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May 27, 1994

Dr. John E. Till, Chairman
Technical Steering Panel
Hanford Environmental Dose
Reconstruction Project
Rt. 2, Box 122
Neeses, SC 29107

Mr. Michael R. Donnelly
Public Health Service
Centers for Disease Control and Prevention
2201 Sixth Avenue, Mail Stop RX-22
Seattle, WA 98121

Dear Dr. Till and Mr. Donnelly:

VALIDATION OF HEDR MODELS

Enclosed is the report, *Validation of HEDR Models* (PNWD-2221 HEDR). This report includes a description of the comparison of predicted values of dose with actual measurements. Validation was performed according to the *HEDR Model Validation Plan* (PNWD-2156 HEDR). This report fulfills Milestone 0204C.

This validation report was originally planned as a component of a HEDR Model Reliability Report, Milestone 0803B. The publication of the validation report was accelerated as a separate milestone at the request of the Technical Steering Panel. Rather than publish a separate reliability report, the other reliability information has been included in the code documentation and dose reports.

Very truly yours,

W.T. Farris for DBS

Dillard B. Shipler, Manager
Hanford Environmental
Dose Reconstruction Project

DBS:prc

Enclosure

cc: MS Power (TSP)

PNWD-2221 HEDR
UC-000

6a

Validation of HEDR Models

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J. V. Ramsdell, Jr.
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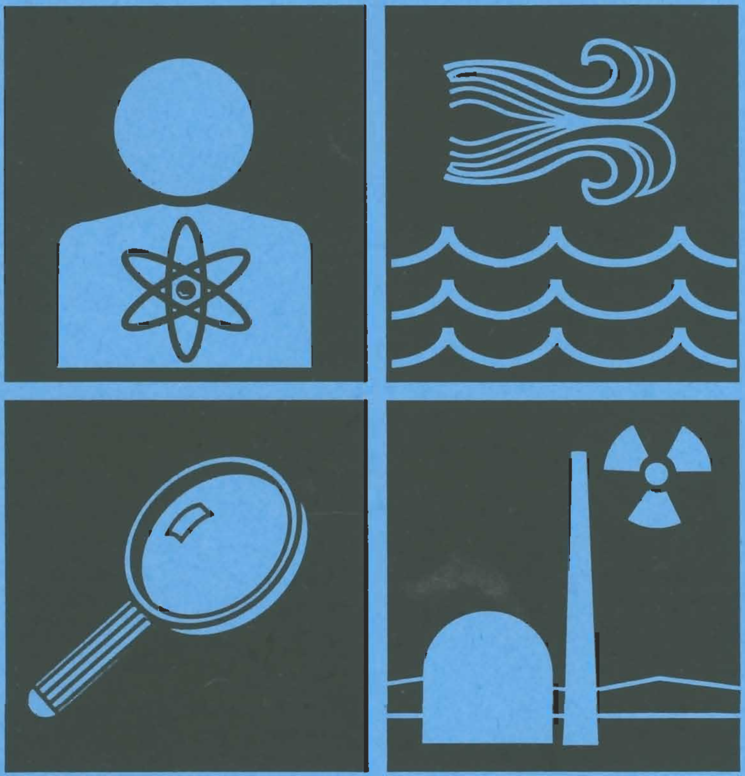
W. H. Walters

May 1994



Prepared for the Technical Steering Panel
and the Centers for Disease Control and Prevention
under Contract 200-92-0503(CDC)/18620(BNW)

Battelle
Pacific Northwest Laboratories

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Battelle
Pacific Northwest Laboratories
Richland, Washington 99352

Validation of HEDR Models

May 1994

This document has been reviewed and
approved by the Technical Steering Panel.

John E. Till

May 22, 1994

J. E. Till, Chair
Technical Steering Panel
Hanford Environmental
Dose Reconstruction Project

Date

Preface

In 1987, the U.S. Department of Energy (DOE) directed the Pacific Northwest Laboratory, operated by Battelle Memorial Institute, to conduct the Hanford Environmental Dose Reconstruction (HEDR) Project. The DOE directive to begin project work followed a recommendation by the Hanford Health Effects Review (HHER) Panel in 1986. The HHER Panel was formed to consider the potential health implications of past releases of radioactive materials from the Hanford Site near Richland, Washington.

Members of a Technical Steering Panel (TSP) were selected to direct the project work. The TSP consists of experts in the various technical fields relevant to HEDR Project work and representatives from the states of Washington, Oregon, and Idaho; Native American Tribes; and the public. The technical members of the panel were selected by the vice presidents for research at major universities in Washington and Oregon. The state representatives were selected by the respective state governments. The Native American tribes and public representatives were selected by the other panel members.

A December 1990 Memorandum of Understanding between the Secretaries of the DOE and the U.S. Department of Health and Human Services (DHHS) transferred responsibility for managing the DOE's dose reconstruction and exposure assessment studies to the DHHS. This transfer resulted in the current contract between Battelle, Pacific Northwest Laboratories (BNW) and the Centers for Disease Control and Prevention (CDC), an agency of the DHHS, to continue the project.

The purpose of the HEDR Project is to estimate the radiation dose that individuals could have received as a result of emissions since 1944 from the Hanford Site. The HEDR Project work is conducted under several technical and administrative tasks, among which are the Technical Integration and Statistics Tasks. The staff on these tasks provide the technical guidance, coordination, and communication among other technical tasks, as well as ensuring the appropriate use of statistics and statistical methods. These efforts include the model reliability analysis, a shared activity between the two tasks. Model reliability involves the review of concepts, testing of the implementation of models in computer codes, uncertainty and sensitivity analyses, and validation of model output.

Validation of the model output is part of the analysis of the various models. A *HEDR Model Validation Plan* has been published (Napier 1993). The model validation results reported in this document are the implementation of the model validation plan and fulfill the requirements of Milestone 0204C. This report had been planned as a component of a HEDR Model Reliability Report, Milestone 0803B. The publication of the validation information was accelerated as a separate milestone at the request of the TSP. The other model reliability information will be reported in the code documentation and the dose reports.

This report completes HEDR Project Milestone 0204C. It is the final report, replacing the previous version dated January 1994. Appendix E is a record of the TSP comments and BNW responses that have been addressed in this final report. Changes made in response to the TSP comments are denoted by numbers in the left margin and italicized text.

Summary

The Hanford Environmental Dose Reconstruction (HEDR) Project has developed a set of computer models for estimating the possible radiation doses that individuals may have received from past Hanford Site operations. This document describes the validation of these models. In the HEDR Project, the model validation exercise consisted of comparing computational model estimates with limited historical field measurements and experimental measurements that are independent of those used to develop the models. The results of any one test do not mean that a model is valid. Rather, the collection of tests together provide a level of confidence that the HEDR models are valid.

Scope

Complete data sets of the various space/time/pathway combinations used in the model dose calculations would lead to the most rigorously defensible validation. However, data are not available to support such an ambitious validation program. Contemporaneous data do not address all the necessary pathways, either geographical or temporal, needed to provide a complete validation. The data sets that have been selected for validation were chosen to provide the best examples of coverage of the HEDR Project domain in space, in time, and for as many pathways as possible. A plan for the HEDR validation activities was published in June 1993. With minor exceptions (see Section 6.4.1), this report follows the activities outlined in that validation plan.

Approach

The general approach of the model validation is to compare the estimated values of dose—or of the available surrogate measurement closest to dose (e.g., estimated concentrations of radioiodine in sagebrush)—with historical measurements obtained from the field or laboratory. The purpose is primarily to characterize the comparisons with respect to the space, time, and pathway elements of the available data. Descriptive statistics rather than formal "hypothesis testing" statistics were used as described in the validation plan (Napier et al. 1993).

Results

6,7,8 *This report discusses the results of comparing the estimates with the data sets available to address the general validation goals. Specific sets of results are provided for both the measured and estimated data. In a general sense, the comparisons are good. Point comparisons, time sequences, and spatial distributions of calculated results agree to within factors of about three or less for most of the comparisons made.*

Each of the following component models, which perform the indicated functions, have been evaluated for validation purposes:

- *Reactor model (RM) (Heeb 1993)*
    - *Radionuclide content in discharges from B, D, and F reactors, 1944-1949*

- *Atmospheric source term release model (STRM) (Heeb 1993)*
    - *Radionuclide release rates from B and T Separations Plants, 1944-1949*

- *Atmospheric transport model (RATCHET) (Ramsdell et al. 1994)*
    - *Radionuclide time-integrated air concentrations in the HEDR spatial domain, 1944-1972*
    - *Radionuclide surface-deposition rates in the HEDR spatial domain, 1944-1972*

- *Environmental accumulation model (DESCARTES) (Eslinger 1992)*
    - *Accumulation of iodine-131 in different plant products at numerous space/time combinations*
    - *Accumulation of iodine-131 in different animal products at numerous space/time combinations*

- *Individual dose model (CIDER) (Eslinger 1992)*
    - *Iodine-131 body burdens and doses in humans of various ages and both sexes from terrestrial, ingestion, and inhalation pathways*

- *River source term release model (STRRM) (Heeb and Bates 1994)*
    - *Emission rates of seven*(a) *radionuclides released to the Columbia River, 1944-1972*

- *River transport model (WSU-CHARIMA) (Walters et al. 1994)*
    - *Monthly concentrations in Columbia River water of six*(a) *radionuclides at 12 locations*

- *River dose model (CRD) (Farris 1993)*
    - *Monthly average concentrations in Columbia River fish for five*(a) *radionuclides at 12 locations*
    - *Annual average radionuclide concentrations in Willapa Bay oysters*
    - *Radionuclide body burdens and doses in humans from Columbia River related ingestion and exposures.*

A list of the HEDR models and the results of the particular validation exercises is provided for the atmospheric release models in Table S.1 and for the Columbia River release models in Table S.2. As indicated in these tables, the estimates made by the atmospheric models, particularly those representing the closest surrogates to dose, are generally within a factor of 3 or better of the measurements. The estimates made by the river pathway models are almost uniformly within a factor of 3 of the measurements.

(a) The radionuclides used for dose calculation are sodium-24, phosphorus-32, zinc-65, arsenic-76, and neptunium-239. In addition, chromium-51 and scandium-46 were provided for validation purposes only. Scandium-46, however, was not used for validation because not enough data were available.

Table S.1. Degree of Validation Obtained for the Atmospheric Release Pathway Models

Model/Test	RM	STRM	RATCHET	DESCARTES	CIDER
Burnup	I[(a)]				
Time series at Richland, 1946	I	I	I	P[(b)]	
Time series at Kennewick/Pasco, 1946	I	I	I	P[(b)]	
Time series at Benton City, 1946	I	I	I	P[(b)]	
Daily footprint, April 13, 1946	I	I	I	P[(c)]	
Green Run 1949	I	I	I	P[(d)]	
PUREX 1963			I	D[(a)]	D[(a)]
Krypton-85			P[(a)]		
Thyroid 1945-1946	I	I	I	I	D[(a)]

(a) All estimates within a factor of 3 or less of the measurements.
(b) Means within a factor of 3 of estimated extremes during growing season only.
(c) Quality of historical measurements impacts comparison.
(d) 65 percent of the measurements fall within estimated range.

Key to notations:
I = Indirect validation.
D = Direct validation.
P = Partial validation.

Table S.2. Degree of Validation Obtained for the Columbia River Release Pathway Models[(a)]

Model/Test	STRRM	WSU-CHARIMA	CRD
Hydraulics		D	
Radionuclides in river water	I	D	
Resident fish	I	I	P[(b)]
Oysters	I		P
Zn/Na whole body counts	I	I	D
Individual zinc	I	I	D

(a) Most estimates within a factor of 3 or less of the measurements.
(b) Some estimated/measured ratios exceed 3.

Key to notations:
I = Indirect validation.
D = Direct validation.
P = Partial validation.

4 Because not enough data are available, no individual validation exercise adequately verifies the accuracy of the HEDR computer models. It is only through the compilation of a sufficient number of component validations that the reliability of the HEDR computer models is demonstrated. The results of all of the validation tests that have been performed combine to provide a reasonable validation set for the needs of the project. Sufficient coverage of the spatial, temporal, and pathway variables is achieved and demonstrates a high level of confidence in the adequacy of the HEDR approach and implementation. On the basis of the tests performed and the results obtained, the staff of the HEDR Project conclude that the models in the HEDR toolbox are fully functional and accurate. These models meet the HEDR Project objectives in that they provide sound, supportable estimates of individual radiation doses resulting from historical releases of radionuclides from the Hanford Site. As a result of this validation exercise, no revisions to any of the models are recommended *before estimation of representative individual doses*.

Abstract

The Hanford Environmental Dose Reconstruction (HEDR) Project has developed a set of computer models for estimating the possible radiation doses that individuals may have received from past Hanford Site operations. This document describes the validation of these models. In the HEDR Project, the model validation exercise consisted of comparing computational model estimates with limited historical field measurements and experimental measurements that are independent of those used to develop the models. The results of any one test do not mean that a model is valid. Rather, the collection of tests together provide a level of confidence that the HEDR models are valid.

Contents

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Tables

1.0 Introduction

The Hanford Environmental Dose Reconstruction (HEDR) Project has developed a set of computer models for estimating the possible radiation dose that individuals may have received from past Hanford Site operations. This document describes how these models were validated by comparing computational model estimates with field and experimental measurements that are independent of the measurements used to develop the models.

Validation is one part of the overall model-reliability analysis being performed on the HEDR models. The full reliability analysis includes code testing and verification, and uncertainty and sensitivity analyses, as well as validation (Shipler 1993, pp. 9.7-9.9).

Complete validation of computer models can be said to consist of four steps:

1. peer review of the models as they are being developed
2. verification of the computer implementations as the codes are developed
3. verification of the assumptions and parameters going into the codes
4. comparisons of the results to historical measurements.

The HEDR models have been subjected to numerous reviews; e.g., the Technical Steering Panel (TSP) and the Centers for Disease Control and Prevention (CDC) review of the RATCHET code, the TSP external review of the environmental accumulation/dose code development, and extensive discussions with the TSP during the development of the surface-water modeling effort. Testing of the various codes has been performed by staff independent of the developers to ensure correct implementation of the models. The assumptions and parameters have been published in other HEDR reports and continue to undergo scrutiny; e.g., the commercial milk distribution model initially prepared by Beck et al. (1992) and the environmental accumulation and dose model parameter report (Snyder et al. 1994).

Code verification was completed prior to the validation activities, and the uncertainty/sensitivity analyses will be documented in the dosimetry reports.

A model cannot be considered validated until sufficient comparisons with historical measurements have been performed to ensure an acceptable level of estimative accuracy. These comparisons must be performed over the range of conditions in which the model may be applied. The acceptable level of accuracy is subject to judgment and will vary depending on the specific problems or questions being addressed by the model (IAEA 1989).

This report compares the estimates of the HEDR computer models to historical measurements. The figures in this report illustrate these comparisons. Most of the figures have been previously published in the reports which describe the respective computer models being validated. Because the figures are from a variety of reports, the terminology in the figure legends is inconsistent. An estimate is also labeled as "model output," "prediction," or "computation." A measurement is also "actual data," "original counting data," "observation," or "sample."

1.1 The HEDR Dose Estimation Toolbox

An entire suite of computerized models (the HEDR Toolbox) has been prepared for HEDR dose analysis covering specific time periods, locations, radionuclides, and events. Each of the following component models, which perform the indicated functions, have been evaluated for validation purposes:

- Reactor model (RM) (Heeb 1993)
  - Radionuclide content in discharges from B, D, and F reactors, 1944-1949

- Atmospheric source term release model (STRM) (Heeb 1993)
  - Radionuclide release rates from B and T Separations Plants, 1944-1949

- Atmospheric transport model (RATCHET) (Ramsdell et al. 1994)
  - Radionuclide time-integrated air concentrations in the HEDR spatial domain, 1944-1972
  - Radionuclide surface-deposition rates in the HEDR spatial domain, 1944-1972

- Environmental accumulation model (DESCARTES) (Eslinger 1992)
  - Accumulation of iodine-131 in different plant products at numerous space/time combinations
  - Accumulation of iodine-131 in different animal products at numerous space/time combinations

- Individual dose model (CIDER) (Eslinger 1992)
  - Iodine-131 body burdens and doses in humans of various ages and both sexes from terrestrial, ingestion, and inhalation pathways

- River source term release model (STRRM) (Heeb and Bates 1994)
  - Emission rates of seven[a] radionuclides released to the Columbia River, 1944-1971

- River transport model (WSU-CHARIMA) (Holly et al. 1993)
  - Monthly concentrations in Columbia River water of six[a] radionuclides at 12 locations

- River dose model (CRD) (Farris 1993)
  - Monthly average concentrations in Columbia River fish for five[a] radionuclides at 12 locations
  - Annual average radionuclide concentrations in Willapa Bay oysters
  - Radionuclide body burdens and doses in humans from Columbia River related ingestion and exposures.

(a) The radionuclides used for dose calculation are sodium-24, phosphorus-32, zinc-65, arsenic-76, and neptunium-239. In addition, chromium-51 and scandium-46 were provided for validation purposes only. Scandium-46, however, was not used for validation because not enough data were available.

An integral part of the dose estimating process is the assessment of the uncertainties in the dose estimates. The majority of the HEDR codes (RM, STRM, RATCHET, DESCARTES, CIDER, and STRRM) are designed to be run in a Monte Carlo fashion to provide a distribution of output results. The WSU-CHARIMA and CRD codes require additional analyses to obtain uncertainty results. The full capabilities of the HEDR codes have been used in the validation analyses. The medians or means, as well as the full output distribution, have been used in the comparisons.

1.2 Model Validation Strategy

The HEDR models are used to describe the potential for radiation dose to individuals living in a large spatial area over long periods of time by a number of potentially important exposure pathways. Thus, it would be highly desirable to validate the various models at points throughout the spatial domain in areas of high deposition, light deposition, and sporadic or minimal deposition. The goal would be to measure the variation in time of radionuclide concentrations in each of the pathways at these various locations. A high level of coverage of the various space/time/pathway combinations used in the primary dose estimates would lead to the most rigorously defensible validation. However, data are not available to support such an ambitious validation program. Contemporaneous data do not address all the necessary pathways, over space or over time, needed to provide a complete validation. Consequently, the data sets used for validation were chosen to provide the best possible coverage of the domain in time, in space, and for as many pathways as possible. The comparisons achieved here, along with tests outlined in Napier et al. (1993), represent a reasonable set that sufficiently cover the spatial, temporal, and pathway variables. As it turns out, they also demonstrate the adequacy of the HEDR approach and implementation.

10 *The HEDR models are designed to reproduce the conditions in the Hanford Site surroundings over the past 50 years. Therefore, the sets of data selected by Napier et al. (1993) and described in this report relate to Hanford Site sources. The authors believe that, within the constraints of the HEDR Project, these data sets form the best basis for validating Hanford Site-specific models. Other data sets may be used for additional validation work if desired. These include, but are not limited to, records of tritium releases to the air at the U.S. Department of Energy (DOE) Savannah River Site, iodine releases to the air at the Idaho National Engineering Laboratory, fallout from weapons tests, releases to the Clinch and Tennessee rivers from the DOE Oak Ridge National Laboratory, and measurements made following the accident at the Chernobyl Nuclear Power Plant. Validation efforts conducted with non-Hanford Site data sets could improve the overall validation but are beyond the scope of the current effort.*

Evaluating the results of the validation tests is a necessary component of validation. The approach of this report is to compare the estimated values of dose, or of the available surrogate estimate closest to dose (e.g., concentrations of iodine-131 in sagebrush), with the measurements. This includes validation of intermediate steps in the estimation of dose. The purpose is to understand why there may be differences between the estimated concentrations and doses and the measurements. Thus, the statistical methods used were aimed at describing these differences so that the causes could be understood and recommendations for improvements made if necessary. As a result of these studies, however, no changes to the models or codes are recommended.

1.3 Areas for Model Validation

The models and computational tools described in Section 1.1 provide information used to estimate the radiation dose to real or representative individuals. It is not possible to validate real individual doses because they were not measured and no database of individual dose exists. However, radionuclide concentrations were measured at various times and in various media by environmental monitoring programs operated at the Hanford Site and by the states of Washington and Oregon. Although insufficient for estimating doses directly, these measurements do provide the possibility of validating portions of the HEDR toolbox for particular times and/or occurrences. Compilation of a sufficient number of these component validations would demonstrate the general reliability of the HEDR dose estimation toolbox.

For example, the progression of the calculations required to estimate dose via the atmospheric pathway is illustrated in Figure 1.1. The complete set of HEDR Integrated Codes is collectively called HEDRIC. The progression for estimation of doses via the Columbia River pathway is shown in Figure 1.2. In the figures, the individual computer models are shown as boxes. Intermediate data transfers are listed between the boxes. It would be ideal to validate the output of each model at each of the intermediate points (i.e., in the areas between the boxes), but historical information is not available for all intermediate areas. However, because the intermediate information near the end of the computations is based on information calculated at earlier points, it has sometimes been possible to infer a validation for earlier information from a validated later step. Although there is a potential for compensating errors, the process of attempting to validate numerous intermediate points, as well as end points, helps build confidence in the final results.

The historical measurement information may be used in a number of ways. In some cases, individual measurement values must be used to represent contamination over a large area or over a long period. In other cases, several data points collected over a small area may be combined to provide a measured distribution of radionuclide deposition for a certain time, or several data points collected at several places over a brief time period may be combined to provide a distribution of a deposition pattern in space. Some of the HEDR computational models provide output distributions of estimated values to account for uncertainty. Others, such as the river dose model, provide only single values. Therefore, the possible comparisons of estimated with measured values include distributions against point values, point values against point values, and distributions against distributions. The individual validation exercises must account for these permutations and provide appropriate statistical interpretations.

1.4 Available Data Sets

Several applicable sets of historical measurements have been identified. Some of these are Hanford Site historical measurements, summarized and reported earlier (e.g., Denham et al. 1993a) or prepared but not yet published by the HEDR Project (e.g., "Scenario H" for VAMP). Some consist of Hanford Site occupational records, such as the Site's whole body counting records

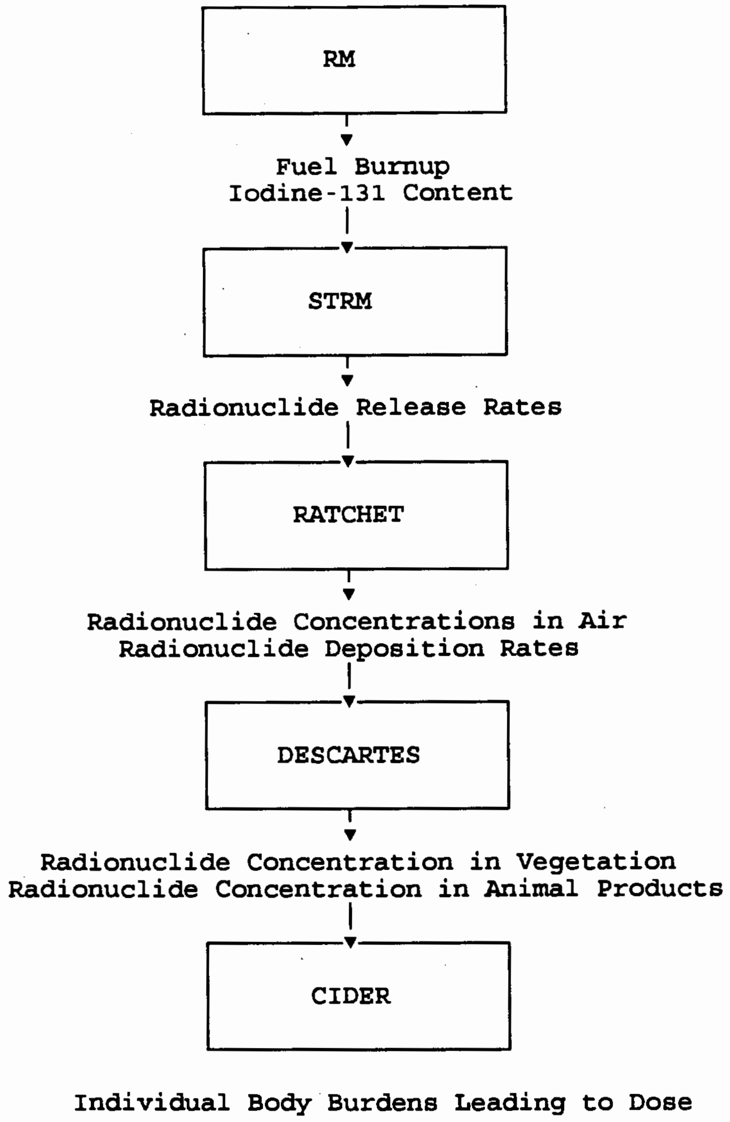

Figure 1.1. HEDR Integrated Codes and Intermediate Calculated Data Used to Estimate Individual Dose from the Atmospheric Pathway

(e.g., Swanberg 1962). Others have been published by HEDR staff, such as the historical "thyroid count data" (Ikenberry 1991). A list of potential data sets was provided to the TSP.[a] The subset of that list selected for detailed investigation is presented in Table 1.1. None of these data sets were used during the development of the models being validated.

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[a] Letter (HEDR Project Document No. 07930008), "Hanford Environmental Dose Reconstruction Project Model Validation Strategy," from D. B. Shipler (Battelle, Pacific Northwest Laboratories), to J. E. Till (HEDR Technical Steering Panel), and M. R. Donnelly (Centers for Disease Control and Prevention), March 5, 1993.

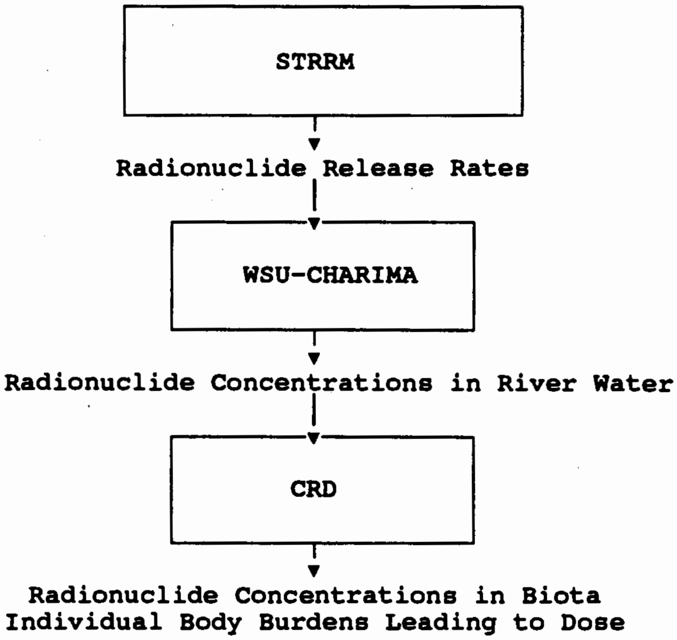

Figure 1.2. Computer Codes and Intermediate Calculated Data Used to Estimate Individual Dose from the Columbia River Pathway

Some of the data sets contain information sufficient to contribute directly to the validation of individual components of the HEDR computational system; e.g., the data collected during the 1963 accidental release from the Plutonium-Uranium Extraction (PUREX) Plant (Soldat 1965). This data set includes direct measurements of the releases from the PUREX stack; measured iodine-131 concentrations in air, vegetation, and milk from cows grazing in the area; and measured thyroid counts of children drinking the locally produced milk. Each component of this data set can be used directly for comparisons. In contrast, the iodine-131 thyroid counts of workers taken in the late 1940s are directly useful only for comparison with the CIDER output. However, if the CIDER estimates are correct, they imply that the entire system, from radionuclide release through transport and accumulation to exposure, is reasonable. Validation exercises may thus be appropriate at several levels. The selected procedures described in the following sections are designed to incorporate these various levels.

1.5 Data Quality Objectives

The International Atomic Energy Agency (IAEA) recommends that performance standards be established prior to validation testing (IAEA 1989, p. 22). The collected data quality objectives (DQOs) described in the HEDR Model Validation Plan (Napier et al. 1993, p. 1.3) essentially set that standard. The model validation activities address the DQOs of most of the technical tasks on the HEDR Project. Comparisons of estimated versus historical measurements must be made, and the general objective is that the measurements and estimates compare to within a factor of 3. The activities described in this report show that this objective is met.

Table 1.1. Data Sets Appropriate for Validation of Applicable Portions of the HEDR Dose Estimation Process

Fuel burnup records (Section 2.0)
- RM iodine-131 contents in fuel

Iodine-131 concentrations in vegetation, 1946 (Sections 3.0, 4.0)
- STRM—RATCHET—DESCARTES integrated vegetation concentrations

Iodine-131 concentrations in air, vegetation, 1949 Green Run release (Section 5.0)
- STRM—RATCHET—DESCARTES vegetation concentrations

Iodine-131 concentrations in air, vegetation, milk, and children, 1963 uncontrolled release (Section 6.0)
- RATCHET—DESCARTES environmental media concentration
- CIDER body burden

Krypton-85 concentrations in air, 1984-1988 (Section 7.0)
- RATCHET monthly average air concentrations

Iodine-131 worker thyroid counts, 1940s (Section 8.0)
- STRM—RATCHET—DESCARTES—CIDER thyroid burdens

Water-surface elevations and discharge rates of Columbia River (Section 9.0)
- WSU-CHARIMA hydraulics, dilution, and travel time

Radionuclides in Columbia River, 1960s (Section 10.0)
- STRRM—WSU-CHARIMA concentrations in water

Radionuclide concentrations in fish and shellfish (Sections 11.0, 12.0)
- STRRM—WSU-CHARIMA—CRD concentrations in fish and shellfish

Zinc-65, sodium-24 worker whole body counts, 1959-1972 (Section 13.0)
- STRRM—WSU-CHARIMA—CRD body burdens

VAMP data sets and scenarios (Section 14.0)
- RATCHET—DESCARTES—CIDER environmental media concentrations, body burdens

A matrix listing all of the HEDR models and the particular validation exercises that demonstrate the fulfillment of the DQOs is provided for the atmospheric release models in Table S.1 and for the Columbia River release models in Table S.2. As indicated in these tables, the estimates made by the atmospheric models, particularly those representing the closest surrogates to dose, are generally within a factor of 3 or better of the measurements. The estimates made by the river pathway models are almost uniformly within a factor of 3 of the measurements.

1.6 Document Overview

Sections 2.0 through 13.0 describe the specific procedures used to qualify the existing data sets, estimate environmental contamination levels or doses, and compare the estimated and measured data. The results of the comparisons are presented graphically and discussed. For those comparisons for which the environmental historical measurements have not been previously published, appendixes are provided containing the raw data.

The comparison of the HEDR models through benchmarking with other international models is described in Section 14.0. The IAEA's Coordinated Research Program on Validation of Radionuclide Transport Models for Terrestrial, Urban, and Aquatic Environments (VAMP) is discussed in that section.

Conclusions about the suitability of the models for use in the HEDR Project are provided in Section 15.0.

2.0 Reactor Model Burnup Estimates

The main output from the reactor model RM is the content of iodine-131 in the fuel at discharge. The Hanford Site reactors were built for the production of plutonium using neutrons from the fission of uranium. Iodine-131 is a product of the uranium fission. The content of iodine-131 in the fuel, however, was never measured directly so that direct validation is not possible. Other information was recorded, though, so calculations based on known reactor physics can provide highly reliable estimates of the iodine-131 content of the discharged fuel (e.g., see Bell and Glasstone 1970, Section 10.2). The primary recorded data were the average reactor power levels and the burnup (the product of power level and time, also called exposure) of the fuel at discharge. These two types of data define the amount of any fission product in the fuel at discharge. If the reactor model accurately estimates the burnup of discharged fuel, the iodine-131 content of the fuel can be known with little uncertainty and the model is valid for use.

The reactor model is described by Heeb (1993, Appendix A), who also summarizes comparisons of the estimated discharge burnup with measured burnups from Hanford Site P-Department Reports (General Electric Company 1948). The comparisons are depicted in Heeb's Figures A.2, A.3, and A.4 (1993). Figure A.2 from Heeb is reproduced here as Figure 2.1. In this figure, the height of the individual columns represents the burnup of the discharged fuel, the width of the columns represents the quantity of fuel discharged per batch (in tons), and the shaded area defines the uncertainty in the estimation of burnup by the model. Heeb (1993, p. A.2) notes that:

> In general, the computed and measured exposure matches fairly well. Of the 226 discharges, 92.5% have estimated exposures within 10% of the reported exposures and 99.9% have estimated exposures within 15% of the reported exposures. Maximum discrepancies are within the ±15% range.

9,11,14 *The burnup is only one of several parameters that go into the calculation of radionuclide concentration in fuel discharged from the reactors. These other parameters are inputs to the approach to determining radionuclide quantities captured in the computer code ORIGEN2 (Croff 1980) used by Heeb (1993). Potential uncertainties in the ORIGEN2 approach were analyzed by Heeb (1991). The overall uncertainty in all of the ORIGEN2 results was determined to be less than 3.6 percent (Heeb 1991, Section 3.3; Heeb 1994, Section 4.0). This small uncertainty, superimposed on the minimal discrepancies induced by the reactor model, does not change the conclusions noted above.* For the purposes of validating the reactor model, this information is considered to be sufficient, and no additional work was proposed (Napier et al. 1993).

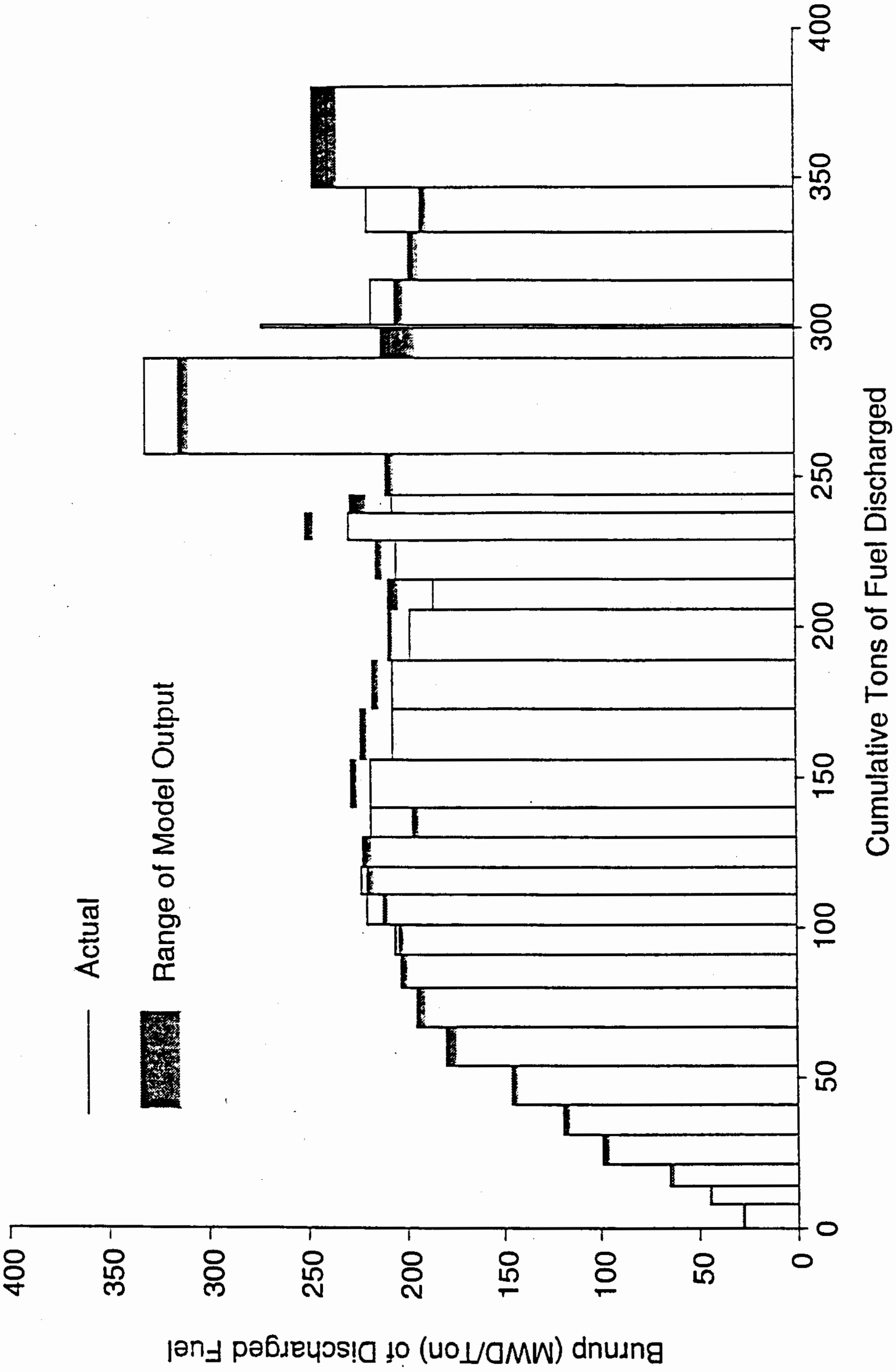

Figure 2.1. Estimated and Measured Fuel Burnup from Hanford Site B Reactor (Heeb 1993)

3.0 Time-Sequence Vegetation Contamination Comparisons

Beginning in late 1945, a substantial number of vegetation samples were collected regularly at standardized locations in the cities of Richland, Kennewick, Pasco, and Benton City, Washington. Several locations within each city were routinely measured. The most extensive data set for these locations was collected in 1946, the year of second-highest iodine-131 emissions. These data provide the possibility of validating a series of estimates over time for these locations.

All transport, accumulation, and dose-related estimates have been performed in HEDRIC on a spatial grid system. The grid consists of a rectangular set of cells numbered sequentially, beginning in the southwest corner. The measurement sequences for Richland fall within two HEDR atmospheric dispersion cells (469 for north Richland and 442 for south Richland); all of the measurements for Pasco and Kennewick fall within a single grid cell (443); and the measurements for Benton City are on the corners of two cells (467 to the north and 440 to the south). The northern-most of the Benton City cells was selected for analysis as more representative because most of the more southern cell is behind Rattlesnake Mountain. Rattlesnake Mountain shields that cell from Hanford Site emissions.

3.1 Assessment Questions

The assessment question addressed is, "What were the time histories of daily concentration of iodine-131 in vegetation (sagebrush) in north Richland, south Richland, Kennewick/Pasco, and Benton City during 1946?"

3.2 Available Time-Sequence Vegetation Data

Hanford Site historical measurements of iodine-131 in vegetation are available to the HEDR Project for the period beginning in mid-1945 through the present. The data for 1945-1947 are published in Denham et al. (1993a). The data for 1948-1951 are published in Hanf et al. (1993). To account for biases that were historically not determined, HEDR staff developed conversion and correction factors. These are published in Mart et al. (1993) for the 1945-1947 data and in Denham et al. (1993b) for the 1948-1951 data. Although the samples used to measure iodine-131 historically were most often labeled "vegetation," Denham et al. (1993a) note that the samples were usually sagebrush.

These vegetation data are essentially all that are available from mid-1945 through 1950, the time period of high interest for atmospheric releases. The data are uneven in geographic coverage (most monitored locations are either on or close to the Hanford Site) and over time (the monitoring, with a few notable exceptions, was not routinely performed at repeated locations). There are over 3500 samples reported for the year 1946. Of these, Richland has a complete history consisting of a total of about 550 values; Pasco and Kennewick combined have about 645; and Benton City has about 200 values.

To illustrate the relative poverty of this data source, consider that of the 3500 vegetation concentrations reported, about 1450 were taken on the Hanford Site and about 1400 were taken in the Tri-Cities/Benton City area. Another 175 or so were taken at various points along Van Giesen Road, west from Richland. This leaves fewer than 500 samples taken throughout the remainder of the Pacific Northwest over the course of the year. A total of 7 were taken in Walla Walla, Washington; 13 in Spokane, Washington, over a 2-day period; 5 in Toppenish, Washington; 10 in The Dalles, Oregon, at various times; 3 in Pendleton, Oregon; 6 in Weston, Oregon; etc. No location had more than 15 samples taken, usually in only one to two sampling expeditions. The remainder of the data, outside the immediate vicinity of the Hanford Site, is not sufficient for long-term trend analysis.

In addition, many of the data points appear to be reported in more than one source; i.e., there are significantly fewer values actually available than the 3500 reported. Denham et al. (1993a) provide original information in the form of laboratory counting records where possible. However, in some instances, secondary references such as internal Hanford Site monthly or quarterly reports had to be used.

15,20 A third source of indeterminable *authorship* and quality is also available. Early in the HEDR Project, a hand-written compilation of data from the mid-1940s was found. This is referred to within the project as the "vegetation correlation data sheets." This compilation was evidently prepared in the late 1940s or early 1950s. The data reported in it obviously duplicate much of what was found in the original counting laboratory records (dates and locations), but it also obviously incorporates many of the later correction factors used to convert from counting data to concentration data (Mart et al. 1993). *Extensive efforts were made in 1988 and 1989 to determine the origin of the "vegetation correlation sheets."* Because the project staff have not been able to track the source of these data, it has not been relied upon for most of the project. However, this source does contain some information (particularly data on concentration of iodine-131 in vegetation during the latter half of 1946) that is not available from other sources. Therefore, data from this source are considered in the validation effort. Wherever used, these data are distinguished from those drawn from other sources. Appendix A provides all the 1946 vegetation data used in the validation comparisons.

3.3 Models Evaluated

Vegetation historical measurements for the Tri-Cities and Benton City areas in 1946 were compared directly with output of the DESCARTES accumulation model, which includes a module for estimating iodine-131 concentrations in sagebrush. This comparison provided indirect validation of the RM and STRM source terms and the RATCHET dispersion model, and partial validation of DESCARTES.

3.4 Evaluation of Results

Input was provided to the DESCARTES code from the STRM/RATCHET output database. Output from DESCARTES constituted the 100 daily and monthly realization values for concentration of iodine-131 in sagebrush in north Richland, south Richland, Kennewick/Pasco, and Benton City. The resultant daily estimated distributions are compared with the available daily measured point values in Figures 3.1, 3.2, 3.3, and 3.4 for each location, respectively. The resultant monthly estimated distributions are compared with average monthly measurement values in Figures 3.5, 3.6, 3.7, and 3.8.

Several points are evident in the figures illustrating the daily sequences of iodine-131 concentration in vegetation. First, the trend of the estimates for all locations roughly follow the measurements. Seasonal patterns are evident of high concentration in winter (January, February, and December) and relatively lower concentration in the mid-summer's warmer months. Second, the highest quality measurements (represented by the solid black dots) are not available for the end of the year. The secondary references and "vegetation correlation data sheets" must be relied on for that period. Third, the models appear to underestimate the concentrations, particularly in the winter at both the beginning and end of the year. Fourth, the estimates best track the measurements immediately downwind of the Hanford Site in Richland and have a larger discrepancy (generally underestimates) at the Benton City location, which is influenced by the proximity of Rattlesnake Mountain.

With the exception of January, the estimated and measured time sequences at each location are all within an order of magnitude throughout the year of 1946. They are closest during the important summer grazing-season, with all monthly measurements being within factors of 3 of estimated medians (with one exception in south Richland and two in Benton City). Each time sequence shows the largest deviation between estimates and measurements during the winter months, with January and December approaching factors of 10 underestimates at all locations. For those cases of greatest underestimate, the monthly means of the measurements are all within factors of 3 or less of the extremes of the estimates.

Deposition of iodine-131 on vegetation during December 1945, just prior to the period considered, was the highest ever recorded. Several potential deposition mechanisms not included in the RATCHET and DESCARTES models may be postulated. Damp weather, including fog, mist, and hoarfrost, may increase the deposition or retention of iodine-131 on vegetation (Sehmel 1984, p.12-2.4). Colder weather may also influence the partitioning of iodine-131 between the organic, inorganic, and particulate forms. Unfortunately, detailed meteorological records for the winter of 1945-1946 are not available (Stone et al. 1983, pp. IV-2, IV-11), so a detailed investigation is not possible.

10,11,16 *Retention of material deposited on vegetation is modeled in DESCARTES, which incorporates a weathering rate. The rate is a stochastic parameter and is not a function of season. The possibility that weathering could occur at different rates in winter and summer, and that a reduced rate of weathering in winter could account for the underestimation during those times, was considered.*

An exploratory calculation was made with the DESCARTES code with the weathering rate set to zero (the effective upper bound assumption that iodine-131, once deposited on sagebrush leaves, remains there until it decays). The results of this calculation are shown in Figures 3.9 and 3.10 for North Richland and Kennewick/Pasco, respectively. The net result of neglecting weathering is an effective doubling of the concentration of iodine-131 on sagebrush leaves. This increase is also applicable to the South Richland and Benton City locations. For the locations investigated, this results in almost all of the measurements falling within the range of the estimates. However, the mean and median estimates of concentration in vegetation are still lower, by about a factor of five, than

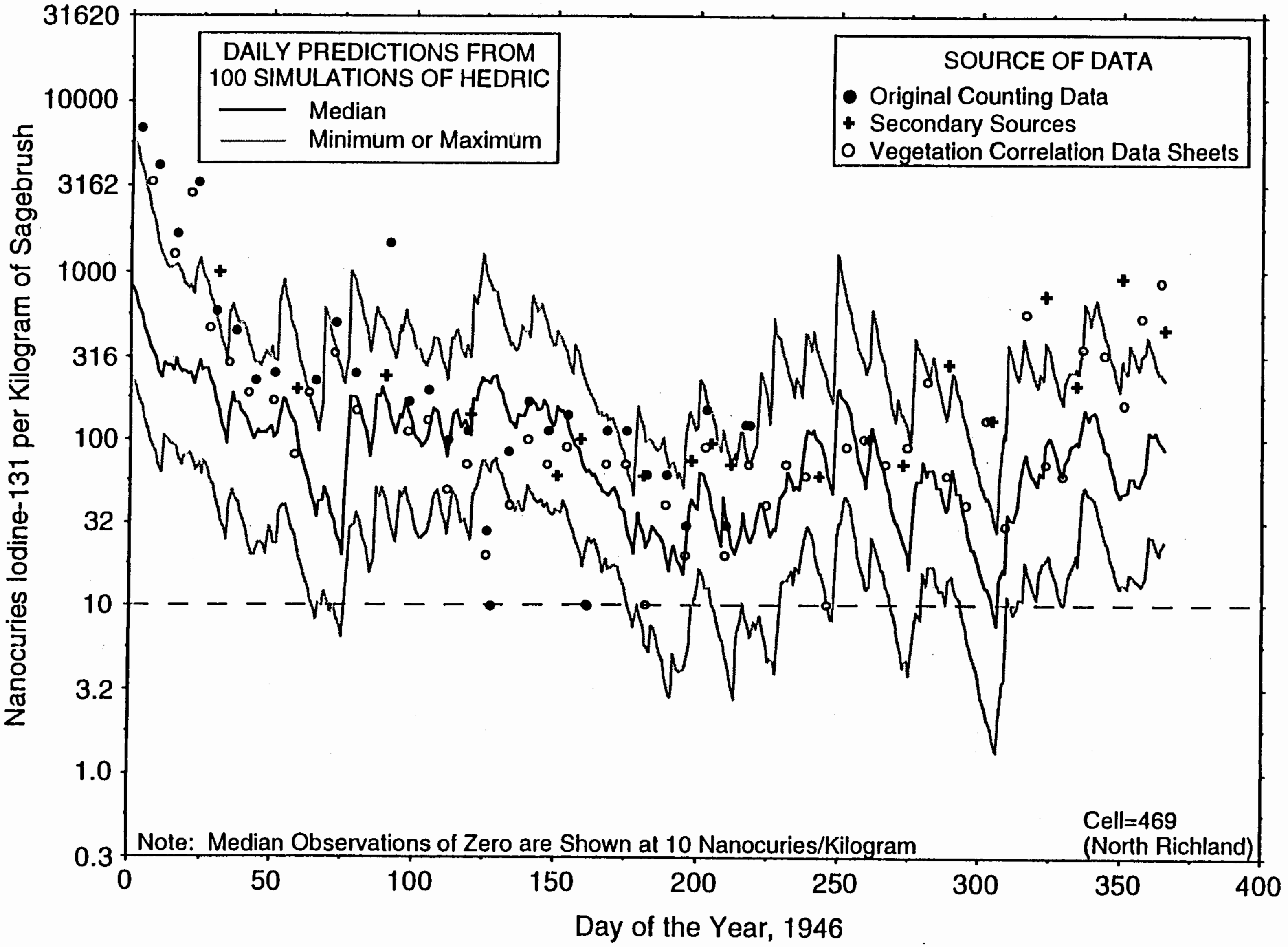

Figure 3.1. Comparison of Daily Estimates and Measurements of Iodine-131 Concentration in Sagebrush for North Richland, 1946

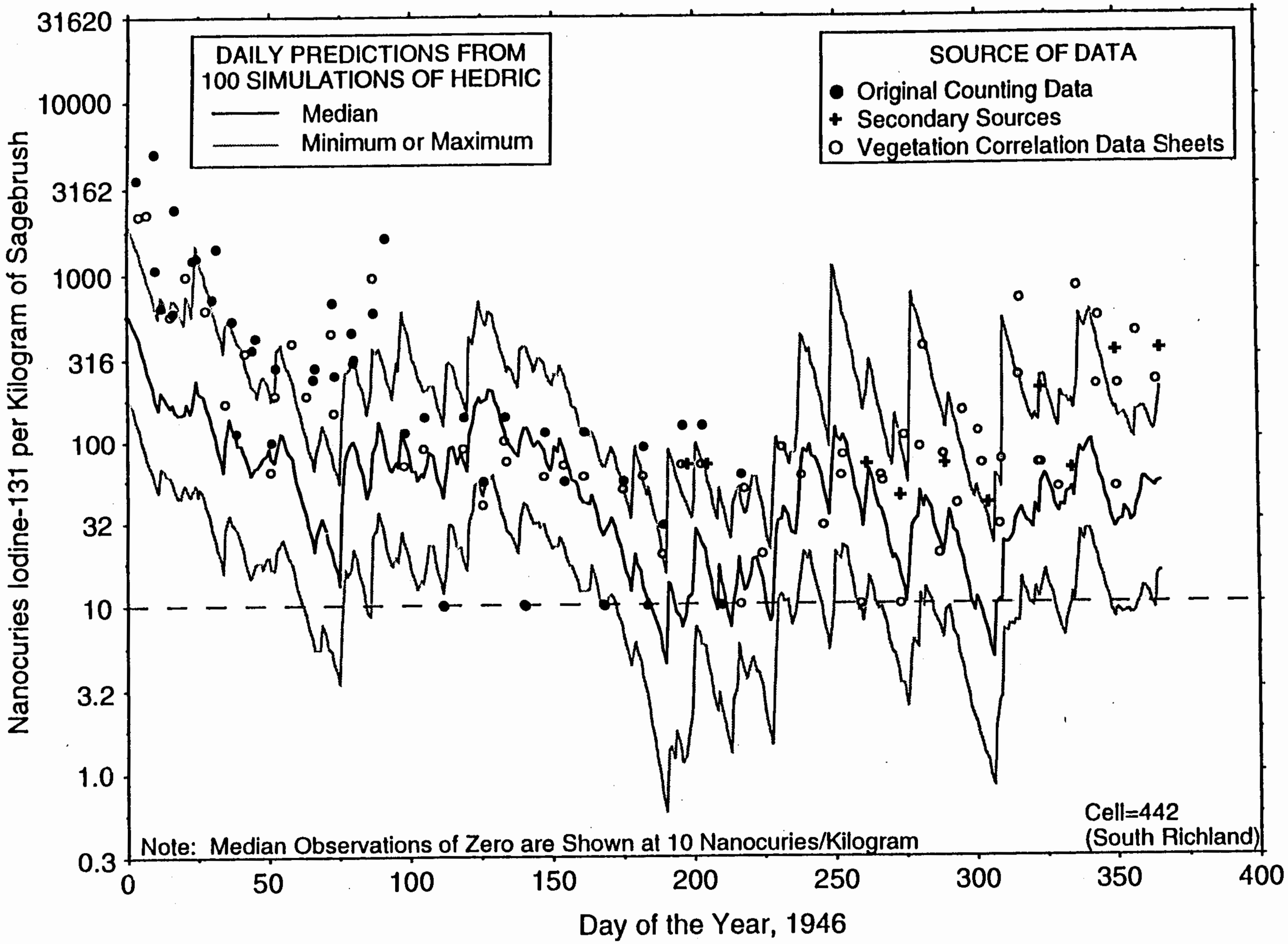

Figure 3.2. Comparison of Daily Estimates and Measurements of Iodine-131 Concentration in Sagebrush for South Richland, 1946

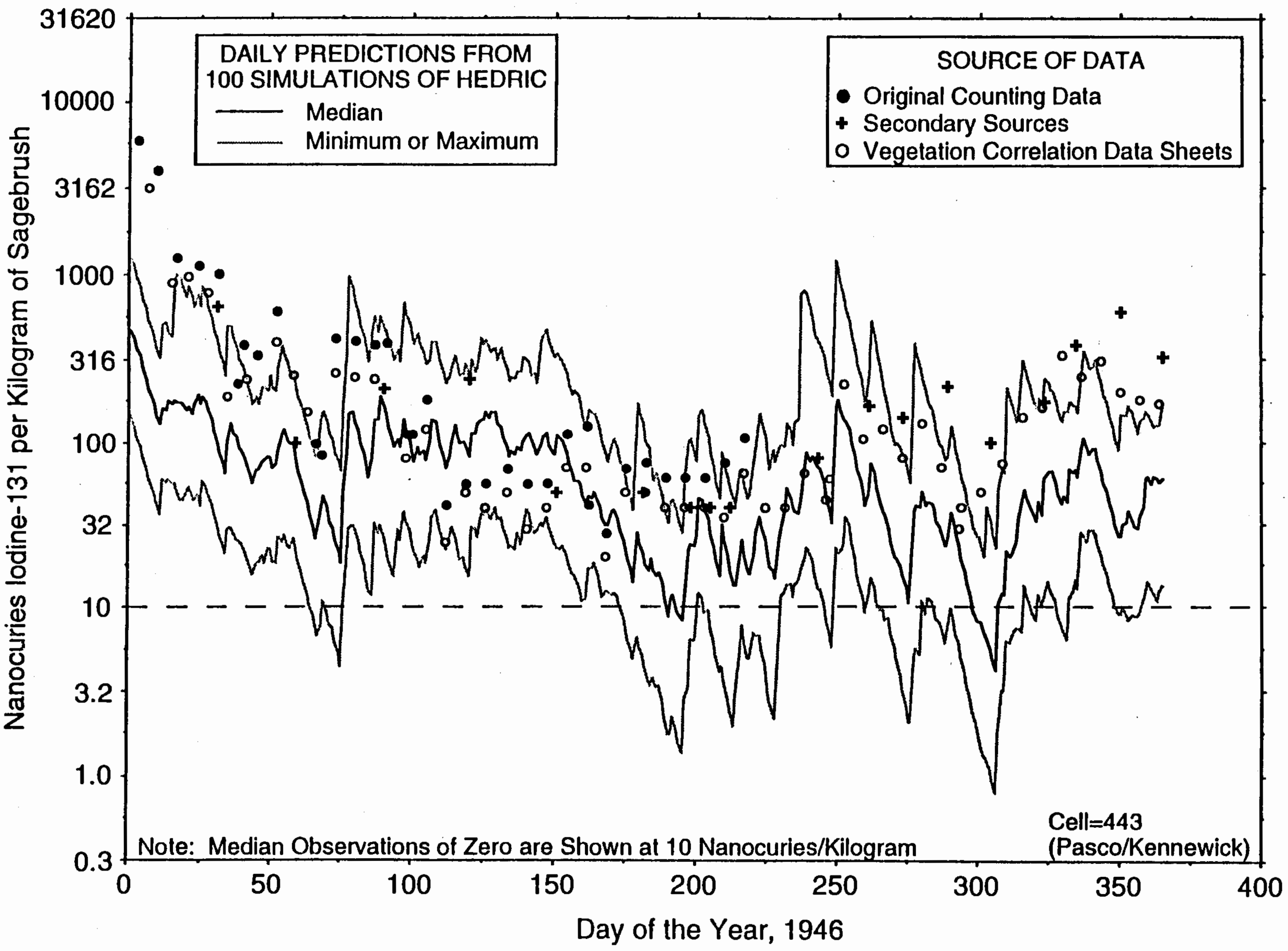

Figure 3.3. Comparison of Daily Estimates and Measurements of Iodine-131 Concentration in Sagebrush for Kennewick/Pasco, 1946

