370 ± 460	50 ± 420	-190 ± 307
6-S3-E12	4	3000 ± 490	4000 ± 480	3430 ± 548
6-S6-E4B	4	22000 ---	28000 ---	24300 ± 2920
6-S6-E4D	4	32000 ---	36000 ---	34300 ± 1940
6-S6E14A ^(b)	5	-400 ± 410	480 ± 550	13 ± 400
6-S7-34	3	-250 ± 430	510 ± 540	173 ± 583
6-S8-19	4	-480 ± 460	350 ± 410	-50 ± 465
6-S11E12A ^(b)	5	-440 ± 450	1500 ± 560	191 ± 777
6-S11E12AP ^(b)	5	45 ± 550	1800 ± 450	1110 ± 711
6-S12-3	4	-100 ± 550	250 ± 440	113 ± 298
6-S19-E13	3	4300 ± 520	4800 ± 450	4500 ± 441
6-S28-E0	5	-320 ± 540	180 ± 550	24 ± 288
6-S29-E12	3	-70 ± 470	240 ± 410	65 ± 327
6-S30E15A	3	-130 ± 430	480 ± 480	157 ± 488
6-S31-1P	4	-430 ± 460	390 ± 420	10 ± 462
6-1-18	4	61000 ---	69000 ---	63800 ± 3890
6-2-3	12	110000 ---	120000 ---	114000 ± 2970
6-2-33A	3	-450 ± 450	390 ± 550	73 ± 635
6-3-45	2	190 ± 540	370 ± 400	280 ± 405
6-4-E6	4	-360 ± 410	330 ± 440	-128 ± 408
6-8-17	4	160000 ---	160000 ---	160000 ---
6-8-25	4	44000 ---	50000 ---	46300 ± 2920
6-8-32	3	-220 ± 410	110 ± 440	-36 ± 351
6-9-E2	5	-360 ± 410	110 ± 480	-112 ± 277
6-10-E12	4	11000 ---	12000 ± 520	11500 ± 541
6-13-64	3	260 ± 440	1200 ± 540	727 ± 696
6-14-E6T	3	37000 ---	39000 ---	38300 ± 1400
6-14-38	3	-110 ± 460	400 ± 530	112 ± 443

TABLE A.11. (contd)

Well Name	No. of Samples	Concentration, pCi/l ^(a)			
		Minimum	Maximum	Average	
6-14-47	4	-52 ± 430	990 ± 540	292 ±	554
6-15-15B	4	-510 ± 450	120 ± 410	-198 ±	383
6-15-26	3	78000 ---	110000 ---	90000 ±	21800
6-17-5	5	-410 ± 440	50 ± 470	-218 ±	273
6-17-70	3	-46 ± 430	390 ± 550	238 ±	401
6-19-43	2	530 ± 540	600 ± 430	565 ±	356
6-20-E5A	5	44000 ---	50000 ---	47400 ±	2320
6-20-E5AP(b)	4	-54 ± 420	530 ± 450	195 ±	371
6-20-E5AQ(b)	4	-310 ± 410	530 ± 450	-45 ±	472
6-20-E5AR(b)	4	-3 ± 420	980 ± 460	318 ±	535
6-20-E12	1	99 ± 600	99 ± 600	99 ±	600
6-20-E12P(b)	3	-250 ± 590	330 ± 430	33 ±	488
6-20-20	4	260000 ---	310000 ---	278000 ±	24300
6-20-39	3	-310 ± 460	770 ± 540	213 ±	787
6-20-82	3	-370 ± 430	1100 ± 540	303 ±	1040
6-21-6	11	52000 ± ---	79000 ± 1000	57900 ±	4530
6-22-70	3	-25 ± 440	370 ± 410	228 ±	380
6-24-1P(b)	3	-290 ± 590	170 ± 430	10 ±	425
6-24-1Q(b)	3	-350 ± 420	82 ± 450	-133 ±	409
6-24-1R(b)	3	-250 ± 420	100 ± 450	-103 ±	371
6-24-1S(b)	3	-52 ± 450	340 ± 600	95 ±	392
6-24-1T	2	9000 ± 520	9800 ± 550	9400 ±	1070
6-24-33	3	28000 ± 670	0000 ---	35000 ±	8190
6-24-46	1	490 ± 540	490 ± 540	490 ±	540
6-25-55	2	-53 ± 570	150 ± 440	49 ±	441
6-25-70	1	1600 ± 420	1600 ± 420	1600 ±	420
6-26-15A	4	330000 ---	420000 ---	388000 ±	43700
6-27-8	3	410000 ---	470000 ---	443000 ±	40900
6-28-40	1	9100 ± 690	9100 ± 690	9100 ±	690
6-28-40P(b)	1	120 ± 600	120 ± 600	120 ±	600
6-28-52A	2	-470 ± 560	230 ± 440	-120 ±	947
6-29-4	12	110000 ---	130000 ± ---	118000 ±	4140
6-29-78	4	11 ± 470	1500 ± 550	541 ±	761
6-31-31	3	140000 ---	160000 ---	147000 ±	13600
6-31-31P(b)	3	13 ± 420	470 ± 610	231 ±	425
6-31-53B	2	-4 ± 570	110 ± 400	53 ±	376
6-32-22	3	350000 ---	490000 ---	420000 ±	95500
6-32-43	4	43000 ---	140000 ---	73000 ±	47100
6-32-62	1	-120 ± 600	-120 ± 600	-120 ±	600
6-32-70B	4	270000 ---	290000 ---	280000 ±	9720
6-32-72	4	130000 ---	140000 ---	135000 ±	4860
6-32-77	3	-320 ± 460	1000 ± 550	370 ±	942
6-33-42	4	100000 ---	280000 ---	180000 ±	87500
6-33-56	3	-280 ± 570	190 ± 400	-107 ±	421
6-34-39A	4	31000 ± 700	69000 ---	52000 ±	18500
6-34-41B	3	75000 ---	89000 ---	80700 ±	9550
6-34-42	4	93000 ---	150000 ---	126000 ±	27700
6-34-51	2	-370 ± 600	16 ± 440	-177 ±	610
6-34-88	3	-190 ± 570	130 ± 440	-73 ±	360
6-35-9	5	160000 ---	180000 ---	168000 ±	7690
6-35-66	4	1200000 ---	1200000 ---	1200000 ---	---
6-35-70	4	1800000 ---	2100000 ---	1930000 ±	146000
6-36-46P(b)	3	-540 ± 560	-120 ± 420	-370 ±	396
6-36-46Q(b)	3	-500 ± 560	760 ± 430	33 ±	903
6-36-61B	3	-470 ± 600	550 ± 470	63 ±	753
6-36-93	2	-88 ± 460	460 ± 400	186 ±	751
6-37-E4	11	19000 ---	32000 ---	24900 ±	2270

TABLE A.11. (contd)

Well Name	No. of Samples	Concentration, pCi/g ^(a)		
		Minimum	Maximum	Average
6-37-43	4	23000 ± 640	38000 ---	28300 ± 7300
6-37-82A	4	-390 ± 570	450 ± 420	90 ± 474
6-38-15	4	530000 ---	580000 ---	560000 ± 24300
6-38-65	4	290000 ---	330000 ---	315000 ± 19400
6-38-70	4	1400 ± 430	2800 ± 570	2130 ± 723
6-39-0	12	230000 ---	250000 ---	240000 ± 4260
6-39-39	2	-170 ± 470	570 ± 400	200 ± 977
6-39-79	3	-400 ± 410	1300 ± 550	450 ± 1190
6-40-1	4	230000 ---	240000 ---	233000 ± 4860
6-40-33A	4	-330 ± 410	43 ± 410	-136 ± 297
6-40-62	4	42000 ---	50000 ---	45500 ± 3890
6-41-1	12	220000 ---	250000 ---	236000 ± 5200
6-41-23	3	260000 ---	310000 ---	283000 ± 34100
6-42-2	12	200000 ---	220000 ---	209000 ± 4580
6-42-12A	4	300000 ---	320000 ---	315000 ± 9720
6-43-3	12	210000 ---	230000 ---	222000 ± 4140
6-43-88	3	-170 ± 430	1600 ± 430	445 ± 1240
6-44-4	12	100000 ---	150000 ---	123000 ± 9320
6-44-64	4	140 ± 440	670 ± 420	440 ± 350
6-45-2	12	140000 ---	200000 ---	179000 ± 129000
6-45-42	4	53000 ---	65000 ---	57300 ± 5830
6-45-69A	4	-360 ± 410	2000 ± 560	583 ± 1170
6-46-4	12	130000 ---	220000 ---	167000 ± 15200
6-46-21B	4	37000 ---	42000 ---	39000 ± 2430
6-47-5	12	60000 ---	170000 ---	121000 ± 22200
6-47-35A	4	-430 ± 410	330 ± 540	-220 ± 433
6-47-46A	4	-560 ± 590	50 ± 410	-190 ± 378
6-47-60	4	-430 ± 440	410 ± 550	-90 ± 468
6-48-7	4	-270 ± 410	320 ± 460	74 ± 368
6-48-18	4	-320 ± 410	150 ± 540	-107 ± 323
6-48-71	3	-23 ± 470	340 ± 420	186 ± 371
6-49-13E	4	-290 ± 410	330 ± 450	35 ± 379
6-49-28	3	-210 ± 590	490 ± 420	27 ± 556
6-49-55A	4	5500 ± 660	6900 ± 490	6280 ± 732
6-49-57	4	5500 ± 510	8100 ± 620	6700 ± 1290
6-49-79	4	-470 ± 560	60 ± 440	-127 ± 347
6-50-28B	4	-150 ± 440	1000 ± 410	435 ± 604
6-50-30	3	-68 ± 430	270 ± 410	137 ± 353
6-50-42	4	1600 ± 440	2400 ± 570	2100 ± 457
6-50-53	4	-300 ± 570	250 ± 420	30 ± 354
6-50-85	4	-500 ± 560	140 ± 440	-215 ± 389
6-51-63	4	-140 ± 430	260 ± 410	54 ± 302
6-51-75	4	-420 ± 560	570 ± 430	-54 ± 536
6-53-35	3	-170 ± 460	180 ± 540	35 ± 363
6-53-103(b)	1	-340 ± 570	-340 ± 570	-340 ± 570
6-54-34	3	-400 ± 410	1200 ± 550	273 ± 1130
6-54-37B	1	530 ± 550	530 ± 550	530 ± ---
6-54-42	2	150 ± 410	230 ± 540	190 ± 354
6-54-45A	1	270 ± 540	270 ± 540	270 ± 540
6-55-40	3	-130 ± 430	510 ± 550	141 ± 513
6-55-44	3	-65 ± 430	1200 ± 550	535 ± 905
6-55-50A	3	240 ± 560	390 ± 460	297 ± 296
6-55-50C	3	3 ± 460	920 ± 550	315 ± 684
6-55-50D	1	-45 ± 410	-45 ± 410	-45 ± 410
6-55-70	3	-490 ± 560	240 ± 410	-93 ± 569
6-55-76	1	-170 ± 420	-170 ± 420	-170 ± 420
6-56-43	3	-210 ± 430	640 ± 550	227 ± 640
6-57-25A	4	-310 ± 410	540 ± 400	108 ± 471

TABLE A.11. (contd)

Well Name	No. of Samples	Concentration, pCi/g ^(a)		
		Minimum	Maximum	Average
6-57-29A	3	270 ± 420	1000 ± 550	660 ± 570
6-58-24	3	-250 ± 430	560 ± 550	126 ± 615
6-59-32	4	360 ± 420	920 ± 460	633 ± 358
6-59-58	4	840 ± 430	1600 ± 560	1190 ± 439
6-60-32	3	420 ± 420	960 ± 550	700 ± 461
6-60-57	4	-290 ± 590	820 ± 460	333 ± 590
6-60-60	3	7600 ± 520	8000 ± 680	7830 ± 429
6-61-41	4	-210 ± 420	5 ± 420	-78 ± 252
6-61-62	4	8000 ± 680	8600 ± 510	8330 ± 406
6-61-66	4	-390 ± 590	240 ± 410	-76 ± 387
6-62-43F	4	49 ± 420	1000 ± 460	597 ± 518
6-63-25A	4	-500 ± 590	240 ± 400	-253 ± 429
6-63-51	2	-100 ± 420	490 ± 480	195 ± 805
6-63-55	4	90 ± 570	1000 ± 480	588 ± 503
6-63-58	4	10 ± 420	710 ± 550	305 ± 413
6-63-90	4	-100 ± 410	240 ± 410	60 ± 266
6-64-27	2	-290 ± 590	100 ± 400	-95 ± 605
6-64-62	4	7100 ± 670	8900 ± 510	8030 ± 918
6-65-23	1	-190 ± 590	-190 ± 590	-190 ± 590
6-65-50	4	310 ± 420	830 ± 580	573 ± 347
6-65-59	4	54 ± 600	750 ± 430	419 ± 415
6-65-72	4	3200 ± 450	3800 ± 640	3500 ± 389
6-65-83	4	750 ± 420	1600 ± 430	1160 ± 477
6-66-58	4	64 ± 600	690 ± 460	284 ± 388
6-66-64	4	5700 ± 470	7000 ± 650	6330 ± 686
6-66-103	2	-58 ± 460	320 ± 400	131 ± 563
6-67-51	4	370 ± 600	1200 ± 440	800 ± 471
6-67-86	4	500 ± 420	1200 ± 430	913 ± 418
6-67-98	3	-58 ± 410	440 ± 610	121 ± 444
6-68-105	2	-61 ± 460	190 ± 400	65 ± 438
6-69-38	3	-590 ± 590	230 ± 410	-167 ± 625
6-70-68	1	1300 ± 430	1300 ± 430	1300 ± 430
6-71-30	2	-400 ± 590	60 ± 400	-170 ± 678
6-71-52	4	560 ± 600	1400 ± 430	1010 ± 476
6-71-77	2	2700 ± 440	3400 ± 500	3050 ± 938
6-72-73	1	1300 ± 430	1300 ± 430	1300 ± 430
6-72-88	4	2700 ± 630	3300 ± 450	3030 ± 386
6-72-92	2	2100 ± 480	3800 ± 450	2950 ± 2160
6-72-98	1	130 ± 460	130 ± 460	130 ± 460
6-73-61	3	-130 ± 460	590 ± 610	210 ± 571
6-74-44	4	-600 ± 590	150 ± 440	-98 ± 433
6-77-36	4	-480 ± 590	300 ± 400	-99 ± 445
6-81-58	4	-490 ± 590	60 ± 420	-200 ± 357
6-83-47	2	510 ± 580	600 ± 430	555 ± 378
6-84-35A0	2	-590 ± 590	-120 ± 420	-355 ± 691
6-87-55	4	62000 ---	70000 ---	64800 ± 3890
6-90-45	4	4800 ± 650	5400 ± 520	5100 ± 396
6-96-49	4	17000 ---	18000 ---	17300 ± 542
6-97-43	4	9900 ± 570	11000 ± 530	10200 ± 610
6-97-51A	4	13000 ± 560	16000 ± 570	14500 ± 1480
6-101-48B	2	-290 ± 590	140 ± 420	-75 ± 649

- (a) Maximum and minimum values ± 2 sigma counting error. Averages ± 2 standard error of the calculated mean.
- (b) Wells that sample the confined aquifer or a composite of the unconfined/confined aquifers.
- (c) The counting error was not reported when it was less than 2% of the concentration value.

TABLE A.12. Iodine-129 Concentrations in Wells Sampled in 1985

Sample Locations (a)	Date Sampled	Result, pCi/l	% Error (b)
699-25-55	9/12/85	0.00005	6.1
699-26-15A	9/12/85	2.78	7.2
699-27-8	9/12/85	2.08	5.7
699-32-22	9/12/85	5.58	7.1
699-35-66	5/30/85 8/20/85	6.97 5.72(c)	7.3 7.2
699-35-70	5/30/85 8/20/85	66.9 57.1(c)	7.3 7.1
699-37-E4	9/12/85 1/7/86	0.022 0.024	5.4 5.6
699-39-39	5/30/85 8/20/85	0.00029 0.0464(c)	7.4 7.3
699-41-1	9/10/85 1/8/86	0.255 0.214	5.4 5.6
699-41-23	9/12/85	2.94	7.1
699-46-4	9/10/85 1/8/86	0.093 0.140	5.4 5.6
699-50-85	9/12/85	0.000008	6.4
699-101-488	9/12/85	0.000016	6.1
299E-17-1	4/1/85 5/30/85 6/21/85 7/12/85 8/1/85 8/20/85 9/24/85 11/12/86 1/2/86	22.5(c) 14.5(c) 18.6(c) 23.0(c) 34.0(c) 26.7(c) 24.4(c) 25.2(c) 29.4(c)	6.4 7.3 7.6 7.2 9.3 7.1 5.7 5.7 5.6
299E-17-9	4/1/85 5/30/85 6/21/85 8/1/85 8/20/85 9/24/85 11/12/85 1/2/86	32.0(c) 20.5(c) 28.0(c) 22.8(c) 32.4(c) 30.2(c) 26.1(c) 31.6(c)	6.4 7.2 7.6 7.1 7.2 5.7 5.7 5.7
299E-24-2	4/1/85 5/30/85 7/12/85 8/20/85 11/12/85	12.3(c) 10.6(c) 13.9(c) 33.4(c) 17.1(c)	6.4 7.3 7.2 7.2 5.7
299E-25-20	4/8/85 5/30/85 7/18/85 8/20/85 10/16/85	0.69(c) 0.32(c) 0.31(c) 0.48(c) 0.87(c)	6.4 7.6 7.6 7.2 5.6
299W-22-14	5/30/85 8/22/85	4.42(c) 7.07(c)	7.4 7.3

(a) The well locations are identified in Figure 17.

(b) The percent error estimates are standard (1σ) counting errors.

(c) Iodine-129 samples which were collected and analyzed for RH0; the wells located in the 200 Areas can be located in Hanford Wells (McGhan, Mitchell, and Argo 1985).

TABLE A.13. Radionuclide Concentration Measured in Columbia River Water Upstream from Hanford Operations in 1985

Radionuclide ^(b)	No. of Samples	Concentration, pCi/L ^(a)			Drinking Water Screening Levels ^(c)	
		Minimum	Maximum	Average		
³ H	12	64 ± 11	160 ± 13	110 ± 18	20,000	
⁶⁰ Co	Particulate	21	* ^(d) -0.0035 ± 0.0053	0.0075 ± 0.0061	*0.0017 ± 0.0017	100
	Dissolved	21	*-0.012 ± 0.013	0.0070 ± 0.011	*-0.00026 ± 0.0033	
⁸⁹ Sr	12	*-0.036 ± 0.063	0.19 ± 0.11	0.087 ± 0.052	20	
⁹⁰ Sr	12	0.085 ± 0.025	0.21 ± 0.046	0.15 ± 0.025	8	
⁹⁵ Zr	Particulate	21	*-0.0066 ± 0.010	*0.0079 ± 0.011	*-0.00056 ± 0.0022	200
	Dissolved	21	*-0.011 ± 0.011	*0.0095 ± 0.012	*-0.0017 ± 0.0042	
⁹⁵ Nb	Particulate	21	*-0.0025 ± 0.039	*0.0069 ± 0.0089	*0.0014 ± 0.0015	300
	Dissolved	21	*-0.0064 ± 0.017	*0.012 ± 0.013	*0.00086 ± 0.0029	
¹⁰⁶ Ru	Particulate	21	*-0.53 ± 0.052	0.058 ± 0.036	*-0.011 ± 0.014	30
	Dissolved	21	*-0.011 ± 0.099	*0.032 ± 0.047	*-0.016 ± 0.022	
¹²⁹ I	Dissolved	4	8.2x10 ⁻⁶ ± 1.1x10 ⁻⁶	9.4x10 ⁻⁶ ± 1.2x10 ⁻⁶	8.9x10 ⁻⁶ ± 8.5x10 ⁻⁶	1
¹³¹ I	Particulate	21	*-0.0031 ± 0.0062	0.021 ± 0.014	*0.0019 ± 0.0026	3
	Dissolved	21	*-0.013 ± 0.017	0.029 ± 0.023	*0.0034 ± 0.0057	
¹³⁷ Cs	Particulate	21	*-0.0056 ± 0.0063	0.022 ± 0.0047	0.0091 ± 0.0032	200
	Dissolved	21	*-0.0070 ± 0.012	0.038 ± 0.0084	0.018 ± 0.0058	
¹⁴⁴ Ce	Particulate	21	*-0.032 ± 0.021	0.011 ± 0.0095	*-0.0039 ± 0.0050	-- ^(e)
	Dissolved	21	*-0.043 ± 0.038	*0.015 ± 0.018	*-0.0096 ± 0.0083	
U (Natural)	12	0.19 ± 0.00	0.66 ± 0.20	0.38 ± 0.10	--	
²³⁸ Pu	Particulate	4	*-4.8x10 ⁻⁶ ± 7.7x10 ⁻⁶	*3.7x10 ⁻⁶ ± 12x10 ⁻⁶	*9.2x10 ⁻⁷ ± 5.8x10 ⁻⁶	--
	Dissolved	4	*-1.7x10 ⁻⁴ ± 1.7x10 ⁻⁴	*1.3x10 ⁻⁴ ± 3.3x10 ⁻⁴	*-1.7x10 ⁻⁵ ± 2.4x10 ⁻⁴	
^{239,240} Pu	Particulate	4	*1.8x10 ⁻⁵ ± 2.4x10 ⁻⁵	2.6x10 ⁻⁵ ± 0.88x10 ⁻⁵	2.14x10 ⁻⁵ ± 1.0x10 ⁻⁵	--
	Dissolved	4	*1.5x10 ⁻⁴ ± 3.0x10 ⁻⁴	*5.1x10 ⁻⁴ ± 12x10 ⁻⁴	*3.45x10 ⁻⁴ ± 4.4x10 ⁻⁴	

(a) Maximum and minimum values ±2 sigma counting error. Average ±2 standard error of the calculated mean.
 (b) Radionuclides measured using the large-volume sampler show the particulate and dissolved fractions separately. Other radionuclides are based on samples collected by the cumulative sample (see text).
 (c) From State of Washington and EPA (see Appendix C).
 (d) The * signifies that the associated uncertainty is equal to or greater than the result.
 (e) Dashes indicate no guide value.

TABLE A.14. Radionuclide Concentrations Measured in Columbia River Water Downstream from Hanford Operations in 1985

Radionuclide ^(b)	No. of Samples	Concentration, pCi/g ^(a)			Drinking Water Screening Levels ^(c)	
		Minimum	Maximum	Average		
³ H	12	94 ± 12	220 ± 13	150 ± 21	20,000	
⁶⁰ Co	Particulate	23	* ^(d) 0.0027 ± 0.0073	0.011 ± 0.0055	0.0044 ± 0.0020	100
	Dissolved	23	*-0.0047 ± 0.0075	0.023 ± 0.0082	0.0076 ± 0.0036	
⁸⁹ Sr	12	*-0.049 ± 0.090	0.29 ± 0.12	0.10 ± 0.065	20	
⁹⁰ Sr	12	0.052 ± 0.029	0.21 ± 0.050	0.16 ± 0.029	8	
⁹⁵ Zr	Particulate	23	*-0.0041 ± 0.0070	0.0064 ± 0.0058	*0.0006 ± 0.0019	200
	Dissolved	23	*-0.0098 ± 0.012	*-0.011 ± 0.013	*0.0022 ± 0.0033	
⁹⁵ Nb	Particulate	23	*-0.0018 ± 0.0030	0.0052 ± 0.0037	0.0017 ± 0.0012	300
	Dissolved	23	*-0.0036 ± 0.0057	*0.0086 ± 0.0086	0.0027 ± 0.0021	
¹⁰⁶ Ru	Particulate	23	*-0.046 ± 0.036	*0.031 ± 0.034	*-0.0010 ± 0.010	30
	Dissolved	23	*-0.14 ± 0.078	*0.036 ± 0.060	*-0.0087 ± 0.022	
¹²⁹ I	Dissolved	4	4.9x10 ⁻⁵ ± 7.3x10 ⁻⁶	1.5x10 ⁻⁴ ± 1.9x10 ⁻⁵	8.8x10 ⁻⁵ ± 4.9x10 ⁻⁵	1
¹³¹ I	Particulate	23	*-0.0047 ± 0.005	0.0063 ± 0.0056	0.0017 ± 0.0016	3
	Dissolved	23	*-0.0024 ± 0.011	0.046 ± 0.010	0.019 ± 0.0062	
¹³⁷ Cs	Particulate	23	*-0.0040 ± 0.0050	0.014 ± 0.0040	0.0072 ± 0.0025	200
	Dissolved	23	*-0.0054 ± 0.011	0.030 ± 0.0074	0.016 ± 0.0049	
¹⁴⁴ Ce	Particulate	23	*-0.020 ± 0.011	0.012 ± 0.010	*-0.0027 ± 0.0043	--- ^(e)
	Dissolved	23	*-0.030 ± 0.027	*-0.011 ± 0.021	*-0.0064 ± 0.0063	
U (Natural)	12	0.29 ± 0.11	0.66 ± 0.20	0.48 ± 0.19	---	
²³⁸ Pu	Particulate	4	*-4.4x10 ⁻⁶ ± 9.8x10 ⁻⁶	*4.8x10 ⁻⁶ ± 3.9x10 ⁻⁶	*6.8x10 ⁻⁷ ± 5.4x10 ⁻⁶	---
	Dissolved	4	*-4.2x10 ⁻⁵ ± 6.3x10 ⁻⁵	*4.1x10 ⁻⁵ ± 4.4x10 ⁻⁵	*-5.7x10 ⁻⁶ ± 4.8x10 ⁻⁵	
^{239,240} Pu	Particulate	4	*1.3x10 ⁻⁵ ± 1.7x10 ⁻⁵	7.8x10 ⁻⁵ ± 4.0x10 ⁻⁵	*3.20x10 ⁻⁵ ± 3.3x10 ⁻⁵	---
	Dissolved	4	*1.5x10 ⁻⁴ ± 1.8x10 ⁻⁴	4.2x10 ⁻⁴ ± 3.8x10 ⁻⁴	2.79x10 ⁻⁴ ± 1.9x10 ⁻⁴	

(a) Maximum and minimum values ±2 sigma counting error. Average ±2 standard error of the calculated mean.
 (b) Radionuclides measured using the large-volume sampler show the particulate and dissolved fractions separately. Other radionuclides are based on samples collected by the cumulative sample (see text).
 (c) From State of Washington and EPA (see Appendix C).
 (d) The * signifies that the associated uncertainty is equal to or greater than the result.
 (e) Dashes indicate no guide value.

TABLE A.15. Radionuclide Concentrations in Onsite Ponds in 1985

Location	Radionuclide	No. of Samples	Concentration, pCi/l ^(a)		
			Minimum	Maximum	Average
West Lake	Gross Alpha	4	82 ± 8	210 ± 14	160 ± 62
	Gross Beta	4	130 ± 22	350 ± 40	220 ± 110
	³ H	4	710 ± 230	920 ± 180	780 ± 140
	⁹⁰ Sr	4	1.2 ± 0.11	2.7 ± 0.20	1.8 ± 0.73
	¹³⁷ Cs	4	*(b) -1.5 ± 2.4	3.4 ± 2.3	*0.045 ± 2.8
Gable Pond	Gross Alpha	4	0.59 ± 0.40	1.6 ± 0.57	1.0 ± 0.54
	Gross Beta	4	13 ± 2.8	29 ± 3.9	19 ± 7.9
	³ H	4	*66 ± 170	380 ± 220	190 ± 180
	⁹⁰ Sr	4	0.58 ± 0.065	4.6 ± 0.1	2.1 ± 2.0
	¹³⁷ Cs	4	5.1 ± 1.7	17 ± 2.6	9.1 ± 5.8
B Pond	Gross Alpha	4	*-0.023 ± 0.26	1.1 ± 0.50	*0.47 ± 0.62
	Gross Beta	4	4.3 ± 2.0	24.0 ± 3.7	11 ± 10
	³ H	4	220 ± 220	1100 ± 200	570 ± 450
	⁹⁰ Sr	4	0.45 ± 0.74	4.1 ± 0.2	*1.5 ± 1.8
	¹³⁷ Cs	4	*-1.07 ± 1.36	2.5 ± 2.1	*1.1 ± 1.9
FFTF Pond	Gross Alpha	4	*-0.49 ± 1.2	11 ± 3.5	*3 ± 6
	Gross Beta	4	28 ± 9.9	37 ± 11	32 ± 7
	³ H	4	21000 ± 420	29000 ± 560	25000 ± 3900
	¹³⁷ Cs	4	*0.57 ± 2.4	*0.92 ± 1.6	*0.73 ± 0.87
	²² Na	4	*-0.15 ± 2.2	2.8 ± 2.5	*1.3 ± 1.7

(a) Maximum and minimum values ±2 sigma counting error. Averages ±2 standard error of the calculated mean.

(b) The * signifies that the associated uncertainty is greater than or equal to the result.

TABLE A.16. Radionuclides in Milk Samples

Location(b)	Concentration, pCi/l(a)					
	¹³¹ I			¹³⁷ Cs		
	No. of Samples	Maximum	Average	No. of Samples	Maximum	Average
Wahluke East Area Composite	13	0.14 ± 0.09	* ^(c) -0.044 ± 0.15	13	5.6 ± 4.4	*1.2 ± 2.5
Sagemoor Area Composite	25	0.32 ± 0.28	*-0.026 ± 0.07	26	6.0 ± 4.7	*0.8 ± 1.4
Riverview Area ^(d)	11	0.23 ± 0.22	*0.006 ± 0.078	11	2.4 ± 3.8	*0.7 ± 2.2
Benton City Area	12	*0.12 ± 0.24	*-0.004 ± 0.061	13	9.6 ± 4.2	2.5 ± 2.1
Sunnyside Area	26	0.07 ± 0.05	*-0.01 ± 0.06	27	6.6 ± 6.0	*0.66 ± 1.5
Moses Lake Area	10	0.23 ± 0.22	* 0.02 ± 0.09	10	6.4 ± 3.9	*1.2 ± 2.5

Location(b)	Concentration, pCi/l(a)					
	⁸⁹ Sr			⁹⁰ Sr		
	No. of Samples	Maximum	Average	No. of Samples	Maximum	Average
Wahluke East Area Composite	4	*0.82 ± 0.75	*-0.91 ± 3.0	4	1.1 ± 0.19	0.85 ± 0.36
Sagemoor Area	-(e)	-	-	5	1.1 ± 0.37	0.94 ± 0.23
Riverview Area ^(d)	4	*0.53 ± 0.62	*-0.019 ± 0.65	4	1.7 ± 0.27	1.2 ± 0.5
Benton City Area	-	-	-	4	1.8 ± 0.5	1.5 ± 0.35
Sunnyside Area	4	*0.48 ± 0.57	*0.28 ± 0.36	4	1.1 ± 0.25	0.88 ± 0.31
Moses Lake Area	-	-	-	3	1.6 ± 0.3	1.4 ± 0.3

Location(b)	Concentration, pCi/g					
	³ H			¹²⁹ I		
	No. of Samples	Maximum	Average	No. of Samples	Maximum	Average
Wahluke East Area Composite	13	430 ± 180	230 ± 89	2	0.044 ± 0.006	*0.026 ± 0.045
Sagemoor Area Composite	13	580 ± 190	310 ± 89	2	0.040 ± 0.006	*0.027 ± 0.032
Riverview Area ^(d)	11	370 ± 220	160 ± 92	2	0.022 ± 0.001	*0.018 ± 0.009
Benton City Area	13	880 ± 230	240 ± 140	2	0.19 ± 0.03	*0.098 ± 0.23
Sunnyside Area	14	350 ± 160	120 ± 73	2	0.013 ± 0.002	*0.009 ± 0.011
Moses Lake Area	10	750 ± 180	250 ± 160	2	0.001 ± 0.0002	*0.001 ± 0.001

- (a) Maximum values ±2 sigma counting error. Averages ±2 standard error of the calculated mean.
 (b) Refer to Figure 35.
 (c) The * signifies that the associated uncertainty is equal to or greater than the result.
 (d) Drinking and irrigation water obtained from the Columbia River downstream of Hanford.
 (e) Dashes indicate no sample was analyzed.

