United States Nuclear Regulatory Commission Official Hearing Exhibit

In the Matter of: Entergy Nuclear Operations, Inc.
(Indian Point Nuclear Generating Units 2 and 3)

ASLBP #: 07-858-03-LR-BD01
Docket #: 05000247 | 05000286
Exhibit #: NYS000248-00-BD01
Identified: 10/15/2012
Admitted: 10/15/2012
Withdrawn:
Rejected:
Stricken:
Other:

NYS000248
Submitted: December 21, 2011

NUREG/CR-4551
SAND86-1309
Vol. 2, Rev. 1, Part 7

Evaluation of Severe Accident Risks: Quantification of Major Input Parameters

MACCS Input

Prepared by
J. L. Sprung, J. A. Rollstin, J. C. Helton, H-N Jow

Sandia National Laboratories
Operated by
Sandia Corporation

Prepared for
U.S. Nuclear Regulatory Commission

AVAILABILITY NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources

1 The NRC Public Document Room, 2120 L Street, NW, Lower Level Washington, DC 20555

2 The Superintendent of Documents, U S Government Printing Office, P O Box 37082 Washington, DC 20013-7082

3 The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications it is not intended to be exhaustive

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda, NRC Office of Inspection and Enforcement bulletins, circulars, information notices, inspection and investigation notices, Licensee Event Reports, vendor reports and correspondence Commission papers, and applicant and licensee documents and correspondence

The following documents in the NUREG series are available for purchase from the GPO Sales Program formal NRC staff and contractor reports, NRC-sponsored conference proceedings and NRC booklets and brochures Also available are Regulatory Guides, NRC regulations in the *Code of Federal Regulations* and *Nuclear Regulatory Commission Issuances*

Documents available from the National Technical Information Service include NUREG series reports and technical reports prepared by other federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission

Documents available from public and special technical libraries include all open literature items such as books, journal and periodical articles, and transactions *Federal Register* notices, federal and state legislation, and congressional reports can usually be obtained from these libraries

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited

Single copies of NRC draft reports are available free, to the extent of supply, upon written request to the Office of Information Resources Management, Distribution Section, U S Nuclear Regulatory Commission, Washington DC 20555

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library 7920 Norfolk Avenue, Bethesda, Maryland, and are available there for reference use by the public Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway New York NY 10018

DISCLAIMER NOTICE

This report was prepared as an account of work sponsored by an [illegible] Government. Neither the United States Government nor any agency thereof, or any [illegible] warranty, expressed or implied, or assumes any legal liability of responsibility [illegible] the results of such use, of any information, apparatus, product or process disclosed [illegible] use by such third party would not infringe privately owned rights

NUREG/CR-4551
SAND86-1309
Vol. 2, Rev. 1, Part 7

Evaluation of Severe Accident Risks: Quantification of Major Input Parameters

MACCS Input

Manuscript Completed: November 1990
Date Published: December 1990

Prepared by
J. L. Sprung, J. A. Rollstin[1], J. C. Helton[2], H-N Jow

Sandia National Laboratories
Albuquerque, NM 87185

Prepared for
Division of Systems Research
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN A1853

---

[1] GRAM, Inc., Albuquerque, NM
[2] Arizona State University, Tempe, AZ

ABSTRACT

Estimation of offsite accident consequences is the customary final step in a probabilistic assessment of the risks of severe nuclear reactor accidents. Recently, the Nuclear Regulatory Commission reassessed the risks of severe accidents at five U.S. power reactors (NUREG-1150). Offsite accident consequences for NUREG-1150 source terms were estimated using the MELCOR Accident Consequence Code System (MACCS). Before these calculations were performed, most MACCS input parameters were reviewed, and for each parameter reviewed, a best-estimate value was recommended. This report presents the results of these reviews. Specifically, recommended values and the basis for their selection are presented for MACCS atmospheric and biospheric transport, emergency response, food pathway, and economic input parameters. Dose conversion factors and health effect parameters are not reviewed in this report.

CONTENTS

Page

1. Introduction 1-1
   - 1.1 Offsite Accident Progression 1-1
   - 1.2 Input Data and Quantities Calculated 1-1
   - 1.3 Phenomena Modeled 1-2
   - 1.4 Computational Framework 1-4

2. Transport Parameters 2-1
   - 2.1 Reactor Dimensions 2-2
   - 2.2 Plume Rise 2-4
   - 2.3 Plume Meander 2-7
   - 2.4 Plume Dispersion 2-8
   - 2.5 Dry Deposition Velocity 2-18
   - 2.6 Wet Deposition Parameters 2-22
   - 2.7 Weathering 2-24
   - 2.8 Runoff and Washoff 2-28
   - 2.9 Resuspension 2-38

3. Emergency Response Parameters 3-1
   - 3.1 Evacuation Parameters 3-1
   - 3.2 Shielding Factors and Breathing Rate 3-10

4.0 MACCS Food Pathway Input Parameters 4-1
   - 4.1 Introduction 4-1
   - 4.2 Food Pathway Definition Input Parameters 4-2
   - 4.3 Transfer Factor Component Input Parameters 4-7
   - 4.4 Mitigative Action Input Parameters 4-54

5.0 Economic Parameters 5-1
   - 5.1 Nonfarm Parameters: Recommended Values 5-1
   - 5.2 Nonfarm Parameters: Discussion 5-2
   - 5.3 Farm Parameters: Recommended Values 5-3

Appendix A: Sample NUREG-1150 MACCS Input Files A-1
   - A.1 ATMOS A-2
   - A.2 EARLY A-11
   - A.3 CHRONIC A-19
   - A.4 DOSDATA A-29
   - A.5 SITE A-43

FIGURES

Figure Page

1.1 Progression of a Consequence Calculation ... 1-4
2.1 Stability Class A: σ_y vs Distance ... 2-12
2.2 Stability Class B: σ_y vs Distance ... 2-12
2.3 Stability Class C: σ_y vs Distance ... 2-13
2.4 Stability Class D: σ_y vs Distance ... 2-13
2.5 Stability Class E: σ_y vs Distance ... 2-14
2.6 Stability Class F: σ_y vs Distance ... 2-14
2.7 Stability Class A: σ_z vs Distance ... 2-15
2.8 Stability Class B: σ_z vs Distance ... 2-15
2.9 Stability Class C: σ_z vs Distance ... 2-16
2.10 Stability Class D: σ_z vs Distance ... 2-16
2.11 Stability Class E: σ_z vs Distance ... 2-17
2.12 Stability Class F: σ_z vs Distance ... 2-17
2.13 Predicted Deposition Velocities at 1 m for $u^* = 50$ cm/s and Partical Densities of 1.4 and 11.5 g/cm^3 ... 2-20
4.1 Transfer of released Radionuclides to Man via the Food Pathway as Depicted in the MACCS Code ... 4-8

TABLES

Table Page

2.1 Values for Initial Plume Dimensions ... 2-2
2.2 Plume Rise Scaling Factors ... 2-4
2.3 MACCS Correction Parameters ... 2-7
2.4 Power-Law Parameter Values for MACCS ... 2-8
2.5 Values for Constants in Equation 2.1 ... 2-10
2.6 Dry Deposition Velocity ... 2-18
2.7 Values of z_0 and u_* ... 2-19
2.8 Experimental Values for v_d ... 2-21
2.9 Plume Washout from Rainfall ... 2-22
2.10 Weathering of Radionuclides on Ground ... 2-24
2.11 MACCS Weathering Values ... 2-27
2.12 Base Value and Range for Variables Associated with Surface-Water Contamination ... 2-28
2.13 Values for WSHFRI (λ_a) and WSRTH (λ_b) ... 2-31
2.14 Removal Rates for Fallout Radionuclides Determined on a Regional Basis ... 2-32
2.15 Additional Removal Rates for Radionuclides Determined on a Regional Basis ... 2-33
2.16 Vaules for WINGF ... 2-37
2.17 Base Values and Ranges for Resuspension Variables ... 2-38
2.18 Values for Ki and ri ... 2-40
2.19 Values in Reactor Safety Study ... 2-40
2.20 Values in Lassey (1980) ... 2-40
3.1 Recommended Evacuation Parameter Values ... 3-1
3.2 Surry Emergency Response Data ... 3-2
3.3 Surry Evacuation Parameter Values Estimated for the Seasons and Time of Week ... 3-3