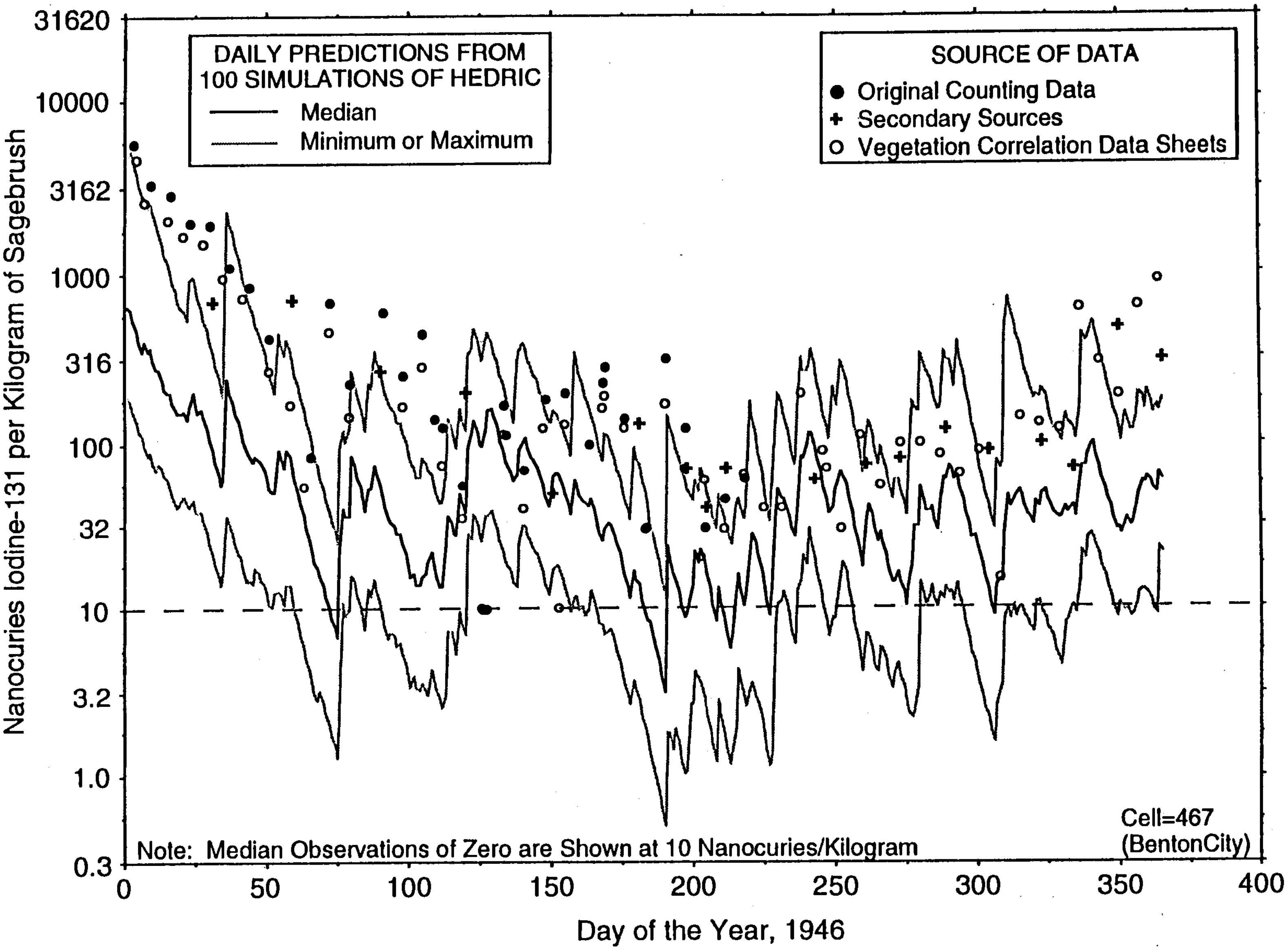

Figure 3.4. Comparison of Daily Estimates and Measurements of Iodine-131 Concentration in Sagebrush for Benton City, 1946

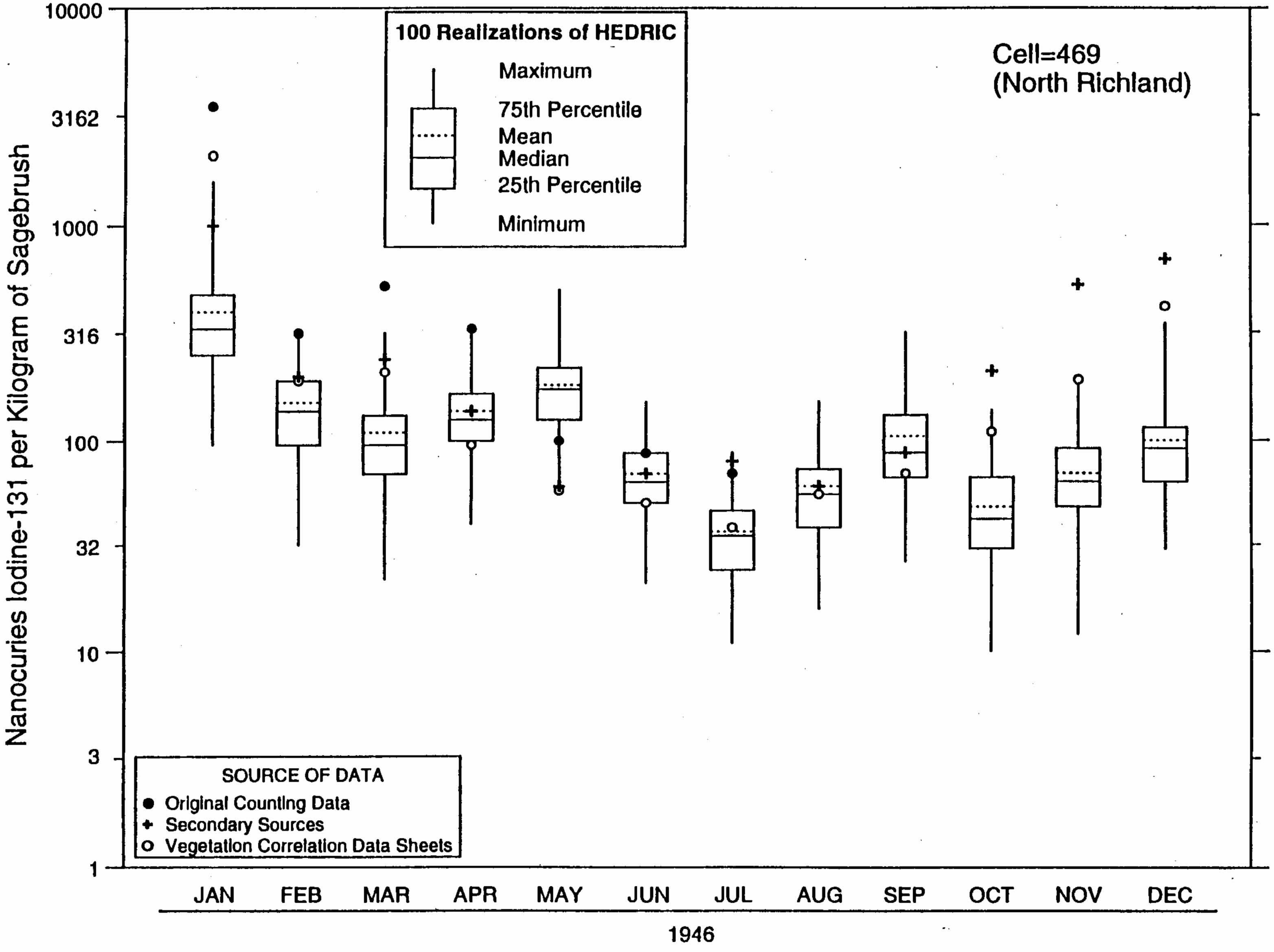

Figure 3.5. Comparison of Monthly Average Estimates and Measurements of Iodine-131 Concentration in Sagebrush for North Richland, 1946

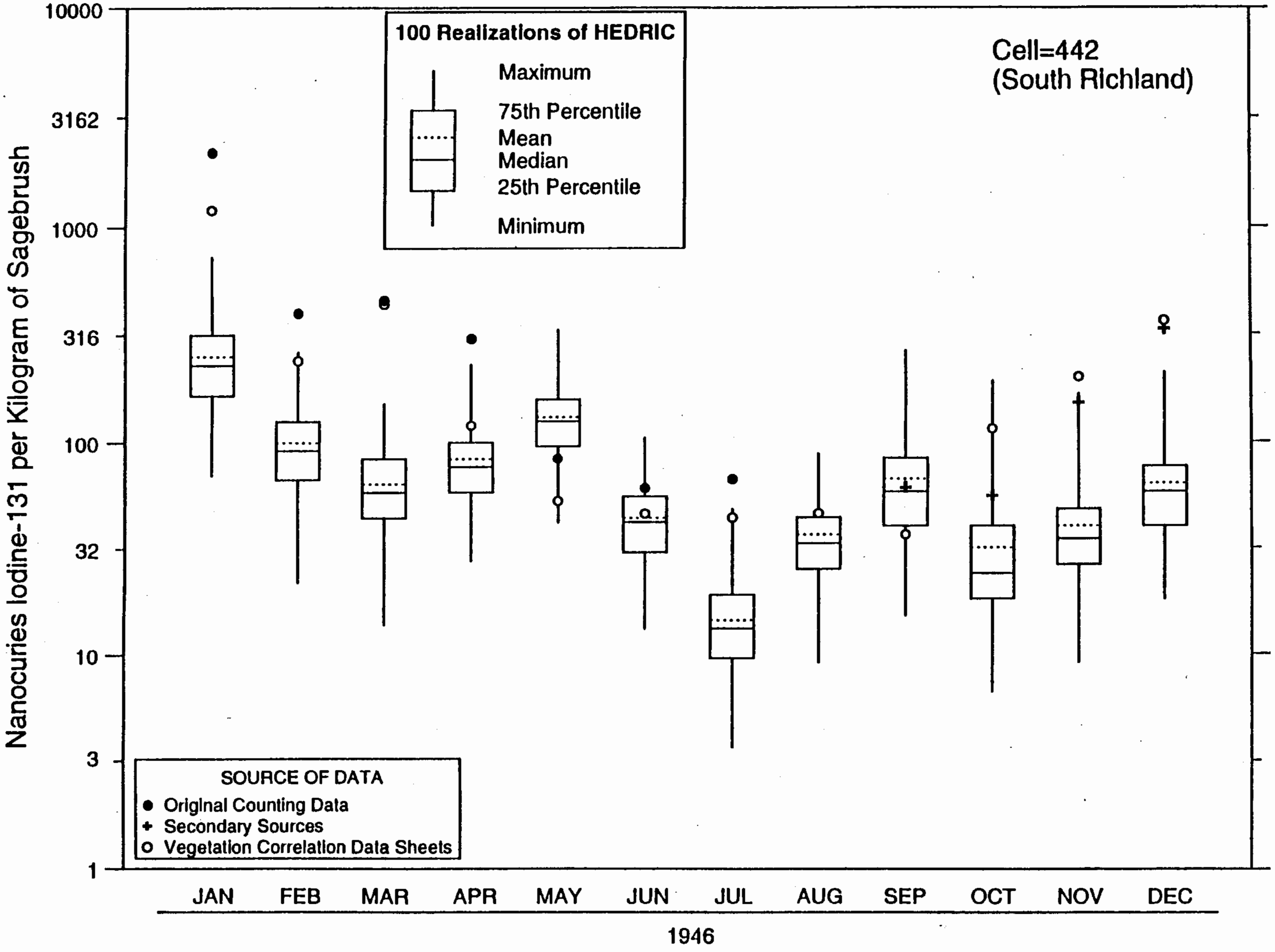

Figure 3.6. Comparison of Monthly Average Estimates and Measurements of Iodine-131 Concentration in Sagebrush for South Richland, 1946

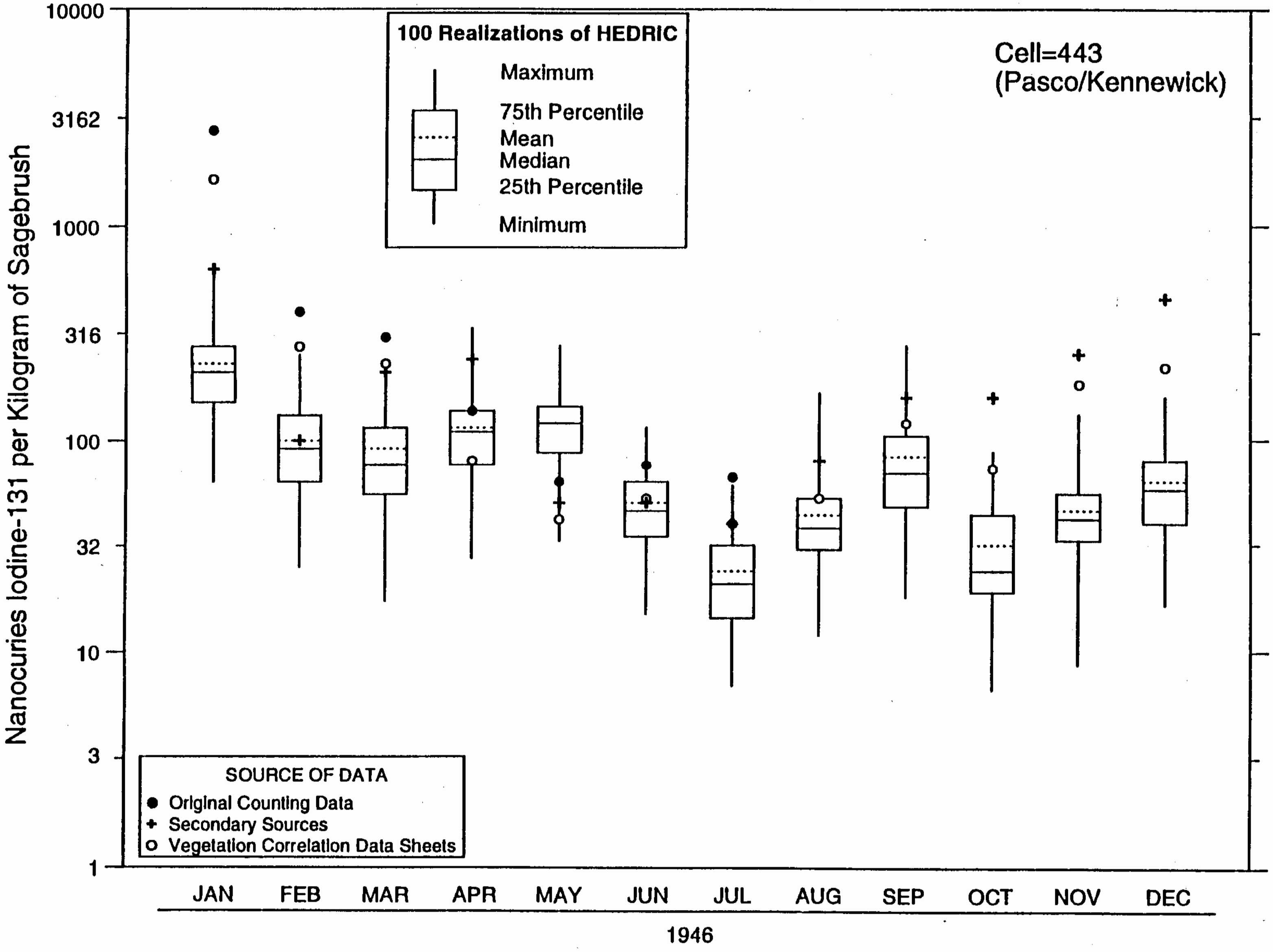

Figure 3.7. Comparison of Monthly Average Estimates and Measurements of Iodine-131 Concentration in Sagebrush for Kennewick/Pasco, 1946

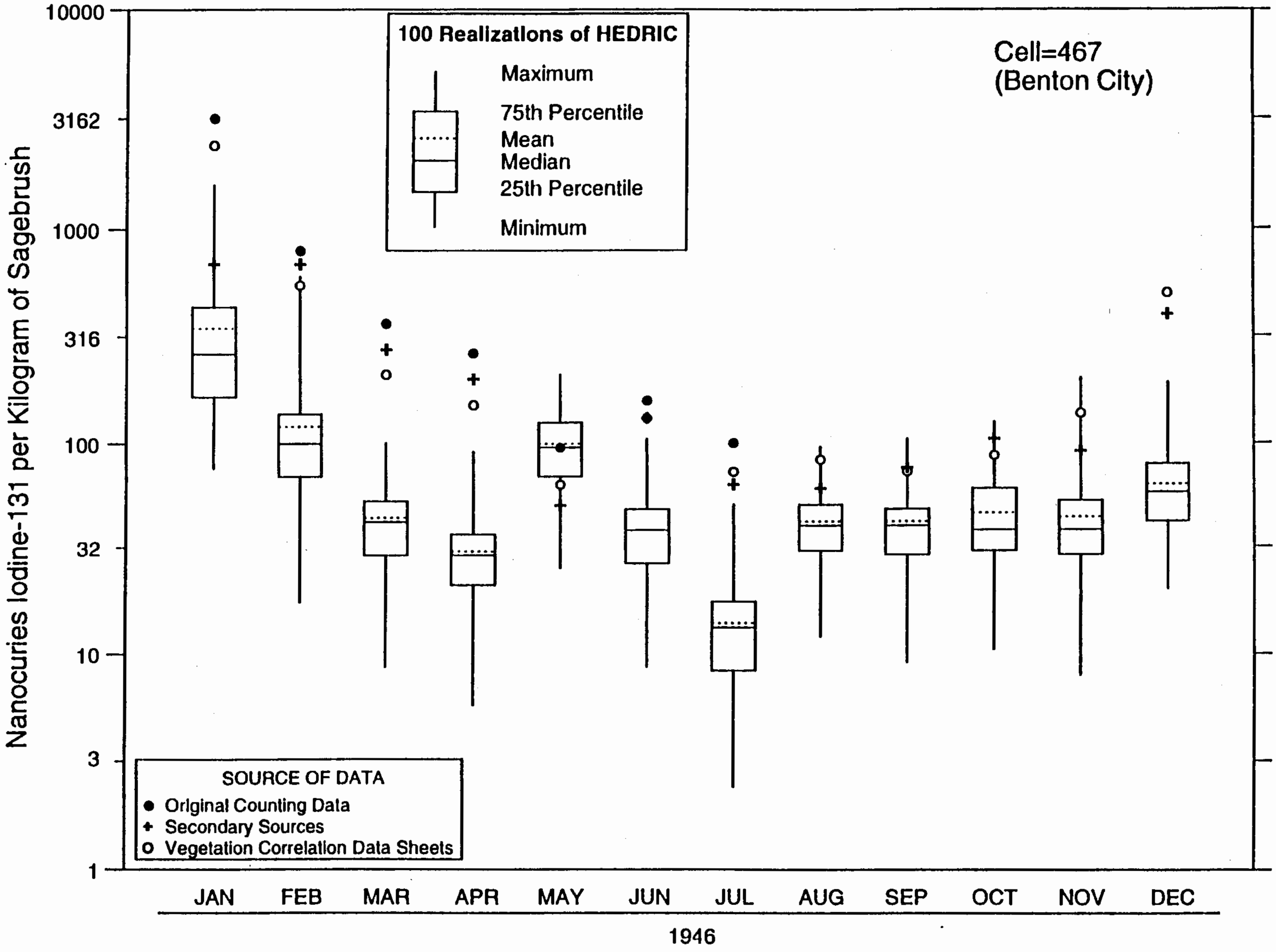

Figure 3.8. Comparison of Monthly Average Estimates and Measurements of Iodine-131 Concentration in Sagebrush for Benton City, 1946

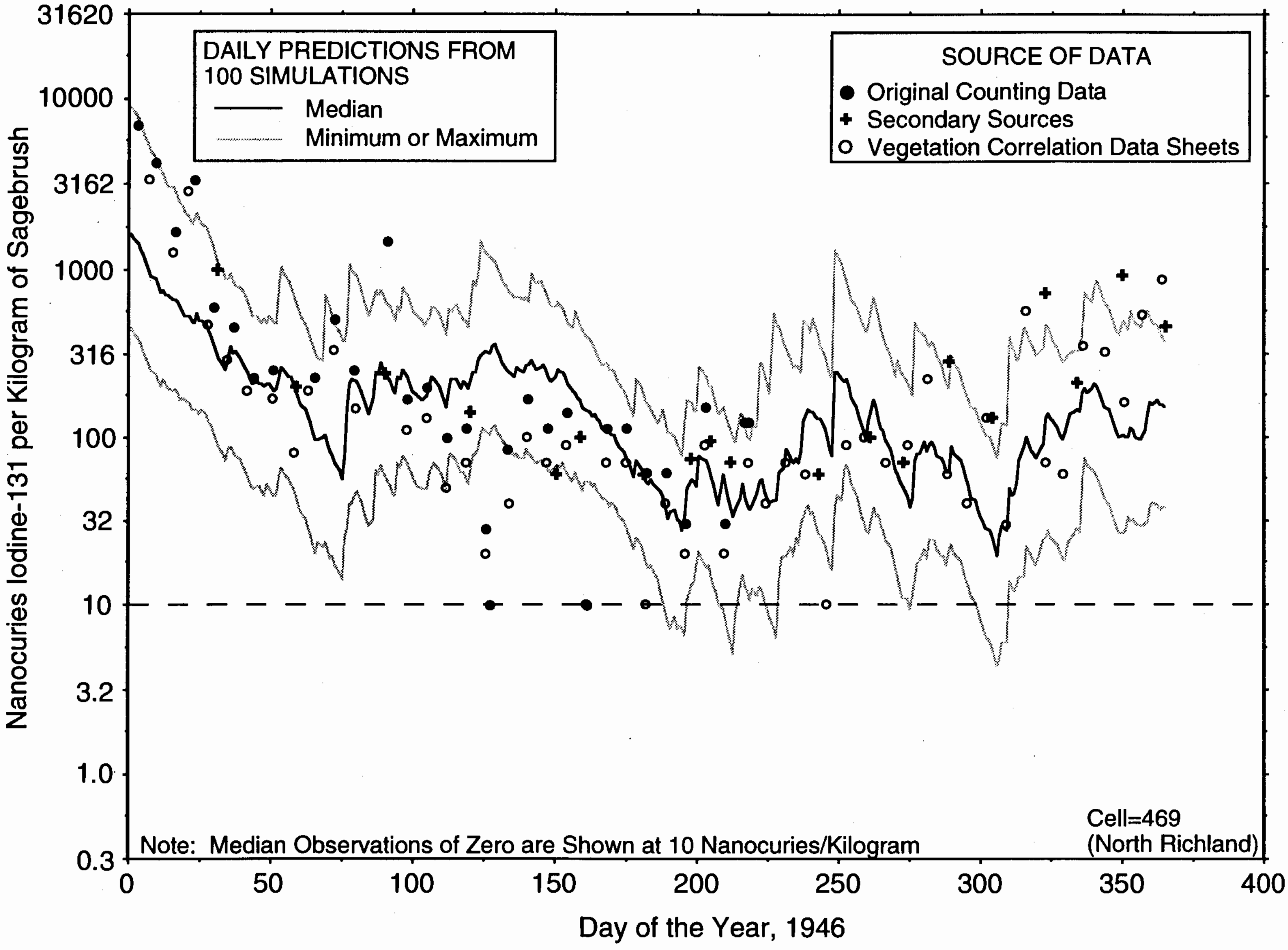

Figure 3.9. Comparison of Daily Estimates and Measurements of Iodine-131 Concentration in Sagebrush for North Richland, 1946

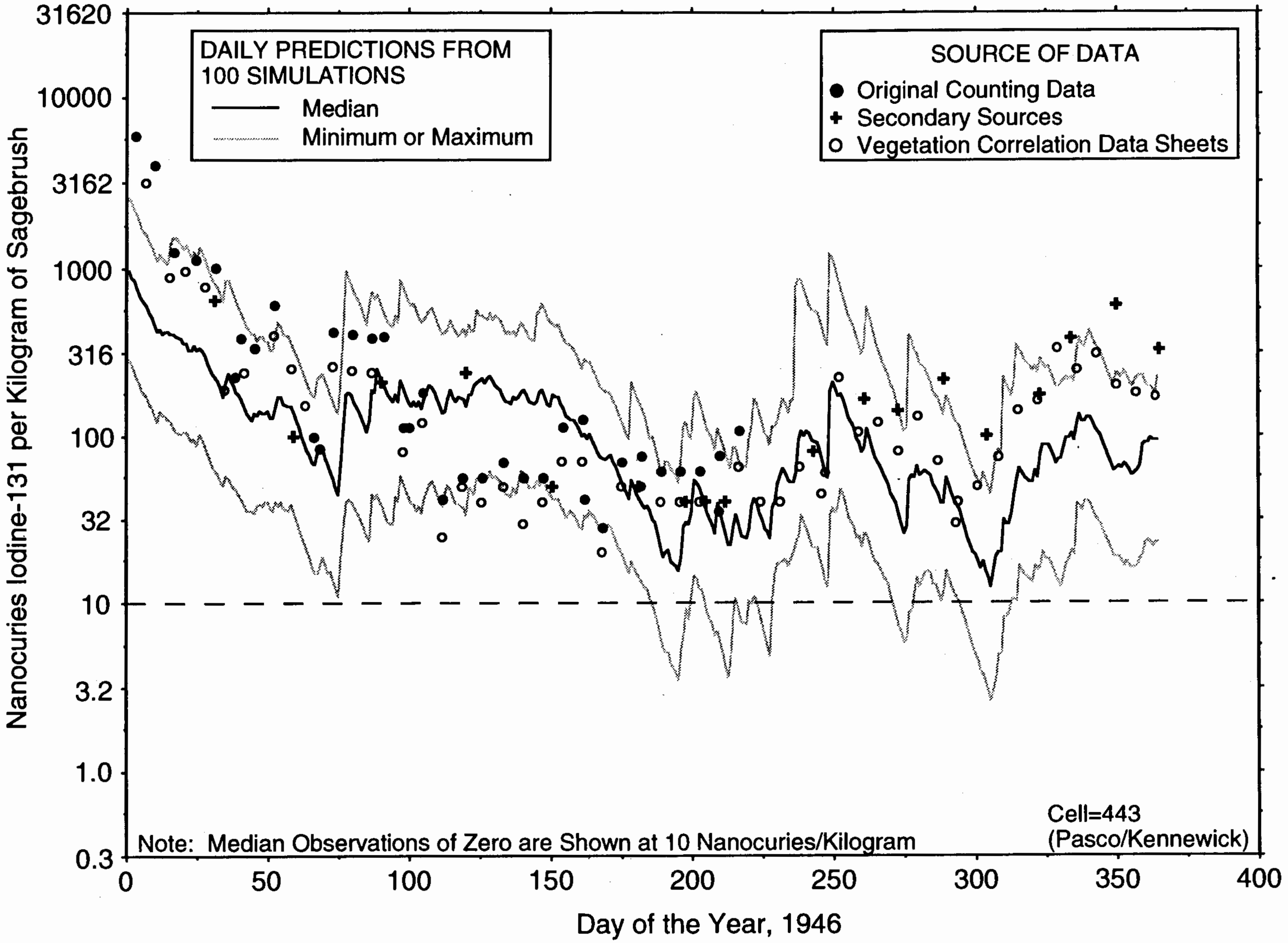

Figure 3.10. Comparison of Daily Estimates and Measurements of Iodine-131 Concentration in Sagebrush for Pasco/Kennewick, 1946

the measurements for the December/January periods. It is apparent that weathering may partially contribute to the underestimation of radionuclide concentration during the winter months, but weathering alone is insufficient to explain the discrepancies, and additional deposition mechanisms must be invoked as suggested above.

Ideally, the project would prefer to use the traceable information provided in Denham et al. (1993a) and Hanf et al. (1993), represented by the solid circles and crosses in Figures 3.1 through 3.4. However, it is obvious from these figures that for the latter months of 1946, only data from the secondary sources (represented by the crosses) and from the "vegetation correlation data sheets" (represented by the open circles) are available. But comparison of the pairs of data points for the "vegetation correlation data sheets" and the traceable information shows that when both sets of information are available in 1946, they actually track very well. The two sources agree to within a few percent. This allows some confidence that the vegetation correlation data sheets may be reasonably reliable for the remainder of the period.

In 1946, contamination was measured with a Geiger-Muller detector directly on the vegetation samples (Mart et al. 1993). Gilbert et al. (1992) indicate that the uncertainty in the conversion of these count data to concentration could be a factor of up to 4 for this period. Only the deterministic "best estimate" of Mart et al. (1993) has been used in these analyses. Incorporation of this uncertainty in the analyses would indicate a greater overlap than is apparent in the figures.

4.0 Dispersion/Deposition Footprint, April 13, 1946

Data collected by the Hanford Site monitoring groups in the late 1940s and early 1950s tended to focus on the Hanford Site or adjacent areas. Most detailed monitoring occurred in a few preferred downwind locations (often guided by the availability of good roads). Sweeps of outlying areas were performed at erratic intervals, the first in early 1946. The erratic nature of these efforts is apparent when the data in Denham et al. (1993a) are sorted by location. On January 12, 1946, about 82 samples were taken in the directions of Walla Walla, Washington; Ellensburg-Ritzville, Washington; Toppenish, Washington; and The Dalles, Oregon. About 110 samples extending from Lewiston, Idaho, to Portland, Oregon, and from Moses Lake, Washington, to Pendleton, Oregon, were taken on February 9, 1946. About 83 samples from Ellensburg to Ritzville and from Sprague to Spokane, Washington, and from Umatilla to The Dalles, Oregon, were taken on April 13, 1946. About 114 samples were taken in the southeast-to-northeast quadrant on November 11, 1948. These were the major offsite investigations recorded in the Hanford Site records prior to the multitude of samples before and after the 1949 Green Run (see Section 5.0). Because it is during the growing season that contamination of plant products is most important to dose, only the April 13, 1946, set (taken during "growing season" conditions) is used for validation.

4.1 Assessment Question

The question addressed is, "What was the spatial footprint of iodine-131 deposition on April 13, 1946?" This assessment question addresses the deposition over all measured cells within the HEDR atmospheric domain. The April date is selected to be within the growing season of 1946.

4.2 Available Spatial Deposition Data

It appears from the spatial distribution of the samples taken on April 13, 1946, that three vehicles were sent out with instructions to sample vegetation at intervals on preselected routes. The routes taken by these sampling vehicles are illustrated in Figure 4.1. One vehicle made a loop up the Yakima Valley to Ellensburg, then east to Ritzville. Another went north to Ritzville and then northeast to Spokane. The third went south along the Oregon side of the Columbia River Gorge toward The Dalles.

Concentration measurements of approximately 83 vegetation samples from throughout the region are available. Some of the measurements were taken from within the same HEDR grid cell, so the total number of comparisons that may be made is actually only 72. The evidence indicates that all of the samples taken were sagebrush or shrubs sufficiently similar to be categorized as sagebrush. The concentration data were developed in a manner similar to that for the time sequence data described in Section 3.0: Geiger-Muller detector data converted to concentration. The lower limit of detection was relatively high. One count per minute above background on the detector was equivalent to 2.8×10^{-8} Ci/kg of iodine-131 (Mart et al. 1993).

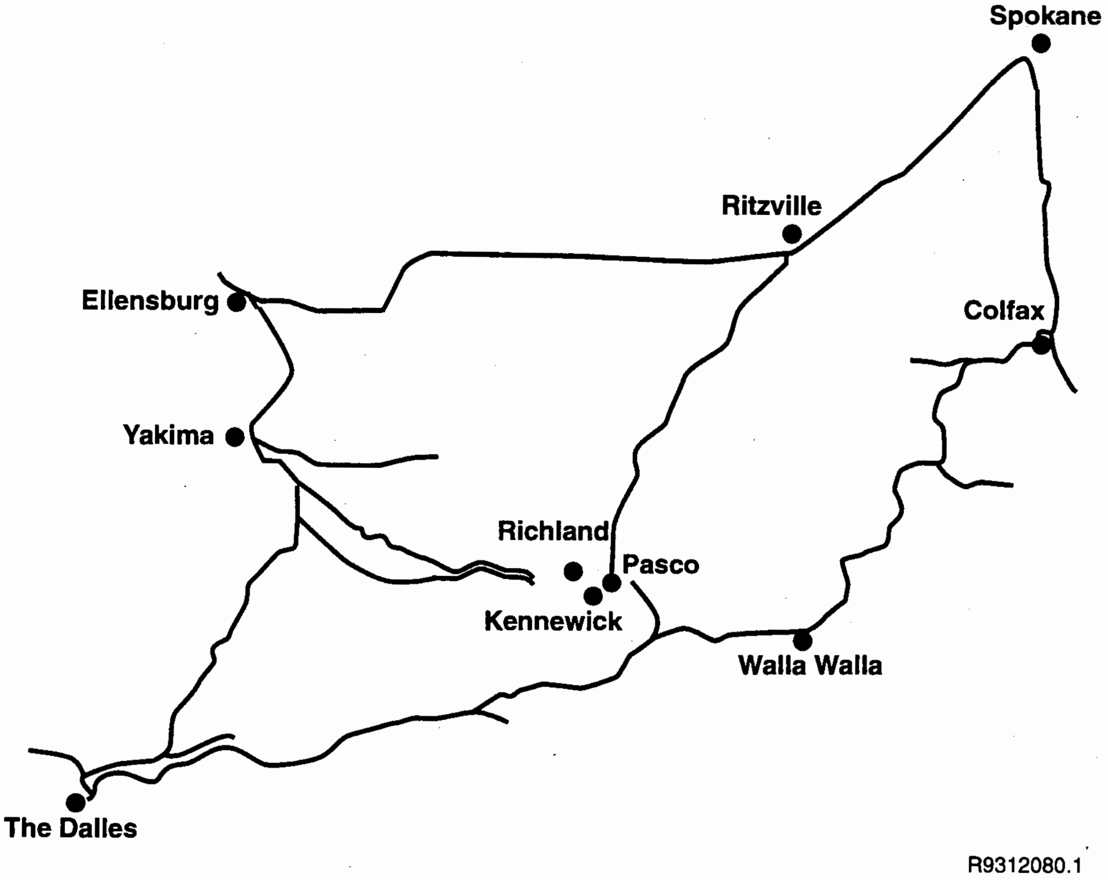

Figure 4.1. Map Indicating Routes Traveled by Vegetation Sampling Teams on April 13, 1946

Summaries of the measured and estimated data for this evaluation are provided in Appendix B. The full database of environmental measurements is described in Thiede and Duncan (1994).

4.3 Models Evaluated

Vegetation historical measurements for the measured areas on April 13, 1946, were compared directly with output of the DESCARTES accumulation model. This provides partial validation of DESCARTES, indirect validation of the RM and STRM source terms, and indirect validation of the RATCHET dispersion model.

4.4 Evaluation of Results

Input was provided to the DESCARTES code from the STRM/RATCHET output database. Output from DESCARTES was the 100 daily realization values for sagebrush concentration at all cells for which historical measurements are available. The resultant daily distributions were compared with the available April 13, 1946 data. To facilitate this comparison, a scoring system (1 to 6) was developed for showing where the measured values fall compared to the distribution of the estimates:

1 - The median measurement falls below the minimum of the estimated range.

2 - The median measurement falls between the estimated minimum and 25th percentiles.

3 - The median measurement falls between the estimated 25th percentile and the median.

4 - The median measurement falls between the estimated median and the 75th percentile.

5 - The median measurement falls between the 75th percentile and the maximum estimated.

6 - The median measurement is greater than the maximum estimated.

This scoring is illustrated in Figure 4.2. The results of applying these scores to the total number of paired measurements/estimates are summarized in Table 4.1. This table indicates that roughly the same number of measurements fall above, within, and below the estimates.

Table 4.1. Application of the Measurement Score to the Measurements for April 13, 1946

Measurement Score	Number of Measurements
1 Below minimum	21
2 Minimum - 25th	4
3 25th - median	4
4 Median - 75th	3
5 75th - maximum	12
6 Above maximum	28
Total	72

The results of the evaluation score are shown in Figure 4.3, plotted on a map of the area at the location of each measurement. The isopleth lines indicate the spatial pattern of the median values of the estimated deposition of iodine-131. The resulting map of scores may be used to look for patterns of agreement over the area.

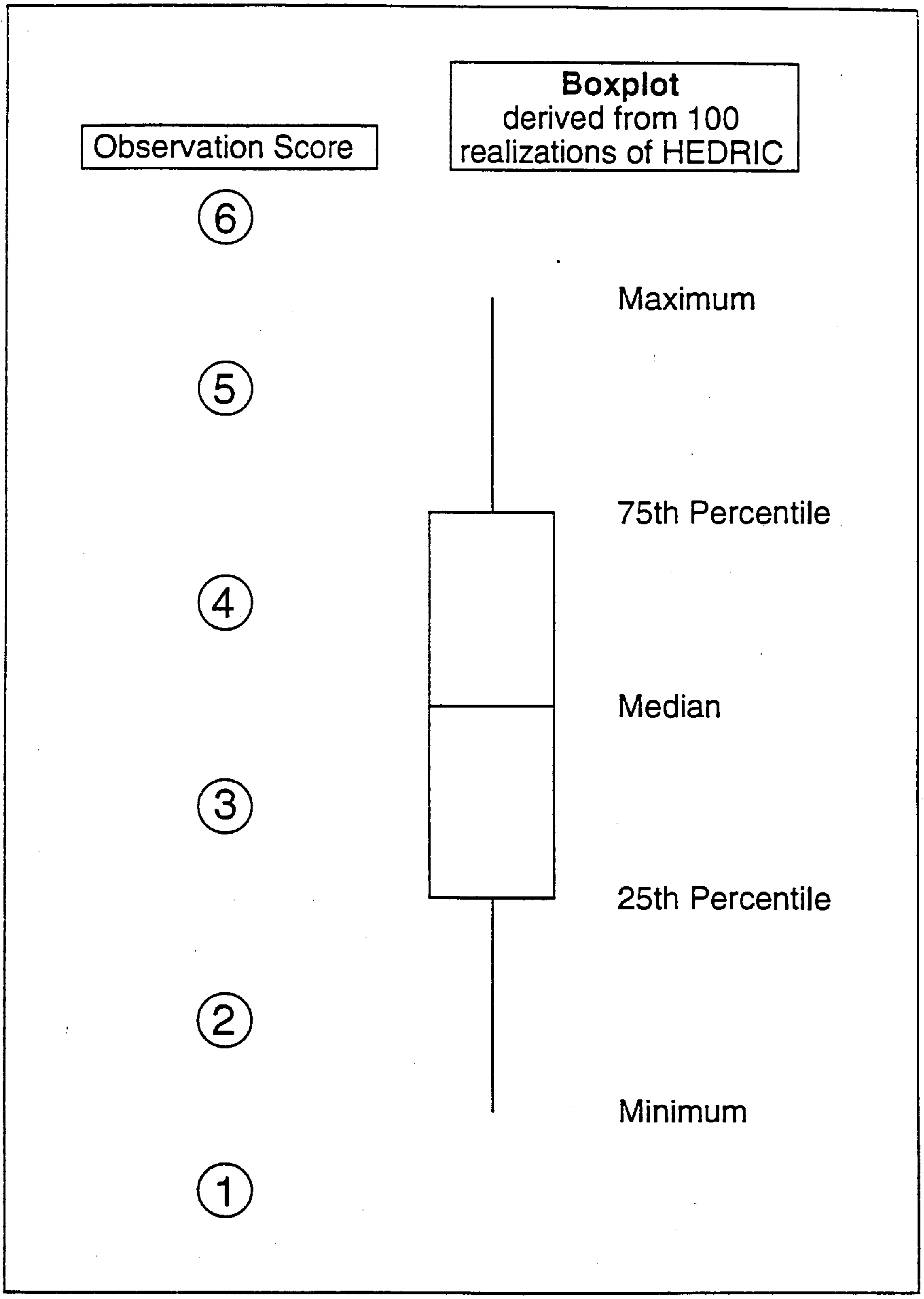

Figure 4.2. Relationship of Measurement Score (Value from 1 to 6) to Distribution of Estimated Concentration in Vegetation

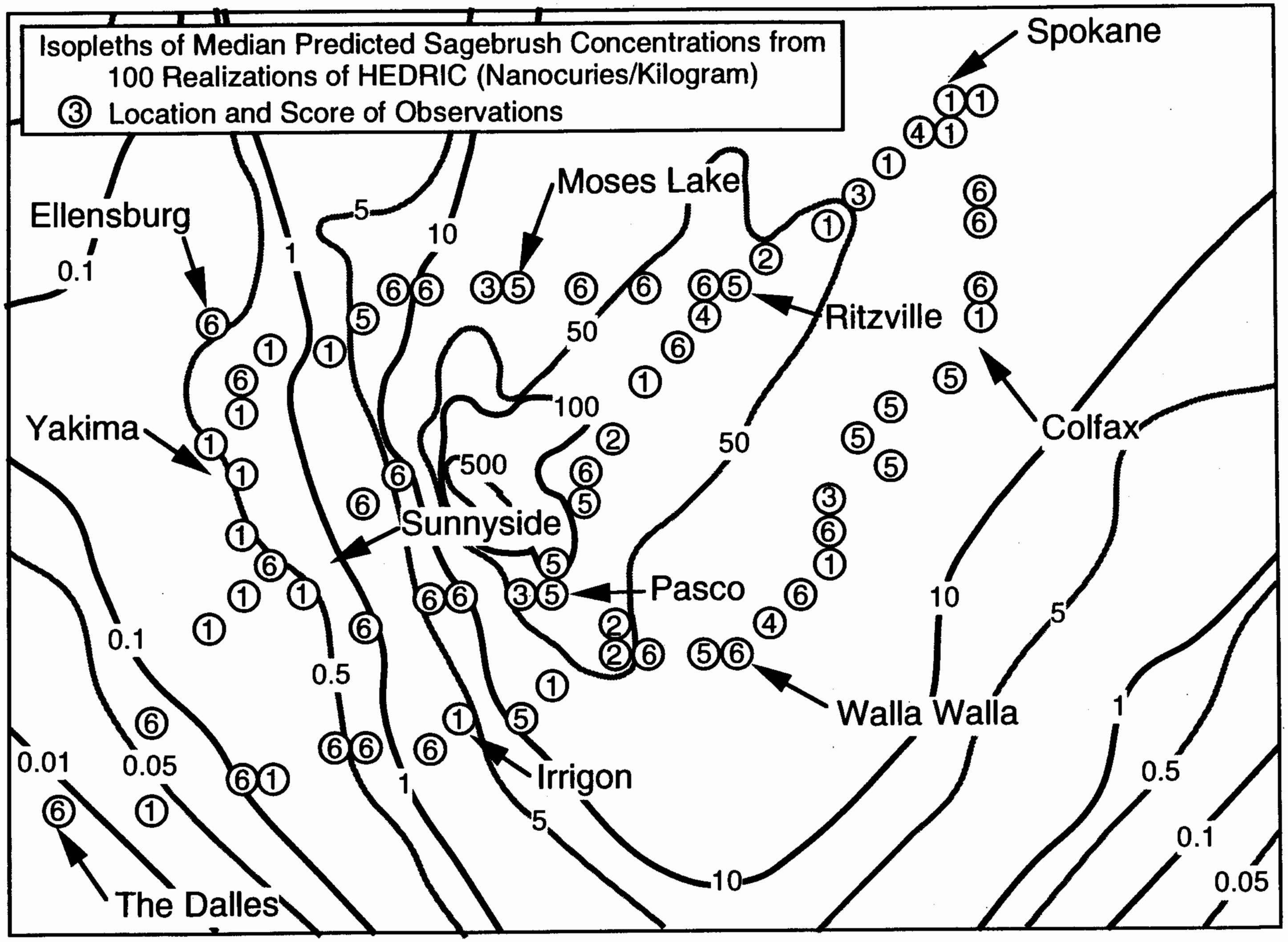

Figure 4.3. Map Illustrating Estimated Deposition of Iodine-131 on Sagebrush for April 13, 1946, and Score of Estimates Relative to Measurements

21,22 *Extreme ranges in the score may correlate to the topography of the area. A series of high ridges extend diagonally across the landscape, separating Ellensburg, Yakima, and Sunnyside from the higher concentration areas beginning at the Hanford Site and tending northeast.* From the map of Figure 4.3, it is apparent that the indices do not match well in the area to the west of the Hanford Site release point (Sunnyside, Yakima, Ellensburg, and The Dalles). All scores in this area are values of 1 or 6; i.e., overestimates or underestimates. The estimated deposition in this area is less than 1 x 10^{-8} Ci/kg of sagebrush. Recall that the limit of detection at 1 count per minute above background was 2.8 x 10^{-8} Ci/kg. It is apparent in this region that the measurements show mild statistical fluctuations around "measurement zero." The measurements cannot be expected to show the detail of the deposition, only that it is below about 10^{-8} Ci/kg. This agrees with the estimates of the models.

The region downwind of the Hanford Site to the east shows areas where more of the measurements fall within the range estimated by the models. Again, the correspondence is not ideal, indicative of the limited resolution of the measurements. A better idea of the agreement may be obtained by looking at the number of measurements greater than 5 x 10^{-8} Ci/kg (i.e., measurements well above the lower limit of detection) provided in Table 4.2. For this range, 9 of 15 measurements fall within the estimated range; i.e., they have scores of 2, 3, 4, or 5. Apparently, if the magnitude of the deposition had been greater, the comparison would be better. In this instance, the releases from the Hanford Site were not sufficiently great to be readily measurable in most locations. The comparison of the estimates to the measurements is hindered by the poor resolution of the detection equipment used in 1946.

Table 4.2. Application of the Measurement Score to the Estimates as a Function of Absolute Magnitude

Rank\Range	Number of Measurements >5 x 10^{-8}	Number of Measurements <5 x 10^{-8} but >1 x 10^{-8}	Number of Measurements <1 x 10^{-8}	Total Number of Measurements
1	2	7	12	21
2	3	1		4
3	1	3		4
4	1	2		3
5	4	7	1	12
6	4	9	15	28
Total	15	29	28	72

In addition to the spatial score plot, the ratio of the median measured value to the median estimated value was computed for each cell where measured values exist. A boxplot in Figure 4.4 shows the distribution of these ratios. The upper pair of boxplots indicate that the models tended to underestimate the deposition.

However, as the measured depositions increased above the lower limit of detection, this underestimate was lessened. This is particularly evident in the lower pair of boxplots, which show that the median model estimate was within a factor of 2 or less of the median measurement when the deposition was greater than 10 nCi/kg.

It is important to note that, as illustrated in both Figure 4.4 and in Table 4.2, in all but one of the cases where the measurements indicate that the model was overestimating, the measurements were, in fact, "less than detectable" zero counts. Upwind, where the measured data ranged from zero to 1 count per minute, the models estimates values less than 5×10^{-8} Ci/kg. Downwind, most of the measurements fall within the range of the estimates. Almost all of the measurements are single counts, from samples taken within the 36-square-mile area represented by the model cells, and the resultant description of the environmental contamination is fairly poor.

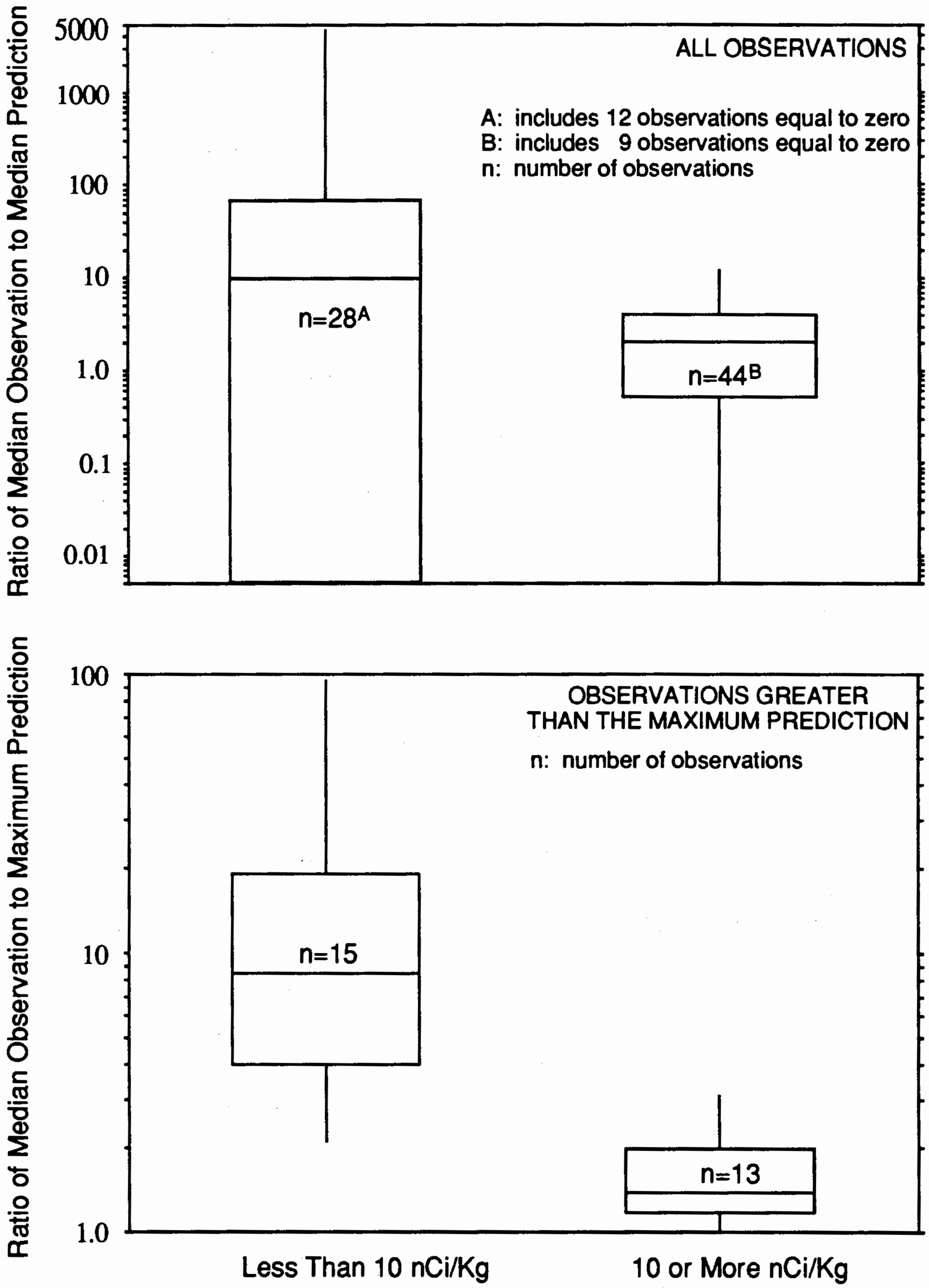

Figure 4.4. Ratios of Measurement to Estimate for Estimated Medians Greater Than and Less Than 10 nCi/kg

5.0 1949 Green Run

The Green Run experiment that began on December 2, 1949, was part of the development of monitoring methods for intelligence efforts directed towards the emerging Soviet nuclear program. A description of the experiment was released (Jenne and Healy 1950). In brief, a planned release of about 7000 curies of iodine-131 to the atmosphere was made over a brief period in December 1949. Extensive environmental monitoring efforts were made throughout the inland Northwest in the weeks following the release.

5.1 Assessment Question

The assessment question to be addressed is, "What was the spatial distribution of iodine-131 deposition following the Green Run release of December 1949?" This assessment question will address the deposition at each of the HEDR cells for which data are available, based on the measurements taken. Therefore, deposition of iodine-131 prior to the beginning of the Green Run release must be accounted for.

5.2 Available Green Run Vegetation Data

It appears from the available historical measurements that preparations for the Green Run began about two weeks prior to the actual release. Between November 17, 1949, and the start of the experiment in December, about 234 offsite samples were taken—the most coordinated effort since the start of the program in 1945. These samples were taken in routes up the Yakima Valley to Ellensburg, from Ritzville to Spokane, and down the Columbia River from Umatilla through the Columbia Gorge.

Sampling intensified during and after the Green Run release. About 618 samples taken during the month of December 1949 are available from throughout the HEDR atmospheric dispersion domain. Singlevich (1950) and Parker (1950) both report that 1365 vegetation samples were taken. Many of these, however, were onsite. An additional 100 samples taken in January 1950 are available, but at fewer offsite locations. Less obvious effort went into collecting these.

During the initial days after the release, most monitoring concentrated on the Hanford Site. The first offsite forays were made on December 5. Two cars were sent north, one to Ritzville, Moses Lake, and Coulee City, Washington; the other to Walla Walla, Colfax, and Spokane, Washington. On December 6, these two groups continued west to Ellensburg and north of Spokane, Washington, respectively. Additional measurements were taken on December 7 between Yakima, Pasco, and Ritzville, Washington. Very few measurements were made on December 8. Shortly after, forays traveled toward The Dalles and Ontario, Oregon, and then to points in southern Oregon. (These latter forays appear to have resulted from mistaking contamination introduced in the laboratory for contamination from the field samples.) The area covered by the post-Green-Run surveys is illustrated in Figure 5.1.