TABLE A.17. Radionuclides in Leafy Vegetables

Location(b)	Concentration, pCi/g, wet weight ^(a)					
	⁹⁰ Sr			¹³⁷ Cs		
	No. of Samples	Maximum	Average	No. of Samples	Maximum	Average
Wahluke East Area	3	0.007 ± 0.003	0.006 ± 0.003	3	*-0.004 ± 0.007	* ^(c) -0.005 ± 0.005
Sagemoor Area	3	0.006 ± 0.003	0.005 ± 0.002	3	0.013 ± 0.004	*0.004 ± 0.011
Riverview Area ^(d)	3	0.032 ± 0.006	0.028 ± 0.008	3	0.012 ± 0.007	*0.008 ± 0.01
Benton City Area	3	0.006 ± 0.002	0.005 ± 0.002	3	0.008 ± 0.006	*-0.001 ± 0.017
Sunnyside Area	3	0.004 ± 0.002	0.004 ± 0.001	3	*0.003 ± 0.006	*0.002 ± 0.004
Moses Lake Area	3	0.010 ± 0.004	0.007 ± 0.004	3	*0.005 ± 0.009	*-0.003 ± 0.014

- (a) Maximum and minimum concentrations ±2 sigma counting error. Averages ±2 standard error of the calculated mean.
 (b) Refer to Figure 35.
 (c) The * signifies that the associated uncertainty is equal to or greater than the result.
 (d) Irrigated with Columbia River water.

TABLE A.18. Radionuclides in Fruit

Fruit/ Location(c)	Concentration, pCi/g, wet weight(a,b)								
	¹³⁷ Cs			⁹⁰ Sr			³ H		
	Number of Samples	Maximum	Average	Number of Samples	Maximum	Average	Number of Samples	Maximum	Average
Apples									
Sagemoor Area	3	0.013±0.0053	*(d) 0.008±0.10	3	0.003±0.002	0.002±0.001	3	320±220	*160±250
Cold Creek Area	3	*-0.001±0.007	*-0.003±0.006	3	0.003±0.001	0.003±0.001	3	*140±220	*90±140
Sunnyside Area	3	*0.003±0.006	* 0.001±0.004	3	0.005±0.003	0.004±0.003	3	410±250	*180±290
Cherries									
Sagemoor Area	3	*0.006±0.006	* 0.007±0.017	3	*0.002±0.002	0.002±0.001	3	*92±240	*66±140
Sunnyside Area	3	0.01±0.007	* 0.005±0.011	3	0.003±0.002	*0.002±0.002	3	460±250	*180±340
Grapes									
Sagemoor Area	3	*0.004±0.006	* 0.001±0.005	3	0.006±0.002	0.005±0.002	3	350±240	250±200
Cold Creek Area	3	*0.000±0.006	*-0.003±0.006	3	0.009±0.002	0.008±0.002	3	*10±180	*-12±110
Sunnyside Area	3	*0.006±0.006	*0.003±0.005	3	0.006±0.002	0.004±0.003	3	460±240	380±170

- (a) Except for ³H, which is given in pCi/l of water.
 (b) Maximum values ±2 sigma counting error. Averages ±2 standard error of the calculated mean.
 (c) Refer to Figure 35.
 (d) The * signifies that the associated uncertainty is equal to or greater than the result.

TABLE A.19. Radionuclides in Wheat and Alfalfa

Type/Location(b)	Concentration, pCi/g, dry weight(a)					
	⁹⁰ Sr			¹³⁷ Cs		
	No. of Samples	Maximum	Average	No. of Samples	Maximum	Average
Wheat						
Wahluke East Area	3	0.015 ± 0.006	0.015 ± 0.004	3	0.008 ± 0.006	*(c)0.004 ± 0.006
Sagemoor Area	3	0.014 ± 0.006	0.012 ± 0.004	3	0.006 ± 0.005	*0.004 ± 0.004
Riverview Area(d)	3	0.016 ± 0.005	0.013 ± 0.004	3	*0.004 ± 0.006	*0.001 ± 0.007
Benton City Area	3	0.041 ± 0.008	0.027 ± 0.015	3	0.022 ± 0.014	*0.002 ± 0.002
Sunnyside Area	3	0.013 ± 0.006	0.012 ± 0.004	3	*0.000 ± 0.006	*-0.002 ± 0.004
Moses Lake Area	3	0.011 ± 0.003	0.009 ± 0.004	3	0.009 ± 0.008	*0.003 ± 0.008
Alfalfa						
Wahluke East Area	3	0.120 ± 0.015	0.110 ± 0.017	3	0.019 ± 0.001	*0.011 ± 0.013
Sagemoor Area	3	0.095 ± 0.008	0.085 ± 0.012	3	0.016 ± 0.011	*0.003 ± 0.020
Riverview Area(d)	3	0.160 ± 0.012	0.110 ± 0.050	3	*0.077 ± 0.010	*-0.003 ± 0.018
Benton City Area	3	0.083 ± 0.007	0.076 ± 0.009	3	*0.010 ± 0.010	*0.005 ± 0.011
Sunnyside Area	3	0.120 ± 0.012	0.095 ± 0.027	3	0.042 ± 0.020	*0.022 ± 0.024
Moses Lake Area	3	0.190 ± 0.010	0.019 ± 0.008	3	0.016 ± 0.014	*0.000 ± 0.022

- (a) Maximum values ±2 sigma counting error. Averages ±2 standard error of the calculated mean.
 (b) Refer to Figure 35.
 (c) The * signifies that the associated uncertainty is equal to or greater than the result.
 (d) Irrigated with Columbia River water.

TABLE A.20. Radionuclides in Beef, Chickens, and Eggs

Type/Location ^(b)	Concentration, pCi/g, wet weight ^(a)					
	⁹⁰ Sr			¹³⁷ Cs		
	Number of Samples	Maximum	Average	Number of Samples	Maximum	Average
Beef						
Sagemoor Area	1	---	*(c) 0.003 ± 0.004	1	---	0.002 ± 0.007
Riverview Area (d)	1	---	0.003 ± 0.002	1	---	0.008 ± 0.007
Horn Rapids Area	1	---	0.006 ± 0.004	1	---	*-0.0002 ± 0.006
Chickens						
Sagemoor Area	2	0.007 ± 0.005	0.006 ± 0.005	2	*0.004 ± 0.018	*0.002 ± 0.013
Sunnyside Area	2	0.003 ± 0.002	0.003 ± 0.002	2	*0.006 ± 0.025	*-0.008 ± 0.039
Eggs						
Sagemoor Area	2	0.006 ± 0.003	0.005 ± 0.003	2	0.017 ± 0.007	*0.006 ± 0.027
Sunnyside Area	2	0.003 ± 0.002	0.003 ± 0.002	2	*0.004 ± 0.006	*0.003 ± 0.004

(a) Maximum values ±2 sigma counting area. Averages ±2 standard error of the calculated mean.

(b) Refer to Figure 35.

(c) The * signifies that the associated uncertainty is equal to or greater than the result.

(d) Water supplied from the Columbia River.

TABLE A.21. Special Riverview Foodstuff Sampling Results

Foodstuff ^(d)	Concentration, pCi/g, wet weight ^(a,b,c)			
	³ H	⁶⁰ Co	⁹⁰ Sr	¹³⁷ Cs
Apples	*(e) -8.4 ± 180	*-0.001 ± 0.016	0.003 ± 0.001	*-0.001 ± 0.005
Cantelope	280 ± 150	*0.002 ± 0.009	0.003 ± 0.001	*-0.002 ± 0.004
Grapes	360 ± 220	*0.004 ± 0.009	0.003 ± 0.001	*-0.001 ± 0.006
Beans	--- (f)	*0.0007 ± 0.006	0.008 ± 0.003	*-0.002 ± 0.007
Beets	---	*0.004 ± 0.009	0.004 ± 0.002	*-0.001 ± 0.010
Carrots	---	*0.001 ± 0.010	0.008 ± 0.002	*-0.001 ± 0.011
Corn	---	*-0.003 ± 0.010	0.002 ± 0.0008	*0.003 ± 0.012
Potatoes	---	*-0.0007 ± 0.006	0.008 ± 0.002	*0.006 ± 0.006
Squash	---	*-0.001 ± 0.007	0.003 ± 0.002	*0.0002 ± 0.006
Tomatoes	---	*0.006 ± 0.009	0.001 ± 0.0007	*-0.001 ± 0.004

(a) Except for ³H, which is given in pCi/l of water.

(b) A sufficient sample was collected to provide 3 aliquots for analysis.

(c) Average ±2 standard error of the calculated mean.

(d) Irrigated with Columbia River water.

(e) The * signifies that the associated uncertainty is equal to or greater than the result.

(f) Dashed lines indicate no analysis.

TABLE A.22. Cesium-137 in Deer Muscle and Plutonium-239,240 in Deer Liver

		Concentration, pCi/g, wet weight (a)					
		¹³⁷ Cs			^{239,240} Pu		
Location	Type	Number of Samples	Maximum	Average	Number of Samples	Maximum	Average
Random (road kills)	Muscle	4	0.02 ± 0.009	* ^(b) 0.007 ± 0.01	---	---	---
	Liver	---	---	---	4	0.00016 ± 0.00015	*0.00004 ± 0.00009
200 Area Ponds	Muscle	1	---	0.52 ± 0.028	---	---	---
	Liver	---	---	---	1	---	*0.00004 ± 0.00015

(a) Maximum values ±2 sigma counting error. Averages ±2 standard error of the calculated mean.
 (b) The * signifies that the associated uncertainty is equal to or greater than the result.
 (c) Dashes indicate no analysis or no calculation.

TABLE A.23. Radionuclides in Columbia River Fish

		Concentration, pCi/g, wet weight (a)								
		⁶⁰ Co			⁹⁰ Sr			¹³⁷ Cs		
Type/Location (b)	Number of Samples	Maximum	Average	Number of Samples	Maximum	Average	Number of Samples	Maximum	Average	
Whitefish										
Upstream of Site Boundary	4	0.052 ± 0.023	* ^(c) 0.027 ± 0.028	4	0.004 ± 0.002	0.004 ± 0.001	4	*0.029 ± 0.031	*0.009 ± 0.023	
1000 Area Vicinity	10	0.058 ± 0.029	*0.002 ± 0.02	10	0.008 ± 0.003	0.005 ± 0.001	10	0.042 ± 0.024	*0.016 ± 0.018	
Hass										
100F Sloughs	5	0.004 ± 0.002	*-0.004 ± 0.015	5	*0.004 ± 0.002	*0.002 ± 0.002	5	0.07 ± 0.002	0.035 ± 0.03	

(a) Maximum values ±2 sigma counting error. Averages ±2 standard error of the calculated mean.
 (b) Refer to Figure 39.
 (c) The * signifies that the associated uncertainty is equal to or greater than the result.

TABLE A.24. Cobalt-60 and Cesium-137 in Muscle Tissue of Upland Gamebirds

		Concentration, pCi/g, wet weight (a)					
		⁶⁰ Co			¹³⁷ Cs		
Location (b)	Number of Samples	Maximum	Average	Number of Samples	Maximum	Average	
100 Areas Pheasant	10	0.019 ± 0.012	* ^(c) 0.009 ± 0.009	10	0.035 ± 0.015	*0.009 ± 0.01	
200 Areas Chukar + Pheasant	5	*0.012 ± 0.019	*-0.012 ± 0.033	5	0.06 ± 0.03	0.03 ± 0.027	
300 Area Pheasant	3	*0.01 ± 0.018	*0.008 ± 0.010	3	0.13 ± 0.03	*0.048 ± 0.088	

(a) Maximum values ±2 sigma counting error. Averages ±2 standard error of the calculated mean.
 (b) Refer to Figure 39.
 (c) The * signifies that the associated uncertainty is equal to or greater than the result.

TABLE A.25. Cesium-137 in Muscle Tissue of Mallard Ducks

Location ^(b)	Number of Samples	Concentration, pCi/g, wet weight ^(a)		
		Maximum	Minimum	Average
200 Area B Pond	12	11 ± 0.3	*0.022 ± 0.19	2.9 ± 1.6
300 Area Pond	4	1.3 ± 0.1	*0.01 ± 0.02	* ^(c) 0.56 ± 0.65

(a) Maximum and minimum values ±2 sigma counting error. Average ±2 standard error of the calculated mean.

(b) Refer to Figure 39.

(c) The * signifies that the associated uncertainty is equal to or greater than the result.

TABLE A.26. Strontium-90 and Cesium-137 in Bone and Muscle Tissue of Rabbits

Location ^(b)	Number of Samples	Concentration, pCi/g, wet weight ^(a)				
		⁹⁰ Sr (Bone)		¹³⁷ Cs (Muscle)		
		Maximum	Average	Number of Samples	Maximum	Average
100 Area Cottontail	3	3.1 ± 0.4	2.0 ± 1.5	3	0.037 ± 0.022	* ^(c) 0.006 ± 0.046
200 Area Jack Rabbit	5	38 ± 0.5	*9.1 ± 14	5	0.045 ± 0.014	0.022 ± 0.016

(a) Maximum values ±2 sigma counting error. Averages ±2 standard error of the calculated mean.

(b) Refer to Figure 39.

(c) The * signifies that the associated uncertainty is equal to or greater than the result.

TABLE A.27. ⁹⁰Sr Concentrations in Soil (pCi/g, dry weight)^(a)

LOCATION	HAP LOCATION ^(b)	1980	1981	1982	1983	1984	1985
ONSITE							
1 Mile NE of N Area	1			0.20 ± 0.03	0.70 ± 0.023	0.29 ± 0.017	0.28 ± 0.058
1 Mile E of N Area	2			0.15 ± 0.06	0.85 ± 0.026	0.22 ± 0.010	0.44 ± 0.091
100 Area Fire Station	3			0.28 ± 0.04	1.7 ± 0.033	0.45 ± 0.020	0.57 ± 0.11
200 EHC	4	0.70 ± 0.06	0.45 ± 0.02	0.93 ± 0.13	2.7 ± 0.047	0.20 ± 0.19	1.2 ± 0.23
E of 200E	5			0.33 ± 0.09	0.78 ± 0.033	0.73 ± 0.48	0.90 ± 0.18
200 ESE	6	0.29 ± 0.02	0.18 ± 0.007	0.29 ± 0.05	1.3 ± 0.028	0.44 ± 0.060	0.20 ± 0.042
SW of BC Cribs	7			0.13 ± 0.10	0.79 ± 0.033	0.12 ± 0.050	0.39 ± 0.079
S of 200E	8			0.18 ± 0.05	0.38 ± 0.020	0.50 ± 0.11	0.14 ± 0.030
E of 200W	9	0.83 ± 0.01	0.48 ± 0.03	0.48 ± 0.11	2.6 ± 0.048	0.33 ± 0.020	0.61 ± 0.12
2 Miles S of 200W	10			0.06 ± 0.005	0.28 ± 0.015	0.14 ± 0.020	0.37 ± 0.078
NE of FFTF	11	0.04 ± 0.01	0.04 ± 0.007	0.042 ± 0.035	0.52 ± 0.020	0.18 ± 0.021	0.17 ± 0.039
SE of FFTF	12	0.09 ± 0.007	0.05 ± 0.002	0.047 ± 0.045	0.54 ± 0.019	0.032 ± 0.054	0.20 ± 0.042
N of 300 Area	13			0.22 ± 0.030	0.73 ± 0.023	0.58 ± 0.029	0.32 ± 0.068
Hanford Townsite	14	0.23 ± 0.007	0.40 ± 0.004	0.24 ± 0.080	1.9 ± 0.048	0.31 ± 0.029	0.25 ± 0.052
Wye Barricade	15	0.23 ± 0.007	0.20 ± 0.020	0.21 ± 0.030	0.81 ± 0.026	0.31 ± 0.040	0.31 ± 0.062
Onsite Mean		0.34 ± 0.22	0.30 ± 0.15	0.25 ± 0.12	1.1 ± 0.40	0.32 ± 0.10	0.42 ± 0.15
OFFSITE							
Riverview	16	* 0.001 ± 0.007	0.21 ± 0.009	0.12 ± 0.040	0.90 ± 0.044	0.039 ± 0.012	0.074 ± 0.019
Byers Landing	17	* 0.003 ± 0.007	0.06 ± 0.003	0.02 ± 0.01	0.30 ± 0.020	0.064 ± 0.008	0.18 ± 0.016
Sagemoor	18	0.02 ± 0.007	0.02 ± 0.002	0.006 ± 0.003	0.28 ± 0.017	0.25 ± 0.046	0.081 ± 0.019
Taylor Flats #2	19	0.25 ± 0.010	0.25 ± 0.009	0.23 ± 0.060	0.23 ± 0.039	0.042 ± 0.008	0.046 ± 0.013
W End Fir Road	20	0.17 ± 0.007	0.05 ± 0.003	0.07 ± 0.007	1.20 ± 0.031	0.14 ± 0.015	0.091 ± 0.022
Ringold	21	0.07 ± 0.007	0.20 ± 0.002	0.08 ± 0.040	1.80 ± 0.032	0.24 ± 0.014	0.20 ± 0.042
Berg Ranch	22	0.14 ± 0.007	0.11 ± 0.006	0.20 ± 0.090	0.92 ± 0.023	0.20 ± 0.019	0.15 ± 0.033
Wahluke #2 ^(d)	23	0.31 ± 0.010	0.09 ± 0.002	0.10 ± 0.030	0.65 ± 0.023	0.16 ± 0.017	0.21 ± 0.046
Vernita Bridge ^(d)	24			0.11 ± 0.070	0.52 ± 0.017	0.17 ± 0.015	0.31 ± 0.064
Yakima Barricade ^(d)	25	0.02 ± 0.007	0.22 ± 0.020	0.09 ± 0.003	0.59 ± 0.023	0.13 ± 0.017	0.54 ± 0.109
Rattlesnake Springs ^(d)	26			0.17 ± 0.040	0.89 ± 0.033	0.075 ± 0.009	0.33 ± 0.069
ALE ^(d)	27	* 0.00 ± 0.007	0.27 ± 0.030	0.30 ± 0.060	1.60 ± 0.032	0.36 ± 0.039	0.61 ± 0.12
Prosser Barricade ^(d)	28	* 0.003 ± 0.007	0.13 ± 0.007	0.29 ± 0.020	1.10 ± 0.027	0.36 ± 0.020	0.45 ± 0.092
S of 300 Area ^(d)	29			0.24 ± 0.150	1.4 ± 0.039	0.35 ± 0.015	0.51 ± 0.10
Benton City	30	0.29 ± 0.005	0.30 ± 0.003	0.21 ± 0.030	0.42 ± 0.018	0.36 ± 0.031	0.12 ± 0.027
Sunnyside	31	0.19 ± 0.020	0.16 ± 0.020	0.12 ± 0.030	1.60 ± 0.040	0.31 ± 0.029	0.26 ± 0.055
Walla Walla	32						0.31 ± 0.015
McNary Dam	33						0.29 ± 0.019
Offsite Mean		0.11 ± 0.066	0.14 ± 0.039	0.15 ± 0.045	1.0 ± 0.29	0.20 ± 0.059	0.26 ± 0.080

(a) Individual results ± two sigma counting error. Means ± 2 standard error of the calculated mean.

(b) Locations are identified in Figure 46.

(c) The * signifies that the associated uncertainty is greater than or equal to the result.

(d) Perimeter location onsite near site boundary.

TABLE A.28. ¹³⁷Cs Concentrations in Soil (pCi/g, dry weight)^(a)

LOCATION	HAP LOCATION ^(b)	1980	1981	1982	1983	1984	1985
ONSITE							
1 Mile NE of N Area	1			0.67 ± 0.08	0.48 ± 0.04	0.70 ± 0.05	0.76 ± 0.065
1 Mile E of N Area	2			0.54 ± 0.04	0.77 ± 0.05	0.67 ± 0.04	0.62 ± 0.057
100 Area Fire Station	3			0.99 ± 0.06	1.40 ± 0.07	0.98 ± 0.06	1.2 ± 0.082
200 ENC	4	28 ± 0.44	18 ± 0.16	22 ± 0.37	28 ± 0.33	21 ± 0.23	23 ± 1.4
E of 200E	5			1.5 ± 0.10	1.30 ± 0.07	1.4 ± 0.06	3.0 ± 0.20
200 ESE	6	1.2 ± 0.90	1.2 ± 0.05	1.8 ± 0.08	0.16 ± 0.03	0.54 ± 0.04	0.55 ± 0.048
SW of BC Cribs	7			0.31 ± 0.06	0.31 ± 0.03	0.06 ± 0.02	0.14 ± 0.022
S of 200E	8			0.54 ± 0.07	0.15 ± 0.03	0.14 ± 0.02	0.56 ± 0.053
E of 200W	9	4.8 ± 0.18	2.5 ± 0.08	3.2 ± 0.10	5.70 ± 0.15	0.59 ± 0.04	2.0 ± 0.069
2 Miles S of 200W	10			0.21 ± 0.06	0.07 ± 0.02	0.17 ± 0.03	0.30 ± 0.030
NE of FFTF	11	0.22 ± 0.04	0.11 ± 0.02	0.13 ± 0.02	0.18 ± 0.03	0.12 ± 0.02	0.080 ± 0.028
SE of FFTF	12	0.40 ± 0.05	0.08 ± 0.02	0.19 ± 0.03	0.20 ± 0.04	0.08 ± 0.02	0.083 ± 0.022
N of 300 Area	13			0.85 ± 0.05	0.53 ± 0.04	0.43 ± 0.04	0.46 ± 0.052
Hanford Townsite	14	1.7 ± 0.12	1.6 ± 0.06	0.96 ± 0.08	1.00 ± 0.07	0.91 ± 0.05	1.1 ± 0.086
Wye Barricade	15	1.1 ± 0.10	0.69 ± 0.04	1.1 ± 0.06	0.84 ± 0.05	0.68 ± 0.04	1.3 ± 0.098
Onsite Mean		^(c) 5.3 ± 7.7	4.6 ± 4.5	*2.4 ± 2.9	*2.8 ± 3.7	*1.9 ± 2.8	*2.3 ± 3.0
OFFSITE							
Riverview	16	1.1 ± 0.09	0.46 ± 0.03	0.49 ± 0.07	1.2 ± 0.07	0.077 ± 0.021	0.21 ± 0.026
Byers Landing	17	0.34 ± 0.05	0.23 ± 0.02	0.28 ± 0.07	0.59 ± 0.05	0.20 ± 0.03	0.19 ± 0.035
Sagemoor	18	0.55 ± 0.06	0.06 ± 0.02	0.06 ± 0.04	0.14 ± 0.03	1.0 ± 0.06	0.10 ± 0.023
Taylor Flats #2	19	1.4 ± 0.11	1.1 ± 0.05	0.61 ± 0.05	2.2 ± 0.07	0.084 ± 0.031	0.085 ± 0.028
W End Fir Road	20	0.19 ± 0.04	0.15 ± 0.02	0.35 ± 0.05	0.25 ± 0.03	0.12 ± 0.03	0.14 ± 0.025
Ringold	21	0.68 ± 0.07	0.94 ± 0.05	0.83 ± 0.06	1.6 ± 0.08	0.44 ± 0.044	1.1 ± 0.046
Berg Ranch	22	0.58 ± 0.06	0.40 ± 0.02	0.83 ± 0.05	0.61 ± 0.05	0.49 ± 0.046	0.58 ± 0.052
Wahluke #2 ^(d)	23	0.35 ± 0.05	0.10 ± 0.02	0.34 ± 0.07	0.25 ± 0.03	0.27 ± 0.03	0.47 ± 0.047
Vernita Bridge ^(d)	24			0.58 ± 0.07	0.55 ± 0.05	0.29 ± 0.03	0.46 ± 0.037
Yakima Barricade ^(d)	25	0.77 ± 0.07	0.31 ± 0.03	0.42 ± 0.04	0.70 ± 0.033	0.10 ± 0.028	1.1 ± 0.066
Rattlesnake Springs ^(d)	26			0.70 ± 0.05	0.52 ± 0.05	0.14 ± 0.03	0.46 ± 0.037
ALE ^(d)	27	1.2 ± 0.10	0.37 ± 0.03	1.1 ± 0.10	1.5 ± 0.07	0.55 ± 0.04	1.6 ± 0.069
Prosser Barricade ^(d)	28	0.95 ± 0.08	0.21 ± 0.02	1.2 ± 0.06	0.77 ± 0.05	0.15 ± 0.03	0.73 ± 0.045
S of 300 Area ^(d)	29			1.1 ± 0.06	1.1 ± 0.06	1.1 ± 0.06	0.88 ± 0.072
Benton City	30	1.0 ± 0.09	0.89 ± 0.04	0.75 ± 0.05	0.54 ± 0.05	0.53 ± 0.04	0.87 ± 0.064
Sunnyside	31	0.65 ± 0.08	0.63 ± 0.04	0.41 ± 0.06	1.1 ± 0.06	1.5 ± 0.071	0.29 ± 0.036
Halla Walla	32						0.29 ± 0.024
McNary Dam	33						0.52 ± 0.040
Offsite Mean		0.75 ± 0.20	0.46 ± 0.13	0.63 ± 0.15	0.85 ± 0.28	0.44 ± 0.21	0.56 ± 0.19

(a) Individual results ± two sigma counting error. Means ± 2 standard error of the calculated mean.

(b) Locations are identified in Figure 46.

(c) The * signifies that the associated uncertainty is greater than or equal to the result.

(d) Perimeter location onsite near site boundary.

TABLE A.29. ^{239,240}Pu Concentrations in Soil (pCi/g, dry weight)^(a)

LOCATION	MAP LOCATION ^(b)	1980	1981	1982	1983	1984	1985
ONSITE							
1 Mile NE of N Area	1			0.015 ± 0.003	0.012 ± 0.0030	0.015 ± 0.0020	0.016 ± 0.0016
1 Mile E of N Area	2			0.026 ± 0.003	0.0069 ± 0.0014	0.016 ± 0.0027	0.013 ± 0.0011
100 Area Fire Station	3			0.016 ± 0.003	0.0022 ± 0.0015	0.021 ± 0.0017	0.024 ± 0.0016
200 ENC	4	0.030 ± 0.0020	0.040 ± 0.0020	0.059 ± 0.009	0.051 ± 0.0065	0.033 ± 0.0040	0.030 ± 0.0019
E of 200E	5			0.015 ± 0.002	0.011 ± 0.002	0.012 ± 0.0015	0.026 ± 0.0017
200 ESE	6		0.030 ± 0.0040	0.024 ± 0.004	0.028 ± 0.0050	0.0091 ± 0.0017	0.022 ± 0.0016
SW of BC Cribs	7			0.012 ± 0.001	0.0076 ± 0.0012	0.0034 ± 0.0019	0.024 ± 0.0022
S of 200E	8			0.012 ± 0.001	0.0088 ± 0.0017	0.0056 ± 0.0031	0.0041 ± 0.0014
E of 200W	9	0.63 ± 0.02	0.42 ± 0.008	0.78 ± 0.016	0.83 ± 0.027	0.074 ± 0.0040	0.33 ± 0.0069
2 Miles S of 200W	10			0.004 ± 0.002	*0.0006 ± 0.00095	0.0036 ± 0.0019	0.0094 ± 0.0011
NE of FFTF	11	0.004 ± 0.002	0.003 ± 0.0008	0.002 ± 0.001	0.0029 ± 0.0007	0.0021 ± 0.0007	0.0025 ± 0.0005
SE of FFTF	12	0.007 ± 0.002	0.003 ± 0.0008	0.005 ± 0.002	0.0042 ± 0.0018	0.0087 ± 0.0011	0.0021 ± 0.0005
N of 300 Area	13			0.016 ± 0.003	0.013 ± 0.002	0.0064 ± 0.0029	0.010 ± 0.0011
Hanford Townsite	14	0.04 ± 0.003	0.02 ± 0.002	0.015 ± 0.003	0.021 ± 0.004	0.016 ± 0.0030	0.0059 ± 0.0009
Wye Barricade	15	0.013 ± 0.002	0.012 ± 0.001	0.018 ± 0.003	0.017 ± 0.0022	0.014 ± 0.0020	0.017 ± 0.0015
Onsite Mean		*0.12 ± 0.20	*0.069 ± 0.10	*0.062 ± 0.10	*0.068 ± 0.11	0.016 ± 0.0090	*0.035 ± 0.042
OFFSITE							
Riverview	16	0.02 ± 0.002	0.01 ± 0.001	0.006 ± 0.002	0.021 ± 0.005	*0.0018 ± 0.0018	0.0052 ± 0.0098
Ryers Landing	17		0.005 ± 0.001	0.002 ± 0.0009	0.012 ± 0.002	0.0066 ± 0.0040	0.0027 ± 0.0006
Sagemoor	18	0.008 ± 0.002	0.003 ± 0.0007	0.003 ± 0.0009	0.0079 ± 0.0015	0.019 ± 0.0021	0.0018 ± 0.0005
Taylor Flats #2	19	0.03 ± 0.004	0.04 ± 0.002	0.016 ± 0.003	0.031 ± 0.005	0.0014 ± 0.0005	0.0008 ± 0.0003
W End Fir Road	20	0.008 ± 0.002	0.004 ± 0.001	0.005 ± 0.001	0.0059 ± 0.0017	0.0022 ± 0.0015	0.0017 ± 0.0005
Ringold	21	0.018 ± 0.003	0.02 ± 0.002	0.013 ± 0.002	0.028 ± 0.005	0.0075 ± 0.0012	0.017 ± 0.0016
Berg Ranch	22	0.009 ± 0.002	0.01 ± 0.001	0.012 ± 0.002	0.014 ± 0.003	0.0097 ± 0.0015	0.011 ± 0.0011
Wahluke #2 ^(d)	23	0.006 ± 0.002	0.004 ± 0.0008	0.006 ± 0.002	0.010 ± 0.002	0.0061 ± 0.0029	0.0087 ± 0.0015
Vernita Bridge ^(d)	24			0.009 ± 0.002	0.015 ± 0.0026	0.0060 ± 0.0024	0.0095 ± 0.0010
Yakima Barricade ^(d)	25	0.02 ± 0.003	0.02 ± 0.002	0.011 ± 0.001	0.014 ± 0.002	0.0016 ± 0.0011	0.022 ± 0.0015
Rattlesnake Springs ^(d)	26			0.019 ± 0.002	0.026 ± 0.0049	0.0032 ± 0.0016	0.0085 ± 0.0009
ALE ^(d)	27	0.023 ± 0.003	0.01 ± 0.001	0.03 ± 0.002	0.031 ± 0.005	0.0091 ± 0.0014	0.034 ± 0.0021
Prosser Barricade ^(d)	28		0.006 ± 0.001	0.033 ± 0.004	0.020 ± 0.004	0.0039 ± 0.0016	0.019 ± 0.0019
S of 300 Area ^(d)	29			0.019 ± 0.003	0.022 ± 0.0013	0.022 ± 0.0023	0.018 ± 0.0015
Benton City	30	0.02 ± 0.003	0.02 ± 0.002	0.024 ± 0.003	0.015 ± 0.0017	0.0099 ± 0.0015	0.019 ± 0.0020
Sunnyside	31	0.01 ± 0.003	0.01 ± 0.001	0.009 ± 0.002	0.026 ± 0.005	0.025 ± 0.0026	0.015 ± 0.0016
Walla Walla	32						0.013 ± 0.0012
McNary Dam	33						0.015 ± 0.0023
Offsite Mean		0.015 ± 0.004	0.011 ± 0.005	0.013 ± 0.005	0.019 ± 0.004	0.0084 ± 0.0037	0.012 ± 0.0046

(a) Individual results ± two sigma counting error. Means ± 2 standard error of the calculated mean.

(b) Locations are identified in Figure 46.

(c) The * signifies that the associated uncertainty is greater than or equal to the result.

(d) Perimeter location onsite near site boundary.