Table Page

3.4 Estimation of Surry Evacuation Times from Vehicle Capacities and Populations 3-4
3.5 Values Recommended for Surry Evacuation Parameters 3-4
3.6 Evacuation Data for Grand Gulf 3-4
3.7 Values Recommended for Grand Gulf and Evacuation Parameters 3-5
3.8 Peach Bottom Evacuation Data 3-6
3.9 Values Recommended for Peach Bottom Evacuation Parameters 3-7
3.10 Sequoyah Evacuation Data 3-8
3.11 Values Recommended for Sequoyah Evacuation Parameters 3-10
3.12 Recommended Shielding Factor Values 3-10
3.13 Building Inhalation and Skin Shielding Factors (Indoor/Outdoor Ratios) 3-12
3.14 Urban and Suburban Skidding Factors for People Located Outdoors 3-13
3.15 Densities of Building Materials 3-14
3.16 Vehicle Groundshine Shielding Factors 3-16
3.17 Cloudshine Shielding Factors 3-17
3.18 Cloudshine Shielding Factors Recommended by Burson and Profio [18] for People Located in Buildings 3-18
3.19 Recommended Cloudshine Shielding Factor for People Located in Buildings 3-19
3.20 Groundshine Shielding Factors for Buildings 3-20
3.21 Census Data for Population Groups 3-21
3.22 Estimates of Time Spent in Different Locations by Population Groups 3-22
3.23 Time Fractions by Locations for the General Population 3-22
3.24 Time Fractions by Locations for Working Adults 3-23
3.25 Regional Building Data 3-24
3.26 Upper and Lower Bounds for Population Fractions 3-24
3.27 Input Data for Calculation of Shielding Factors Using Equations 3.9 and 3.10 3-26
3.28 Recommended Shielding Factor Values 3-28
4.1 Crop Categories 4-3
4.2 Values for TGSBEG and TGSEND 4-7
4.3 Recommended Values for $CTCOEF_1$ 4-9
4.4 Recommended Values for $CTHALF_1$ 4-9
4.5 Recommended Values for $CTCOEF_2$ 4-10
4.6 Recommended Values for $CTHALF_2$ 4-10
4.7 Interception Fraction, Availability Fraction, and Half-Lives 4-13
4.8 Values for CTCOEF and CTHALF 4-14
4.9 Summary of Empirical Transfer Factors 4-14
4.10 Recommended Values for $DCYPBH_i$ 4-15
4.11 Recommended Values for $DCYPCB_{i,j}$ and $DCYPCM_{i,j}$ for Crops Consumed by Cattle 4-17
4.12 Recommended Values for All Nuclides for Crops Not Consumed by Cattle 4-17
4.13 Recommended Values of $DCYPCH_{i,j}$ for Crops Consumed by Man 4-20
4.14 Recommended Values for $DCYPCH_{i,j}$ for Crops Not Consumed by Man 4-20
4.15 Consumption Patterns 4-23
4.16 Values for Time Variables 4-25
4.17 Recommended Values for $DCYPMH_i$ 4-25
4.18 U.S. Milk Utilization 4-27
4.19 Consumption Intervals for Milk Products 4-28

Table **Page**

4.20 Recommended Values for FPLSCH$_{i,j}$ for Crops Consumed by Man..... 4-29
4.21 Recommended Value of FPLSCH$_{i,j}$ for Crops Not Consumed by Man... 4-29
4.22 Values for FRCTCH, FRCTCM, and FRCTCB.......................... 4-31
4.23 Crop Utilization Patterns.................................. 4-32
4.24 Crop Utililzation.. 4-33
4.25 Utilization of Grains, Legumes, and Nuts.................... 4-33
4.26 Daily Consumption Rates of Feeds by Animals in Pounds per Day.. 4-34
4.27 "Standing Crops" (Animials)................................. 4-35
4.28 Crop Consumption by Animal.................................. 4-35
4.29 Recommended Values for TCROOT$_{i,j}$ for Sr and Cs Nuclides........ 4-36
4.30 Recommended Values for TCROOT$_{i,j}$ for I Nuclides................ 4-37
4.31 Values for Concentration Ratios (CR) and Crop Yield Values (CM)... 4-40
4.32 Values for Root Uptake (RU)................................. 4-41
4.33 Values for Radioactive Decay................................ 4-42
4.34 Percolation Rate for Sr and Cs.............................. 4-42
4.35 Values for ITF and ISI...................................... 4-43
4.36 Values for RSI for All Nuclides............................. 4-43
4.37 Recommended Values for TFBF$_i$................................ 4-44
4.38 Equilibrium Transfer Factors (ETFs)......................... 4-45
4.39 Values for Revised Equilibrium Transfer Factors............. 4-50
4.40 Meat Produced at Slaughter.................................. 4-50
4.41 Values for the Fraction of Animals Slaughtered per day (TR).... 4-51
4.42 Recommended Values for TFMLK$_i$............................... 4-51
4.43 ETF for Nuclides.. 4-52
4.44 Values for Stable Iodine.................................... 4-53
4.45 Adjusted ETF Values... 4-53
4.46 ETF Values for TFMLK$_i$....................................... 4-54
4.47 Recommended Values for GCMAXR$_i$, PSCMLK$_i$, and PSCOTH$_i$.......... 4-55
4.48 Recommended Values for QROOT................................ 4-59
4.49 Root Uptake (RU) by Crop and Element........................ 4-60
4.50 Values for Root Uptake (RU)................................. 4-60
4.51 Values for Radioactive Decay, RD$_i$ (yr^{-1}).................... 4-61
4.52 Values for Rate of Percolation (RP$_i$)......................... 4-61
4.53 Values for Binding Rate, RB................................. 4-62
5.1 Economic Parameter Values for MACCS......................... 5-1
5.2 Value to Region... 5-5
5.3 Rates of Return... 5-5
5.4 Recommended Values for VALWF and FRFIM....................... 5-6
5.5 Value of Farm Land and Buildings (1988)..................... 5-7
5.6 Values for VALWF by State................................... 5-7
5.7 Value of Buildings.. 5-8
5.8 Value of Buildings per Acre................................. 5-8
5.9 Values of FRFIM... 5-9

1. INTRODUCTION

Estimation of offsite accident consequences is the customary final step in a **probabilistic assessment of the risks of severe nuclear** reactor accidents. For NUREG-1150 source terms [1,2], offsite accident consequences were estimated using the MELCOR Accident Consequence Code System (MACCS) [3-5]. In preparing for the performance of those calculations, most input parameters for the MACCS offsite consequences analysis code were reviewed, and for each parameter reviewed, a best estimate value and an uncertainty range were estimated. The following chapters summarize these reviews. Sample MACCS input files for the NUREG-1150 calculations are presented in Appendix A. The remainder of this chapter provides a brief overview of offsite consequence modeling.

1.1 Offsite Accident Progression

Should a severe reactor accident culminate in containment failure, winds would transport the radioactive gases and aerosols in the plume released to the atmosphere away from the reactor site. Downwind populations would be exposed to radiation, and land, buildings, and crops would be contaminated by radioactive materials deposited from the plume. Estimation of the range and probability of the health effects induced by the radiation exposures, and of the economic costs and losses that would result from the contamination of land, buildings, and crops is the object of an ex-plant consequence analysis [6,7].

1.2 Input Data and Quantities Calculated

MACCS calculations require the following data:

- The *inventory* at accident initiation (reactor scram) of those radioactive isotopes important for the calculation of ex plant consequences (e.g., an end-of-cycle reactor core contains about 10^8 Ci of ^{131}I).

- The atmospheric *source term* produced by the accident (number of plume segments released, sensible heat content of each plume segment, time and duration of release, time when offsite officials are warned that an emergency response should be initiated, and the fraction of each important nuclide's scram inventory released with each plume segment).

- *Meteorological data* characteristic of the site region (usually one year of hourly windspeed, atmospheric stability, and rainfall readings recorded at the site or at a nearby National Weather Service station. Although one year of hourly readings contains 8760 weather sequences, most consequence calculations examine only a representative subset of these sequences (typically about 150 sequences). The representative subset is selected by stratified sampling of the 8760 sequences after sorting of the sequences into categories defined by windspeed, atmospheric stability, and the location (downwind distance) of rain

- **The** ***population distribution*** **about the reactor site (the distribution is usually constructed from census data on a polar coordinate grid having 16 angular sectors aligned with the 16 compass directions and some number of radial intervals that extend outward to 500 miles).**

- *Emergency response assumptions* (evacuation time and average speed, effectiveness and occurrence of sheltering, criteria and timing for post-accident relocation of people, decontamination criteria and effectiveness, temporary interdiction criteria for land and buildings, and disposal criteria for contaminated crops

- *Land usage* (habitable land fractions, farmland fractions), and *economic data* (worth of crops, land, and buildings) for the region about the reactor site.

Given these data, MACCS predicts

- Downwind *transport*, *dispersion*, and *deposition* of the radioactive materials released to the atmosphere from the failed containment.

- Short-term and long-term *radiation doses* received by exposed populations via direct (cloudshine, inhalation, groundshine, resuspension) and indirect (ingestion) pathways

- Mitigation of those doses by *emergency response actions* (evacuation, sheltering, and relocation of people; disposal of milk, meat, and crops; decontamination, temporary interdiction, and condemnation of land and buildings).

- *Fatalities* and *injuries* expected within one year of the accident (early health effects) and the latent *cancer deaths* expected over the lifetime of the exposed individuals.

- *Offsite costs* of emergency response actions and of the decontamination, temporary interdiction, and condemnation of milk, crops, land, and buildings.