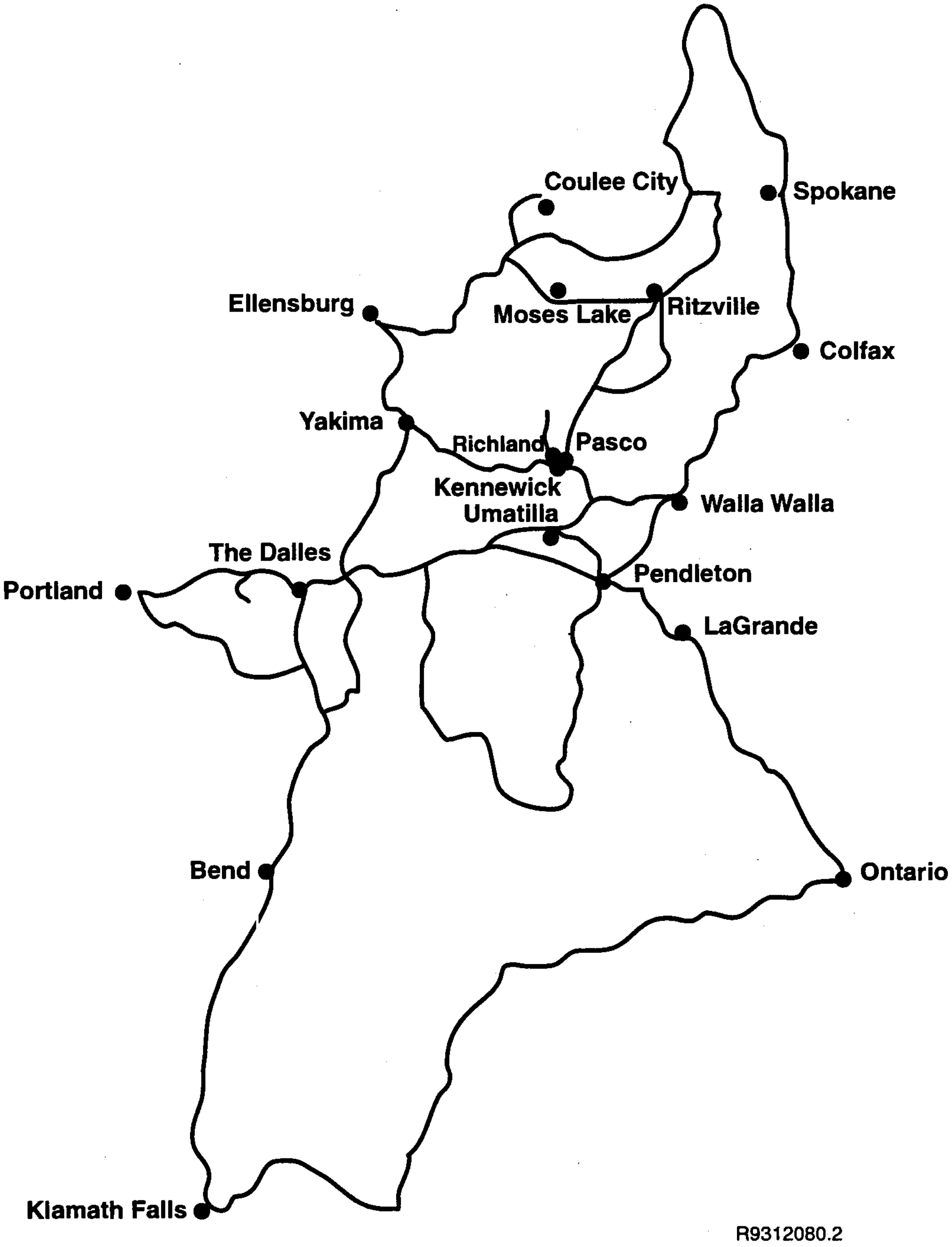

Figure 5.1. Map Indicating Routes Traveled by Vegetation Sampling Teams During December 1949

By 1949, techniques for radionuclide detection in environmental samples had improved over those available in 1946. Concentration measurements of iodine-131 in vegetation were made with a multi-step chemical extraction process, in which the iodine-131 was removed from the sample and the resulting solution counted. This provided much better counting geometry and reduced the uncertainty of the absorption of beta emissions within the sample. The conversion from detected counts per minute to concentration was made as described in Denham et al. (1993b). A complete description of the available information is provided in Hanf et al. (1993).

The laboratory used for counting the environmental samples was contaminated with iodine-131 during the course of the Green Run event, resulting in a detection limit of around 10^{-8} Ci/kg (Jenne and Healy 1950, p. 17). The existence of this contamination was not immediately evident during the post-release monitoring. As a result, for a period of a few weeks, spurious measurements misled the people performing the monitoring, which caused them to send monitoring crews into areas with minimal contamination. The nature of these spurious data and the complexity they add to the current analysis is discussed below.

Appendix C provides a summary of the measurements and estimates for this event.

5.3 Models Evaluated

The hourly data from the STRM model were used for the source term. Dispersion calculations were performed with hourly inputs to the RATCHET code. The DESCARTES code was used to obtain the daily deposition values. This provides indirect validation of RM, STRM, and RATCHET, as well as partial validation of DESCARTES.

5.4 Evaluation of Results

The evaluation score described in Section 4.4, using a code of values from 1 through 6, was employed for the analysis of the Green Run historical measurements. Maps were prepared for each day with available offsite data. The maps for December 5, 6, and 7 are shown in Figures 5.2, 5.3 and 5.4. These figures show the path travelled by the monitoring crews and the ranking of the measurements on the 6-point scale.

Most of the measurements made on December 5 tend to be slightly lower than the estimates, although the majority of them are within the range of the estimates. Seventy-six percent of the measurements made on December 6 fall within the ranges of the HEDR model estimates although a bias towards overestimation is evident for the east side of the pattern and underestimation for the west side of the pattern. A similar pattern is evident on December 7. Maps were also prepared for the days of the next week, but because the measurements taken on those days were generally to the south of the area of the main plume and seemed to be greatly influenced by the limit of detection imposed by the contaminated laboratory, they are summarized in Figure 5.5 without the scores.

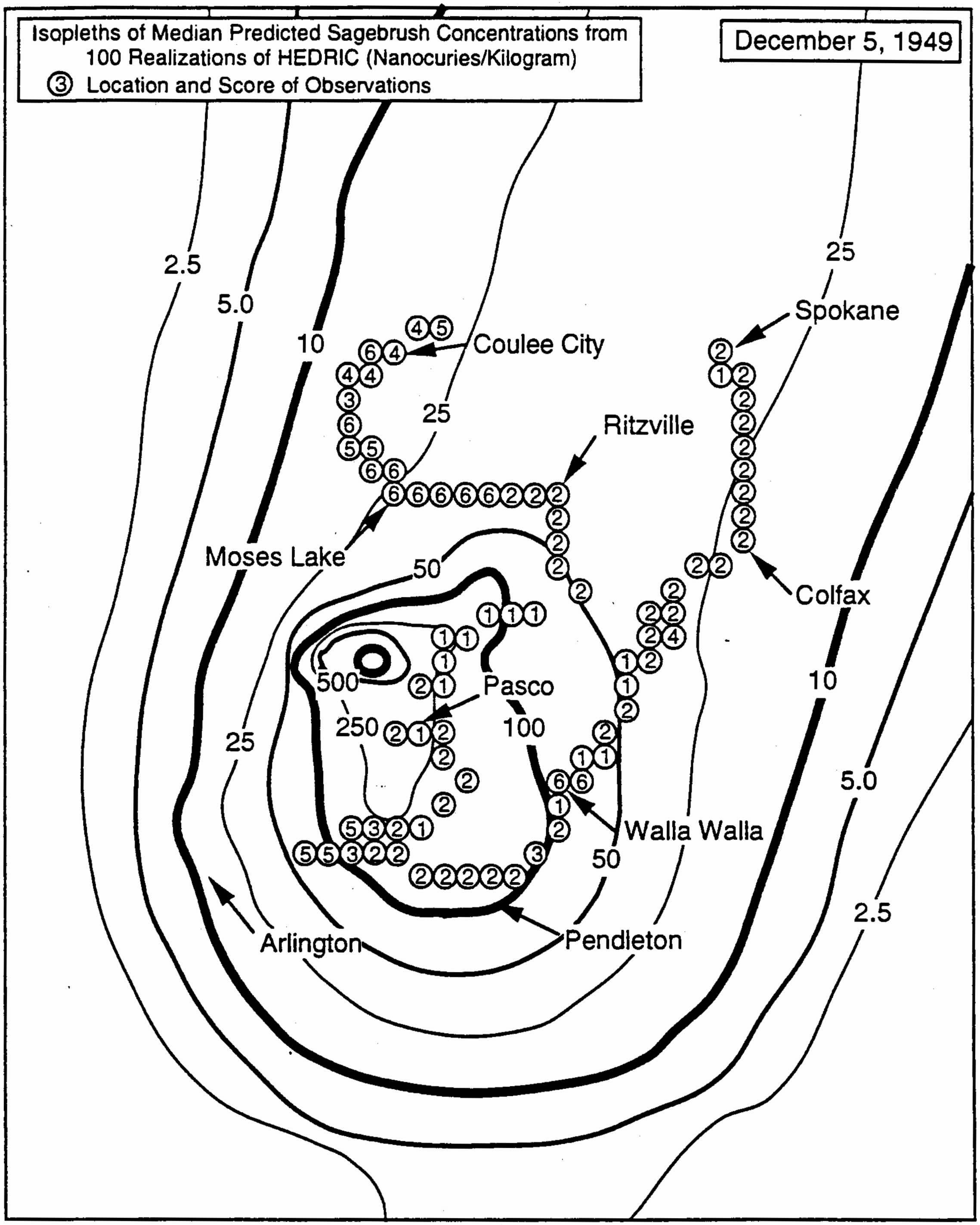

Figure 5.2. Map Illustrating Estimated Deposition of Iodine-131 on Vegetation for December 5, 1949, and Score of Estimates Relative to Measurements

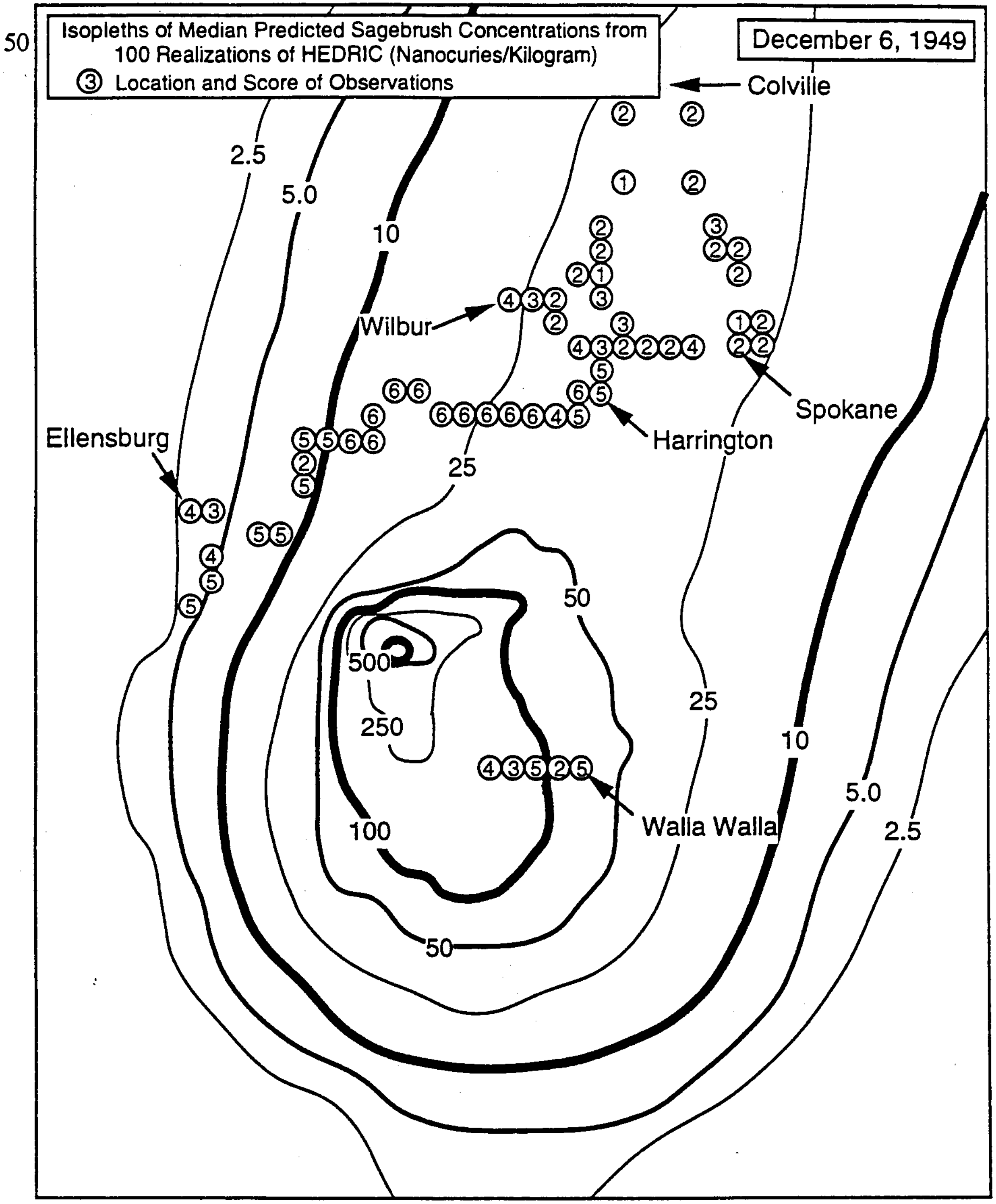

Figure 5.3. Map Illustrating Estimated Deposition of Iodine-131 on Vegetation for December 6, 1949, and Score of Estimates Relative to Measurements

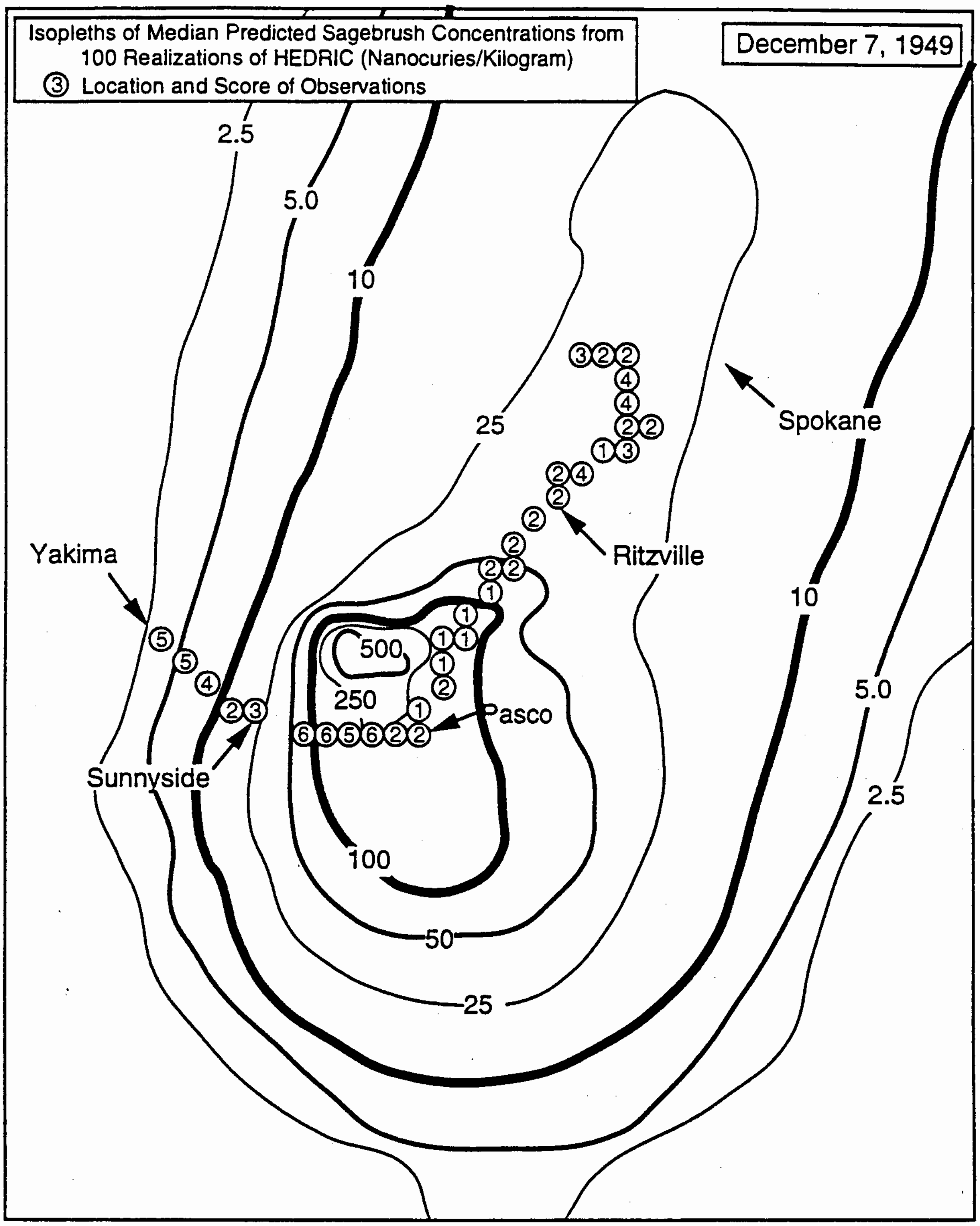

Figure 5.4. Map Illustrating Estimated Depositions of Iodine-131 on Vegetation for December 7, 1949, and Score of Estimates Relative to Measurements

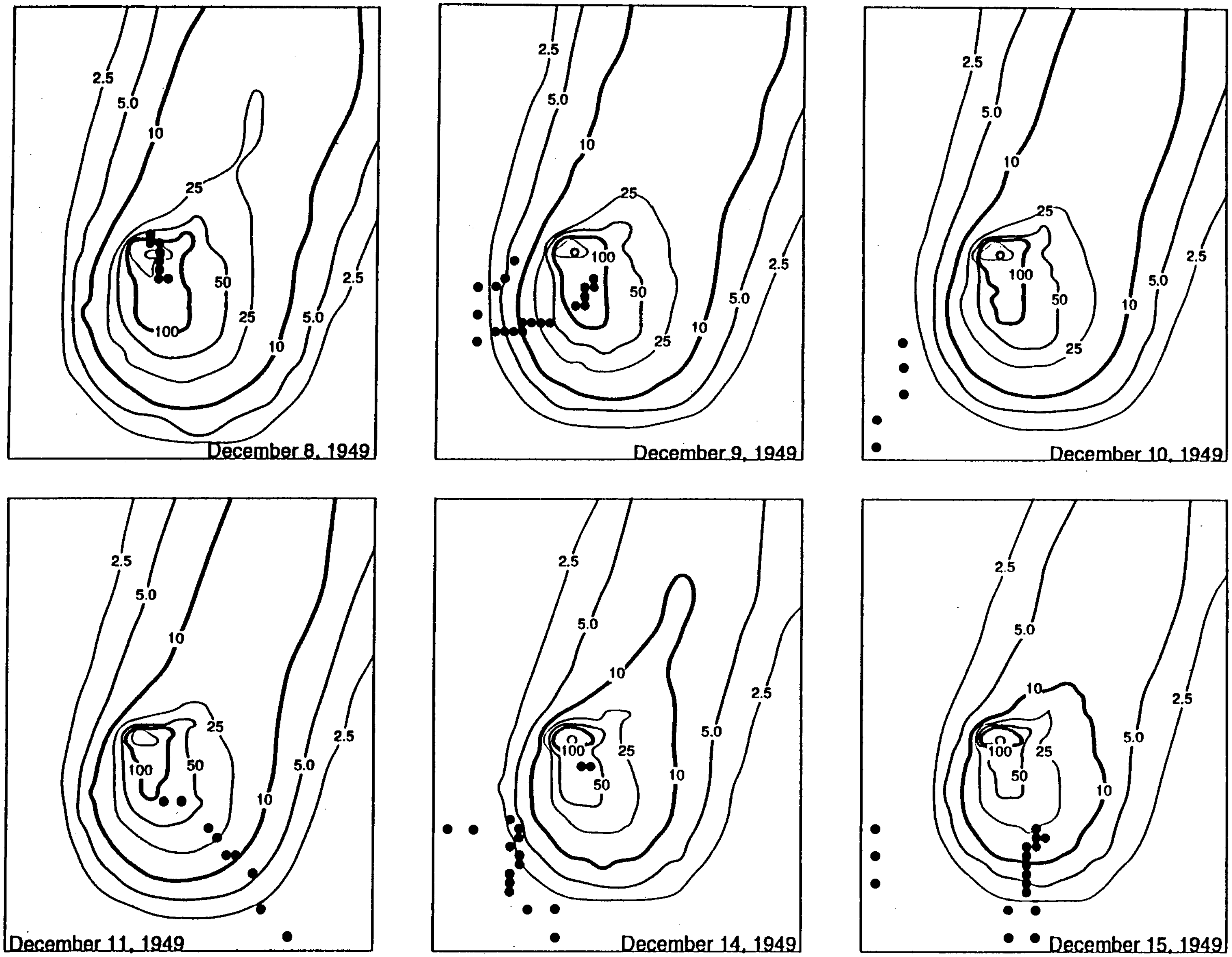

Figure 5.5. Maps Illustrating Estimated Deposition of Iodine-131 on Sagebrush and Locations of Daily Measurements for December 8-15, 1949 (● = location of measurement)

The overall ranking of the daily comparison is summarized in Table 5.1. This table shows that nearly two-thirds of the measurements were within the range estimated by the HEDR models. The reason for relatively large number of model overestimates in the early period is illustrated in Figures 5.6 and 5.7.

Table 5.1. Application of the Measurement Score to the Results for the Green Run Measurements, December 3 through 15, 1949

Date/Rank	3	5	6	7	8	9	10	11	14	15	Total
1	2	15	3	7	1			4		1	33
2		40	19	14	4			2		6	85
3		4	7	3	2	1		1		2	20
4		5	7	4		2		1	1	1	21
5		6	12	3	1	9		1	4	3	39
6		11	11	3		8	5		11	4	53
Total	2	81	59	34	8	20	5	9	16	17	251

34% of 251

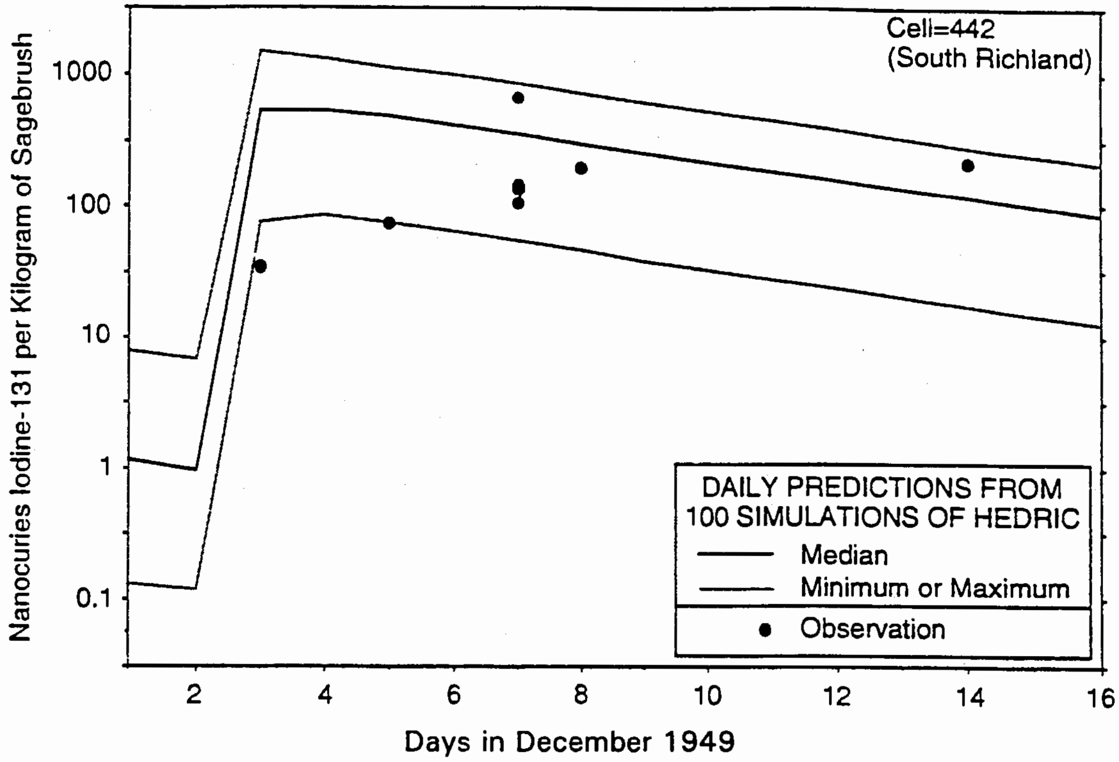

Figure 5.6. Comparison of Daily Estimates and Measurements of Iodine-131 Concentration in Vegetation for South Richland, December 1949

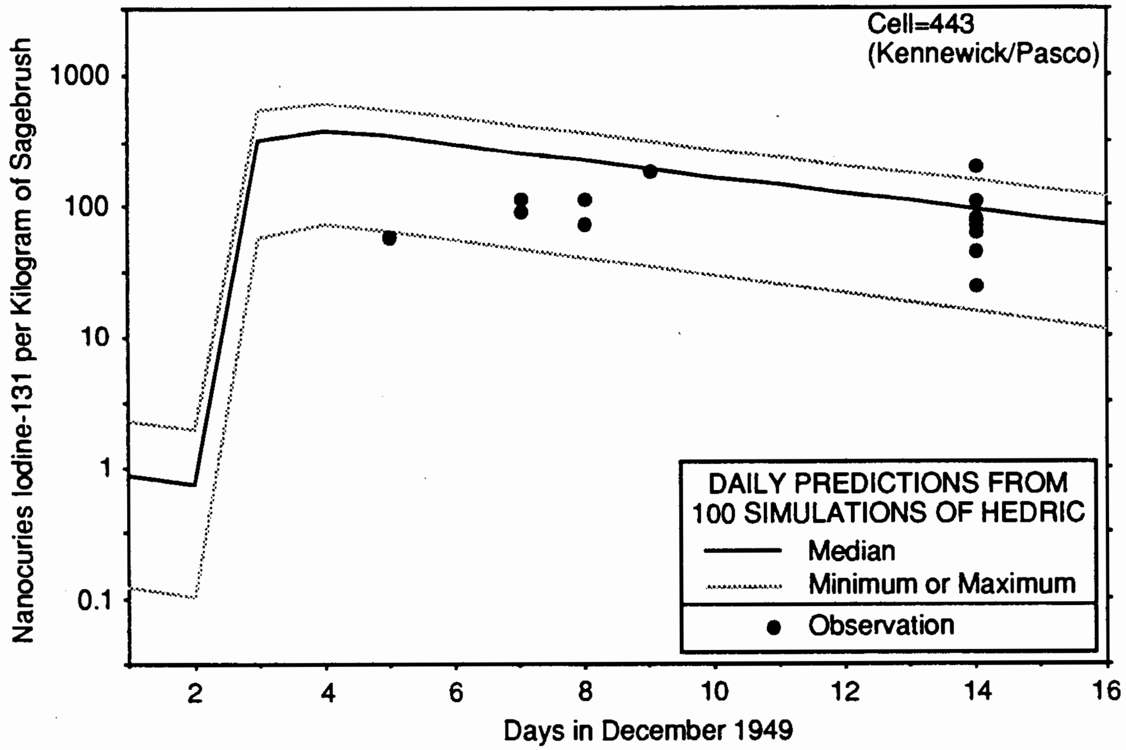

Figure 5.7. Comparison of Daily Estimates and Measurements of Iodine-131 Concentration in Vegetation for Kennewick/Pasco, December 1949

These figures show time series measurements made in the two HEDR cells corresponding to south Richland and Kennewick/Pasco. The measurements for December 3 and 5, 1949, during the initial passage of the contaminated plume, indicate an overestimate on the part of the HEDR models, yet those for following days appear to have reasonable agreement. The HEDR model estimates are for midnight on the days noted, following a full day's deposition. However, it is quite likely that the measurements were made earlier in the day (probably during working hours), and it is likely that the full day's deposition had not yet occurred at these locations. If the measurement is compared to the previous day's estimates, it allows for the possibility that the measurement was made before the full expression of the deposition. The results of the recalculated measurement score are as shown in Table 5.2. Significant improvement in the comparison of model results and measurements is shown for December 3 and 5, with no improvement in the succeeding days. Note that this is only an analysis technique; the model results were not altered.

A feature of Figures 5.2 and 5.3 is an apparent overestimation in the eastern half of the domain and underestimation in the western half. The plume of contamination drifted off the Hanford Site and stagnated for several days in the vicinity of Walla Walla. A weather front moved through the area from south to north beginning December 5. If the model has a relatively small error as a function of time, a very minor misestimate from December 2 through December 5 could be amplified by this feature of the Green Run deposition pattern. This possibility was investigated as a sensitivity analysis

Table 5.2. Application of the Measurement Score to the Results for the Green Run Measurements, December 3 through 15, 1949, Including Previous Day's Estimates

Rank/Date	3	5	6	7	8	9	10	11	14	15	Total
1		7	3	7	1			4		1	23
2		27	19	15	4			3		7	75
3	2	13	7	3	2	2				1	30
4		12	8	3		1		1	1	1	27
5		11	12	3	1	10		1	6	4	48
6		11	10	3		7	5		9	3	48
Total	2	81	59	34	8	20	5	9	16	17	251

by shifting the estimated deposition pattern one cell to the west to see whether this would compensate for the general pattern of misestimate. The results of this single 6-mile shift are shown in Table 5.3, combined with the 1-day adjustment. With these adjustments, almost 82 percent of the measurements fall within the range of the HEDR model estimates. Again, the model results were not altered; this shift was made for analysis purposes only.

Another possible explanation for the apparent tendency to place the plume footprint slightly too far to the east was also investigated. The data reveal that the people performing the original monitoring did not use consistent techniques. In particular, the measurements made on December 5

Table 5.3. Application of the Measurement Score to the Results for the Green Run Measurements, December 3 through 15, 1949, with Previous Day's Estimate Included and the Entire Pattern Shifted by One Cell

Rank/Date	3	5	6	7	8	9	10	11	14	15	Total
1			2	2				3		1	8
2		33	20	19	5			4		7	88
3	1	13	7	4	2	2				1	30
4	1	13	8	3		1		1	1	1	29
5		15	15	3	1	13		1	6	4	58
6		7	7	3		4	5		9	3	38
Total	2	81	59	34	8	20	5	9	16	17	251

are notable. The people traversing the path on the east side of Figure 5.2 sampled mostly grass and weeds, while the people travelling on the west path sampled mostly sagebrush. All prior evaluations were made using sagebrush as the assumed vegetation. If the locations at which the sampling was known not to be sagebrush are represented as late-season pasture grass (the closest surrogate media in DESCARTES), the estimates are raised relative to the measurements and the overall pattern is slightly improved.

The bias introduced by the contaminated laboratory was evaluated to determine the influence on the measurement rank score by the magnitude of the estimated result. In other words, were the small estimated values towards the southern portion of the domain treated as underestimates by the ranking?

The results are presented in Table 5.4. It appears that almost all estimated concentrations with magnitudes smaller than 1 x 10^{-9} Ci/kg, and most with magnitudes less than 1 x 10^{-8} Ci/kg, are considered to be underestimates in this comparison. Because the general level of detection was found to be about 1 x 10^{-8} Ci/kg, it is likely that the 55 measurements so described are actually estimates of values less than the limit of detection and so should be ranked better than they are.

Table 5.4. Green Run Ranking as a Function of Estimated Magnitude of Deposition in Ci/kg of Sagebrush

Magnitude/Rank	$>1\mathrm{x}10^{-7}$	$<1\mathrm{x}10^{-7}$ $>3\mathrm{x}10^{-8}$	$<3\mathrm{x}10^{-8}$ $>1\mathrm{x}10^{-8}$	$<1\mathrm{x}10^{-8}$ $>1\mathrm{x}10^{-9}$	$<1\mathrm{x}10^{-9}$	Total
1	15	11	6	1		33
2	20	31	31	3		85
3	7	4	6	3		20
4	2	4	9	5	1	21
5	7	7	7	15	3	39
6	3	9	17	13	11	53
Total	54	66	76	40	15	251

55

The results of Table 5.4 are summarized in another way in Figure 5.8. The ratio of the median estimated value to the median measured value was computed for each cell where measured values exist and boxplots that show the distribution of these ratios provide summaries of the results. These boxplots are a function of the magnitude of the median estimated deposition. It is apparent from these boxplots that the median estimates are very close for the depositions greater than 10^{-8} Ci/kg (10 nCi/kg), but that the estimates deviate for the smaller depositions. This is particularly obvious for the values less than 10^{-9} Ci/kg (1 nCi/kg), which are estimated for the region southwest of the Hanford Site, where the effects of the laboratory contamination are most evident. Discounting this portion of

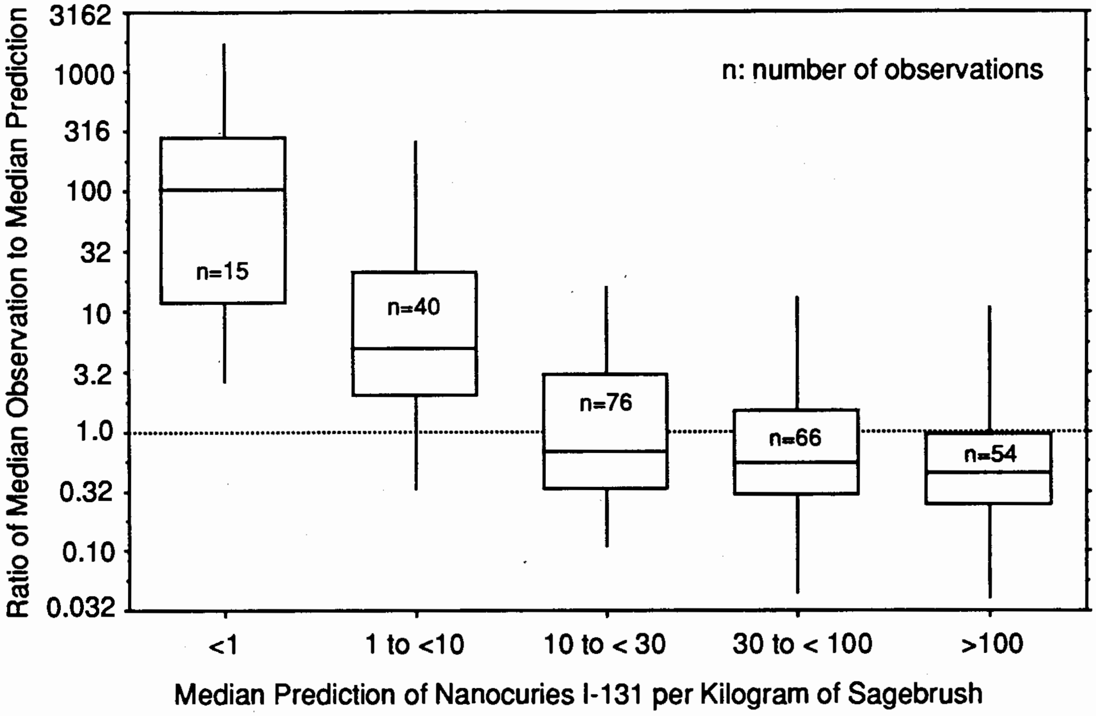

Figure 5.8. Ratios of Measurement to Estimate for Various Estimated Median Deposition Values

the data for which measurements reported were likely in error, the comparison of the measured to measured data is within factors of 2 to 4, with a minor tendency to overestimate for depositions greater than 10^{-8} Ci/kg.

Figure 5.9 summarizes information for the measurements that were outside of the estimated range. In instances for which the minimum estimate exceeded the measurements, as shown in the boxplot on the right of the figure, only rarely were the measurements less than the estimates by more than a factor of 2. Instances where the measurements were greater than the maximum of the estimated range are shown in the two boxplots to the left, one for estimates of greater than 10^{-8} Ci/kg and one for estimates less than 10^{-8} Ci/kg. Again, for the region where the laboratory results were relatively unaffected by the contamination ($> 10^{-8}$ Ci/kg), the maximum estimates were rarely lower than the measurements by more than a factor of 3. However, for the region modeled to be contaminated to less than 10^{-8} Ci/kg, it is obvious that the model results are distinctly less than the reported measured values.

Overall, the comparisons are best for the estimates that correspond to the period of active transport and deposition, early in the 2-week period investigated. This is largely because the highest results measured were from this early period. The later results were concentrated in the southern portion of the domain where transport is dubious and the level of detection was compromised by the contamination of the laboratory. Only 53 measurements were greater than the maximum estimated.

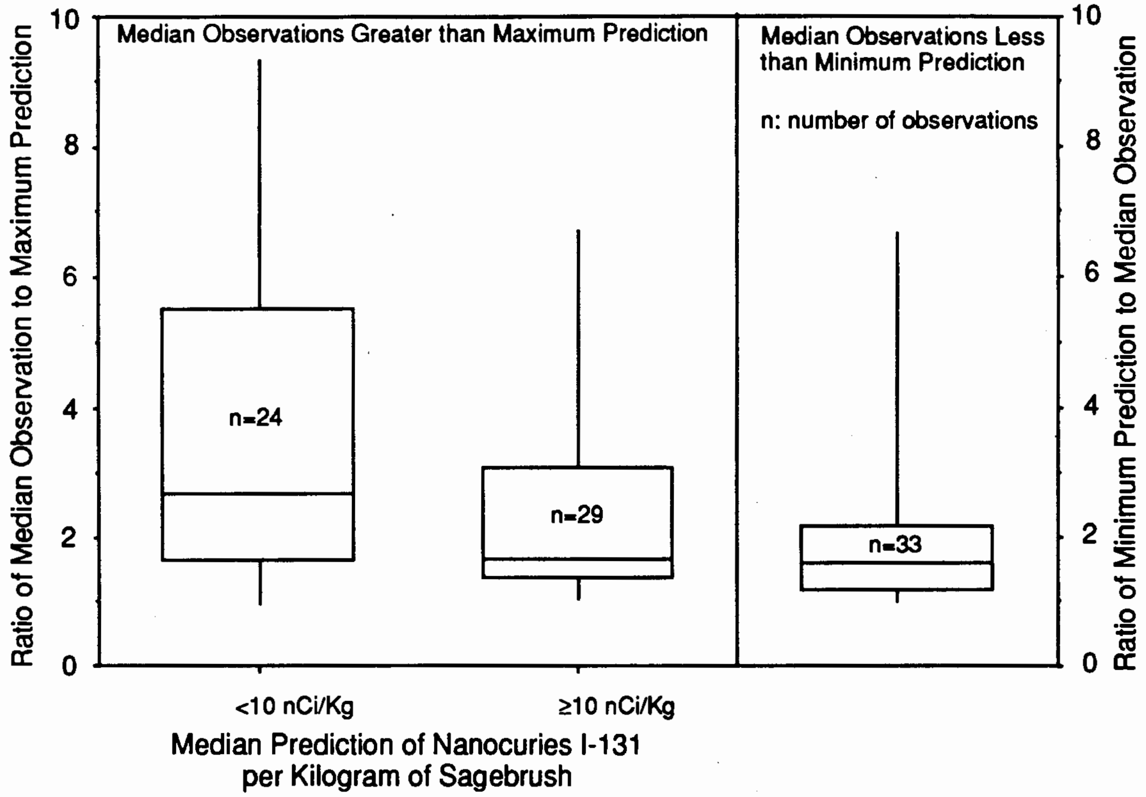

Figure 5.9. Ratios of Measurement to Estimate for Cases where Measured Deposition Values are Outside the Estimated Range

These generally exceeded the maximum estimated by no more than a factor of 3 when misreporting by the counting laboratory is accounted for. There were 33 measurements lower than the minimum estimated. Some of these were zero counts, and most of the remainder were caused by temporal mismatch—the estimates were for midnight on a day when the samples were taken many hours earlier. A minor misestimate of the footprint of the plume occurred, on average about 6 miles too far to the east over a period of 4 to 5 days. In summary, the model estimates were very close to the actual occurrence for this single release event. On a long-term average, over a number of releases, the effects of exact locations of individual plumes will be less noticeable.

6.0 PUREX Plant Release, September 1963

An event similar to the 1949 Green Run occurred at the PUREX Plant in 1963. This PUREX Plant release, however, was by accident and had a much smaller release. An acute, inadvertent release of iodine-131 from the 60-meter stack at the PUREX Plant occurred from September 2 to 5, 1963, as a result of inadvertently charging short-cooled fuel elements into the dissolver (Soldat 1965). Plant operations were shut down as soon as the abnormal release was detected and steps were taken immediately to retain as much of the iodine-131 as possible within the plant. Laboratory analyses of stack effluent samples were made. The routine program of environmental monitoring at the Hanford Site was augmented with additional sampling. In particular, milk sampling at several locations was increased from weekly to daily for a period of several weeks. Measurements of wind velocity and temperature were made routinely at the site meteorology tower. No significant rainfall occurred in the HEDR domain during the period. No protective measures were taken following the release. There were no significant atmospheric nuclear tests in the several months prior to the accident (Carter and Moghissi 1977).

6.1 Assessment Questions

There are several questions that may be addressed for this case. The first is, "What was the spatial distribution of iodine-131 deposition following the release?" The second is, "What was the concentration of iodine-131 in pasture grass and alfalfa at Horn Rapids (HEDR grid cell 468)?" The third is, "What was the concentration of iodine-131 in milk in the vicinity of Horn Rapids following the deposition?" Finally, "What were the thyroid burdens in a 4-year-old and an 8-year-old child drinking 1 gallon and 1 quart of milk per day, respectively, from a single cow in the backyard at this location?"

6.2 Available September 1963 Data

This particular incident was extensively studied. A public report of the results is available (Soldat 1965). Air measurements were taken at daily intervals (24-hour samples) at Benton City, Richland, and Kennewick, as well as at 18 onsite locations. Measurements of pasture grass were taken daily at two farms in cell 468 and sporadically at numerous other locations. Milk was measured at two farms in the Benton City area and at the local creameries. Thyroid counts were taken on two children who were consuming milk from a cow in the backyard of one of the farms.

As described in Section 14.0, this data set was selected as input to the IAEA cooperative research program on environmental model validation. All of the available data have been prepared in a scenario description provided to the participants of that program.(a) This scenario description is

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(a) Napier, B. A. Unpublished. *VAMP Multiple Pathways Assessment - Description of Test Scenario "H"*. Presented to VAMP Participants in Helsinki, Finland, October 1993.

sufficiently complete to allow modelers from other organizations to independently estimate the resulting distribution of environmental contamination and dose.

The source term for this event is presented in Table 6.1, adapted from handwritten measurements by J. K. Soldat and the September 1963 monthly environmental summary (Foster 1963).

To mitigate the results of the accident, the dissolver solution was transferred to a holding tank and the fuel in the dissolver was covered with clean water (Investigating Committee 1963). The initial pulse of the release occurred from the dissolver, but the long tail was a result of continued off-gassing into the PUREX Plant exhaust airstream from the holding tank. The fuel and solution remained in this configuration until November 6, 1963.[a] As a result, continued release at a low level occurred, such that following the initial release on September 2-5, of about 63 Ci, another 9 Ci was emitted over the course of the rest of September 1963.

6.3 Models Evaluated

The source term for this particular accident is known. Meteorological data are available. A special run of RATCHET for the local area was required with daily inputs for the months of June through September 1963. This was coupled with a special run of the DESCARTES code for the 49 cells in a 7-x-7 grid around the Hanford Site. The DESCARTES output included iodine-131 concentration in vegetation and animal products. The CIDER code was used to estimate the uptake by the two subject children. The available data allow this to be a direct validation of the DESCARTES and CIDER models and an indirect validation of RATCHET.

6.4 Evaluation of Results

The RATCHET model was used to provide 100 realization values of the air concentration at the cells surrounding the Hanford Site to be compared with the historical measurements. The DESCARTES model provided 100 realizations of the daily concentrations of iodine-131 in pasture grass, milk from a single family cow, and other local food products. The CIDER model provided estimated distributions of intake by the subject children. Rather than post-process these to arrive at a body burden, substitute dose factors were used in CIDER to directly compare the doses estimated with those estimated in 1963 for the exposed people. The substitute dose factors were required because the contemporaneous estimates (Soldat 1965) were made with values that differ from the ones currently used by the HEDR Project by about a factor of 2. The change in dose factors between 1965 and now is largely a result of accumulated information about the mass of children's thyroids.

(a) Unpublished report (HEDR Project Document No. 01940001), "Monthly Report, Environmental Studies and Evaluation," from J. K. Soldat (General Electric Company) to R. F. Foster (General Electric Company), November 1963.

Table 6.1. Release Rate of Iodine-131 to the Atmosphere from the September 1963 PUREX Plant Release Event[a]

Date	Time	^{131}I Activity Released (Ci)
September 2	12:25 - 16:25	5.5
September 2	16:25 - 23:30	18.5
September 2-3	23:30 - 09:10	22.3
September 3	09:10 - 11:55	3.9
September 3	11:55 - 15:05	2.3
September 3	15:10 - 23:30	5.3
September 3	23:30 - 08:50	2.3
September 4	08:50 - 15:00	1.3
September 4-5	15:00 - 09:10	1.1
September 5	09:10 - 14:45	0.21
September 5-6	14:45 - 00:30	0.16
September 6	00:30 - 09:00	0.18
September 6	09:00 - 14:25	0.095
September 6-7	14:25 - 09:00	0.23
September 7	09:00 - 15:20	0.11
September 7-8	15:20 - 14:00	0.37
September 8-9	14:00 - 09:00	0.29
September 9-10	09:00 - 09:15	0.36
September 10-11	09:15 - 09:00	0.35
to Sept. 30		7 ± 2
Total[b]		72 ± 2

(a) Hourly data from handwritten record by J. K. Soldat, then an employee of General Electric Company.

(b) Monthly total (72 Ci) from Foster (1963, p. 3) estimated as monthly average of 2.4 Ci/day times 30 days. Total for September 12-30 determined by subtraction.

6.4.1 Spatial Distribution Following the Release

The available vegetation contamination data are limited to a few cells along the southern and eastern borders of the Hanford Site. HEDR Project staff determined that insufficient data were available to validate the dispersion footprint. Attention was focused instead on the second and third questions, concerning contamination at Horn Rapids.

6.4.2 Iodine-131 Concentration in Pasture at Horn Rapids

Concentrations of iodine-131 in pasture grass were measured at two farms in the Horn Rapids vicinity: Farm A on the western edge of the cell and Farm B on the eastern edge of the cell. The results of the simulation for pasture grass in cell 468 and the measurements at the two farms are shown in Figure 6.1. Measurements were being routinely made at Farm A prior to the event. The measurement frequency was stepped up to once per working day with no measurements on the weekends. The higher contamination at Farm B was not discovered until 10 days after the release began. The dramatic increase in contamination can be seen to occur immediately following the initiation of the release. The estimate corresponds with the increase seen at Farm A. The decrease is due to weathering and radiological decay until about September 15. At this point, the continuing deposition from the long-term tail of the release is evident in both the measurements and the estimate. After September 11, the simulation assumes that the release continues in a constant manner. Because at this time the PUREX Plant resumed normal operations, it is likely that the differences between estimate and measurement are caused by difficulties with the source term timing. The difference in the data on any day is a result of the cell simulation being near the mid-point between the two locations several miles apart.

6.4.3 Iodine-131 Concentration in Milk

At both Farm A and Farm B, individual family cows were on pasture and providing milk to the residents of the farms. This milk was for personal consumption and not used for commercial sales. The cows' diet was similar to the default feeding regime used in the DESCARTES model. For the simulation, cows were assumed to consume a diet high in pasture, with minimal supplemental feeding from other sources.

Concentration of iodine-131 in milk is modeled in DESCARTES as a simple transfer function directly related to concentration in pasture and other feeds. Therefore, the estimated concentration in milk will directly track with the concentration estimated in the animal feed. This can be seen in Figure 6.1, where the iodine-131 estimated in pasture grasses is directly followed by the estimated concentration in milk shown in Figure 6.2. The rise in measured iodine-131 concentration peaks at Farm A on about September 5, while that estimated by the model peaks on September 3. This behavior of the milk model is expected from the parameterization provided in the model. However, it is remarkable how closely the iodine-131 concentration in milk from cows at both Farm A and Farm B follows the estimated curves. The integrals of the milk concentration from the estimates and measurements at Farm A are essentially equal. The integral of milk concentration for Farm B exceeds the estimate by about a factor of 3, when extrapolated over the entire period.

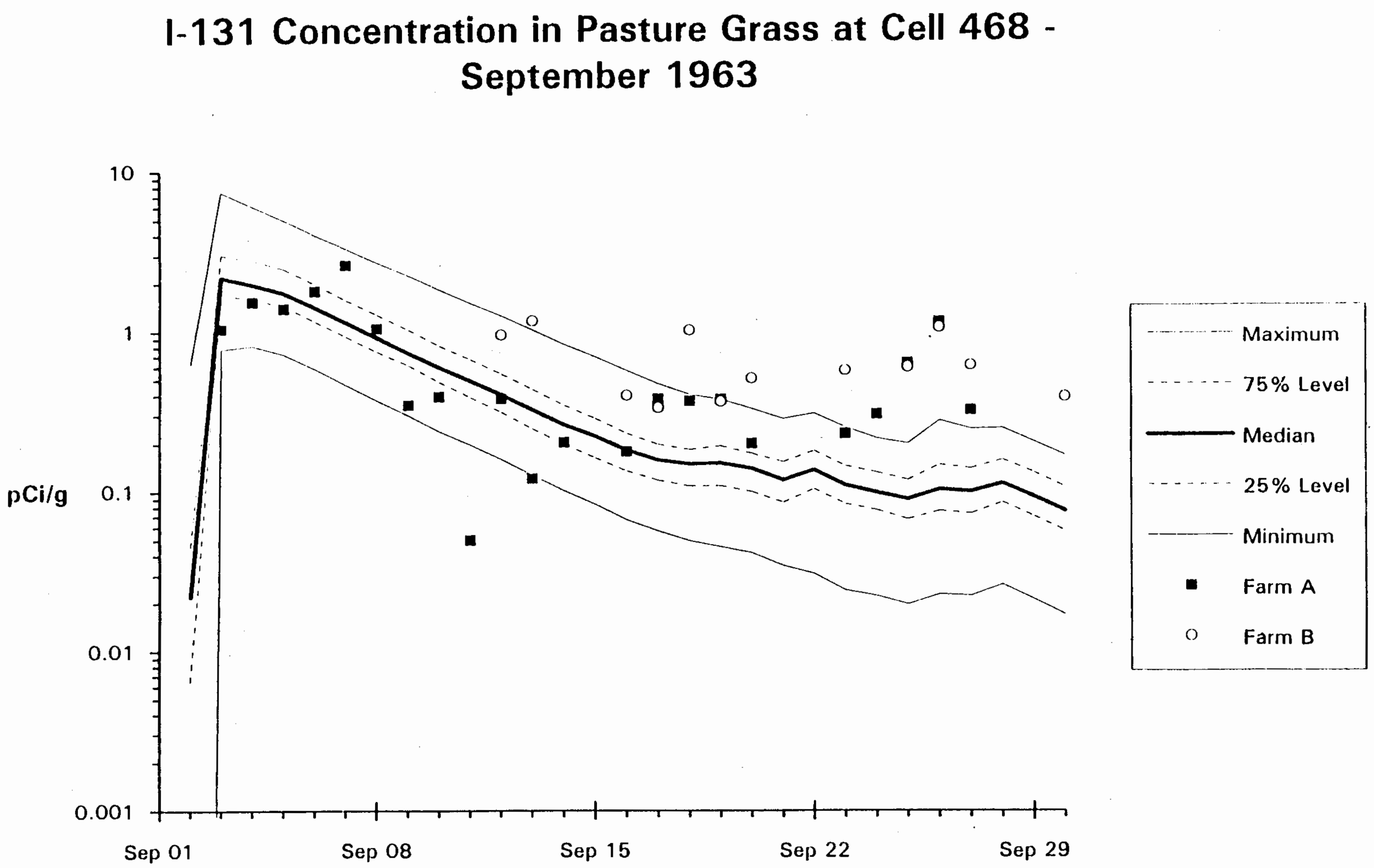

Figure 6.1. Comparison of Daily Estimates and Measurements of Iodine-131 Concentration in Pasture Grass at Horn Rapids Following the 1963 PUREX Plant Release

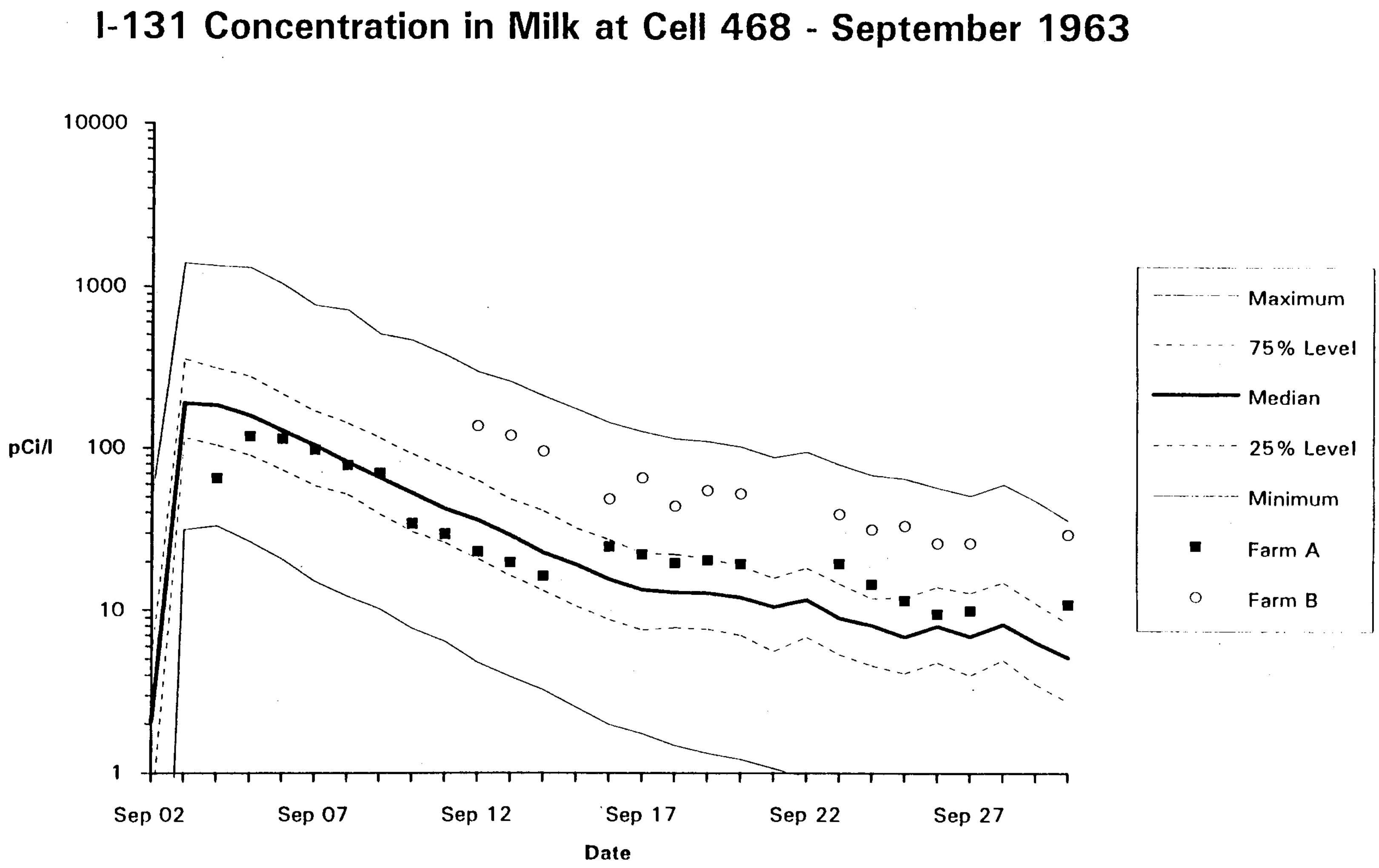

Figure 6.2. Comparison of Daily Estimates and Measurements of Iodine-131 Concentration in Milk at Horn Rapids Following the 1963 PUREX Plant Release

6.4.4 Thyroid Burdens

The thyroid burdens of two children located at Farm B were measured in October 1963. From these measurements, thyroid doses for these two children were estimated at the time. A dose conversion factor of 9.5×10^6 rad/Ci was used in these estimates. This dose conversion factor differs from the two that are currently incorporated in the CIDER dose model. The 1963 dose conversion factor is about one-half the current median value. But for the purpose of the comparison, the CIDER value was replaced with the value used in the 1963 analysis (Soldat 1965).