TABLE A.30. U Concentrations in Soil (pCi/g, dry weight)^(a)

LOCATION	MAP LOCATION ^(b)	1980	1981	1982	1983	1984	1985
ONSITE							
1 Mile NE of N Area	1			0.23 ± 0.08	0.39 ± 0.109	0.42 ± 0.11	0.49 ± 0.16
1 Mile E of N Area	2			0.22 ± 0.08	0.28 ± 0.077	0.32 ± 0.088	0.40 ± 0.13
100 Area Fire Station	3			0.32 ± 0.11	0.22 ± 0.061	0.45 ± 0.12	0.44 ± 0.15
200 ENC	4	0.27 ± 0.10	0.66 ± 0.23	0.45 ± 0.16	0.25 ± 0.071	0.36 ± 0.098	0.39 ± 0.13
E of 200E	5			0.32 ± 0.11	0.26 ± 0.07	0.32 ± 0.08	0.46 ± 0.15
200 ESE	6	0.29 ± 0.10	0.42 ± 0.15	0.37 ± 0.13	0.20 ± 0.057	0.37 ± 0.070	0.39 ± 0.13
SW of BC Cribs	7			0.27 ± 0.09	0.28 ± 0.078	1.0 ± 0.15	0.33 ± 0.11
S of 200E	8			0.30 ± 0.11	0.18 ± 0.05	0.46 ± 0.22	0.34 ± 0.11
E of 200W	9	0.62 ± 0.22	0.72 ± 0.25	0.73 ± 0.26	0.53 ± 0.15	0.53 ± 0.29	0.43 ± 0.14
2 Miles S of 200W	10			0.39 ± 0.14	0.26 ± 0.074	0.34 ± 0.092	0.47 ± 0.16
NE of FFTF	11	0.22 ± 0.08	0.49 ± 0.17	0.30 ± 0.10	0.25 ± 0.068	0.30 ± 0.082	0.39 ± 0.13
SE of FFTF	12	0.23 ± 0.08	0.47 ± 0.16	0.28 ± 0.10	0.16 ± 0.046	0.27 ± 0.073	0.40 ± 0.13
N of 300 Area	13			0.99 ± 0.35	0.50 ± 0.14	0.76 ± 0.20	3.9 ± 1.1
Hanford Townsite	14	0.28 ± 0.10	0.40 ± 0.14	0.32 ± 0.11	0.24 ± 0.067	0.34 ± 0.093	0.35 ± 0.12
Wye Barricade	15	0.26 ± 0.09	0.37 ± 0.13	0.38 ± 0.13	0.19 ± 0.053	0.65 ± 0.10	0.29 ± 0.097
Onsite Mean		0.31 ± 0.12	0.49 ± 0.11	0.39 ± 0.11	0.28 ± 0.061	0.46 ± 0.11	0.82 ± 0.66
OFFSITE							
Riverview	16	0.33 ± 0.11	0.64 ± 0.23	0.14 ± 0.05	0.37 ± 0.10	0.32 ± 0.085	0.44 ± 0.14
Byers Landing	17	0.34 ± 0.12	0.47 ± 0.17	0.55 ± 0.19	0.32 ± 0.09	0.43 ± 0.11	0.39 ± 0.13
Sage Moor	18	0.37 ± 0.13	0.63 ± 0.22	0.31 ± 0.11	0.38 ± 0.11	0.50 ± 0.13	0.58 ± 0.18
Taylor Flats #2	19	0.61 ± 0.21	0.73 ± 0.26	0.59 ± 0.21	0.47 ± 0.13	1.0 ± 0.26	1.3 ± 0.36
W End Fir Road	20	0.46 ± 0.16	0.88 ± 0.31	0.28 ± 0.10	0.47 ± 0.13	0.54 ± 0.14	0.73 ± 0.22
Ringold	21	0.34 ± 0.12	0.82 ± 0.29	0.43 ± 0.15	0.37 ± 0.10	0.78 ± 0.21	0.84 ± 0.26
Berg Ranch	22	0.23 ± 0.08	0.27 ± 0.10	0.26 ± 0.09	0.24 ± 0.07	0.41 ± 0.11	0.43 ± 0.14
Wahluke #2(c)	23	0.34 ± 0.12	0.46 ± 0.16	0.36 ± 0.13	0.35 ± 0.10	0.43 ± 0.12	0.35 ± 0.12
Vernita Bridge(c)	24			0.38 ± 0.13	0.37 ± 0.10	0.92 ± 0.26	0.73 ± 0.22
Yakima Barricade(c)	25	0.29 ± 0.10	0.50 ± 0.17	0.23 ± 0.08	0.26 ± 0.071	0.21 ± 0.056	0.35 ± 0.12
Rattlesnake Springs(c)	26			0.30 ± 0.11	0.25 ± 0.07	0.26 ± 0.069	0.44 ± 0.14
ALE(c)	27	0.36 ± 0.13	0.31 ± 0.11	0.35 ± 0.12	0.28 ± 0.08	0.25 ± 0.067	0.46 ± 0.15
Prosser Barricade(c)	28	0.16 ± 0.06	0.35 ± 0.12	0.20 ± 0.07	0.25 ± 0.07	0.36 ± 0.06	0.80 ± 0.24
S of 300 Area(c)	29			0.506 ± 0.177	0.31 ± 0.08	1.0 ± 0.29	0.66 ± 0.21
Benton City	30	0.70 ± 0.24	0.63 ± 0.22	0.56 ± 0.19	0.44 ± 0.12	0.91 ± 0.24	0.64 ± 0.20
Sunnyside	31	0.41 ± 0.14	0.34 ± 0.12	0.17 ± 0.06	0.20 ± 0.05	0.26 ± 0.071	0.26 ± 0.090
Walla Walla	32						0.20 ± 0.071
McNary Dam	33						0.15 ± 0.055
Offsite Mean		0.38 ± 0.089	0.53 ± 0.11	0.35 ± 0.078	0.32 ± 0.048	0.54 ± 0.15	0.54 ± 0.14

(a) Individual results ± two sigma counting error. Means ± 2 standard error of the calculated mean.
 (b) Locations are identified in Figure 46.
 (c) Perimeter location onsite near site boundary.

TABLE A.31. ^{240}Pu to ^{239}Pu Ratios for Soil Samples Collected On and Around the Hanford Area in 1978, 1982, 1983, and 1984, in Ascending Order

Location	1978	1982	1983	1984	Median
E 200W	0.040 ^(a)	0.042	0.046	0.035	0.041
200 ENC	--- ^(b)	0.085	0.087	0.092	0.087
2 Mi. S. 200W	---	0.104	0.094	0.115	0.104
200 ESE	0.088	0.100	0.109	0.123	0.105
1.25 Mi. E. PUREX	---	0.101	0.109	0.112	0.109
2 Mi. S. PUREX	---	0.108	0.170	0.112	0.112
SW BC Crib	---	0.103	0.161	---	0.132
SE FFTF	---	0.142	0.160	0.042	0.142
Rattlesnake Springs	---	0.129	0.152	0.146	0.146
Yakima Barricade	---	0.135	0.146	0.156	0.146
NE FFTF	---	0.096	0.147	0.148	0.147
Wye Barricade	---	0.157	0.143	0.162	0.148
Wye Barricade	---	0.146	0.150	---	---
Wye Barricade	---	0.149	0.130	0.132	---
Prosser Barricade	0.156	0.151	0.150	0.150	0.151
1 Mi. E. 100N	---	0.152	0.163	0.141	0.152
100 Fire Station	---	0.155	0.151	0.153	0.153
N 300	---	0.129	0.153	0.172	0.153
Benton City	0.170	0.137	0.109	0.179	0.154
NE of 100N	---	0.136	0.172	0.155	0.155
Vernita Bridge	---	0.156	0.153	0.176	0.156
ALE	---	0.156	0.158	0.160	0.158
Taylor Flats #2	---	0.158	0.159	0.162	0.159
W End Fir Road	---	0.167	0.110	0.160	0.160
Byers Landing	---	0.161	0.165	0.155	0.161
Sagemoor	---	0.161	0.135	0.169	0.161
Sagemoor	---	---	0.135	0.168	---
Sagemoor	---	0.164	0.143	---	---
Hanford Townsite	---	0.152	0.162	0.165	0.162
S 300 Area	---	0.154	0.166	0.169	0.166
Wahluke #2	---	0.122	0.167	0.167	0.167
Berg Ranch	---	0.172	0.165	---	0.169
Riverview	---	0.170	0.173	0.140	0.170
Ringold	---	0.171	0.175	0.171	0.171
Sunnyside	0.174	0.155	0.175	0.183	0.177
Sunnyside	---	0.180	---	---	---
Sunnyside	---	0.179	---	---	---

(a) Uncertainties (error terms) for all ratios were less than 1%.
 (b) Dashed line means no sample was collected.

TABLE A.32. ⁹⁰Sr Concentrations in Vegetation (pCi/g, dry weight)^(a)

LOCATION	MAP LOCATION ^(b)	1980	1981	1982	1983	1984	1985
ONSITE							
1 Mile NE of N Area	1			0.03 ± 0.002	0.11 ± 0.017	0.069 ± 0.007	0.078 ± 0.072
1 Mile E of N Area	2			0.05 ± 0.005	0.29 ± 0.018	0.12 ± 0.012	0.012 ± 0.0012
100 Area Fire Station	3			0.05 ± 0.007	0.37 ± 0.020	0.11 ± 0.011	0.17 ± 0.017
200 ENC	4	0.07 ± 0.01	0.14 ± 0.003	0.10 ± 0.020	0.63 ± 0.024	0.39 ± 0.020	0.41 ± 0.018
E of 200E	5			0.14 ± 0.009	0.91 ± 0.030	0.20 ± 0.030	0.25 ± 0.019
200 ESC	6	0.05 ± 0.01	0.07 ± 0.005	0.03 ± 0.003	0.91 ± 0.031	0.20 ± 0.013	0.53 ± 0.018
SW of BC Cribs	7			0.05 ± 0.003	0.34 ± 0.016	0.11 ± 0.030	0.41 ± 0.016
S of 200E	8			0.17 ± 0.005	0.53 ± 0.017	1.1 ± 0.066	0.44 ± 0.022
E of 200M	9	0.05 ± 0.01	0.09 ± 0.005	0.07 ± 0.005	0.47 ± 0.022	0.13 ± 0.020	1.1 ± 0.026
2 Miles S of 200W	10			0.05 ± 0.003	0.34 ± 0.016	0.19 ± 0.007	0.89 ± 0.035
NE of FFTF	11	0.03 ± 0.01	0.04 ± 0.004	0.009 ± 0.002	1.2 ± 0.037	0.022 ± 0.006	0.28 ± 0.015
SE of FFTF	12	0.19 ± 0.05	0.04 ± 0.005	0.02 ± 0.002	1.7 ± 0.040	0.088 ± 0.009	0.28 ± 0.019
N of 300 Area	13			0.008 ± 0.001	0.93 ± 0.029	0.023 ± 0.004	0.13 ± 0.016
Hanford Townsite	14	0.12 ± 0.01	0.06 ± 0.003	0.06 ± 0.003	0.29 ± 0.015	0.044 ± 0.006	0.18 ± 0.013
Wye Barricade	15	0.03 ± 0.01	0.05 ± 0.006	0.04 ± 0.008	0.16 ± 0.012	0.016 ± 0.007	0.15 ± 0.012
Onsite Mean		0.078 ± 0.045	0.069 ± 0.028	0.058 ± 0.024	0.61 ± 0.22	0.19 ± 0.14	0.36 ± 0.16
OFFSITE							
Riverview	16	0.04 ± 0.01	0.05 ± 0.003	0.01 ± 0.002	1.1 ± 0.033	0.015 ± 0.010	0.069 ± 0.085
Byers Landing	17	0.06 ± 0.04	0.03 ± 0.004	0.008 ± 0.002	0.12 ± 0.006	0.018 ± 0.008	0.057 ± 0.089
Sagemoor	18	0.05 ± 0.01	0.03 ± 0.004	0.01 ± 0.004	* ^(c) -0.006 ± 0.017	0.067 ± 0.012	0.097 ± 0.011
Taylor Flats #2	19	0.08 ± 0.05	0.04 ± 0.02	0.06 ± 0.003	0.037 ± 0.024	0.063 ± 0.010	0.10 ± 0.010
W End Fir Road	20		0.06 ± 0.007	*0.009 ± 0.014	0.086 ± 0.020	0.047 ± 0.016	0.076 ± 0.088
Ringold	21	0.04 ± 0.01	0.10 ± 0.015	*0.018 ± 0.019	0.65 ± 0.026	0.051 ± 0.010	0.066 ± 0.0081
Bery Ranch	22	0.05 ± 0.01	0.03 ± 0.003	*0.04 ± 0.002	*0.023 ± 0.027	0.092 ± 0.026	0.050 ± 0.079
Wahiuke #2 ^(d)	23	0.02 ± 0.01	0.05 ± 0.005	0.01 ± 0.004	0.018 ± 0.016	0.046 ± 0.013	0.15 ± 0.012
Vernita Bridge ^(d)	24			0.03 ± 0.003	0.10 ± 0.011	0.073 ± 0.011	0.21 ± 0.011
Yakima Barricade ^(d)	25	0.07 ± 0.01	0.06 ± 0.005	0.05 ± 0.01	0.04 ± 0.008	0.022 ± 0.003	0.21 ± 0.011
Rattlesnake Springs ^(d)	26			0.024 ± 0.004	0.69 ± 0.026	0.087 ± 0.011	1.7 ± 0.033
ALE ^(d)	27	0.09 ± 0.01	0.05 ± 0.005	0.05 ± 0.005	*0.017 ± 0.023	0.082 ± 0.007	0.095 ± 0.090
Prosser Barricade ^(d)	28	0.03 ± 0.01	0.06 ± 0.005	0.05 ± 0.02	*0.021 ± 0.022	0.12 ± 0.009	NS
S of 300 Area ^(d)	29			0.03 ± 0.004	0.05 ± 0.011	0.047 ± 0.005	0.091 ± 0.014
Benton City	30	0.08 ± 0.01	0.04 ± 0.005	0.05 ± 0.008	0.12 ± 0.013	0.055 ± 0.016	0.30 ± 0.013
Sunnyside	31	0.05 ± 0.01	0.19 ± 0.02	0.005 ± 0.003	0.18 ± 0.016	0.037 ± 0.008	0.061 ± 0.075
Offsite Mean		0.054 ± 0.014	0.058 ± 0.023	0.031 ± 0.0095	0.20 ± 0.16	0.057 ± 0.015	0.22 ± 0.21

(a) Individual results ± two sigma counting error. Means ± 2 standard error of the calculated mean.

(b) Locations are identified in Figure 46.

(c) The * signifies that the associated uncertainty is greater than or equal to the result.

(d) Perimeter location onsite near site boundary.

NS = No Sample

TABLE A.33. ¹³⁷Cs Concentrations in Vegetation (pCi/g, dry weight)^(a)

LOCATION	MAP LOCATION(b)	1980	1981	1982	1983	1984	1985
ONSITE							
1 Mile NE of N Area	1			*(c)0.04 ± 0.06	*0.003 ± 0.012	*0.0097 ± 0.014	0.015 ± 0.011
1 Mile E of N Area	2			0.09 ± 0.07	0.026 ± 0.008	*0.0032 ± 0.013	*0.003 ± 0.025
100 Area Fire Station	3			*0.04 ± 0.07	0.015 ± 0.008	0.015 ± 0.012	0.016 ± 0.014
200 ENC	4	0.57 ± 0.23	0.11 ± 0.03	0.23 ± 0.05	0.18 ± 0.014	0.24 ± 0.020	0.36 ± 0.042
E of 200E	5			0.37 ± 0.13	0.069 ± 0.010	0.069 ± 0.013	0.12 ± 0.030
200 ESE	6	*0.08 ± 0.12	0.05 ± 0.02	0.08 ± 0.05	0.053 ± 0.009	0.079 ± 0.017	0.078 ± 0.020
SW of BC Cribs	7			0.05 ± 0.02	0.0085 ± 0.0055	0.018 ± 0.013	0.038 ± 0.016
S of 200E	8			0.05 ± 0.04	0.019 ± 0.007	0.022 ± 0.011	0.068 ± 0.015
E of 200W	9	*0.01 ± 0.015	0.05 ± 0.02	*-0.03 ± 0.04	0.03 ± 0.009	0.055 ± 0.016	0.052 ± 0.017
2 Miles S of 200W	10			*0.0004 ± 0.06	0.025 ± 0.009	*0.011 ± 0.012	*0.019 ± 0.023
NE of FFTF	11	*0.11 ± 0.13	0.04 ± 0.01	*-0.03 ± 0.04	0.02 ± 0.008	*0.0064 ± 0.11	0.048 ± 0.020
SE of FFTF	12	*0.06 ± 0.23	0.05 ± 0.02	*0.01 ± 0.02	0.03 ± 0.009	*-0.0095 ± 0.015	0.032 ± 0.018
N of 300 Area	13			*0.02 ± 0.05	0.010 ± 0.006	0.011 ± 0.009	0.024 ± 0.016
Hanford Townsite	14	0.32 ± 0.15	0.03 ± 0.02	0.07 ± 0.02	*0.011 ± 0.011	*0.010 ± 0.020	0.038 ± 0.022
Wye Barricade	15	*0.02 ± 0.15	0.05 ± 0.02	*0.035 ± 0.045	*-0.01 ± 0.016	0.0037 ± 0.011	0.035 ± 0.015
Onsite Mean		*0.16 ± 0.17	0.054 ± 0.024	0.072 ± 0.055	0.035 ± 0.023	0.034 ± 0.033	0.062 ± 0.045
OFFSITE							
Riverview	16	*0.02 ± 0.12	*0.02 ± 0.02	*-0.006 ± 0.03	0.021 ± 0.007	*-0.0001 ± 0.014	*-0.0054 ± 0.011
Byers Landing	17	*0.18 ± 0.20	*-0.006 ± 0.02	0.08 ± 0.06	0.013 ± 0.011	0.024 ± 0.012	0.017 ± 0.011
Sagemoor	18	*0.03 ± 0.08	*0.02 ± 0.02	0.05 ± 0.03	*0.012 ± 0.012	*0.003 ± 0.012	*0.013 ± 0.014
Taylor Flats #2	19	0.27 ± 0.17	0.05 ± 0.02	*0.02 ± 0.04	0.025 ± 0.012	0.016 ± 0.013	*0.011 ± 0.022
W End Fir Road	20	*0.02 ± 0.16	0.03 ± 0.02	*-0.07 ± 0.04	0.021 ± 0.010	*0.095 ± 0.021	0.022 ± 0.021
Ringold	21	0.21 ± 0.17	*-0.01 ± 0.02	*0.0005 ± 0.08	0.020 ± 0.008	*-0.0008 ± 0.013	*0.0083 ± 0.013
Berg Ranch	22	*0.01 ± 0.14	*-0.04 ± 0.02	0.05 ± 0.04	0.014 ± 0.009	0.027 ± 0.011	*0.0073 ± 0.014
Wahluke #2(d)	23	*-0.05 ± 0.12	*-0.005 ± 0.02	*-0.04 ± 0.07	0.02 ± 0.008	*-0.0012 ± 0.012	0.023 ± 0.013
Vernita Bridge(d)	24			0.09 ± 0.03	0.014 ± 0.010	*0.005 ± 0.010	*0.0061 ± 0.015
Yakima Barricade(d)	25	0.18 ± 0.17	*0.02 ± 0.02	*0.02 ± 0.02	0.012 ± 0.010	*0.00 ± 0.013	*0.0027 ± 0.015
Rattlesnake Springs(d)	26			0.03 ± 0.02	*0.004 ± 0.009	*0.0054 ± 0.013	0.016 ± 0.014
ALE(d)	27	*0.03 ± 0.11	0.04 ± 0.03	0.03 ± 0.02	*0.0093 ± 0.0095	*-0.0006 ± 0.012	0.022 ± 0.013
Prosser Barricade(d)	28	*0.04 ± 0.11	0.08 ± 0.03	*0.006 ± 0.02	0.011 ± 0.008	*0.012 ± 0.012	NS
S of 300 Area(d)	29			0.02 ± 0.01	*0.005 ± 0.012	*0.0032 ± 0.013	*0.013 ± 0.020
Benton City	30	*-0.01 ± 0.18	0.03 ± 0.02	*0.06 ± 0.08	0.022 ± 0.007	*0.0041 ± 0.011	0.093 ± 0.021
Sunnyside	31	*0.05 ± 0.14	0.03 ± 0.02	0.04 ± 0.02	*0.005 ± 0.009	0.018 ± 0.012	0.018 ± 0.015
Offsite Mean		0.075 ± 0.069	*0.015 ± 0.022	*0.023 ± 0.023	0.014 ± 0.0041	0.0078 ± 0.0055	0.018 ± 0.012

(a) Individual results ± two sigma counting error. Means ± 2 standard error of the calculated mean.

(b) Locations are identified in Figure 46.

(c) The * signifies that the associated uncertainty is greater than or equal to the result.

(d) Perimeter location onsite near site boundary.

NS = No Sample

TABLE A.34. ^{239,240}Pu Concentrations in Vegetation (pCi/g, dry weight)^(a)

LOCATION	MAP LOCATION ^(b)	1980	1981	1982	1983	1984	1985
ONSITE							
1 Mile NE of N Area	1			* ^(c) 0.0009 ± 0.0006	0.00000 ± 0.00000	0.0005 ± 0.00015	*0.00013 ± 0.00015
1 Mile E of N Area	2			0.0012 ± 0.0010	*0.00022 ± 0.00045	*0.00012 ± 0.00030	0.00036 ± 0.00020
100 Area Fire Station	3			*0.0002 ± 0.0004	0.032 ± 0.0020	*0.00012 ± 0.00025	0.00032 ± 0.00018
200 ENC	4		0.001 ± 0.0004	*0.00062 ± 0.00067	*0.00028 ± 0.00039	0.00042 ± 0.00022	0.00067 ± 0.00026
E of 200E	5			0.0008 ± 0.0007	0.00066 ± 0.00046	0.00074 ± 0.00066	0.0075 ± 0.0011
200 ESE	6	0.06 ± 0.008	0.004 ± 0.001	*0.0001 ± 0.0006	*0.00046 ± 0.00061	0.00093 ± 0.00066	0.0018 ± 0.00043
SW of BC Cribs	7			*0.0004 ± 0.0006	*0.00016 ± 0.00018	*0.00054 ± 0.00061	0.00096 ± 0.00032
S of 200E	8			*0.0005 ± 0.0006	*0.00020 ± 0.00025	0.00044 ± 0.00037	0.0025 ± 0.00051
E of 200W	9		0.003 ± 0.001	0.004 ± 0.0008	0.0044 ± 0.0010	0.0065 ± 0.0018	0.0060 ± 0.00083
2 Miles S of 200W	10			0.00074 ± 0.00067	0.0021 ± 0.00084	*0.0001 ± 0.00020	0.00059 ± 0.00028
NE of FFTF	11		0.001 ± 0.0007	*0.0006 ± 0.0010	*0.00022 ± 0.00026	*0.00036 ± 0.00039	0.00047 ± 0.00023
SE of FFTF	12		0.001 ± 0.0006	*0.0003 ± 0.0004	0.00070 ± 0.00069	0.00083 ± 0.00063	0.00049 ± 0.00030
N of 300 Area	13			0.003 ± 0.0007	0.00046 ± 0.00034	0.0022 ± 0.0011	0.00026 ± 0.00014
Hanford Townsite	14		0.002 ± 0.0006	0.0004 ± 0.0003	*0.0007 ± 0.0010	0.00055 ± 0.00035	*0.00042 ± 0.00022
Wye Barricade	15	0.002 ± 0.0007	0.003 ± 0.0007	*0.0006 ± 0.0008	0.00026 ± 0.00024	*0.00078 ± 0.00088	0.0012 ± 0.00038
Onsite Mean		*0.033 ± 0.077	0.0022 ± 0.0010	0.00087 ± 0.00065	*0.0028 ± 0.0042	0.0010 ± 0.00085	0.0016 ± 0.0012
OFFSITE							
Riverview	16		0.002 ± 0.0009	*0.0005 ± 0.0007	0.00220 ± 0.00086	*-0.00013 ± 0.00017	0.00075 ± 0.00039
Byers Landing	17		0.0006 ± 0.0004	*0.00079 ± 0.00083	0.00040 ± 0.00038	*0.00010 ± 0.00010	0.00015 ± 0.00013
Sagemoor	18		0.002 ± 0.0009	*-0.00040 ± 0.0004	*0.00020 ± 0.00060	*0.00012 ± 0.00014	0.00022 ± 0.00017
Taylor Flats #2	19		0.002 ± 0.0006	*0.00004 ± 0.0004	0.00056 ± 0.00036	*-0.00019 ± 0.00010	0.00036 ± 0.00028
W End Fir Road	20	0.09 ± 0.009	0.002 ± 0.0007	*0.0007 ± 0.0009	*0.00021 ± 0.00029	*0.00039 ± 0.00048	0.00019 ± 0.00015
Ringold	21		0.001 ± 0.0009	*0.0001 ± 0.0004	*0.00000 ± 0.00000	*-0.00007 ± 0.00030	0.00019 ± 0.00017
Berg Ranch	22		0.003 ± 0.0008	*0.0002 ± 0.0004	0.00050 ± 0.00030	0.00080 ± 0.00059	0.00058 ± 0.00031
Wahluke #2(d)	23	0.03 ± 0.008	0.001 ± 0.0005	0.003 ± 0.0008	*-0.00001 ± 0.00002	*0.00017 ± 0.00028	0.00026 ± 0.00021
Vernita Bridge(d)	24			0.002 ± 0.0009	*0.00008 ± 0.00030	0.00035 ± 0.00025	0.00017 ± 0.00028
Yakima Barricade(d)	25		0.002 ± 0.0008	*0.001 ± 0.0010	0.00038 ± 0.00029	*0.00027 ± 0.00044	0.00056 ± 0.00022
Rattleshake Springs(d)	26			0.0004 ± 0.0003	*0.00083 ± 0.00096	*0.00022 ± 0.00022	0.00040 ± 0.00021
ALE(d)	27	0.15 ± 0.010	0.001 ± 0.0008	*0.0005 ± 0.0006	0.00033 ± 0.00028	0.00074 ± 0.00063	0.00054 ± 0.00025
Prosser Barricade(d)	28		0.004 ± 0.0010	*-0.00008 ± 0.0005	*0.00034 ± 0.00034	*0.00017 ± 0.00031	NS
S of 300 Area(d)	29			0.001 ± 0.0007	*0.00014 ± 0.00021	*0.00036 ± 0.00067	0.00045 ± 0.00021
Benton City	30	0.10 ± 0.010	0.002 ± 0.0007	0.001 ± 0.0009	0.00070 ± 0.00050	*-0.00015 ± 0.00025	0.0019 ± 0.00048
Sunnyside	31		0.003 ± 0.0008	0.001 ± 0.0008	0.00031 ± 0.00029	0.00031 ± 0.00025	0.00017 ± 0.00014
Offsite Mean		0.093 ± 0.058	0.0036 ± 0.0033	0.00077 ± 0.00045	0.00045 ± 0.00028	0.00022 ± 0.00017	0.00046 ± 0.00023

(a) Individual results ± two sigma counting error. Means ± 2 standard error of the calculated mean.

(b) Locations are identified in Figure 46.

(c) The * signifies that the associated uncertainty is greater than or equal to the result.

(d) Perimeter location onsite near site boundary.

NS = No Sample

TABLE A.35. U Concentrations in Vegetation (pCi/g, dry weight)^(a)

LOCATION	MAP LOCATION ^(b)	1980	1981	1982	1983	1984	1985
ONSITE							
1 Mile NE of N Area	1			0.01 ± 0.005	0.006 ± 0.003	0.007 ± 0.0034	0.0076 ± 0.0056
1 Mile E of N Area	2			0.02 ± 0.007	0.007 ± 0.003	0.0061 ± 0.0030	0.013 ± 0.0074
100 Area Fire Station	3			0.008 ± 0.003	0.007 ± 0.003	0.0067 ± 0.0033	0.016 ± 0.0078
200 ENC	4	* ^(c) 0.01 ± 0.01	0.01 ± 0.004	0.006 ± 0.002	0.007 ± 0.004	0.0092 ± 0.0037	0.015 ± 0.0076
E of 200E	5			0.01 ± 0.005	0.008 ± 0.003	0.0066 ± 0.0042	0.011 ± 0.0064
200 ESE	6	*0.005 ± 0.01	0.008 ± 0.003	0.006 ± 0.002	0.007 ± 0.003	0.0052 ± 0.0040	0.016 ± 0.0080
SW of BC Cribs	7			0.01 ± 0.003	0.005 ± 0.003	0.017 ± 0.0077	0.014 ± 0.0077
S of 200E	8			0.01 ± 0.004	0.009 ± 0.004	0.011 ± 0.0054	0.035 ± 0.014
E of 200W	9	*0.004 ± 0.01	0.01 ± 0.004	0.01 ± 0.004	0.011 ± 0.004	0.016 ± 0.0065	0.022 ± 0.0096
2 Miles S of 200W	10			0.01 ± 0.003	0.007 ± 0.003	0.015 ± 0.0058	0.0096 ± 0.0063
NE of FFTF	11	*0.01 ± 0.01	0.02 ± 0.006	0.002 ± 0.0008	0.005 ± 0.003	0.014 ± 0.005	0.0081 ± 0.0054
SE of FFTF	12	*0.01 ± 0.01	0.008 ± 0.003	0.007 ± 0.002	0.01 ± 0.004	0.0050 ± 0.0027	0.022 ± 0.0098
N of 300 Area	13			0.01 ± 0.005	0.018 ± 0.006	0.012 ± 0.0046	0.082 ± 0.027
Hanford Townsite	14	0.04 ± 0.20	0.005 ± 0.003	0.01 ± 0.004	*0.011 ± 0.048	0.0032 ± 0.0022	0.015 ± 0.0080
Nye Barricade	15	0.02 ± 0.01	*0.01 ± 0.040	0.005 ± 0.002	0.0077 ± 0.0035	0.0045 ± 0.0036	0.021 ± 0.0095
Onsite Mean		*0.016 ± 0.031	0.010 ± 0.0037	0.0099 ± 0.0025	0.0083 ± 0.0018	0.0093 ± 0.0026	0.021 ± 0.0099
OFFSITE							
Riverview	16	*0.008 ± 0.01	0.02 ± 0.0008	0.02 ± 0.006	0.014 ± 0.005	0.021 ± 0.0076	0.0099 ± 0.0060
Byers Landing	17	0.03 ± 0.02	0.02 ± 0.0080	0.04 ± 0.010	0.015 ± 0.006	0.022 ± 0.0078	0.19 ± 0.058
Sagemoor	18	*0.003 ± 0.01	0.02 ± 0.0080	0.02 ± 0.006	0.013 ± 0.005	0.012 ± 0.0050	0.019 ± 0.0086
Taylor Flats #2	19	0.11 ± 0.04	0.03 ± 0.010	0.03 ± 0.009	0.016 ± 0.006	0.011 ± 0.0044	0.022 ± 0.0096
W End Fir Road	20	*0.003 ± 0.01	0.02 ± 0.0070	0.03 ± 0.010	0.02 ± 0.007	0.036 ± 0.012	0.038 ± 0.014
Ringold	21	0.02 ± 0.01	0.04 ± 0.010	0.03 ± 0.010	0.027 ± 0.009	0.025 ± 0.0085	0.041 ± 0.015
Berg Ranch	22	*0.0008 ± 0.01	0.01 ± 0.0050	*0.02 ± 0.060	0.012 ± 0.005	0.017 ± 0.0066	0.0097 ± 0.0063
Wahluke #2(d)	23	*0.002 ± 0.01	0.02 ± 0.0060	0.01 ± 0.005	0.011 ± 0.005	0.0088 ± 0.0039	0.015 ± 0.0079
Vernita Bridge (d)	24			0.01 ± 0.005	0.013 ± 0.005	0.011 ± 0.0045	0.020 ± 0.0090
Yakima Barricade (d)	25	*0.01 ± 0.01	0.12 ± 0.040	0.01 ± 0.003	0.0078 ± 0.0035	0.0037 ± 0.0020	0.020 ± 0.0090
Rattlesnake Springs (d)	26			0.004 ± 0.001	0.012 ± 0.005	0.0042 ± 0.0022	0.013 ± 0.0068
ALE (d)	27	0.07 ± 0.03	0.007 ± 0.0020	0.008 ± 0.003	0.0055 ± 0.0029	0.0057 ± 0.0025	0.0075 ± 0.0054
Prosser Barricade (d)	28	*0.01 ± 0.01	0.006 ± 0.0030	0.01 ± 0.003	0.011 ± 0.005	0.0042 ± 0.0023	NS
S of 300 Area (d)	29			0.006 ± 0.002	0.0118 ± 0.0056	0.014 ± 0.0053	0.036 ± 0.014
Benton City	30	0.03 ± 0.02		0.01 ± 0.004	0.015 ± 0.006	0.014 ± 0.0056	0.013 ± 0.0074
Sunnyside	31	0.02 ± 0.01	0.01 ± 0.0050	0.01 ± 0.005	0.009 ± 0.004	*0.0013 ± 0.0014	0.0086 ± 0.0057
Offsite Mean		0.024 ± 0.018	0.027 ± 0.016	0.017 ± 0.0052	0.013 ± 0.0028	0.013 ± 0.0049	*0.041 ± 0.041

(a) Individual results ± two sigma counting error. Means ± 2 standard error of the calculated mean.