1.3 Phenomena Modeled

1.3.1 Atmospheric Transport [8,9]

As in most consequence codes [10-14], MACCS neglects wind trajectories. The 16 compass sector population distributions are assumed to constitute a representative set of downwind exposed populations The exposure probability of each of the 16 compass sector population distributions is assumed to be given by the frequency with which wind blows from the site into the sector (i.e., compass sector site wind rose frequencies) Windspeed determines the rate of downwind transport. Release duration and windspeed determine plume length. Dispersion of the plume in the downwind direction is neglected. Dispersion in the vertical and crosswind directions is estimated using a Gaussian plume model and therefore varies with windspeed and atmospheric stability. Vertical plume expansion is capped by the mixing depth (seasonal mixing layer height).

1.3.2 Deposition

Aerosols are removed from the plume by washout, which varies with rainfall rate, and by diffusion to, impaction on, and gravitational settling onto surfaces. The combined removal rate because of diffusion, impaction, and settling is modeled using an empirical, particle-size dependent, dry deposition velocity. Runoff of rain and weathering decrease surface concentrations of radioactive aerosols deposited on the ground. Decrease of radioactivity because of radioactive decay is also modeled (only parent and daughter nuclides are followed, since doses from second generation daughters are insignificant).

1.3.3 Emergency Response

Population doses are mitigated by user-specified emergency response actions (evacuation, sheltering, and post-accident relocation of people; decontamination, temporary interdiction, and condemnation of land and buildings; disposal of contaminated meat, milk, and crops).

1.3.4 Dosimetry and Health Effects

Populations located on the MACCS computational grid receive doses from the passing plume (cloudshine), by exposure to materials deposited on the ground (groundshine), by inhalation of airborne radioactive materials (from the plume or from mechanical or wind driven resuspension of materials deposited on the ground), and by ingestion of contaminated water and foods. Contaminated water and foods may also be consumed by populations off of the computational grid.

Health effects are calculated from doses to specific organs [15]. Doses to specific organs are calculated using dose conversion factors [16]. Early injuries and fatalities (those that occur within one year of the accident) are estimated using nonlinear dose-response models. A recent expert review of radiation induced health effects [17] recommended the use of Hazard functions (H_i) when calculating early injuries or fatalities due to damage to organ i. Thus, the risk (r) per person of contracting a given early health effect is given by

$$r = 1 - \exp\left(\sum_i -H_i\right)$$

$$H_i = \ln 2\,(D_i / D_{50,i})^{\beta}$$

$$H_i = 0 \text{ if } D_i < D_{th,i}$$

where D_i is the dose received by the impaired organ, $D_{th,i}$ is the damage threshold (dose threshold values are poorly known and variable over any population cohort), $D_{50,i}$ is the dose that induces the specified health effect in half of the exposed population (LD_{50} value for deaths), and β is a parameter that determines the slope of the dose-response curve. Sums of Hazard functions are used (1) to model any health effect that has D_{50} values that vary significantly with exposure period, (2) to model early fatalities where death may be caused by the impaired functioning of several organs.

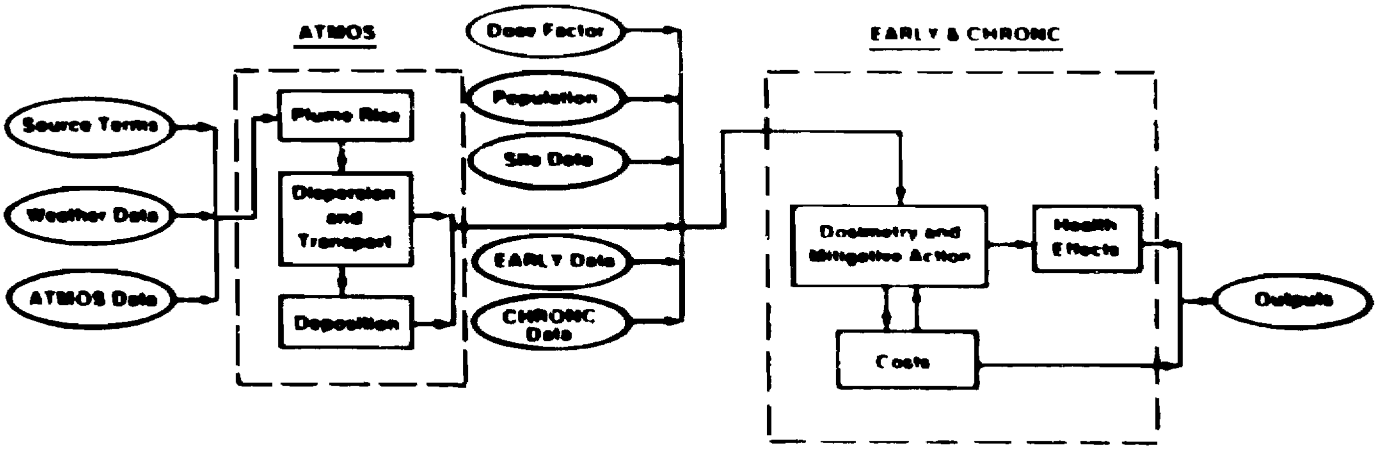
Linear-quadratic, zero-threshold, dose-response models are recommended by several recent reviews of mortality caused by radiation induced cancers [18-20]. However, the quadratic portion of the model is not important, when long term individual exposures are limited to 25 rems in 30 years, as is done in most consequence calculations. Accordingly, cancer fatality predictions are linear with dose. Cancer fatality predictions are not always linear with source term magnitude because dose is avoided by crop disposal and by decontamination and interdiction of land and buildings.

1.3.5 Economic Effects

Economic consequences [21] are estimated by summing the following costs: evacuation costs, temporary relocation costs (food, lodging, lost income), costs of decontaminating land and buildings, the value of crops destroyed because they were contaminated by direct deposition or root uptake, the value of farmland and of nonfarm commercial, public, and individual property that is condemned. Costs for damage to the reactor, the purchase of replacement power, medical care, life-shortening, and litigation are not calculated by MACCS.

1.4 Computational Framework

Figure 1-1 depicts the progression of a consequence calculation for one source term, one weather sequence, and one exposed population distribution. However, severe accidents can lead to source terms of quite different magnitudes (e.g., negligible at TMI, substantial at Chernobyl), and the weather conditions at the time of the release can greatly alter consequence magnitudes (e.g., intense rain at the time of the release or plume transport out to sea would largely eliminate health effects, while rainout of the plume onto a downwind city would greatly increase early fatalities.



[illegible]

Because consequences vary with source term magnitude, weather, and population density, to develop statistical distributions of consequence measures (doses, health effects, costs) that depict the range and probability of consequences for the reactor being examined, consequence assessments must examine all possible combinations of representative sets of source terms, weather sequences, and exposed populations. Usually distributions that display the variation of consequences with weather and population density are first developed for each representative source term. Then an integral depiction of consequences may be constructed by weighted summation of these source term dependent distributions, with each distribution weighted by the estimated absolute probability of occurrence of its underlying source term.

REFERENCES

[1] U.S. Nuclear Regulatory Commission, Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants, NUREG-1150, June 1989.

[2] E. Gorham Bergeron et al., Evaluation of Severe Accident Risks, Vol. 1, Part 1: Methodology for the Accident Progression, Source Term, Consequence, Risk Integration and Uncertainty Analyses, NUREG/CR-4551, SAND86-1309, Sandia National Laboratories, Albuquerque, NM, in preparation.

[3] D. I. Chanin et al., MELCOR Accident Code System (MACCS), Vol. I: User's Guide, NUREG/CR-4691, SAND86-1562, Sandia National Laboratories, Albuquerque, NM, 1990.

[4] H. N. Jow et al., MELCOR Accident Code System (MACCS), Vol. II: Model Description, NUREG/CR-4691, SAND86-1562, Sandia National Laboratories, Albuquerque, NM, 1990.

[5] J. A. Rollstin et al., MELCOR Accident Code System (MACCS), Vol. III: Programmer's Reference Manual, NUREG/CR-4691, SAND86-1562, Sandia National Laboratories, Albuquerque, NM, 199

[6] U.S. Nuclear Regulatory Commission, PRA Procedures Guide, Vol. II, Chapter 9, "Environmental Transport and Consequence Analysis," NUREG/CR-2300, Washington, DC, 1983.

[7] CEC, Radiation Protection: Methods for Assessing the Off-Site Radiological Consequences of Nuclear Accidents, EUR 10 [illegible] en, Commission of the European Communities, Luxemburg, 1984.

[8] D. Randerson, ed., Atmospheric Science and Power Production, DOE/TIC-27601, U.S. Department of Energy, Washington, DC, 1984.

[9] S. R. Hanna, Handbook on Atmospheric Diffusion, [illegible] U.S. Department of Energy, Washington, DC, 1982.

[10] U.S. Nuclear Regulatory Commission, Reactor Safety Study, Appendix VI, "Calculation of Reactor Accident Consequences," WASH-1400, Washington, DC, 19[illegible]

(11) L. T. Ritchie et al., *Calculation of Reactor Accident Consequences, Version 2*, NUREG/CR-2324, Sandia National Laboratories, Albuquerque, NM 1981

12 K. Woodard and T. E. Potter, "Modification of the Reactor Safety Study Consequence Computer Program (CRAC) to Incorporate Plume Trajectories," *Trans. Am. Nucl. Soc.*, Vol. 33, No. 193 (1979)

13 A. Bayer et al., "The German Risk Study: Accident Consequence Model and Results of the Study," *Nucl. Technol.*, Vol. 59, No. 2 (1982).