The parents of the children indicated that at the time of the exposure, the 4-year-old boy was consuming about 1 gallon of milk per day from the family cow, and his 8-year-old sister was consuming about 1 quart per day. No other dietary information was available. A default diet, listed in Table 6.2, was estimated for both subjects (Anderson et al. 1993, p. C.73). On the basis of this diet, the doses presented by pathway in Table 6.3 were estimated for the boy and girl using CIDER. The dose from ingestion of milk from the backyard cow obviously dominates the total dose. The distribution of the doses from milk alone is presented in Table 6.4. The dose estimated in 1963 for the boy was 35 mrad to the thyroid, that for the girl was 25 percent of the boy's or about 9 mrad (Soldat 1965). The measured doses fall well within the ranges estimated by the HEDR models using the 1963 dose conversion factor.

Table 6.2. Daily Food Consumption Estimated for Subjects at Horn Rapids, September 1963 (adapted from Anderson et al. 1993)

Food	4-yr old Boy	8-yr old Girl
Milk	4 L	1 L
Leafy Vegetables	11.6 g	22.3 g
Other Vegetables	117 g	152 g
Fruit	45.5 g	58 g
Grain	104 g	138 g
Eggs	20.0 g	15.0 g
Meat	38.5 g	58.0 g
Poultry	7.2 g	9.0 g

Table 6.3. Estimated Mean Thyroid Doses (mrad) from Various Pathways for Children at Horn Rapids, September 1963

Food	4-yr-old Boy	8-yr-old Girl
Inhalation	0.54	0.50
External	0.001	0.001
Milk	45.3	11.3
Leafy Vegetables	0.043	0.082
Other Vegetables	0.036	0.047
Fruit	0.37	0.47
Grain	0	0
Eggs	0.14	0.10
Meat	0	0
Poultry	0.001	0.001

Table 6.4. Estimated Thyroid Dose Distributions (mrad) from Milk for Children at Horn Rapids, September 1963

	4-yr-old Boy	8-yr-old Girl
Minimum	6.2	1.6
25% Level	26.1	6.5
Median	45.3	11.3
75% Level	73.5	18.4
Maximum	356.0	89.0

7.0 Krypton-85 Atmospheric Dispersion

Relatively recent Hanford Site data on atmospheric dispersion include a data set of coupled monthly source terms and environmental measurements of atmospheric krypton-85. These data were collected on a network established with the restart of the PUREX Plant in late 1983 and through its campaign until 1988. The individual historical measurements are available in the Hanford Site annual reports for each year. The source term measurements are unpublished. The environmental and source term historical measurements were used by Ramsdell et al. (1994) to validate the RATCHET model. This section provides a summary of the results presented in Ramsdell et al. (1994).

The krypton-85 data allow partial, direct validation of the RATCHET transport models independent of the later deposition and vegetation models. Using these data, RATCHET estimates of monthly time-integrated air concentrations for a non-depositing material can be evaluated. The measured and estimated concentrations are functions of release rate and timing, atmospheric transport, and diffusion. They are not affected by deposition. It is assumed that iodine-131 acts similarly to krypton-85 because there is no reason to believe that krypton would disperse differently than any other gases or submicron particles.

7.1 Assessment Question

The assessment question addressed is, "What was the monthly average concentration of krypton-85 at the selected monitoring stations from 1983 through 1988?"

7.2 Available Krypton-85 Historical Measurements

The Hanford Site historical measurements consist of individual samples for 14 to 38 days' duration collected at several locations within the Columbia Basin. The cryogenic monitoring network expanded over the period, so the number of locations sampled per year increased from four in 1984 to eleven in 1987, with up to twelve samples per year at each location. However, not all locations provided data 12 months per year for various reasons, and not all monitors were left at the same location throughout the period. The locations were 300 Area Trench (two monitors), Fir Road, Eltopia, Othello, Pasco, Prosser Barricade, Ringold, Sage Hill (near Othello), Sunnyside, and Yakima; all were in Washington. The data used from each location represent a monthly composite sample. The first three monitors listed were all in the same HEDR grid cell. The results for these three monitors were combined. Additional investigations were performed with these multiple-monitor data to study the variability of the measurements themselves. Although the monitoring system continued to expand and operate beyond 1987, releases of krypton-85 from the PUREX Plant declined precipitously after that time.

Air samples at each monitoring station were collected by slowly pumping air into a bag at a low flow rate over a 4-week period. The krypton-85 was cryogenically separated from the rest of the sample and counted. The counting error for each krypton-85 sample is reported to be about ±10 percent (e.g., Jaquish and Mitchell 1988, Section 3.1).

The krypton-85 source term for the period 1984 through 1987 was reconstructed for this validation exercise by using PUREX Plant logbook records and the same technique used for the HEDR source term in the 1940s (Ramsdell et al. 1994).

For the evaluations, a nominal global background of 24 pCi/m^3 has been added to all estimated values to allow straightforward comparison with the measurements (Ramsdell et al. 1994).

7.3 Models Evaluated

Using the available monthly source terms for krypton-85, the RATCHET model was used to estimate the distribution of krypton-85 concentrations in air for the relevant months between 1984 and 1987. This is a direct validation of the transport portions of the RATCHET model. The deposition algorithms are not used for noble gases such as krypton because krypton does not deposit.

During the 1980s, numerous wind stations were installed on the Hanford Site. This system of 25 meteorological stations provided additional input data for the RATCHET model that are not available during the period of the 1940s. For the evaluation of model validity, RATCHET was run both with and without all available meteorological data. This allows validation of the model under ideal conditions and under the conditions for which it must be applied on the HEDR Project.

7.4 Evaluation of Results

The measurements and median of the estimates of krypton-85 concentration in air at the cell representing the stations north of the Hanford Site 300 Area and across the Columbia River at Fir Road are presented in Figure 7.1. This figure was prepared using all of the available atmospheric data. The dips in the estimates and measurements in September/October of each year are a result of PUREX Plant operating practices. The plant was run in a batch mode, and the system was cleaned out at the end of every fiscal year, which ends September 30. The estimates can be seen to be within factors of about 2 for most periods. Note that the variability between the measurements made at each of these three stations is of approximately the same magnitude as the discrepancy of the estimate from each individual measurement. This is highlighted in Figure 7.2, which shows the variability in measured krypton-85 concentration between two samplers located within a few meters of each other.

Figure 7.3 illustrates the median results of RATCHET estimates using an atmospheric input data set limited to only those weather stations available in the 1940s. The pattern of the estimate is the same as that shown in Figure 7.1, but the absolute magnitude is somewhat higher. This implies that the lack of the additional weather stations in the 1940s should result in an overestimate of air concentration of contaminants in the vicinity of the Hanford Site 300 Area by about a factor of 3.

A summary of all results including the other more distant monitoring stations is shown in Figure 7.4. This shows cumulative frequency plots developed from the ratios of the median estimated value to the measured value for all stations for all months. One curve represents the results using all available meteorological data, the other the results using only the meteorological stations available in the 1940s. A total of over 300 data points are reflected in these curves. For the curve using all

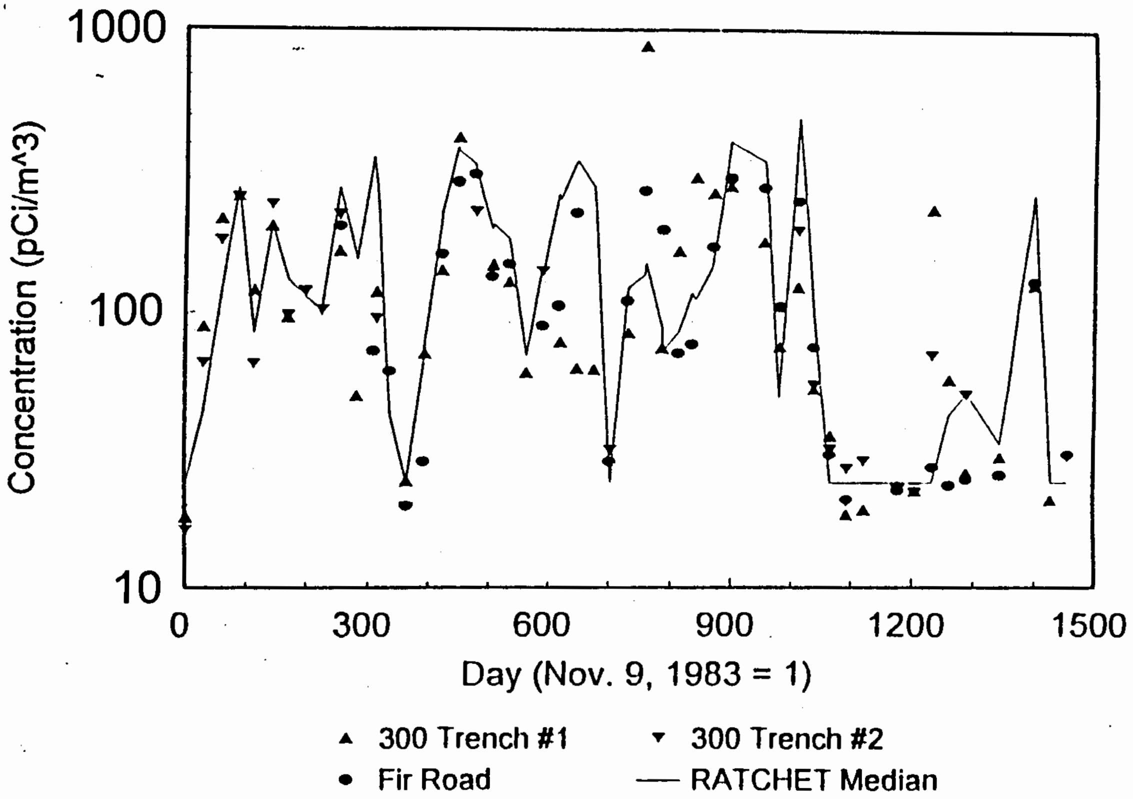

Figure 7.1. Comparison of Monthly Average Estimates and Measurements of Krypton-85 Concentration in Air (Ramsdell et al. 1994)

available meteorological data, the median ratio of estimate to measurement is about 1.25. This means that the RATCHET results have a median bias of only about 25 percent. There is 73 percent confidence that the RATCHET results are within a factor of 2 of the measurements, and nearly 85 percent confidence that the results are within a factor of 3 under ideal conditions. For the curve generated using data equivalent to that available in the 1940s, the median ratio of estimated to measured increases slightly to 1.38, indicating a bias of about 38 percent. There is about a 64 percent confidence that the estimates are within a factor of 2 of the measurements, and about 80 percent confidence that the estimates are within factors of 3, with the input equivalent to that available in the 1940s.

The correspondence of the estimates and measurements for all monitoring locations is illustrated in a different manner in Figure 7.5. This figure shows a scatter plot of the estimated and measured time-integrated air concentrations of krypton-85 at each of the 9 distinct reporting locations (the two 300 Area monitors considered together), using all available historical measurements. A perfect correspondence would result in a straight line on the diagonal. All but one of the stations are within a factor of 2 of this line.

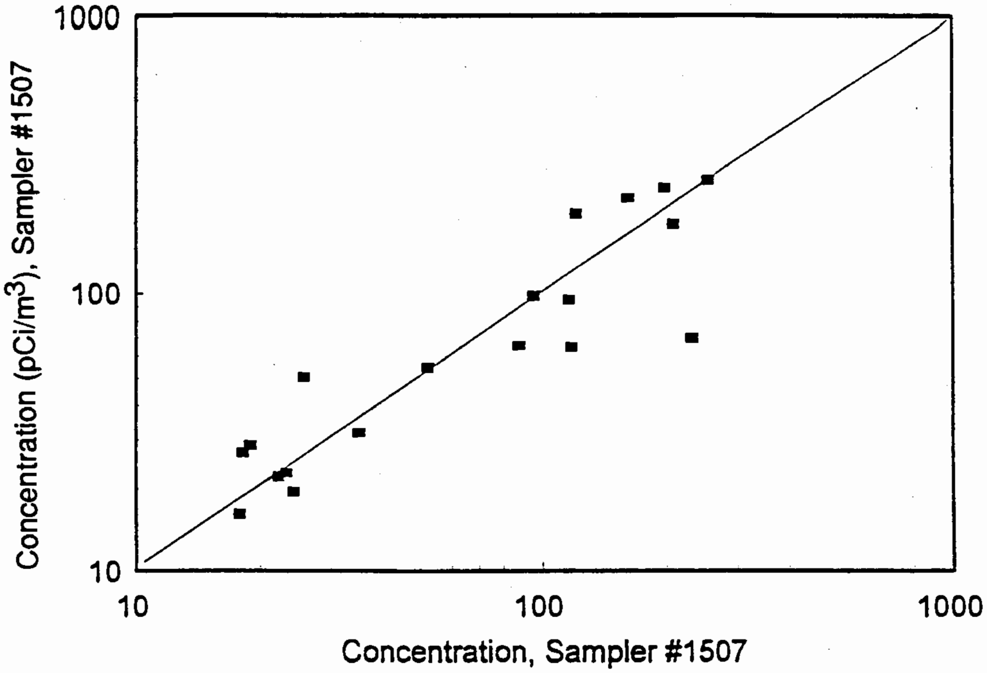

Figure 7.2. Comparison of Krypton-85 Concentrations in Samples Collected by Two Different Air Samplers at the Same Location (Ramsdell et al. 1994)

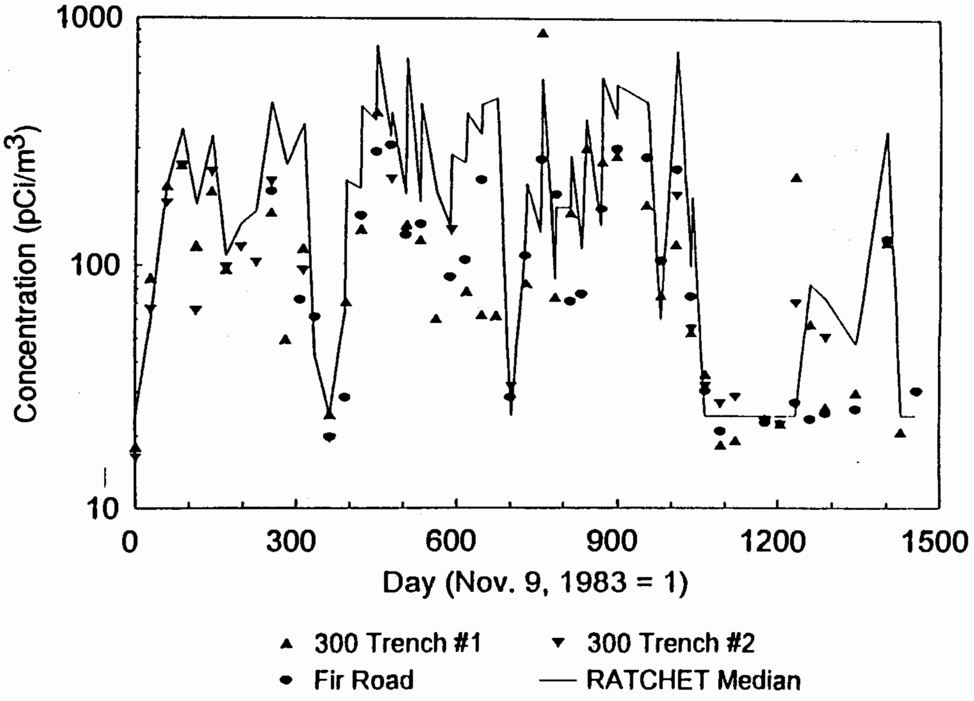

Figure 7.3. Comparison of Monthly Average Estimates (Using Meteorological Data Comparable to Those Available in 1940s) and Measurements of Krypton-85 Concentration in Air

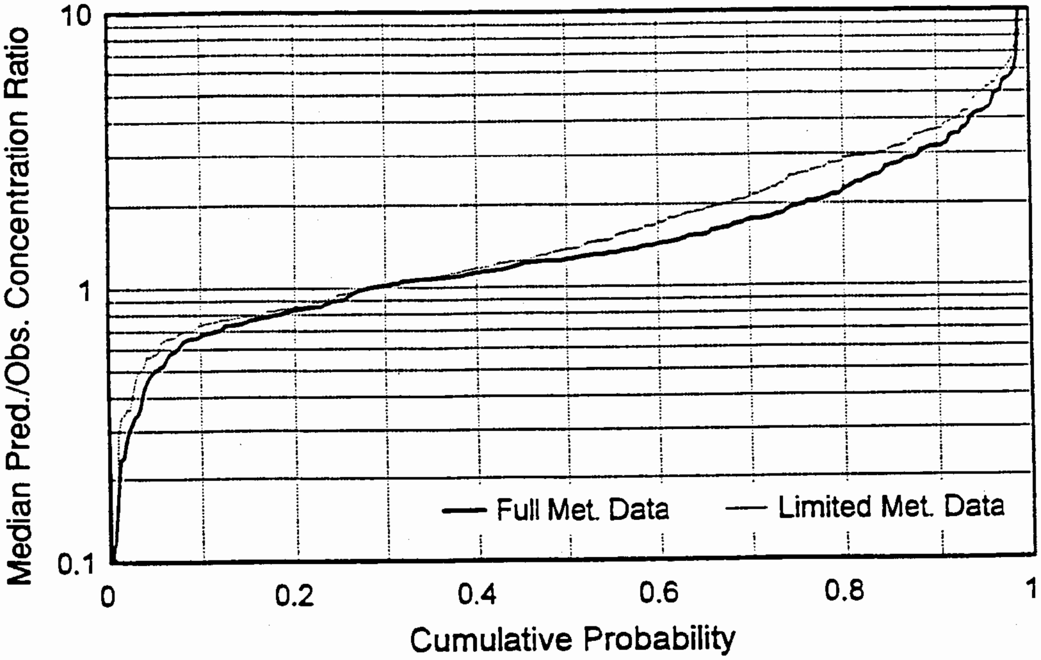

Figure 7.4. Cumulative Frequency Distributions for the Ratio Between the Median Value of Estimated and Measured Concentrations in the Krypton-85 Data Set (Ramsdell et al. 1994)

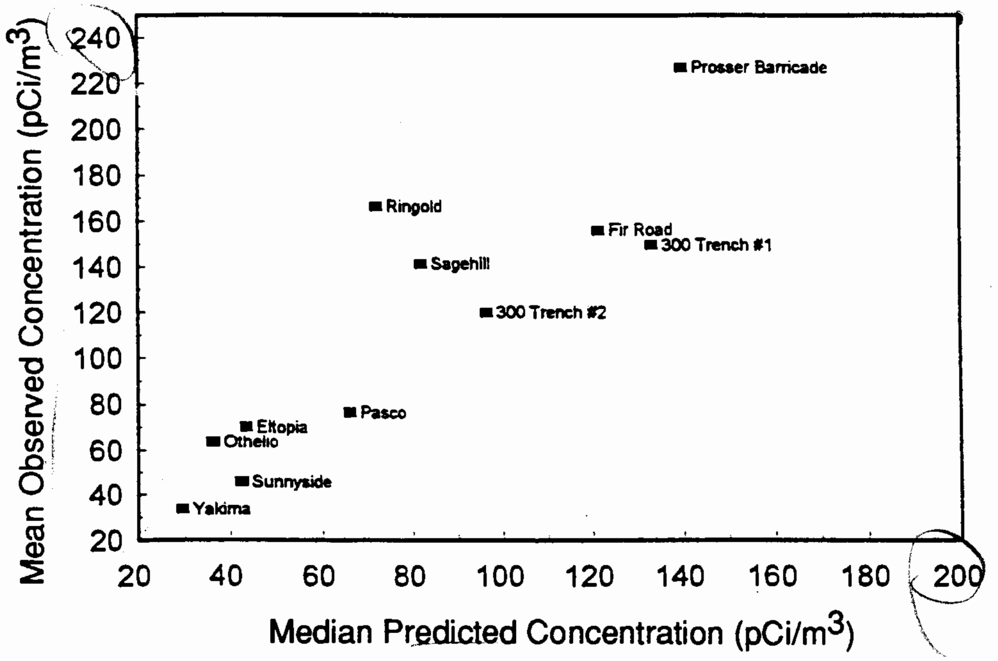

Figure 7.5. Estimated and Measured Time-Integrated Air Concentrations of Krypton-85 at Individual Sampling Locations

The validation calculations were performed with the assumption that the PUREX Plant was the sole source of krypton-85 emissions (about 500,000 Ci/year). Review of the Hanford Site annual reports indicates that in 1985 an additional 350 Ci were emitted from the 400 Area (the Fast Flux Test Facility). This small amount should not affect the measurements. However, in 1986 about 45,000 Ci were released from the Hanford Site N Reactor (PNL 1987). Figure 7.1 shows some potential underestimates by the model for the first half of 1986. Depending on the release rate and time from the N-Reactor, this could have had an impact on the measurements, and the estimate may actually be better than shown in the figure if this release is considered.

26 8.0 *Hanford Site* Worker Thyroid Counts, 1945-1946

Thousands of thyroid radioactivity measurements were made on Hanford Site workers employed in the nuclear fuel reprocessing facilities during the years 1944 through 1946 (Ikenberry 1991). At that time, these measurements were used as a qualitative measurement of radioactive iodine-131 in worker thyroid glands. Called "thyroid checks," the measurements were performed in the general plant environment using portable radiation-detection instruments. The results of the thyroid checks were compared with a screening level for tolerable thyroid exposure to ensure that workers did not receive excessive iodine-131 exposures.

8.1 Assessment Question

26 The assessment question addressed is, "What was the average thyroid burden of iodine-131 for adult male residents of Richland, Washington, for each month between June 1945 through August 1946?" *For the purpose of this assessment, the bulk of the Hanford Site workers are assumed to be males residing in Richland.*

8.2 Available Thyroid Check Data

25 The total database of thyroid counts was prepared and reported by Ikenberry (1991). Nearly 7900 measurements between June 1945 and August 1946 are available and documented. For the purpose of this exercise, it is assumed that all workers have environmental exposures, and *that* occupational exposures *do not impact the mean doses.* Use of the mean of measurements for each month should ensure that extreme measurements caused by occupational contamination are not evaluated as environmental exposure. *Occupational exposures are neither accounted for nor separated from environmental exposures because individual worker exposure histories are not available.*

8.3 Models Evaluated

The atmospheric source term was prepared using the hourly data of the STRM model. Dispersion was estimated with hourly inputs to RATCHET. The DESCARTES code was used to obtain the monthly air concentration and deposition values for the north Richland cell (cell 469) and for the area around Sunnyside, which supplied milk to Richland (Beck et al. 1992, pp. 31-32). The CIDER code was used to generate distributions of intake for a reference adult male living in Richland. The distributions were post-processed to determine thyroid burden. This method provides indirect validation of the RM and STRM source terms, the RATCHET dispersion model, and the DESCARTES environmental accumulation and distribution, and direct validation of the CIDER model.

8.4 Evaluation of Results

Figure 8.1 compares the estimated distribution of worker thyroid burdens as a result of environmental exposure with the mean of the monthly measurements. The estimated values show somewhat more variability than the means of the measurements, but all sets are within factors of 4 or fewer of the medians of the estimated distributions.

The thyroid burdens presented result from inhalation of air in the north Richland vicinity, ingestion of commercial milk from the Sunnyside area, and ingestion of commercial vegetables. Commercial milk was used because it is known that the Richland residents were served under a government milk purchase order with the Morning Milk/Carnation Creamery in Sunnyside during this period (Beck et al. 1992, pp. 34, A.4-A.5). For consistency, it is assumed that commercial vegetables were also used. As opposed to milk from a family cow, the thyroid burden added by commercial milk and vegetables is small in comparison to the inhalation component. This emphasizes the importance of knowing the food source estimate dose. Because the source of commercial milk was upwind from the Hanford Site, the iodine-131 concentrations in pasture, and, therefore, in milk, were low. The contributions of these various pathways to estimated median dose are illustrated in Figure 8.2. It is apparent that inhalation is the largest contributor to the dose, which is understandable considering that the milk is from the upwind Sunnyside location. Figure 8.3 compares

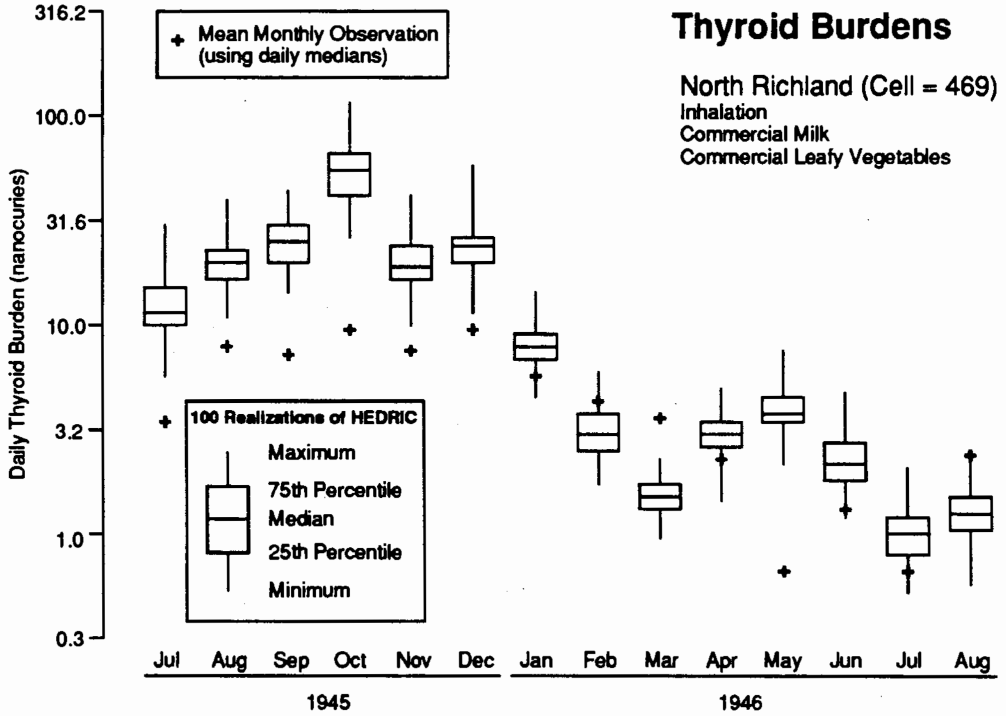

Figure 8.1. Comparison of Monthly Average Estimates and Measurements of Iodine-131 Thyroid Burden in Adult Hanford Site Workers, 1945 and 1946

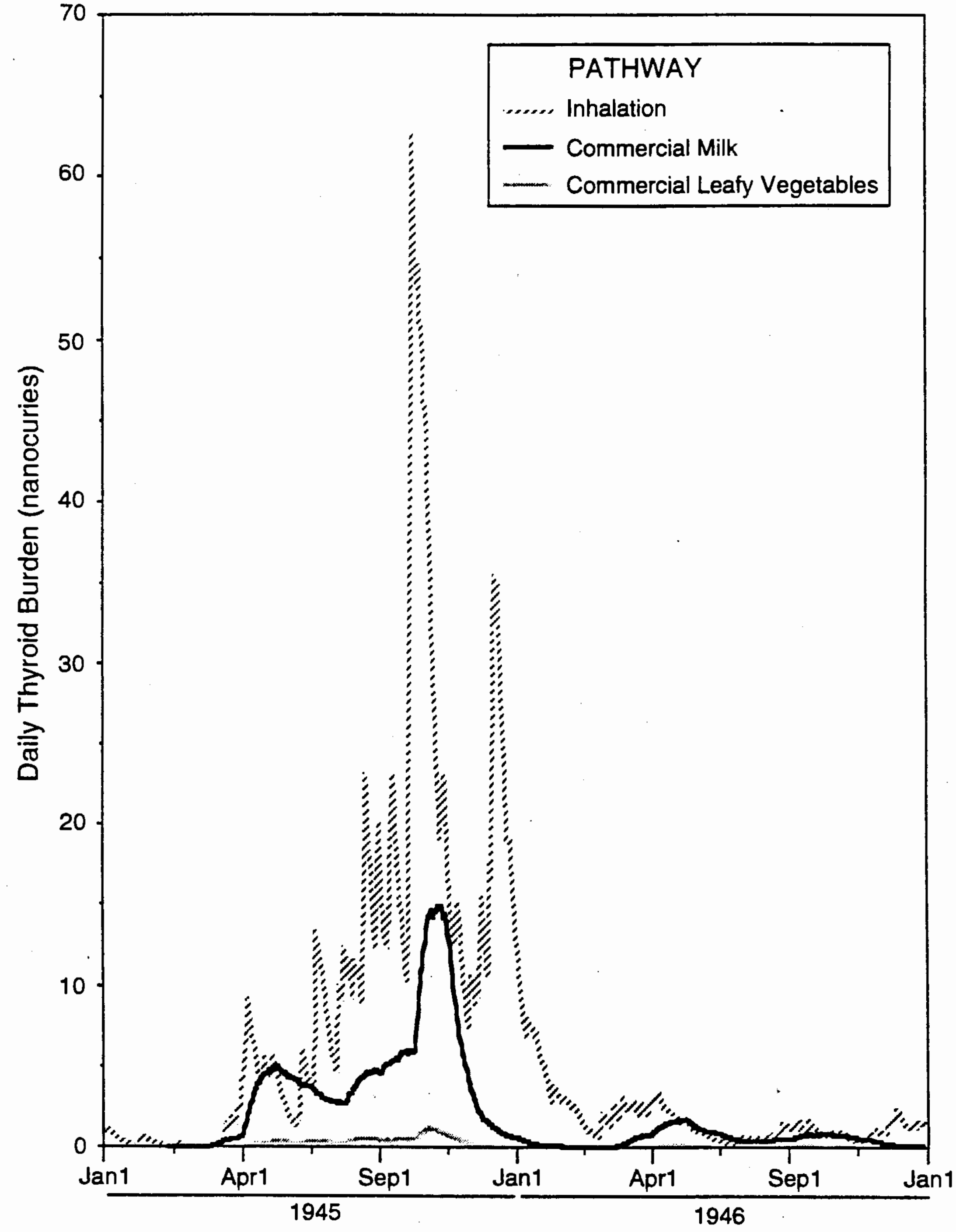

Figure 8.2. Contribution of Inhalation, Commercial Milk and Leafy Vegetable Ingestion to Estimated Thyroid Burden of Iodine-131 in Adult Males in Richland for 1945-1946

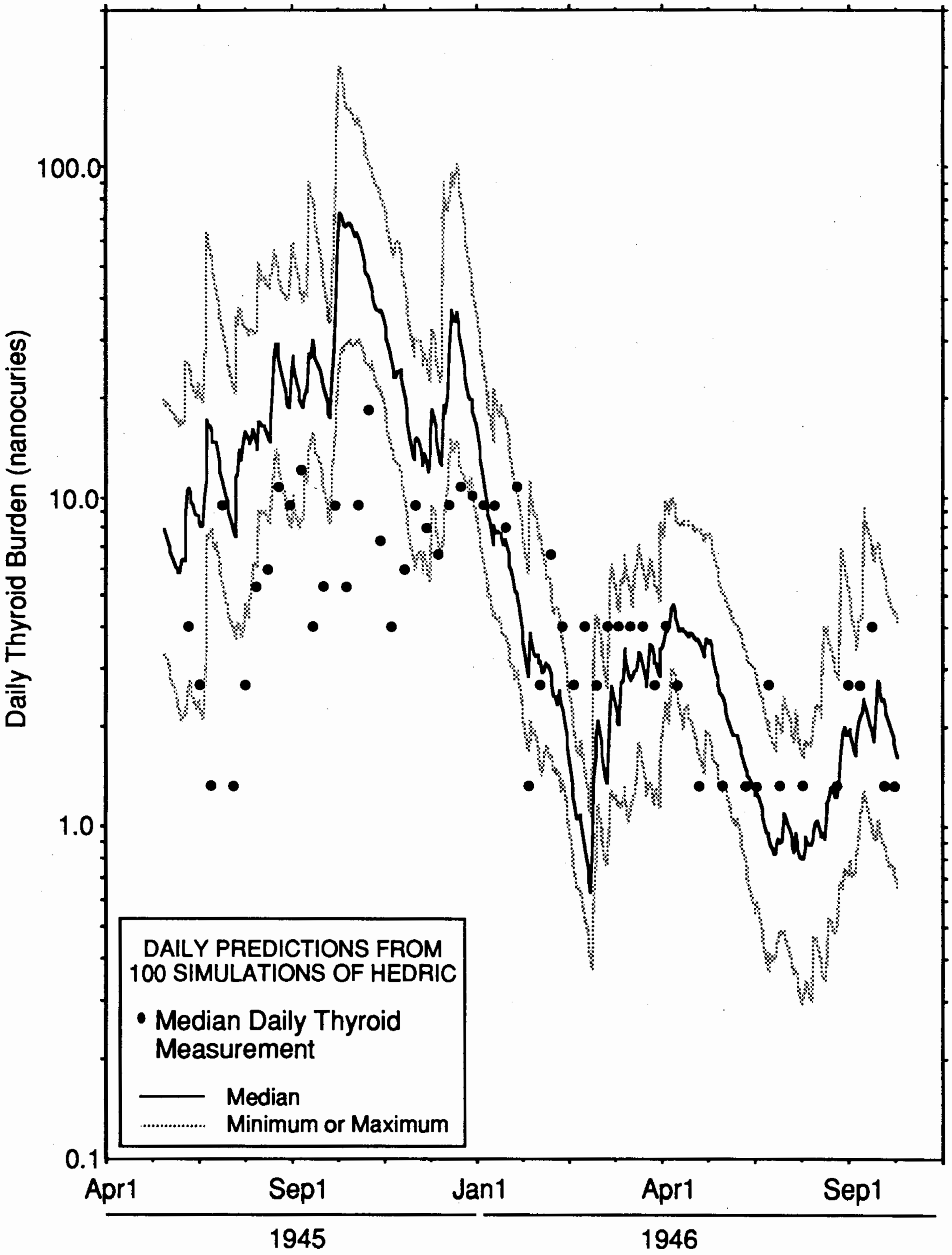

Figure 8.3. Comparison of Estimated with Median Measurements of Daily Thyroid Burden from Inhalation, Commercial Milk and Leafy Vegetable Ingestion

the body burden estimated from inhalation and ingestion of commercial food products with the average body burden measured. The estimates tend to be higher than the measurements but are always within an order of magnitude of the median measurements. The stratification evident in the measurements is caused by the discrete number of counts per minute recorded (i.e., 1 cpm is a body burden of 2.8 nCi, 2 cpm is a body burden of 5.4 nCi, etc.). For each individual, the average of two counts was used (left and right lobes of the thyroid), sometimes resulting in reported counts of 0.5 cpm, 1.5 cpm, 2.5 cpm, etc.

This evaluation emphasizes the importance of the HEDR commercial milk distribution model. Use of local milk sources in the calculation for adult Richland workers would result in a gross overestimate of dose to this type of individual. The nature of this result for commercial milk was also estimated in the early HEDR results (PNL 1991, p. C.18), but not emphasized at that time.

9.0 Columbia River Hydraulics

Modeling the transport of radionuclides released from Hanford Site production reactors on the banks of the Columbia River involves the use of a computer model that accurately reproduces the flow characteristics of the river by which the radionuclides are diluted and undergo radiological decay as they travel downstream. The model selected for use on the HEDR Project is CHARIMA (Holly et al. 1993). This model can accommodate tributary inflows, multiple channels within the river, and the presence of dams and reservoirs, and has the capability to route contaminants to any specified location. For the Columbia River computations, the CHARIMA model was modified to allow for radionuclide decay. The modified model is called WSU-CHARIMA to differentiate it from the acquired model version. Inputs to the model are the water discharge of the Columbia River upstream of the Hanford Site, discharges of the downstream tributaries, and the geometry of the river channel. Estimated river characteristics depend on the quantity of water and on the length of time it takes to travel from one place to the next. A full description of the validation efforts performed for the WSU-CHARIMA model is provided in Walters et al. (1994). Only a summary is provided here.

9.1 Assessment Question

The question addressed is, "What are the discharge hydrograph and water surface elevations of the Columbia River at specific downstream locations?" A satisfactory answer to this question ensures that accurate discharge velocities, water-surface elevations, and mass-balance estimates are produced by the model. This directly validates the dilution and travel time components of the WSU-CHARIMA estimates.

9.2 Available Columbia River Data

Validation of WSU-CHARIMA unsteady-flow hydraulics was accomplished using hourly stage (water-surface elevation) measurements at four gauging stations along the Hanford Reach of the Columbia River. Recent establishment of gauging stations at the 100-B, 100-H, 100-F reactor sites, and the 300 Area provides continuous hourly stage readings of the hydropeaking releases from Priest Rapids Dam. A file of 300 hourly stage measurements at each of the four locations was obtained from Westinghouse Hanford Company.(a) Hourly discharge data from Priest Rapids Dam for 1992 was obtained from the Grant County Public Utility District.(b)

(a) Data file (HEDR Project Document No. 01940003), "Water-Surface Elevations of Columbia River at B, H, F, and 300 Area Reactors, May and October 1992," from W. McMahon (Westinghouse Hanford Company) to B. G. Gilmore (Battelle, Pacific Northwest Laboratories), April 1993.

(b) Data file (HEDR Project Document No. 01940004), "Daily Operations Summary 2 for Priest Rapids, March 1992-February 1993," from D. Lewis (Grant County Public Utility District) to B. G. Gilmore (Battelle, Pacific Northwest Laboratories), April 1993.

9.3 Models Evaluated

Columbia River hydraulics and radionuclide transport are being simulated with the WSU-CHARIMA computer model (Walters et al. 1994). The hydraulics of the river are being evaluated and are independent of the radionuclide source term. The evaluation is a direct validation of WSU-CHARIMA.

9.4 Evaluations Performed

Because measurement data for October 1992 were available for comparison, Columbia River conditions for October 1992 were simulated at each of the four Hanford Site gauging stations. Hourly stages were computed at each station for comparison with the gauge measurements. An example result is shown in Figure 9.1 for the Hanford Site 300 Area gauging station. This figure shows the estimated and measured stage (water level in feet above mean sea level) as a function of time. (The parameter k is Strickler's roughness coefficient, determined during the model calibration efforts to be 35 for the Columbia River from river mile 396 to 348, and to be 50 for river miles below 348). The convergence of the computed and measured hydropeaks are within a few hours, and the hydrograph shape is coincident. The water-surface peaks for all hours are within 1 foot. This is typical of the results for the other gauging stations (Walters et al. 1994).

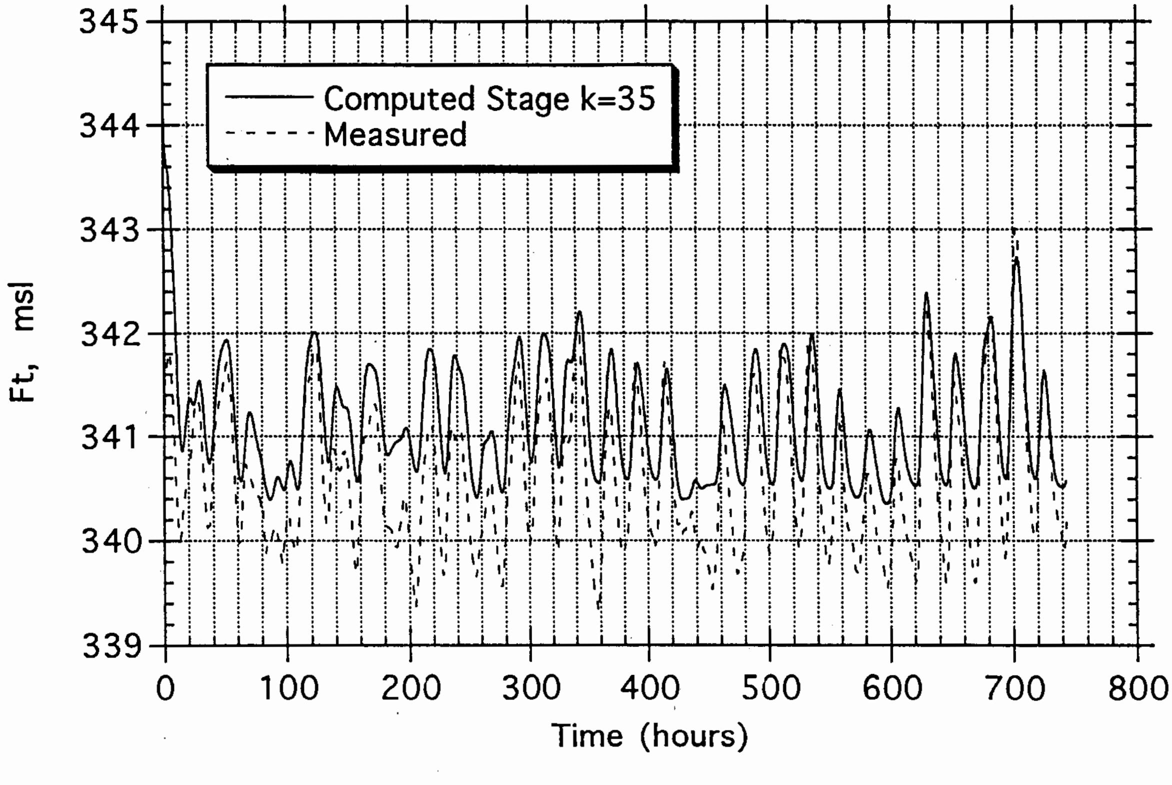

Figure 9.1. Comparison of Estimated and Measured Columbia River Water Surface Elevation at the Hanford Site 300 Area, October 1992 (Walters et al. 1994)

Further investigations were conducted for The Dalles, Oregon, gauging station using daily discharge hydrographs for the year 1964, obtained from the commercially available EARTH INFO database. The discharge hydrograph was computed and compared with the published data, as shown in Figure 9.2. The computed hydrograph is closely coincident with the published data. The closely matching peaks indicate a satisfactory conservation of the mass flow rate.

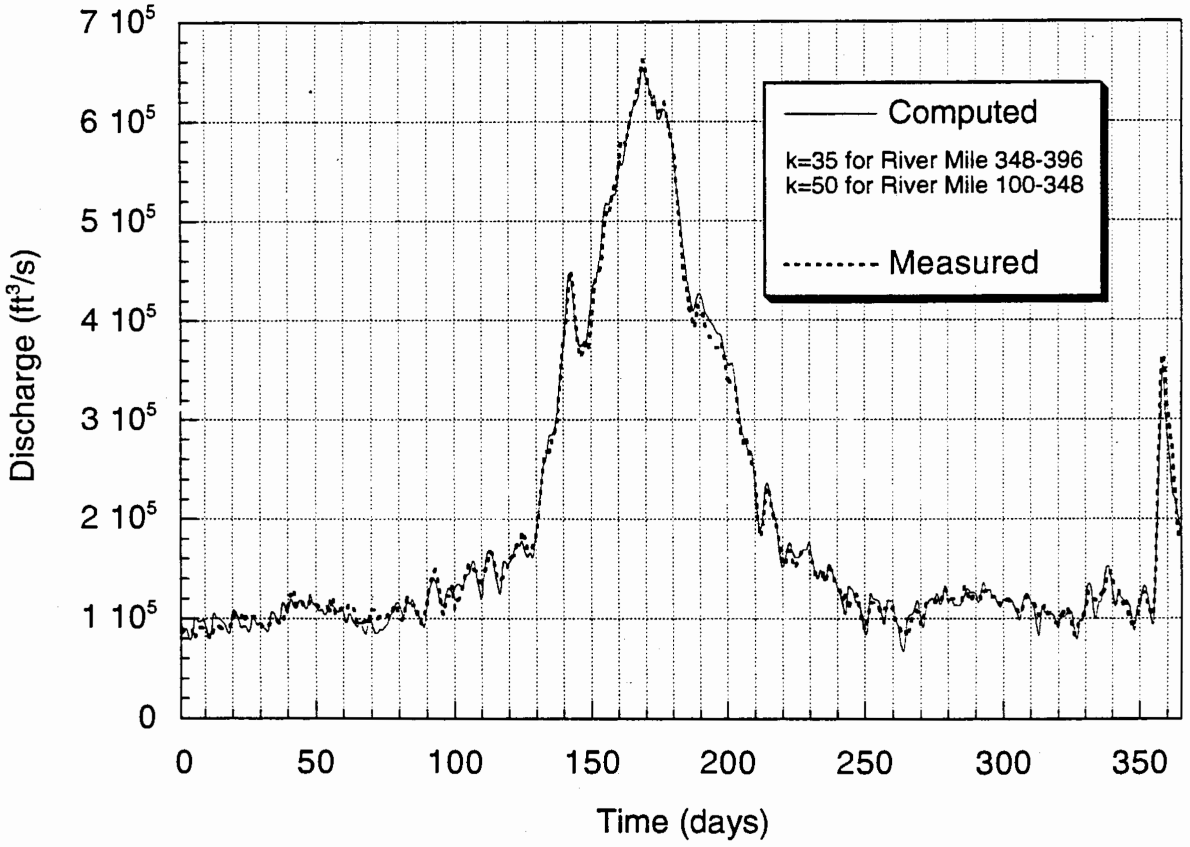

Figure 9.2. Comparison of Estimated and Measured Water Discharge Rate at The Dalles, Oregon, 1964 (Walters et al. 1994)

10.0 Columbia River Water Concentrations, 1967

Concentrations of five radionuclides in Columbia River water are being estimated using the models in the HEDR toolbox. These radionuclides are sodium-24, phosphorus-32, zinc-65, arsenic-76, and neptunium-239. Chromium-51 is being used for validation.

10.1 Assessment Question

The assessment question being addressed is, "What was the monthly average concentration of radionuclides of interest to the HEDR Project in Columbia River water at downstream locations for which historical measurements are available in 1967?" The year 1967 is selected for the purposes of this report to be comparable with the validation of fish and ocean products discussed below in Sections 11.0 and 12.0. For validation purposes, Walters et al. (1994) evaluated all of the historical measurements from 1960 through 1970.

10.2 Available Columbia River Water Concentration Data

Numerous measurements were taken of Columbia River water radionuclide concentrations during the 1960s. Monthly composite samples are available for phosphorus-32, zinc-65, and chromium-51 at several locations downstream of the Hanford Site release points, including Richland, Pasco, McNary Dam, The Dalles, and Bonneville Dam. In addition, grab samples of the other, shorter-lived, radionuclides are available for intermittent times during this same period.

10.3 Models Evaluated

Estimated concentration of radionuclides in water depends on both the source term and transport estimates. The direct comparison is made with the WSU-CHARIMA outputs. Validation of those outputs serves as indirect validation of the river source term release model, STRRM, as well.

10.4 Evaluation of Results

The estimation process involves the use of the monthly realizations of the radionuclide release source term, transported using the WSU-CHARIMA model. This provides values of water concentration of each radionuclide at each location. These were compared with the monthly grab and composite water samples taken at the respective sampling locations. A complete description of the comparisons for each radionuclide at each location for the years 1960 through 1970 is provided in Walters et al. (1994).

The monthly measurements and model estimates were plotted for each month on a time-series plot. The set of time-series plots was used to look for patterns of model-estimate bias over time and space for the different variables. Examples of these plots, taken from Walters et al. (1994), are provided as Figures 10.1 and 10.2 for chromium-51 in composite and grab samples, respectively, at the Richland location. Additional figures of this nature are provided in Walters et al. (1994) for other years during the 1960s, for the additional radionuclides of interest, and at additional locations along the Columbia River.

These two figures illustrate the general conclusions that may be drawn from the validation exercise for WSU-CHARIMA. The estimated and measured values for the composite samples (which best approximate the monthly averaging used for the simulation) track very well (see Figure 10.1). The estimated values almost always fall within the spread of the available historical measurements for each month. Estimated and measured values are always well within a factor of 2 of each other.

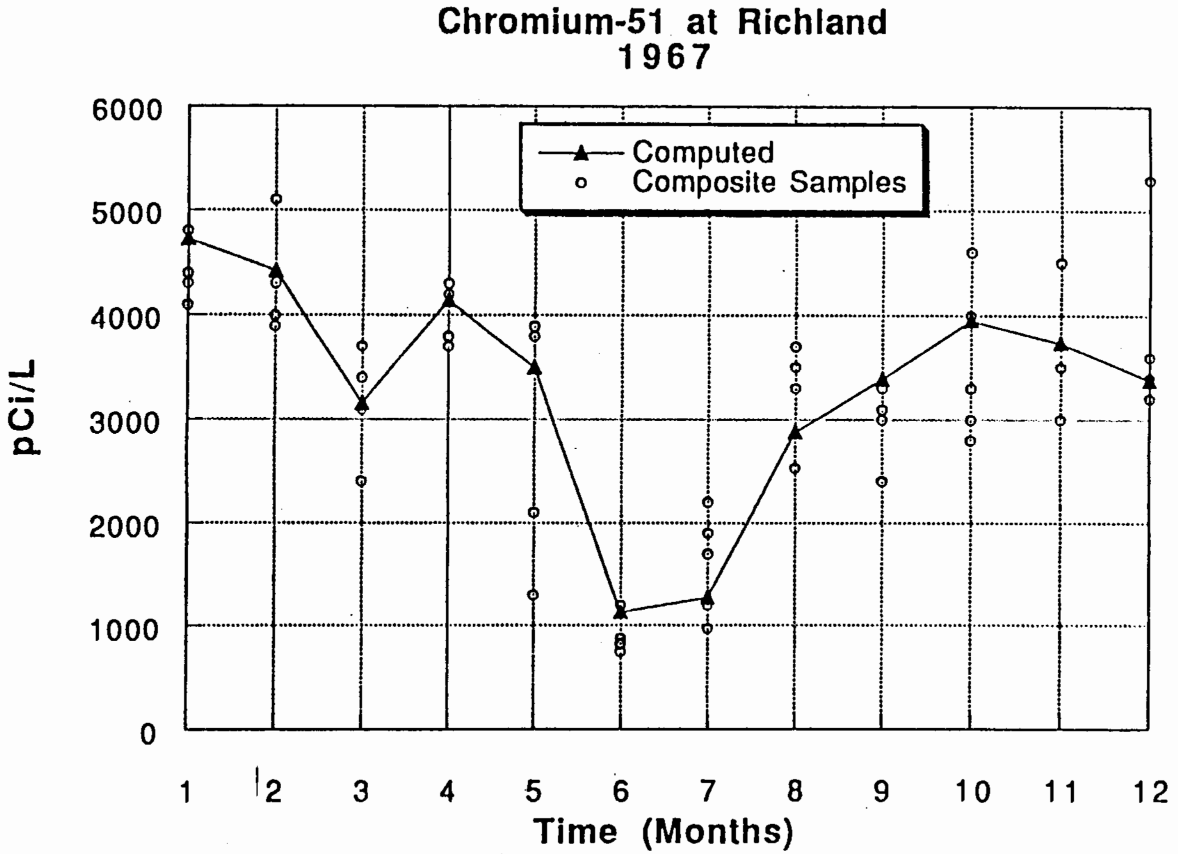

Figure 10.1. Comparison of Estimated Average Concentration of Chromium-51 in Columbia River Water at Richland with Composite Samples, 1967 (Walters et al. 1994)

Similar results can be seen with the grab samples, illustrated in Figure 10.2. Because grab samples represent only an instantaneous measure of radionuclide concentration in river water and the estimated points represent the monthly average at that location, it is remarkable that the two sets of data are as coincident as they are. This figure supports the use of the monthly averages in the subsequent estimates because such minor day-to-day fluctuations are negligible in the estimation of long-term dose.

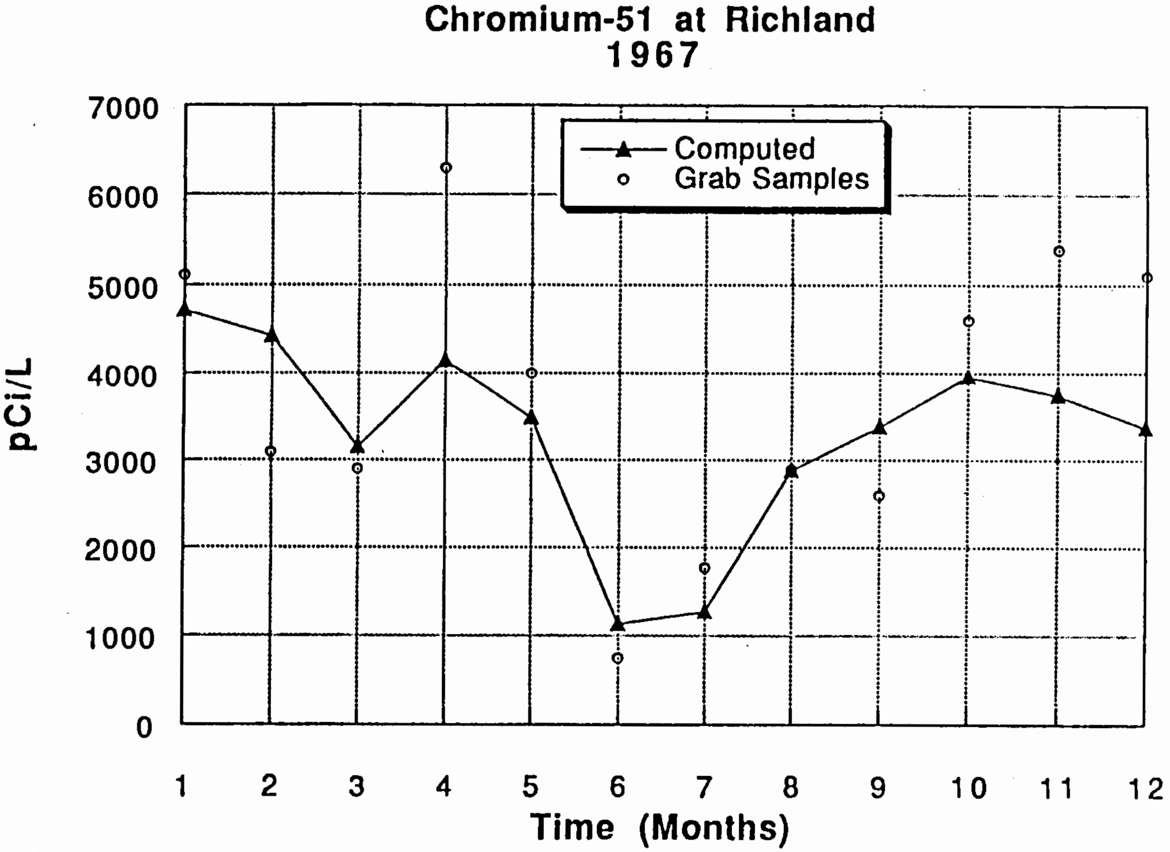

Figure 10.2. Comparison of Estimated Average Concentration of Chromium-51 in Columbia River Water at Richland with Grab Samples, 1967 (Walters et al. 1994)

11.0 Columbia River Resident Fish Concentrations, 1967

Concentrations of five radionuclides in Columbia River fish are being estimated using bioaccumulation factors developed on the basis of ratios of radionuclide concentrations in fish to those in the river water. These radionuclides are sodium-24, phosphorus-32, zinc-65, arsenic-76, and neptunium-239. Data for the years 1960 through 1966 were used to develop the bioaccumulation factors (Thiede et al. 1994). The data for 1967 were reserved for validation use.