(b) Locations are identified in Figure 46.

(c) The * signifies that the associated uncertainty is greater than or equal to the result.

(d) Perimeter location onsite near site boundary.

NS = No Sample.

TABLE A.36. Environmental Dosimeter Measurements - Perimeter and Community Locations

Location	Map Location (b)	No. of Samples	Dose Rate, mrem/yr ^(a)		
			Maximum	Minimum	Average (c)
Perimeter Stations					
Prosser Barricade	1	12	74	58	65 ± 6
ALE	2	12	70	58	65 ± 5
Rattlesnake Springs	3	12	73	55	69 ± 7
Yakima Barricade	4	12	76	58	71 ± 6
Vernita Bridge	5	12	73	57	65 ± 6
Wahluke #2	6	13	84	65	70 ± 7
Berg Ranch	7	11	81	58	71 ± 8
Sagehill	8	11	73	51	64 ± 8
Ringold	9	11	95	51	68 ± 13
Fir Road	10	12	76	55	66 ± 5
Pettett	11	13	72	36	60 ± 10
Sagemoor	12	13	77	43	64 ± 9
Byers Landing	13	12	79	58	68 ± 7
RRC #64	14	13	75	57	62 ± 5
Horn Rapids Rd. Mi. 12	15	13	72	51	62 ± 7
Horn Rapids Rd. Substation	16	13	68	52	59 ± 5
Range of annual averages 59-71 mrem/yr					
Nearby Communities					
Benton City	17	12	61	44	52 ± 6
Othello	18	11	61	47	54 ± 5
Connell	19	11	68	51	58 ± 6
Pasco	20	13	67	41	56 ± 7
Richland	21	13	64	48	55 ± 6
Range of annual averages 52-58 mrem/yr					
Distant Communities					
Walla Walla	22	12	64	47	57 ± 6
NcNary	23	12	72	59	65 ± 5
Sunnyside	24	12	66	52	59 ± 5
Moses Lake	25	11	60	50	54 ± 4
Washtucna	26	11	66	57	61 ± 4
Range of annual averages 54-65 mrem/yr					

(a) Monthly integrated readings in mR were converted to annual dose equivalent rates.

(b) Locations are identified in Figure 51.

TABLE A.37. Immersion Dose Rates Measured in the Columbia River

Location ^(b)	Number of Measurements	Dose Rate, mrem/h ^(a)		
		Maximum	Minimum	Average ^(c)
Coyote Rapids	2	0.005	0.003	0.004 ± 0.003
Richland Pumphouse	4	0.003	0.003	0.003 ± 0.0004

- (a) Monthly integrated readings in mR were converted to hourly dose equivalent rates
 (b) Locations are identified in Figure 53.
 (c) Averages ±2 times the standard error of calculated mean.

TABLE A.38. Environmental Dosimeter Measurements at Publicly Accessible Onsite Locations

Location	Map Location ^(b)	No. of Measurements	Dose Rate, mrem/h ^(a)		
			Maximum	Minimum	Averages ^(c)
100N Area Shoreline					
100N Trench Springs	1	12	0.043	0.008	0.019 ± 0.014
Below 100N Main Stack	2	12	0.036	0.012	0.021 ± 0.008
Upstream Tip 100N Berm	3	12	0.040	0.018	0.022 ± 0.008
Downstream 100N Outfall	4	12	0.036	0.015	0.025 ± 0.007
300 Area Perimeter Fence					
3777-S Fence	5	12	0.028	0.014	0.017 ± 0.004
3705 West Fence	6	13	0.018	0.008	0.012 ± 0.003
400 Area (FFTF) Perimeter Fence					
400 East	7	13	0.008	0.006	0.007 ± 0.0006

- (a) Monthly integrated readings in mR were converted to hourly dose equivalent rates.
 (b) Locations are identified in Figure 54.
 (c) Averages ±2 times the standard error of the calculated mean.

TABLE A.39. Environmental Dosimeter Measurements Along the Hanford Reach of the Columbia River

Location	Map Location (b)	No. of Measurements	Dose Rate, mrem/h ^(a)		
			Maximum	Minimum	Average (c)
Upriver 100B Area	1	4	0.009	0.007	0.008 ± 0.002
Below 100B Retention Basin	2	4	0.017	0.015	0.015 ± 0.002
Above 100K Boat Ramp	3	4	0.008	0.007	0.008 ± 0.002
Downriver 100D	4	4	0.011	0.009	0.010 ± 0.002
Downriver Opposite 100D	5	4	0.008	0.007	0.007 ± 0.001
Lower End Locke Island	6	4	0.009	0.007	0.008 ± 0.002
White Bluffs Slough	7	4	0.017	0.011	0.015 ± 0.005
White Bluffs Ferry Landing	8	4	0.009	0.008	0.008 ± 0.001
Below 100F	9	4	0.008	0.007	0.007 ± 0.001
100F Floodplain	10	4	0.015	0.013	0.015 ± 0.002
Hanford Powerline Crossing	11	4	0.009	0.008	0.008 ± 0.001
Hanford Ferry Landing	12	3	0.008	0.007	0.007 ± 0.002
Hanford Peninsula	13	4	0.014	0.010	0.012 ± 0.004
Hanford Railroad Track	14	4	0.012	0.010	0.011 ± 0.002
Savage Island Slough	15	4	0.012	0.009	0.010 ± 0.002
Ringold Island	16	4	0.009	0.008	0.008 ± 0.001
Powerline Crossing	17	4	0.010	0.008	0.009 ± 0.001
North End Wooded Island	18	3	0.008	0.006	0.007 ± 0.003
South End Wooded Island	19	4	0.010	0.009	0.009 ± 0.001
Island Near 300 Area	20	4	0.013	0.009	0.011 ± 0.004
Below Bateman Island	21	2	0.010	0.008	0.009 ± 0.003

(a) Quarterly, integrated readings in mR were converted to hourly dose equivalent rates.

(b) Locations are identified in Figure 53.

(c) Averages ±2 times the standard error of the calculated mean.

TABLE A.40. Onsite External Penetrating Dose Measurements

Location	Map Location ^(b)	No. of Measurements	Dose Rate, mrem/h ^(a)		
			Maximum	Minimum	Average ^(c)
100 Area					
100K	1	13	0.008	0.006	0.007 ± 0.0007
100N	2	13	0.011	0.007	0.009 ± 0.002
100D	3	12	0.009	0.007	0.008 ± 0.0008
100 Area Fire Station	4	12	0.008	0.005	0.006 ± 0.0009
200 Area					
N of 200E	5	12	0.009	0.007	0.008 ± 0.0006
E of 200E	6	12	0.009	0.007	0.008 ± 0.0009
200ESE	7	12	0.008	0.006	0.008 ± 0.0007
GTE Building	8	12	0.007	0.005	0.007 ± 0.0007
SW of BC Cribs	9	12	0.008	0.007	0.008 ± 0.0006
S of 200E	10	12	0.009	0.007	0.008 ± 0.0006
300 Area					
300 Pond	11	13	0.009	0.006	0.007 ± 0.0008
3614 A Building	12	13	0.008	0.004	0.007 ± 0.0008
300S Gate	13	13	0.008	0.006	0.007 ± 0.0006
300SW Gate	14	13	0.008	0.005	0.009 ± 0.0009
3705 West Fence	15	13	0.018	0.008	0.012 ± 0.003
377 Building South Fence	16	12	0.028	0.008	0.017 ± 0.004
400 Area					
400E	17	13	0.008	0.006	0.007 ± 0.0006
400W	18	13	0.009	0.005	0.007 ± 0.001
400S	19	13	0.008	0.006	0.007 ± 0.0006
400N	20	13	0.011	0.006	0.008 ± 0.001
FFTF North	21	13	0.008	0.005	0.007 ± 0.0008
FFTF Southeast	22	13	0.008	0.006	0.007 ± 0.0006
600 Area					
Rt. 11A Mi. 9	23	12	0.008	0.007	0.007 ± 0.0005
Hanford	24	13	0.008	0.006	0.007 ± 0.0006
Wye Barricade	25	13	0.009	0.007	0.007 ± 0.0007
Army Loop Camp	26	12	0.008	0.007	0.008 ± 0.0006

(a) Monthly integrated reading in mR were converted to hourly rates.

(b) Locations are identified in Figure 55.

(c) Averages ±2 standard error of the mean.

TABLE A.41. Water Quality Parameters Analyzed by HEHF, 1985

Well Location No. (a)	Date	pH	Cond. $\mu\text{mho/cm}$	in mg/l												
				Total Alk as CaCO_3	HCO_3^- Alk as CaCO_3	CO_3 Alk as CaCO_3	TDS	Cl	SO_4	$\text{NO}_3\text{-N}^{(b)}$	Ca	Mg	Na	K	B	
699-26-15	12-2	7.7	485	113	110	0.6	289	12.6	50	9.1	44	11	21	6.7	0.07	
699-S-31-01-P	12-2	7.9	247	88	85	0.6	150	5.1	16	0.76	25	5.8	9.0	4.0	0.05	
699-02-03	12-2	7.7	470	118	120	0.6	268	9.9	52	6.7	41	11	19	5.7	0.06	
699-02-07	12-2	7.5	1316	163	170	0.7	855	50	350	14.0	132	41	53	11.4	0.20	
699-S-03E-12	12-2	7.9	306	106	115	1.0	222	7.4	21	5.2	33	9.5	11	4.5	<0.05	
699-59-58	12-2	7.9	282	114	120	1.2	181	5.5	14	0.20	19	6.6	27	5.2	0.25	
699-S-19E-13	12-2	7.8	408	122	130	0.8	284	16.0	48	4.3	39	12	21	6.2	0.15	
699-49-13E	12-9	7.1	366	131	126	<0.5	205	4.9	24	1.4	29	6.8	25	5.5	0.09	
699-50-28B	12-9	7.6	298	124	116	0.5	213	7.4	28	0.85	25	11	20	4.0	0.20	
699-50-53	12-9	7.7	836	80	76	<0.5	595	61	208	16.8	89	30	34	10.5	0.09	
699-55-50C	12-9	7.9	201	113	109	1.0	155	5.4	16	0.34	31	9.3	4.7	4.0	0.08	
699-71-77	12-9	7.7	229	122	120	0.7	189	3.4	22	0.86	20	10	14	5.0	0.17	
699-72-88	12-9	7.5	235	99	96	<0.5	178	4.6	35	1.02	26	7.1	8.0	4.3	0.12	
699-74-44	12-9	8.4	189	64	60	1.4	130	7.5	36	0.12	12	4.8	26	2.6	0.20	
699-81-58B	12-9	7.8	177	97	95	0.6	123	1.1	16	0.25	25	7.4	3.6	2.5	0.12	
699-87-55	12-9	7.9	185	86	83	0.8	165	3.1	24	3.8	21	8.6	12	3.4	0.08	
699-89-35	12-9	7.6	196	153	150	0.7	240	4.6	37	2.1	31	12	31	5.0	0.20	
699-64-27	12-16	7.8	831	147	140	1.0	557	33	186	8.7	64	20	47	7.7	0.11	
199H-04-05	12-16	7.9	372	120	113	0.8	248	5.0	38	4.6	46	8.6	6.9	4.2	0.11	
199H-04-03	12-16	8.0	2150	118	114	1.6	1520	7.1	90	210	51	9.2	336	9.7	0.20	
199H-04-04	12-16	7.9	412	102	96	0.9	290	4.8	39	14.6	23	4.9	48	4.1	0.10	
699-78-62	12-16	7.9	346	104	100	0.8	250	6.7	55	1.6	33	11	13	4.9	0.09	
699-45-42	12-16	7.8	294	106	101	0.7	208	5.1	30	1.6	20	10	14	4.4	0.08	
699-66-64	12-16	7.9	318	115	107	1.0	206	6.2	23	2.4	26	9.2	14	5.7	0.10	
699-45-69A	12-16	7.9	433	114	108	1.0	299	13.1	50	7.1	38	17	7.4	3.7	0.09	
699-26-89	12-16	7.6	371	150	142	0.5	231	4.5	17	0.67	32	14	17	3.8	0.09	
699-10-54	12-16	7.9	330	120	114	0.9	214	5.0	20	3.0	29	11	11	3.3	0.09	
699-19-43	12-16	7.8	405	114	107	0.7	270	7.4	56	2.3	37	10	18	5.5	0.09	
699-20-E-05A	12-23	7.4	298	116	111	<0.5	227	7.1	31	4.7	35	10	12	5.1	0.09	
699-31-53B0	12-23	7.8	221	159	153	1.0	244	6.0	27	1.3	39	13	18	4.9	0.09	
699-34-42	12-23	7.9	224	101	99	0.8	224	4.1	29	6.2	22	8.6	25	5.9	0.12	
699-35-70	12-23	7.8	202	133	128	0.8	282	24	31	7.9	38	14	23	5.5	0.11	
699-36-93	12-23	7.8	157	72	69	<0.5	196	13.8	46	1.7	18	16	13	6.2	0.10	
699-49-79	12-23	7.9	229	97	95	0.8	254	8.6	46	9.7	39	14	8.4	3.6	0.17	
699-63-90	12-23	7.8	229	121	116	0.8	210	8.4	28	1.2	30	13	11	4.4	<0.05	
699-S-03-25	12-30	7.7	400	132	127	0.5	338	28	80	<0.1	53	14	25	7.5	0.16	
699-14-47	12-30	7.7	163	99	94	0.5	172	11.5	156	<0.1	20	8.2	16	5.6	0.07	
699-15-26	12-30	7.8	324	127	123	0.5	298	13.1	55	5.3	44	12	23	7.7	0.07	
699-25-70-0	12-30	7.6	231	109	102	<0.5	223	6.6	21	3.1	27	12	15	3.9	0.16	
699-40-01	12-30	7.8	308	106	100	0.6	295	10.3	41	9.0	39	13	18	6.3	0.14	
699-40-33A	12-30	8.0	270	143	138	1.2	227	2.8	<2	<0.1	11	4.0	51	6.7	0.09	

(a) Well locations are identified in Figure 17.

(b) Nitrate analyzed as nitrogen. To convert to nitrate ion multiply by 4.4.

TABLE A.42. Constituents Detected in Sampling of 75 Wells in the Site-Wide Network

<u>Constituent</u>	<u>Detection Limit (DL), ppb</u>	<u>No. of Wells Above DL/Proportion^(a)</u>
Barium	6	74/99%
Cadmium	2	17/23%
Chromium	10	26/35%
Copper	10	16/21%
Manganese	5	46/61%
Sodium	100	75/100%
Nickel	10	19/25%
Vanadium	5	68/91%
Aluminum	150	11/15%
Potassium	100	75/100%
Iron	50	65/87%
Arsenic	5	8/11%
Mercury	0.1	2/3%
Total Organic Carbon (TOC)	1 ppm	36/48%
Nitrate	500	74/99%
Sulfate	500	75/100%
Fluoride	500	22/29%
Chloride	500	75/100%
Phosphate	1000	1/1%
Coliform Bacteria	3 mpn ^(b)	15/20%
Radium	1 pCi/l	12/16%
Gross Beta	8 pCi/l	73/97%
Gross Alpha	4 pCi/l	53/71%
Ammonium ion	20	32/100% ^(c)

(a) The proportion is the number of wells above the detection limit divided by the number of wells in the data set used for the table.

(b) mpn = most probable number

(c) Not all wells were sampled for this constituent.

TABLE A.43. Constituents Detected in Sampling of Two Wells at the 100B Area

<u>Constituent</u>	<u>Detection Limit (DL), ppb</u>	<u>No. of Wells Above DL/Proportion (a)</u>
Barium	6	2/100%
Cadmium	2	1/50%
Chromium	10	2/100%
Manganese	5	1/50%
Sodium	100	2/100%
Vanadium	5	1/50%
Potassium	100	2/100%
Iron	50	1/50%
Total Organic Carbon (TOC)	1 ppm	1/50%
Nitrate	500	2/100%
Sulfate	500	2/100%
Chloride	500	2/100%
Coliform Bacteria	3 mpn ^(b)	1/50%
Gross Beta	8 pCi/l	2/100%
Gross Alpha	4 pCi/l	2/100%

(a) The proportion is the number of wells above the detection limit divided by the number of wells in the data set used for the table.

(b) mpn = most probable number.

TABLE A.44. Constituents Detected in Sampling of Two Wells at the 100D Area

<u>Constituent</u>	<u>Detection Limit (DL), ppb</u>	<u>No. of Wells Above DL/Proportion (a)</u>
Barium	6	2/100%
Chromium	10	2/100%
Sodium	100	2/100%
Vanadium	5	2/100%
Potassium	100	2/100%
Iron	50	2/100%
Total Organic Carbon (TOC)	1 ppm	2/100%
Nitrate	500	2/100%
Sulfate	500	2/100%
Chloride	500	2/100%
Radium	1 pCi/l	1/50%
Gross Beta	8 pCi/l	2/100%

(a) The proportion is the number of wells above the detection limit divided by the number of wells in the data set used for the table.

TABLE A.45. Constituents Detected in Sampling of Three Wells at the 100F Area

<u>Constituent</u>	<u>Detection Limit (DL), ppb</u>	<u>No. of Wells Above DL/Proportion^(a)</u>
Barium	6	3/100%
Chromium	10	1/33%
Manganese	5	3/100%
Sodium	100	3/100%
Vanadium	5	1/33%
Potassium	100	3/100%
Iron	50	2/67%
Total Organic Carbon (TOC)	1 ppm	3/100%
Nitrate	500	3/100%
Sulfate	500	3/100%
Chloride	500	3/100%
Coliform Bacteria	3 mpn ^(b)	3/67%
Gross Beta	8 pCi/l	2/100%
Gross Alpha	4 pCi/l	3/100%

(a) The proportion is the number of wells above the detection limit divided by the number of wells in the data set used for the table.

(b) mpn = most probable number.

TABLE A.46. Constituents Detected in Sampling of Two Wells at the 100K Area

<u>Constituent</u>	<u>Detection Limit (DL), ppb</u>	<u>No. of Wells Above DL/Proportion^(a)</u>
Barium	6	2/100%
Cadmium	2	1/50%
Chromium	10	1/50%
Copper	10	1/50%
Manganese	5	2/100%
Sodium	100	2/100%
Nickel	10	1/50%
Vanadium	5	2/100%
Aluminum	150	1/50%
Potassium	100	2/100%
Iron	50	2/100%
Total Organic Carbon (TOC)	1 ppm	2/100%
Nitrate	500	2/100%
Sulfate	500	2/100%
Chloride	500	2/100%
Radium	1 pCi/l	1/50%
Gross Beta	8 pCi/l	2/100%
Gross Alpha	4 pCi/l	2/100%

(a) The proportion is the number of wells above the detection limit divided by the number of wells in the data set used for the table.

TABLE A.47. Constituents Detected in Sampling of Six Wells at the 100N Area

<u>Constituent</u>	<u>Detection Limit (DL), ppb</u>	<u>No. of Wells Above DL/Proportion (a)</u>
Barium	6	6/100%
Cadmium	2	1/17%
Manganese	5	3/50%
Sodium	100	6/100%
Vanadium	5	6/100%
Aluminum	150	1/17%
Potassium	100	6/100%
Iron	50	4/67%
Total Organic Carbon (TOC)	1 ppm	6/100%
Nitrate	500	6/100%
Sulfate	500	6/100%
Chloride	500	6/100%
Gross Beta	8 pCi/l	6/100%
Gross Alpha	4 pCi/l	1/17%

(a) The proportion is the number of wells above the detection limit divided by the number of wells in the data set used for the table.

TABLE A.48. Constituents Detected in Sampling of 26 Wells in or Near the 200 Areas

<u>Constituent</u>	<u>Detection Limit (DL), ppb</u>	<u>No. of Wells Above DL/Proportion (a)</u>
Barium	6	25/96%
Cadmium	2	9/35%
Chromium	10	14/54%
Copper	10	9/35%
Manganese	5	18/69%
Sodium	100	26/100%
Nickel	10	8/31%
Vanadium	5	25/96%
Aluminum	150	5/19%
Potassium	100	26/100%
Iron	50	24/92%
Arsenic	5	4/15%
Mercury	0.1	2/8%
Total Organic Carbon (TOC)	1 ppm	8/31%
Nitrate	500	25/96%
Sulfate	500	26/100%
Fluoride	500	14/54%
Chloride	500	26/100%
Coliform Bacteria	3 mpn ^(b)	3/12%
Radium	1 pCi/l	3/12%
Gross Beta	8 pCi/l	26/100%
Gross Alpha	4 pCi/l	16/62%
Ammonium Ion	20	16/100% ^(c)

(a) The proportion is the number of wells above the detection limit divided by the number of wells in the data set used for the table.

(b) mpn = most probable number.

(c) Not all wells were sampled for this constituent.

TABLE A.49. Constituents Detected in Sampling of 34 Wells in the 600 Area^(a)

Constituent	Detection Limit (DL), ppb	No. of Wells Above DL/Proportion ^(a)
Barium	6	34/100%
Cadmium	2	5/15%
Chromium	10	6/18%
Copper	10	6/18%
Manganese	5	19/56%
Sodium	100	34/100%
Nickel	10	10/29%
Vanadium	5	31/91%
Aluminum	150	4/12%
Potassium	100	34/100%
Iron	50	30/88%
Arsenic	5	
Total Organic Carbon (TOC)	1 ppm	14/41%
Nitrate	500	34/100%
Sulfate	500	34/100%
Fluoride	500	8/24%
Chloride	500	34/100%
Phosphate	1000	1/3%
Coliform Bacteria	3 mpn ^(c)	9/26%
Radium	1 pCi/l	7/21%
Gross Beta	8 pCi/l	32/94%
Gross Alpha	4 pCi/l	29/85%
Ammonium Ion	20	16/100% ^(d)

- (a) The 600 Area encompasses the portion of the site not included in the other areas.
- (b) The proportion is the number of wells above the detection limit divided by the number of wells in the data set used for the table.
- (c) mpn = most probable number.
- (d) Not all wells were sampled for this constituent.

TABLE A.50. Columbia River Water Quality Data

Analysis	Units	No. of Samples	Maximum	Minimum	Annual Average ^(a)	No. of Samples	Maximum	Minimum	Annual Average ^(a)	State Standard ^(b)
PML Environmental Monitoring										
pH	pH units	13	8.6	6.4	NA	13	8.7	6.7	NA	6.5 - 8.5
Fecal coliform	#/100 ml	13	8	2	2 ^(c)	13	350	2	8 ^(c)	100
Total coliform	#/100 ml	13	920	8	27 ^(c)	13	>2400	8	130 ^(c)	
Biological oxygen demand	mg/l	13	4.7	2.4	3.3 ± 0.4	13	3.6	1.3	2.5 ± 9.5	
Nitrate	mg/l	13	0.55	0.03	0.13 ± 0.08	13	0.32	0.02	0.10 ± 0.05	
USGS Sampling Program^(d)										
Temperature ^(e)	°C	330	20	1.7	11 ± 3.8	351	21	0.9	11 ± 3.9	20 (maximum)
Dissolved oxygen	mg/l	6	14.8	9.8	12 ± 1.5	4	14	9.9	12 ± 1.6	8 (minimum)
Turbidity	NTU ^(f)	5	2.4	0.7	1.4 ± 0.6	3	2.9	1.3	1.9 ± 1.0	5 + background
pH	pH units	6	8.2	6.8	NA	4	8.3	6.4	NA	6.5 - 8.5
Fecal coliform	#/100 ml	5	10	1	1 ^(c)	3	13	<1	6 ± 7	100
Suspended solids, 105°C	mg/l	5	7	1	2.4 ± 2.3	3	7	5	6.0 ± 1.2	
Dissolved solids, 180°C	mg/l	5	93	66	76 ± 9	3	85	68	75 ± 10	
Specific conductance	[micron]mhos	6	160	130	140 ± 9	4	160	130	140 ± 18	
Hardness, as CaCO ₃	mg/l	5	79	62	69 ± 7	3	78	60	67 ± 12	
Phosphorus, total	mg/l	6	0.03	0.01	0.02 ± 0.007	4	0.02	0.01	0.015 ± 0.006	
Chloride, dissolved	mg/l	5	2.1	1.0	1.3 ± 0.4	3	1.1	1.0	1.1 ± 0.07	
Chromium, dissolved	μg/l	3	1	<1	* ^(g) 1.0 ± 1.2	3	<10	<10	<10	
Nitrogen, Kjeldahl	mg/l	6	0.40	0.20	0.30 ± 0.08	4	0.40	<0.20	0.28 ± 0.09	
Total Organic Carbon	mg/l	4	4.6	1.4	3.1 ± 1.5	4	6.1	1.0	3.2 ± 2.5	
Iron, dissolved	μg/l	3	11	6	8 ± 3	3	11	<3	6 ± 5	
Ammonia, dissolved (as N)	mg/l	6	0.04	0.01	0.03 ± 0.008	4	0.04	0.02	0.035 ± 0.010	

(a) Average values ± two standard error of the calculated mean.

(b) See Appendix C.

(c) Annual median.

(d) Provisional data subject to revision.

(e) Maximum and minimum represent daily averages. Missing data due to equipment failures.

(f) Nephelometric Turbidity Units.

(g) * Signifies that the uncertainty associated with the value is greater than or equal to the value.

NA = Not Applicable.

TABLE A.51. Estimates of Total Precision Based on 1985 Replicate Sampling and Analysis

Medium	Analysis	Coefficient of Variation (%) ^(a)
Air	Gross alpha	26
	Gross beta	28
	^{239,240} Pu	40
	⁹⁰ Sr	56
	³ H	52
Uranium	20	
Water	Gross alpha	9
	Gross beta	30
Uranium	47	
	⁹⁰ Sr	75
	³ H	60
Milk	⁹⁰ Sr	21
Wheat	⁹⁰ Sr	16
Soil onsite	^{239,240} Pu	43
Soil onsite	Uranium	28
Soil onsite	¹³⁷ Cs	23
Soil onsite	⁹⁰ Sr	28
Soil offsite	Uranium	29
Soil offsite	⁹⁰ Sr	16

(a) Coefficient of variation calculated from the mean of standard deviation between replicates divided by the mean, multiplied by 100 (AOAC 1975).

TABLE A.52. U.S. Testing Analysis of National Bureau of Standards Standard Reference Soil

Radionuclide	NBS (pCi/g)	UST $\pm 2\sigma$ (pCi/g)	Normalized Deviation From the Known ^(a)
⁴⁰ K	19.5	15.9 \pm 1.9	-1.8
⁹⁰ Sr	0.206	0.24 \pm 0.05	+1.6
¹³⁷ Cs	0.476	0.35 \pm 0.9	-2.6
²²⁶ Ra	1.16	0.86 \pm 0.19	-1.7
^{239,240} Pu	0.217	0.18 \pm 0.01	-1.1

(a) Normalized deviation calculated according to Jarvis and Siu 1981.

TABLE A.53. U.S. Testing ^{90}Sr Analysis of Environmental Measurements Laboratory Vegetation Samples

<u>Sample Type</u>	<u>EML (pCi/g)</u>	<u>UST (pCi/g)</u>	<u>Normalized Deviation From the Known^(a)</u>
Potato ash	0.39 ± 0.03	0.34 ± 0.03	-1.3
Dried vegetation	12.2 ± 0.8	12.2 ± 0.01	0

(a) Normalized deviation calculated according to Jarvis and Siu 1981.

TABLE A.54. ^{85}Kr Analysis of Compressed Air Sample Split With REECO

<u>UST (pCi/m³)</u>	<u>REECO (pCi/m³)</u>	<u>Allowable Range Between Duplicates^(a)</u>
62 ± 12	108 ± 4.5	66

(a) Control limits on range calculated according to ASTM 1976.

TABLE A.55. Comparison of TLD Results With Known Exposures

Month	% Bias ^(a)		
	Low ^(b)	Medium	High
January	-3.8	-3.3	-6.5
February	-1.6	+0.4	+5.0
March	-1.0	-1.6	+1.7
April	-4.2	-5.4	-4.4
May	-4.8	-5.8	-5.3
June	-0.6	+0.7	-2.1
July	-5.3	-4.4	-3.3
August	+2.0	-7.8	-1.6
September	-1.4	-4.0	-3.7
October	-7.2	-3.8	-3.9
November	+0.3	-2.1	-3.5
December	+5.9	+4.8	+3.5
Average	-1.8	-2.7	-2.0

(a) The percent bias was calculated by

$$100 \left(\frac{x_1 + x_2}{2} - E \right) / E$$

where x_1 and x_2 are the two measured exposures and E is the known exposure.

(b) Range of exposures from low to high range were between 15 and 28 mR.

TABLE A.56. Radiation Response of PNL and State of Washington DSHS Environmental Dosimeters

Irradiation Source	Energy	Delivered Dose	Reported Dose	
			DSHS	PNL
Beta				
⁸⁵ Kr	0.7 MeV	28 mrad	1.3 mrad	0 mrad
⁹⁰ Sr	2.3	20	15.2	0
¹⁰⁶ Ru	3.5	20	16.6	0
U (natural)	2.3	20	9.9	0
Photon				
⁶⁰ S (x-ray)	36 keV	20 mR	30 mR	0.4 mR
¹⁵⁰ M (x-ray)	70	20	24.7	13.0
¹³⁷ Cs	662	20	20	20.6

TABLE A.57. Washington State-DSHS and PNL Shared TLD Stations (mR/day)

Location	1985 Calendar Quarter					
	First		Second		Third	
	DSHS ^(a)	PNL	DSHS	PNL	DSHS	PNL
U.S. Ecology NE Corner			0.20 ± 0.06	0.18 ± 0.01	0.20 ± 0.02	0.19 ± 0.01
NW Corner			0.21 ± 0.02	0.19 ± 0.01	0.21 ± 0.08	0.19 ± 0.01
SW Corner			0.32 ± 0.04	0.28 ± 0.00	0.30 ± 0.04	0.26 ± 0.00
SE Corner	0.33 ± 0.04	0.22 ± 01	0.38 ± 0.06	0.31 ± 0.01	0.39 ± 0.06	0.30 ± 0.01
WPPSS Station 1			0.25 ± 0.04	0.18 ± 0.00	0.18 ± 0.08	0.20 ± 0.01
WPPSS Station 4			0.21 ± 0.02	0.16 ± 0.00	0.16 ± 0.08	0.18 ± 0.00
WPPSS Station 8			0.26 ± 0.02	0.20 ± 0.01	0.20 ± 0.08	0.22 ± 0.00

(a) DSHS dosimeters were in place at these locations since 1977. The co-locating of PNL dosimeters was started January 1985 with one station and expanded to seven in March 1985.

TABLE A.58. Results of Split Samples Analyzed by State of Washington, State of Oregon and Department of Energy - Pacific Northwest Laboratory. Columbia River and spring samples (units pCi/l $\pm 2\sigma$), July 30, 1985

Location	Analyzed By	Alpha	Beta	⁹⁰ Sr	Uranium	Tritium
River Water Mile 27.5	DOE/PNL	0.7 \pm 0.6	1.0 \pm 1.1	0.18 \pm 0.06	NA	115 \pm 220
	Washington	<2	1 \pm 1	<1	NA	<300
	Oregon	1.1 \pm 0.8	1.8 \pm 0.8	<1	NA	<450
River Water Mile 36.0	DOE/PNL	0.5 \pm 0.6	1.0 \pm 1.1	0.16 \pm 0.09	NA	127 \pm 220
	Washington	<2	1 \pm 1	<1	NA	<300
	Oregon	0.5 \pm 0.4	0.8 \pm 0.6	<1	NA	<450
Spring 27-3	DOE/PNL	0.9 \pm 0.9	8.6 \pm 2.3	0.14 \pm 0.04	NA	47,600 \pm 700
	Washington	3 \pm 2	6 \pm 1	<1	NA	45,600 \pm 1,000
	Oregon	3.6 \pm 2.1	12.8 \pm 1.4	<1	NA	46,000 \pm 3,300
Spring 28-2	DOE/PNL	1.4 \pm 0.9	10.0 \pm 2.2	0.28 \pm 0.06	NA	20,900 \pm 400
	Washington	<2	7 \pm 1	<1	NA	22,600 \pm 600
	Oregon	1.5 \pm 1.4	11.7 \pm 1.3	<1	NA	22,700 \pm 1,590
Spring 42-2	DOE/PNL	13.2 \pm 2.5	10.5 \pm 2.2	0.03 \pm 0.02	11.5 \pm 0.3	209 \pm 214
	Washington	11 \pm 2	12 \pm 1	<1	11.4 \pm 0.5	364 \pm 289
	Oregon	9.4 \pm 2.8	12.5 \pm 1.3	<1	14.7	<450
Greenpeace Sample	DOE/PNL	4.3 \pm 1.4	6.7 \pm 1.9	0.15 \pm 0.05	NA	14,400 \pm 400
	Washington	6 \pm 2	6 \pm 1	<1	3.9 \pm 0.3	14,500 \pm 440
	Oregon	7.5 \pm 2.6	10.2 \pm 1.2	<1	5.0	14,500 \pm 950
			State of Washington	State of of Oregon	DOE/ PNL	EPA (Known Value)
EPA Quality Assurance Samples	Tritium		3,500 \pm 258	NA	3,670 \pm 278	3,560
	Gross Alpha		36.5 \pm 2.5	35.8 \pm 1.9	55.8 \pm 2.7	32
	Gross Beta		83.0 \pm 2.5	93.8 \pm 1.5	59.1 \pm 1.6	72
	Gamma Scan					
	⁶⁰ Co		18 \pm 3	14.0 \pm 1.9	15.7 \pm 1.3	15
	¹³⁴ Cs		18 \pm 3	11.7 \pm 1.7	13.5 \pm 1.1	15
	¹³⁷ Cs		14 \pm 3	11.6 \pm 0.7	13.2 \pm 1.2	12
	Uranium, Total					
	Bishop Method		6 \pm 1	NA	NA	7
	Alpha Spec Method		5.8 \pm 0.8			

ND - Nondetectable.