14 R. H. Clarke and G. N. Kelly, *The NRPB Methodology for Assessing Radiological Consequences of Accidental Releases of Activity*," NRPB-R127, National Radiological Protection Board, Chilton, England, 1981.

15 G. E. Runkle and R. M. Ostmeyer, *An Assessment of Dosimetry Data for Accidental Radionuclide Release from Nuclear Reactors*, NUREG/CR-4185, Sandia National Laboratories, Albuquerque, NM 1985

16 D. C. Kocher, "Dose Rate Conversion Factors for External Exposure to Photons and Electron Radiation from Radionuclides Occurring in Routine Releases from Nuclear Fuel Cycle Facilities," *Health Phys.*, Vol. 38, p. 543 (1980)

17 J. S. Evans et al., *Health Effects Model for Nuclear Power Plant Accident Consequence Analysis*, NUREG/CR-4214, Sandia National Laboratories, Albuquerque NM (1985)

18 United Nations Scientific Committee of Atomic Radiation, *Sources and Effects on Ionizing Radiation*, United Nations, NY, 1977.

19 Advisory Committee on the Biological Effects of Ionizing Radiation, *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation*, National Academy of Sciences, Washington, DC, 1980

20 National Council on Radiation Protection and Measurements, *Influence of Dose and Its Distribution in Time on Dose-Response Relationships for Low-LET Radiations*, NCRP Rept. No. 64, Washington, DC 1980.

21 R. P. Burke et al., *Economic Risks of Nuclear Power Reactor Accidents*, NUREG/CR-3673, Sandia National Laboratories, Albuquerque, NM 1984.

2. TRANSPORT PARAMETERS

MACCS allows a release of radioactive materials to the atmosphere to be divided into plume segments, which can have different compositions, release durations, and energies (amounts of sensible heat). Plume segment lengths are determined by the product of the segment's release duration and the average windspeed during release. The initial vertical and horizontal dimensions of each plume segment are user specified. If release occurs into a building wake, then wake dimensions can be used to set the [illegible] crosswind dimensions of the plume. If not, a point source can be specified.

A liftoff criterion (a critical windspeed that increases as plume buoyancy increases) [illegible] determines whether buoyant plumes are subject to plume rise. When the windspeed at release equals or exceeds the critical windspeed, plume rise is prevented. When the windspeed at release is less than the critical windspeed, plume rise is allowed, and the height to which a buoyant plume rises is determined using equations recommended by [illegible].

After release, windspeed determines the rates at which plume segments transport in the downwind direction, and wind direction at the time of release determines the direction of travel. As is done by most consequence codes, [illegible] MACCS neglects wind trajectories. The sixteen compass sector population distributions are assumed to constitute a [illegible] set of downwind exposed populations. The exposure probability of each of the 16 compass sector population distributions is assumed to be given by the frequency with which wind blows from the site into the sector [illegible] compass sector site wind rose frequencies).

During transport, dispersion in the vertical and horizontal (crosswind) directions is estimated using a Gaussian plume model [illegible]. Dispersion rates depend on windspeed and on atmospheric stability. The crosswind Gaussian distribution of each plume segment is approximated by a multistep histogram. Although horizontal dispersion of plume segments is unconstrained, vertical dispersion is bounded by the ground and by the top of the mixing layer (as specified by annual or seasonal mixing layer heights [illegible]), which are modeled as totally reflecting layers using mirror image sources [illegible]. Since the number of reflections increases as travel time lengthens, the vertical distribution of each plume segment eventually becomes [illegible] and is so modeled thereafter 8.

In MACCS, aerosols are removed from the plume by [illegible], which varies with rainfall rate (9), and by diffusion to, impaction on, and gravitational settling onto surfaces. The combined removal rate due to diffusion, impaction, and settling is modeled using an empirical dry deposition velocity (10). Because dry deposition velocity varies with particle size, if the aerosol size distribution is divided into ranges, a dry deposition velocity must be specified for each range.

Water bodies (rivers, great lakes, oceans) are contaminated by direct deposition of radioactive materials onto their surfaces, by runoff of contaminated rain that falls on land, and by washoff from land by uncontaminated rain of previously deposited contamination. Weathering, resuspension, runoff, washoff, and radioactive [illegible] concentrations of radioactive materials deposited on the ground. Weathering is modeled using Gale's equation [11]. Resuspension is modeled using resuspension factors [10] that attempt to represent the average effect of resuspension by many processes at very different rates throughout large regions. Runoff is modeled by assuming that some fixed fraction of all materials initially deposited onto land is rapidly transferred to water bodies either during the initial rain event or by rain events that occur very soon after the initial deposition [12]. Washoff is modeled as a first order removal process that is integrated over all time after the initial deposition [12]. Decrease of radioactivity due to radioactive decay treats only first generation daughter products, since doses from second generation daughters are insignificant.

2.1 Reactor Dimensions

2.1.1 Recommendation

Table 2.1 gives the values recommended for initial plume (reactor wake) dimensions for the MACCS NUREG-1150 calculations.

Table 2.1 Values for Initial Plume Dimensions

	BUILDH[a]			BUILDW[b]		
Reactor	Value	Range	Distribution	Value	Range	Distribution
Surry	50	10-50	Uniform	40	[illegible]	Uniform
Sequoyah	40	10-40	Uniform	40	10-22[illegible]	Uniform
Peach Bottom	50	10-50	Uniform	50	[illegible]	Uniform
Grand Gulf	60	10-60	Uniform	40	[illegible]	Uniform

[a] BUILDH - Building height
[b] BUILDW - Building width

2.1.2 Discussion

In MACCS, the values specified for BUILDH and BUILDW determine the initial size of the plume upon escape from the wake of the reactor. Specifically, initial values for σ_z and σ_y, the vertical and crosswind standard deviations of the Gaussian plume, are calculated using the following relations [13]:

$$BUILDH = 2.15\ \sigma_z$$

$$BUILDW = 4.3\ \sigma_y$$

These equations allow mixing of the plume into the reactor wake to be modeled by first setting crosswind plume dimensions upon escape from the wake equal to the crosswind dimensions of the wake and then backcalculating an upwind virtual point source for a plume with these dimensions.

Both theory [13b] and experiments [1] suggest that a plume released from a building under turbulent conditions will be entrained by the building's wake and before escaping from that wake will become well mixed throughout its volume. As long as windspeeds are significant, entrainment and thorough mixing occur not only when the release occurs from the lee face of the building, but also from its side, top, or upwind face. However, when conditions are not turbulent, the plume is observed to escape from the wake before becoming well mixed throughout its full volume.

These observations suggest that selecting values for BUILDH and BUILDW may not be straightforward. For example, for release from a rectangular building under turbulent conditions, the crosswind dimensions of the wake will depend on the orientation of the wind relative to the building. Moreover, when turbulence is minimal, initial plume dimensions upon escape from the building wake may be much smaller than the crosswind dimensions of the wake itself. Indeed, if windspeeds are very low, initial plume dimensions may be much closer to the dimensions of the hole in the building from which the plume issues than to the dimensions of the building's wake.

Experiments also indicate that when prevailing conditions are turbulent, plume growth is so rapid that downwind size soon becomes independant of size upon escape from the building wake. Therefore, use of initial plume dimensions appropriate for release under nonturbulent conditions will not lead to significant errors if applied to releases under turbulent conditions. But failure dimensions are not known for NUREG-1150 source terms and no simple model for mixing into a portion of a building wake is available. Therefore, the specification of plume dimensions upon escape from the building wake when conditions are nonturbulent must be largely a guess.

Since some mixing into the building wake will occur whenever the prevailing wind is not stagnant, use of dimensions significantly larger than the dimensions of the containment failure seems appropriate. This will also be correct for blowdown plumes where dissipation of the energy of the jet produces substantial expansion of the plume (e.g., a jet that issues from a 1 m^2 hole will produce a plume with a cross-sectional area of about 100 m^2 after expansion dissipates the initial energy of the jet [14]). Therefore, somewhat arbitrarily, after rounding to the nearest multiple of 10 m, the dimensions of the reactor containment as read from FSAR drawings [15-18] are given above for BUILDH and BUILDW.

2.1.3 Correlations

BUILDH and BUILDW will be strongly correlated with prevailing atmospheric stability. Specifically, when unstable (Classes A-C) or neutral (Class D) atmospheric conditions prevail, the plume will become well mixed throughout the wake cavity before it escapes from the building wake. Therefore, when unstable or neutral conditions prevail, values at the upper end of the ranges specified above for BUILDH and BUILDW should be used. Conversely, when stable atmospheric conditions prevail (Classes E and F), the plume may either not be completely entrained into the building wake or, if completely entrained, may not become well mixed throughout its volume before escaping.