11.1 Assessment Question

The assessment question being addressed is, "What was the monthly average concentration of sodium-24, phosphorus-32, and zinc-65 in Columbia River omnivores, first-order predators, and second-order predators in the Ringold, Kennewick/Pasco, and Snake/Walla Walla rivers segments of the Columbia River in 1967?" The omnivorous fish are bullhead, catfish, suckers, whitefish, and chiselmouth. First-order predators are perch and crappie, and second-order predators include bass and squawfish. The assessment question omits the short-lived radionuclides arsenic-76 and neptunium-239 because they were not measured during most of the 1960s.

11.2 Available Columbia River Fish Concentration Data

Numerous measurements of Columbia River fish radionuclide concentrations were taken by Hanford Site monitoring groups. Samples are available for sodium-24, phosphorus-32, and zinc-65 at several locations near the Hanford Site release points. Few samples are available at locations below McNary Dam. As discussed by Walters et al. (1992, Sections 7.3 and 9.0), offsite agencies were interested in water and sediment, but not in resident fish. Summaries of the historical measurements for the fish sampled in 1967 are provided in Appendix D, Table D.1, for comparison with the estimated radionuclide concentrations in fish shown in Table D.2.

11.3 Models Evaluated

Estimated concentration of radionuclides in fish depends on the source term and transport estimates and on the bioaccumulation modeled in the Columbia River Dose (CRD) model. The direct comparison will be with the CRD intermediate output. Validation of the output will serve as indirect validation of the river source term (STRRM) and transport (WSU-CHARIMA) models.

The bioaccumulation factors (ratio of measured concentration of the radionuclide in biota to the estimated water concentration) used were prepared from the 1960-1966 fish measurements and the estimates of water contamination discussed in Section 10.0. In a sense, this process allows the indirect use of the historical measurements in the estimation of radionuclide concentrations in fish as

$$\left[\frac{B_{\text{measured}}}{W_{\text{calculated}}}\right] W_{\text{calculated}} = B_{\text{measured}} \qquad (11.1)$$

where B_{measured} = measured concentration of the radionuclide in biota
$W_{\text{estimated}}$ = estimated water concentration
[B/W] = definition of bioaccumulation factor

For the year 1967, the values of B_{measured} were retained for use in this validation exercise.

11.4 Evaluation of Results

Table 11.1 presents the ratios of the estimated concentration of radionuclides in the three general types of fish to the average of that measured in the Ringold, Kennewick/Pasco, and Snake/Walla Walla river segments of the Columbia River. Only six fish were monitored in the Richland segment of the Columbia in 1967, so that segment was omitted from the analysis. Only the radionuclides sodium-24, phosphorus-32, and zinc-65 were measured, and the short-lived sodium was measured only in the upstream segment of the river near Ringold. The analyses for each month, location, and species are based on historical measurements for 1 to 30 fish. In general, more omnivorous fish were caught than predators, and more predator-1 fish were caught than predator-2 fish. The measured radionuclide concentrations in the samples were quite variable, often ranging over two orders of magnitude for a given type of fish at a given location for any one month.

A sampling of the results of Table 11.1 is graphically presented in Figures 11.1 and 11.2 for selected locations and fish types. Estimates for sodium-24 were made for the Ringold segment of the Columbia River, the only one for which historical measurements were available. The average of monthly ratios of estimated value to mean measured value is 0.77, meaning that for the year 1967 the estimates were about 23 percent lower than the measurements.

Estimates for phosphorus-32 at Ringold were similar to those for sodium-24; the annual average ratio of monthly estimates/measurements was 0.76, although there were larger month-to-month variations. However, the estimated/measured ratio for phosphorus-32 was not as close at other locations, reaching a maximum ratio of 17 for omnivorous fish in the Kennewick/Pasco segment of the river. Overestimates of phosphorus-32 concentrations were generally highest in the early portion of the year, when the "cool season" bioaccumulation factor was employed. Estimates were better in the other months. This pattern was similar for the other fish types and other locations, but much less pronounced. The initial data used to develop the cool season phosphorus bioaccumulation factor was extremely variable (the 90-percent confidence interval of the resulting bioaccumulation factor covers two orders of magnitude), so some variability of this type should be expected. In addition, the overestimates appeared to be highest for the Kennewick/Pasco location. All fish from this location were caught at a sampling area known as Islandview, near the mouth of the Yakima River. It is possible that the fish at this location were living largely in water derived from the Yakima River, and thus were not as highly exposed as the model assumes.

Table 11.1. Ratios of Estimated to Measured Radionuclide Concentrations in Fish, 1967

Ratios of Estimated to Measured							
	Omnivores			Predator 1		Predator 2	
Month	Na-24	P-32	Zn-65	P-32	Zn-65	P-32	Zn-65
Ringold Segment							
Jan-67	1.61	0.47	1.40	(a)	(a)	(a)	(a)
Feb-67	1.02	0.41	1.39				
Mar-67	0.92	0.19	1.91				
Apr-67	0.79	0.63	2.59				
May-67	1.01	0.55	1.65				
Jun-67	0.54	2.67	0.86				
Jul-67	0.28	2.51	1.91				
Aug-67	0.42	0.56	1.45				
Sep-67	0.71	0.39	2.18				
Oct-67	0.51	0.27	1.00				
Nov-67	0.44	0.33	0.94				
Dec-67	0.97	0.10	0.60				
Averages	0.77	0.76	1.49				
Kennewick/Pasco Segment							
Jan-67	(b)	0.94	11.83	0.09	2.02	4.51	2.72
Feb-67		49.00	14.55	0.77	4.93	0.93	3.65
Mar-67		10.25	5.27	7.30	5.71	5.84	10.86
Apr-67		67.00	9.44	4.72	5.41	12.00	9.09
May-67		28.64	8.00	2.75	2.66	6.79	6.43
Jun-67		6.27	3.06				
Jul-67		19.33	6.98	2.15	2.36	2.11	0.55
Aug-67		15.56	4.25	0.90	1.94	1.88	1.47
Sep-67		1.57	5.74	2.37	8.35	1.20	1.57
Oct-67		1.05	2.42	1.27	2.93	3.53	1.74
Nov-67		1.52	2.87	3.36	2.62	31.00	1.77
Dec-67		2.87	1.43	0.66	1.33	2.84	2.11
Averages		17.00	6.32	2.39	3.66	6.60	3.82
Snake/Walla Walla Segment							
Jan-67	(b)	0.80	1.91	1.81	1.07		
Feb-67		8.89	2.41	0.62	1.71		
Mar-67		28.00	4.45	1.22	2.62	5.10	2.95
Apr-67		24.87	3.63	3.91	2.44	7.70	2.38
May-67		11.33	2.17	0.89	1.22	3.32	1.24
Jun-67		2.34	1.33	1.03	1.08	8.00	0.40

Table 11.1. (contd)

Ratios of Estimated to Measured

	Omnivores			Predator 1		Predator 2	
Month	Na-24	P-32	Zn-65	P-32	Zn-65	P-32	Zn-65
Jul-67		2.82	1.52	1.32	1.84		
Aug-67		1.95	1.94	0.63	1.94		
Sep-67		0.99	1.57	0.30	1.68	1.06	2.30
Oct-67		1.76	1.31	0.47	1.10	1.52	0.97
Nov-67		1.86	1.21	4.78	1.97		1.08
Dec-67		12.44	1.21	0.78	0.50		0.74
Averages		8.17	2.06	1.48	1.60	4.45	1.51

(a) No predator fish were sampled in the Ringold Segment.
(b) Short-lived sodium-24 was measured only in the upstream segment of the river near Ringold.

The model appears to slightly overestimate the bioaccumulation of zinc-65. For all fish types from all locations sampled in 1967, the model overestimated the average monthly concentrations in fish by about a factor of 3, although a few monthly averages were underestimated by the model. The overestimates were generally highest for omnivores in the cooler months and also appeared to be highest for the Kennewick/Pasco location. As was the case with phosphorus-32, all fish from this location were caught at the Islandview location. This supports the suggestion that the fish at this location were dwelling largely in water derived from the Yakima River and thus were not as highly exposed as assumed by the model.

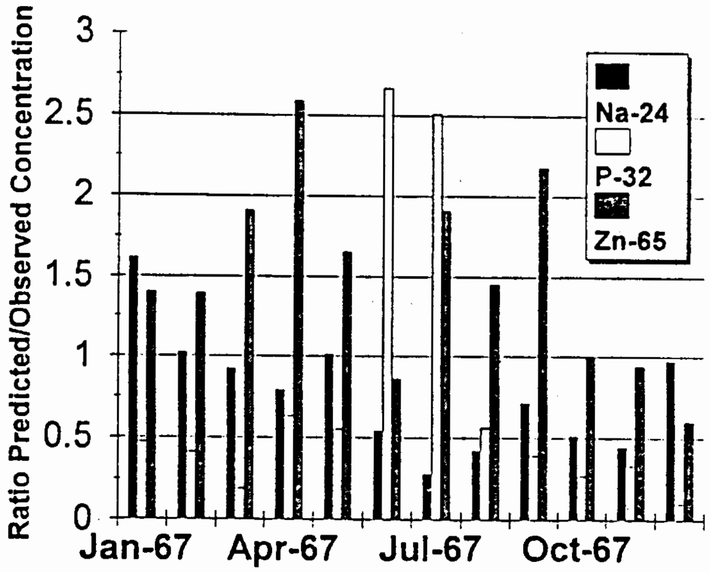

Figure 11.1. Ratios of Estimated to Measured Radionuclide Concentrations in Omnivorous Fish Caught at Ringold, 1967

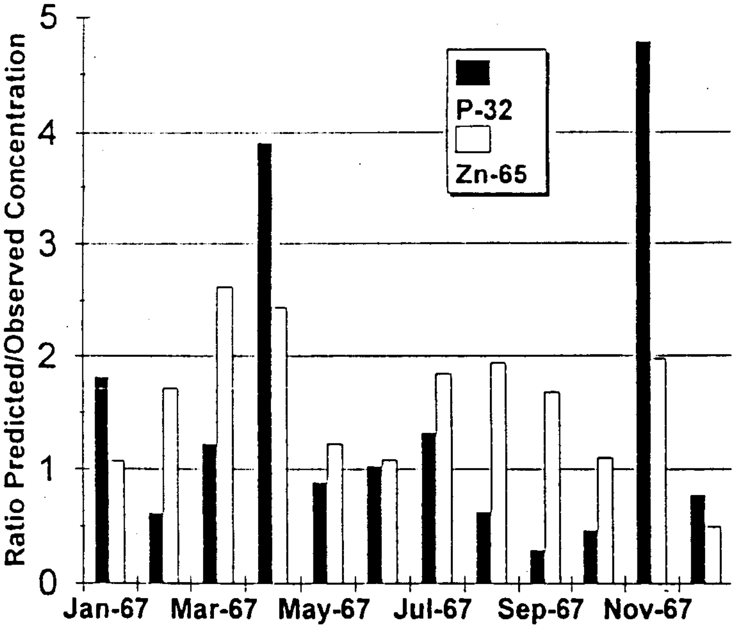

Figure 11.2. Ratios of Estimated to Measured Radionuclide Concentrations in First-Order Predator Fish Caught in the Confluence of the Snake and Walla Walla Rivers with the Columbia River, 1967

12.0 Pacific Coast Oyster Concentrations, 1967

Concentrations of zinc-65 in Pacific Ocean shellfish were estimated as annual averages for application to all locations because the major source of the contamination in the shellfish is a chronic, dilute source in the Pacific Ocean and is only indirectly tied to the monthly concentrations in the Columbia River. The concentrations are based on annual cumulative source terms and the historical measurements from Willapa Bay oysters. Data are available for every year in the 1960s. Most data were used to develop the functional relationships, but the 1967 data were reserved for validation use.

12.1 Assessment Question

The assessment question being addressed is, "What was the 1967 annual average concentration of zinc-65 in Willapa Bay oysters resulting from Hanford Site operations?"

12.2 Available Oyster Concentration Data

Data are available for oysters from Willapa Bay, Washington. These oysters were measured from 1959 through 1977 although contamination levels declined dramatically after reactor shutdown in 1971. The samples from 1959 and 1960 were nonroutine special collections. Beginning in 1961, samples were taken at roughly 2-week intervals. Nonroutine samples were also taken at other Pacific coast locations, but the Willapa Bay area always reported the highest contamination levels. The data are provided in Hanf et al. (1992).

12.3 Model Evaluated

The concentrations of zinc-65 in oysters were estimated using a linear relationship between cumulative annual release of zinc-65 into the Columbia River and measured contamination based on the available historical measurements. The data from 1960 through 1970 were used to develop the functional relationships. The data for the year 1967 were retained for validation use because there was still a sufficient source term in that year to provide reliable measurements. The comparison yields an indirect validation of STRRM and direct validation of the CRD model.

12.4 Evaluation of Results

A simple linear regression of the annual average concentrations of zinc-65 in oysters compared with the annual emissions of zinc-65 into the Columbia River yielded a coefficient of 1.9×10^{-3} pCi/g of zinc-65 in oysters per Ci/year released. Figure 12.1 illustrates a comparison of the measured values of concentration in oysters to the values estimated using the CRD model described. The data for 1959, 1960, and 1967 were not used in the development of the model.

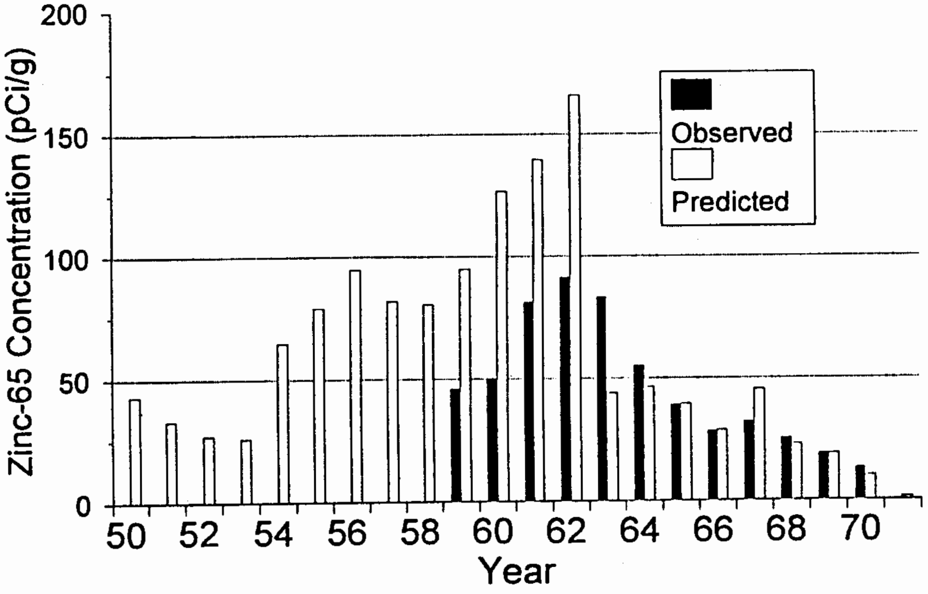

Figure 12.1. Comparison of Estimated and Measured Zinc-65 Concentration in Willapa Bay Oysters, 1950-1971

The 1959 data consisted of one set of six measurements, and the 1960 data similarly consisted of only a few samples. The more complete 1967 data set was reserved for validation. The model estimate is within 40 percent of the 1967 measurements. For the entire decade of the 1960s, use of the model would result in an underestimate of about 10 percent below the measurements.

The CRD implementation of this model is based on the simple relation of emissions to estimated concentrations in oysters for the period prior to the initiation of the measurements. For the period 1959 through 1971, the measurement summaries are used in the CRD calculations, so the dose estimates for that latter period are actually based directly on historical measurements, not on the approximation of the model. The model results are used only for the period prior to the year 1959.

30,31

13.0 *Hanford Site Worker Bioassay Data*, 1960-1971

Tens of thousands of whole-body radioactivity measurements were made on Hanford Site workers employed throughout the Hanford Site operations during the years 1959 through the present. These measurements were used as a measure of exposure to radioactive substances in the workplace. The measurements reflect large numbers of individuals, some measured regularly (annually, monthly) and others only sporadically (e.g., upon hiring, termination, or during particular events). A large fraction of the Hanford Site workers lived in the Tri-Cities area and were routinely exposed to contaminants in the Columbia River water through drinking and recreational activities. Almost all of the whole-body counts taken during the period of reactor operation indicate the presence of sodium-24, zinc-65, cesium-137 (from fallout), and naturally occurring potassium-40 (e.g., Swanberg 1962). Because the data were not complete for 1959 and because the last of the single-pass production reactors from which radionuclides were emitted to the Columbia River shut down in January 1971, the data sets used for validation were from January 1960 through January 1971.

13.1 Assessment Questions

10,35 The assessment question being addressed is, "What were the average body burdens of sodium-24 and zinc-65 for adult male residents of Richland, Washington, for each month between January 1960 through January 1971?" Since the preparation of the HEDR model validation plan (Napier et al. 1993), an additional question has also been framed: "What was the body burden in 1962-1963 of zinc-65 in an individual consuming a known amount of Columbia River whitefish?" *Only four radionuclides are generally available for comparison (cesium-137, potassium-40, sodium-24, and zinc-65). Only two of these are of Hanford Site origin (sodium-24 and zinc-65). Because no other radionuclides were routinely entered in the Hanford Site database and adequate information about them was not available, the assessment questions address only sodium-24 and zinc-65.*

30

13.2 Available Whole Body Count *and Bioassay* Data

HEDR Project staff have acquired all of the routine, worker-related whole body counts from 1959 through 1971. In all, the database consists of over 40,000 records. Foster and Honstead (1967) reported the results of an experiment during which a single individual regularly consumed Columbia River whitefish and had the resulting body burden of zinc-65 measured. The body burdens reported in Foster and Honstead (1967) stand out as the largest in the worker-related records during this period.

A later experiment in which volunteers consumed Columbia River whitefish and were measured for uptake of phosphorus-32 (Honstead and Brady 1967) was also investigated as a source of validation data. The report of that experiment provides insufficient information to allow computer simulation of the experiment.

None of these data were used in the development or for calibration of the CRD model.

13.3 Models Evaluated

The source term was prepared using the monthly data of the river release model STRRM. Monthly estimates of radionuclide concentration in river water were prepared using the transport model WSU-CHARIMA. The river dose model incorporated in CRD was used to obtain the monthly intake values for the Richland location. Intake for a reference adult male living in Richland was used. Body burden, rather than dose, of the radionuclides was estimated. This provides indirect validation of the source terms and the WSU-CHARIMA transport model, as well as direct validation of the CRD formulation.

Use of the Richland individual allows an additional comparison to be made. The Richland Columbia River water treatment plant initiated operations in October 1963. Prior to this time, Richland drinking water was obtained from the uncontaminated Yakima River. A step increase in body burden is, therefore, anticipated for this date.

13.4 Evaluation of Results

Results were prepared for both a representative individual, representing the bulk of the exposures measured in the worker database, and for a specific individual with known exposures.

13.4.1 Reference Individual

31 The reference adult male used in the calculations was assumed to live in Richland and to consume 1 liter per day of treated Columbia River water. Use of 1 liter per day assumes that the workers had additional uncontaminated sources of drinking fluids (e.g., canned drinks, uncontaminated upstream water, etc.). Uptake and retention in the body were modeled using the parameters developed by the International Commission on Radiological Protection (ICRP) for ingestion dose factors (ICRP 1980). These ingestion dose factors are the ones used in the CRD code. *Because the ingestion dose factors were developed for radiation protection purposes, they are inclined to provide somewhat of an overestimate.*

For validation purposes, the comparison is made with the distribution of body burdens listed in the complete worker database. For the calculation, no Columbia River water ingestion is used for the early period (prior to October 1963) during which real residents would not have been using the Columbia River in Richland as a source of drinking water. The measured body burdens for the pre-1964 period provide an idea of the background body burdens that would be expected from other sources of exposure to the Hanford Site worker population, such as occupational exposure and other environmental sources (e.g., drinking water in Kennewick or Pasco).

The comparison of estimated and measured body burdens for sodium-24 is shown in Figure 13.1, which shows just the median of the measurements. The estimate assumes ingestion beginning when the Richland water source became available in October 1963. It is apparent from the measurements that prior to October 1963 there was little exposure of the workers to sodium-24 from routinely recurring sources such as drinking water. Starting in late 1963, the estimates track in both magnitude and temporal pattern with the measurements. The greatest single monthly deviation is a

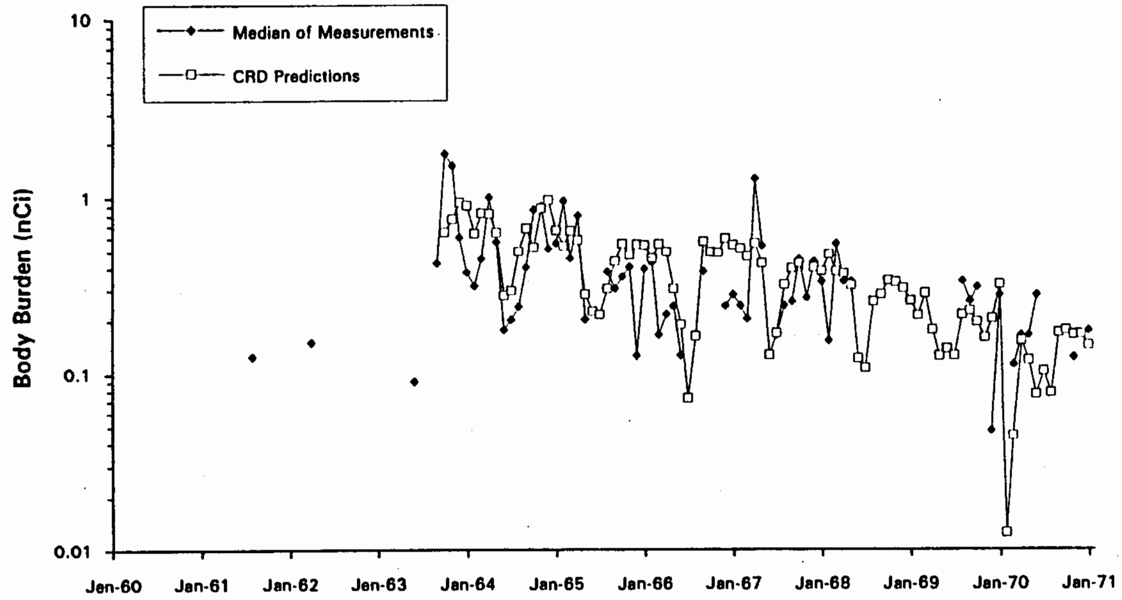

Figure 13.1. Comparison of Estimated and Measured Average Body Burdens of Sodium-24 in Richland Residents, 1960-1971

factor of 4, and the long-term average ratio of estimates to measurements is 1.40. Boxplots of the measured data were prepared, and the estimates, with few exceptions, fall between the 25th and 75th percentiles of the measured distributions. The HEDR estimates always fall within the range of the measured data, which has an intra-month variability of about a factor of 10. For sodium-24, the minimum values measured, and often the lower quartile, were below detection limits.

The comparison of the zinc-65 estimates to the measurements is presented in Figure 13.2. Following the October 1963 startup of the Richland water treatment plant, the estimated body burden of zinc-65 rises to closely follow the median of the measurements. The long-term average ratio of estimate to measurement is 1.39.

The increase in body burden occasioned by the opening of the Richland water treatment plant is not as obvious in the measured zinc-65 data as it was in the sodium-24 data. Under cursory examination, it would appear that the measured body burdens before and after the introduction of Columbia River water are not significantly different. However, the trend of water contamination, also shown in Figure 13.2, was distinctly downward despite the noticeable increase in measured body burdens between early 1963 and late 1963.

It is likely that a significant fraction of the worker population lived in the other downriver communities of Pasco and Kennewick, where the drinking water was also from the Columbia River. Body burdens of workers from Kennewick and Pasco are included in the database. The body burdens of these workers could perturb the comparisons made above. If the holdup times for these other water distribution systems were somewhat longer than that for Richland, it is possible that the

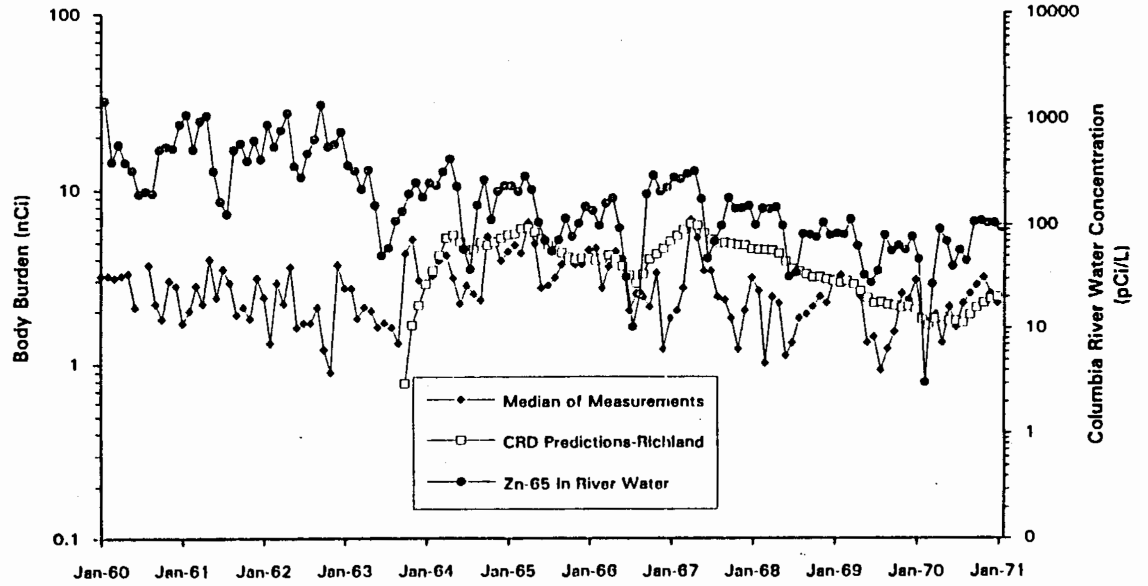

Figure 13.2. Comparison of Estimated and Measured Average Body Burdens of Zinc-65 in Richland Residents and Zinc-65 Concentration in Columbia River Water, 1960-1971

sodium-24 (with a 15-hour half-life) would have decayed below the detection limits, but an additional holdup would not affect the zinc-65 (250-day half-life) concentrations at all. This could explain the lack of measurable body burdens of sodium-24 in workers prior to October 1963 but the presence of a background level of zinc-65.

13.4.2 Specific Individual

An experiment was conducted between January 1962 and late 1963 in which an individual consumed an average of 220 grams of whitefish containing measured quantities of zinc-65 from the Columbia River at weekly intervals. His body burden of zinc-65 was then measured weekly. The body burdens, reported in Foster and Honstead (1967, p.41), also are recorded in the Hanford Site worker database. They are the among the highest recorded and are the highest in the database for the entire period of the experiment.

31 For use in validating the HEDR model, the experiment was simulated as an individual consuming 257 g/meal of Richland whitefish at the rate indicated in Foster and Hornstad (1967) and in addition consuming 1 liter per day of treated Columbia River water starting in October 1963. The concentrations of zinc-65 in the whitefish were estimated using the bioaccumulation factors derived for the project. Body burden was estimated using uptake and retention parameters used by the ICRP. These uptake and retention parameters are the basis of the ingestion dose factors used in the CRD code, *and, as noted earlier, are designed to err slightly towards overestimates.*

31 The results of the estimate are compared to the actual measurements in Figure 13.3. The estimates and measurements are within factors of 2. An overestimate in September 1962 shifts the right-hand portion of the estimated curve higher, but the dynamics thereafter are appropriate. *This September 1962 overestimate is noted in Foster and Honstead (1967) as a period during which the subject's metabolism of zinc departed significantly from the ICRP assumptions.* This comparison indicates that if the consumption rates of locally caught fish can be determined, estimates of radiation dose should have very low uncertainties.

A second conclusion may be drawn from the investigation of this individual's body burden of zinc-65. This experimental subject has the highest continuously measured body burden of zinc-65 of any individual in the Hanford Site worker database. This implies that the great majority of the Hanford Site worker population consumed fewer than one fish per week from the Columbia River. Over the year of 1962, during the experimental subject's highest intake, the total amount of zinc-65 ingested with the fish was about 770 nCi, leading to an estimated dose of less than 11 mrem. It is apparent that it would require consumption of very large quantities of fish in order to receive doses approaching the TSP's dose decision level of 100 mrem per year.(a)

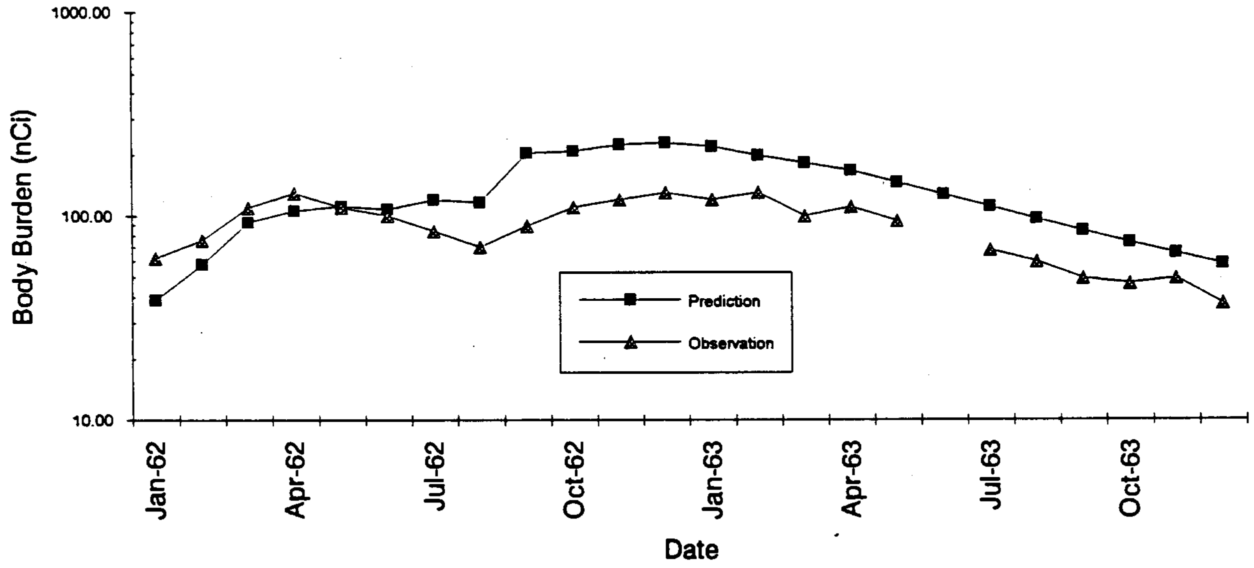

Figure 13.3. Comparison of Estimated and Measured Body Burden of Zinc-65 in an Individual Consuming a Known Amount of Columbia River Whitefish

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(a) Unpublished Report (HEDR Project Document No. 12920011), "Scoping Document for Determination of Temporal and Geographic Domains for the HEDR Project," from B. Shleien (HEDR Technical Steering Panel) to the HEDR Technical Steering Panel, Washington State Department of Ecology, 1992.

14.0 IAEA VAMP Project Coordination

This section was included to provide the reader with information about on-going efforts that will continue beyond the time of issuance of this report, and to provide references so the interested reader may obtain this information. In 1988, the IAEA started a coordinated research program on the Validation of Models for the Transfer of Radionuclides in Terrestrial, Urban, and Aquatic Environments, or VAMP (IAEA 1990). Since 1989, the HEDR Project has been active in the VAMP program. The principal objectives of VAMP are

- to facilitate the validation of assessment models by acquiring suitable sets of environmental measurement data from the results of national research and monitoring programs, especially those established following the Chernobyl accident in 1986
- to guide environmental research and monitoring efforts to acquire data for the validation of models used to assess the radiologically most significant exposure pathways
- to produce reports reviewing the current status of environmental assessment modeling, including principal remaining areas of uncertainty in models used for radiation dose assessment.

The VAMP program is not concerned with models for atmospheric transport, but it does consider the interaction of aerosols with terrestrial and aquatic surfaces. The HEDR Technical Integration Task leader is a member of the multiple pathways working group of VAMP. The activities of this working group are described in the Progress Reports of the VAMP program (IAEA 1990, 1991, 1992). In brief, this group has established a set of "blind tests" in which the participants take basic input information and prepare assessments of environmental behavior of specific environmental contamination incidents. To date, the Central Bohemia (CB) and Finland scenarios, based on Chernobyl data, have been investigated (IAEA 1990, 1991, 1992). The early HEDR atmospheric pathways model (PNL 1991) was the best estimator of 3-year cumulative dose among the 18 international models participating. However, there were several instances of compensating over- and underestimation with the early HEDR model. The final documentation of the CB scenario is to be issued by IAEA in December 1993.

14.1 The VAMP Central Bohemia Scenario

The CB scenario was based on measured deposition in the area of Prague in what was then Czechoslovakia. The HEDR Phase I model was the most appropriate for simulating the regional nature of the contamination, and it was one of the very few models that included stochastic calculations of uncertainty. It was also one of the best estimators, although detailed analysis indicated several areas for improvement. These improvements were incorporated into DESCARTES and CIDER.

The VAMP procedure is to allow the participating modelers to improve their models and then demonstrate the improvement with the original data set. Because of the delays in finishing the new HEDR models, the HEDR Project has not been able to formally complete the CB demonstration. However, the CB data set, which includes air, soil, vegetation, animal product, and human concentrations of cesium-137, remains one of the best data sets for comparison purposes. It is planned to repeat the CB scenario when the DESCARTES/CIDER combination is completed.

14.2 The VAMP Hanford Scenario

As a participant in the multiple pathways group, the HEDR Project has volunteered a Hanford-based data set and scenario description for the use of the VAMP participants. The Hanford (H) scenario is the PUREX Plant release described in Section 6.0. This scenario was discussed at the October 1993 meeting of the VAMP members and was finalized for use by the multiple pathways working group. Besides the direct members of the VAMP working group, the HEDR staff have also received expressions of interest from modeling groups in Canada and Germany. The Canadian group intends to model the atmospheric transport as well as the terrestrial pathways.

Use of the Hanford Site data by up to 20 outside modeling groups will provide additional information to the HEDR Project about the nature of model uncertainty, parameter variability, and the range of results that other users would estimate for the Hanford Site environment. International participation in the estimation of dose resulting from the Hanford Site will provide additional exposure and credibility to the HEDR Project.

15.0 Conclusions

A complex suite of calculations has been performed for both the atmospheric and Columbia River pathways contribution of dose to individuals from past Hanford Site operations. Portions of all of the HEDR computational models have been exercised. Comparisons with respect to spatial, temporal, and pathway elements of available historical measurements have been made.

15.1 Individual Data Set Comparisons

For the reactor model, maximum discrepancies between estimates and measurements (Section 2.0) are in the range of 15 percent.

10 The comparisons of estimates to measurements for the four 1946 time series for north Richland, south Richland, Kennewick/Pasco, and Benton City (Section 3.0) show order-of-magnitude agreement. The comparisons for 1946 correlate to within factors of 3 during the grazing season months. *Comparisons during winter months are not as close.* The historical measurements themselves, however, are of variable quality. Comparisons made for later times (see Sections 5.0 and 7.0) are better, in part possibly because the monitoring methods for the later periods were improved. *The largest underestimates are at depositions greater than 300 nCi/kg, which occur during the winter months. However, the DESCARTES results tend to overestimate the deposition resulting from the Green Run (also a December/winter release resulting in comparable deposition). Differences in the data sets include the way that the contamination was measured at the time and the regional weather during the release. This result argues against a systematic error.*

The April 13, 1946, data set (Section 4.0) represents a small number of measurements taken very near the contemporaneous level of detection. Consequently, the use of this data set was limited.

For the comparison of estimated and measured deposition during the 1949 Green Run (Section 5.0), the comparisons are best for the estimates that correspond to the period of active transport and deposition, early in the 2-week period investigated. Only 53 of 251 measurements were greater than the maximum estimated. These generally exceeded the maximum estimated by no more than a factor of 3 when misreporting by the counting laboratory is accounted for. There were 33 measurements lower than the minimum estimated. Some of these were zero counts, and most of the remainder were caused by temporal mismatch because the estimates were for midnight on a day when the samples were taken many hours earlier. A minor misestimate of the footprint of the plume occurred on average about 6 miles too far to the east over a period of 4 to 5 days.

2,33 For the 1963 PUREX Plant release data set (Section 6.0), the HEDR models perform extremely well. The deposition estimated on grass is within the range estimated for the first 2 weeks following the release. The uptake in cow's milk parallels the measured values, within the limitations of the quasi-equilibrium model used, and the measurements are always within the estimated range. The doses measured to the thyroids of the two subjects are in the middle of the range estimated. For this validation case, it is apparent that the entire system of computer models for transport, deposition, uptake, and dose functioned as designed. Each component worked well, the result is *representative*, and there is no indication of compensating errors (the results for each step of the calculation appear to be reasonable).

The comparison of estimated to measured concentrations of krypton-85 in the 1980s (Section 7.0) showed that, using all available meteorological data, the RATCHET model has *a median* bias of about 25 percent, which increases to about 38 percent when meteorological data are limited. The model has an 80-85 percent probability of being within a factor of 3 of the measured value, depending on input data availability.

For the comparison of estimated and measured Richland adult thyroid burdens of iodine-131 (Section 8.0), the estimates showed somewhat more variability than the measurements. The median estimates were within a factor of 4 or less of the measurements. The results indicated that the primary pathway of exposure was inhalation, which supports the results obtained using the 1940s milk distribution model.

Based on the results of comparing the measured data from Columbia River gauging stations at the Hanford Reach and The Dalles to the estimated stage and discharge (Section 9.0), the WSU-CHARIMA model was determined to accurately simulate the dilutions and travel times over a wide range of river characteristics.

Comparisons were made of estimated and measured concentrations of radionuclides in Columbia River water (Section 10.0). Additional comparisons are presented in Walters et al. (1994). Estimates of radionuclide concentration in Columbia River water are within factors of 2 for both composite and grab sample measurements over long time periods and, as shown in Walters et al. (1994), over numerous locations downstream.

Comparisons of estimated and measured concentration of radionuclides in Columbia River fish (Section 11.0) indicate that the model used tended to overestimate the quantities of radionuclides in all types of fish at all locations, although there was substantial variability between months. A portion of the variability appeared to be a result of applying bioaccumulation factors to the entire Columbia River because there appeared to be an influence of uncontaminated water from tributary rivers causing lower concentrations in fish than estimated. The variability in radionuclide uptake in fish is very high. The range for the bioaccumulation factors covers more than an order of magnitude. Given the variability of the quantity being estimated, the model overestimates were not extreme.

Comparison of estimated to measured values of zinc-65 concentration in Pacific coast oysters (Section 12.0) showed that the CRD model is within 40 percent for the year 1967, and within 10 percent for the period 1960-1970. The model results are used only for the period prior to 1959; concentrations for the later years are input directly from the historical measurements. Doses from this pathway are quite small.

The HEDR model validation plan (Napier et al. 1993) indicated that modeling of radionuclide concentrations in Columbia River salmon would be addressed in the validation efforts. Insufficient information was obtained for salmon and other anadromous species to allow development of estimation techniques. At the direction of the HEDR TSP at the October 7-8, 1993, meeting, anadromous species have been excluded from the model validation effort. Available salmon data is reported in Thiede and Duncan (1994).

Comparisons were made of estimates of body burden of Columbia River radionuclides from ingestion of drinking water and fish with measurements recorded in the Hanford Site worker whole body count database. Without calibration of the model or adjustment of assumptions, the ratio of estimate to measurement for sodium-24 was 1.40 and for zinc-65 was 1.39. The CRD model estimates always fell within the range of the measurements.

15.2 Suitability of Models for HEDR Use

2,4,36 Because not enough data are available, no individual validation exercise adequately verifies the accuracy of the HEDR computer models. It is only through the compilation of a sufficient number of component validations that the reliability of the HEDR computer models is demonstrated. The results of all of the validation tests that have been performed combine to provide a reasonable validation set for the needs of the project. Sufficient coverage of the spatial, temporal, and pathway variables is achieved and demonstrates a high level of confidence in the adequacy of the HEDR approach and implementation. On the basis of the tests performed and the results obtained, the staff of the HEDR Project conclude that the models in the HEDR toolbox are fully functional and *representative*. These models meet the HEDR Project objectives in that they provide sound, supportable estimates of individual radiation doses resulting from historical releases of radionuclides from the Hanford Site. As a result of this validation exercise, no revisions to any of the models are recommended *before estimation of representative individual doses.*

32 *To add to the credibility of the HEDRIC suite, HEDR estimates and measurements could be compared with sets of non-Hanford Site data not used in the HEDR Project. The report authors will continue to interact with VAMP and other validation-related activities after the conclusion of the HEDR contract. The results of their activities will be published by the sponsoring organizations and made available to the CDC and TSP. The TSP may wish to consider this for future work.*

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Appendix A

1946 Time-Sequence Vegetation Data

Appendix A

1946 Time-Sequence Vegetation Data

All of the information used in the 1946 vegetation validation comparisons is provided in this appendix. The source of the information is provided so that the reader can track the source of all data, and distinguish the "vegetation correlation data sheet" results from the other sources. .

Early in the HEDR Project, a hand-written compilation of data from the mid-1940s was found. This is referred to within the project as the "vegetation correlation data sheets." This compilation is of indeterminable source and quality but was evidently prepared in the late 1940s or early 1950s. The data reported in it duplicate much of what was found in the original counting laboratory records (dates and locations), but it also obviously incorporates many of the later correction factors used to convert counting data to concentration data (Mart et al. 1993). Because the project staff have not been able to track the source of these data, it has not been relied upon for most of the project. However, this source does contain some information (particularly data on concentration of iodine-131 in vegetation in the latter half of 1946) that is not available from other sources. Therefore, data from this source are also considered in the validation effort. It is denoted as "Veg. Corr." in the reference column of the following table.

Table A.1 provides the data for north Richland, Washington. Table A.2 provides the data for south Richland. Table A.3 provides the data for the cities of Kennewick and Pasco, Washington, which are located within the same HEDR computational cell. Table A.4 provides the data for Benton City, Washington.

Although the samples used to measure iodine-131 were historically most often labelled "vegetation," Denham et al. (1993b, p. 3.2) note that the samples were usually sagebrush.

Comments on Data Table Listings

A short explanation of the data columns is necessary to facilitate a full understanding of their contents.

Date	This date (expressed as year/month/day) provided with the sampling data is assumed to be the date the sample was collected. Occasionally, dates were listed as week or month ending dates.
Location	It is not uncommon to find the same sampling location described in several ways. Whenever possible, attempts were made to standardize location names. This made it easier to compare data obtained from different locations.

Type	Vegetation type is included in this column if it was noted in the reference document. The word "vegetation" is used when the type of plant was unknown. The predominant vegetation in the area is commonly referred to as sage or sagebrush. Other sample type entries were taken directly from the original records and no attempt was made to clarify the abbreviations.
μCi/kg	Sometimes both the raw counting data and the concentrations were reported in the same document. However, some references provided only derived concentration values. Generally, a zero in the table indicates that no value was reported.
CPM/g	These are net counting rates (counts per minute, corrected for background only) as reported in the reference documents. Generally, a zero in the table indicates that no value was reported. The number of significant figures is an artifact of converting the database values (stored in scientific notation) to non-scientific notation, rather than an indication of the precision of the reported values.
Reference	Reference numbers starting with HEW or HW are the assigned document numbers, which may refer to internal memoranda, laboratory notebooks, and weekly, monthly, quarterly, or annual reports.

Table A.1. Iodine-131 Concentration in Vegetation in North Richland, Cell 469

Date	Location	Type	μCi/kg	CPM/g	Reference
19460103	Richland, N.E.	Sagebrush	0	251.9	HEW-578-L
19460103	Richland, Kadlec Hospital	Sagebrush	0	161.3	HEW-578-L
19460103	Richland, N.W.	Sagebrush	0	511.3	HEW-578-L
19460107	Richland, Kadlec Hospital	Vegetation	3.35	0	Veg. Corr.
19460107	Richland, N.E.	Vegetation	5.17	0	Veg. Corr.
19460107	Richland, N.W.	Vegetation	2.46	0	Veg. Corr.
19460109	Richland, Kadlec Hospital	Sagebrush	0	150.6	HEW-578-L
19460109	Richland, N.W.	Sagebrush	0	233.3	HEW-578-L
19460109	Richland, N.W.	Sagebrush	0	110.8	HEW-578-L
19460115	Richland, N.W.	Vegetation	1.18	0	Veg. Corr.
19460115	Richland, Kadlec Hospital	Vegetation	1.26	0	Veg. Corr.
19460115	Richland, N.E.	Vegetation	1.83	0	Veg. Corr.
19460116	Richland, N.W.	Vegetation	0.33	57.8	HEW-616-T
19460116	Richland, N.E.	Vegetation	0.53	89.5	HEW-616-T
19460116	Richland, Kadlec Hospital	Vegetation	0.35	59.5	HEW-616-T
19460121	Richland, N.E.	Vegetation	0.96	0	Veg. Corr.
19460121	Richland, Kadlec Hospital	Vegetation	2.88	0	Veg. Corr.
19460121	Richland, N.W.	Vegetation	4.33	0	Veg. Corr.
19460123	Richland, N.E.	Vegetation	0.24	42.9	HEW-616-T
19460123	Richland, N.W.	Vegetation	0.99	177	HEW-616-T
19460123	Richland, Kadlec Hospital	Vegetation	0.66	118.1	HEW-616-T
19460128	Richland, N.E.	Vegetation	0.82	0	Veg. Corr.
19460128	Richland, N.W.	Vegetation	0.47	0	Veg. Corr.
19460128	Richland, Kadlec Hospital	Vegetation	0.27	0	Veg. Corr.
19460130	Richland, N.E.	Vegetation	0.63	37	HEW-616-T
19460130	Richland, N.W.	Vegetation	0.35	21	HEW-616-T
19460130	Richland, Kadlec Hospital	Vegetation	0.2	12	HEW-616-T
19460131	Richland	Vegetation	1	0	HW-7-3322
19460204	Richland, N.W.	Vegetation	0.29	0	Veg. Corr.
19460204	Richland, N.E.	Vegetation	0.48	0	Veg. Corr.
19460204	Richland, Kadlec Hospital	Vegetation	0	0	Veg. Corr.
19460206	Richland, N.E.	Vegetation	0.3	20	HEW-616-T
19460206	Richland, Kadlec Hospital	Vegetation	0.03	0	HEW-616-T
19460206	Richland, N.W.	Vegetation	0.1	12	HEW-616-T
19460211	Richland, Kadlec Hospital	Vegetation	0.42	0	Veg. Corr.
19460211	Richland, N.W.	Vegetation	0.19	0	Veg. Corr.
19460211	Richland, N.E.	Vegetation	0.09	0	Veg. Corr.
19460213	Richland, N.E.	Vegetation	0.07	4	HEW-616-T
19460213	Richland, N.W.	Vegetation	0.14	8	HEW-616-T
19460213	Richland, Kadlec Hospital	Vegetation	0.32	19	HEW-616-T
19460220	Richland, N.E.	Vegetation	0	22	HEW-616-T
19460220	Richland, Kadlec Hospital	Vegetation	0	9	HEW-616-T
19460220	Richland, N.W.	Vegetation	0	4	HEW-616-T
19460220	Richland, N.E.	Vegetation	0.41	0	Veg. Corr.
19460220	Richland, Kadlec Hospital	Vegetation	0.17	0	Veg. Corr.