NA - Not analyzed.

TABLE A.59. Results of Duplicate Samples Analyzed for Tritium, 1985

Well Number	Sample Date	Record Sample, pCi/l	Duplicate Sample, pCi/l	Difference, pCi/l	Relative ^(a) Difference	Coefficient ^(b) of Variation
699 2-3	8-15-85	120,000	110,000	10,000	8.7	6.2
199 B4-1	2-15-85	59,000	60,000	1,000	1.7	1.2
699 49-57	6-15-85	5,500 ± 510	5,600 ± 510	100	1.8	1.3
199 B4-3	2-15-85	4,900 ± 580	4,800 ± 580	100	2.1	1.5
699 S11-E12AP	9-10-85	1,800 ± 450	1,700 ± 450	100	5.7	4.0
699 S11-E12AP	5-23-85	910 ± 470	540 ± 460	370	51.0	36.1
699 45-69A	5-28-85	610 ± 470	440 ± 470	170	32.4	22.9
199 H4-3	7-13-85	250 ± 470	120 ± 470	130	70.3	49.7
699 S11-312A0	9-10-85	290 ± 440	-290 ± 430	580	(c)	(c)
699 63-90	3-25-85	16 ± 600	-170 ± 570	186	241.6	170.8
699 81-580	3-22-85	-490 ± 590	-250 ± 590	240	64.9	45.9
699 S11-E12A0	5-23-85	-440 ± 450	-380 ± 450	60	14.6	10.4

(a) Calculated as 100 times the absolute difference of the duplicates divided by their mean.

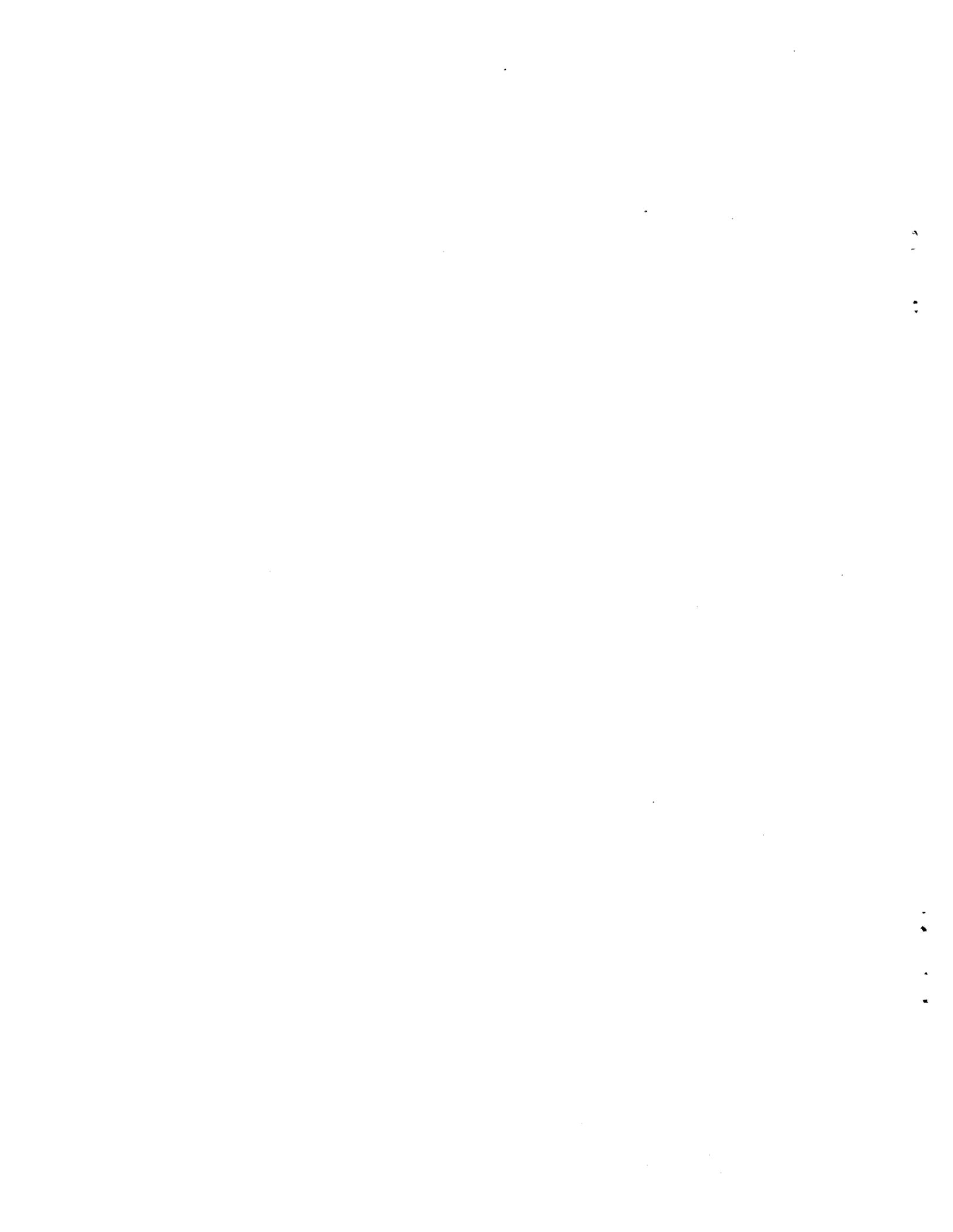
(b) Calculated as 100 times the standard deviation of the duplicates divided by their mean.

(c) Divisor was zero.

APPENDIX B

REFERENCE GUIDE

- **Glossary**
- **Acronyms and Abbreviations**
- **Miscellaneous Abbreviations**
- **Conversion Table**
- **Table of Unit Prefixes**



APPENDIX B REFERENCE GUIDE

Appendix B provides the reader with a reference guide that includes a glossary, an explanation of acronyms and abbreviations, and a conversion table that enables better comprehension of the data presented in this report.

GLOSSARY

Activation Product - A material made radioactive by exposure to neutron radiation in a nuclear reactor.

Airlift - A means of collecting water samples from wells by pumping air down a tube placed inside the well and then forcing water up the annular space between the tube and a larger pipe or the well casing.

Aquifer - An underground formation through which ground water can easily percolate.

Background Radiation - The radioactivity in the environment, including cosmic rays from space and radiation that exists elsewhere - in the air, in the earth and in manmade materials that surround us. In the United States, most people receive 100 to 250 millirems (mrem) of background radiation per year.

Bailer - A cylindrical steel container attached to a wire line that is lowered down a well to just below the water surface, filled with water, and then brought to the surface.

Bankstorage - A hydrologic term that describes water that is absorbed and retained in permeable material adjacent to a stream during periods of high water, and then returned as effluent seepage or flow during periods of low water.

Confined Aquifer - An aquifer that is bounded above and below by impermeable layers of rock. Ground water in the confined aquifer is under pressure.

Controlled Area - An area that has controlled access to protect individuals from exposure to radiation or radioactive materials.

Cosmic Radiation - High-energy subatomic particles from outer space, which bombard the earth's atmosphere. Cosmic radiation is part of natural background radiation.

Counting Error - The variability caused by the inherent random nature of radioactive disintegration and the detection process.

Curie (Ci) - A unit of radioactivity equal to 37 billion (3.7×10^{10}) nuclear transformations per second.

Detection Level - The minimum concentration of a substance that can be measured with a 99% confidence that the analytical concentration is greater than zero.

Derived Concentration Guide (DCG) - Concentrations of radionuclides in air and water that could not be continuously consumed or inhaled and could not exceed an effective dose equivalent of 100 mrem/yr.

Dosimeter - A device, such as a TLD, that can be worn and used to measure the external radiation dosage a person receives over a period of time.

Effluent - A liquid or gaseous stream that flows or is discharged from a source; in environmental monitoring, a liquid or gas discharged as waste, such as contaminated water or air from a factory.

Effluent Monitoring - Sampling or measuring specific liquid or gaseous effluent streams for the presence of pollutants.

Exposure - Subjecting a target (usually living tissue) to radiation.

Fallout - Radioactive materials mixed into the earth's atmosphere following a nuclear explosion. Fallout constantly falls onto the earth.

"Fence-post" Dose Rate - The dose rate measured or calculated at the point of highest exposure at the boundary of the Hanford Site.

Fission - The splitting or breaking apart of a heavy atom into two new atoms. When a heavy atom, such as uranium, is split, large amounts of energy and one or more neutrons are released.

Fission Products - The atoms formed when uranium is split in a nuclear reactor. Fission products are usually radioactive.

Fuel Cladding - The metal skin used to retain the fuel pellets and separate the fuel and the coolant in a nuclear reactor.

Glaciofluvial Sediments - A sedimentary deposit consisting of material transported by, suspended in, or laid down by the meltwater streams flowing from wasting glacier ice.

Ground Water - Water that is in the pore space in soil and geologic units.

Half-life - The length of time in which any radioactive substance will lose one-half of its radioactivity. The half-life may vary in length from a fraction of a second to thousands of years.

Hazardous Materials - Any liquid, solid, gas, or sludge that exhibits characteristics such as ignitability, corrosivity, reactivity, or extraction procedure toxicity.

Ion Exchange - The reversible exchange of ions contained in a crystal for different ions in solution without destroying the crystal structure or disturbing the electrical neutrality.

Isotope - Different forms of the same chemical element that are distinguished by having different numbers of neutrons in the nucleus. A single element may have many isotopes. For example, the three isotopes of hydrogen are protium, deuterium, and tritium.

Long-lived Isotope - A radionuclide that decays at such a slow rate that a quantity of it will exist for an extended period (half-life is greater than 3 years).

Short-lived Isotope - A radionuclide that decays so rapidly that a given quantity is transformed almost completely into decay products within a short period (half-life of a day or less).

Lacustrine Sediments - A sedimentary deposit consisting of material pertaining to, produced by, or formed in a lake or lakes.

Lithology - The description of the physical characteristics of rocks that make up geologic units.

This may include such characteristics as color, mineralogic composition, and grain size.

Man-rem - See "Collective Dose Equivalent" under "Radiation Dose".

Mean - The average value of a series of measurements.

Mechanical Dispersion - A form of hydrodynamic dispersion whereby solutes are spread or mixed as they are transported by ground water as it moves through heterogeneous sediments.

Median - The middle value in a set of results arranged in order from lowest to highest.

Millirem (mrem) - A unit of radiation dose that is equal to one one-thousandth of a rem. An individual member of the public can receive up to 500 millirems per year according to DOE standards. This limit does not include radiation received for medical treatment or the 100 to 250 millirems (mrem) that people receive annually from background radiation.

Minimum Detectable Concentration - The smallest amount or concentration of a radioactive or nonradioactive element that can be reliably detected in a sample.

Molecular Diffusion - A form of hydrodynamic dispersion where concentrations of dissolved substances move from a region of higher to one of lower concentration. Diffusion is only important at very low ground-water velocities.

Offsite Locations - Sampling and measurement locations outside the Hanford Site boundary.

Onsite Locations - Sampling and measurement locations within the Hanford Site boundary.

Outfall - The end of a drain or pipe that carries waste water or other effluents into a ditch, pond, or river.

Plume - The distribution of a pollutant in air or water after being released from a source.

Plutonium - A heavy, radioactive, manmade metallic element. Its most important isotope is fissionable ^{239}Pu , which is produced by the irradiation of ^{238}U . Routine analysis cannot distinguish between the ^{239}Pu and ^{240}Pu isotopes, hence, the term $^{239, 240}\text{Pu}$.

Primary Cooling Loop - A closed system of piping that provides cooling water to the reactor. Heat energy is transferred to the secondary loop through a heat exchanger.

Radiation - Refers to the process of emitting energy in the form of rays or particles that are thrown off by disintegrating atoms; may consist of alpha, beta, or gamma radiation.

Alpha Radiation - The least penetrating type of radiation. Alpha radiation can be stopped by a sheet of paper or outer dead layer of skin.

Beta Radiation - Emitted from a nucleus during fission. Beta radiation can be stopped by an inch of wood or a thin sheet of aluminum.

External Radiation - Radiation originating from a source outside the body, such as cosmic radiation or natural and manmade radionuclides.

Gamma Radiation - A form of electromagnetic, high-energy radiation emitted from a nucleus. Gamma rays are essentially the same as x-rays and require heavy shieldings, such as concrete or steel, to be stopped.

Internal Radiation - Radiation originating from a source within the body as a result of the inhalation, ingestion, or implantation of natural or manmade radionuclides in body tissues.

Radiation Dose - For the purpose of this report, radiation doses are defined as follows:

Absorbed Dose - The amount of energy deposited by radiation in a given amount of material. Absorbed dose is measured in units of "rads" (see dose equivalent).

Collective Dose Equivalent - The sum of the dose equivalents for individuals comprising a defined population. The per capita dose equivalent is the quotient of the collective dose equivalent and the population size.

Committed Dose Equivalent - The total dose equivalent accumulated in an organ or tissue in the 50 years following a single intake of radioactive materials into the body.

Cumulative Dose Equivalent - The total dose one could receive in a period of 50 years following release of the radionuclides to the environment, including the dose that could incur as a result of residual radionuclides remaining in the environment beyond the year of release.

Dose Equivalent - The product of the absorbed dose, the quality factor, and any other modifying factors. The dose equivalent is a quantity for comparing the biological effectiveness of different kinds of radiation on a common scale. The unit of dose equivalent is the rem. A millirem (mrem) is one one-thousandth of a rem.

Effective Dose Equivalent - An estimate of the total risk of potential health effects from radiation exposure. It is the sum of the individual organ committed dose equivalents (50 year) multiplied by weighting factors that represent the proportion of the total random risk that each organ would receive from uniform irradiation of the whole body.

Radioactivity - A property possessed by some elements, such as uranium, whereby alpha, beta, or gamma rays are spontaneously emitted.

Radioisotope - A radioactive isotope of a specified element. Carbon-14 is a radioisotope of carbon. Tritium is a radioisotope of hydrogen.

Radionuclide - A radioactive nuclide. There are several hundred known nuclides, both man-made and naturally occurring; nuclides are characterized by the number of neutrons and protons in an atom's nucleus.

REM - An acronym for Roentgen Equivalent Man; a unit of radiation exposure that indicates the potential impact on human cells.

Spent Fuel - Nuclear fuel that has been exposed in a nuclear reactor; this fuel contains uranium, activation products, fission products, and plutonium. Spent fuel is processed in the PUREX plant.

Standard Deviation - An indication of the dispersion of a set of results around their average.

Standard Error of the Mean - An indication of the dispersion of an estimated mean from the average of other estimates of the same mean.

Thermoluminescent Dosimeters (TLD) - A material that, after being exposed to radiation, luminesces upon being heated. The amount of light emitted is proportional to the amount of radiation (dose) to which it is exposed.

Unconfined Aquifer - Contains ground water that is not confined by or under pressure from relatively impermeable rocks. The pressure in the unconfined aquifer is equal to that of the atmosphere. At Hanford, the unconfined aquifer is the uppermost aquifer and is most susceptible to contamination from Site operations.

Uncontrolled Area - An area on or near a nuclear facility that is not restricted to public access.

Vadose Zone - (also called zone of aeration, unsaturated zone) - A subsurface zone containing water that is under pressure less than that of the atmosphere, including water held by capillarity. This zone is limited above by the land surface and below by the water table.

Water Table - A water surface that represents the filling of pores and fractures in soils and geologic units.

Whole-Body Dose - A radiation dose commitment that involves exposure of the entire body.

Windrose - A star-shaped diagram showing how often winds of various speeds blow from different directions, usually based on yearly averages.

\bar{X}/Q (Chi over Que) - A dispersion factor calculated using an atmospheric dispersion model from average annual meteorological data. It is used to estimate the average annual air concentration from the total airborne release of each radionuclide. The resulting estimates of average annual air concentrations at specific locations from the source are used to calculate potential doses.

ACRONYMS AND ABBREVIATIONS

ALARA	as low as reasonably achievable	MDC	minimum detectable concentrations
ALE	Arid Lands Ecology (Reserve)	MI	maximum individual
α	alpha	NCRP	National Council on Radiation Protection
APHA	American Public Health Association	NERP	National Environmental Research Park
β	beta	NPDES	National Pollutant Discharge Elimination System
BMI	Battelle Memorial Institute	NTU	nephelometric turbidity units
BOD	biological oxygen demand	PNL	Pacific Northwest Laboratory
BWIP	Basalt Waste Isolation Project	PSD	Prevention of Significant Deterioration
CFS	cubic feet per second	PUREX Plant	Plutonium and Uranium Extraction Plant
DOE	Department of Energy	σ	standard deviation
DCG	Derived Concentration Guide	RCRA	Resource Conservation and Recovery Act
DL	detection level	TLD	thermoluminescent dosimeter
DWS	Drinking Water Standards	TRU	transuranic
EML	Environmental Measurements Laboratory	UNC	United Nuclear Industries
EPA	Environmental Protection Agency	UO	U ₃ Plant Uranium Oxide Plant
ERDA	Energy Research and Development Administration	UO	Unusual Occurrence
FFTF	Fast Flux Test Facility	UST	United States Testing Company, Inc.
FRC	Federal Radiation Council	USGS	U.S. Geological Survey
γ	gamma	VCP	vitriified clay pipe
HEDL	Hanford Engineering Development Laboratory	WHC	Westinghouse Hanford Company
HEHF	Hanford Environmental Health Foundation	WPPSS	Washington Public Power Supply System
HTO	titrated water vapor		
ICRP	International Commission on Radiological Protection		

MISCELLANEOUS ABBREVIATIONS

Radioactivity	
Symbol	Name
Ci	curie
mCi	millicurie (10^{-3} Ci)
μ Ci	microcurie (10^{-6} Ci)
nCi	nanocurie (10^{-9} Ci)
pCi	picocurie (10^{-12} Ci)
fCi	femtocurie (10^{-15} Ci)
aCi	attocurie (10^{-18} Ci)

Length	
Symbol	Name
ft	feet
km	kilometer (10^3 m)
m	meter (m)
cm	centimeter (10^{-2} m)
mm	millimeter (10^{-3} m)
μ m	micrometer (10^{-6} m)

Area	
Symbol	Name
ha	hectare ($10,000$ m ²)

Volume	
Symbol	Name
cm ³	cubic centimeter
l	liter
ml	millileter (10^{-3} l)
m ³	cubic meter
ppm	parts per million
ppb	parts per billion

Mass	
Symbol	Name
g	gram
kg	kilogram (10^3 g)
μ g	microgram (10^{-6} g)
ng	nanogram (10^{-9} g)
MT	metric ton (or tonne: 10^3 kg)

Time	
Symbol	Name
yr	year
d	day
h	hour
m	minute
s	second

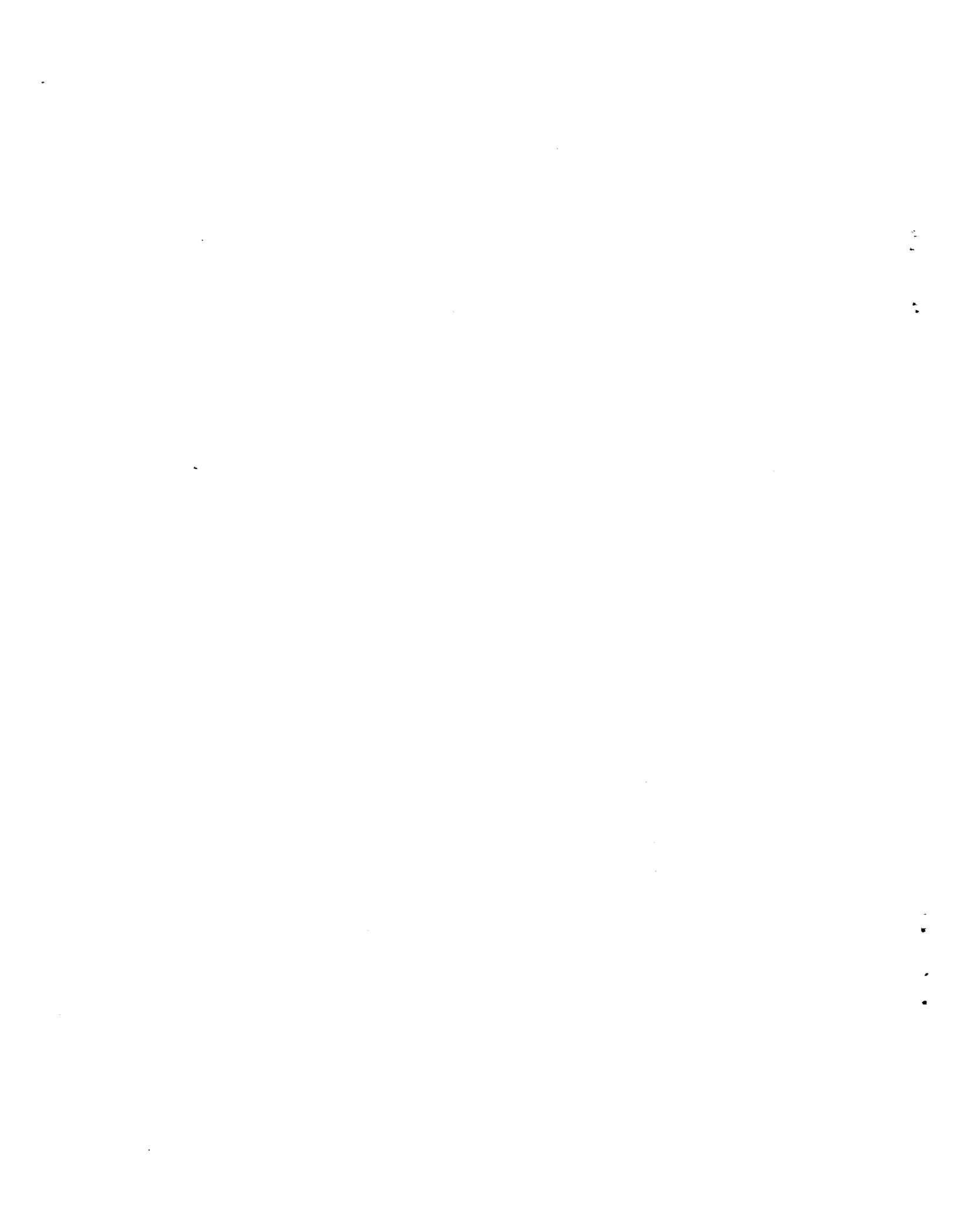
CONVERSION TABLE

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>	<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
in.	2.54	cm	cm	0.394	in.
ft	0.305	m	m	3.28	ft
mi	1.61	km	km	0.621	mi
lb	0.454	kg	kg	2.205	lb
liq qt	0.946	ℓ	ℓ	1.057	liq qt
ft ²	0.093	m ²	m ²	10.76	ft ²
ha	2.47	acres	acres	0.405	ha
mi ²	2.59	km ²	km ²	0.386	mi ²
ft ³	0.028	m ³	m ³	35.7	ft ³
mCi/mi ²	0.386	mCi/km ²	mCi/km ²	2.57	mCi/mi ²
dpm	0.450	pCi	pCi	2.22	dpm
nCi	1000	pCi	pCi	0.001	nCi
pCi/ℓ	10 ⁻⁹	mCi/mℓ	mCi/mℓ	10 ⁹	pCi/ℓ
pCi/m ³	10 ⁻¹²	Ci/m ³	Ci/m ³	10 ¹²	pCi/m ³
pCi/cm ³	10 ⁻¹²	mCi/cm ³	mCi/cm ³	10 ¹²	pCi/cm ³
mCi/km ²	1.0	nCi/m ²	nCi/m ²	1.0	mCi/km ²
bequerel	2.7 x 10 ⁻¹¹	curie	curie	3.7 x 10 ¹⁰	bequerel
sievert	100	rem	rem	0.01	sievert
ppb	0.001	ppm	ppm	1000	ppb
ppm	1.0	mg/ℓ	mg/ℓ	1.0	ppm

TABLE OF UNIT PREFIXES

<u>Factor</u>	<u>Prefix</u>	<u>Symbol</u>
10 ⁶	mega	M
10 ³	kilo	k
10 ²	hecto	h
10 ¹	deka	da
10 ⁻¹	deci	d
10 ⁻²	centi	c
10 ⁻³	milli	m
10 ⁻⁶	micro	μ
10 ⁻⁹	nano	n
10 ⁻¹²	pico	p
10 ⁻¹⁵	femto	f
10 ⁻¹⁸	atto	a

APPENDIX C
APPLICABLE STANDARDS AND PERMITS



APPENDIX C

APPLICABLE STANDARDS AND PERMITS

Operations at the Hanford Site must conform to a variety of federal and state standards and permits designed to ensure the radiological, chemical, biological, and physical quality of the environment for either aesthetic or public health considerations. Standards and permits applicable to Hanford operations in 1985 are listed in the following tables. The State of Washington has promulgated water-quality standards for the Columbia River (WDOE 1982). Of interest to Hanford operations is the designation of the Hanford reach of the Columbia River as Class A, Excellent. This designation requires that the water be usable for substantially all needs including drinking water, recreation, and wildlife. Class A water standards are summarized in Table C.1. Drinking water standards promulgated by EPA (1976) are summarized in Table C.2. Environmental radiation protection standards are published in DOE Order 5480.1A Environmental Protection, Safety, and Health Protection Program for DOE Operations (USDOE 1981a). These standards (shown in Table C.3) are based

Federal Radiation Council (FRC) and other scientific groups such as the International Commission on Radiological Protection (ICRP), and the National Commission on Radiation Protection and Measurements (NCRP). In September 1985, DOE issued a revision to this order that incorporates a system for evaluating and controlling radiation exposures to members of the public in uncontrolled areas. The revised standards are shown in Table C.4. These standards govern allowable exposures to ionizing radiation from DOE operations; DOE has also prepared draft tables of Derived Concentration Guides that reflect the new standards (Table C.5).

Permits required for regulated releases to water and air have been issued by the EPA under the National Pollution Discharge Elimination System of the Clean Water Acts and the Prevention of Significant Deterioration requirements of the Clean Air Act. Permits for collecting wildlife for environmental sampling are issued by the Washington State Department of Game and the U.S. Fish and Wildlife Service. Current permits are listed in Table C.6.

TABLE C.1. Washington State Water Quality Standards for the Hanford Reach of the Columbia River

Parameter	Permissible Levels
Fecal coliform organism	1) ≤ 100 organisms/100 ml (median) 2) $\leq 10\%$ of samples may exceed 200 organisms/100 ml
Dissolved oxygen	> 8 mg/l
Temperature	1) $\leq 20^\circ\text{C}$ (68°F) due to human activities 2) When natural conditions exceed 20°C , no temperature increase of greater than 0.3°C allowed. 3) Increases not to exceed $34/(T - 9)$, where T = highest existing temperature in $^\circ\text{C}$ outside of dilution zone
pH	1) 6.5 to 8.5 range 2) < 0.5 unit induced variation
Turbidity	≤ 5 NTU ^(a) over background turbidity
Toxic, radioactive, or deleterious materials	Concentrations shall be below those of public health significance, or which cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.
Aesthetic value	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch or taste.

(a) NTU = Nephelometric Turbidity Units—Standard Candle.

Copies of these regulations may be obtained from the following organizations:

State of Washington,
Department of Ecology
Olympia, WA 98504

U.S. Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, WA 98101

U.S. Department of Energy
Richland Operations Office
Richland, WA 99352

TABLE C.2. Drinking Water Standards: Environmental Protection Agency, National Interim Primary Drink Water Regulations and State of Washington, Rules and Regulations of the State Board of Health Regarding Public Water systems

Contaminant	Limit
Gross alpha (excluding uranium)	15 pCi/ℓ
Combined radium-226 and radium-228	5 pCi/ ℓ
Radium-226 (State of Washington only)	3 pCi/ ℓ
Gross beta and gamma radioactivity from man made radionuclides	Annual average concentration shall not from manmade radionuclides produce an annual dose equivalent to the total body or any internal organ greater than 4 mrem/yr. If two or more radionuclides are present, the sum of their annual dose equivalent shall not exceed 4 mrem/yr. Compliance may be assumed if annual average concentrations for gross beta activity, tritium, and strontium-90 are less than 50 pCi/ℓ , 20,000 pCi/ℓ and 8 pCi/ℓ, respectively. It should be noted that these "screening levels" are conservatively calculated and not directly equivalent to an annual dose of 4 mrem.

The following table provides the annual average concentrations, with respect to the Columbia River, for selected manmade radionuclides of interest. These radionuclides are assumed to yield an annual dose of 4 mrem to the indicated organ, taken from the National Interim Primary Drinking Water Regulations, Table IV-2A, (EPA1976).

Radionuclide	Critical Organ	Concentration, pCi/
Tritium	Whole Body	20,000
⁶⁰ Co	GI (LLI)	100
⁸⁹ Sr	Bone	20
⁸⁹ Sr	Bone Marrow	80
⁹⁰ Sr	Bone Barrow	8
⁹⁵ Zr	GI (LLI)	200
⁹⁵ Nb	GI (LLI)	300
¹⁰⁶ Ru	GI (LLI)	30
¹²⁹ I	Thyroid	1
¹³¹ I	Thyroid	3
¹³⁷ Cs	Whole Body	200

**TABLE C.3. DOE Radiation Protection Standards for External and Internal Exposure
Prior to September 1, 1985**

Type of Exposure	Annual Dose Equivalent or Dose Commitment, millirem ^(a)	
	Based on Dose to Individuals at Points of Maximum Probable Exposure	Based on an Average Dose to a Suitable Sample of the Exposed Population ^(b)
Whole body, gonads, or bone marrow	500	170
Other Organs	1500	500

- (a) In keeping with DOE policy on lowest practicable exposure, exposures to the public shall be limited to as small a fraction of the respective annual dose limits as is reasonably achievable.
- (b) See paragraph 5.4, Federal Radiation Council Report No. 1, for discussion on concept of suitable sample of exposed population.

Table C.4. Radiation Standards for Protection of the Public in the Vicinity of DOE Facilities

DOSE LIMITS

ALL PATHWAYS

The effective dose equivalent for any member of the public from all routine DOE operations^(a) (natural background and medical exposures excluded) shall not exceed the values given below:

	Effective Dose Equivalent ^(b)	
	<u>mrem/yr</u>	<u>(mSv/yr)</u>
Occasional Annual Exposures	500	(5)
Prolonged Period of Exposure ^(c)	100	(1)

No individual organ shall receive a committed effective dose equivalent of 5rem/yr (500 mSv/yr) or greater.

AIR PATHWAYS ONLY (Limits of 40 CFR 61, Subpart H)

	Dose Equivalent	
	<u>mrem/yr</u>	<u>(mSv/yr)</u>
Whole-Body Dose	25	(0.25)
Any Organ	75	(0.75)

^(a) Routine DOE operations implies normal planned operations and does not include actual or potential accidental or un-planned releases.

^(b) Effective dose equivalent is expressed in rem (or millirem) with the corresponding value in Sievert (or milliSievert) in parentheses.

^(c) For the purposes of these standards, a prolonged exposure will be one that lasts, or is predicted to last, longer than 5 years.