Therefore, when stable atmospheric conditions prevail, values at the lower end of the ranges specified above for BUILDH and BUILDW should be used. Because BUILDH and BUILDW are both correlated in the same way with atmospheric stability, they are also positively correlated with each other. For blowdown plumes, BUILDH and BUILDW will also be strongly and positively correlated with the energy of the blowdown jet. Finally, for plumes not initialized by blowdown the nature of the correlation of BUILDH and BUILDW with atmospheric stability may cause the distributions of these variables to be bimodal, having small values when stable conditions prevail and large values when neutral or unstable conditions prevail

2.2 Plume Rise

2.2.1 Recommendation

The values in Table 2.2 are recommended for plume rise scaling factors

Table 2.2. Plume Rise Scaling Factors

Variable	Summary
SCLCRW	Linear scaling factor on the critical wind speed (U_c) used in MACCS to determine whether buoyant plumes will be trapped in the turbulent wake of the reactor building complex. For any release, if the wind speed is greater than U_c, the plume is assumed to be trapped in the building wake thereby preventing plume rise. By scaling the value of U_c, the MACCS user can examine the effect of the critical wind speed for escape from the building wake on the occurrence of plume rise. Base value: 1.0 Range [illegible]
SCLADP	Linear scaling factor on the amount of plume rise that will occur when the prevailing atmospheric conditions are characterized by stability classes A-D. Base value: 1.0 Range [illegible]
SCLEFP	Linear scaling factor on the amount of plume rise that will occur when the prevailing atmospheric conditions are characterized by stability classes E-F Base value 1.0 Range [illegible]

2.2.2 Discussion

The parameter values that determine plume rise are all hardwired in MACCS. The user can modify them only by using the scaling factors, SCLCRW, SCLADP, or SCLEFP. A short overview of the plume rise formula that these scaling factors modify is presented below.

SCLCRW is a factor that linearly scales the critical wind speed, U_c, that MACCS uses to determine if buoyant plumes escape from the turbulent wake of a reactor complex before they dissipate all of their buoyancy. The critical wind speed is defined by [1]:

$$U_c = (9.09\ F/L)^{1/3}$$

where
- F = buoyancy flux from the source = $8.8 \times 10^{-6}Q$,
- Q = energy release rate (Joules/s), and
- L = suitable length scale for the reactor building (m).

This expression was first suggested by Briggs [19] and later experimentally confirmed by Hall and Waters during wind tunnel experiments with 1/300 scale models [1]. However, it should be noted that the critical wind speed does not mark a sudden change in the plume position as ground level concentrations change relatively slowly with the buoyancy parameter F/U^3L. Since the coefficient 9.09 is uncertain by something like an order of magnitude, U_c must be uncertain by about a factor of two.

SCLADP is a factor that linearly scales the amount of plume rise predicted by MACCS when the prevailing atmospheric stability class is A through D. The plume rise formula for stability classes A through D used in MACCS is Equation 2.15 in Hanna et al. [3].

$$\Delta h = \frac{1.6\ F^{1/3}\ X^{2/3}}{U}$$

where
- Δh = plume rise above release height (m),
- F = buoyancy flux parameter (m^4/s^3) = $8.8 \times 10^{-6}Q$,
- Q = energy release rate (Joules/s),
- X = down wind distance (m), and
- U = wind speed (m/s).

The above expression is the so called "2/3 law," wh[illegible] studies and laboratory data. In Reference [3] the [illegible] the coefficient 1.6 can be expected to be accurate [illegible] value of Δh must be uncertain by at least a factor [illegible]

SCLEFP **is a factor that linearly scales the amount of plume rise predicted by MACCS when the prevailing atmospheric stability class is E or F. The plume rise formula for stability classes E and F is Equation 3.19 in Hanna et al.** [3]

$$\Delta h = 2.6\ [F/(US)]^{1/3}$$

where

Δh = plume rise above release height (m),
F = buoyancy flux parameter (m^4/s^3) = $8.8 \times 10^{-6}\ Q$,
Q = energy release rate (Joules/s),
U = wind speed (m/s), and
S = stability parameter (see discussion for details)
= $(g/T)\ (dT/dZ + 0.01\ K/m)$.

where

g = gravitational constant = $9.8\ m/s^2$,
T = ambient temperature (K), and
dT/dZ = vertical temperature gradient for stability class E or F.

In NRC Regulatory Guide 1.23 [20], dT/dZ is expressed by

dT/dZ = -0.5 to 1.5 K/100 m, for class E
dT/dZ = 1.5 to 4.0 K/100 m, for class F

By taking the midpoints of these ranges, we have

$dT/dZ = 0.5\ K/100\ m = 0.005\ K/m$, for class E
$dT/dZ = 2.75\ K/100\ m = 0.0275\ K/m$, for class F

After substituting the above values for dT/dZ and 288 K (the reference temperature for the standard atmosphere) for T, we have

$S = 5.1 \times 10^{-4}$, for stability class E
$S = 1.27 \times 10^{-3}$, for stability class F

These values are currently hardwired in MACCS. Note that S is a function of ambient temperature T, which could vary from 270 K to 308 K for a site with a temperate climate.

2.3 Plume Meander

2.3.1 Recommendation

Table 2.3 lists the values recommended for the parameters used in MACCS to correct Pasquill-Gifford σ_y values for the effects of horizontal meandering of plume segments:

Table 2.3. MACCS Correction Parameters

Variable	Definition	Value
TIMBAS	Release time for the Prairie Grass experiments (s)	180
XPFAC1	Release time exponent for releases shorter than BRKPNT	0.2
XPFAC2	Release time exponent for releases greater than or equal to BRKPNT	0.25
BRKPNT	Release time break point for changing from XPFAC1 to XPFAC2 (s)	3600

2.3.2 Discussion

MACCS uses the following equation to correct Pasquill-Gifford σ_y values for the effect of horizontal meandering of plume segments [21]:

$$\sigma_{y,MACCS}(x) = \sigma_{y,P\text{-}G}(x)\ [\Delta t_{seg}/\Delta t_{P\text{-}G}]^m$$

where x is the downwind distance of the plume segment from its point of release, $\sigma_{y,MACCS}(x)$ is the σ_y value used in MACCS, $\sigma_{y,P\text{-}G}(x)$ is the Pasquill-Gifford value for σ_y at the distance x, Δt_{seg} is the release duration of the plume segment, and $\Delta t_{P\text{-}G}$ = 10 minutes [22,23,3b] is the release duration of the Prairie Grass Project [24] plumes, which are the experimental basis for the Pasquill-Gifford curves that express the increase of σ_y with downwind distance [25]. Parameter values for this equation have been reviewed by Gifford [26] who suggests that m = 0.2 when Δt is greater than 3 minutes but less than 1 hour, that m = 0.25 when t = 1 hour, and that m = 0.3 when Δt = 100 hours. Since in MACCS plume segment durations may not exceed 10 hours, m = 0.25 is recommended for plume segments having release durations between 1 and 10 hours.

2.4 Plume Dispersion

The power-law parameter values recommended in Table 2.4 for use in MACCS to **estimate stability-class dependent values for** σ_y and σ_z are the values **developed by Tadmor and Gur** [27]:

Table 2.4 Power-Law Parameter Values for MACCS

<table>
<tr><th>Variable</th><th colspan="6">Definition</th></tr>
<tr><td rowspan="4">DPCYSIGA</td><td colspan="6">Stability class dependent pre-exponential coefficient in the power-law expression for σ_y</td></tr>
<tr><td colspan="6">Values by Pasquill-Gifford Stability Class</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr>
<tr><td>0.3658</td><td>0.2751</td><td>0.2089</td><td>0.1474</td><td>0.1046</td><td>0.0722</td></tr>
<tr><td rowspan="4">DPCYSIGB</td><td colspan="6">Stability class dependent exponent in the power-law expression for σ_y</td></tr>
<tr><td colspan="6">Values by Pasquill-Gifford Stability Class</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr>
<tr><td>0.9031</td><td>0.9031</td><td>0.9031</td><td>0.9031</td><td>0.9031</td><td>0.9031</td></tr>
<tr><td rowspan="5">DPCZSIGA</td><td colspan="6">Stability class dependent pre-exponential coefficient in the power-law expression for σ_y</td></tr>
<tr><td colspan="6">Values by Pasquill-Gifford Stability Class</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr>
<tr><td>0.9031</td><td>0.9031</td><td>0.9031</td><td>0.9031</td><td>0.9031</td><td>0.9031</td></tr>
<tr><td>0.00025</td><td>0.0019</td><td>0.2</td><td>0.3</td><td>0.4</td><td>0.2</td></tr>
<tr><td rowspan="4">DPCZSIGB</td><td colspan="6">Stability class dependent exponent in the power-law expression for σ_y</td></tr>
<tr><td colspan="6">Values by Pasquill-Gifford Stability Class</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr>
<tr><td>2.1250</td><td>1.6021</td><td>0.8543</td><td>0.6532</td><td>0.6021</td><td>0.6020</td></tr>
</table>

2.4.1 Discussion

In MACCS, horizontal and vertical dispersion of plume segments about their centerlines are calculated using Gaussian plume models [21]. These models assume that dispersion of plume materials produces normal distributions in the horizontal (y) and vertical (z) directions. Thus, the standard deviations (σ_y and σ_z) of these distributions determine the horizontal and vertical extent of each plume segment and are calculated using the following:

$$\sigma_y = ax^b \qquad\qquad \sigma_z = cx^d \tag{2.1}$$

where a = DPCYSIGA, b = DPCYSIGB, c = DPCZSIGA, d = DPCZSIGB, and x is the distance from the segment's release point to its present location. The values of the coefficients a, b, c, and d depend on atmospheric stability and thus vary with the six stability classes (Pasquill-Gifford classes A-F) used in MACCS. So whenever stability class changes, the apparent upwind location of the release (virtual source distance) must be recalculated by solving Equation 2.1 for x using the current value of σ_y or σ_z and the values of the parameters a, b, c, and d that correspond to the new atmospheric stability class.