Table A.1. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460220	Richland, N.W.	Vegetation	0.07	0	Veg. Corr.
19460227	Richland, Kadlec Hospital	Vegetation	0.08	0	Veg. Corr.
19460227	Richland, N.E.	Vegetation	0.56	0	Veg. Corr.
19460227	Richland, N.W.	Vegetation	0.04	0	Veg. Corr.
19460228	Richland	Vegetation	0.2	0	HW-7-3517
19460304	Richland, N.W.	Vegetation	0.26	0	Veg. Corr.
19460304	Richland, N.E.	Vegetation	0.12	0	Veg. Corr.
19460306	Richland, N.W.	Vegetation	0	11	HEW-616-T
19460306	Richland, N.E.	Vegetation	0	5	HEW-616-T
19460313	Richland, N.W.	Vegetation	0.33	0	Veg. Corr.
19460313	Richland, N.E.	Vegetation	0.61	0	Veg. Corr.
19460313	Richland, N.E.	Cheat Gr.	0	33	HEW-616-T
19460313	Richland, Kadlec Hospital	Vegetation	0.13	0	Veg. Corr.
19460313	Richland, N.W.	Wht Flr Wd	0	18	HEW-616-T
19460313	Richland, Kadlec Hospital	Sage	0	7	HEW-616-T
19460320	Richland, N.W.	Green Sage	0	6	HEW-616-T
19460320	Richland, Kadlec Hospital	Dry Grass	0	14	HEW-616-T
19460320	Richland, N.E.	Green Sage	0	9	HEW-616-T
19460321	Richland, N.W.	Vegetation	0.11	0	Veg. Corr.
19460321	Richland, Kadlec Hospital	Vegetation	0.26	0	Veg. Corr.
19460321	Richland, N.E.	Vegetation	0.15	0	Veg. Corr.
19460331	Richland	Vegetation	0.24	0	HW-7-3694
19460401	Richland, N.E.	Dead Weed	0	65	HEW-616-T
19460401	Richland, Kadlec Hospital	Green Sage	0	43	HEW-616-T
19460401	Richland, N.W.	Vegetation	0	52	HEW-616-T
19460408	Richland, Kadlec Hospital	Dry Grass	0	7	HEW-616-T
19460408	Richland, N.E.	Vegetation	0.11	0	Veg. Corr.
19460408	Richland, N.W.	Vegetation	0.09	0	Veg. Corr.
19460408	Richland, Kadlec Hospital	Vegetation	0.13	0	Veg. Corr.
19460408	Richland, N.W.	Dry Grass	0	5	HEW-616-T
19460408	Richland, N.E.	Green Sage	0	6	HEW-616-T
19460415	Richland, Kadlec Hospital	Vegetation	0.17	0	Veg. Corr.
19460415	Richland, N.E.	Vegetation	0.13	0	Veg. Corr.
19460415	Richland, N.W.	Vegetation	0	4	HEW-616-T
19460415	Richland, N.W.	Vegetation	0.07	0	Veg. Corr.
19460415	Richland, Kadlec Hospital	Vegetation	0	9	HEW-616-T
19460415	Richland, N.E.	Vegetation	0	7	HEW-616-T
19460422	Richland, Kadlec Hospital	Alfalfa	0	2	HEW-616-T
19460422	Richland, N.E.	Vegetation	0	15	HEW-616-T
19460422	Richland, N.W.	Vegetation	0.05	0	Veg. Corr.
19460422	Richland, N.W.	Vegetation	0	3	HEW-616-T
19460422	Richland, Kadlec Hospital	Vegetation	0.03	0	Veg. Corr.
19460422	Richland Barricade	Vegetation	0	4	HEW-616-T
19460422	Richland, N.E.	Vegetation	0.26	0	Veg. Corr.
19460429	Richland, N.E.	Vegetation	0	3	HEW-616-T

Table A.1. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460429	Richland, Kadlec Hospital	Vegetation	0.11	0	Veg. Corr.
19460429	Richland, Kadlec Hospital	Vegetation	0	6	HEW-616-T
19460429	Richland, N.W.	Vegetation	0	4	HEW-616-T
19460429	Richland, N.W.	Vegetation	0.07	0	Veg. Corr.
19460429	Richland, N.E.	Vegetation	0.06	0	Veg. Corr.
19460430	Richland	Vegetation	0.14	0	HW-7-3933
19460506	Richland, N.E.	Vegetation	0.04	0	Veg. Corr.
19460506	Richland, Kadlec Hospital	Vegetation	0	1	HEW-616-T
19460506	Richland, N.W.	Vegetation	0	0	HEW-616-T
19460506	Richland, Kadlec Hospital	Vegetation	0.02	0	Veg. Corr.
19460506	Richland, N.E.	Vegetation	0	2	HEW-616-T
19460506	Richland, N.W.	Vegetation	0	0	Veg. Corr.
19460507	Richland	Green Asp.	0	0	HEW-616-T
19460513	Richland, N.W.	Vegetation	0	4	HEW-616-T
19460513	Richland, Geo. Wash. Way and Van	Vegetation	0	2	HEW-616-T
19460513	Richland, Kadlec Hospital	Vegetation	0	1	HEW-616-T
19460513	Richland Barricade	Vegetation	0	5	HEW-616-T
19460514	Richland, N.E.	Vegetation	0.04	0	Veg. Corr.
19460514	Richland, N.W.	Vegetation	0.07	0	Veg. Corr.
19460514	Richland, Kadlec Hospital	Vegetation	0.02	0	Veg. Corr.
19460520	Richland, Kadlec Hospital	Vegetation	0.02	0	Veg. Corr.
19460520	Richland, N.W.	Vegetation	0.1	0	Veg. Corr.
19460520	Richland, N.W.	Vegetation	0	6	HEW-616-T
19460520	Richland, Kadlec Hospital	Vegetation	0	1	HEW-616-T
19460520	Richland, N.E.	Vegetation	0	6	HEW-616-T
19460520	Richland, N.E.	Vegetation	0.1	0	Veg. Corr.
19460527	Richland, N.E.	Vegetation	0	9	HEW-616-T
19460527	Richland, Kadlec Hospital	Vegetation	0	2	HEW-616-T
19460527	Richland, N.E.	Vegetation	0.17	0	Veg. Corr.
19460527	Richland, N.W.	Vegetation	0	4	HEW-616-T
19460527	Richland, N.W.	Vegetation	0.07	0	Veg. Corr.
19460527	Richland, Kadlec Hospital	Vegetation	0.04	0	Veg. Corr.
19460531	Richland	Vegetation	0.06	0	HW-7-4312
19460603	Richland, Kadlec Hospital	Vegetation	0	2	HEW-616-T
19460603	Richland, Kadlec Hospital	Vegetation	0.04	0	Veg. Corr.
19460603	Richland, N.E.	Vegetation	0	5	HEW-616-T
19460603	Richland, N.W.	Vegetation	0.09	0	Veg. Corr.
19460603	Richland, N.E.	Vegetation	0.09	0	Veg. Corr.
19460603	Richland, N.W.	Vegetation	0	5	HEW-616-T
19460608	Richland, Kadlec Hospital	Vegetation	0.1	0	HW-7-5042
19460610	Richland, Kadlec Hospital	Vegetation	0	0	Veg. Corr.
19460610	Richland, N.E.	Vegetation	0	3	HEW-616-T
19460610	Richland, N.W.	Vegetation	0	0	Veg. Corr.
19460610	Richland, N.E.	Vegetation	0.06	0	Veg. Corr.
19460610	Richland, Kadlec Hospital	Vegetation	0	0	HEW-616-T

Table A.1. (contd)

Date	Location	Type	μCi/kg	CPM/g	Reference
19460610	Richland, N.W.	Vegetation	0	0	HEW-616-T
19460617	Richland, Kadlec Hospital	Vegetation	0	4	HEW-616-T
19460617	Richland, N.W.	Vegetation	0.07	0	Veg. Corr.
19460617	Richland, N.W.	Vegetation	0	4	HEW-616-T
19460617	Richland, N.E.	Vegetation	0.04	0	Veg. Corr.
19460617	Richland, N.E.	Vegetation	0	2	HEW-616-T
19460617	Richland, Kadlec Hospital	Vegetation	0.07	0	Veg. Corr.
19460624	Richland, Kadlec Hospital	Vegetation	0	0	Veg. Corr.
19460624	Richland, N.W.	Vegetation	0	4	HEW-616-T
19460624	Richland, N.E.	Vegetation	0	9	HEW-616-T
19460624	Richland, N.E.	Vegetation	0.15	0	Veg. Corr.
19460624	Richland, Kadlec Hospital	Vegetation	0	0	HEW-616-T
19460624	Richland, N.W.	Vegetation	0.07	0	Veg. Corr.
19460630	Richland	Vegetation	0.06	0	HW-7-4312
19460701	Richland, N.E.	Vegetation	0	0	Veg. Corr.
19460701	Richland, Kadlec Hospital	Vegetation	0	0	HEW-616-T
19460701	Richland, N.E.	Vegetation	0	0	HEW-616-T
19460701	Richland, Kadlec Hospital	Vegetation	0	0	Veg. Corr.
19460701	Richland, N.W.	Vegetation	0	3	HEW-616-T
19460701	Richland, N.E.	Vegetation	0	2	HEW-616-T
19460701	Richland, N.W.	Vegetation	0.08	0	Veg. Corr.
19460701	Richland, N.W.	Vegetation	0	4	HEW-616-T
19460708	Richland, N.W.	Vegetation	0	0	Veg. Corr.
19460708	Richland, N.E.	Vegetation	0.04	0	Veg. Corr.
19460708	Richland, N.E.	Vegetation	0	2	HEW-616-T
19460708	Richland, N.W.	Vegetation	0	0	HEW-616-T
19460708	Richland, Kadlec Hospital	Vegetation	0.04	0	Veg. Corr.
19460708	Richland, Kadlec Hospital	Vegetation	0	2	HEW-616-T
19460715	Richland, N.W.	Vegetation	0	1	HEW-616-T
19460715	Richland, N.E.	Vegetation	0	20	HEW-616-T
19460715	Richland, N.W.	Vegetation	0.02	0	Veg. Corr.
19460715	Richland, Kadlec Hospital	Vegetation	0	1	HEW-616-T
19460715	Richland, Kadlec Hospital	Vegetation	0.02	0	Veg. Corr.
19460715	Richland, N.E.	Vegetation	0.37	0	Veg. Corr.
19460717	Richland, N.W.	Vegetation	0.04	0	HW-7-4423
19460717	Richland, Kadlec Hospital	Vegetation	0.04	0	HW-7-4423
19460717	Richland, N.E.	Vegetation	0.34	0	HW-7-4423
19460717	Richland	Vegetation	0.11	0	HW-7-4423
19460722	Richland, N.E.	Vegetation	0.13	0	Veg. Corr.
19460722	Richland, Kadlec Hospital	Vegetation	0.09	0	Veg. Corr.
19460722	Richland, N.W.	Vegetation	0.05	0	Veg. Corr.
19460722	Richland, Kadlec Hospital	Vegetation	0	5	HEW-616-T
19460722	Richland, N.E.	Vegetation	0	7	HEW-616-T
19460722	Richland, N.W.	Vegetation	0	3	HEW-616-T
19460724	Richland, Kadlec Hospital	Vegetation	0.09	0	HW-7-4440

Table A.1. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460724	Richland, N.E.	Vegetation	0.12	0	HW-7-4440
19460724	Richland	Vegetation	0.1	0	HW-7-4440
19460724	Richland, N.W.	Vegetation	0.05	0	HW-7-4440
19460729	Richland, N.W.	Vegetation	0	1	HEW-616-T
19460729	Richland, N.W.	Vegetation	0.02	0	Veg. Corr.
19460729	Richland, N.E.	Vegetation	0	0	Veg. Corr.
19460729	Richland, Kadlec Hospital	Vegetation	0.17	0	Veg. Corr.
19460729	Richland, Kadlec Hospital	Vegetation	0	10	HEW-616-T
19460729	Richland, N.E.	Vegetation	0	0	HEW-616-T
19460731	Richland	Vegetation	0.07	0	HW-7-4474
19460805	Richland, Kadlec Hospital	Vegetation	0	3	HEW-616-T
19460805	Richland, N.W.	Vegetation	0	5	HEW-616-T
19460806	Richland, Kadlec Hospital	Vegetation	0.06	0	Veg. Corr.
19460806	Richland, Van Giesen	Apple	0	2	HEW-616-T
19460806	Richland, Van Giesen	Apple Lvs.	0	4	HEW-616-T
19460806	Richland, N.E.	Vegetation	0.07	0	Veg. Corr.
19460806	Richland, N.E.	Vegetation	0	4	HEW-616-T
19460806	Richland, N.W.	Vegetation	0.09	0	Veg. Corr.
19460812	Richland, Kadlec Hospital	Vegetation	0.06	0	Veg. Corr.
19460812	Richland, N.W.	Vegetation	0.04	0	Veg. Corr.
19460812	Richland, N.E.	Vegetation	0.02	0	Veg. Corr.
19460819	Richland, N.E.	Vegetation	0.07	0	Veg. Corr.
19460819	Richland, N.W.	Vegetation	0.07	0	Veg. Corr.
19460819	Richland, Kadlec Hospital	Vegetation	0.11	0	Veg. Corr.
19460826	Richland, N.W.	Vegetation	0.13	0	Veg. Corr.
19460826	Richland, N.E.	Vegetation	0.06	0	Veg. Corr.
19460826	Richland, Kadlec Hospital	Vegetation	0.06	0	Veg. Corr.
19460831	Richland	Vegetation	0.06	0	HW-7-4699
19460903	Richland, N.W.	Vegetation	0.12	0	Veg. Corr.
19460903	Richland, N.E.	Vegetation	0	0	Veg. Corr.
19460903	Richland, Kadlec Hospital	Vegetation	0	0	Veg. Corr.
19460910	Richland, N.W.	Vegetation	0.02	0	Veg. Corr.
19460910	Richland, Kadlec Hospital	Vegetation	0.09	0	Veg. Corr.
19460910	Richland, N.E.	Vegetation	0.22	0	Veg. Corr.
19460916	Richland, Kadlec Hospital	Vegetation	0.1	0	Veg. Corr.
19460916	Richland, N.W.	Vegetation	0.14	0	Veg. Corr.
19460916	Richland, N.E.	Vegetation	0	0	Veg. Corr.
19460918	Richland, N.W.	Vegetation	0.07	0	HW-7-5042
19460918	Richland, Kadlec Hospital	Vegetation	0.06	0	HW-7-5042
19460918	Richland, N.W.	Vegetation	0.12	0	HW-7-5042
19460918	Richland, N.E.	Vegetation	0.22	0	HW-7-5042
19460918	Richland, N.E.	Vegetation	0.12	0	HW-7-5042
19460918	Richland	Vegetation	0.08	0	HW-7-5042
19460924	Richland, Kadlec Hospital	Vegetation	0.07	0	Veg. Corr.
19460924	Richland, N.E.	Vegetation	0.07	0	Veg. Corr.

Table A.1. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460924	Richland, N.W.	Vegetation	0.04	0	Veg. Corr.
19460930	Richland	Vegetation	0.14	0	HW-7-5042
19460930	Richland	Vegetation	0.07	0	HW-7-5145
19460930	Richland	Vegetation	0.06	0	HW-7-5042
19461001	Richland, N.W.	Vegetation	0.17	0	Veg. Corr.
19461001	Richland, N.E.	Vegetation	0.09	0	Veg. Corr.
19461001	Richland, Kadlec Hospital	Vegetation	0	0	Veg. Corr.
19461008	Richland, Kadlec Hospital	Vegetation	0.22	0	Veg. Corr.
19461008	Richland, N.W.	Vegetation	0.29	0	Veg. Corr.
19461008	Richland, N.E.	Vegetation	0.14	0	Veg. Corr.
19461015	Richland, N.W.	Vegetation	0.01	0	Veg. Corr.
19461015	Richland, Kadlec Hospital	Vegetation	0.06	0	Veg. Corr.
19461015	Richland, N.E.	Vegetation	0.07	0	Veg. Corr.
19461016	Richland	Vegetation	0.18	0	HW-7-5042
19461016	Richland	Vegetation	0.39	0	HW-7-5042
19461022	Richland, Kadlec Hospital	Vegetation	0.03	0	Veg. Corr.
19461022	Richland, N.W.	Vegetation	0.09	0	Veg. Corr.
19461022	Richland, N.E.	Vegetation	0.04	0	Veg. Corr.
19461029	Richland, N.W.	Vegetation	0.36	0	Veg. Corr.
19461029	Richland, N.E.	Vegetation	0.13	0	Veg. Corr.
19461029	Richland, Kadlec Hospital	Vegetation	0.05	0	Veg. Corr.
19461031	Richland	Vegetation	0.08	0	HW-7-5042
19461031	Richland	Vegetation	0.13	0	HW-7-5301
19461031	Richland	Vegetation	0.17	0	HW-7-5042
19461105	Richland, Kadlec Hospital	Vegetation	0	0	Veg. Corr.
19461105	Richland, N.W.	Vegetation	0.12	0	Veg. Corr.
19461105	Richland, N.E.	Vegetation	0.03	0	Veg. Corr.
19461112	Richland, N.E.	Vegetation	0.56	0	Veg. Corr.
19461112	Richland, Kadlec Hospital	Vegetation	1	0	Veg. Corr.
19461112	Richland, N.W.	Vegetation	0.25	0	Veg. Corr.
19461119	Richland, Kadlec Hospital	Vegetation	0.07	0	Veg. Corr.
19461119	Richland	Vegetation	0.28	0	HW-7-5042
19461119	Richland, N.E.	Vegetation	0.07	0	Veg. Corr.
19461119	Richland, N.W.	Vegetation	0.2	0	Veg. Corr.
19461119	Richland	Vegetation	1.16	0	HW-7-5042
19461125	Richland, N.E.	Vegetation	0.23	0	Veg. Corr.
19461125	Richland, N.W.	Vegetation	0.06	0	Veg. Corr.
19461125	Richland, Kadlec Hospital	Vegetation	0.05	0	Veg. Corr.
19461130	Richland	Vegetation	0.24	0	HW-7-5042
19461130	Richland	Vegetation	0.21	0	HW-7-5428
19461130	Richland	Vegetation	0.11	0	HW-7-5042
19461202	Richland, Kadlec Hospital	Vegetation	0.11	0	Veg. Corr.
19461202	Richland, N.E.	Vegetation	1.07	0	Veg. Corr.
19461202	Richland, N.W.	Vegetation	0.35	0	Veg. Corr.
19461210	Richland, N.E.	Vegetation	0.73	0	Veg. Corr.

Table A.1. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19461210	Richland, Kadlec Hospital	Vegetation	0.17	0	Veg. Corr.
19461210	Richland, N.W.	Vegetation	0.32	0	Veg. Corr.
19461216	Richland	Vegetation	1.26	0	HW-7-5042
19461216	Richland	Vegetation	0.57	0	HW-7-5042
19461217	Richland, N.W.	Vegetation	0.16	0	Veg. Corr.
19461217	Richland, N.E.	Vegetation	0.53	0	Veg. Corr.
19461217	Richland, Kadlec Hospital	Vegetation	0.12	0	Veg. Corr.
19461223	Richland, N.W.	Vegetation	0.53	0	Veg. Corr.
19461223	Richland, N.E.	Vegetation	0.6	0	Veg. Corr.
19461223	Richland, Kadlec Hospital	Vegetation	0.24	0	Veg. Corr.
19461230	Richland, N.W.	Vegetation	0.98	0	Veg. Corr.
19461230	Richland, N.E.	Vegetation	0.57	0	Veg. Corr.
19461230	Richland, Kadlec Hospital	Vegetation	0.86	0	Veg. Corr.
19461231	Richland	Vegetation	0.61	0	HW-7-5042
19461231	Richland	Vegetation	0.35	0	HW-7-5042
19461231	Richland	Vegetation	0.46	0	HW-7-5605

Table A.2. Iodine-131 Concentration in Vegetation in South Richland, Cell 442

Date	Location	Type	µCi/kg	CPM/g	Reference
19460103	Richland, S.W.	Sagebrush	0	105.4	HEW-578-L
19460103	Richland "Y"	Sagebrush	0	153.8	HEW-578-L
19460104	Richland "Y"	Vegetation	2.22	0	Veg. Corr.
19460107	Richland, S.E.	Vegetation	5.82	0	Veg. Corr.
19460107	Richland, S.W.	Vegetation	2.24	0	Veg. Corr.
19460107	Richland "Y"	Vegetation	0.84	0	Veg. Corr.
19460109	Richland, S.W.	Sagebrush	0	101.3	HEW-578-L
19460109	Richland, S.E.	Sagebrush	0	261.9	HEW-578-L
19460110	Richland "Y"	Sagebrush	0	38.1	HEW-578-L
19460112	Richland "Y"	Vegetation	0	22.4	HEW-616-T
19460115	Richland, S.W.	Vegetation	0.57	0	Veg. Corr.
19460115	Richland "Y"	Vegetation	1.72	0	Veg. Corr.
19460115	Richland, S.E.	Vegetation	0.28	0	Veg. Corr.
19460116	Richland, S.W.	Vegetation	0.16	28.3	HEW-616-T
19460116	Richland, S.E.	Vegetation	0.08	13.8	HEW-616-T
19460117	Richland "Y"	Vegetation	0.5	85.3	HEW-616-T
19460121	Richland, S.W.	Vegetation	0.96	0	Veg. Corr.
19460121	Richland, S.E.	Vegetation	0.96	0	Veg. Corr.
19460121	Richland "Y"	Vegetation	0.96	0	Veg. Corr.
19460123	Richland, S.W.	Vegetation	0.24	43.4	HEW-616-T
19460123	Richland, S.E.	Vegetation	0.24	42.4	HEW-616-T
19460124	Richland "Y"	Vegetation	0.25	44	HEW-616-T
19460128	Richland "Y"	Vegetation	1.13	0	Veg. Corr.
19460128	Richland, S.W.	Vegetation	0.49	0	Veg. Corr.
19460128	Richland, S.E.	Vegetation	0.62	0	Veg. Corr.
19460130	Richland, S.W.	Vegetation	0.37	22	HEW-616-T
19460130	Richland, S.E.	Vegetation	0.47	28	HEW-616-T
19460131	Richland "Y"	Vegetation	0.86	51	HEW-616-T
19460204	Richland "Y"	Vegetation	0.09	0	Veg. Corr.
19460204	Richland, S.W.	Vegetation	0.74	0	Veg. Corr.
19460204	Richland, S.E.	Vegetation	0.17	0	Veg. Corr.
19460206	Richland, S.W.	Vegetation	0.5	31	HEW-616-T
19460206	Richland, S.E.	Vegetation	0.1	7	HEW-616-T
19460207	Richland "Y"	Vegetation	0.1	4	HEW-616-T
19460211	Richland "Y"	Vegetation	0.36	0	Veg. Corr.
19460211	Richland, S.W.	Vegetation	0.2	0	Veg. Corr.
19460211	Richland, S.E.	Vegetation	0.34	0	Veg. Corr.
19460213	Richland, S.W.	Vegetation	0.19	11	HEW-616-T
19460213	Richland, S.E.	Vegetation	0.24	14	HEW-616-T
19460214	Richland "Y"	Vegetation	0.25	15	HEW-616-T
19460220	Richland, S.W.	Vegetation	0.06	0	Veg. Corr.
19460220	Richland, S.E.	Vegetation	0.07	0	Veg. Corr.
19460220	Richland, S.W.	Vegetation	0	3	HEW-616-T
19460220	Richland, S.E.	Vegetation	0	4	HEW-616-T
19460221	Richland "Y"	Vegetation	0	10	HEW-616-T

Table A.2. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460221	Richland "Y"	Vegetation	0.19	0	Veg. Corr.
19460227	Richland, S.W.	Vegetation	0.39	0	Veg. Corr.
19460227	Richland "Y"	Vegetation	0.11	0	Veg. Corr.
19460227	Richland, S.E.	Vegetation	0.41	0	Veg. Corr.
19460304	Richland "Y"	Vegetation	0.24	0	Veg. Corr.
19460304	Richland, S.W.	Vegetation	0.17	0	Veg. Corr.
19460304	Richland, S.E.	Vegetation	0.19	0	Veg. Corr.
19460306	Richland, S.E.	Vegetation	0	8	HEW-616-T
19460306	Richland, S.W.	Vegetation	0	9	HEW-616-T
19460307	Richland "Y"	Vegetation	0	10	HEW-616-T
19460313	Richland, S.E.	Vegetation	0.35	0	Veg. Corr.
19460313	Richland, S.W.	Vegetation	0.54	0	Veg. Corr.
19460313	Richland, S.E.	Cheat Gr.	0	19	HEW-616-T
19460313	Richland, S.W.	Cheat Gr.	0	29	HEW-616-T
19460314	Richland "Y"	Vegetation	0.15	0	Veg. Corr.
19460314	Richland "Y"	Cheat Gr.	0	9	HEW-616-T
19460320	Richland, S.E.	Grass	0	6	HEW-616-T
19460320	Richland, S.W.	White	0	26	HEW-616-T
19460321	Richland, S.E.	Vegetation	0.11	0	Veg. Corr.
19460321	Richland "Y"	Vegetation	0	11	HEW-616-T
19460321	Richland, S.W.	Vegetation	0.48	0	Veg. Corr.
19460328	Richland "Y"	Dead Sage	0	21	HEW-616-T
19460328	Richland "Y"	Vegetation	0.95	0	Veg. Corr.
19460401	Richland, S.E.	Cheat Gr.	0	71	HEW-616-T
19460401	Richland "Y"	Dead Weed	0	57	HEW-616-T
19460401	Richland, S.W.	Green Sage	0	17	HEW-616-T
19460408	Richland, S.W.	Vegetation	0	7	HEW-616-T
19460408	Richland "Y"	Vegetation	0	3	HEW-616-T
19460408	Richland, S.W.	Vegetation	0.13	0	Veg. Corr.
19460408	Richland "Y"	Vegetation	0.06	0	Veg. Corr.
19460408	Richland, S.E.	Vegetation	0.07	0	Veg. Corr.
19460408	Richland, S.E.	Vegetation	0	4	HEW-616-T
19460415	Richland, S.E.	Vegetation	0	4	HEW-616-T
19460415	Richland, S.E.	Vegetation	0.07	0	Veg. Corr.
19460415	Richland "Y"	Vegetation	0.09	0	Veg. Corr.
19460415	Richland, S.W.	Vegetation	0.15	0	Veg. Corr.
19460415	Richland, S.W.	Vegetation	0	8	HEW-616-T
19460415	Richland "Y"	Vegetation	0	5	HEW-616-T
19460422	Richland, S.E.	Vegetation	0	0	HEW-616-T
19460422	Richland, S.E.	Vegetation	0	0	Veg. Corr.
19460422	Richland, S.W.	Vegetation	0.12	0	Veg. Corr.
19460422	Richland "Y"	Vegetation	0	0	HEW-616-T
19460422	Richland "Y"	Vegetation	0	0	Veg. Corr.
19460422	Richland, S.W.	Vegetation	0	7	HEW-616-T
19460429	Richland, S.E.	Vegetation	0	2	HEW-616-T

Table A.2. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460429	Richland, S.W.	Vegetation	0.11	0	Veg. Corr.
19460429	Richland, S.W.	Vegetation	0	6	HEW-616-T
19460429	Richland "Y"	Vegetation	0.09	0	Veg. Corr.
19460429	Richland, S.E.	Vegetation	0.04	0	Veg. Corr.
19460429	Richland "Y"	Vegetation	0	5	HEW-616-T
19460506	Richland, S.E.	Vegetation	0.04	0	Veg. Corr.
19460506	Richland, S.E.	Vegetation	0	2	HEW-616-T
19460506	Richland "Y"	Vegetation	0	0	HEW-616-T
19460506	Richland, S.W.	Vegetation	0.04	0	Veg. Corr.
19460506	Richland, S.W.	Vegetation	0	2	HEW-616-T
19460506	Richland "Y"	Vegetation	0	0	Veg. Corr.
19460513	Richland, S.W.	Vegetation	0	6	HEW-616-T
19460513	Richland "Y"	Vegetation	0.1	0	Veg. Corr.
19460513	Richland, S.E.	Vegetation	0	2	HEW-616-T
19460513	Richland "Y"	Vegetation	0	5	HEW-616-T
19460514	Richland, S.W.	Vegetation	0.11	0	Veg. Corr.
19460514	Richland, S.E.	Vegetation	0.04	0	Veg. Corr.
19460520	Richland, S.E.	Vegetation	0	0	HEW-616-T
19460520	Richland, S.W.	Vegetation	0	0	Veg. Corr.
19460520	Richland, S.E.	Vegetation	0	0	Veg. Corr.
19460520	Richland, S.W.	Vegetation	0	0	HEW-616-T
19460520	Richland "Y"	Vegetation	0	0	Veg. Corr.
19460520	Richland "Y"	Vegetation	0	0	HEW-616-T
19460527	Richland, S.W.	Vegetation	0	0	Veg. Corr.
19460527	Richland, S.W.	Vegetation	0	0	HEW-616-T
19460527	Richland "Y"	Vegetation	0.06	0	Veg. Corr.
19460527	Richland, S.E.	Vegetation	0.13	0	Veg. Corr.
19460527	Richland "Y"	Vegetation	0	4	HEW-616-T
19460527	Richland, S.E.	Vegetation	0	7	HEW-616-T
19460603	Richland, S.W.	Vegetation	0.07	0	Veg. Corr.
19460603	Richland, S.W.	Vegetation	0	2	HEW-616-T
19460603	Richland, S.E.	Vegetation	0	5	HEW-616-T
19460603	Richland "Y"	Vegetation	0.02	0	Veg. Corr.
19460603	Richland "Y"	Vegetation	0	1	HEW-616-T
19460603	Richland, S.E.	Vegetation	0.09	0	Veg. Corr.
19460610	Richland "Y"	Vegetation	0	4	HEW-616-T
19460610	Richland, S.W.	Vegetation	0.06	0	Veg. Corr.
19460610	Richland "Y"	Vegetation	0.06	0	Veg. Corr.
19460610	Richland, S.W.	Vegetation	0	3	HEW-616-T
19460610	Richland, S.E.	Vegetation	0.13	0	Veg. Corr.
19460610	Richland, S.E.	Vegetation	0	7	HEW-616-T
19460617	Richland, S.E.	Vegetation	0	0	Veg. Corr.
19460617	Richland, S.E.	Vegetation	0	0	HEW-616-T
19460617	Richland "Y"	Vegetation	0.02	0	Veg. Corr.
19460617	Richland, S.W.	Vegetation	0	0	Veg. Corr.

Table A.2. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460617	Richland, S.W.	Vegetation	0	0	HEW-616-T
19460617	Richland "Y"	Vegetation	0	1	HEW-616-T
19460624	Richland, S.E.	Vegetation	0	0	Veg. Corr.
19460624	Richland, S.W.	Vegetation	0.05	0	Veg. Corr.
19460624	Richland "Y"	Vegetation	0.07	0	Veg. Corr.
19460624	Richland "Y"	Vegetation	0	4	HEW-616-T
19460624	Richland, S.E.	Vegetation	0	0	HEW-616-T
19460701	Richland "Y"	Vegetation	0	3	HEW-616-T
19460701	Richland, S.E.	Vegetation	0.1	0	Veg. Corr.
19460701	Richland, S.W.	Vegetation	0.04	0	Veg. Corr.
19460701	Richland "Y"	Vegetation	0.06	0	Veg. Corr.
19460701	Richland, S.W.	Vegetation	0	2	HEW-616-T
19460701	Richland, S.E.	Vegetation	0	5	HEW-616-T
19460702	Richland, S.E.	Vegetation	0	0	HEW-616-T
19460708	Richland "Y"	Vegetation	0.02	0	Veg. Corr.
19460708	Richland "Y"	Vegetation	0	1	HEW-616-T
19460708	Richland, S.W.	Vegetation	0.02	0	Veg. Corr.
19460708	Richland, S.E.	Vegetation	0	5	HEW-616-T
19460708	Richland, S.W.	Vegetation	0	1	HEW-616-T
19460708	Richland, S.E.	Vegetation	0.09	0	Veg. Corr.
19460715	Richland, S.E.	Vegetation	0	4	HEW-616-T
19460715	Richland "Y"	Vegetation	0	0	HEW-616-T
19460715	Richland, S.W.	Vegetation	0.09	0	Veg. Corr.
19460715	Richland, S.E.	Vegetation	0.07	0	Veg. Corr.
19460715	Richland "Y"	Vegetation	0	0	Veg. Corr.
19460715	Richland, S.W.	Vegetation	0	5	HEW-616-T
19460717	Richland, S.W.	Vegetation	0.09	0	HW-7-4423
19460717	Richland "Y"	Vegetation	0.04	0	HW-7-4423
19460717	Richland, S.E.	Vegetation	0.07	0	HW-7-4423
19460722	Richland "Y"	Vegetation	0	0	Veg. Corr.
19460722	Richland, S.E.	Vegetation	0	11	HEW-616-T
19460722	Richland, S.E.	Vegetation	0	0	HEW-616-T
19460722	Richland, S.E.	Vegetation	0.19	0	Veg. Corr.
19460722	Richland, S.W.	Vegetation	0.07	0	Veg. Corr.
19460722	Richland, S.W.	Vegetation	0	4	HEW-616-T
19460724	Richland "Y"	Vegetation	0.04	0	HW-7-4440
19460724	Richland, S.W.	Vegetation	0.07	0	HW-7-4440
19460724	Richland, S.E.	Vegetation	0.19	0	HW-7-4440
19460729	Richland "Y"	Vegetation	0.09	0	Veg. Corr.
19460729	Richland, S.W.	Vegetation	0	0	Veg. Corr.
19460729	Richland, S.E.	Vegetation	0	0	Veg. Corr.
19460729	Richland, S.E.	Vegetation	0	0	HEW-616-T
19460729	Richland "Y"	Vegetation	0	5	HEW-616-T
19460729	Richland, S.W.	Vegetation	0	0	HEW-616-T
19460805	Richland "Y"	Vegetation	0	0	Veg. Corr.

Table A.2. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460805	Richland, S.W.	Vegetation	0	2	HEW-616-T
19460805	Richland, S.E.	Vegetation	0	3	HEW-616-T
19460805	Richland "Y"	Vegetation	0	0	HEW-616-T
19460806	Richland, S.E.	Vegetation	0.06	0	Veg. Corr.
19460806	Richland, S.W.	Vegetation	0.04	0	Veg. Corr.
19460812	Richland, S.E.	Vegetation	0.02	0	Veg. Corr.
19460812	Richland "Y"	Vegetation	0	0	Veg. Corr.
19460812	Richland, S.W.	Vegetation	0.04	0	Veg. Corr.
19460819	Richland "Y"	Vegetation	0	0	Veg. Corr.
19460819	Richland, S.E.	Vegetation	0.1	0	Veg. Corr.
19460819	Richland, S.W.	Vegetation	0.09	0	Veg. Corr.
19460826	Richland, S.W.	Vegetation	0.09	0	Veg. Corr.
19460826	Richland "Y"	Vegetation	0.06	0	Veg. Corr.
19460826	Richland, S.E.	Vegetation	0.04	0	Veg. Corr.
19460903	Richland, S.E.	Vegetation	0.07	0	Veg. Corr.
19460903	Richland, S.W.	Vegetation	0.02	0	Veg. Corr.
19460903	Richland "Y"	Vegetation	0.03	0	Veg. Corr.
19460909	Richland "Y"	Vegetation	0.06	0	Veg. Corr.
19460910	Richland, S.W.	Vegetation	0.07	0	Veg. Corr.
19460910	Richland, S.E.	Vegetation	0.09	0	Veg. Corr.
19460916	Richland "Y"	Vegetation	0.04	0	Veg. Corr.
19460916	Richland, S.W.	Vegetation	0	0	Veg. Corr.
19460916	Richland, S.E.	Vegetation	0	0	Veg. Corr.
19460918	Richland, S.W.	Vegetation	0.05	0	HW-7-5042
19460918	Richland "Y"	Vegetation	0.05	0	HW-7-5042
19460918	Richland, S.E.	Vegetation	0.12	0	HW-7-5042
19460918	Richland, S.E.	Vegetation	0.1	0	HW-7-5042
19460918	Richland, S.W.	Vegetation	0.07	0	HW-7-5042
19460918	Richland "Y"	Vegetation	0.07	0	HW-7-5042
19460923	Richland "Y"	Vegetation	0.06	0	Veg. Corr.
19460924	Richland, S.W.	Vegetation	0.02	0	Veg. Corr.
19460924	Richland, S.E.	Vegetation	0.09	0	Veg. Corr.
19460930	Richland "Y"	Vegetation	0	0	Veg. Corr.
19460930	Richland "Y"	Vegetation	0.04	0	HW-7-5042
19460930	Richland "Y"	Vegetation	0.05	0	HW-7-5042
19461001	Richland, S.E.	Vegetation	0.05	0	Veg. Corr.
19461001	Richland, S.W.	Vegetation	0.16	0	Veg. Corr.
19461007	Richland "Y"	Vegetation	0.09	0	Veg. Corr.
19461008	Richland, S.E.	Vegetation	0.29	0	Veg. Corr.
19461008	Richland, S.W.	Vegetation	0.42	0	Veg. Corr.
19461014	Richland "Y"	Vegetation	0.02	0	Veg. Corr.
19461015	Richland, S.E.	Vegetation	0.07	0	Veg. Corr.
19461015	Richland, S.W.	Vegetation	0.09	0	Veg. Corr.
19461016	Richland "Y"	Vegetation	0.05	0	HW-7-5042
19461016	Richland "Y"	Vegetation	0.09	0	HW-7-5042

Table A.2. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19461020	Richland "Y"	Vegetation	0.04	0	Veg. Corr.
19461022	Richland, S.E.	Vegetation	0.12	0	Veg. Corr.
19461022	Richland, S.W.	Vegetation	0.18	0	Veg. Corr.
19461028	Richland "Y"	Vegetation	0.11	0	Veg. Corr.
19461029	Richland, S.W.	Vegetation	0.09	0	Veg. Corr.
19461029	Richland, S.E.	Vegetation	0.05	0	Veg. Corr.
19461031	Richland "Y"	Vegetation	0.04	0	HW-7-5042
19461031	Richland "Y"	Vegetation	0.04	0	HW-7-5042
19461104	Richland "Y"	Vegetation	0.03	0	Veg. Corr.
19461105	Richland, S.W.	Vegetation	0.13	0	Veg. Corr.
19461105	Richland, S.E.	Vegetation	0.02	0	Veg. Corr.
19461111	Richland "Y"	Vegetation	0.24	0	Veg. Corr.
19461112	Richland, S.W.	Vegetation	0.25	0	Veg. Corr.
19461112	Richland, S.E.	Vegetation	1.13	0	Veg. Corr.
19461118	Richland "Y"	Vegetation	0.07	0	Veg. Corr.
19461119	Richland, S.E.	Vegetation	0	0	Veg. Corr.
19461119	Richland, S.W.	Vegetation	0.14	0	Veg. Corr.
19461119	Richland "Y"	Vegetation	0.14	0	HW-7-5042
19461119	Richland "Y"	Vegetation	0.26	0	HW-7-5042
19461125	Richland, S.E.	Vegetation	0.05	0	Veg. Corr.
19461125	Richland, S.W.	Vegetation	0.13	0	Veg. Corr.
19461125	Richland "Y"	Vegetation	0.03	0	Veg. Corr.
19461130	Richland "Y"	Vegetation	0.07	0	HW-7-5042
19461130	Richland "Y"	Vegetation	0.06	0	HW-7-5042
19461202	Richland, S.E.	Vegetation	0.79	0	Veg. Corr.
19461202	Richland, S.W.	Vegetation	1.34	0	Veg. Corr.
19461202	Richland "Y"	Vegetation	0.01	0	Veg. Corr.
19461209	Richland "Y"	Vegetation	0.21	0	Veg. Corr.
19461210	Richland, S.E.	Vegetation	0.27	0	Veg. Corr.
19461210	Richland, S.W.	Vegetation	0.81	0	Veg. Corr.
19461216	Richland "Y"	Vegetation	0.37	0	HW-7-5042
19461216	Richland "Y"	Vegetation	0.05	0	Veg. Corr.
19461216	Richland "Y"	Vegetation	0.29	0	HW-7-5042
19461217	Richland, S.E.	Vegetation	0.13	0	Veg. Corr.
19461217	Richland, S.W.	Vegetation	0.29	0	Veg. Corr.
19461223	Richland "Y"	Vegetation	0.43	0	Veg. Corr.
19461223	Richland, S.E.	Vegetation	1	0	Veg. Corr.
19461223	Richland, S.W.	Vegetation	0.21	0	Veg. Corr.
19461230	Richland, S.W.	Vegetation	0.22	0	Veg. Corr.
19461230	Richland "Y"	Vegetation	0.18	0	Veg. Corr.
19461230	Richland, S.E.	Vegetation	0.64	0	Veg. Corr.
19461231	Richland "Y"	Vegetation	0.44	0	HW-7-5042
19461231	Richland "Y"	Vegetation	0.25	0	HW-7-5042

Table A.3. Iodine-131 Concentration in Vegetation in Kennewick/Pasco, Cell 443

Date	Location	Type	μCi/kg	CPM/g	Reference
19460103	Pasco, H & R	Sagebrush	0	187.8	HEW-578-L
19460103	Kennewick	Sagebrush	0	238.2	HEW-578-L
19460107	Pasco, S.E.	Vegetation	2.2	0	Veg. Corr
19460107	Kennewick, N.W.	Vegetation	4.17	0	Veg. Corr
19460110	Kennewick, Golf Course	Sagebrush	0	187.7	HEW-578-L
19460110	Pasco	Sagebrush	0	99.3	HEW-578-L
19460115	Kennewick, N.W.	Vegetation	1.05	0	Veg. Corr
19460115	Pasco, N.W.	Vegetation	0.73	0	Veg. Corr
19460117	Kennewick	Vegetation	0.3	53.2	HEW-616-T
19460117	Pasco, N.W.	Vegetation	0.21	36.1	HEW-616-T
19460121	Pasco, N.W.	Vegetation	0.72	0	Veg. Corr
19460121	Kennewick, N.W.	Vegetation	1.21	0	Veg. Corr
19460124	Kennewick, W. Kennewick Ave.	Vegetation	0.27	48	HEW-616-T
19460124	Pasco, H & R Point	Vegetation	0.17	31	HEW-616-T
19460128	Pasco, N.W.	Vegetation	0.55	0	Veg. Corr
19460128	Kennewick, N.W.	Vegetation	1.02	0	Veg. Corr
19460131	Kennewick, Golf Course	Vegetation	0.78	46	HEW-616-T
19460131	Kennewick	Vegetation	0.64	0	HW-7-3322
19460131	Pasco, H & R Depot	Vegetation	0.42	25	HEW-616-T
19460204	Kennewick, N.W.	Vegetation	0.19	0	Veg. Corr
19460204	Pasco, N.W.	Vegetation	0.19	0	Veg. Corr
19460207	Kennewick	Vegetation	0.1	8	HEW-616-T
19460207	Pasco	Vegetation	0.1	8	HEW-616-T
19460209	Kennewick, E.	Vegetation	0.27	16	HEW-616-T
19460209	Pasco, Rt. 395	Vegetation	0.19	11	HEW-616-T
19460211	Pasco, N.W.	Vegetation	0.19	0	Veg. Corr
19460211	Kennewick, N.W.	Vegetation	0.29	0	Veg. Corr
19460214	Kennewick	Vegetation	0.2	12	HEW-616-T
19460221	Pasco, S.E.	Vegetation	0.3	0	Veg. Corr
19460221	Kennewick, Golf Course	Vegetation	0	27	HEW-616-T
19460221	Pasco, H & R Depot	Vegetation	0	16	HEW-616-T
19460221	Kennewick, S.W.	Vegetation	0.5	0	Veg. Corr
19460227	Kennewick, N.W.	Vegetation	0.22	0	Veg. Corr
19460227	Pasco, N.W.	Vegetation	0.29	0	Veg. Corr
19460228	Kennewick	Vegetation	0.1	0	HW-7-3517
19460304	Kennewick, S.W.	Vegetation	0.07	0	Veg. Corr
19460304	Kennewick, S.E.	Vegetation	0.07	0	Veg. Corr
19460304	Kennewick, N.W.	Vegetation	0.34	0	Veg. Corr
19460304	Pasco, S.E.	Vegetation	0.24	0	Veg. Corr
19460304	Pasco, N.W.	Vegetation	0.09	0	Veg. Corr
19460304	Pasco, S.E.	Vegetation	0.22	0	Veg. Corr
19460307	Pasco, H & R Point	Vegetation	0	4	HEW-616-T
19460307	Pasco, S.E. 3 Miles	Vegetation	0	9	HEW-616-T
19460307	Pasco, S.E. 1 Mile	Vegetation	0	10	HEW-616-T
19460307	Kennewick, N.W. 3 Miles	Vegetation	0	14	HEW-616-T

Table A.3. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460307	Kennewick, Golf Course	Vegetation	0	3	HEW-616-T
19460307	Kennewick, S.E. 3 Miles	Vegetation	0	3	HEW-616-T
19460307	Pasco, Washington Highway Dept.	Vegetation	0	3	HEW-616-T
19460307	Kennewick, S.E. 1 Mile	Vegetation	0	3	HEW-616-T
19460309	Pasco, 12 Miles from	Vegetation	0	3	HEW-616-T
19460314	Pasco, N.E.	Vegetation	0.09	0	Veg. Corr
19460314	Pasco, S.W.	Cheat Gr.	0	8	HEW-616-T
19460314	Kennewick, S.E.	Cheat Gr.	0	11	HEW-616-T
19460314	Pasco, N.E.	Wheat	0	5	HEW-616-T
19460314	Pasco S.E., H & R Depot	Vegetation	0	25	HEW-616-T
19460314	Pasco, S.W.	Vegetation	0.14	0	Veg. Corr
19460314	Pasco, S.E.	Vegetation	0.43	0	Veg. Corr
19460314	Kennewick, N.E.	Weed	0	15	HEW-616-T
19460314	Kennewick, Golf Course	Weed	0	19	HEW-616-T
19460314	Kennewick, N.E.	Vegetation	0.26	0	Veg. Corr
19460314	Kennewick, S.W.	Vegetation	0.32	0	Veg. Corr
19460314	Pasco, N.W.	Yel Flower	0	15	HEW-616-T
19460314	Kennewick, S.W. River Flats	Weed	0	19	HEW-616-T
19460314	Pasco, N.W.	Vegetation	0.26	0	Veg. Corr
19460314	Kennewick, S.E.	Vegetation	0.19	0	Veg. Corr
19460321	Kennewick, N.W.	Vegetation	0.27	0	Veg. Corr
19460321	Kennewick, N.E.	Vegetation	0.24	0	Veg. Corr
19460321	Pasco, High School	Dry	0	10	HEW-616-T
19460321	Kennewick, S.E.	Vegetation	0.26	0	Veg. Corr
19460321	Kennewick, R.R. Bridge	Vegetation	0	65	HEW-616-T
19460321	Kennewick, S.W.	Vegetation	1.11	0	Veg. Corr
19460321	Pasco, Court House	Green Dry	0	6	HEW-616-T
19460321	Pasco, S.W.	Vegetation	0.17	0	Veg. Corr
19460321	Kennewick, War Housing Project	Green	0	14	HEW-616-T
19460321	Kennewick, Columbia River	Dry Grass	0	15	HEW-616-T
19460321	Pasco, N.W.	Vegetation	0.07	0	Veg. Corr
19460321	Kennewick, Golf Course	White Dry	0	16	HEW-616-T
19460321	Pasco, S.E.	Vegetation	0.1	0	Veg. Corr
19460321	Pasco, W.	Green	0	38	HEW-616-T
19460321	Pasco, Roundhouse	Green	0	4	HEW-616-T
19460321	Pasco, N.E.	Vegetation	0.65	0	Veg. Corr
19460328	Kennewick, S.W. River Flats	D Wht Fl W	0	42	HEW-616-T
19460328	Pasco, S.W.	Vegetation	0.93	0	Veg. Corr
19460328	Pasco, S.E., USO Bldg.	Dd Alfalfa	0	9	HEW-616-T
19460328	Pasco, N.W.	Wht Lf Wd	0	12	HEW-616-T
19460328	Kennewick, S.W.	Vegetation	0.78	0	Veg. Corr
19460328	Kennewick, S.E.	Vegetation	0.26	0	Veg. Corr
19460328	Kennewick, N.W.	Vegetation	0.97	0	Veg. Corr
19460328	Kennewick, N.W.	D Wht Fl W	0	52	HEW-616-T
19460328	Pasco, S.W., H & R Depot	D Wht Fl W	0	50	HEW-616-T

Table A.3. (contd)

Date	Location	Type	μCi/kg	CPM/g	Reference
19460328	Kennewick, E.	Yel Flower	0	15	HEW-616-T
19460328	Pasco, N.W.	Vegetation	0.22	0	Veg. Corr
19460328	Pasco, N.E.	Vegetation	0.22	0	Veg. Corr
19460328	Kennewick, N.E.	Fuzzy Weed	0	4	HEW-616-T
19460328	Pasco, N.E.	Dead Sage	0	12	HEW-616-T
19460328	Kennewick, N.E.	Vegetation	0.07	0	Veg. Corr
19460328	Pasco, S.E.	Vegetation	0.17	0	Veg. Corr
19460331	Kennewick	Vegetation	0.21	0	HW-7-3694
19460401	Pasco, S.E.	Yel Flower	0	45	HEW-616-T
19460401	Kennewick, N.W., USO	Vegetation	0	14	HEW-616-T
19460401	Kennewick N.E., Golf Course	Dead Weed	0	17	HEW-616-T
19460401	Pasco, S.W.	Yel Flower	0	8	HEW-616-T
19460401	Kennewick, S.E.	Green Sage	0	12	HEW-616-T
19460401	Pasco, N.W.	Yel Flower	0	4	HEW-616-T
19460401	Kennewick, S.W.	Dead Weed	0	49	HEW-616-T
19460408	Pasco, S.W.	Green	0	4	HEW-616-T
19460408	Kennewick, N.W.	Vegetation	0	7	HEW-616-T
19460408	Kennewick, S.E.	Vegetation	0	11	HEW-616-T
19460408	Kennewick, S.E.	Vegetation	0.26	0	Veg. Corr
19460408	Pasco, N.W.	Green	0	4	HEW-616-T
19460408	Pasco, N.W.	Vegetation	0.07	0	Veg. Corr
19460408	Pasco, N.E.	Vegetation	0	4	HEW-616-T
19460408	Pasco, S.E.	Green	0	7	HEW-616-T
19460408	Pasco, S.W.	Vegetation	0.07	0	Veg. Corr
19460408	Pasco, N.E.	Vegetation	0.07	0	Veg. Corr
19460408	Kennewick, N.E.	Dry Grass	0	2	HEW-616-T
19460408	Kennewick, N.W.	Vegetation	0.13	0	Veg. Corr
19460408	Kennewick, N.E.	Vegetation	0.04	0	Veg. Corr
19460408	Kennewick, S.W.	Green	0	5	HEW-616-T
19460408	Pasco, S.E.	Vegetation	0.13	0	Veg. Corr
19460408	Kennewick, S.W.	Vegetation	0.09	0	Veg. Corr
19460408	Pasco, N.E.	Green	0	4	HEW-616-T
19460410	Pasco, N.E.	Gn Alfalfa	0	4	HEW-616-T
19460415	Pasco, S.E.	Vegetation	0	3	HEW-616-T
19460415	Kennewick, N.W.	Vegetation	0.22	0	Veg. Corr
19460415	Kennewick, N.E.	Vegetation	0	2	HEW-616-T
19460415	Kennewick, S.W.	Vegetation	0	23	HEW-616-T
19460415	Pasco, N.E.	Vegetation	0	10	HEW-616-T
19460415	Kennewick, S.W.	Vegetation	0.43	0	Veg. Corr
19460415	Kennewick, N.E.	Vegetation	0.04	0	Veg. Corr
19460415	Pasco, S.W.	Vegetation	0	4	HEW-616-T
19460415	Pasco, S.E.	Vegetation	0.06	0	Veg. Corr
19460415	Pasco, N.W.	Vegetation	0	6	HEW-616-T
19460415	Kennewick, S.E.	Vegetation	0.13	0	Veg. Corr
19460415	Pasco, N.W.	Vegetation	0.11	0	Veg. Corr

Table A.3. (contd)

Date	Location	Type	μCi/kg	CPM/g	Reference
19460415	Kennewick, S.E.	Vegetation	0	7	HEW-616-T
19460415	Kennewick, N.W.	Vegetation	0	12	HEW-616-T
19460415	Pasco, N.E.	Vegetation	0.19	0	Veg. Corr
19460415	Pasco, S.W.	Vegetation	0.07	0	Veg. Corr
19460422	Pasco, N.W.	Vegetation	0	1	HEW-616-T
19460422	Kennewick, S.W.	Vegetation	0.09	0	Veg. Corr
19460422	Pasco, S.E.	Vegetation	0	1	HEW-616-T
19460422	Pasco, N.E.	Vegetation	0.03	0	Veg. Corr
19460422	Pasco, N.E.	Vegetation	0	2	HEW-616-T
19460422	Pasco, N.W.	Vegetation	0.02	0	Veg. Corr
19460422	Pasco, S.E.	Vegetation	0.02	0	Veg. Corr
19460422	Kennewick, S.E.	Vegetation	0.1	0	Veg. Corr
19460422	Kennewick, S.W.	Vegetation	0	5	HEW-616-T
19460422	Kennewick, S.E.	Vegetation	0	6	HEW-616-T
19460422	Kennewick, N.W.	Vegetation	0	8	HEW-616-T
19460422	Pasco, S.W.	Vegetation	0	1	HEW-616-T
19460422	Kennewick, N.E.	Vegetation	0	1	HEW-616-T
19460422	Kennewick, N.W.	Vegetation	0.14	0	Veg. Corr
19460422	Kennewick, N.E.	Vegetation	0.02	0	Veg. Corr
19460422	Pasco, S.W.	Vegetation	0.02	0	Veg. Corr
19460429	Kennewick, N.W.	Vegetation	0	3	HEW-616-T
19460429	Pasco, N.W.	Vegetation	0	4	HEW-616-T
19460429	Kennewick, S.W.	Vegetation	0	5	HEW-616-T
19460429	Kennewick, S.E.	Vegetation	0.07	0	Veg. Corr
19460429	Pasco, S.W.	Vegetation	0	0	Veg. Corr
19460429	Pasco	Green	0	2	HEW-616-T
19460429	Pasco, N.W.	Vegetation	0.07	0	Veg. Corr
19460429	Pasco, N.E.	Vegetation	0	0	HEW-616-T
19460429	Kennewick, S.E.	Vegetation	0	0.4	HEW-616-T
19460429	Kennewick, N.W.	Vegetation	0.06	0	Veg. Corr
19460429	Kennewick, N.E.	Vegetation	0	2	HEW-616-T
19460429	Kennewick, S.W.	Vegetation	0.09	0	Veg. Corr
19460429	Pasco, S.W.	Vegetation	0	0	HEW-616-T
19460429	Pasco, S.E.	Vegetation	0	0	Veg. Corr
19460429	Pasco, S.E.	Vegetation	0	0	HEW-616-T
19460429	Kennewick, N.E.	Vegetation	0.04	0	Veg. Corr
19460429	Pasco, N.E.	Vegetation	0	0	Veg. Corr
19460430	Kennewick	Vegetation	0.24	0	HW-7-3933
19460506	Pasco, N.W.	Vegetation	0.09	0	Veg. Corr
19460506	Kennewick, S.W.	Vegetation	0	3	HEW-616-T
19460506	Pasco, S.E.	Vegetation	0	0	HEW-616-T
19460506	Pasco, N.W.	Vegetation	0	5	HEW-616-T
19460506	Kennewick, S.E.	Vegetation	0	0	HEW-616-T
19460506	Kennewick, N.E.	Vegetation	0	4	HEW-616-T
19460506	Kennewick, N.W.	Vegetation	0	2	HEW-616-T

Table A.3. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460506	Kennewick, S.E.	Vegetation	0	0	Veg. Corr
19460506	Kennewick, S.W.	Vegetation	0.06	0	Veg. Corr
19460506	Pasco, N.E.	Vegetation	0	2	HEW-616-T
19460506	Kennewick, N.W.	Vegetation	0.04	0	Veg. Corr
19460506	Kennewick, N.E.	Vegetation	0.07	0	Veg. Corr
19460506	Pasco, N.E.	Vegetation	0.04	0	Veg. Corr
19460506	Pasco, S.W.	Vegetation	0	2	HEW-616-T
19460506	Pasco, S.W.	Vegetation	0.04	0	Veg. Corr
19460506	Pasco, S.E.	Vegetation	0	0	Veg. Corr
19460513	Pasco, 12th St. S.E.	Vegetation	0	6	HEW-616-T
19460513	Kennewick, N.W.	Vegetation	0	1	HEW-616-T
19460513	Kennewick, N.E.	Vegetation	0.13	0	Veg. Corr
19460513	Kennewick, N.E.	Vegetation	0	7	HEW-616-T
19460513	Pasco, N.E.	Vegetation	0.04	0	Veg. Corr
19460513	Pasco, S.E.	Vegetation	0.11	0	Veg. Corr
19460513	Pasco, S.W.	Vegetation	0.11	0	Veg. Corr
19460513	Pasco, H & R Depot	Vegetation	0	2	HEW-616-T
19460513	Pasco, N.W.	Vegetation	0	0	Veg. Corr
19460513	Pasco, N.W.	Vegetation	0	0	HEW-616-T
19460513	Kennewick, N.W.	Vegetation	0.02	0	Veg. Corr
19460513	Kennewick, S.W.	Vegetation	0	3	HEW-616-T
19460513	Kennewick, S.W.	Vegetation	0.06	0	Veg. Corr
19460513	Pasco, S.W.	Vegetation	0	6	HEW-616-T
19460513	Kennewick, S.E.	Vegetation	0	1	HEW-616-T
19460513	Kennewick, S.E.	Vegetation	0.02	0	Veg. Corr
19460520	Kennewick, S.W.	Vegetation	0	2	HEW-616-T
19460520	Kennewick, N.E.	Vegetation	0	0	HEW-616-T
19460520	Kennewick, N.E.	Vegetation	0	0	Veg. Corr
19460520	Kennewick, N.W.	Vegetation	0	1	HEW-616-T
19460520	Kennewick, S.W.	Vegetation	0.03	0	Veg. Corr
19460520	Kennewick, S.E.	Vegetation	0	0	HEW-616-T
19460520	Pasco, S.W.	Vegetation	0.03	0	Veg. Corr
19460520	Pasco, S.W.	Vegetation	0	2	HEW-616-T
19460520	Pasco, S.E.	Vegetation	0.04	0	Veg. Corr
19460520	Pasco, N.E.	Vegetation	0	2	HEW-616-T
19460520	Pasco, N.W.	Vegetation	0	2	HEW-616-T
19460520	Pasco, S.E.	Vegetation	0	2	HEW-616-T
19460520	Pasco, N.E.	Vegetation	0.03	0	Veg. Corr
19460520	Pasco, N.W.	Vegetation	0.03	0	Veg. Corr
19460520	Kennewick, S.E.	Vegetation	0	0	Veg. Corr
19460520	Kennewick, N.W.	Vegetation	0.03	0	Veg. Corr
19460527	Pasco, N.E.	Vegetation	0	2	HEW-616-T
19460527	Pasco, N.W.	Vegetation	0	0	HEW-616-T
19460527	Pasco, S.E.	Vegetation	0	0	Veg. Corr
19460527	Kennewick, N.W.	Vegetation	0	4	HEW-616-T