TABLE C.5 Proposed Derived Concentration Guides (DCG)^(a)

Radionuclide	Water pCi/ℓ (10 ⁻⁹ μCi/mℓ)	Air pCi/m ³ (10 ⁻¹² μCi/mℓ)
³ H	2,000,000	200,000
¹⁴ C(CO ₂)	NS ^(b)	500,000
⁵¹ Cr	1,000,000	60,000
⁵⁴ Mn	50,000	2,000
⁶⁰ Co	5,000	80
⁶⁵ Zn	9,000	600
⁸⁹ Sr	20,000	300
⁹⁰ Sr	1,000	9
¹⁰⁶ Ru	6,000	30
¹²⁹ I	500	70
¹³¹ I	3,000	400
¹³⁷ Cs	3,000	400
¹⁴⁴ Ce	7,000	30
²³⁸ Pu	400	0.03
²³⁹ Pu	300	0.02

^(a) Concentrations of Radionuclides in Water and Air that Could be Continuously Consumed or Inhaled, Respectively, and Not Exceed an Effective Dose Equivalent of 100 mrem/yr

^(b) NS indicates no standard

TABLE C.6 Environmental Permits

NPDES Permits

NPDES Permit No. WA-000374-3, issued to DOE Richland Operations Office by Region 10 of the EPA, covers nonradioactive discharges to the Columbia River from eight outfalls.

PSD Permits

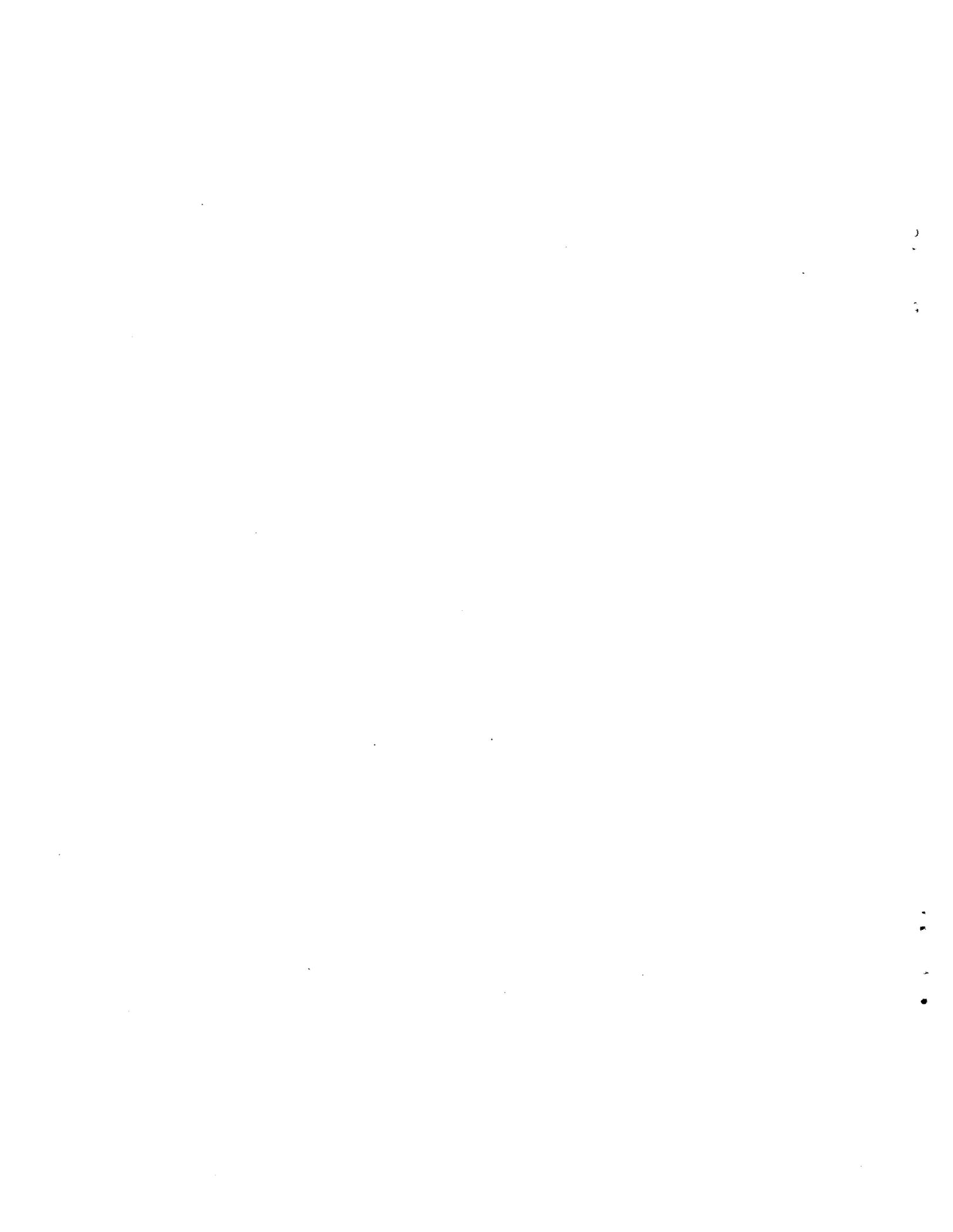
PSD Permit No. PSD-X80-14, issued to the DOE Richland Operations Office by Region 10 of the EPA, covers emission of NO_x to the atmosphere from the PUREX Plant and the Uranium Oxide Plant. No expiration date.

Wildlife Sampling Permits

Scientific Study or Collection Permit No. 011 WM-008-84, issued to Pacific Northwest Laboratory, by Washington State Department of Game, covers the collection of wildlife, including fish, for environmental monitoring purposes. Renewed annually.

Federal Fish and Wildlife Permit No. 671877, issued to Pacific Northwest Laboratory by U. S. Fish and Wildlife.

APPENDIX D
ANALYTICAL PROCEDURES AND
SAMPLING SUMMARY



APPENDIX D

ANALYTICAL PROCEDURES AND SAMPLING SUMMARY

SURFACE MONITORING – RADIOLOGICAL SAMPLES

All routine environmental surveillance samples are analyzed according to detailed, written analytical procedures that are described in general terms below. U.S. Testing's analytical procedures are documented in UST-RD-PM-9-80, January 1986. Minimum detectable concentrations for the various medium/analysis combinations and other analytical information are shown in Table D.1.

Air Samples

Alpha-, Beta-, and Gamma-Emitting Radionuclides are measured by a direct count from the glass fiber filter. Alpha radiation is counted on a low-background gas-flow proportional counter, beta on a gas-flow proportional counter, and gamma on a Ge(Li) detector with a multichannel pulse-height analyzer.

Strontium-90 is leached from the glass fiber filters with nitric acid, scavenged with barium chromate, precipitated as a carbonate, transferred to a stainless steel planchet, and counted with a low-background gas-flow proportional counter.

Uranium is leached from the glass fiber filters with nitric acid and extracted as tetrapropyl ammonium uranyl trinitrate, then extracted back into water. A portion of the water extract is fused with sodium and lithium fluoride and analyzed with a fluorometer.

Plutonium is leached from the glass fiber filters with nitric acid and passed through an anion-exchange resin. The plutonium on the resin column is eluted with nitric and hydrofluoric acids, electrodeposited on a stainless steel disk, and then counted with an alpha spectrometer.

Tritium in air as HTO is measured in water vapor collected in silica gel. The water vapor is removed from the gel by heat and vacuum action. It is then collected in a freeze trap. The tritium content of the water vapor is determined with a liquid scintillation spectrometer.

Iodine-131 is collected on activated charcoal and then counted on a Ge(Li) detector with a multichannel pulse-height analyzer.

Carbon-14 is collected as carbon dioxide gas using soda lime. The carbon dioxide is released from the soda-lime sample with acid and injected into a "Benzene Synthesizer" instrument. The carbon dioxide is quantitatively converted to benzene through a series of catalytic reactions. The benzene product is mixed with scintillator solution and counted on a low-temperature liquid scintillation counter.

Krypton-85 is removed from the air sample and purified using a specially constructed cryogenic chromatography instrument. The sample is passed through a series of cold traps. The purified krypton is then mixed with scintillation solution and counted on a low-temperature liquid scintillation counter.

Water Samples

Alpha-Emitting Radionuclides (Uranium and Plutonium) are extracted into ether from strong nitric acid. The ether phase is evaporated. The residue is plated on a stainless steel planchet and counted with a low-background gas-flow proportional counter.

Beta-Emitting Radionuclides are counted directly from dried residue using a gas-flow proportional counter.

Gamma-Emitting Radionuclides are counted directly from 500 m of sample concentration using a Ge(Li) detector with a multichannel pulse-height analyzer.

Strontium-90 in large-volume water samples is precipitated with fuming nitric acid, scavenged with barium chromate, precipitated as a carbonate, transferred to a stainless steel planchet, and counted with a low-background gas-flow proportional counter. After 15 days, the yttrium-90

TABLE D.1. Radiological Monitoring Sampling Summary

Medium Sampled	Type of Analysis	Frequency of Analysis	Approximate Sample Size	Count Time	Minimum Detectable Concentration (MDC)	Analysis Aliquot Size	Offsite/Onsite
Air	Gross beta	Biweekly	850 m ³	40 min	0.003 pCi/m ³	850 m ³	Offsite/onsite
	Gross alpha	Biweekly	850 m ³	50 min	0.001 pCi/m ³	850 m ³	Offsite/onsite
	¹³¹ I	Biweekly	850 m ³	100 min	0.01 pCi/m ³	850 m ³	Offsite/onsite
	HTO(a)	Monthly	10 m ³	150 min	0.3 pCi/mL	5.0 mL	Offsite/onsite
	¹⁴ C(b)	Bimonthly	40 m ³	150 min	1.0 pCi/m ³	10 g of carbon	Offsite/onsite
	⁸⁵ Kr(c)	Monthly	0.3 m ³	150 min	2.0 pCi/m ³	0.3 m ³	Offsite/onsite
	Gamma scan (¹³⁷ Cs)	Monthly comp.	1,700 m ³ per station	50 min	0.01 pCi/m ³	1,700-7,700 m ³	Offsite/onsite
	⁸⁹ Sr	Quarterly comp.	5,100 m ³ per station	100 min	0.01 pCi/m ³	2,000-10,000 m ³	Offsite/onsite
	⁹⁰ Sr	Quarterly comp.	5,100 m ³ per station	100 min	0.001 pCi/m ³	2,000-10,000 m ³	Offsite/onsite
	²³⁸ Pu	Quarterly comp.	5,100 m ³ per station	1,000 min	1 x 10 ⁻⁴ pCi/m ³	2,000-10,000 m ³	Offsite/onsite
	^{239,240} Pu	Quarterly comp.	5,100 m ³ per station	1,000 min	0.09 pCi/m ³	2,000-10,000 m ³	Offsite/onsite
	U(d)	Quarterly comp.	5,100 m ³ per station	NA	0.01 pCi/m ³	2,000-10,000 m ³	Offsite/onsite
	¹²⁹ I(e)	Quarterly	850 m ³ per station	NA	1 x 10 ⁻⁵ pCi/m ³	850 m ³	Offsite/onsite
Ground water	Gross Alpha	Q	1 L	100 min	4 pCi/L	100 mL	Onsite
	Gross Beta	Q	1 L	30 min	16 pCi/L	100 mL	Onsite
	Gamma Scan	M,Q,SA,A	1 L	30 min	30 pCi/L	500 mL	Onsite
	³ H	M,Q,SA	1 L	100 min	300 pCi/L	4 mL	Onsite
	Plutonium (gross)	Q	1 L	100 min	0.10 pCi/L	1,000 mL	Onsite
	²³⁸ Pu	Q	1 L	1,000 min	0.10 pCi/L	1,000 mL	Onsite
	⁹⁰ Sr	Q,SA	1 L	30 min	0.6 pCi/L	0.6 mL	Onsite
	⁶⁰ Co	M,Q,SA,A	1 L	30 min	20 pCi/L	20 mL	Onsite
	Uranium (natural)	M,Q	1 L	100 min	0.5 pCi/L	0.5 mL	Onsite
	¹³⁷ Cs	M,Q,SA,A	1 L	30 min	30 pCi/L	30 mL	Onsite
	¹²⁹ I	A	4 L	NA	1 x 10 ⁻⁶ pCi/L	1-4 mL	Onsite
River water	Gross Beta	Monthly comp.	40 L	20 min	4.0 pCi/L	500 mL	Offsite
	Gross Alpha	Monthly comp.	40 L	50 min	4.0 pCi/L	500 mL	Offsite
	³ H (enriched)	Monthly comp.	40 L	450 min	50 pCi/L	150 mL	Offsite

TABLE D.1. (contd)

Medium Sampled	Type of Analysis	Frequency of Analysis	Approximate Sample Size	Count Time	Minimum Detectable Concentration (MDC)	Analysis Aliquot Size	Offsite/Onsite
River water (contd)	^{89}Sr	Monthly comp.	40 ℓ	100 min	0.6 pCi/ ℓ	10 ℓ	Offsite
	^{90}Sr	Monthly comp.	40 ℓ	100 min	0.06 pCi/ ℓ	4-10 ℓ	Offsite
	U	Monthly comp.	40 ℓ	NA	0.5 pCi/ ℓ	100-1,000 mL	Offsite
	Gamma Scan (^{137}Cs)	Monthly comp.	40 ℓ	50 min	8.0 pCi/ ℓ	4-10 ℓ	Offsite
River water (Resin & particulate)	Gamma scan (^{137}Cs)	Biweekly	1,000 ℓ	1,000 min	0.01 pCi/ ℓ	250-500 ℓ	Offsite/onsite
(Resin & particulate)	^{90}Sr	Quarterly comp.	6,000 ℓ	100 min	0.01 pCi/ ℓ	1,500-3,000 ℓ	Offsite/onsite
(Resin & particulate)	Pu	Quarterly comp.	6,000 ℓ	24-72 h	1×10^{-4} pCi/ ℓ	1,500-3,000 ℓ	Offsite/onsite
(Resin)	^{129}I	Quarterly comp.	6,000 ℓ	NA	1×10^{-6} pCi/ ℓ	1,500-3,000 ℓ	Offsite/onsite
Surface water	Gross beta	Quarterly	10 ℓ	20 min	40 pCi/ ℓ	500 mL	Onsite
	Gross alpha	Quarterly	10 ℓ	50 min	4.0 pCi/ ℓ	500 mL	Onsite
	^3H	Quarterly	10 ℓ	150 min	300 pCi/ ℓ	5 mL	Onsite
	^{89}Sr	Quarterly	10 ℓ	100 min	0.06 pCi/ ℓ	4-10 ℓ	Onsite
	Gamma scan (^{137}Cs)	Quarterly	10 ℓ	50 min	8.0 pCi/ ℓ	4-10 ℓ	Onsite
Milk	$^{131}\text{I}(f)$	Biweekly	10 ℓ	100 min	0.5 pCi/ ℓ	4 ℓ	Offsite
	^{129}I	Semiannually	4 ℓ	NA	5×10^{-5} pCi/ ℓ	3-4 ℓ	Offsite
	Gamma scan (^{137}Cs)(f)	Biweekly	10 ℓ	1,000 min	10 pCi/ ℓ	450 ℓ	Offsite
	^3H	Monthly	10 ℓ	150 min	300 pCi/ ℓ	5 ℓ	Offsite
	^{89}Sr	Quarterly	10 ℓ	100 min	5.0 pCi/ ℓ	1 ℓ	Offsite
	^{90}Sr	Quarterly	10 ℓ	100 min	2.0 pCi/ ℓ	1 ℓ	Offsite
	^3H	Annually	2 kg	150 min	300 pCi/ ℓ	5 mL (water)	Offsite
Fruit	^{90}Sr	Annually	2 kg	200 min	0.005 pCi/g	100 g	Offsite
	Gamma scan (^{137}Cs)	Annually	2 kg	1,000 min	0.015 pCi/g	250-500 g	Offsite
	^{90}Sr	Annually	2 kg	200 min	0.005 pCi/g	100 g	Offsite
Crops and produce	Gamma scan (^{137}Cs)	Annually	2 kg	1,000 min	0.015 pCi/g	250-500 g	Offsite
	^{90}Sr	Annually	1 kg	100 min	0.005 pCi/g	100 g	Offsite
Beef	Gamma scan (^{137}Cs)	Annually	1 kg	1,000 min	0.015 pCi/g	250-500 g	Offsite
	^{90}Sr	Annually	1 kg	100 min	0.005 pCi/g	100 g	Offsite
Poultry	^{90}Sr	Semiannually	1 chicken (breast)	100 min	0.005 pCi/g	100 g	Offsite

TABLE D.1. (contd)

Medium Sampled	Type of Analysis	Frequency of Analysis	Approximate Sample Size	Count Time	Minimum Detectable Concentration (MDC)	Analysis Aliquot Size	Offsite/Onsite
Poultry (contd)	^{90}Sr	Semiannually	1 chicken (breast)	100 min	0.005 pCi/g	100 g	Offsite
	Gamma scan (^{137}Cs)	Semiannually	1 chicken (breast)	1,000 min	0.015 pCi/g	250-500 g	Offsite
Eggs	^{90}Sr	Semiannually	1 doz.	100 min	0.005 pCi/g	100 g	Offsite
	Gamma scan (^{137}Cs)	Semiannually	1 doz.	1,000 min	0.015 pCi/g	250-500 g	Offsite
Fish fillet	^{90}Sr	20 per year	1 fish fillet	100 min	0.005 pCi/g	100 g	Offsite/onsite
	Gamma scan (^{137}Cs)	20 per year	1 fish fillet	1,000 min	0.015 pCi/g	250-500 g	Offsite/onsite
Fish carcass	^{90}Sr	20 per year	1 fish carcass	100 min	0.005 pCi/g	100 g	Offsite/onsite
	Gamma scan (^{137}Cs)	20 per year	1 fish carcass	1,000 min	0.015 pCi/g	250-500 g	Offsite/onsite
Ducks	Gamma scan (^{137}Cs)	32 per year	1 duck (breast)	1,000 min	0.015 pCi/g	250-500 g	Onsite
Game birds	Gamma scan (^{137}Cs)	22 per year	1 bird (muscle)	1,000 min	0.015 pCi/g	250-500 g	Onsite
Deer	Gamma scan (^{137}Cs)	8 per year	1 kg (muscle)	1,000 min	0.015 pCi/g	250-500 g	Onsite
	Pu	8 per year	1 kg (liver)	1,000 min	6×10^{-4} pCi/g	100 g	Onsite
	^{90}Sr	2 per year	500 gm (bone)	100 min	0.005 pCi/g	100 g	Onsite
Rabbits	Gamma scan (^{137}Cs)	16 per year	500 gm (muscle)	1,000 min	0.015 pCi/g	250-500 g	Onsite
	Pu	16 per year	1 liver	1,000 min	6×10^{-4} pCi/g	100 g	Onsite
	^{90}Sr	16 per year	250 gm (bone)	100 min	0.005 pCi/g	100 g	Onsite
Soil	^{90}Sr	Annually	1.5 kg	100 min	0.005 pCi/g	100 g	Offsite/onsite
	U	Annually	1.5 kg	NA	0.01 pCi/g	10 g	Offsite/onsite
	Pu	Annually	1.5 kg	1,000 min	6×10^{-4} pCi/g	100 g	Offsite/onsite
	^{241}Am	Annually	1.5 kg	1,000 min	0.05 pCi/g	10 g	Offsite/onsite
	Gamma scan (^{137}Cs)	Annually	1.5 kg	100 min	0.03 pCi/g	500 g	Offsite/onsite
Native vegetation	^{90}Sr	Annually	1 kg	200 min	0.005 pCi/g	100 g	Offsite/onsite
	U	Annually	1 kg	NA	0.01 pCi/g	10 g	Offsite/onsite
	Pu	Annually	1 kg	1,000 min	6×10^{-4} pCi/g	100 g	Offsite/onsite
	Gamma scan (^{137}Cs)	Annually	1 kg	1,000 min	0.03 pCi/g	125 g	Offsite/onsite
Direct radiation exposure	Thermoluminescent dosimeter	Monthly	5 TLDs per dosimeter	NA	1.0 mR ^(g)	NA	Offsite/onsite

(a) Tritiated water vapor.

(b) Ten locations.

(c) Eight locations.

(d) Fifteen locations.

(e) Four locations.

(f) Four dairies are sampled monthly.

(g) Absolute sensitivity in the manner it is used is well below one millirem.

NA = Not applicable.

decay product is separated and then counted with a proportional counter.

Tritium samples can be counted directly with a liquid scintillation spectrometer, or the sample can be enriched by alkaline electrolysis and then counted with a liquid scintillation spectrometer.

Filter-Resin Samples are analyzed for gamma-emitting radionuclides using a Ge(Li) detector with a multichannel gamma-ray spectrometer. Aliquots of the samples are analyzed by neutron-activation analysis for ^{129}I and by chemical separation and alpha spectrometry for plutonium.

Milk

Gamma-Emitting Radionuclides in milk are counted directly using a Ge(Li) detector with a multichannel pulse-height analyzer.

Tritium water distilled from milk is counted directly with a liquid scintillation spectrometer.

Iodine-129 is separated from milk with an anion exchange resin, purified, and analyzed by the neutron-activation method.

Iodine-131 is removed from milk with an anion-exchange resin. The iodine is eluted with sodium hypochlorite, precipitated as palladium iodide, and beta-counted with a low-background gas-flow proportional counter.

Strontium-89,90 is removed from milk with a cation resin, eluted with sodium chloride, precipitated as a carbonate, and transferred to a stainless steel planchet for counting with a low-background gas-flow proportional counter.

Foodstuffs

Gamma-Emitting Radionuclides in foodstuffs are counted directly on a Ge(Li) detector with a multichannel pulse-height analyzer.

Tritium in water distilled from farm produce is counted directly with a liquid scintillation spectrometer.

Plutonium in foodstuffs is measured as it is in air-filter samples, after it is dried, ashed in a furnace, and treated with nitric acid.

Uranium in foodstuffs is measured as it is in water samples. However, the samples are dried, ashed in a furnace, and treated with nitric acid before the ether extraction step.

Strontium-90 is measured as it is in air samples, after being dried, ashed in a furnace, and treated with nitric acid, before the fuming nitric acid step.

Vegetation and Wildlife

Uranium, Plutonium, Strontium, and Gamma-Emitting Radionuclides are measured using the procedures described for foodstuffs.

Soil

Gamma-Emitting Radionuclides are counted on a Ge(Li) detector with a multichannel pulse-height analyzer, after the sample is placed into a marinelli beaker.

Plutonium and Strontium-89,90 are measured after the soil sample is dried, mixed thoroughly, leached with nitric acid and then precipitated as strontium oxalate. The sample is then precipitated as a carbonate, transferred to a planchet, and counted with a low-background gas-flow proportional counter. After the strontium has been removed from the sample, the plutonium is coprecipitated with calcium oxalate, dissolved, and loaded onto an ion-exchange resin column. The plutonium is eluted from the resin column with nitric and hydrofluoric acids, deposited on a stainless steel disk, and counted with an alpha spectrometer.

Uranium analysis is conducted after the sample is dried, ashed in a furnace, and leached with hot nitric acid. Uranium is extracted from the acid leachate as tetrapropyl ammonium uranyl trinitrate and then extracted back into water. A portion of the water extract is fused with sodium and lithium fluoride and analyzed with a fluorometer.

SURFACE MONITORING – NONRADIOLOGICAL SAMPLES

Surface Water Samples

Water samples collected to monitor water quality of the Columbia River are analyzed according to standard methods. Most onsite analyses make use of the most applicable methods recommended by the American Public Health Association in their publication *Standard Methods for the Examination of Water and Wastewater* (APHA 1975). Supplemental USGS samples are analyzed according to approved USGS standard methods.

GROUND-WATER MONITORING RADIOLOGICAL SAMPLES

All ground-water monitoring samples are analyzed according to detailed, written analytical procedures that are briefly described below. Minimum detectable concentrations for the various medium/analysis combinations and other analytical information are shown in Table D.1.

Total Alpha-Emitting Radionuclide measurements are made after the samples are evaporated and the salts and solids are dissolved in nitric acid and extracted from the acid by the diethyl ether method. Each sample is then evaporated, dried on a counting dish, and measured by the ZnS scintillation counter. The chemical yield is about 83%.

Total Beta-Emitting Radionuclides are measured after each sample has been evaporated onto a 1-inch counting dish. The residue is then counted with a gas-flow proportional counter.

Gamma-Emitting Radionuclide data are obtained by analyzing 500 ml samples in a 0.47-l polyethylene bottles. An NaI or a Lithium Drifted Germanium [Ge(Li)] detector are used to count the samples. The standards are traceable to the National Bureau of Standards. The gamma-emitting radionuclides of primary interest are ^{137}Cs and ^{60}Co . Other gamma-emitting radionuclides may be measured as necessary.

Tritium samples are first distilled from a neutralized aliquot to which holdback carriers have

been added. After the first fraction of distillate is discarded, 20 ml are collected in a single vial. Aliquots of distillate are counted with a liquid scintillation spectrometer. Duplicate counts are made to reduce the error of the measurements.

GROUND-WATER MONITORING NONRADIOLOGICAL SAMPLES

Samples collected to monitor the quality of the ground water are analyzed according to standard methods. The most applicable methods are recommended by the American Public Health Association in these publications: *Standard Methods for the Examination of Water and Wastewater* (APHA 1976,1981), *ASTM's Annual Book of ASTM Standards*, Part 31, and *Manual on Water*, STP 442A.

The samples taken for Cr^{+6} are filtered and treated with diphenyl carbazide reagent. The optical density of the sample is measured in 10-cm cells at 540 millimicrons and compared against a similarly prepared distilled water blank. The concentrations are determined from a standard curve obtained by analyzing solutions prepared containing known amounts of Cr^{+6} .

To measure **Fluoride**, a 20-ml sample is filtered and 5 ml of fluoride reagent (AMADAC-F) added for color development. The optical density of the sample is then measured at 620 ml in 1-cm cells and compared against the reagent blank. The concentrations are determined from a standard curve obtained by analyzing solutions prepared containing known amounts of fluoride.

Nitrate is measured with a nitrate-specific electrode. The electrode voltage is measured, and then the nitrate concentration is determined from a standard curve prepared by analyzing solutions containing known amounts of nitrate in distilled water.

HAZARDOUS MATERIALS MONITORING

Temperature, pH, and Conductivity are determined in the field according to field instrument instructions.

Coliform Count is determined by multiple tube fermentation.

Metals are measured by either the Inductively Coupled Plasma (ICP) method or the Graphite Furnace Atomic Absorption (GFAA) method. In either case, the sample is first acid-digested. In the ICP method, the digest is then nebulized, with the resultant aerosol being transported to the plasma torch where excitation occurs. The atomic emission is then measured by an optical spectroscopic technique. In the GFAA method, the digest is dried, ashed, and atomized in a graphite tube furnace. The constituent concentration is proportional to the absorption of hollow-cathode radiation during atomization.

Inorganic Anions are determined by ion chromatography. After it is injected into the ion chromatograph, the sample is pumped through three different ion exchange columns to convert the anions in the sample to their corresponding acids. The separated anions in their acid form are measured using an electrical-conductivity cell.

Volatile and Semivolatile Organic Chemicals are determined by Gas Chromatography/Mass Spectrometry (GC/MS). Volatile organic chemicals are introduced to the mass spectrometer by the purge-and-trap method, in which the volatile components are converted from an aqueous phase to a vapor phase, trapped on a sorbent column, and then desorbed onto a gas chromatographic column. This column is heated to elute the components, which are then detected by the mass spectrometer. Semivolatile organic chemicals are extracted using the continuous liquid-liquid extraction method. After it is placed in the continuous extraction apparatus, the sample is extracted for 16 hours with the appropriate solvent. The extract is then collected, dried, and concentrated. The extract is eluted from a gas chromatographic fused-silica capillary column, and the eluted components are then detected by the mass spectrometer.

Certain Organic Constituents are analyzed by direct aqueous injection, which requires no preparatory steps before the samples are injected into the gas chromatograph and detected by the mass spectrometer. Substances identified in samples by GC/MS techniques are verified by comparing the suspect mass spectra to the mass spectrum of a standard of the suspected substance. A computerized mass-spectrometry library search system is used that is capable of providing a forward comparison using the standard spectra contained in the Environmental Protection Agency/National Institute of Health mass spectral data base.

Pesticides and Herbicides are measured by gas chromatography with an appropriate detector. Extractions are performed as necessary. Positive concentrations are verified by reanalysis of the extract using a confirmation gas chromatography column or by GC/MS.

Total Organic Halogens are measured after the sample is passed through a column containing activated carbon. The column is washed to remove trapped inorganic halides, and the carbon is then analyzed to convert the adsorbed organohalides to a titratable species that can be measured by a microcoulometric detector.

Total Organic Carbon is determined by the combustion-infrared method. The sample is sparged with hydrochloric acid to remove inorganic carbon. The homogenized sample is vaporized with an oxidative catalyst, thereby converting the organic carbon to CO₂. The CO₂ is measured by means of a nondispersive infrared analyzer.

A summary of analytical methods used for hazardous materials monitoring is shown in Table D.2.

TABLE D.2. List of Parameters and Analytical Methods for Ground-Water Hazardous Materials Monitoring

Constituent	Collection ^(a) Preservation ^(b)	Method	Detection Limit ug/l ^(c)
Chromium	P, HNO ₃ to pH <2	SW-846	10
Manganese		#6010	5
Cadmium			2
Barium			6
Silver			10
Sodium			100
Iron			50
Mercury	P, HNO ₃ to pH <2	SW-846 #7470	0.1
Lead	P, HNO ₃ to pH <2	SW-846 #7421	5
Arsenic	P, HNO ₃ to pH <2	SW-846 #7060	5
Selenium	P, HNO ₃ to pH <2	SW-846 #7740	5
Tetrachloromethane xylene 1,1,2-trichloroethylene	G, Silicon/teflon septa, no headspace	SW-846 #8240	10
Hydrazine	G, None	Direct Aqueous Injection ^(d)	3 mg/l
Polychlorinated biphenols	G, None	SW-846 #8080	1
Radium	P, HNO ₃ to pH <2	EPA Method #903.0	1 pCi/l
Gross alpha	P, HNO ₃ to pH <2	EPA Method	4 pCi/l
Gross beta		680/4-75-001	8 pCi/l
Coliform bacteria	P, None	Std. Methods #908A,C	3 mpn ^(e)
Total organic halogen	G, Silicon/teflon septa, no headspace	SW-846 #9020	0.1 mg/μ
Total organic carbon	G, H ₂ SO ₄ to pH <2	Std. Methods #505	1 mg/l
Specific conductance	Field measurement	MA-580 #14.4	1 μmho
pH	Field measurement	MA-580 #14.5	0.01 pH unit
Temperature	Field measurement	MA-580 #14.3	0.1°C
Chloride	P, None	Ion Chroma- tography ^(d)	500
Fluoride			500
Sulfate			500
Nitrate			500
Ammonium	G, H ₂ SO ₄ to pH <2	Std. Methods #417-A-E	50
Endrin	G, None	SW-846	1
Lindane		#8080	
Methoxychlor			
Toxaphene			
2,4-D	G, None	SW-846	1
2,4,5-TP Silvex		#8150	

(a) P = plastic, G = glass.