Analytical fits of Equation 2.1 to experimental diffusion data measured in the field have been developed for all of the six Pasquill-Gifford stability classes by Tadmor and Gur [27], by Klug [28], and by Geiss [28]. The fits of Tadmur and Gur and of Klug are based on data gathered during the Prairie Grass Project [24]. The fits of Geiss are based on field studies of diffusion performed near the Julich Nuclear Research Center in Germany. The Prairie Grass experiments were conducted over flat terrain covered by prairie grass (low surface roughness). The releases were cold, of short duration (10 min.), and made at ground level. Downwind measurements were made to a distance of 0.8 km. The Julich experiments were conducted over farmland (medium surface roughness) and woodland (high surface roughness). The releases were cold, had one hour durations, and were made at three heights ([illegible], 100, and 180 m). Downwind measurements were made to a distance of 11 km.

Table 2.5 presents the values of a, b, c, and d developed by Tadmor and Gur, by Klug, and by Geiss:

Table 2.5. Values for Constants in Equation 2.1

		Pasquill-Gifford Diffusion Class					
Study	Constant	A	B	C	D	E	F
Tadmor & Gur	a	0.3658	0.2751	0.2089	0.1474	0.1046	0.0722
	b	0.9031	0.9031	0.9031	0.9031	0.9031	0.9031
	c	0.0002	0.0019	0.2000	0.3000	0.4000	0.2000
	d	2.125	1.6021	0.8543	0.6532	0.6021	0.6020
Klug	a	0.4690	0.3060	0.2300	0.2190	0.2370	0.2730
	b	0.9030	0.8850	0.8550	0.7640	0.6910	0.5940
	c	0.0170	0.0720	0.0760	0.1400	0.2170	0.2620
	d	1.3800	1.0210	0.8790	0.7270	0.6100	0.5000
Geiss 50m	a	1.503	0.876	0.659	0.640	0.801	.294
	b	0.833	0.823	0.807	0.784	0.754	0.718
	c	0.151	0.127	0.165	0.215	0.264	0.241
	d	1.219	1.108	0.996	0.885	0.774	0.662
Geiss 100m	a	0.170	0.324	0.446	0.504	0.411	0.253
	b	1.296	1.025	0.866	0.818	0.882	1.057
	c	0.051	0.070	0.137	0.265	0.487	0.717
	d	1.317	1.151	0.985	0.818	0.652	0.486
Geiss 180m	a	0.671	0.415	0.232	0.208	0.345	0.671
	b	0.903	0.903	0.903	0.903	0.903	0.903
	c	0.2045	0.0330	0.104	0.307	0.546	0.484
	d	1.500	1.320	0.997	0.734	0.5[illegible]	0.500

Figures 2.1 through 2.12 compare the effect of these five sets of parameter values on the increase of σ_y and σ_z with downwind distance. Figures 2.1 through 2.6 present the fits for σ_y. The fits for σ_z are presented in Figures 2.7 through 2.12.

Because in MACCS reactor building dimensions determine the initial size (initial σ_y and σ_z values) of plume segments, the slope of the fits displayed in Figures 2.1 through 2.12 is important, but the magnitude of σ_y or σ_z (size of the plume) at a given distance is not. For example, if the width of the reactor building specified in MACCS input corresponds to an initial σ_y value of 250 m and the atmospheric stability at plume release is Class E, then Figure 2.5 shows that MACCS will calculate an initial upwind virtual source distance of 100 m if the Geiss 100 m σ_y fit is used and an initial upwind virtual source distance of 400 m if the Tadmur and Gur σ_y fit is used. After this initialization step is completed, plume growth with downwind transport distance will be about the same using either σ_y fit, since both fits have about the same slope.

Figures 2.1 through 2.12 show that for any stability class all the fits have similar slopes with but two exceptions: for stability classes A and B, the Geiss σ_y fits to 100 m releases and the Tadmor and Gur σ_z fits have significantly larger slopes than the other fits to those stability classes. The figures also show that the fits of Geiss to 180 m releases and the fits of Klug have slopes that are qualitatively representative of the envelope of slopes for the fits to any single stability class. Since buovant plumes typically rise 180 m or so after release and most U.S. reactors are situated in regions having surface roughnesses greater than that of prairie grass, use of the Geiss 100 m fits seems indicated. Nevertheless, for the NUREG-1150 calculations, use of the Tadmur and Gur fits is recommended because relative to their uncertainties all of the fits are more or less equivalent and because the Tadmor and Gur fits have been used in most previous NRC consequence modeling studies.