Table A.3. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460527	Pasco, S.E.	Vegetation	0	0	HEW-616-T
19460527	Kennewick, S.W.	Vegetation	0	0	HEW-616-T
19460527	Pasco, N.E.	Vegetation	0.04	0	Veg. Corr
19460527	Pasco, S.W.	Vegetation	0.04	0	Veg. Corr
19460527	Kennewick, N.E.	Vegetation	0.06	0	Veg. Corr
19460527	Kennewick, S.E.	Vegetation	0.06	0	Veg. Corr
19460527	Kennewick, S.W.	Vegetation	0	0	Veg. Corr
19460527	Kennewick, S.E.	Vegetation	0	3	HEW-616-T
19460527	Pasco, N.W.	Vegetation	0	0	Veg. Corr
19460527	Kennewick, N.W.	Vegetation	0.07	0	Veg. Corr
19460527	Kennewick, N.E.	Vegetation	0	3	HEW-616-T
19460527	Pasco, S.W.	Vegetation	0	2	HEW-616-T
19460531	Kennewick	Vegetation	0.05	0	HW-7-4312
19460603	Kennewick, N.W.	Vegetation	0.11	0	Veg. Corr
19460603	Pasco, N.W.	Vegetation	0	4	HEW-616-T
19460603	Kennewick, S.W.	Vegetation	0	4	HEW-616-T
19460603	Pasco, S.E.	Vegetation	0.11	0	Veg. Corr
19460603	Pasco, S.E.	Vegetation	0	6	HEW-616-T
19460603	Pasco, N.E.	Vegetation	0	4	HEW-616-T
19460603	Kennewick, N.W.	Vegetation	0	6	HEW-616-T
19460603	Kennewick, S.E.	Vegetation	0.04	0	Veg. Corr
19460603	Kennewick, N.E.	Vegetation	0.03	0	Veg. Corr
19460603	Kennewick, S.E.	Vegetation	0	2	HEW-616-T
19460603	Kennewick, N.E.	Vegetation	0	4	HEW-616-T
19460603	Kennewick, S.W.	Vegetation	0.07	0	Veg. Corr
19460603	Pasco, N.W.	Vegetation	0.07	0	Veg. Corr
19460603	Pasco, S.W.	Vegetation	0.11	0	Veg. Corr
19460603	Pasco, N.E.	Vegetation	0.07	0	Veg. Corr
19460603	Pasco, S.W.	Vegetation	0	4	HEW-616-T
19460610	Kennewick, N.W.	Vegetation	0	0	HEW-616-T
19460610	Pasco, N.W.	Vegetation	0	5	HEW-616-T
19460610	Kennewick, S.W.	Vegetation	0	5	HEW-616-T
19460610	Pasco, N.W.	Vegetation	0.09	0	Veg. Corr
19460610	Pasco, S.E.	Vegetation	0.09	0	Veg. Corr
19460610	Pasco, S.W.	Vegetation	0	6	HEW-616-T
19460610	Pasco, N.E.	Vegetation	0.02	0	Veg. Corr
19460610	Kennewick, N.W.	Vegetation	0	0	Veg. Corr
19460610	Kennewick, S.E.	Vegetation	0.02	0	Veg. Corr
19460610	Pasco, S.E.	Vegetation	0	5	HEW-616-T
19460610	Kennewick, S.E.	Vegetation	0	1	HEW-616-T
19460610	Kennewick, N.E.	Vegetation	0.07	0	Veg. Corr
19460610	Kennewick, S.W.	Vegetation	0.09	0	Veg. Corr
19460610	Kennewick, N.E.	Vegetation	0	4	HEW-616-T
19460610	Pasco, N.E.	Vegetation	0	1	HEW-616-T
19460611	Kennewick, Hilands	Cherry Skn	0	1	HEW-616-T

Table A.3. (contd)

Date	Location	Type	μCi/kg	CPM/g	Reference
19460611	Kennewick, Hilands	Grape Lvs.	0	2	HEW-616-T
19460617	Pasco, N.E.	Vegetation	0	0	HEW-616-T
19460617	Pasco, N.E.	Vegetation	0	5	HEW-616-T
19460617	Kennewick, S.W.	Vegetation	0	0	Veg. Corr
19460617	Kennewick, N.W.	Vegetation	0	0	Veg. Corr
19460617	Kennewick, S.W.	Vegetation	0	0	HEW-616-T
19460617	Kennewick, N.W.	Vegetation	0	0	HEW-616-T
19460617	Pasco, N.W.	Vegetation	0.09	0	Veg. Corr
19460617	Kennewick, N.E.	Vegetation	0.04	0	Veg. Corr
19460617	Kennewick, S.E.	Vegetation	0.07	0	Veg. Corr
19460617	Pasco, S.E.	Vegetation	0	0	Veg. Corr
19460617	Pasco, S.E.	Vegetation	0	0	HEW-616-T
19460617	Pasco, N.E.	Vegetation	0.09	0	Veg. Corr
19460617	Kennewick, N.E.	Vegetation	0	2	HEW-616-T
19460617	Pasco, N.W.	Vegetation	0	5	HEW-616-T
19460617	Kennewick, S.E.	Vegetation	0	4	HEW-616-T
19460617	Pasco, S.W.	Vegetation	0	0	Veg. Corr
19460624	Pasco, S.W.	Vegetation	0	2	HEW-616-T
19460624	Kennewick, S.W.	Vegetation	0.05	0	Veg. Corr
19460624	Pasco, S.E.	Vegetation	0.1	0	Veg. Corr
19460624	Pasco, S.W.	Vegetation	0.03	0	Veg. Corr
19460624	Kennewick, N.E.	Vegetation	0	9	HEW-616-T
19460624	Kennewick, S.E.	Vegetation	0.03	0	Veg. Corr
19460624	Kennewick, S.E.	Vegetation	0	2	HEW-616-T
19460624	Kennewick, N.E.	Vegetation	0.15	0	Veg. Corr
19460624	Pasco, S.E.	Vegetation	0	6	HEW-616-T
19460624	Pasco, N.W.	Vegetation	0.05	0	Veg. Corr
19460624	Pasco, N.W.	Vegetation	0	3	HEW-616-T
19460624	Pasco, N.E.	Vegetation	0	1	HEW-616-T
19460624	Kennewick, S.W.	Vegetation	0	3	HEW-616-T
19460624	Kennewick, N.W.	Vegetation	0.07	0	Veg. Corr
19460624	Kennewick, N.W.	Vegetation	0	1	HEW-616-T
19460624	Pasco, N.E.	Vegetation	0.02	0	Veg. Corr
19460630	Kennewick	Vegetation	0.05	0	HW-7-4312
19460701	Pasco, N.E.	Vegetation	0.08	0	Veg. Corr
19460701	Kennewick, N.E.	Vegetation	0.04	0	Veg. Corr
19460701	Pasco, N.E.	Vegetation	0	4	HEW-616-T
19460701	Kennewick, N.E.	Vegetation	0	2	HEW-616-T
19460701	Pasco, N.W.	Vegetation	0	0	Veg. Corr
19460701	Pasco, N.W.	Vegetation	0	0	HEW-616-T
19460701	Kennewick, N.W.	Vegetation	0	3	HEW-616-T
19460701	Kennewick, S.E.	Vegetation	0	3	HEW-616-T
19460701	Pasco, S.E.	Vegetation	0	0	HEW-616-T
19460701	Kennewick, N.W.	Vegetation	0.06	0	Veg. Corr
19460701	Pasco, S.W.	Vegetation	0	1	HEW-616-T

Table A.3. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460701	Kennewick, S.W.	Vegetation	0	4	HEW-616-T
19460701	Kennewick, S.E.	Vegetation	0.06	0	Veg. Corr
19460701	Pasco, S.W.	Vegetation	0.02	0	Veg. Corr
19460701	Kennewick, S.W.	Vegetation	0.08	0	Veg. Corr
19460701	Pasco, S.E.	Vegetation	0	0	Veg. Corr
19460708	Kennewick, N.W.	Vegetation	0.07	0	Veg. Corr
19460708	Kennewick, S.E.	Vegetation	0.04	0	Veg. Corr
19460708	Kennewick, S.W.	Vegetation	0.04	0	Veg. Corr
19460708	Kennewick, S.W.	Vegetation	0	2	HEW-616-T
19460708	Pasco, S.W.	Vegetation	0	3	HEW-616-T
19460708	Pasco, N.W.	Vegetation	0	0	HEW-616-T
19460708	Pasco, N.W.	Vegetation	0	0	Veg. Corr
19460708	Pasco, S.E.	Vegetation	0	0	HEW-616-T
19460708	Kennewick, N.W.	Vegetation	0	4	HEW-616-T
19460708	Pasco, S.W.	Vegetation	0.06	0	Veg. Corr
19460708	Pasco, N.E.	Vegetation	0	0	HEW-616-T
19460708	Kennewick, S.E.	Vegetation	0	2	HEW-616-T
19460708	Pasco, S.E.	Vegetation	0	0	Veg. Corr
19460708	Pasco, N.E.	Vegetation	0	0	Veg. Corr
19460708	Kennewick, N.E.	Vegetation	0	2	HEW-616-T
19460708	Kennewick, N.E.	Vegetation	0.04	0	Veg. Corr
19460715	Pasco, S.W.	Vegetation	0.04	0	Veg. Corr
19460715	Kennewick, N.W.	Vegetation	0.04	0	Veg. Corr
19460715	Pasco, S.W.	Vegetation	0	2	HEW-616-T
19460715	Kennewick, N.W.	Vegetation	0	2	HEW-616-T
19460715	Kennewick, S.E.	Vegetation	0	0	HEW-616-T
19460715	Kennewick, N.E.	Vegetation	0	4	HEW-616-T
19460715	Pasco, N.W.	Vegetation	0	2	HEW-616-T
19460715	Kennewick, S.E.	Vegetation	0	0	Veg. Corr
19460715	Kennewick, S.W.	Vegetation	0.04	0	Veg. Corr
19460715	Pasco, N.W.	Vegetation	0.04	0	Veg. Corr
19460715	Kennewick, S.W.	Vegetation	0	2	HEW-616-T
19460715	Pasco, S.E.	Vegetation	0.13	0	Veg. Corr
19460715	Pasco, N.E.	Vegetation	0	5	HEW-616-T
19460715	Kennewick, N.E.	Vegetation	0.07	0	Veg. Corr
19460715	Pasco, N.E.	Vegetation	0.09	0	Veg. Corr
19460715	Pasco, S.E.	Vegetation	0	7	HEW-616-T
19460717	Kennewick, S.W.	Vegetation	0.04	0	HW-7-4423
19460717	Kennewick, N.W.	Vegetation	0.04	0	HW-7-4423
19460717	Pasco, N.W.	Vegetation	0.04	0	HW-7-4423
19460717	Kennewick, N.E.	Vegetation	0.07	0	HW-7-4423
19460717	Pasco, N.E.	Vegetation	0.09	0	HW-7-4423
19460717	Kennewick, S.E.	Vegetation	0.04	0	HW-7-4423
19460717	Pasco, S.E.	Vegetation	0.12	0	HW-7-4423
19460717	Pasco, S.W.	Vegetation	0.04	0	HW-7-4423

Table A.3. (contd)

Date	Location	Type	μCi/kg	CPM/g	Reference
19460717	Pasco	Vegetation	0.07	0	HW-7-4423
19460722	Pasco, N.E.	Vegetation	0.04	0	Veg. Corr
19460722	Kennewick, N.W.	Vegetation	0	0	Veg. Corr
19460722	Kennewick, S.E.	Vegetation	0	0	Veg. Corr
19460722	Pasco, S.E.	Vegetation	0	7	HEW-616-T
19460722	Kennewick, S.E.	Vegetation	0	0	HEW-616-T
19460722	Kennewick, N.W.	Vegetation	0	0	HEW-616-T
19460722	Kennewick, N.E.	Vegetation	0	2	HEW-616-T
19460722	Pasco, N.W.	Vegetation	0.09	0	Veg. Corr
19460722	Pasco, S.W.	Vegetation	0.06	0	Veg. Corr
19460722	Pasco, N.W.	Vegetation	0	5	HEW-616-T
19460722	Kennewick, S.W.	Vegetation	0	2	HEW-616-T
19460722	Pasco, S.E.	Vegetation	0.13	0	Veg. Corr
19460722	Pasco, N.E.	Vegetation	0	2	HEW-616-T
19460722	Kennewick, N.E.	Vegetation	0.04	0	Veg. Corr
19460722	Kennewick, S.W.	Vegetation	0.04	0	Veg. Corr
19460722	Pasco, S.W.	Vegetation	0	3	HEW-616-T
19460724	Pasco, S.W.	Vegetation	0.03	0	HW-7-4440
19460724	Pasco, N.E.	Vegetation	0.04	0	HW-7-4440
19460724	Kennewick, N.W.	Vegetation	0.04	0	HW-7-4440
19460724	Kennewick, N.E.	Vegetation	0.04	0	HW-7-4440
19460724	Pasco, S.E.	Vegetation	0.12	0	HW-7-4440
19460724	Pasco, N.W.	Vegetation	0.07	0	HW-7-4440
19460724	Kennewick, S.W.	Vegetation	0.04	0	HW-7-4440
19460724	Kennewick, S.E.	Vegetation	0.04	0	HW-7-4440
19460724	Kennewick	Vegetation	0.04	0	HW-7-4440
19460729	Kennewick, N.W.	Vegetation	0.04	0	Veg. Corr
19460729	Pasco, S.E.	Vegetation	0.07	0	Veg. Corr
19460729	Pasco, N.E.	Vegetation	0	2	HEW-616-T
19460729	Pasco, S.E.	Vegetation	0	4	HEW-616-T
19460729	Pasco, N.W.	Vegetation	0.03	0	Veg. Corr
19460729	Kennewick, N.E.	Vegetation	0	2	HEW-616-T
19460729	Pasco, S.W.	Vegetation	0	6	HEW-616-T
19460729	Pasco, N.W.	Vegetation	0	0	HEW-616-T
19460729	Kennewick, S.W.	Vegetation	0.02	0	Veg. Corr
19460729	Kennewick, S.E.	Vegetation	0	17	HEW-616-T
19460729	Kennewick, S.W.	Vegetation	0	1	HEW-616-T
19460729	Kennewick, S.E.	Vegetation	0.29	0	Veg. Corr
19460729	Pasco, S.W.	Vegetation	0	0	Veg. Corr
19460729	Pasco, N.E.	Vegetation	0.04	0	Veg. Corr
19460729	Kennewick, N.E.	Vegetation	0.03	0	Veg. Corr
19460729	Kennewick, N.W.	Vegetation	0	3	HEW-616-T
19460731	Kennewick	Vegetation	0.04	0	HW-7-4474
19460805	Kennewick, S.W.	Vegetation	0	2	HEW-616-T
19460805	Pasco, S.W.	Vegetation	0	6	HEW-616-T

Table A.3. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460805	Kennewick, N.E.	Vegetation	0.09	0	Veg. Corr
19460805	Kennewick, N.W.	Vegetation	0.09	0	Veg. Corr
19460805	Kennewick, N.W.	Vegetation	0	5	HEW-616-T
19460805	Pasco, N.W.	Vegetation	0	2	HEW-616-T
19460805	Kennewick, S.W.	Vegetation	0.04	0	Veg. Corr
19460805	Kennewick, S.E.	Vegetation	0	1	HEW-616-T
19460805	Pasco, N.W.	Vegetation	0.04	0	Veg. Corr
19460805	Kennewick, N.E.	Vegetation	0	5	HEW-616-T
19460805	Pasco, N.E.	Vegetation	0	8	HEW-616-T
19460805	Pasco, N.E.	Vegetation	0.15	0	Veg. Corr
19460805	Kennewick, S.E.	Vegetation	0.02	0	Veg. Corr
19460805	Pasco, S.W.	Vegetation	0.11	0	Veg. Corr
19460805	Pasco, S.E.	Vegetation	0.04	0	Veg. Corr
19460805	Pasco, S.E.	Vegetation	0	2	HEW-616-T
19460812	Kennewick, N.W.	Vegetation	0.02	0	Veg. Corr
19460812	Kennewick, S.E.	Vegetation	0.04	0	Veg. Corr
19460812	Pasco, N.E.	Vegetation	0.04	0	Veg. Corr
19460812	Pasco, S.E.	Vegetation	0.06	0	Veg. Corr
19460812	Kennewick, S.W.	Vegetation	0.04	0	Veg. Corr
19460812	Kennewick, N.E.	Vegetation	0.02	0	Veg. Corr
19460812	Pasco, N.W.	Vegetation	0.06	0	Veg. Corr
19460812	Pasco, S.W.	Vegetation	0.13	0	Veg. Corr
19460819	Pasco, N.E.	Vegetation	0.04	0	Veg. Corr
19460819	Pasco, S.W.	Vegetation	0.02	0	Veg. Corr
19460819	Pasco, N.W.	Vegetation	0.18	0	Veg. Corr
19460819	Kennewick, S.E.	Vegetation	0	0	Veg. Corr
19460819	Kennewick, N.E.	Vegetation	0.24	0	Veg. Corr
19460819	Kennewick, S.W.	Vegetation	0.04	0	Veg. Corr
19460819	Kennewick, N.W.	Vegetation	0.04	0	Veg. Corr
19460819	Pasco, S.E.	Vegetation	0.02	0	Veg. Corr
19460826	Pasco, N.E.	Vegetation	0.04	0	Veg. Corr
19460826	Pasco, S.W.	Vegetation	0	0	Veg. Corr
19460826	Kennewick, S.W.	Vegetation	0.04	0	Veg. Corr
19460826	Kennewick, S.E.	Vegetation	0.09	0	Veg. Corr
19460826	Pasco, S.E.	Vegetation	0.11	0	Veg. Corr
19460826	Kennewick, N.W.	Vegetation	0.17	0	Veg. Corr
19460826	Kennewick, N.E.	Vegetation	0.18	0	Veg. Corr
19460826	Pasco, N.W.	Vegetation	0.04	0	Veg. Corr
19460831	Kennewick	Vegetation	0.08	0	HW-7-4699
19460903	Pasco, N.W.	Vegetation	0.04	0	Veg. Corr
19460903	Pasco, N.E.	Vegetation	0.2	0	Veg. Corr
19460903	Pasco, S.W.	Vegetation	0.01	0	Veg. Corr
19460903	Pasco, S.E.	Vegetation	0.05	0	Veg. Corr
19460904	Kennewick, N.W.	Vegetation	0.07	0	Veg. Corr
19460904	Kennewick, S.E.	Vegetation	0	0	Veg. Corr

Table A.3. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460904	Kennewick, S.W.	Vegetation	0.08	0	Veg. Corr
19460904	Kennewick, N.E.	Vegetation	0.05	0	Veg. Corr
19460909	Kennewick, S.W.	Vegetation	0.51	0	Veg. Corr
19460909	Kennewick, N.E.	Vegetation	0.25	0	Veg. Corr
19460909	Pasco, S.W.	Vegetation	0.25	0	Veg. Corr
19460909	Kennewick, N.W.	Vegetation	0.2	0	Veg. Corr
19460909	Pasco, N.E.	Vegetation	0.09	0	Veg. Corr
19460909	Kennewick, S.E.	Vegetation	0.09	0	Veg. Corr
19460909	Pasco, N.W.	Vegetation	0	0	Veg. Corr
19460909	Pasco, S.E.	Vegetation	0.45	0	Veg. Corr
19460916	Pasco, S.E.	Vegetation	0.29	0	Veg. Corr
19460916	Pasco, N.E.	Vegetation	0	0	Veg. Corr
19460916	Kennewick, S.W.	Vegetation	0.1	0	Veg. Corr
19460916	Kennewick, S.E.	Vegetation	0.19	0	Veg. Corr
19460916	Pasco, N.W.	Vegetation	0.18	0	Veg. Corr
19460916	Kennewick, N.W.	Vegetation	0.11	0	Veg. Corr
19460916	Kennewick, N.E.	Vegetation	0	0	Veg. Corr
19460916	Pasco, S.W.	Vegetation	0	0	Veg. Corr
19460918	Pasco, N.W.	Vegetation	0.04	0	HW-7-5042
19460918	Pasco, N.W.	Vegetation	0.04	0	HW-7-5042
19460918	Kennewick, N.W.	Vegetation	0.13	0	HW-7-5042
19460918	Pasco, S.W.	Vegetation	0.15	0	HW-7-5042
19460918	Pasco, N.E.	Vegetation	0.2	0	HW-7-5042
19460918	Kennewick, N.E.	Vegetation	0.27	0	HW-7-5042
19460918	Kennewick, N.E.	Vegetation	0.16	0	HW-7-5042
19460918	Pasco, N.E.	Vegetation	0.15	0	HW-7-5042
19460918	Kennewick, S.W.	Vegetation	0.58	0	HW-7-5042
19460918	Kennewick, S.W.	Vegetation	0.34	0	HW-7-5042
19460918	Pasco, S.E.	Vegetation	0.51	0	HW-7-5042
19460918	Pasco	Vegetation	0.15	0	HW-7-5042
19460918	Kennewick, S.E.	Vegetation	0.1	0	HW-7-5042
19460918	Kennewick, S.E.	Vegetation	0.06	0	HW-7-5042
19460918	Pasco, S.E.	Vegetation	0.28	0	HW-7-5042
19460918	Kennewick, N.W.	Vegetation	0.2	0	HW-7-5042
19460918	Kennewick	Vegetation	0.17	0	HW-7-5042
19460918	Pasco, S.W.	Vegetation	0.27	0	HW-7-5042
19460923	Pasco, S.W.	Vegetation	0.14	0	Veg. Corr
19460923	Kennewick, N.E.	Vegetation	0.1	0	Veg. Corr
19460923	Kennewick, N.W.	Vegetation	0.04	0	Veg. Corr
19460923	Pasco, S.E.	Vegetation	0.06	0	Veg. Corr
19460923	Pasco, N.E.	Vegetation	0.14	0	Veg. Corr
19460923	Kennewick, S.W.	Vegetation	0.07	0	Veg. Corr
19460923	Pasco, N.W.	Vegetation	0.18	0	Veg. Corr
19460923	Kennewick, S.E.	Vegetation	0.23	0	Veg. Corr
19460930	Pasco, S.E.	Vegetation	0.7	0	Veg. Corr

Table A.3. (contd)

Date	Location	Type	μCi/kg	CPM/g	Reference
19460930	Kennewick	Vegetation	0.11	0	HW-7-5042
19460930	Pasco	Vegetation	0.14	0	HW-7-5145
19460930	Pasco	Vegetation	0.29	0	HW-7-5042
19460930	Pasco, N.E.	Vegetation	0.02	0	Veg. Corr
19460930	Pasco	Vegetation	0.12	0	HW-7-5042
19460930	Kennewick, S.E.	Vegetation	0.05	0	Veg. Corr
19460930	Kennewick, N.W.	Vegetation	0.07	0	Veg. Corr
19460930	Pasco, S.W.	Vegetation	0.07	0	Veg. Corr
19460930	Kennewick, S.W.	Vegetation	0.09	0	Veg. Corr
19460930	Pasco, N.W.	Vegetation	0.11	0	Veg. Corr
19460930	Kennewick, N.E.	Vegetation	0.09	0	Veg. Corr
19460930	Kennewick	Vegetation	0.14	0	HW-7-5145
19460930	Kennewick	Vegetation	0.22	0	HW-7-5042
19461007	Kennewick, N.W.	Vegetation	0.14	0	Veg. Corr
19461007	Pasco, N.W.	Vegetation	0.07	0	Veg. Corr
19461007	Kennewick, S.W.	Vegetation	0.28	0	Veg. Corr
19461007	Kennewick, S.E.	Vegetation	0.24	0	Veg. Corr
19461007	Pasco, S.W.	Vegetation	0.06	0	Veg. Corr
19461007	Kennewick, N.E.	Vegetation	0.05	0	Veg. Corr
19461007	Pasco, N.E.	Vegetation	0.12	0	Veg. Corr
19461007	Pasco, S.E.	Vegetation	0.22	0	Veg. Corr
19461014	Kennewick, S.E.	Vegetation	0.07	0	Veg. Corr
19461014	Kennewick, N.E.	Vegetation	0.08	0	Veg. Corr
19461014	Kennewick, N.W.	Vegetation	0.12	0	Veg. Corr
19461014	Pasco, N.E.	Vegetation	0.06	0	Veg. Corr
19461014	Pasco, N.W.	Vegetation	0.05	0	Veg. Corr
19461014	Kennewick, S.W.	Vegetation	0.05	0	Veg. Corr
19461014	Pasco, S.W.	Vegetation	0.07	0	Veg. Corr
19461014	Pasco, S.E.	Vegetation	0.14	0	Veg. Corr
19461016	Kennewick	Vegetation	0.12	0	HW-7-5042
19461016	Pasco	Vegetation	0.71	0	HW-7-5042
19461016	Pasco	Vegetation	0.16	0	HW-7-5042
19461016	Kennewick	Vegetation	0.27	0	HW-7-5042
19461020	Pasco, S.E.	Vegetation	0.06	0	Veg. Corr
19461020	Pasco, N.E.	Vegetation	0.02	0	Veg. Corr
19461020	Pasco, S.W.	Vegetation	0.04	0	Veg. Corr
19461020	Pasco, N.W.	Vegetation	0.02	0	Veg. Corr
19461021	Kennewick, S.W.	Vegetation	0.09	0	Veg. Corr
19461021	Kennewick, N.E.	Vegetation	0	0	Veg. Corr
19461021	Kennewick, N.W.	Vegetation	0.02	0	Veg. Corr
19461021	Kennewick, S.E.	Vegetation	0.06	0	Veg. Corr
19461028	Pasco, N.E.	Vegetation	0.03	0	Veg. Corr
19461028	Kennewick, N.E.	Vegetation	0.05	0	Veg. Corr
19461028	Pasco, S.E.	Vegetation	0.05	0	Veg. Corr
19461028	Pasco, N.W.	Vegetation	0	0	Veg. Corr

Table A.3. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19461028	Kennewick, N.W.	Vegetation	0.11	0	Veg. Corr
19461028	Kennewick, S.W.	Vegetation	0.09	0	Veg. Corr
19461028	Pasco, S.W.	Vegetation	0.08	0	Veg. Corr
19461028	Kennewick, S.E.	Vegetation	0.05	0	Veg. Corr
19461031	Pasco	Vegetation	0.11	0	HW-7-5301
19461031	Pasco	Vegetation	0.15	0	HW-7-5042
19461031	Pasco	Vegetation	0.06	0	HW-7-5042
19461031	Kennewick	Vegetation	0.09	0	HW-7-5301
19461031	Kennewick	Vegetation	0.06	0	HW-7-5042
19461031	Kennewick	Vegetation	0.13	0	HW-7-5042
19461104	Pasco, N.E.	Vegetation	0.07	0	Veg. Corr
19461104	Pasco, S.W.	Vegetation	0.1	0	Veg. Corr
19461104	Kennewick, S.W.	Vegetation	0.05	0	Veg. Corr
19461104	Kennewick, N.E.	Vegetation	0.15	0	Veg. Corr
19461104	Pasco, N.W.	Vegetation	0.03	0	Veg. Corr
19461104	Pasco, S.E.	Vegetation	0.08	0	Veg. Corr
19461104	Kennewick, S.E.	Vegetation	0.07	0	Veg. Corr
19461104	Kennewick, N.W.	Vegetation	0.13	0	Veg. Corr
19461111	Pasco, S.E.	Vegetation	0.13	0	Veg. Corr
19461111	Kennewick, S.W.	Vegetation	0.35	0	Veg. Corr
19461111	Kennewick, N.W.	Vegetation	0.15	0	Veg. Corr
19461111	Kennewick, S.E.	Vegetation	0.11	0	Veg. Corr
19461111	Pasco, N.W.	Vegetation	0.02	0	Veg. Corr
19461111	Pasco, S.W.	Vegetation	0.21	0	Veg. Corr
19461111	Pasco, N.E.	Vegetation	0	0	Veg. Corr
19461111	Kennewick, N.E.	Vegetation	0.24	0	Veg. Corr
19461118	Kennewick, N.W.	Vegetation	0.45	0	Veg. Corr
19461118	Pasco, S.E.	Vegetation	0.12	0	Veg. Corr
19461118	Pasco, S.W.	Vegetation	0.18	0	Veg. Corr
19461118	Kennewick, S.E.	Vegetation	0.14	0	Veg. Corr
19461118	Pasco, S.E.	Vegetation	1.16	0	Veg. Corr
19461118	Kennewick, S.W.	Vegetation	0.16	0	Veg. Corr
19461118	Pasco, N.E.	Vegetation	0.12	0	Veg. Corr
19461118	Kennewick, N.E.	Vegetation	0.5	0	Veg. Corr
19461118	Pasco, N.W.	Vegetation	0.09	0	Veg. Corr
19461119	Pasco	Vegetation	0.22	0	HW-7-5042
19461119	Kennewick	Vegetation	0.13	0	HW-7-5042
19461119	Kennewick	Vegetation	0.36	0	HW-7-5042
19461119	Pasco	Vegetation	0.09	0	HW-7-5042
19461125	Pasco, N.W.	Vegetation	1.03	0	Veg. Corr
19461125	Kennewick, S.E.	Vegetation	0.34	0	Veg. Corr
19461125	Pasco, S.E.	Vegetation	1.21	0	Veg. Corr
19461125	Pasco, N.E.	Vegetation	1.09	0	Veg. Corr
19461125	Kennewick, N.E.	Vegetation	0.11	0	Veg. Corr
19461125	Kennewick, N.W.	Vegetation	0.18	0	Veg. Corr

Table A.3. (contd)

Date	Location	Type	μCi/kg	CPM/g	Reference
19461125	Kennewick, S.W.	Vegetation	0.32	0	Veg. Corr
19461125	Pasco, S.W.	Vegetation	0.14	0	Veg. Corr
19461130	Pasco	Vegetation	0.3	0	HW-7-5428
19461130	Kennewick	Vegetation	0.46	0	HW-7-5042
19461130	Kennewick	Vegetation	0.28	0	HW-7-5042
19461130	Pasco	Vegetation	1.2	0	HW-7-5042
19461130	Kennewick	Vegetation	0.19	0	HW-7-5428
19461130	Pasco	Vegetation	0.62	0	HW-7-5042
19461202	Kennewick, S.E.	Vegetation	0.2	0	Veg. Corr
19461202	Pasco, S.W.	Vegetation	0.47	0	Veg. Corr
19461202	Kennewick, N.E.	Vegetation	0.28	0	Veg. Corr
19461202	Kennewick, N.W.	Vegetation	0.14	0	Veg. Corr
19461202	Pasco, N.E.	Vegetation	0.12	0	Veg. Corr
19461202	Kennewick, S.W.	Vegetation	2.65	0	Veg. Corr
19461202	Pasco, N.W.	Vegetation	0.21	0	Veg. Corr
19461202	Pasco, S.E.	Vegetation	0.33	0	Veg. Corr
19461209	Kennewick, N.E.	Vegetation	0.44	0	Veg. Corr
19461209	Kennewick, S.W.	Vegetation	0.54	0	Veg. Corr
19461209	Pasco, S.E.	Vegetation	0.34	0	Veg. Corr
19461209	Pasco, N.W.	Vegetation	0.18	0	Veg. Corr
19461209	Pasco, S.W.	Vegetation	0.27	0	Veg. Corr
19461209	Pasco, N.E.	Vegetation	0.22	0	Veg. Corr
19461209	Kennewick, N.W.	Vegetation	0.23	0	Veg. Corr
19461209	Kennewick, S.E.	Vegetation	0.42	0	Veg. Corr
19461216	Kennewick, N.E.	Vegetation	0.18	0	Veg. Corr
19461216	Pasco	Vegetation	0.26	0	HW-7-5042
19461216	Pasco, N.W.	Vegetation	0.12	0	Veg. Corr
19461216	Pasco, N.E.	Vegetation	0.42	0	Veg. Corr
19461216	Pasco, S.E.	Vegetation	0.32	0	Veg. Corr
19461216	Kennewick, S.E.	Vegetation	0.16	0	Veg. Corr
19461216	Kennewick, S.W.	Vegetation	0.29	0	Veg. Corr
19461216	Kennewick, N.W.	Vegetation	0.14	0	Veg. Corr
19461216	Pasco, S.W.	Vegetation	0.22	0	Veg. Corr
19461216	Kennewick	Vegetation	2.7	0	HW-7-5042
19461216	Kennewick	Vegetation	0.6	0	HW-7-5042
19461223	Kennewick, N.W.	Vegetation	0	0	Veg. Corr
19461223	Pasco, N.E.	Vegetation	0.16	0	Veg. Corr
19461223	Kennewick, N.E.	Vegetation	0.2	0	Veg. Corr
19461223	Kennewick, S.W.	Vegetation	0.2	0	Veg. Corr
19461223	Kennewick, S.E.	Vegetation	0.45	0	Veg. Corr
19461223	Pasco, S.E.	Vegetation	0.05	0	Veg. Corr
19461223	Pasco, N.W.	Vegetation	0.06	0	Veg. Corr
19461223	Pasco, S.W.	Vegetation	0.58	0	Veg. Corr
19461230	Pasco, S.E.	Vegetation	0.22	0	Veg. Corr
19461230	Pasco, S.W.	Vegetation	0.18	0	Veg. Corr

Table A.3. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19461230	Pasco, N.W.	Vegetation	0.16	0	Veg. Corr
19461230	Pasco, N.E.	Vegetation	0.16	0	Veg. Corr
19461230	Kennewick, N.W.	Vegetation	0.09	0	Veg. Corr
19461230	Kennewick, S.W.	Vegetation	0.28	0	Veg. Corr
19461230	Kennewick, S.E.	Vegetation	0.09	0	Veg. Corr
19461230	Kennewick, N.E.	Vegetation	0.52	0	Veg. Corr
19461231	Pasco	Vegetation	0.6	0	HW-7-5042
19461231	Pasco	Vegetation	0.24	0	HW-7-5042
19461231	Kennewick	Vegetation	0.2	0	HW-7-5042
19461231	Kennewick	Vegetation	0.4	0	HW-7-5605
19461231	Pasco	Vegetation	0.25	0	HW-7-5605
19461231	Kennewick	Vegetation	0.46	0	HW-7-5042

Table A.4. Iodine-131 Concentration in Vegetation in Benton City, Cell 440/467

Date	Location	Type	μCi/kg	CPM/g	Reference
19460103	Benton City	Sagebrush	0	202.7	HEW-578-L
19460104	Benton City, 614 Bldg.	Vegetation	4.68	0	Veg. Corr
19460107	Benton City, 614 Bldg.	Vegetation	2.64	0	Veg. Corr
19460109	Benton City	Sagebrush	0	119.3	HEW-578-L
19460115	Benton City, 614 Bldg.	Vegetation	2.07	0	Veg. Corr
19460116	Benton City	Vegetation	0.6	102.4	HEW-616-T
19460121	Benton City, 614 Bldg.	Vegetation	1.69	0	Veg. Corr
19460123	Benton City	Vegetation	0.4	72.1	HEW-616-T
19460128	Benton City, 614 Bldg.	Vegetation	1.53	0	Veg. Corr
19460130	Benton City	Vegetation	1.2	69	HEW-616-T
19460131	Benton City	Vegetation	0.69	0	HW-7-3322
19460204	Benton City, 614 Bldg.	Vegetation	0.94	0	Veg. Corr
19460206	Benton City	Vegetation	0.7	39	HEW-616-T
19460211	Benton City, 614 Bldg.	Vegetation	0.72	0	Veg. Corr
19460213	Benton City	Vegetation	0.51	30	HEW-616-T
19460220	Benton City, 614 Bldg.	Vegetation	0.19	0	Veg. Corr
19460220	Benton City, Post Office	Vegetation	0	20	HEW-616-T
19460220	Benton City, 614 Bldg.	Vegetation	0	10	HEW-616-T
19460220	Benton City, S.	Vegetation	0.34	0	Veg. Corr
19460227	Benton City, 614 Bldg.	Vegetation	0.17	0	Veg. Corr
19460228	Benton City	Vegetation	0.7	0	HW-7-3517
19460304	Benton City, 614 Bldg.	Vegetation	0.07	0	Veg. Corr
19460304	Benton City, 614 Bldg.	Vegetation	0.04	0	Veg. Corr
19460306	Benton City, 614 Bldg.	Vegetation	0	4	HEW-616-T
19460306	Benton City	Vegetation	0	2	HEW-616-T
19460313	Benton City, 614 Bldg.	Cheat Gr.	0	25	HEW-616-T
19460313	Benton City, 614 Bldg.	Vegetation	0.46	0	Veg. Corr
19460313	Benton City, High School	D Wt Fl Wd	0	23	HEW-616-T
19460320	Benton City, 614 Bldg.	Vegetation	0	11	HEW-616-T
19460320	Benton City, 2 miles from 614 Bldg.	Green	0	5	HEW-616-T
19460320	Benton City, 614 Bldg.	Vegetation	0.2	0	Veg. Corr
19460320	Benton City, S.	Vegetation	0.09	0	Veg. Corr
19460331	Benton City	Vegetation	0.27	0	HW-7-3694
19460401	Benton City, 614 Bldg.	Green Sage	0	25	HEW-616-T
19460401	Benton City, High School	Green Sage	0	17	HEW-616-T
19460408	Benton City, 2 Miles S. of 614 Bldg.	Green	0	14	HEW-616-T
19460408	Benton City, 614 Bldg.	Vegetation	0.07	0	Veg. Corr
19460408	Benton City, 614 Bldg.	Green	0	4	HEW-616-T
19460408	Benton City, S.	Vegetation	0.26	0	Veg. Corr
19460415	Benton City, 614 Bldg.	Vegetation	0	4	HEW-616-T
19460415	Benton City	Vegetation	0	27	HEW-616-T
19460415	Benton City, S.	Vegetation	0.5	0	Veg. Corr
19460415	Benton City, 614 Bldg.	Vegetation	0.07	0	Veg. Corr
19460419	Benton City, 6 mi. W. on Van Giesen	Vegetation	0	6	HEW-616-T

Table A.4. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460419	Benton City, Van Giesen Intersection	Vegetation	0	4	HEW-616-T
19460419	Benton City, 2 mi. W. on Van Giesen	Vegetation	0	6	HEW-616-T
19460419	Benton City, 4 mi. W. on Van Giesen	Vegetation	0	3	HEW-616-T
19460422	Benton City, High School	Vegetation	0.07	0	Veg. Corr
19460422	Benton City, High School	Vegetation	0	4	HEW-616-T
19460422	Benton City, 614 Bldg.	Vegetation	0	5	HEW-616-T
19460422	Benton City, 614 Bldg.	Vegetation	0.08	0	Veg. Corr
19460429	Benton City, S.	Vegetation	0.07	0	Veg. Corr
19460429	Benton City, 614 Bldg.	Vegetation	0	0	Veg. Corr
19460429	Benton City, 0.5 Mile S. of 614 Bldg.	Vegetation	0	4	HEW-616-T
19460429	Benton City, 614 Bldg.	Green	0	0	HEW-616-T
19460430	Benton City	Vegetation	0.2	0	HW-7-3933
19460506	Benton City, Yakima Bridge	Vegetation	0	0	HEW-616-T
19460506	Benton City, 614 Bldg.	Vegetation	0	0	HEW-616-T
19460506	Benton City, 614 Bldg.	Vegetation	0	0	Veg. Corr
19460507	Benton City	Green Asp.	0	0	HEW-616-T
19460513	Benton City N., 614 Bldg.	Vegetation	0	4	HEW-616-T
19460513	Benton City, High School	Vegetation	0.15	0	Veg. Corr
19460513	Benton City, High School	Vegetation	0	8	HEW-616-T
19460513	Benton City, S.	Vegetation	0.08	0	Veg. Corr
19460514	Benton City, Van Giesen Intersection	Vegetation	0	4	HEW-616-T
19460520	Benton City, 614 Bldg.	Vegetation	0.03	0	Veg. Corr
19460520	Benton City, N.	Vegetation	0	2	HEW-616-T
19460520	Benton City, S.	Vegetation	0	3	HEW-616-T
19460520	Benton City, S.	Vegetation	0.05	0	Veg. Corr
19460527	Benton City, S.	Vegetation	0.06	0	Veg. Corr
19460527	Benton City, 614 Bldg.	Vegetation	0.19	0	Veg. Corr
19460528	Benton City, S.	Vegetation	0	3	HEW-616-T
19460528	Benton City, N.	Vegetation	0	10	HEW-616-T
19460531	Benton City	Vegetation	0.05	0	HW-7-4312
19460602	Benton City, S.	Vegetation	0	0	Veg. Corr
19460604	Benton City, Intersection with Van Giese	Vegetation	0	7	HEW-616-T
19460604	Benton City, 614 Bldg.	Vegetation	0	7	HEW-616-T
19460604	Benton City, 3 Miles E. of Van Giesen In	Vegetation	0	0	HEW-616-T
19460604	Benton City, 6 Miles E. of Van Giesen In	Vegetation	0	0	HEW-616-T
19460604	Benton City, High School	Vegetation	0	7	HEW-616-T
19460604	Benton City, High School	Vegetation	0.13	0	Veg. Corr
19460604	Benton City, 614 Bldg.	Vegetation	0.13	0	Veg. Corr
19460612	Benton City, N.E.	Cherry Lvs	0	5	HEW-616-T
19460612	Benton City, N.E.	Cherry	0	2	HEW-616-T
19460617	Benton City, S.	Vegetation	0	8	HEW-616-T
19460617	Benton City, S.	Vegetation	0.16	0	Veg. Corr
19460618	Benton City, 614 Bldg.	Vegetation	0.19	0	Veg. Corr
19460618	Benton City, N.	Vegetation	0	10	HEW-616-T

Table A.4. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460625	Benton City, Van Giesen Intersection	Vegetation	0	6	HEW-616-T
19460625	Benton City, 6 Miles W. on Van Giesen	Vegetation	0	0	HEW-616-T
19460625	Benton City, 614 Bldg	Vegetation	0	10	HEW-616-T
19460625	Benton City, High School	Vegetation	0	5	HEW-616-T
19460625	Benton City, 3 Miles W. on Van Giesen	Vegetation	0	3	HEW-616-T
19460625	Benton City, High School	Vegetation	0.08	0	Veg. Corr
19460625	Benton City, 614 Bldg.	Vegetation	0.17	0	Veg. Corr
19460630	Benton City	Vegetation	0.13	0	HW-7-4312
19460702	Benton City, N.	Vegetation	0	2	HEW-616-T
19460702	Benton City, S.	Vegetation	0	0	HEW-616-T
19460702	Benton City, 614 Bldg.	Vegetation	0.03	0	Veg. Corr
19460709	Benton City, S.	Vegetation	0.27	0	Veg. Corr
19460709	Benton City, 614 Bldg.	Vegetation	0.07	0	Veg. Corr
19460709	Benton City, N.	Vegetation	0	4	HEW-616-T
19460709	Benton City, S.	Vegetation	0	16	HEW-616-T
19460716	Benton City, 614 Bldg.	Vegetation	0.07	0	Veg. Corr
19460716	Benton City, High School	Vegetation	0.07	0	Veg. Corr
19460716	Benton City, High School	Vegetation	0	4	HEW-616-T
19460716	Benton City, 614 Bldg.	Vegetation	0	4	HEW-616-T
19460717	Benton City, S.	Vegetation	0.07	0	HW-7-4423
19460717	Benton City, N. 614 Bldg.	Vegetation	0.07	0	HW-7-4423
19460722	Benton City, S.	Vegetation	0.02	0	Veg. Corr
19460723	Benton City, N.	Vegetation	0	1	HEW-616-T
19460723	Benton City, 614 Bldg.	Vegetation	0.06	0	Veg. Corr
19460723	Benton City, S.	Vegetation	0	1	HEW-616-T
19460724	Benton City, S.	Vegetation	0.04	0	HW-7-4440
19460724	Benton City, N, 614 Bldg.	Vegetation	0.04	0	HW-7-4440
19460730	Benton City, N.	Vegetation	0	1	HEW-616-T
19460730	Benton City, 614 Bldg.	Vegetation	0.02	0	Veg. Corr
19460730	Benton City, S.	Vegetation	0.04	0	Veg. Corr
19460730	Benton City, S.	Vegetation	0	2	HEW-616-T
19460731	Benton City	Vegetation	0.07	0	HW-7-4474
19460806	Benton City, High School	Vegetation	0	0	HEW-616-T
19460806	Benton City, High School	Vegetation	0	0	Veg. Corr
19460806	Benton City, 614 Bldg.	Vegetation	0.13	0	Veg. Corr
19460806	Benton City, 614 Bldg.	Vegetation	0	3	HEW-616-T
19460806	Benton City, Van Giesen Intersection	Vegetation	0	2	HEW-616-T
19460813	Benton City, 614 Bldg.	Vegetation	0.03	0	Veg. Corr
19460813	Benton City, S.	Vegetation	0.05	0	Veg. Corr
19460819	Benton City, 614 Bldg.	Vegetation	0.04	0	Veg. Corr
19460819	Benton City, High School	Vegetation	0.04	0	Veg. Corr
19460826	Benton City, 614 Bldg.	Vegetation	0.2	0	Veg. Corr
19460826	Benton City, 614 Bldg.	Vegetation	0.19	0	Veg. Corr
19460831	Benton City	Vegetation	0.06	0	HW-7-4699

Table A.4. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19460903	Benton City, S.	Vegetation	0.09	0	Veg. Corr
19460904	Benton City, 614 Bldg.	Vegetation	0.07	0	Veg. Corr
19460909	Benton City, S.	Vegetation	0.06	0	Veg. Corr
19460909	Benton City, 614 Bldg.	Vegetation	0	0	Veg. Corr
19460916	Benton City, 614 Bldg.	Vegetation	0.12	0	Veg. Corr
19460916	Benton City, S.	Vegetation	0.1	0	Veg. Corr
19460918	Benton City, S.	Vegetation	0.08	0	HW-7-5042
19460918	Benton City, S.	Vegetation	0.09	0	HW-7-5042
19460918	Benton City, N. 614 Bldg.	Vegetation	0.05	0	HW-7-5042
19460918	Benton City, N. 614 Bldg.	Vegetation	0.07	0	HW-7-5042
19460923	Benton City, 614 Bldg.	Vegetation	0.04	0	Veg. Corr
19460923	Benton City, S.	Vegetation	0.07	0	Veg. Corr
19460930	Benton City	Vegetation	0.11	0	HW-7-5042
19460930	Benton City	Vegetation	0.08	0	HW-7-5042
19460930	Benton City, S.	Vegetation	0.11	0	Veg. Corr
19460930	Benton City, 614 Bldg.	Vegetation	0.09	0	Veg. Corr
19460930	Benton City	Vegetation	0.07	0	HW-7-5145
19461007	Benton City, S.	Vegetation	0.05	0	Veg. Corr
19461007	Benton City, 614 Bldg.	Vegetation	0.15	0	Veg. Corr
19461014	Benton City, S.	Vegetation	0.1	0	Veg. Corr
19461014	Benton City, 614 Bldg.	Vegetation	0.07	0	Veg. Corr
19461016	Benton City	Vegetation	0.1	0	HW-7-5042
19461016	Benton City	Vegetation	0.14	0	HW-7-5042
19461021	Benton City, 614 Bldg.	Vegetation	0.04	0	Veg. Corr
19461021	Benton City, S.	Vegetation	0.09	0	Veg. Corr
19461028	Benton City, 614 Bldg.	Vegetation	0.09	0	Veg. Corr
19461028	Benton City, S.	Vegetation	0.09	0	Veg. Corr
19461031	Benton City	Vegetation	0.09	0	HW-7-5301
19461031	Benton City	Vegetation	0.1	0	HW-7-5042
19461031	Benton City	Vegetation	0.07	0	HW-7-5042
19461104	Benton City, S.	Vegetation	0	0	Veg. Corr
19461104	Benton City, 614 Bldg.	Vegetation	0.03	0	Veg. Corr
19461111	Benton City, 614 Bldg.	Vegetation	0.14	0	Veg. Corr
19461118	Benton City, 614 Bldg.	Vegetation	0.13	0	Veg. Corr
19461119	Benton City	Vegetation	0.06	0	HW-7-5042
19461119	Benton City	Vegetation	0.14	0	HW-7-5042
19461125	Benton City, 614 Bldg.	Vegetation	0.12	0	Veg. Corr
19461130	Benton City	Vegetation	0.07	0	HW-7-5042
19461130	Benton City	Vegetation	0.06	0	HW-7-5428
19461130	Benton City	Vegetation	0.12	0	HW-7-5042
19461202	Benton City, 614 Bldg.	Vegetation	0.61	0	Veg. Corr
19461209	Benton City, 614 Bldg.	Vegetation	0.3	0	Veg. Corr
19461216	Benton City	Vegetation	0.33	0	HW-7-5042
19461216	Benton City	Vegetation	0.61	0	HW-7-5042

Table A.4. (contd)

Date	Location	Type	µCi/kg	CPM/g	Reference
19461216	Benton City, 614 Bldg.	Vegetation	0.19	0	Veg. Corr
19461223	Benton City, 614 Bldg.	Vegetation	0.63	0	Veg. Corr
19461230	Benton City, 614 Bldg.	Vegetation	0.89	0	Veg. Corr
19461231	Benton City	Vegetation	0.3	0	HW-7-5042
19461231	Benton City	Vegetation	0.31	0	HW-7-5605
19461231	Benton City	Vegetation	0.63	0	HW-7-5042

Appendix B

Ratios of Estimated and Measured Iodine-131 Concentration in Vegetation, April 13, 1946

Appendix B

Ratios of Estimated and Measured Iodine-131 Concentration in Vegetation, April 13, 1946

This appendix provides the distribution of the radionuclide concentrations in vegetation estimated by the STRM/RATCHET/DESCARTES model combination for each of the monitored locations on April 13, 1946, as described in Section 4.0. The distributions are defined by the minimum estimates of the 100 stochastic realizations computed (labelled MIN), the first quartile (i.e., the 25th percentile, labelled Q1), the median value (labelled MED), the third quartile (i.e., the 75th percentile, labelled Q3), and the maximum value computed (labelled MAX). The computed distribution is compared to the measured values.

The data for the measured values are provided in Denham et al. (1993a). In some instances, there was more than one sample available in a HEDR grid cell for April 13, 1946. In these cases, the median of the measurements was used. The number of available measurements (labelled N) is given along with the median of the measurements (labelled MED MEAS).

As described in Section 4.4, a ranking score was developed based on the relative location of the measured median in the estimated distribution. This score is between 1 and 6, where 1 indicates that the median measurement falls below the minimum of the estimated range, 2 indicates that the median measurement falls between the minimum and 25th percentiles, 3 indicates that the median measurement falls between the 25th percentile and the median, 4 indicates that the median measurement falls between the median and the 75th percentile, 5 indicates that the median measurement falls between the 75th percentile and the maximum estimated, and 6 indicates that the median measurement is greater than the maximum estimated. This ranking score is presented in the column labelled SCORE.

An additional analysis was prepared to indicate the potential for misestimation by determining how far outside the estimated range an measured value fell. If the median measured value fell within the estimated range (a score of 2 to 5), an indicator of fit was computed as the median of the measurements divided by the median of the estimates, labelled RATIO1. If the median measured value fell outside of the estimated range, a measure of misestimation was calculated either as the median measurement divided by the maximum estimate if the score was 6 or as the minimum estimate divided by the median measurement if the score was 1. This is labelled RATIO2.

Table B.1. Ratios of Estimated and Measured Iodine-131 Concentration in Vegetation, April 13, 1946

CELL	N	MED MEAS	ESTIMATE					SCORE	RATIO1	RATIO2
			MIN	Q1	MED	Q3	MAX			
228	4	42.7	0.00	0.00	0.01	0.04	0.45	6	4706.27	95.83
229	4	0.0	0.00	0.01	0.02	0.08	0.93	1	0.00	*
261	1	28.5	0.00	0.04	0.10	0.22	2.18	6	281.07	13.09
262	1	0.0	0.01	0.07	0.15	0.34	2.84	1	0.00	*
291	1	56.9	0.07	0.24	0.46	0.81	5.47	6	124.26	10.40
292	1	28.5	0.10	0.36	0.67	1.13	7.36	6	42.84	3.87
294	1	56.9	0.22	0.88	1.71	2.50	13.22	6	33.27	4.30
315	2	56.9	0.00	0.02	0.06	0.14	1.18	6	984.78	48.18
324	1	0.0	0.49	2.21	3.60	5.74	26.82	1	0.00	*
326	1	28.5	1.59	8.19	12.70	17.11	56.44	5	2.24	
357	1	0.0	5.19	17.84	29.44	38.92	134.80	1	0.00	*
386	2	14.2	7.99	32.01	56.95	74.90	279.50	2	0.25	
387	1	142.0	8.11	27.78	40.39	65.22	141.50	6	3.52	1.00
389	1	56.9	6.24	18.16	27.07	41.07	109.20	5	2.10	
390	1	142.0	5.83	14.06	22.55	37.53	119.60	6	6.30	1.19
402	1	0.0	0.02	0.10	0.20	0.38	2.29	1	0.00	*
407	1	256.0	0.06	0.42	0.86	1.53	9.51	6	297.12	26.92
415	1	28.5	9.03	35.70	56.59	84.53	173.20	2	0.50	
420	1	28.5	6.07	13.47	22.40	39.37	107.40	4	1.27	
433	1	0.0	0.03	0.18	0.30	0.53	3.06	1	0.00	*
435	1	0.0	0.05	0.30	0.48	0.84	5.27	1	0.00	*
439	1	56.9	1.35	3.77	5.97	8.27	22.53	6	9.54	2.53
440	1	85.4	2.21	6.38	9.01	13.28	40.47	6	9.48	2.11
442	1	56.9	12.33	38.80	57.30	69.21	244.30	3	0.99	
443	1	313.0	17.82	54.69	84.51	113.20	387.10	5	3.70	
451	1	199.0	5.53	14.18	23.16	32.45	84.42	6	8.59	2.36
461	1	85.4	0.06	0.29	0.43	0.70	4.05	6	196.37	21.06
470	1	342.0	28.08	77.55	114.60	155.80	423.10	5	2.98	
479	1	0.0	5.06	15.14	22.29	31.65	78.32	1	0.00	*
489	1	0.0	0.09	0.30	0.43	0.66	3.16	1	0.00	*
508	1	114.0	6.27	17.53	26.83	39.33	94.24	6	4.25	1.21
523	1	85.4	0.34	1.34	2.02	2.96	10.11	6	42.28	8.45
530	1	199.0	19.82	59.73	80.72	107.80	269.90	5	2.47	
538	1	28.5	8.55	20.06	29.91	48.28	122.10	3	0.95	
546	1	0.0	0.13	0.36	0.57	0.92	3.19	1	0.00	*
551	2	85.5	1.48	3.49	5.27	8.18	23.76	6	16.21	3.60
557	1	285.0	19.22	51.53	64.05	88.41	179.50	6	4.45	1.59
567	1	56.9	6.03	16.79	25.64	40.16	86.30	5	2.22	
574	1	0.0	0.11	0.33	0.49	0.81	2.54	1	0.00	*
587	1	28.5	15.42	41.07	55.84	71.95	129.90	2	0.51	
595	1	142.0	9.05	21.51	30.97	52.04	241.00	5	4.59	
605	1	0.0	0.13	0.43	0.64	1.10	3.45	1	0.00	*
626	1	56.9	8.99	20.18	33.02	47.13	161.60	5	1.72	

Table B.1. (contd)

			ESTIMATE							
CELL	N	MED MEAS	MIN	Q1	MED	Q3	MAX	SCORE	RATIO1	RATIO2
632	1	28.5	0.12	0.45	0.66	1.04	3.85	6	43.22	7.40
645	1	0.0	15.74	47.53	68.73	93.25	201.30	1	0.00	*
655	1	56.9	7.96	17.65	28.37	42.05	103.90	5	2.01	
662	1	0.0	0.13	0.52	0.73	1.14	6.89	1	0.00	*
664	1	0.0	0.31	1.21	2.14	3.67	17.90	1	0.00	*
675	1	199.0	22.78	52.51	73.07	102.00	195.10	6	2.72	1.02
690	2	42.7	0.09	0.32	0.48	0.68	3.52	6	88.85	12.14
695	1	28.5	0.81	3.32	7.07	11.48	63.59	5	4.03	
706	1	85.4	25.72	47.92	68.92	95.45	243.80	4	1.24	
715	1	0.0	8.28	17.54	28.19	41.95	96.37	1	0.00	*
723	1	142.0	1.06	3.24	6.38	10.22	28.30	6	22.25	5.02
724	1	142.0	1.98	6.63	11.54	17.96	45.58	6	12.31	3.12
726	1	28.5	6.00	22.74	39.32	77.15	371.30	3	0.72	
727	1	114.0	5.05	13.10	21.78	36.31	149.60	5	5.23	
729	1	256.0	3.98	15.08	24.05	34.73	130.80	6	10.64	1.96
731	1	228.0	10.36	45.38	61.47	83.61	164.50	6	3.71	1.39
733	1	427.0	22.18	46.74	63.71	93.64	209.90	6	6.70	2.03
734	2	199.5	17.42	40.39	56.34	85.05	216.30	5	3.54	
742	1	142.0	8.65	17.56	29.26	42.65	87.00	6	4.85	1.63
764	1	28.5	15.05	35.93	49.09	70.59	188.30	2	0.58	
796	1	0.0	16.61	35.11	51.63	76.96	168.30	1	0.00	*
801	1	142.0	9.36	19.51	30.02	43.35	108.80	6	4.73	1.31
824	1	28.5	14.28	27.70	41.10	58.78	120.80	3	0.69	
828	1	114.0	7.65	19.04	30.84	42.58	103.70	6	3.70	1.10
854	1	0.0	10.88	23.65	32.19	44.62	83.10	1	0.00	*
885	1	28.5	7.04	19.60	26.71	40.41	69.58	4	1.07	
886	1	0.0	5.84	19.40	25.70	36.65	70.99	1	0.00	*
913	1	0.0	4.67	16.79	23.35	35.58	54.96	1	0.00	*
914	1	0.0	4.96	16.52	21.91	34.74	56.54	1	0.00	*

RATIO1 = MEDIAN MEASUREMENT/MEDIAN ESTIMATE
RATIO2 = MEDIAN MEASUREMENT/MAXIMUM ESTIMATE if SCORE=6
MINIMUM ESTIMATE/MEDIAN MEASUREMENT if SCORE=1
(* when median measurement is zero)

Appendix C

Ratios of Estimated and Measured Iodine-131 Concentration in Vegetation, December 1949

Appendix C

Ratios of Estimated and Measured Iodine-131 Concentration in Vegetation, December 1949

This appendix provides the distribution of the radionuclide concentrations in vegetation estimated by the STRM/RATCHET/DESCARTES model combination for each of the monitored locations during the period after the Green Run in December 1949, as described in Section 5.0. The distributions are defined by the minimum estimate of the 100 stochastic realizations computed (labelled MIN), the first quartile (i.e., the 25th percentile, labelled Q1), the median value (labelled MED), the third quartile (i.e., the 75th percentile, labelled Q3), and the maximum value computed (labelled MAX). The computed distribution is compared to the measured values.