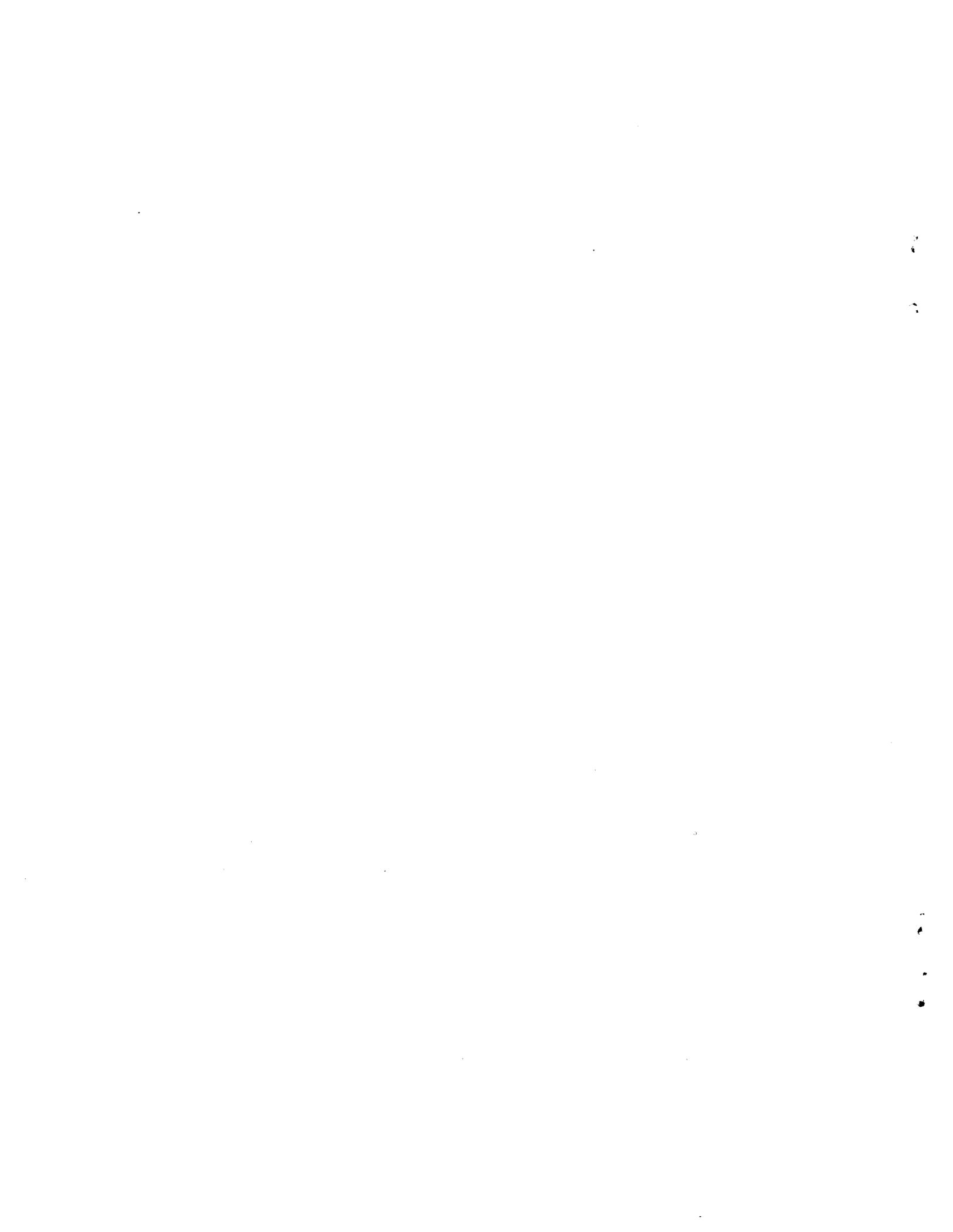
(b) All samples will be cooled to 4°C upon collection.

(c) Detection limit units except where indicated.

(d) In-house analytical method.

(e) Most probable number.

APPENDIX E
DATA ANALYSIS



Appendix E

Data Analysis

Measuring any physical quantity (e.g., temperature, distance, time, or radioactivity) has some degree of inherent uncertainty. This uncertainty results from the combination of all possible inaccuracies in the measurement process including such factors as the reading of the result, the calibration of the measurement device, and numerical rounding errors. In this report, individual radioactivity measurements are accompanied by a plus or minus (\pm) value, which is the uncertainty term known as a two-sigma counting error. Because measuring a radionuclide requires a process of counting random radioactive emissions from a sample, the two-sigma counting error gives information on what the measurement might be if the same sample were counted again under identical conditions. The two-sigma counting error implies that approximately 95% of the time a recount of the same sample would give a value somewhere between the reported value minus the two-sigma counting error and the reported value plus the two-sigma counting error. An asterisk (*) has been placed by the values in the tables that are less than the two-sigma counting error as an indication that the reported result might have come from a sample with no radioactivity. Also note that each radioactive measurement must have the random background radioactivity of the measuring instrument subtracted; therefore, negative results are possible, especially when the sample has very little radioactivity.

Just as the individual values are accompanied by two-sigma counting errors, the reported means (\bar{x}) are accompanied by two standard errors of the mean. This value is used to give an approximate indication of how good the estimate of the mean is under certain simplifying assumptions. The standard errors are approximate, since these assumptions are not always applicable. The standard error of the mean was computed as follows:

$$SE = \sqrt{\left(\frac{\sum_{i=1}^n s_{C,i}^2 + s_v^2}{n} \right) / n}$$

where n = the number of measurements used in the mean

$s_{C,i}^2$ = the counting variance for the n measurement (square of one-sigma counting error)

s_v^2 = the variance of the n measurements, x_i computed as

$$s_v^2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2$$

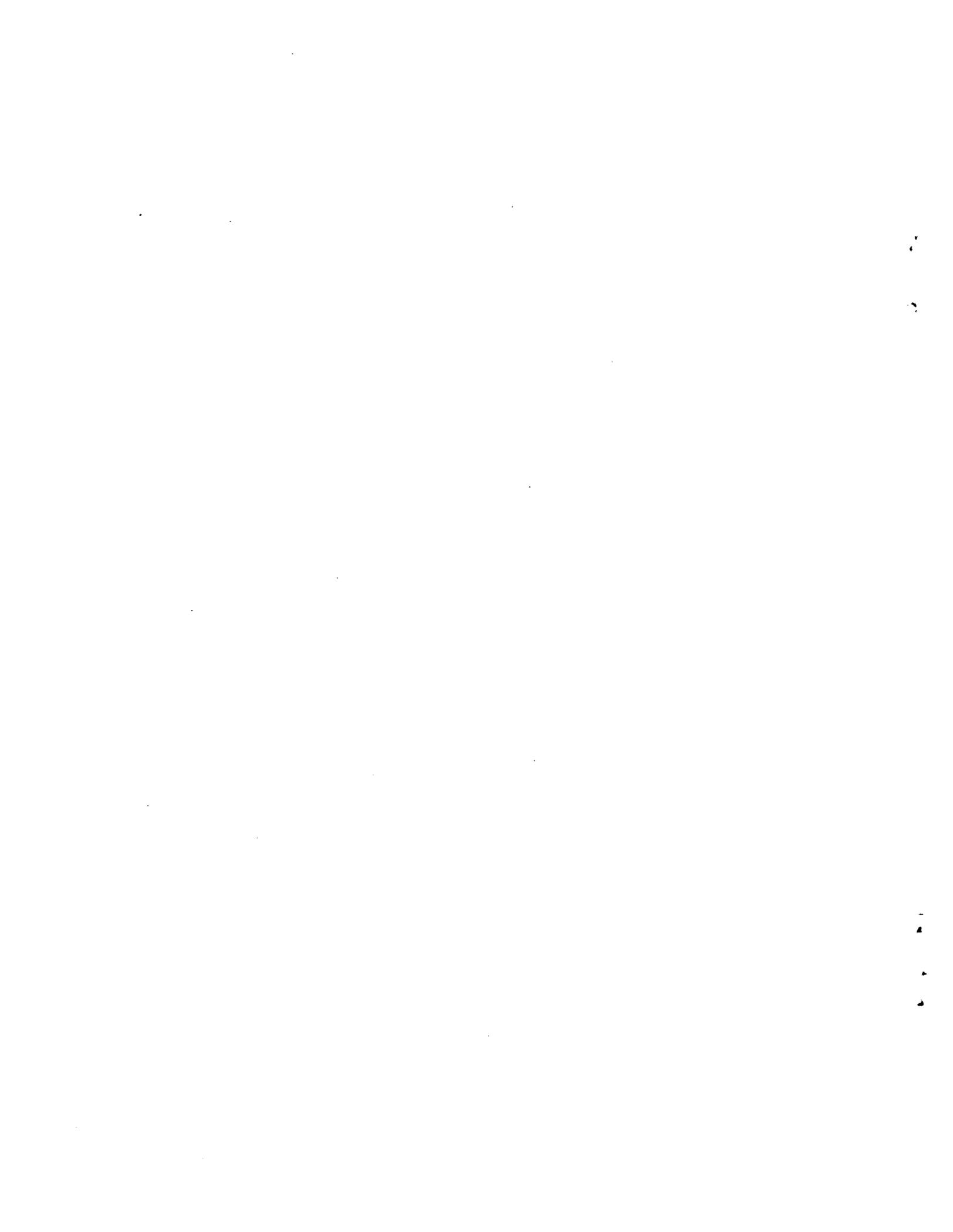
where x_i = the n measurement

\bar{x} = arithmetic mean of the n measurements and is computed as

$$\frac{1}{n} \sum_{i=1}^n x_i$$

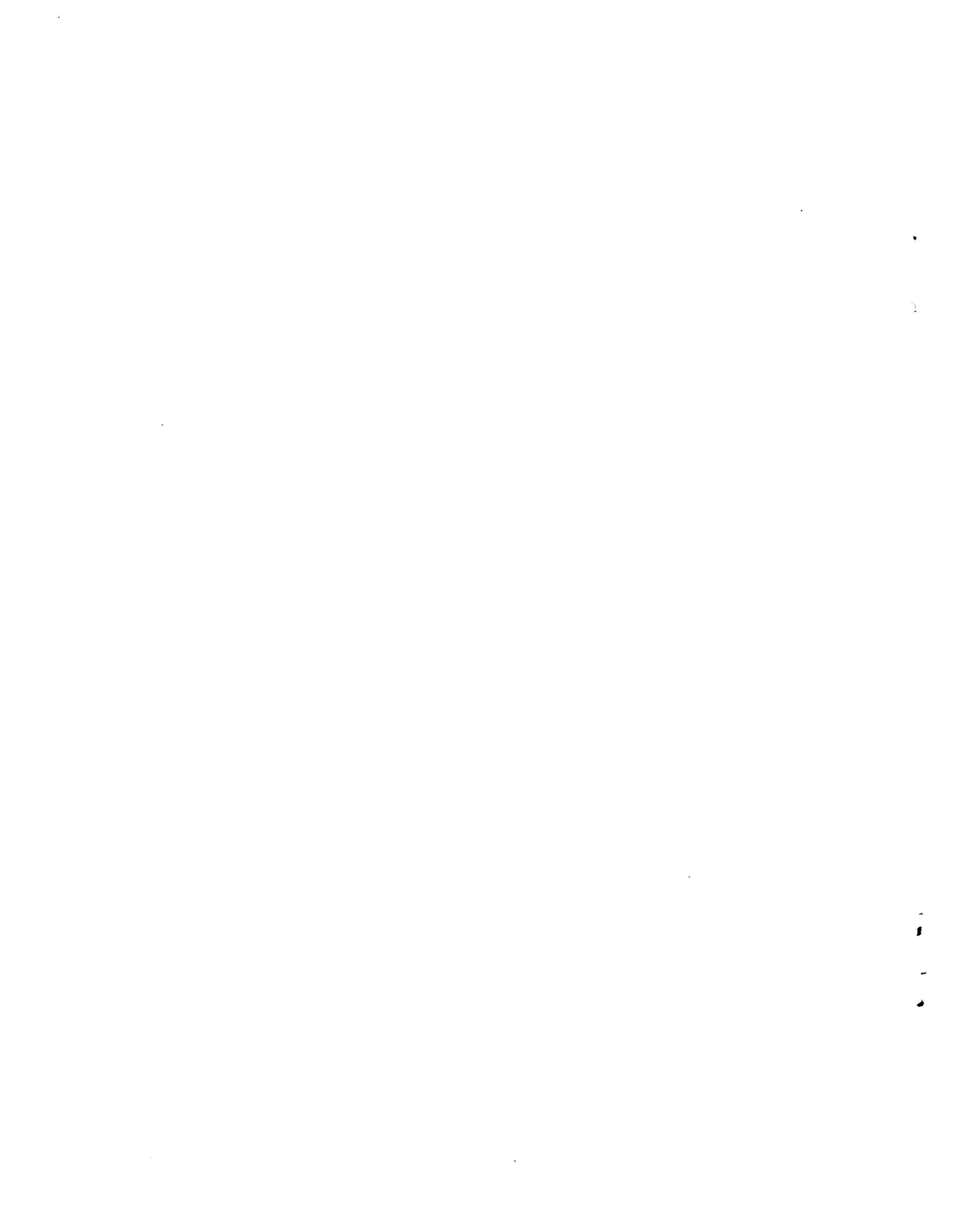
When n is less than 10, then s_v^2 is computed as

$s_v^2 = (fR)^2$ where f is a factor from Table 2.4.1 in Snedecor and Cochran (1967) that depends on the value of n , and R is the range of the n measurement (largest minus smallest measurement).



APPENDIX F

DOSE CALCULATIONS AND EFFLUENT DATA



APPENDIX F

DOSE CALCULATIONS AND EFFLUENT DATA

The radiological impact on the public from operations involving radioactive materials at the Hanford Site is assessed in terms of the "dose equivalent" and "effective dose equivalent." These dose quantities are given in units of millirems (mrem) for individuals and in units of man-rems for the collective dose to the total population within an 80-km radius of the Site. These quantities provide a way to express the radiation impact regardless of the type or source of radiation, or the means by which it is delivered. The dose equivalent values and effective dose equivalent values given in this report may be compared to standards for radiation protection (Appendix C) established by DOE. This appendix describes how the dose equivalents and effective dose equivalents were calculated for this report.

The transport of radionuclides from the environment to the body is illustrated by empirical exposure pathway models. These pathways account for inhalation or ingestion of radionuclides present in air, water, and foods. Radionuclides taken into the body may be distributed among different organs and retained for various time periods. In addition, long-lived radionuclides deposited on the ground become possible sources for long-term external exposure and uptake by agricultural products.

To account for the radiation dose delivered to the body over a long period of time from a short-term intake, the dose is described by a quantity called the "committed dose equivalent." An additional quantity called the "50-year cumulative dose" is calculated to account for the dose from continual intake of residual radionuclides and external exposure to residual radionuclides in soil and sediment. Therefore, to calculate the cumulative dose, the long-term residency of the individual or population involved is considered.

Where possible, the dose values calculated for this report were based on measured radionuclide concentrations in environmental samples.

Dietary factors and exposure parameters were applied to convert the environmental concentrations to exposure in terms of cumulative dose. Ideally, such calculations would be based on a precise understanding of the amount of radionuclides taken into the body. However, radionuclide release rates from Hanford Site activities are usually too low to be measured in the offsite air, drinking water, and food crops. Therefore, in most cases, the dose calculations were based on measurements made at the point of release (stacks and effluent streams). Environmental concentrations were estimated from these effluent measurements by mathematical models and computer simulations. Dietary and exposure parameters were then applied to calculate radionuclide intakes and radiation doses to man (see Figure 4, Section I, "Environmental Monitoring"). A set of standardized computer programs were used to perform the calculations (Houston, Strenge and Watson 1974; Napier, Kennedy and Soldat 1980; Strenge and Watson 1973). These programs contain internally consistent mathematical models that use site-specific dispersion and uptake parameters. The assumptions and input data used in these calculations are described below.

TYPES OF DOSE CALCULATIONS PERFORMED

Radiation dosimetry for radionuclides released into the environment is performed to ensure that the health and safety of the public is not compromised and to determine compliance with applicable standards and regulations. The following types of radiation doses were estimated:

1. **"Fence-Post" Whole-Body Dose Rate** (mrem/h and mrem/yr). The maximum external radiation dose rate during the year in areas accessible by the general public was determined from measurements obtained at locations of potential public access in proximity to operating facilities.

2. **"Maximally Exposed" Individual Dose** (mrem). The maximally exposed individual is a hypothetical member of the public residing near the Hanford Site who, by virtue of his location and living habits, could receive the highest possible radiation dose from radioactive effluents. All potentially significant short- and long-term exposure pathways to this hypothetical individual were considered, including the following:

- inhalation of airborne radionuclides
- submersion in airborne radionuclide effluents
- ingestion of foodstuffs contaminated by radionuclides deposited on vegetation and the ground by both airborne deposition and irrigation water drawn from the Columbia River downstream of the Hanford Site
- drinking sanitary water obtained from Columbia River at Pasco
- exposure to ground contaminated by both airborne deposition and irrigation water
- ingestion of fish taken from the Columbia River
- recreation along the Columbia River, including boating, swimming, and shoreline activities.

3. **80-km Population Doses (man-rem)**. Regulatory limits have not been established for collective population doses. Nonetheless, evaluation of the collective population dose to all residents within an 80-km radius of Hanford Site operations provides an indication of the overall environmental impact of Site operations. The 80-km population dose equivalent represents the summed products of the individual dose and number of individuals involved for all potential exposure pathways.

The pathways depicted in Figure 4 for the "maximally exposed" individual were also assumed to be applicable to the offsite population at large.

Consideration was given, however, to the fraction of the offsite population actually affected by each pathway. The river-related exposure pathways for the population are as follows:

- **Drinking Water.** The cities of Richland and Pasco obtain their municipal water from the Columbia River downstream from the Hanford Site. The city of Kennewick began drawing a portion of its municipal water from the river in late 1980. During 1985, approximately 40% of Kennewick's drinking water was drawn from the Columbia River. The total affected population was approximately 70,000.
- **Irrigated Foodstuff.** Columbia River water is withdrawn for irrigation of small vegetable gardens in the Riverview District of Pasco in Franklin County. Enough foodstuffs are grown in this District to feed an estimated 2,000 people.
- **River Recreation.** These activities include swimming (10 h/yr), boating (5 h/yr), and shoreline recreation (17 h/yr). The population residing adjacent to the river within 80 km of the Hanford Site was assumed to be affected by these pathways and was estimated to number 125,000.
- **Fish Consumption.** Population doses from the consumption of fish obtained locally from the Columbia River were calculated from an estimated total annual catch of 15,000 kg/yr (without reference to a specified population group).

DATA

Data that are needed to perform dose calculations based on measured effluent releases include information on initial transport through the atmosphere or river, transfer or accumulation in terrestrial and aquatic pathways, and public exposure. By comparison, calculations based on measured concentrations of radionuclides in foodstuffs only require data describing dietary and recreational activities, exposure times, and dosimetry. These data are discussed in the following sections.

Population Distribution

Geographic distributions of population residing within an 80-km radius of the four Hanford Site operating areas are listed in Tables F.1 through F.4. These distributions are based on 1980 Bureau of Census data (Sommer, Rau, and Robinson 1981).

Atmospheric Dispersion

Radioactive material released to the atmosphere becomes diluted as the wind carries it away from the release point. The degree of dilution and the magnitude of resultant air concentrations were predicted by atmospheric dispersion models that employ site-specific measurements of the occurrence frequency for wind speed, wind direction, and atmospheric stability. The products of the dispersion model are annual average dispersion factors (\bar{X}/Q' , in units of Ci/m³ per Ci/sec, or sec/m³) that, when combined with annual average release rates, will predict average radionuclide air concentrations for the year. Annual average dispersion factors for the 100, 200, 300, and 400 Areas during 1985 are given in Tables F.5 through F.8. Population exposure to airborne effluents was determined using values of population-weighted atmospheric dispersion factors for each compass sector and annular ring.

Terrestrial and Aquatic Pathways

Following their release and initial transport through the environment, radioactive materials may enter terrestrial or aquatic pathways that lead to public exposure. These potential pathways include consumption of fish, drinking water, and locally grown foodstuffs. For example, radioactive material released to the river is diluted and may be withdrawn downstream for irrigation. Radionuclides deposited on the plants and soil during irrigation can subsequently be taken into plants through their roots and leaves. This vegetation may be eaten by man or farm animals. The numerous transfer factors required for pathway and dose calculations have

been previously described [Houston, Strenge and Watson (1974) and Napier, Kennedy and Soldat (1980)].

Important parameters affecting the movement of radionuclides within potential exposure pathways, such as irrigation rates, growing period, and holdup period, are listed in Table F.9. Note that certain parameters are specific to either "maximum" or "average" individuals.

Public Exposure

Offsite radiation dose impact is related to the extent of public exposure to or intake of radionuclides associated with Hanford Site operations. Tables F.10 through F.12 give the parameters describing the diet, residency, and river recreation assumed for "maximum" and "average" individuals.

Dose Calculation Documentation

The quality of the calculated doses was determined in several ways. First, comparisons were made with doses calculated for previous annual reports, and differences were investigated. Second, the Hanford Dose Overview Committee has defined standard, documented computer codes and input parameters to be used for radiation dose calculations for the public in the vicinity of the Hanford Site. Third, all computed doses were reviewed by the Hanford Dose Overview Committee. Summaries of dose calculation documentation for this report are given in Tables F.13 through F.17.

EFFLUENTS

During 1985, both radioactive and nonradioactive materials were released from routine operations to the Hanford environment. The releases consisted of airborne effluents, liquid effluents, and solid wastes. Tables F.18 through F.24 summarize the effluents reported by the operating contractors. These tables are subdivided into the four major operating areas (100, 200, 300, 400).

TABLE F.1. Distribution of Population in 80-km Radius of the N Reactor by Population Grid Sector^(a)

Compass Direction	Number of People					Totals
	0-16 km	16-32 km	32-48 km	48-64 km	64-80 km	
NORTH	36	953	420	1,492	7,583	10,484
NNE	5	285	561	18,531	1,350	20,732
NE	0	624	1,013	2,691	259	4,587
ENE	0	620	5,884	1,129	429	8,062
EAST	0	294	625	2,742	605	4,266
ESE	0	306	1,493	596	247	2,642
SE	0	54	2,113	28,922	5,001	36,090
SSE	0	0	35,127	50,292	3,354	88,773
SOUTH	0	127	4,592	2,041	176	6,936
SSW	0	258	1,676	12,603	625	15,162
SW	0	547	4,946	16,747	469	22,709
WSW	0	680	1,699	8,297	15,274	25,950
WEST	18	395	936	5,149	75,686	82,184
WNW	54	573	377	490	1,598	3,092
NW	74	277	425	515	683	1,974
NNW	64	277	438	1,030	4,696	6,505
TOTALS	251	6,270	62,325	153,267	118,035	340,148

(a) Based on 1980 census data.

TABLE F.3. Distribution of Population in 80-km Radius of the FFTF by Population Grid Sector^(a)

Compass Direction	Number of People					Totals
	0-16 km	16-32 km	32-48 km	48-64 km	64-80 km	
NORTH	0	78	859	811	16,267	18,015
NNE	20	343	5,728	2,945	1,021	10,057
NE	114	377	760	1,033	217	2,501
ENE	211	1,041	2,644	492	451	4,839
EAST	229	600	183	169	183	1,364
ESE	229	442	544	292	1,060	2,567
SE	344	25,267	13,654	2,105	952	42,322
SSE	10,829	40,933	5,688	719	2,364	60,533
SOUTH	11,760	9,385	1,525	5,611	15,691	43,972
SSW	1,446	4,550	583	185	1,927	8,691
SW	179	1,538	5,234	535	239	7,725
WSW	0	1,206	7,748	14,956	481	24,391
WEST	0	190	3,339	6,089	17,171	26,789
WNW	0	0	932	1,221	3,176	5,329
NW	0	0	295	903	705	1,903
NNW	0	0	264	1,302	1,182	2,748
TOTALS	25,361	85,950	49,980	39,368	63,087	263,746

(a) Based on 1980 census data.

TABLE F.2. Distribution of Population in 80-km Radius of 200 Area Hanford Meteorological Tower by Population Grid Sector^(a)

Compass Direction	Number of People					Totals
	0-16 km	16-32 km	32-48 km	48-64 km	64-80 km	
NORTH	0	174	1,124	772	1,957	4,027
NNE	0	92	656	5,547	14,822	21,117
NE	0	262	5,930	2,963	596	9,751
ENE	0	235	773	2,366	435	3,809
EAST	0	340	1,329	1,659	588	3,916
ESE	0	283	1,374	230	652	2,539
SE	0	6,757	48,661	50,519	3,474	109,411
SSE	0	1,997	13,161	2,717	5,218	23,093
SOUTH	0	1,532	1,489	195	1,799	5,015
SSW	0	905	5,283	652	129	6,969
SW	0	1,190	19,786	2,182	459	23,617
WSW	5	1,840	5,063	15,088	4,573	26,569
WEST	32	648	949	6,874	78,635	87,138
WNW	73	444	802	833	2,833	4,985
NW	0	555	398	493	1,454	2,900
NNW	0	246	456	864	4,521	6,087
TOTALS	110	17,500	107,234	93,954	122,145	340,943

(a) Based on 1980 census data.

TABLE F.4. Distribution of Population in 80-km Radius of 300 Area by Population Grid Sector^(a)

Compass Direction	Number of People					Totals
	0-16 km	16-32 km	32-48 km	48-64 km	64-80 km	
NORTH	289	241	989	5,655	5,317	12,491
NNE	307	475	841	1,950	2,269	5,842
NE	18	966	2,583	562	205	4,334
ENE	307	465	349	470	238	1,829
EAST	291	114	137	174	687	1,403
ESE	338	288	863	594	17,891	19,974
SE	2,549	26,150	2,922	877	1,235	33,733
SSE	7,161	30,357	1,114	1,117	1,113	40,862
SOUTH	15,561	6,651	96	17,223	5,127	44,658
SSW	11,124	4,034	99	1,209	2,038	18,504
SW	10,066	3,931	706	182	181	15,066
WSW	4,429	1,810	5,531	8,988	621	21,379
WEST	294	984	2,226	16,878	16,293	36,675
WNW	0	0	692	1,543	1,679	3,914
NW	0	0	74	923	785	1,782
NNW	0	0	8	875	1,212	2,095
TOTALS	52,734	76,466	19,230	59,220	56,891	264,541

(a) Based on 1980 census data.

TABLE F.5. Annual Average Atmospheric Dispersion (\bar{X}/Q') Around the 100N Area During 1985 for an 89-meter Release Height^(a)

Direction	Sec/m ³									
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km
N	4.95E-08	6.07E-08	4.90E-08	3.77E-08	2.99E-08	1.74E-08	7.78E-09	4.20E-09	2.78E-09	2.05E-09
NNE	2.96E-08	4.71E-08	4.13E-08	3.33E-08	2.72E-08	1.68E-08	7.97E-09	4.46E-09	3.01E-09	2.24E-09
NE	5.57E-08	5.67E-08	4.93E-08	3.98E-08	3.25E-08	1.99E-08	9.40E-09	5.22E-09	3.51E-09	2.61E-09
ENE	7.69E-08	5.81E-08	5.16E-08	4.25E-08	3.54E-08	2.27E-08	1.15E-08	6.76E-09	4.73E-09	3.61E-09
E	1.02E-07	1.05E-07	9.45E-08	7.77E-08	6.43E-08	4.07E-08	2.03E-08	1.18E-08	8.20E-09	6.23E-09
ESE	1.04E-07	9.16E-08	7.89E-08	6.36E-08	5.20E-08	3.22E-08	1.55E-08	8.81E-09	6.02E-09	4.52E-09
SE	1.01E-07	8.19E-08	7.10E-08	5.79E-08	4.78E-08	3.04E-08	1.53E-08	8.96E-09	6.25E-09	4.76E-09
SSE	1.23E-07	7.99E-08	6.96E-08	5.73E-08	4.77E-08	3.09E-08	1.61E-08	9.68E-09	6.87E-09	5.29E-09
S	1.64E-07	8.20E-08	6.61E-08	5.27E-08	4.30E-08	2.70E-08	1.35E-08	7.96E-09	5.59E-09	4.27E-09
SSW	5.54E-08	4.08E-08	3.41E-08	2.72E-08	2.21E-08	1.37E-08	6.76E-09	3.97E-09	2.79E-09	2.14E-09
SW	5.97E-08	4.56E-08	3.80E-08	3.02E-08	2.45E-08	1.50E-08	7.22E-09	4.11E-09	2.82E-09	2.13E-09
WSW	6.01E-08	5.12E-08	4.22E-08	3.38E-08	2.77E-08	1.76E-08	8.84E-09	5.19E-09	3.63E-09	2.76E-09
W	1.15E-07	1.00E-07	8.36E-08	6.68E-08	5.45E-08	3.39E-08	1.65E-08	9.45E-09	6.49E-09	4.88E-09
WNW	6.02E-08	1.02E-07	8.62E-08	6.74E-08	5.38E-08	3.18E-08	1.44E-08	7.84E-09	5.22E-09	3.85E-09
NW	6.22E-08	6.40E-08	5.10E-08	3.90E-08	3.07E-08	1.77E-08	7.77E-09	4.15E-09	2.73E-09	2.00E-09
NNW	3.95E-08	3.97E-08	3.27E-08	2.55E-08	2.03E-08	1.19E-08	5.33E-09	2.88E-09	1.91E-09	1.40E-09

(a) Calculated from meteorological data collected at the 100N Area and the Hanford Meteorological Station.

TABLE F.6. Annual Average Atmospheric Dispersion (\bar{X}/Q') Around the 200 Area During 1985 for an 89-Meter Release Height^(a)

Direction	Sec/m ³									
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km
N	3.56E-08	1.77E-08	1.37E-08	1.09E-08	8.93E-09	5.71E-09	2.91E-09	1.72E-09	1.20E-09	9.10E-10
NNE	1.66E-08	1.16E-08	1.03E-08	8.27E-09	6.66E-09	3.95E-09	1.78E-09	9.61E-10	6.38E-10	4.70E-10
NE	1.80E-08	1.18E-08	1.04E-08	8.59E-09	7.14E-09	4.56E-09	2.27E-09	1.32E-09	9.09E-10	6.87E-10
ENE	3.31E-08	1.55E-08	1.37E-08	1.14E-08	9.45E-09	6.06E-09	3.06E-09	1.80E-09	1.26E-09	9.62E-10
E	3.97E-08	3.14E-08	3.07E-08	2.65E-08	2.26E-08	1.50E-08	7.79E-09	4.62E-09	3.23E-09	2.47E-09
ESE	3.40E-08	5.10E-08	5.00E-08	4.30E-08	3.67E-08	2.45E-08	1.27E-08	7.48E-09	5.22E-09	3.96E-09
SE	6.66E-08	8.13E-08	7.50E-08	6.25E-08	5.22E-08	3.37E-08	1.69E-08	9.86E-09	6.84E-09	5.18E-09
SSE	7.17E-08	6.41E-08	5.53E-08	4.45E-08	3.63E-08	2.25E-08	1.09E-08	6.22E-09	4.27E-09	3.22E-09
S	1.11E-07	9.83E-08	8.14E-08	6.39E-08	5.12E-08	3.06E-08	1.42E-08	7.92E-09	5.36E-09	4.00E-09
SSW	1.05E-07	7.13E-08	5.63E-08	4.34E-08	3.44E-08	2.02E-08	9.20E-09	5.03E-09	3.37E-09	2.49E-09
SW	9.89E-08	9.54E-08	7.66E-08	5.87E-08	4.61E-08	2.65E-08	1.17E-08	6.33E-09	4.21E-09	3.11E-09
WSW	9.14E-08	6.63E-08	5.17E-08	3.93E-08	3.09E-08	1.77E-08	7.86E-09	4.26E-09	2.85E-09	2.10E-09
W	1.36E-07	1.08E-07	8.58E-08	6.62E-08	5.26E-08	3.09E-08	1.40E-08	7.68E-09	5.14E-09	3.80E-09
WNW	8.49E-08	6.14E-08	5.00E-08	3.92E-08	3.14E-08	1.89E-08	8.91E-09	5.05E-09	3.47E-09	2.61E-09
NW	5.77E-08	4.13E-08	3.54E-08	2.88E-08	2.38E-08	1.51E-08	7.53E-09	4.35E-09	3.00E-09	2.27E-09
NNW	3.42E-08	1.90E-08	1.54E-08	1.23E-08	1.01E-08	6.43E-09	3.28E-09	1.94E-09	1.36E-09	1.04E-09

(a) Calculated from meteorological data collected at the Hanford Meteorological Station.