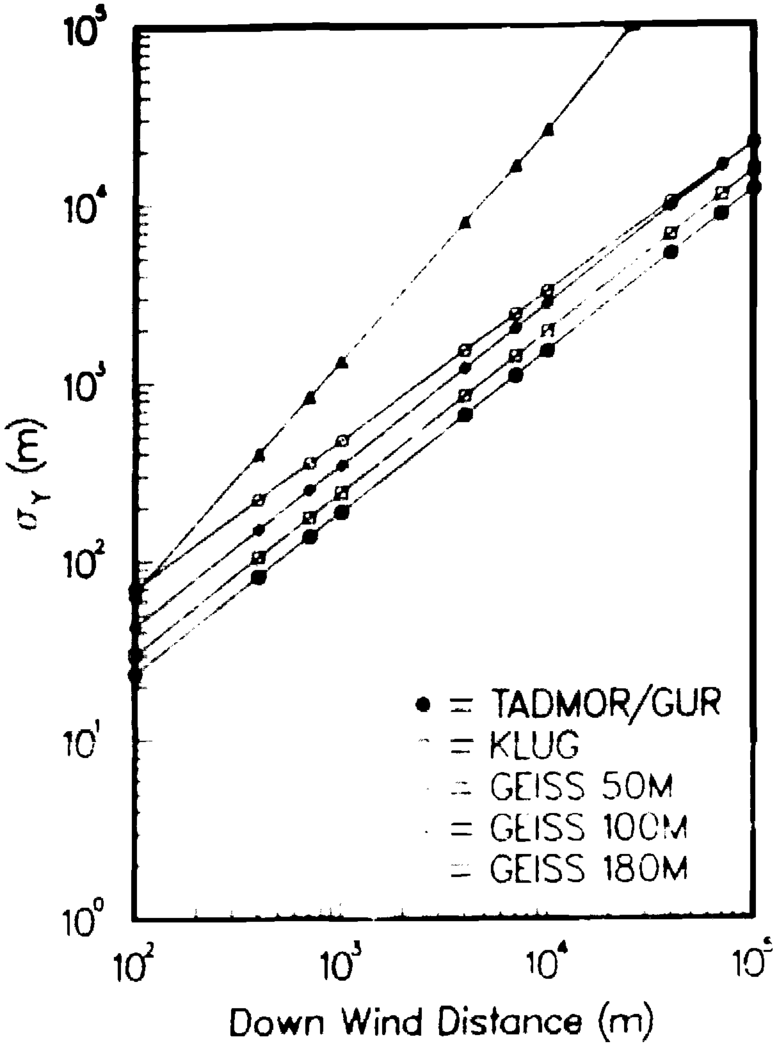


Figure 2-1. Stability Class A. σ_y vs Distance

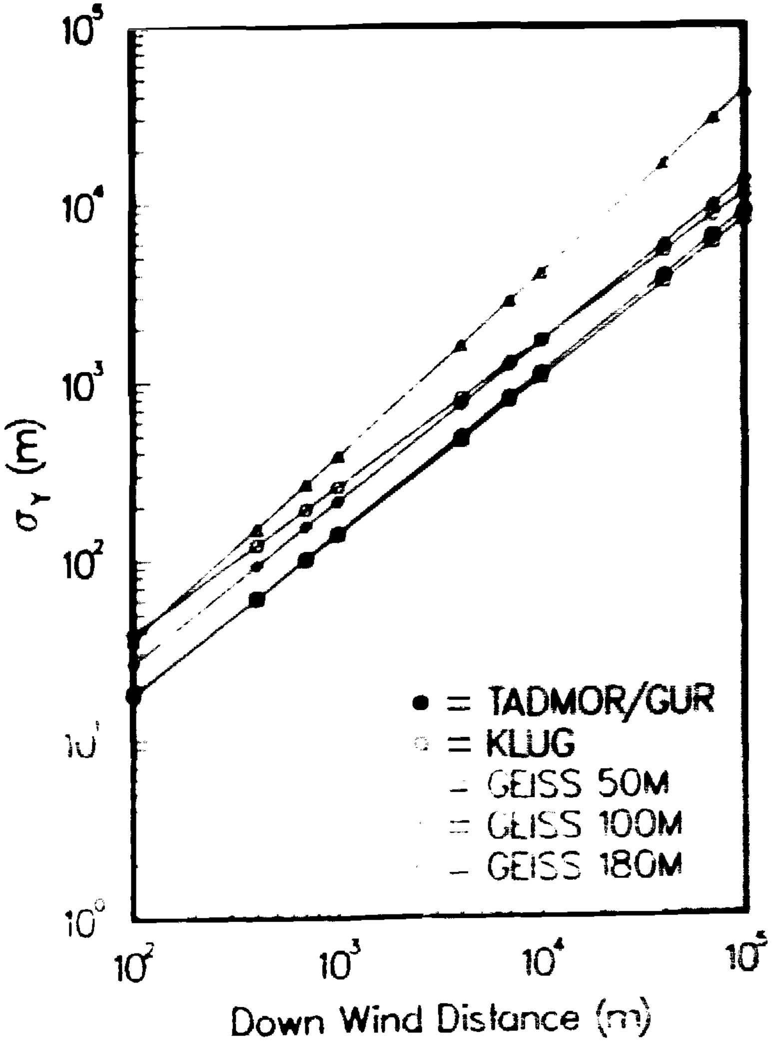


Figure 2-2. Stability Class B. σ_y vs Distance

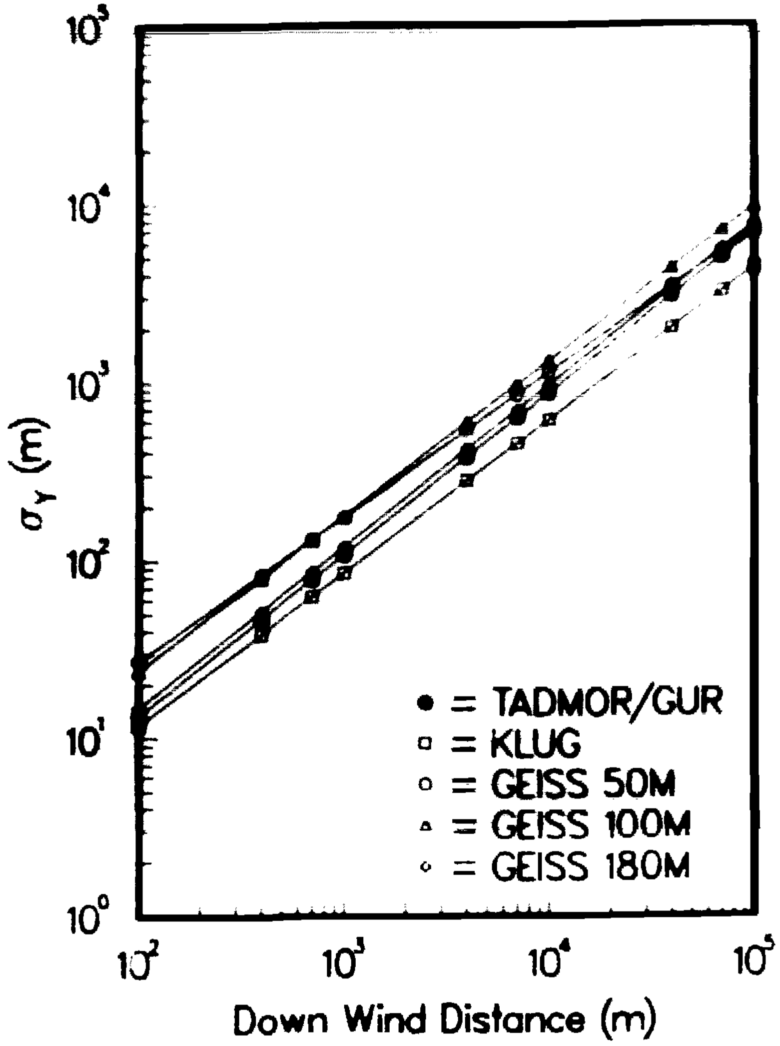


Figure 2-3. Stability Class C: σ_y vs Distance

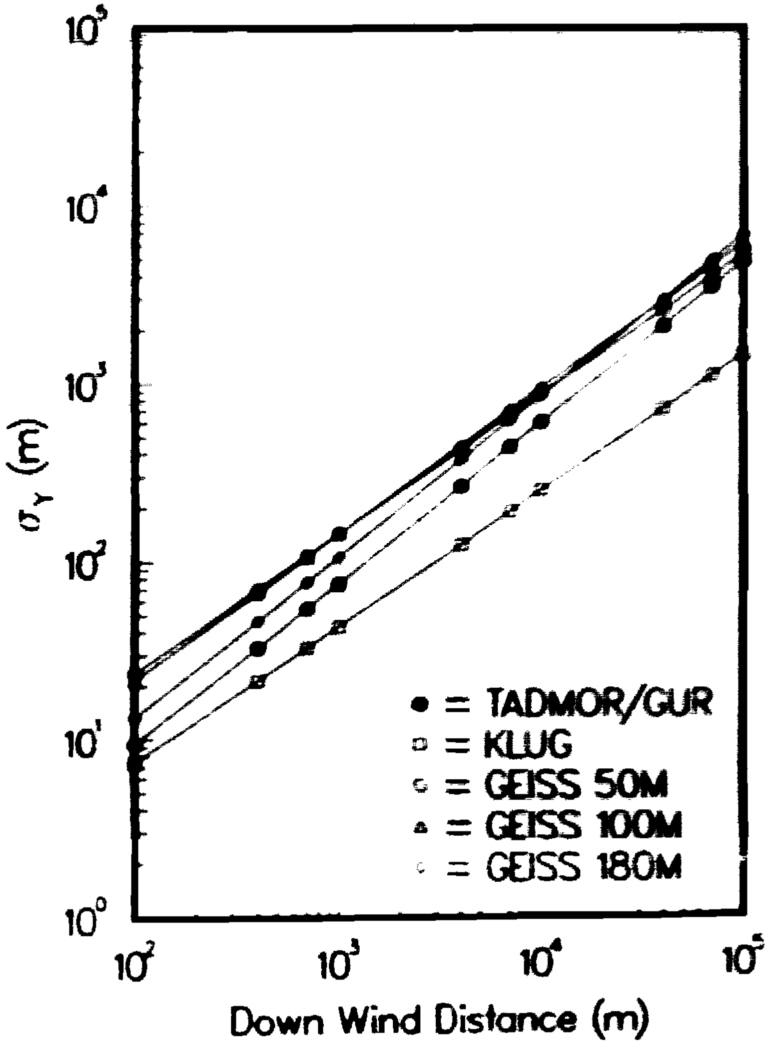


Figure 2-4. Stability Class D: σ_y vs Distance

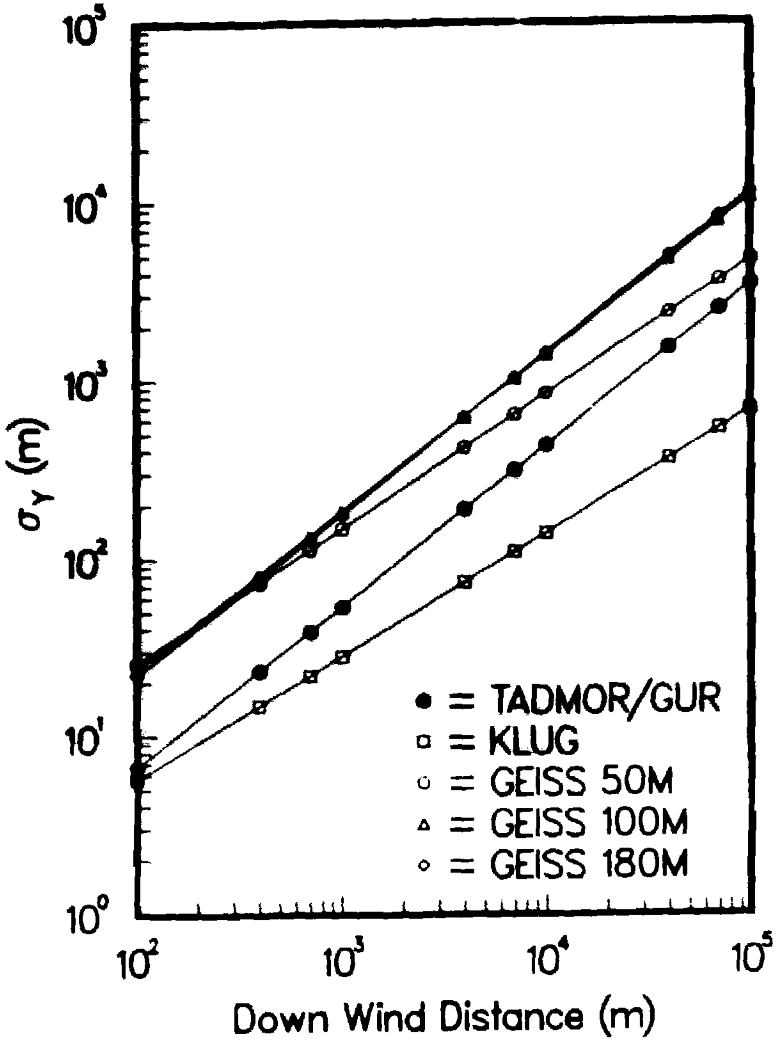


Figure 2-5. Stability Class E: σ_y vs Distance.