The data for the measured values are provided in Hanf et al. (1993). In some instances, there were more than one sample available in a HEDR grid cell. In these cases, the median of the measurements was used. The number of available measurements (labelled N) is given along with the median of the measurements (labelled MED MEAS). As described in Section 5.4, a ranking score was developed based on the relative location of the measured median in the estimated distribution. This score, a value between 1 and 6, depended on the relative position of the median of the measurements within the estimated distributions, where 1 indicates that the median measurement falls below the minimum of the estimated range, 2 indicates that the median measurement falls between the minimum and 25th percentiles, 3 indicates that the median measurement falls between the 25th percentile and the median, 4 indicates that the median measurement falls between the median and the 75th percentile, 5 indicates that the median measurement falls between the 75th percentile and the maximum estimated, and 6 indicates that the median measurement is greater than the maximum estimated. This ranking score is presented in the column labelled SCORE.

An additional analysis was prepared to indicate the potential for misestimation by determining how far outside the estimated range an measured value fell. If the median measured value fell within the estimated range (a score of 2 to 5), an indicator of fit was computed as the median of the measurements divided by the median of the estimates, labelled RATIO1. If the median measured value fell outside of the estimated range, a measure of misestimation was calculated either as the median measurement divided by the maximum estimate if the score was 6 or as the minimum estimate divided by the median measurement if the score was 1. This is labelled RATIO2.

Table C.1. Ratios of Estimated and Measured Iodine-131 Concentration in Vegetation, December 1949

			ESTIMATE								
DAY	CELL	N	MED MEAS	MIN	Q1	MED	Q3	MAX	SCORE	RATIO1	RATIO2
337	442	1	36.21	75.77	218.20	368.70	532.80	1471.00	1	0.10	2.09
337	469	3	44.37	83.31	238.90	388.10	520.50	1132.00	1	0.11	1.88
339	271	1	64.26	35.90	101.00	160.80	228.90	1056.00	2	0.40	
339	272	1	47.60	34.97	93.03	157.60	224.50	979.60	2	0.30	
339	273	2	47.60	33.46	85.51	147.70	213.00	946.60	2	0.32	
339	274	2	36.12	31.54	80.92	132.00	179.70	893.90	2	0.27	
339	275	1	33.49	29.39	72.21	108.10	154.70	720.00	2	0.31	
339	293	1	173.40	1.11	36.18	74.71	108.80	354.70	5	2.32	
339	294	2	255.51	10.05	65.21	99.04	156.00	683.90	5	2.58	
339	295	1	99.28	36.14	91.49	133.00	206.60	878.90	3	0.75	
339	296	1	68.34	40.89	114.70	169.70	239.40	1185.00	2	0.40	
339	297	2	97.58	41.48	121.00	197.10	268.30	1213.00	2	0.50	
339	303	2	97.58	23.54	68.01	103.80	140.20	453.00	3	0.94	
339	324	1	365.84	42.67	119.70	183.00	242.90	1072.00	5	2.00	
339	325	2	182.24	47.14	137.20	231.50	304.70	1688.00	3	0.79	
339	326	1	137.53	47.64	144.70	232.20	326.40	1358.00	2	0.59	
339	327	1	43.01	46.78	139.80	223.00	324.30	942.20	1	0.19	1.09
339	333	2	52.78	17.31	58.94	88.71	118.00	230.00	2	0.60	
339	358	2	134.47	50.37	145.70	205.20	317.00	893.00	2	0.66	
339	363	1	10.54	16.49	58.72	86.73	127.10	221.20	1	0.12	1.56
339	386	2	70.63	43.77	127.20	173.00	259.20	796.60	2	0.41	
339	390	2	254.32	15.70	59.63	81.05	122.80	211.50	6	3.14	1.20
339	391	1	224.74	12.46	47.84	70.39	98.59	165.90	6	3.19	1.35
339	414	1	100.30	54.54	152.60	203.10	285.50	544.70	2	0.49	
339	420	1	3.06	12.03	48.55	68.32	93.91	161.30	1	0.04	3.93
339	421	1	8.50	9.66	39.62	57.90	75.74	134.10	1	0.15	1.14
339	442	1	76.16	75.97	213.40	329.00	483.30	1140.00	2	0.23	
339	443	2	60.18	65.62	179.10	253.00	349.50	552.80	1	0.24	1.09
339	444	1	137.36	52.37	149.80	203.50	261.80	441.30	2	0.67	
339	451	2	16.91	9.46	38.62	56.81	73.26	127.10	2	0.30	
339	479	2	15.55	7.65	29.96	45.04	58.60	100.60	2	0.35	
339	499	1	72.08	69.90	193.60	267.90	360.00	659.00	2	0.27	
339	500	1	28.73	46.45	131.90	183.90	242.70	463.10	1	0.16	1.62
339	508	2	5.10	7.62	29.34	43.25	58.81	94.40	1	0.12	1.49
339	530	1	35.19	58.56	163.00	222.40	305.60	631.10	1	0.16	1.66
339	538	1	6.46	7.63	27.95	41.93	56.33	92.65	1	0.15	1.18
339	539	1	10.71	6.42	24.68	33.46	47.80	77.31	2	0.32	
339	557	1	20.57	94.68	221.40	295.60	438.10	855.30	1	0.07	4.60
339	558	1	19.55	62.99	143.40	183.80	258.30	543.50	1	0.11	3.22
339	566	1	11.22	6.54	23.87	33.28	47.49	79.03	2	0.34	
339	567	1	33.15	5.55	20.61	28.16	40.88	65.17	4	1.18	
339	588	2	25.33	56.34	100.20	141.20	194.50	534.00	1	0.18	2.22
339	589	1	6.63	28.84	64.63	89.64	120.10	231.80	1	0.07	4.35
339	590	2	16.23	17.67	45.91	65.02	86.14	177.00	1	0.25	1.09
339	595	1	7.31	6.70	23.75	32.91	48.35	81.64	2	0.22	
339	596	1	9.01	5.09	20.81	28.94	41.37	70.11	2	0.31	
339	622	1	14.96	10.48	31.89	48.67	65.31	160.20	2	0.31	

Table C.1. (contd)

DAY	CELL	N	ESTIMATE						SCORE	RATIO1	RATIO2
			MED MEAS	MIN	Q1	MED	Q3	MAX			
339	626	1	6.46	4.84	20.50	28.77	40.65	77.50	2	0.22	
339	648	1	15.81	12.12	34.70	51.79	70.21	188.40	2	0.31	
339	654	3	12.07	2.60	18.37	25.60	36.27	78.50	2	0.47	
339	655	1	8.16	1.30	15.61	22.81	32.75	70.49	2	0.36	
339	677	2	31.62	11.60	32.39	48.40	67.67	195.10	2	0.65	
339	685	2	9.94	0.71	13.97	21.40	30.24	70.08	2	0.46	
339	707	1	19.21	11.35	30.07	44.19	63.79	200.10	2	0.43	
339	715	2	9.01	0.90	14.48	21.84	30.71	78.34	2	0.41	
339	727	2	162.09	1.69	16.59	26.25	35.00	70.18	6	6.18	2.31
339	728	2	137.10	3.52	20.82	28.51	40.00	69.86	6	4.81	1.96
339	729	4	117.30	7.12	23.40	32.32	44.86	68.79	6	3.63	1.71
339	730	2	125.80	10.44	25.21	38.25	47.50	86.56	6	3.29	1.45
339	731	1	451.18	11.18	27.75	40.76	54.95	123.30	6	11.07	3.66
339	732	1	25.50	11.73	28.28	42.15	61.13	160.20	2	0.60	
339	733	2	21.84	11.96	28.99	43.14	59.93	189.40	2	0.51	
339	734	1	14.45	11.43	29.43	42.66	60.28	202.80	2	0.34	
339	742	1	11.05	1.17	15.26	22.50	31.18	86.49	2	0.49	
339	755	1	250.92	0.61	12.14	20.72	28.82	58.41	6	12.11	4.30
339	756	2	168.47	1.37	15.27	24.20	31.38	59.29	6	6.96	2.84
339	771	1	5.61	1.54	15.90	23.71	32.30	94.21	2	0.24	
339	784	1	23.97	0.24	9.32	16.78	23.97	48.95	5	1.43	
339	785	1	36.55	0.46	10.98	19.69	27.04	50.47	5	1.86	
339	801	1	2.72	1.98	16.62	25.36	32.84	101.20	2	0.11	
339	811	2	46.49	0.18	8.45	15.74	22.61	43.21	6	2.95	1.08
339	828	2	17.51	2.47	17.58	26.70	35.73	107.00	2	0.66	
339	840	1	9.69	0.15	7.63	14.51	21.48	38.79	3	0.67	
339	857	1	10.37	2.98	19.01	27.55	38.88	113.50	2	0.38	
339	870	1	15.13	0.15	7.21	13.94	20.34	37.40	4	1.09	
339	871	1	20.40	0.28	8.76	16.63	22.72	40.90	4	1.23	
339	886	1	4.59	5.91	21.64	32.42	46.74	134.60	1	0.14	1.29
339	887	1	5.10	3.45	19.49	29.05	40.63	121.50	2	0.18	
339	898	1	51.17	0.24	8.19	15.65	22.22	39.63	6	3.27	1.29
339	899	2	19.97	0.29	10.21	17.34	24.13	45.01	4	1.15	
339	913	1	7.82	6.67	22.78	33.78	49.36	140.00	2	0.23	
339	929	1	21.93	0.27	12.05	19.04	27.06	49.84	4	1.15	
339	930	2	37.91	0.63	14.04	21.38	29.86	55.87	5	1.77	
340	386	2	202.72	37.57	108.90	148.80	223.10	683.00	4	1.36	
340	387	1	106.76	27.82	92.18	123.20	184.90	631.00	3	0.87	
340	388	1	176.80	21.54	74.98	103.00	152.40	465.30	5	1.72	
340	389	2	50.49	16.98	61.61	86.50	131.70	289.00	2	0.58	
340	390	11	148.7	13.45	51.42	69.75	106.70	184.00	5	2.13	
40	574	1	20.57	0.01	0.81	4.26	9.58	47.20	5	4.83	
340	605	1	15.98	0.01	1.37	5.15	11.28	49.73	5	3.10	
340	632	1	7.14	0.01	1.16	4.82	10.41	44.50	4	1.48	
340	663	1	15.47	0.02	2.75	7.32	14.63	51.53	5	2.11	
340	664	1	45.05	0.02	3.94	9.15	17.03	58.79	5	4.92	
340	690	1	6.97	0.01	0.55	3.27	7.54	31.29	4	2.13	
340	691	1	2.04	0.01	0.88	4.21	8.90	35.28	3	0.48	

Appendix D

Estimated and Measured Radionuclide Concentrations in Columbia River Fish

Appendix D

Estimated and Measured Radionuclide Concentrations in Columbia River Fish

The Hanford monitoring database contains information on several thousand samples of various species of fish at several locations on the Columbia River downstream of Hanford in 1967. This database is described in detail in Hanf (1992). The information from this database for 1967 was stratified by month, fish type, radionuclide, and location for the purposes of validation. The measurements were accumulated into three general types of fish: omnivorous fish (e.g., bullhead, catfish, suckers, whitefish, chiselmouth), first order predators (e.g., perch, crappie), and second order predators (e.g., bass, squawfish). Historical measurements for 1967 include measurements of sodium-24, phosphorus-32, zinc-65, and cesium-137. The cesium-137 was derived from global fallout and was not included in these analyses. Only about a half-dozen samples were available from the Richland stretch of the river and so were not included. This left the Ringold, Kennewick/Pasco, and Snake/Walla Walla river segments with useful data. The 1967 database information is summarized in Table D.1.

Calculations were performed with the production version of the Columbia River Dose (CRD) program to provide the estimates of radionuclides in the corresponding types of fish at the various locations of interest. The results of the calculations are presented in Table D.2.

The result of the comparison of the estimated and measured radionuclide concentrations in fish is provided in Section 11.0.

Table D.1. Average Measured Radionuclide Concentrations in Fish

	Omnivore (pCi/kg)					Predator 1 (pCi/kg)					Predator 2 (pCi/kg)				
Month	Na-24	P-32	Zn-65	As-76	Np-239	Na-24	P-32	Zn-65	As-76	Np-239	Na-24	P-32	Zn-65	As-76	Np-239
Ringold															
Jan-67	25500	104000	26400												
Feb-67	38200	135000	25100												
Mar-67	37100	223000	20400												
Apr-67	52000	118000	16200												
May-67	29800	123000	13300												
Jun-67	15400	19100	11600												
Jul-67	39000	23900	7850												
Aug-67	54200	250000	14500												
Sep-67	40800	485000	17400												
Oct-67	62200	735000	30000												
Nov-67	67600	459000	33000												
Dec-67	29900	439000	33300												
Kennewick/Pasco															
Jan-67		45600	2790				85400	12400				1750	6250		
Feb-67		1000	2200				11600	4870				9550	4380		
Mar-67		4000	7020				1000	4900				1250	1750		
Apr-67		1000	4130				2540	5360				1000	2200		
May-67		2200	2750				4000	6020				1620	1710		
Jun-67		7820	3270												
Jul-67		3000	2150				17700	7210				18000	13000		
Aug-67		9000	4940				100000	12400				48000	6800		
Sep-67		108000	6270				46500	5030				92000	10800		
Oct-67		181000	12000				94400	11600				34000	8040		
Nov-67		92200	10100				27700	13000				3000	7900		
Dec-67		13600	12600				10700	9790				2500	4400		
Snake/Walla Walla Rivers															
Jan-67		35200	11500				2770	14900							
Feb-67		3600	8710				9390	9380							
Mar-67		1000	5840				4170	7240				1000	4400		
Apr-67		1730	7160				1970	7780				1000	5470		
May-67		3090	5520				7110	7540				1900	5100		
Jun-67		15800	5700				23400	8140				3000	9300		
Jul-67		17400	8570				24200	8160							
Aug-67		56300	9300				119000	10800							
Sep-67		142000	18500				293000	19600				83800	6080		
Oct-67		74000	16000				182000	22800				56700	10300		
Nov-67		53200	17300				13600	12200					9250		
Dec-67		2250	10700				6500	19500					9250		

Table D.2. Estimated Radionuclide Concentrations in Fish

	Omnivore (pCi/kg)					Predator 1 (pCi/kg)					Predator 2 (pCi/kg)				
Month	Na-24	P-32	Zn-65	As-76	Np-239	Na-24	P-32	Zn-65	As-76	Np-239	Na-24	P-32	Zn-65	As-76	Np-239
Ringold															
Jan-67	41000	49000	37000	240000	23000	10000	8900	27000	240000	23000	10000	8900	19000	240000	23000
Feb-67	39000	55000	35000	150000	20000	9600	10000	26000	150000	20000	9600	10000	18000	150000	20000
Mar-67	34000	43000	39000	170000	24000	8400	7900	29000	170000	24000	8400	7900	20000	170000	24000
Apr-67	41000	74000	42000	280000	24000	10000	13000	31000	280000	24000	10000	13000	21000	280000	24000
May-67	30000	68000	22000	190000	26000	7500	12000	16000	190000	26000	7500	12000	11000	190000	26000
Jun-67	8300	51000	10000	58000	8100	2100	33000	12000	58000	8100	2100	33000	5000	58000	8100
Jul-67	11000	60000	15000	53000	9600	2800	39000	18000	53000	9600	2800	39000	7300	53000	9600
Aug-67	23000	140000	21000	130000	18000	5700	94000	25000	130000	18000	5700	94000	10000	130000	18000
Sep-67	29000	190000	38000	140000	37000	7300	120000	44000	140000	37000	7300	120000	18000	140000	37000
Oct-67	32000	200000	30000	220000	31000	8000	130000	35000	220000	31000	8000	130000	15000	220000	31000
Nov-67	30000	150000	31000	160000	27000	7600	100000	36000	160000	27000	7600	100000	15000	160000	27000
Dec-67	29000	44000	20000	200000	23000	7300	7900	15000	200000	23000	7300	7900	10000	200000	23000
Kennewick/Pasco															
Jan-67	1.60E+04	4.30E+04	3.30E+04	1.30E+05	1.70E+04	4.00E+03	7.90E+03	2.50E+04	1.30E+05	1.70E+04	4.00E+03	7.90E+03	1.70E+04	1.30E+05	1.70E+04
Feb-67	1.50E+04	4.90E+04	3.20E+04	8.40E+04	1.40E+04	3.80E+03	8.90E+03	2.40E+04	8.40E+04	1.40E+04	3.80E+03	8.90E+03	1.60E+04	8.40E+04	1.40E+04
Mar-67	1.50E+04	4.10E+04	3.70E+04	1.00E+05	1.90E+04	3.80E+03	7.30E+03	2.80E+04	1.00E+05	1.90E+04	3.80E+03	7.30E+03	1.90E+04	1.00E+05	1.90E+04
Apr-67	1.80E+04	6.70E+04	3.90E+04	1.70E+05	1.80E+04	4.50E+03	1.20E+04	2.90E+04	1.70E+05	1.80E+04	4.50E+03	1.20E+04	2.00E+04	1.70E+05	1.80E+04
May-67	1.40E+04	6.30E+04	2.20E+04	1.20E+05	2.00E+04	3.60E+03	1.10E+04	1.60E+04	1.20E+05	2.00E+04	3.60E+03	1.10E+04	1.10E+04	1.20E+05	2.00E+04
Jun-67	5.80E+03	4.90E+04	1.00E+04	4.70E+04	7.30E+03	1.40E+03	3.20E+04	1.20E+04	4.70E+04	7.30E+03	1.40E+03	3.20E+04	4.90E+03	4.70E+04	7.30E+03
Jul-67	7.40E+03	5.80E+04	1.50E+04	4.20E+04	8.50E+03	1.90E+03	3.80E+04	1.70E+04	4.20E+04	8.50E+03	1.90E+03	3.80E+04	7.20E+03	4.20E+04	8.50E+03
Aug-67	1.20E+04	1.40E+05	2.10E+04	9.00E+04	1.50E+04	3.00E+03	9.00E+04	2.40E+04	9.00E+04	1.50E+04	3.00E+03	9.00E+04	1.00E+04	9.00E+04	1.50E+04
Sep-67	1.20E+04	1.70E+05	3.60E+04	8.10E+04	2.80E+04	3.10E+03	1.10E+05	4.20E+04	8.10E+04	2.80E+04	3.10E+03	1.10E+05	1.70E+04	8.10E+04	2.80E+04
Oct-67	1.30E+04	1.90E+05	2.90E+04	1.20E+05	2.30E+04	3.20E+03	1.20E+05	3.40E+04	1.20E+05	2.30E+04	3.20E+03	1.20E+05	1.40E+04	1.20E+05	2.30E+04
Nov-67	1.20E+04	1.40E+05	2.90E+04	9.50E+04	2.00E+04	3.10E+03	9.30E+04	3.40E+04	9.50E+04	2.00E+04	3.10E+03	9.30E+04	1.40E+04	9.50E+04	2.00E+04
Dec-67	1.30E+04	3.90E+04	1.80E+04	1.20E+05	1.70E+04	3.20E+03	7.10E+03	1.30E+04	1.20E+05	1.70E+04	3.20E+03	7.10E+03	9.30E+03	1.20E+05	1.70E+04
Snake/Walla Walla Rivers															
Jan-67	6.20E+03	2.80E+04	2.20E+04	6.40E+04	9.40E+03	1.60E+03	5.00E+03	1.60E+04	6.40E+04	9.40E+03	1.60E+03	5.00E+03	1.10E+04	6.40E+04	9.40E+03
Feb-67	6.00E+03	3.20E+04	2.10E+04	4.10E+04	8.30E+03	1.50E+03	5.80E+03	1.60E+04	4.10E+04	8.30E+03	1.50E+03	5.80E+03	1.10E+04	4.10E+04	8.30E+03
Mar-67	6.70E+03	2.80E+04	2.60E+04	5.50E+04	1.10E+04	1.70E+03	5.10E+03	1.90E+04	5.50E+04	1.10E+04	1.70E+03	5.10E+03	1.30E+04	5.50E+04	1.10E+04
Apr-67	7.60E+03	4.30E+04	2.60E+04	8.40E+04	1.10E+04	1.90E+03	7.70E+03	1.90E+04	8.40E+04	1.10E+04	1.90E+03	7.70E+03	1.30E+04	8.40E+04	1.10E+04
May-67	5.40E+03	3.50E+04	1.20E+04	5.40E+04	1.00E+04	1.40E+03	6.30E+03	9.20E+03	5.40E+04	1.00E+04	1.40E+03	6.30E+03	6.30E+03	5.40E+04	1.00E+04
Jun-67	3.60E+03	3.70E+04	7.60E+03	3.20E+04	5.20E+03	9.10E+02	2.40E+04	8.80E+03	3.20E+04	5.20E+03	9.10E+02	2.40E+04	3.70E+03	3.20E+04	5.20E+03
Jul-67	5.10E+03	4.90E+04	1.30E+04	3.20E+04	6.90E+03	1.30E+03	3.20E+04	1.50E+04	3.20E+04	6.90E+03	1.30E+03	3.20E+04	6.20E+03	3.20E+04	6.90E+03
Aug-67	7.00E+03	1.10E+05	1.80E+04	6.00E+04	1.10E+04	1.70E+03	7.50E+04	2.10E+04	6.00E+04	1.10E+04	1.70E+03	7.50E+04	8.60E+03	6.00E+04	1.10E+04
Sep-67	5.70E+03	1.40E+05	2.90E+04	4.70E+04	1.90E+04	1.40E+03	8.90E+04	3.30E+04	4.70E+04	1.90E+04	1.40E+03	8.90E+04	1.40E+04	4.70E+04	1.90E+04
Oct-67	5.20E+03	1.30E+05	2.10E+04	6.30E+04	1.40E+04	1.30E+03	8.60E+04	2.50E+04	6.30E+04	1.40E+04	1.30E+03	8.60E+04	1.00E+04	6.30E+04	1.40E+04
Nov-67	4.90E+03	9.90E+04	2.10E+04	4.90E+04	1.20E+04	1.20E+03	6.50E+04	2.40E+04	4.90E+04	1.20E+04	1.20E+03	6.50E+04	1.00E+04	4.90E+04	1.20E+04
Dec-67	5.90E+03	2.80E+04	1.30E+04	6.40E+04	1.10E+04	1.50E+03	5.10E+03	9.80E+03	6.40E+04	1.10E+04	1.50E+03	5.10E+03	6.80E+03	6.40E+04	1.10E+04

Appendix E

Summary of Technical Steering Panel Comments and Battelle, Pacific Northwest Laboratories Responses

Summary of Technical Steering Panel Comments and Battelle, Pacific Northwest Laboratories Responses

Document Number: **PNWD-2221 HEDR** Document Title: **"Validation of HEDR Models"**

Summary Comments by: **D. S. Barth**

The comments received from various members of the TSP on the subject report are all included as an attachment to this summary. Many of the comments are essentially editorial in nature in that they recommend changes which will improve the clarity of the report. These should be carefully considered and responded to by making appropriate changes or rebutting the comments.

There are several substantive comments which are believed to be of greater importance. Of these, the ones believed to be of highest priority are summarized below.

It should be made clear in the introduction what acceptable goals for the model validation will be and specifically what information will be used to accomplish this validation. Whether or not off-site information exists, and its nature and extent, should be presented and a judgment reached as to whether or not this off-site information should be used in an additional HEDR model validation effort to strengthen the existing validation effort.

A short section added to Section 1.0

The underestimates of the models in winter compared to summer should be discussed in greater detail and specific efforts identified for testing and evaluating possible reasons for this problem. With regard to the thyroid count data, the TSP and the CDC should jointly investigate the possibility of obtaining specific residence histories and milk consumption information for these subjects without violating the Privacy Act.

A discussion of the influence of the weathering rate has been added to Section 3.4.

If the scientific justification is adequate for altering input parameters in the dose models, those input parameters should be changed. Careful evaluation is indicated for I-131 cow intake to milk concentration conversion factors and to weathering effective disappearance half times for I-131 on vegetation or hay in summer and in winter.

No changes have been made to the models; the TSP addressed the question of feed to milk transfer in the February 18, 1994 meeting in Seattle. See Section 3.4 for information about weathering.

If feasible, specific recommendations should be made for additional research and/or information gathering exercises which have the potential for addressing the uncertainty in estimated doses.

A paragraph has been added to Section 15.0.

NA = No Action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
<u>TSP COMMENTS:</u>				
1	N. Germond	Full Report	No specific comments.	NA.
2	P. McGavran	Full Report	The word "accurate" may be overused in this document. Valid, adequate, etc. may be better, more precise words to use. Accurate is an appropriate term for describing what the computer models should strive for; as you do in sections 2 and 9—but in describing results of the validation, accurate seems an overstatement. Accurate, to me, means free from error, exactly matching the truth. The models may be as accurate as they can be but 'accurate' is strong language.	Text changed in Section 15.1 and 15.2 from "accurate" to "representative." The word "accurate" was only used two other times: in the summary and in Section 15.1. This terminology remains unchanged because the text describes the results of the CHARIMA model, and "accurate" is the flavor that the authors were intending.
3	W. Bishop	General Comment	A discussion should be provided on the impacts of DOE's disclosure of secret radiation experiments on data validation, if any. It would appear that the 1945-1946 thyroid counts and 1960-1970 whole body counts could be impacted if those individuals were also subject to significant doses through experimentation. If nothing else, a general consideration should be given in the text regarding the discovery of new information which supports or refutes the validation efforts presented in this document.	NA. Information on known Hanford-related human radiation studies was provided to the Department of Energy and subsequently to Congress in 1984. The 1984 search was conducted at the request of a Congressional subcommittee. The search identified 10 studies conducted between 1951 and 1975, involving about 300 people. None of these studies were classified, and all participants have been identified as volunteers. Several of these studies were known to the authors, and two are referenced in Section 13.2.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
4	A. Murphy	General Comment	Comparison of model forecasts with measurements is only the first step in the validation process. Ideally, this step would be followed by serious efforts to investigate any deficiencies in model performance (e.g., under-forecasting in winter - see Figures 3.1-3.8), to identify possible reasons for these deficiencies, to conduct experiments and other studies involving potential model refinements, to evaluate the impacts of these refinements using independent data, and to implement those refinements that seem appropriate from a "physical" point of view and that lead to improved performance. Whatever the reasons, it is extremely unfortunate that the Battelle contract will end in a few months with a model validation process that has been truncated after the first step.	NA.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
4 (contd)	A. Murphy	General Comment	It was agreed that concentration, deposition, etc., estimates within a factor of three would be considered acceptable. However, this agreement did not relieve us (the TSP, if not Battelle) of the responsibility to obtain the most accurate estimates possible, or at least to make an effort to reduce or eliminate known model deficiencies (see comment above). Although the appropriate adjective may be subject to debate (i.e., is it "many" or "some"), various results presented in the report indicate that errors (or biases) approaching or exceeding this factor-of-three threshold occur in many/some situations. Whatever biases of this type remain, it is important to keep in mind that they must be taken into account when individual or representative doses are estimated.	NA. Continuing evaluation of model performance and/or reliability are outside of the scope of the HEDR Project contract.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
4 (contd)	A. Murphy	General Comment	In addition to estimates of expected (i.e., mean or median) dose, potentially affected individuals will be provided with estimates characterizing the uncertainty in their doses. Although the report (qualitatively) compares measurements with the range of model forecasts in some cases, no validation of these uncertainty estimates is reported. For example: Do approximately 50% of the measurements fall above and below the median of the model forecasts? Do approximately 25% of the measurements fall below the lower quartile and above the upper quartile of the model forecasts? Etc.	NA. Estimates of doses to specific individuals and "validation of uncertainty" are not within the scope of the HEDR Project. Dose estimates will be provided to specific individuals in future TSP-sponsored work. The TSP discussed "validation of uncertainty" at the February 18, 1994 meeting in Seattle, and deferred it as future work.
4 (contd)	A. Murphy	General Comment	I do not believe that the next to last sentence in Section 15.2 accurately reflects at least some of the results presented in the report. On the contrary, some evidence does exist that the models are deficient (if not inadequate). Unfortunately, no time or resources are available (under the Battelle contract) to investigate or correct these deficiencies. Thus, the recommendation "no revisions to any of the models" (last sentence) appears to have been dictated largely by time/resource constraints rather than by carefully considered scientific judgment.	Agree. Sentence deleted in Section 15.2; text added: "As a result of this validation exercise, no revisions to any of the models are recommended before estimation of representative individual doses."

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
5	G. Roessler	General Comment	This is a very important document and, in general, very well done. It is reassuring to see how well the estimated versus measured values match. It's rather incredible actually.	NA. Thank you.
			The document is well organized and well documented.	NA. Thank you.
			It would have been better if a consistent Y-axis had been used throughout. Some are semi-log graphs and some are linear. I would like to see the river data on semi-log plots.	NA. Figures in Sections 9 and 10 were taken directly from Walters et al. (1994). For comparability and fiscal prudence, they were not redrawn. The very minor deviations illustrated in these figures would not be visible in semi-log representation.
6	M. L. Blazek	Pg v, Results	This section of the summary is too lengthy and complex. The last paragraph describes the findings. The comparisons described in the body of the "Results" could be added as bullets to simplify reading.	Agree. Results section of summary was rewritten for clarity.
7	G. Roessler	Pg vi, Para 3, Line 5	Do a better job of explaining what "misreporting by the counting laboratory" means.	Agree. Results section of summary was rewritten for clarity.
8	G. Roessler	Pg vi, Para 5, Line 2	Before a discussion of any of the models, put a sentence in parentheses referring to page 1.4 and 1.5 which shows which models are used for what.	Agree. Results section of summary was rewritten for clarity.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
9	S. Davis	Pg 1.1	A general question for the introduction would be: "How many attempts were made at validation which failed to show a useful result?" For example, an attempt was made to validate the total nonvolatile beta count by taking the sum of measured beta emissions from individual radionuclides. This effort at validation failed. Why?	NA. Section 1.0 addresses validation steps and the scope of this report. All of the model "validation" tests performed by the project are listed in this report. A number of checks and tests were made during the development of each of the HEDR computer codes. Some of these, such as the example given, were not "validation" in the sense of this report but internal consistancy checks.
9 (contd)	S. Davis		Also, the fact that radionuclide production was not fully validated might be explained. That is, the data necessary for ORIGEN2 are only approximate, and estimates based on ORIGEN2 have not, to my knowledge, been balanced against actual measured activities of radioactive waste at Hanford.	Agree. Text added to Section 2.0. The potential for misestimate using the ORIGEN2 models was addressed initially in Heeb 1991, "Uncertainties in Source Term Calculations Generated by the ORIGEN2 Computer Code for Hanford Production Reactors," PNL-7223 HEDR, and again in Heeb 1994, "Radionuclide Releases to the Atmosphere from Hanford Operations, 1944-1972," PNWD-2222 HEDR.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
9	S. Davis	Pg 1.1	A general question for the introduction would be: "How many attempts were made at validation which failed to show a useful result?" For example, an attempt was made to validate the total nonvolatile beta count by taking the sum of measured beta emissions from individual radionuclides. This effort at validation failed. Why?	NA. Section 1.0 addresses validation steps and the scope of this report. All of the model "validation" tests performed by the project are listed in this report. A number of checks and tests were made during the development of each of the HEDR computer codes. Some of these, such as the example given, were not "validation" in the sense of this report but internal consistancy checks.
9 (contd)	S. Davis		Also, the fact that radionuclide production was not fully validated might be explained. That is, the data necessary for ORIGEN2 are only approximate, and estimates based on ORIGEN2 have not, to my knowledge, been balanced against actual measured activities of radioactive waste at Hanford.	Agree. Text added to Section 2.0. The potential for misestimate using the ORIGEN2 models was addressed initially in Heeb 1991, "Uncertainties in Source Term Calculations Generated by the ORIGEN2 Computer Code for Hanford Production Reactors," PNL-7223 HEDR, and again in Heeb 1994, "Radionuclide Releases to the Atmosphere from Hanford Operations, 1944-1972," PNWD-2222 HEDR.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
10	B. Shleien	Pg 1.3	I do not agree that data are not available to support "an ambitious validation program" (they may be at INEL, Oak Ridge, or SRS). Furthermore, the space/time/pathway combinations that would lead to the most rigorously defensible validation requires the use of off-site testing. I have recommended that this be discussed as additional work at the February TSP meeting.	Text added to Section 1.2 clarifying the scope of this report. The phrase "ambitious validation program" refers to Hanford Site data for the entire period of interest; these data do not exist. The topic was discussed at the TSP's Seattle meeting and deferred as potential future work.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
10 (contd)	B. Shleien		Time-Sequence Vegetation Contamination Comparisons: My visual evaluation of the HEDRIC model is that only below about 316 nanocuries of I-131 per kilogram of vegetation does the model agree within a factor of three with the measured results. At higher concentrations model estimate is within an order of magnitude agreement. Furthermore, the model underestimates the resultant I-131 in the great majority of cases. The report confirms this observation and indicates that it is most likely because of weather conditions. However, because only one year's data are compared, one cannot be assured of this. One would have to compare the model with winter and summer results for other annual periods in order to agree that the differences are due to meteorology and not to a systematic error in the model.	Text added to Section 3.4 describing a test of the impact of weathering rates in response to a suggestion by D. Barth of the TSP. It is not desirable to draw definitive conclusions from the results of one test. The largest underestimates are in fact at depositions greater than 300 nCi/kg, which also occur during the winter months. However, in Section 5.4, the DESCARTES results tend to OVERESTIMATE the deposition resulting from the Green Run (also a December/winter release resulting in comparable deposition). Table 5.4 and Figure 5.8 both illustrate this phenomenon. Differences in the data sets include the way that the contamination was measured at the time, and the regional weather during the release. This result argues against a systematic error. Additional calculations are outside the scope of the HEDR Project.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
10 (contd)	B. Shleien		Dispersion/Deposition Footprint, April 13, 1946: Fewer than 10% of the results are within the 25 to 75 percentile. If one limits ones observations to measurements to the highest range $>1x10^{-8}$ Ci/kg, the degree of agreement still is about 10-15% within the 25 to 75 percentile. Battelle's acceptability is the range between the minimum and maximum (assume 5th and 95th percentile). Using broader limit bounds increases the "agreement" of the model with the measured spacial deposition values to 30 and 60 percent when all or only high concentrations are compared respectively. In this case the under-estimates appear about balanced with the overestimates. The deposition levels are at the lower end of the time-sequence values above.	NA. Use of this data set was limited because original measurements were inadequate.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
10 (contd)	B. Shleien		There is an inconsistency between the conclusions illustrated by the two comparisons above. In the dispersion/deposition footprint, the conclusion is that at higher concentrations of I-131 on vegetation the model agrees better with the measurements. On the other hand, from the time-sequence comparison, the model shows increasing disagreement as I-131 deposition levels increase. My own impression of the data is that the model and the measurements agree within the 25th to 75th percentile only in the range between 10 and 100 nCi/kg of vegetation. Up to about 300 nCi/kg the model encompasses the results within the 5th to 95th percentile in some cases. The procedure could have, but did not evaluate if this is due to meteorological phenomena. The results of the spacial comparison would tend to indicate that the operative phenomena may not be meteorological.	Text added to Section 3.4 discussing apparent inconsistencies. Only 3 of the April 13 measurements exceed 300 nCi/kg; two of these fall within the estimated ranges, one exceeds the maximum estimate by a factor of 2.03.
10 (contd)	B. Shleien		1949 Green Run: The same patterns as noted above are evident.	Text added to Section 3.4 discussing apparent estimate inconsistencies. It is not the case that the patterns are the same. It is obvious from Table 5.4 that the model is OVERESTIMATING the deposition for concentrations greater than 100 nCi/kg.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
10 (contd)	B. Shleien		PUREX Release, September 1993: These comparisons of the model with the measurements are impressive. The measurements were most likely more precise and accurate than earlier deposition data. The releases were several orders of magnitude below the period of major concern for the HEDR Project.	NA. Thank you.
10 (contd)	B. Shleien		KRYPTON-85 Atmospheric Dispersion: Unless there are pertinent data indicating that I-131 acts similarly to Kr-85 upon release and dispersion this data set is not convincing. It does not adequately validate the dispersion aspects of the RATCHET model. The report should indicate its relevance to the HEDR Project and explain the possible differences between the behavior of Kr-85 and I-131.	Text added to Section 7.0 discussing this issue. The atmospheric model has two submodels: transport and deposition. Unless that transport is approximately correct, the deposition will be totally incorrect. The krypton data set allows partial validation of transport alone. There is no reason to believe that krypton would disperse differently than any other gas or submicron particles. This is discussed in Ramsdell et al. (1994).
10 (contd)	B. Shleien		Richland Worker Thyroid Counts, 1945-1956: Contention that I-131 in thyroids of workers residing in Richland in the 1945-1946 period is due primarily to inhalation is surprising. One could further prove this by comparing workers who were known to have ingested milk from a local source to the others as per J. E. Till's suggestion.	NA. This topic was discussed at the TSP's February 1994 meeting in Seattle and deferred as future work. Follow-up of individuals in the data set is beyond the scope of the HEDR Project. The thyroid counts result is confirmed in the dose calculations for reference individuals.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
10 (contd)	B. Shleien		CONCLUSION: Validation work air pathway—the HEDRIC model compares well with I-131 vegetation measurements when these measurements are in the range of 10 to 100 nanocuries/kg. At high levels of I-131 on vegetation the HEDRIC model underestimates the measured amount by a factor of about 10. Since the levels for 1945 are in the higher range, this disagreement is very important. The report speculates that meteorological factors are responsible but does not present data or arguments that this is indeed the case. The difficulty could be systematic or have some other genesis. Battelle must show that the winter/summer pattern is repeated during other years or delineate other factors that may be operative.	NA. Topic addressed in preceding responses to comment 10.
10 (contd)	B. Shleien		Columbia River Hydraulics: No comments.	NA.
10 (contd)	B. Shleien		Columbia River Water Concentrations, 1967: My memo of January 20, 1994 to the TSP gave good agreement for doses calculated using data obtained from the CHARIMA model and those calculated using a simple dilution/decay model (GENII-S) at Pasco, WA, 1950-1971. This supports the data presented in the subject report.	NA. We appreciate the corroboration.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
10 (contd)	B. Shleien		Pacific Coast Oyster Concentrations, 1967: No comments.	NA.
10 (contd)	B. Shleien		Richland Whole-Body Counts, 1960-1970: Resultant Zn-65 whole-body counts were directly proportional to the intake of the material, and hence the subjects diet. Because body burdens of Zn-65 are dependent on intake, is the comparison employed by Battelle valid for other parameters? Furthermore, validation of the model using this test method is appropriate for only two radionuclides. No validation exists for other radionuclides. Rather than limiting the assessment question to the time and radionuclides for which data are available, Battelle needs to ask a broad assessment question and then indicate why it cannot be answered in its entirety.	Text added to Section 13.1 discussing how assessment questions were framed. All of the assessment questions were phrased with some knowledge of the available data (e.g., why "April 13, 1946," and why the four time-sequence locations and not others?). The questions could be made more general (as indeed they started), but one of the admonitions of IAEA (1989) is to unambiguously specify the question so that the answers are directly related. As stated in Section 13.0, only four radionuclides are generally available for comparison, and only two of these are of Hanford origin (Na-24 and Zn-65). Similar explanations are provided in the introductions to each other section. It is not that the questions were tailored to data Battelle was ABLE to employ. They were tailored to the data that ARE AVAILABLE.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
10 (contd)	B. Shleien		CONCLUSIONS - Surface Water Pathway - Assessment questions appear to have been tailored to the data that Battelle was able to employ in the validation exercise. The assessment questions should be modified to be as broad as possible, then the reasons why the entire question cannot be adequately answered needs to be stated.	NA.
10 (contd)	B. Shleien		IAEA VAMP Project Coordination: Why is this in the document? It provides no details as to the methodology employed or comparisons that are in process.	Text added to Section 14.0: "This section was included to provide the reader with information about on-going efforts that will continue beyone the time of issuance of this report, and to provide reference so the interested reader may obtain this information."
10 (contd)	B. Shleien		Conclusions (of PNWD-2221): The definition of the word "agreement" needs to be delineated. At times it appears to be a factor of 2 or 3 between a measurement and the model. Battelle needs to define if "agreement" means agreement for the 50th percentile of the model, or at the minimum (5th percentile) or maximum (95th percentile of the model).	"Agreement" was used to describe the relationship between the median estimated values and actual measurements.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
10 (contd)	B. Shleien		Statements as to agreement within a factor of three for a single year, at least during the grazing season, raise questions that require answers.	Text reworded in Section 15.1: "The comparisons for 1946 correlate to within factors of 3 during the grazing season months. Comparisons during winter months are not as close." Issue also addressed in Section 3.4: see preceding responses to comment 10.
11	G. Roessler	Page 1.3, Para 3, Last line	"As a result of these studies, however, no changes to the models or codes are recommended." I agree. However, I think the TSP would agree that it would be okay to change some parameters if there is sufficient information to do so. For example, D. Barth's suggestion on the differences on disappearance time in vegetation should be looked at carefully and, if there is good support for doing so, this parameter should be changed.	Text added to Section 3.4; see also response to comments 10 and 16.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
12	J. Till	Pg 1.6	A comment should be included that states clearly that Battelle has used all available data for validation and has not just used the best fitting data. Validation often includes comparisons of data sets that do not fit and the disparity cannot be explained. Has Battelle used all available data for validation?	NA. The nature of the data is discussed in each section of the report. The rationale for selection of data sets was presented in Napier et al. 1993. "HEDR Model Validation Plan." A considerable body of additional raw data does exist for the early years of Hanford operations. However, it is badly fragmented in space, time, and environmental media. The data "sets" selected were those that comprise a coherent picture of a particular time or place. This is what makes them "sets," rather than just "compilations." Detailed comparisons against the thousands of essentially random (in time, space, and medium) measurements would be much beyond the scope of the environmental calculations authorized by the TSP (i.e., monthly averages).
13	G. Roessler	Pg 1.6, Para 1, Last line	"None of these data sets were used during the development of the models being validated." I believe this, but how can I convince the public that this is true. An examination of the "parameters" document, or at least a spot check, will help, but that doesn't prove that these equations went into the programs exactly as given in the document. If anyone has a way of handling this, I would like to know about it.	NA. No calibration of the models has been performed as a result of these validation exercises. The inputs were as described in Snyder et al. (1994). References for the selection of the individual parameters are listed therein.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
14	G. Roessler	Pg 2.1, Para 2, Line 1	This section needs further explanation. As it is written, one wonders why calculate burnup when you have the recorded data.	Text added to Section 2.0. The estimated burnup is actually a byproduct of the calculation of iodine content, not a primary result. It is fortunate that records of this related, but not definitive, calculation exist.
15	G. Caldwell	Page 3.2, Para 2, Line 1	The first sentence is clumsy and unclear. "A third source of source..." Should the second "source" be "authorship"?	Agree. Text changed in Section 3.2 to "A third source of indeterminable authorship..."
16	G. Caldwell	Pg 3.3-3.11, Para 2, Fig 3.1-3.8	The mismatch between the model and data in winter suggests either some structural defect in the model or differences in weathering, deposition, temperature or other factors. What can be done to improve the model's correlation with the data? (J. Till, I believe, suggested a different weathering factor between summer and winter).	Text added to Section 3.4 discussing influence of weathering rate. See response to comment 10.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
17	G. Roessler	Pg 3.3, Fig 3.1	It would be nice to have as good an agreement in the winter as in the summer, but it is very reassuring to have the agreement that exists. Even though the data looks better on this semi-log plot that it would on a linear plot, I think this data set is excellent when you consider the problems associated with putting together the information necessary to do this historical calculation and comparison with measured data. It should make V. Ramsdell's day and should quiet those who still don't believe in RATCHET. Of course it also validated RM and STRM too, but there don't seem to be as many questions about these codes.	NA. Thank you.
18	G. Caldwell	Pg 3.6, Fig 3.6	Are the overall low estimates by the model the result of being upwind of the releases for the most part or some other factor? Could this be the result of either the person doing the sampling or miscalibration of the counter?	NA. The most likely explanation for the results being underestimated at the Benton City location is the presence of 3000-foot Rattlesnake Ridge immediately to the northwest of this location. Counting of the data was done in a similar manner for all of the locations, by the same staff.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
19	G. Caldwell	Pg 3.11, Para 3	Are there any other records or even human memory available to shed light on this extraordinary deposition?	NA. The daily summary records for this month are not available for Hanford. Monthly summaries indicate that December 1945 was not unusual (Stone et al. 1983, "Climatological Summary for the Hanford Area," PNL-4622. However, daily records are available for the Pasco airport, which indicate continuous occurrance of fog from December 18 to 21, 1945.
20	G. Caldwell	Pg 3.11, Para 4	Have old timers been contacted to ascertain if anyone can identify the author of these important data?	Text added to Section 3.2: Extensive efforts were made in 1988-1989 to determine the origin of the "vegetation correlation data sheets."
21	J. Till	Pg 4.5, Fig 4.3	This is an important graphic that needs a more careful analysis. For example, is there any correlation between the extreme ranges of the scale (1 and 6) and topography? Any plausible explanation of the pattern would be helpful.	Text added to Section 4.4: "Extreme ranges in scale may correlate to the topography of the area. A series of high ridges extend diagonally across the landscape, separating Ellensburg, Yakima, and Sunnyside from the higher concentration areas beginning at Hanford and tending northeast."
22	G. Roessler	Pg 4.5, Fig 4.3	This set of data is going to continue to be hard to explain to the public because of the number of measurements that were near the limit of detection. I appreciate Battelle's openness in presenting it though. We understand why there are so many 1s and 6s to the west even if the public doesn't.	Text added to Section 4.4. See response to comment 21.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
23	G. Roessler	Pg 6.5, Fig 6.1 and Pg 6.6, Fig 6.2	One can't help but wonder how these figures would look if the milk transfer factor being evaluated by Dave Price would impact these comparisons. Any changes in this parameter should be based on the science though and not how it might impact these curves.	NA. The milk transfer factor was discussed at the TSP's February 1994 meeting in Seattle and future work was deferred. The minor revisions to point values described by D. Price fall well within the overall uncertainty range used in the calculation.
24	G. Caldwell	Pg 7.2, Para 3, Line 7	Change sentence to read "Note that ...." omitting "To" and "is", which may improve clarity.	Agree. Text revised as suggested.
25	P. McGavran	Pg 8.1	"It is assumed...only some have occupational exposure." This reads as if you might have had and used occupational information for some—perhaps you should explain here that occupational exposures were not accounted for nor separated from environmental exposures.	Agree. Text added to Section 8.2: "...that occupational exposures do not impact the mean doses... Occupational exposures are neither accounted for nor separated from environmental exposures because individual water exposure histories are not available."
26	G. Caldwell	Pg 8.1	Are these "adult male residents" or adult male Hanford employees residing in Richland? The assumption that they were all from Richland needs to be verified because it is suspect.	Agree. Text added to Section 8.1: "For the purpose of this assessment the bulk of the Hanford Site workers are assumed to be males residing in Richland."

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
27	J. Till	Pg 8.1	I am still extremely troubled by the Richland worker thyroid counts. As I have mentioned several times at TSP meetings, these data could be excellent for validation except the analysis is insufficient. As I have commented, Battelle should pursue that fact that those workers who did not live in Richland would likely be the ones to have higher thyroid burdens. I believe there are avenues to take that would allow identification of people who lived outside Richland and that if their records could be used (through agreement of individuals), then we would have confidence in our theory that the lower burdens were caused by uncontaminated, imported milk. What a solid piece of evidence that would be! If this is not to be done, a sound argument must be presented because to date, I do not think this idea has been followed up on.	NA. Individual dose reconstruction is outside the scope of the HEDR Project. The TSP must pursue this issue with the CDC and DOE.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
28	G. Roessler	Pg 8.1	I don't think this data set has been used to the fullest. The assumption that most of these workers lived in the Richland area is probably valid, but so much more information could be derived if the location of the individuals were known. Exactly what is in the record that would help determine the location. Is this something the TSP could help with? I wouldn't mind looking at this data if we can get around the Freedom of Information problem.	NA. Individual dose reconstruction is outside the scope of the HEDR Project. The TSP must pursue this issue with the CDC and DOE.
29	G. Caldwell	Pg 11.2, Para 3	Is there a seasonal effect on fish uptake of phosphorus-32 similar to the on and off pasture for cattle in relationship to the frost data?	The data were investigated for monthly differences. The scatter of the derived bioconcentration factors was such that only two distinct "seasons" could be ascertained. These have a more gradual shift from one to the other than the dramatic change induced by pasture on/off, as a result of the relatively slow change in water temperature in the Columbia River with season.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
30	G. Roessler	Pg 13.1, Para 4, Line 1	The discussion on ^{32}P should not be included under Whole Body Count Data since ^{32}P cannot be determined by whole body counting. Either leave that paragraph out, change the title to the section or put that paragraph somewhere. I guess I would prefer that it be mentioned and the title to that section be change to "Available Whole Body Count and Bioassay Data." Then the paragraph should include a description of how the ^{32}P was monitored.	Agree. Title revised.
31	G. Roessler	Pg 13.3, Fig 13.1	Change title to Hanford Workers instead of Richland Residents as recommended by "member of the public" Bill Templeton.	Agree. Title revised.
31 (contd)	G. Roessler		Bruce's evaluation that the differences between the measured and the estimated regarding the ICRP values and their conservative nature could be added to the discussion.	Agree. Text added to Sections 13.4.1 and 13.4.2.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
32	W. Bishop	Pg 14.1	As stated on page 1.1, complete validation consists of more than the comparison of computer results to estimated measurements. Validation is also completed by "verification of the computer implementations." It appears from the text on page 14.1 that certain validation efforts, such as the VAMP Project, will continue to take place after issuance of the final report. The final report should discuss how continuing validation efforts will be considered, especially if such exercises do not validate the HEDR codes.	Agree. Text added to Section 15.2: "To add to the credibility of the HEDRIC suite, HEDR estimates and measurements could be compared with sets of non-Hanford data not used in the HEDR Project. The report authors will continue to interact with VAMP and other validation-related activities after the conclusion of the HEDR contract. The results of their activities will be published by the sponsoring organizations and made available to the CDC and TSP. The TSP may wish to consider this for future work."
33	P. McGavran	Pg 15.1	"Each component worked well, the result is accurate...the results for each step of the calculation appear to be reasonable."	Text changed in Section 15.1 and 15.2 from "accurate" to "representative."
34	P. McGavran	Pg 15.2	"CHARIMA model was determined to accurately simulate..."	NA. This terminology remains unchanged because the text describes the results of the CHARIMA model, and "accurate" is the flavor that the authors were intending.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
35	B. Shleien	Pg 15.2	The conclusion that the thyroid counts support the 1940s milk model reaches a bit too far. For this to be true, Battelle needs to prove that the thyroid counts are indeed substantially due to inhalation. This may be done by comparison of thyroid counts for workers with diet high in milk from a local source versus those ingesting milk from an up-wind source...such as is the case for the Hanford Site workers. It would not appear to be an insurmountable problem. Battelle needs to do this comparison before the assumption in the statement would carry sufficient weight for general acceptability.	NA. Individual dose reconstruction is beyond the scope of the HEDR Project. The result does indicate that the doses are much lower for monitored Hanford Site workers using commercial milk than would be obtained using locally produced milk. The milk distribution model indicates that this is the most likely case for the majority of Hanford Site workers. See response to comment 27.
35 (contd)	B. Shleien		The comparison of data for the Columbia River pathways is constricted to "assessment questions" which limit the time/spacial/radionuclide factors. Battelle needs to broaden the "Assessment Questions" so that their choices are indeed limited by the data available and not by the structures put on the validation exercise. For example, extend radionuclide validation to P-32, Np-236, and As-76 and the temporal domain to the 1950-1971 period.	Text added to Section 13.0. See response to comment 10.
35 (contd)	B. Shleien		For the reasons stated above, I do not agree with the statement in paragraph 15.2, page 15.3	Sentence removed from Section 15.2. See response to comment 4.

NA = No action.

Comment Number	Commenter	Page, Paragraph	Comment Summary	Resolution
36	P. McGavran	Pg 15.3	"On the basis of...models in the toolbox are fully functional and accurate"...	Text changed in Section 15.1 and 15.2 from "accurate" to "representative."
PUBLIC COMMENTS:				
None				

NA = No action.

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