TABLE F.7. Annual Average Atmospheric Dispersion (\bar{X}/Q') Around the 300 Area During 1985 for a Ground-Level Release Height^(a)

Direction	Sec/m ³									
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km
N	6.60E-06	1.04E-06	4.70E-07	2.84E-07	1.96E-07	9.38E-08	3.54E-08	1.75E-08	1.11E-08	7.90E-09
NNE	5.15E-06	8.03E-07	3.63E-07	2.18E-07	1.50E-07	7.16E-08	2.68E-08	1.32E-08	8.32E-09	5.91E-09
NE	6.47E-06	1.01E-06	4.59E-07	2.77E-07	1.91E-07	9.08E-08	3.40E-08	1.67E-08	1.05E-08	7.49E-09
ENE	4.13E-06	6.47E-07	2.93E-07	1.77E-07	1.22E-07	5.81E-08	2.18E-08	1.07E-08	6.77E-09	4.82E-09
E	4.91E-06	7.75E-07	3.53E-07	2.13E-07	1.48E-07	7.09E-08	2.68E-08	1.33E-08	8.43E-09	6.01E-09
ESE	3.39E-06	5.36E-07	2.45E-07	1.48E-07	1.03E-07	4.94E-08	1.87E-08	9.30E-09	5.90E-09	4.21E-09
SE	4.96E-06	7.82E-07	3.55E-07	2.14E-07	1.48E-07	7.07E-08	2.66E-08	1.31E-08	8.27E-09	5.88E-09
SSE	5.64E-06	8.86E-07	4.01E-07	2.41E-07	1.66E-07	7.89E-08	2.94E-08	1.44E-08	9.08E-09	6.44E-09
S	5.24E-06	8.15E-07	3.68E-07	2.21E-07	1.52E-07	7.21E-08	2.69E-08	1.32E-08	8.30E-09	5.89E-09
SSW	9.08E-07	1.33E-07	5.83E-08	3.43E-08	2.32E-08	1.07E-08	3.84E-09	1.84E-09	1.15E-09	8.06E-10
SW	7.60E-07	1.14E-07	5.08E-08	3.03E-08	2.07E-08	9.75E-09	3.60E-09	1.76E-09	1.11E-09	7.86E-10
WSW	6.14E-07	9.07E-08	3.97E-08	2.34E-08	1.58E-08	7.29E-09	2.62E-09	1.26E-09	7.81E-10	5.50E-10
W	2.02E-06	3.04E-07	1.35E-07	8.05E-08	5.51E-08	2.59E-08	9.56E-09	4.67E-09	2.94E-09	2.09E-09
WNW	3.86E-06	5.98E-07	2.70E-07	1.62E-07	1.12E-07	5.33E-08	2.00E-08	9.90E-09	6.26E-09	4.46E-09
NW	5.59E-06	8.74E-07	3.97E-07	2.40E-07	1.66E-07	7.93E-08	3.00E-08	1.49E-08	9.42E-09	6.72E-09
NNW	4.79E-06	7.50E-07	3.41E-07	2.06E-07	1.43E-07	6.85E-08	2.60E-08	1.29E-08	8.19E-09	5.85E-09

(a) Calculated from meteorological data collected at the 300 Area (in 1982) at the Hanford Meteorological Station.

TABLE F.8. Annual Average Atmospheric Dispersion (\bar{X}/Q') Around the 400 Area During 1985 for a Ground-Level Release Height^(a)

Direction	Sec/m ³									
	0.8 km	2.4 km	4.0 km	5.6 km	7.2 km	12 km	24 km	40 km	56 km	72 km
N	6.91E-06	1.08E-06	4.95E-07	3.00E-07	2.08E-07	1.00E-07	3.83E-08	1.91E-08	1.21E-08	8.68E-09
NNE	4.30E-06	6.76E-07	3.08E-07	1.87E-07	1.30E-07	6.25E-08	2.38E-08	1.18E-08	7.53E-09	5.38E-09
NE	2.01E-06	3.14E-07	1.42E-07	8.59E-08	5.93E-08	2.83E-08	1.06E-08	5.24E-09	3.31E-09	2.35E-09
ENE	1.20E-06	1.88E-07	8.58E-08	5.19E-08	3.60E-08	1.73E-08	6.54E-09	3.25E-09	2.06E-09	1.47E-09
E	2.80E-06	4.38E-07	1.99E-07	1.20E-07	8.32E-08	3.98E-08	1.50E-08	7.44E-09	4.71E-09	3.36E-09
ESE	3.11E-06	4.89E-07	2.21E-07	1.33E-07	9.15E-08	4.34E-08	1.62E-08	7.91E-09	4.96E-09	3.51E-09
SE	4.58E-06	7.21E-07	3.26E-07	1.97E-07	1.36E-07	6.45E-08	2.41E-08	1.18E-08	7.44E-09	5.28E-09
SSE	5.02E-06	7.91E-07	3.59E-07	2.17E-07	1.50E-07	7.14E-08	2.68E-08	1.32E-08	8.33E-09	5.92E-09
S	6.37E-06	9.98E-07	4.54E-07	2.75E-07	1.90E-07	9.14E-08	3.47E-08	1.72E-08	1.09E-08	7.79E-09
SSW	4.06E-06	6.36E-07	2.90E-07	1.76E-07	1.22E-07	5.90E-08	2.25E-08	1.12E-08	7.15E-09	5.12E-09
SW	3.38E-06	5.32E-07	2.44E-07	1.48E-07	1.03E-07	4.98E-08	1.91E-08	9.54E-09	6.08E-09	4.35E-09
WSW	2.42E-06	3.79E-07	1.72E-07	1.04E-07	7.22E-08	3.46E-08	1.31E-08	6.50E-09	4.12E-09	2.94E-09
W	3.59E-06	5.59E-07	2.55E-07	1.55E-07	1.07E-07	5.16E-08	1.97E-08	9.80E-09	6.23E-09	4.46E-09
WNW	3.70E-06	5.77E-07	2.62E-07	1.59E-07	1.10E-07	5.26E-08	1.99E-08	9.85E-09	6.24E-09	4.45E-09
NW	3.81E-06	5.97E-07	2.72E-07	1.65E-07	1.14E-07	5.50E-08	2.09E-08	1.04E-08	6.61E-09	4.72E-09
NNW	4.83E-06	7.62E-07	3.49E-07	2.12E-07	1.47E-07	7.10E-08	2.71E-08	1.35E-08	8.61E-09	6.16E-09

(a) Calculated from meteorological data collected at the 400 Area and the Hanford Meteorological Station.

TABLE F.9. Pathway Parameters Used in 1985 Dose Calculations

	Holdup (days, except as noted) ^(a)		Growing Period, Days	Yield, kg/m ²	Irrigation Rate, μ /m ² /month
	Maximum Individual	Average Individual			
Leafy vegetables	1	14	90	1.5	150
Other aboveground vegetables	1	14	60	0.7	160
Potatoes	10	14	90	4	180
Other root vegetables	1	14	90	5	150
Berries	1	14	60	2.7	150
Melons	1	14	90	0.8	150
Orchard fruit	10	14	90	1.7	150
Wheat	10	14	90	0.72	0
Other grains	1	14	90	1.4	150
Eggs	1	18	90	0.84	150
Milk	1	4	30	1.3	200
Beef	15	34	90	0.84	140
Pork	15	34	90	0.84	140
Poultry	1	34	90	0.84	140
Fish	24 h	24 h	--	—	--
Drinking water	24 h	24 h	--	—	--

(a) Holdup is the time between harvest and consumption.

TABLE F.10. Dietary Parameters

	Consumption, kg/yr	
	Maximum Individual	Average Individual
Leafy vegetables	30	15
Other aboveground vegetables	30	15
Potatoes	110	100
Other root vegetables	72	17
Berries	30	6
Melons	40	8
Orchard fruit	265	50
Wheat	80	72
Other grains	8.3	7.5
Eggs	30	20
Milk(a)	274	230
Beef	40	40
Pork	40	30
Poultry	18	8.5
Fish	40	--(b)
Drinking water(a,c)	730	438

(a) Units μ /yr.

(b) Average individual consumption not identified; radiation doses were calculated based on estimated total annual catch of 15,000 kg.

(c) 330 μ /yr for infant.

TABLE F.11. Residency Parameters

Parameter	Exposure, h/yr	
	Maximum Individual	Average Individual
Ground contamination	4383	2920
Air submersion	8766	8766
Inhalation(a)	8766	8766

(a) Inhalation rates: Adult 270 cm^3 /sec routine
 Infant 44 cm^3 /sec.

TABLE F.12. Recreational Activities

Parameter	Exposure, h/yr(a)	
	Maximum Individual	Average Individual
Shoreline	500	17
Boating	100	5
Swimming	100	10

(a) Assumes 8-h holdup for maximum individual and 13-h holdup for average.

TABLE F.13. Documentation of 100 Area Airborne Release Dose Calculation

Facility name:	100 Area.
Releases:	See Table F.18.
Meteorological conditions:	1985 annual average, calculated from data collected at the 100N Area and the Hanford Meteorological Station from January 1985 through December 1985. (See Table F.5).
\bar{X}/Q' :	Maximum individual, $7.5E-9$ sec/m ³ at 53 km SSE, 80-km population $1.9E-3$ person-sec/m ³ .
Release height:	89-m effective stack height.
Population distribution:	340,000, (see Table F.1).
Computer code:	DACRIN, Rev. 1.2, 1980.
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 50-yr dose commitment.
Files addressed:	Organ Data Library, Rev. 8-1-84. Radionuclide Library, Rev. 3-19-84.
Computer code:	PABLM, Rev. 2.2, 10-1-80.
Calculated dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, 50-yr cumulative dose.
Files addressed:	Radionuclide Library, Rev. 3-19-85. Food Transfer Library, Rev. 11-11-83. Organ Data Library, Rev. 8-1-84. Ground Dose Factor Library, Rev. 3-15-78.
Computer code:	KRONIC, Rev. 3-11-83.
Calculated dose:	Chronic air submersion, maximum individual and 80-km population, first year dose.
Files addressed:	OLD RNBET, OLD GISLIB.
Computer code:	PABKID, Rev. 1.0, 3-10-86.
Calculated dose:	Chronic inhalation, ingestion, and ground contamination exposure, maximum individual and 80-km population, effective dose equivalent (ICRP-30 methods).
Files addressed:	Radionuclide Library, 3-19-85. Food Transfer Library, 9-24-85. ICRP-26/30 Dose Factor Library, 3-14-86. Ground Dose Factor Library, Rev. 3-15-78.

TABLE F.14. Documentation of 100 Area Liquid Release Dose Calculation

Facility name:	100 Area
Releases:	See Table F.23.
River flow:	130,000 ft ³ /sec.
Mixing ratio:	1
Reconcentration formula:	3
Shore-width factor:	0.2
Population:	70,000 for drinking water pathway, 125,000 for fish consumption and direct exposure, 2,000 for consumption of irrigated foodstuff.
Computer code:	PABLM, Rev. 2.2, 10-1-80.
Calculated dose:	Chronic ingestion, direct exposure to water and shoreline, maximum individual and 80-km population, and ground contamination, 50-yr cumulative dose.
Files addressed:	Radionuclide Library, Rev. 3-19-85. Organ Data Library, Rev. 8-1-84. Hanford Specific Bio. Accum. Library. Ground Dose Factor Library, Rev. 3-15-78. Food Transfer Library, Rev. 9-24-85.
Computer code:	PABLM, Rev. 2.2, 10-1-80.
Calculated dose:	Chronic ingestion and ground contamination, maximum individual and 80-km population, 50-yr cumulative dose.
Files addressed:	Radionuclide Library, Rev. 3-19-85. Food Transfer Library, Rev. 11-11-83. Organ Data Library, Rev. 8-1-84. Ground Dose Factor Library, Rev. 3-15-78.
Computer code:	PABKID, Rev. 1.0, 3-10-86.
Calculated dose:	Chronic inhalation, ingestion, and ground contamination exposure, maximum individual and 80-km population, effective dose equivalent (ICRP-30 methods).
Files addressed:	Radionuclide Library, 3-19-85. Food Transfer Library, 9-24-85. ICRP-26/30 Dose Factor Library, 3-14-86. Ground Dose Factor Library, Rev. 3-15-78. Hanford-Specific Bioaccumulation Factor Library.

TABLE F.15. Documentation of 200 Area Airborne Release Dose Calculation

Facility name: 200 Area.
Releases: See Table F.18.
Meteorological conditions: 1985 annual average, calculated from data collected at the 100N Area and the Hanford Meteorological Station from January 1985 through December 1985. (See Table F.6).
 \bar{X}/Q' : Maximum individual, $9.3E-9$ sec/m³ at 43 km SE, 80-km population $1.9E-3$ person-sec/m³.
Release height: 82.3 m effective (61 m actual) stack height.
Population distribution: 341,000, (see Table F.2).
Computer code: DACRIN, Rev. 1.2, 1980.
Calculated dose: Chronic inhalation, maximum individual and 80-km population, 50-yr dose commitment.
Files addressed: Organ Data Library, Rev. 8-1-84.
Radionuclide Library, Rev. 3-19-85.
Computer code: PABLM, Rev. 2.2, 10-1-80.
Calculated Dose: Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, 50-yr cumulative dose.
Files addressed: Radionuclide Library, Rev. 3-19-85.
Food Transfer Library, Rev. 9-24-85.
Organ Data Library, Rev. 8-1-84.
Ground Dose Factor Library, Rev. 3-15-78.
Computer code: KRONIC, Rev. 3-11-83.
Calculated dose: Chronic air submersion, maximum individual and 80-km population, first year dose.
Files addressed: OLD RNOBET, OLD GISLIB.
Computer code: PABKID, Rev. 1.0, 3-10-86.
Calculated dose: Chronic inhalation, ingestion, and ground contamination exposure, maximum individual and 80-km population, effective dose equivalent (ICRP-30 methods).
Files addressed: Radionuclide Library, 3-19-85.
Food Transfer Library, 9-24-85.
ICRP-26/30 Dose Factor Library, 3-14-86.
Ground Dose Factor Library, Rev. 3-15-78.

TABLE F.16. Documentation of 300 Area Airborne Release Dose Calculation

Facility name:	300 Area.
Releases:	See Table F.18.
Meteorological conditions:	1985 annual average, calculated from data collected at the 300 Area and the Hanford Meteorological Station from January 1982 through December 1982. (See Table F.7).
\bar{X}/Q' :	Maximum individual, $7.5E-8 \text{ sec/m}^3$ at 13 km SSE, 80-km population $6.1E-3 \text{ person-sec/m}^3$.
Release height:	Ground level.
Population distribution:	265,000, (see Table F.4).
Computer code:	DACRIN, Rev. 1.2, 1980.
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 50-yr dose commitment.
Files addressed:	Organ Data Library, Rev. 8-1-84. Radionuclide Library, Rev. 3-19-85.
Computer code:	PABLM, Rev. 2.2, 10-1-80.
Calculated Dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, 50-yr cumulative dose.
Files addressed:	Radionuclide Library, Rev. 3-19-85. Food Transfer Library, Rev. 9-24-85. Organ Data Library, Rev. 8-1-84. Ground Dose Factor Library, Rev. 3-15-78.
Computer code:	KRONIC, Rev. 3-11-83.
Calculated dose:	Chronic air submersion, maximum individual and 80-km population, first year dose.
Files addressed:	OLD RND BET, OLD GISLIB.
Computer code:	PABKID, Rev. 1.0, 3-10-86.
Calculated dose:	Chronic inhalation, ingestion, and ground contamination exposure, maximum individual and 80-km population, effective dose equivalent (ICRP-30 methods).
Files addressed:	Radionuclide Library, 3-19-85. Food Transfer Library, 9-24-85. ICRP-26/30 Dose Factor Library, 3-14-86. Ground Dose Factor Library, Rev. 3-15-78.

TABLE F.17. Documentation of 400 Area Airborne Release Dose Calculation

Facility name:	400 Area.
Releases:	See Table F.18.
Meteorological conditions:	1985 annual average, calculated from data collected at the 400 Area and the Hanford Meteorological Station from January 1985 through December 1985. (See Table F.8).
\bar{X}/Q' :	Maximum individual, $3.5E-8 \text{ sec/m}^3$ at 22 km SSE, 80-km population $6.5E-3 \text{ person-sec/m}^3$.
Release height:	Ground level.
Population distribution:	264,000, (see Table F.3).
Computer code:	DACRIN, Rev. 1.2, 1980.
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 50-yr dose commitment.
Files addressed:	Organ Data Library, Rev. 8-1-84. Radionuclide Library, Rev. 3-19-85.
Computer code:	PABLM, Rev. 2.2, 10-1-80.
Calculated Dose:	Chronic ingestion and ground contamination exposure, maximum individual and 80-km population, 50-yr cumulative dose.
Files addressed:	Radionuclide Library, Rev. 3-19-85. Food Transfer Library, Rev. 9-24-85. Organ Data Library, Rev. 8-1-84. Ground Dose Factor Library, Rev. 3-15-78.
Computer code:	KRONIC, Rev. 3-11-83.
Calculated dose:	Chronic air submersion, maximum individual and 80-km population, first year dose.
Files addressed:	OLD RND BET, OLD GISLIB.
Computer code:	PABKID, Rev. 1.0, 3-10-86.
Calculated dose:	Chronic inhalation, ingestion, and ground contamination exposure, maximum individual and 80-km population, effective dose equivalent (ICRP-30 methods).
Files addressed:	Radionuclide Library, 3-19-85. Food Transfer Library, 9-24-85. ICRP-26/30 Dose Factor Library, 3-14-86. Ground Dose Factor Library, Rev. 3-15-78.

TABLE F.18. Radionuclides in Gaseous Effluents Discharged to the Atmosphere

Radionuclide ^(b)	Half-Life	Release, Ci ^(a)			
		Airborne			
		100 Area	200 Area	300 Area	400 Area
³ H	12.3 yr	1.8 x 10 ¹	2.0 x 10 ²	(c)	
¹⁴ C	5730 yr	-	4.0 x 10 ⁰		
²⁴ Na	15.0 h	1.5 x 10 ⁻¹			
⁴¹ Ar	1.8 h	6.9 x 10 ⁴			
⁵¹ Cr	27.7 d	5.9 x 10 ⁻³			
⁵⁴ Mn	312 d	6.3 x 10 ⁻³			
⁵⁶ Mn	2.6 h	4.4 x 10 ⁻¹			
⁵⁹ Fe	44.5 d	7.5 x 10 ⁻³			
⁵⁸ Co	70.8 d	2.0 x 10 ⁻³			
⁶⁰ Co	5.3 yr	2.2 x 10 ⁻²		5.0 x 10 ⁻⁶ (d)	
⁷⁶ As	26.3 h	1.2 x 10 ⁰			
^{85m} Kr	4.5 h	2.6 x 10 ²			
⁸⁵ Kr	10.7 yr		7.0 x 10 ⁵		3.5 x 10 ²
⁸⁷ Kr	76.3 min	7.7 x 10 ²			
⁸⁸ Kr	2.8 h	6.5 x 10 ²			
⁸⁹ Sr	50.5 d	1.7 x 10 ⁻²			
⁹⁰ Sr	29.1 yr	5.0 x 10 ⁻⁴	8.5 x 10 ⁻³	6.1 x 10 ⁻⁵ (e)	2.8 x 10 ⁻⁵
⁹¹ Sr	9.5 h	1.8 x 10 ⁻¹			
⁹⁵ Zr	64.0 d	5.0 x 10 ⁻³	6.0 x 10 ⁻²		
⁹⁹ Mo	66.0 h	2.1 x 10 ⁻¹			
¹⁰³ Ru	39.5 d	1.7 x 10 ⁻³	5.2 x 10 ⁻¹		
¹⁰⁶ Ru	368 d	8.7 x 10 ⁻³	6.0 x 10 ⁻¹		
¹¹³ Sn	115 d		4.3 x 10 ⁻¹		
¹²⁵ Sb	2.8 yr		1.5 x 10 ⁻²		
¹²⁹ I	1.6 x 10 ⁷ yr		3.0 x 10 ⁻¹		
¹³¹ I	8.0 d	2.3 x 10 ⁻¹	2.0 x 10 ⁻¹	2.2 x 10 ⁻³	8.1 x 10 ⁻⁶
¹³² I	2.3 h	2.7 x 10 ⁰			
¹³³ I	20.3 h	1.8 x 10 ⁰			
¹³⁵ I	6.6 h	2.9 x 10 ⁰			
¹³³ Xe	5.2 d	1.8 x 10 ²			
¹³⁵ Xe	9.1 h	1.0 x 10 ³			
¹³⁴ Cs	2.1 yr	8.7 x 10 ⁻⁴	7.0 x 10 ⁻⁴		
¹³⁷ Cs	30.0 yr	1.4 x 10 ⁻⁴	1.0 x 10 ⁻²		
¹³⁸ Cs	32.2 min	1.8 x 10 ³			
¹⁴⁰ Ba	12.7 d	1.3 x 10 ⁻¹			
¹⁴¹ Ce	32.5 d	1.1 x 10 ⁻³			
¹⁴⁴ Ce	284 d	1.7 x 10 ⁻²	1.0 x 10 ⁻¹		
¹⁴⁷ Pm	2.6 yr	7.0 x 10 ⁻²			
²¹² Pb	10.6 h		2.0 x 10 ⁻¹		
U-Nat	4.5 x 10 ⁹ yr		1.1 x 10 ⁻⁴	1.3 x 10 ⁻⁴	
²³⁸ Pu	87.7 yr	1.9 x 10 ⁻⁷	1.0 x 10 ⁻³		
^{239,240} Pu	2.4 x 10 ⁴	9.2 x 10 ⁻⁷	1.0 x 10 ⁻²	1.1 x 10 ⁻⁵	2.0 x 10 ⁻⁶
²⁴¹ Pu	14.4 yr		1.0 x 10 ⁻¹		
²⁴¹ Am	432 yr		5.0 x 10 ⁻⁴		

- (a) Except as noted in this table, all effluent releases are as reported by operating contractors via the DOE's Effluent Information System.
- (b) The curve quantities of radioactivity are for the listed radionuclides only. For those radionuclides with radioactive daughters, the daughter activity is included in the dose calculations.
- (c) Blank entry indicates no value reported by the operating contractor.
- (d) Includes 2.2 x 10⁻⁷ Ci reported as mixed activation products, but assumed to be ⁶⁰Co for dose calculations.
- (e) Includes 1.1 x 10⁻⁵ Ci reported as mixed fission products but assumed to be ⁹⁰Sr for dose calculations.

TABLE F.19. Nonradioactive Constituents in Gaseous Effluents Discharged to the Atmosphere in 1985

Constituent	Release, kg			
	100 Area	200 Area	300 Area	1100 Area
Particulates	3.7×10^4	3.9×10^5	2.5×10^4	1.5×10^2
Nitrogen oxides	1.1×10^5	1.0×10^6	1.3×10^5	7.8×10^2
Sulfur oxides	5.2×10^5	1.5×10^6	4.4×10^5	4.9×10^2
Carbon monoxide	1.0×10^4	1.1×10^5	--	4.9×10^1
Hydrocarbons	2.1×10^3	5.4×10^4	--	9.8×10^0

TABLE F.20. Radionuclide in Liquid Effluents Discharged to Ground Disposal Facilities in 1985

Radionuclide	Half-Life	Release, Ci ^(a)		
		100 Area	200 Areas	300 Area
³ H	12.3 yr	2.7 x 10 ²	1.9 x 10 ⁴	(b)
³² P	14.3 d	2.2 x 10 ¹		
⁵¹ Cr	27.7 d	7.5 x 10 ¹		
⁵⁴ Mn	312 d	7.1 x 10 ²		
⁵⁹ Fe	44.5 d	2.6 x 10 ²		
⁵⁸ Co	70.8 d	2.8 x 10 ¹		
⁶⁰ Co	5.3 yr	5.9 x 10 ²		
⁶⁵ Zn	244 d	1.5 x 10 ¹		
⁸⁹ Sr	50.5 d	3.9 x 10 ²		
⁹⁰ Sr	29.1 yr	2.4 x 10 ²	4.7 x 10 ⁰	
⁹⁵ Zr	64.0 d	3.2 x 10 ²		
⁹⁹ Tc	2.1 x 10 ⁵ yr		3.5 x 10 ⁻¹	
⁹⁹ Mo	66.0 h	7.8 x 10 ²		
¹⁰³ Ru	39.3 d	5.4 x 10 ¹	4.0 x 10 ⁰	
¹⁰⁶ Ru	368 d	8.0 x 10 ¹	2.8 x 10 ¹	
¹¹³ Sn	115 d	1.5 x 10 ⁰		
¹²⁴ Sb	60.2 d	6.1 x 10 ⁰		
¹²⁵ Sb	2.8 yr	1.2 x 10 ¹		
¹²⁹ I	1.6 x 10 ⁶ yr	9.4 x 10 ⁻²		
¹³¹ I	8.0 d	3.7 x 10 ²		
¹³³ Xe	5.2 d	2.9 x 10 ²		
¹³⁴ Cs	2.1 yr	5.7 x 10 ⁰		
¹³⁷ Cs	30.0 yr	8.8 x 10 ¹	2.0 x 10 ⁰	
¹⁴⁰ Ba	12.7 d	4.1 x 10 ³		
¹⁴¹ Ce	32.5 d	7.4 x 10 ¹		
¹⁴⁴ Ce	284 d	2.8 x 10 ²		
¹⁴⁷ Pm	2.6 yr		9.3 x 10 ⁰	
¹⁵³ Sm	46.7 h	7.2 x 10 ¹		
Unidentified beta				1.1 x 10 ⁻²
Short-lived radionuclides ^(c)		2.6 x 10 ⁴		
²³⁴ U	2.4 x 10 ⁵ yr			1.3 x 10 ⁻¹
²³⁵ U	7.0 x 10 ⁸ yr			7.0 x 10 ⁻³
²³⁸ U	4.5 x 10 ⁹ yr		-5.5 x 10 ⁻¹ (d)	
²⁴¹ Am	432 yr		9.5 x 10 ⁻¹	
²³⁸ Pu	87.7 yr	5.0 x 10 ⁻¹	2.8 x 10 ⁻¹	
^{239,240} Pu	2.4 x 10 ⁴ yr	3.4 x 10 ⁰	1.9 x 10 ⁰	
²⁴¹ Pu	14.4 yr		3.6 x 10 ¹	
²³⁹ Np	2.4 d	3.2 x 10 ²		

(a) Values are those reported by operating contractors.

(b) Blank entry indicates no value reported by the operating contractor.

(c) Short-lived radionuclides T_{1/2} < 48 h.

(d) Negative value includes 0.55 curies (approximately 800 kg) recovered from the ground water.

TABLE F.21. Nonradioactive Constituents in Liquid Discharged to Ground Disposal Facilities in 1985

Constituent	Release, kg (a)	
	200 Area	300 Area
Total organic carbon	1.6×10^4	
Nitrates	3.6×10^5	7.3×10^4
Copper		2.9×10^2
Fluoride		1.5×10^3
Chromium		2.9×10^1

(a) Values are those reported by operating contractors.

TABLE F.22. Quantities of Materials Discharged to the 183-H Evaporation Basins in 1985^(a)

Constituent	Quantities, kg (b)
Ammonium ion	2.4×10^2
Fluoride ion	1.2×10^4
Nitrate ion	2.5×10^5
Chromium	4.0×10^1
Copper	2.2×10^4
Manganese	9.1×10^1
Sulfate ion	4.4×10^4
Uranium	2.0×10^2

(a) Disposal practices for the 183-H Evaporation Basins were discontinued after November 8, 1985.

(b) Reported by the operating contractor.

TABLE F.23. Radionuclides in Liquid Effluents Discharged to the Columbia River in 1985

Radionuclide	Half-Life	Release, Ci (a)
^3H	12.3 yr	2.7×10^2
^{24}Na	15.0 h	1.3×10^{-1}
^{32}P	14.3 d	1.1×10^{-2}
^{51}Cr	27.8 d	2.6×10^{-1}
^{54}Mn	312 d	5.5×10^{-1}
^{59}Fe	44.5 d	3.6×10^{-1}
^{58}Co	70.8 d	4.1×10^{-2}
^{60}Co	5.3 yr	2.0
^{89}Sr	50.5 d	1.4
^{90}Sr	29.1 yr	8.7
^{95}Zr	64.0 d	2.7×10^{-1}
^{99}Mo	66.0 h	1.5
^{103}Ru	39.3 d	4.2×10^{-1}
^{106}Ru	368 d	3.0×10^{-1}
^{124}Sb	60 d	1.5×10^{-2}
^{125}Sb	2.8 yr	3.5×10^{-1}
^{131}I	8.0 d	5.7
^{133}I	20.8 h	1.6
^{133}Xe	5.2 d	1.9
^{137}Cs	30.0 yr	2.7×10^{-1}
^{140}Ba	12.7 d	5.0×10^{-1}
^{141}Ce	32.5 d	8.1×10^{-2}
^{144}Ce	284 d	5.5×10^{-1}
^{238}Pu	87.7 yr	3.8×10^{-6}
$^{239,240}\text{Pu}$	2.4×10^4 yr	1.1×10^{-3}

(a) Values are those reported by contractors.

TABLE F.24. Composition of Solid Wastes Buried Onsite During 1985

Constituent	Quantities (a)
Radioactive	
Uranium	2.0×10^6 g
Plutonium	5.3×10^0 g
Americium	2.5×10^{-4} g
Strontium	7.4×10^4 Ci
Ruthenium	3.8×10^0 Ci
Cesium	7.0×10^4 Ci
Other fission and activation products	1.6×10^4 Ci
Nonradioactive	
Nonhazardous trash, refuse	3.3×10^4 m ³
Asbestos	5.1×10^2 m ³
Waste hazardous chemicals	3.5×10^0 m ³
Septic sludge	9.6×10^2 m ³

(a) Values are those reported by the operating contractors.

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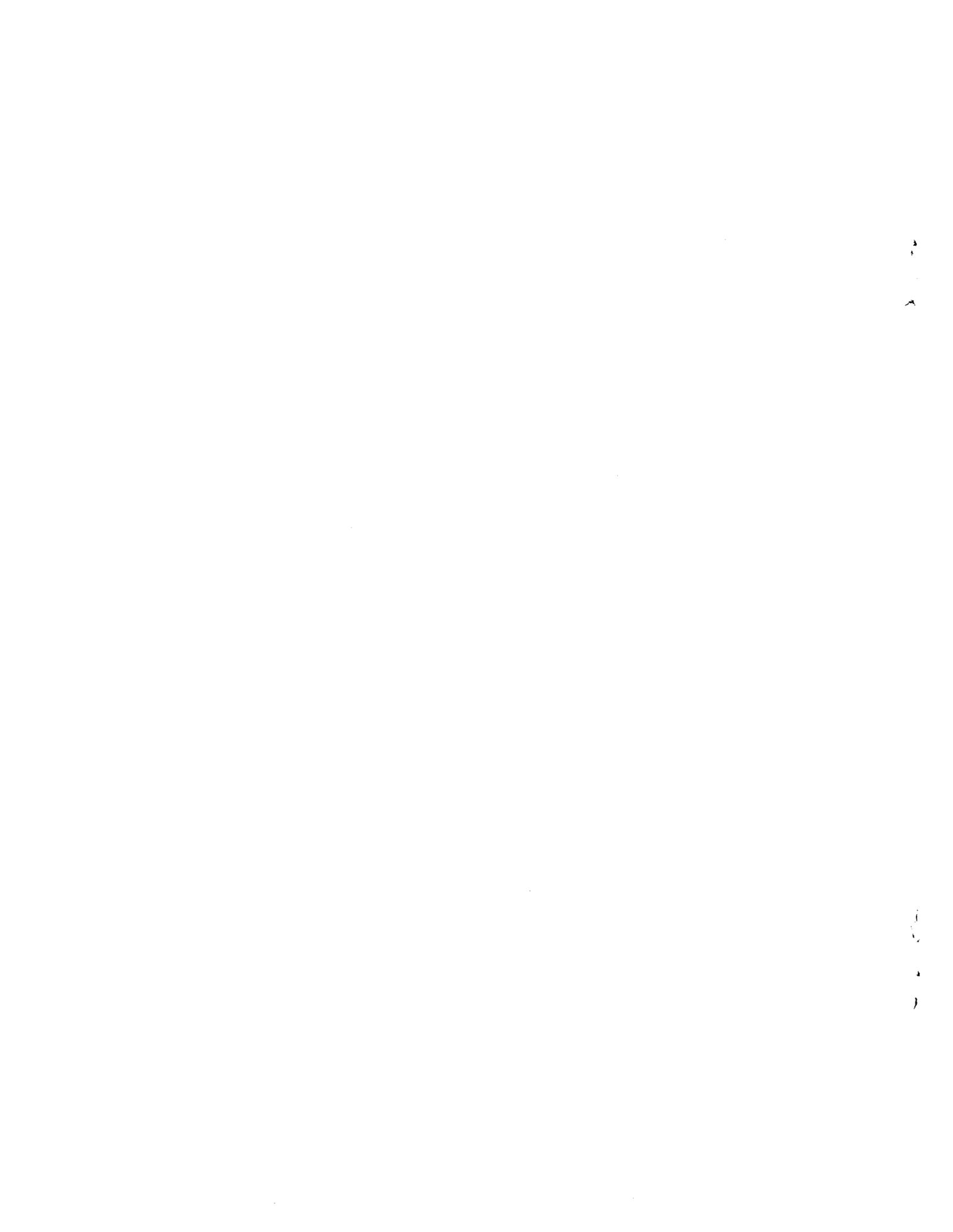
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