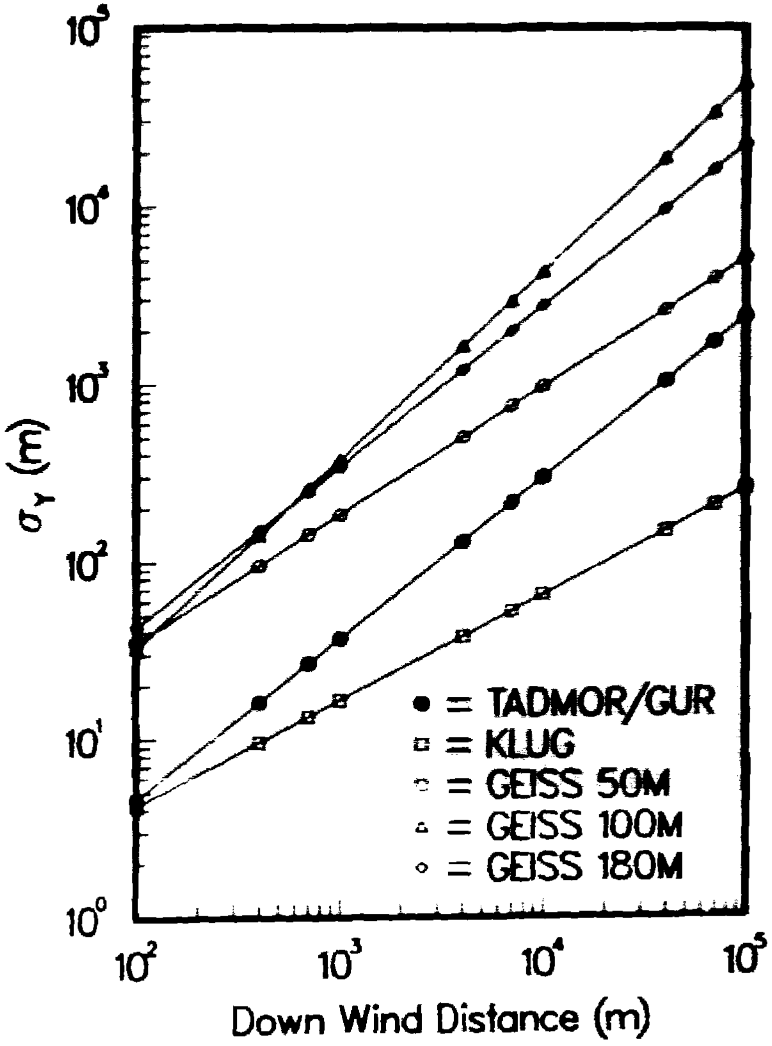


Figure 2-6. Stability Class F: σ_y vs Distance.

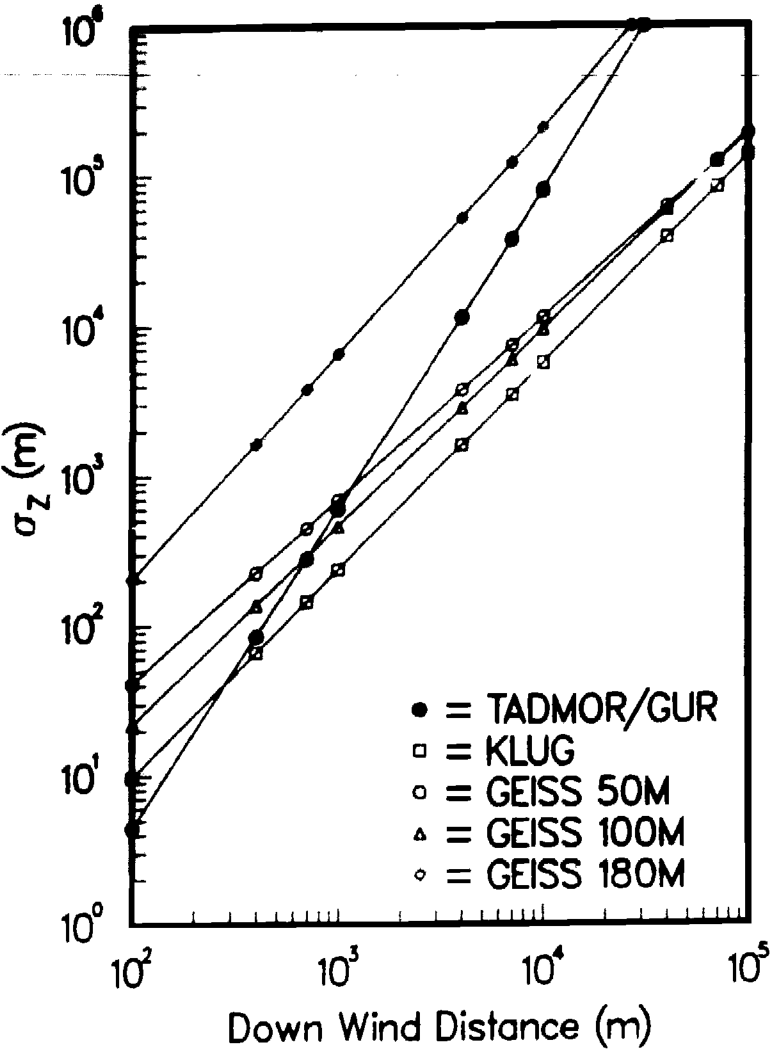


Figure 2-7. Stability Class A: σ_z vs Distance.

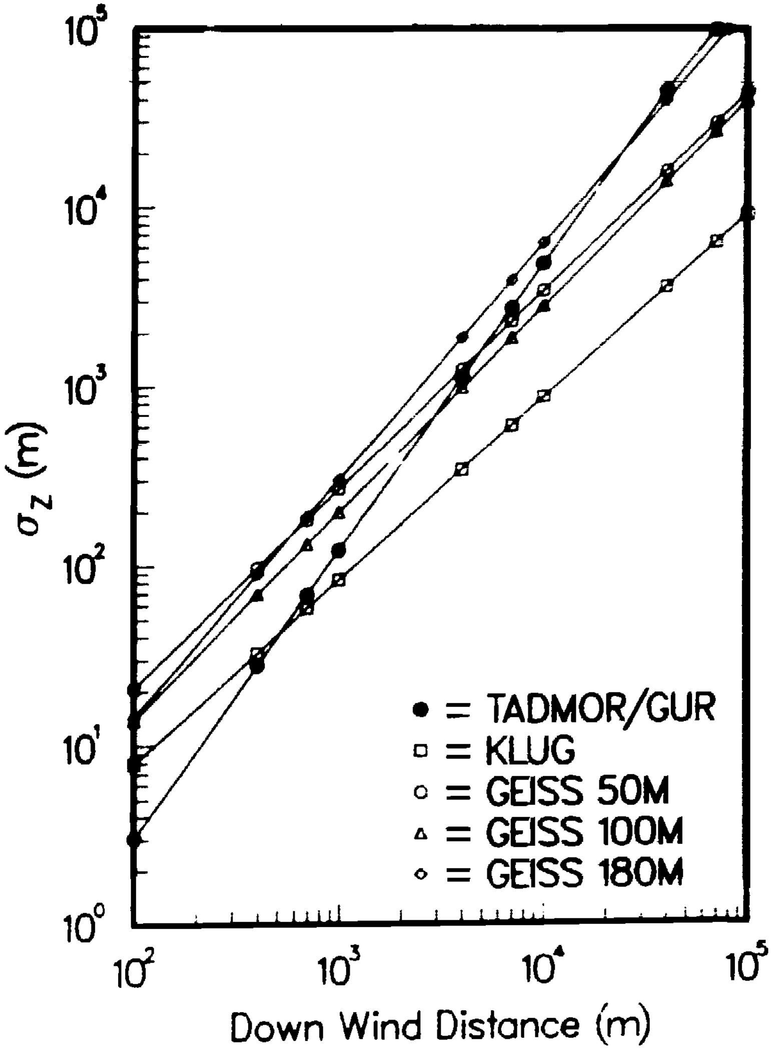


Figure 2-8. Stability Class B: σ_z vs Distance.

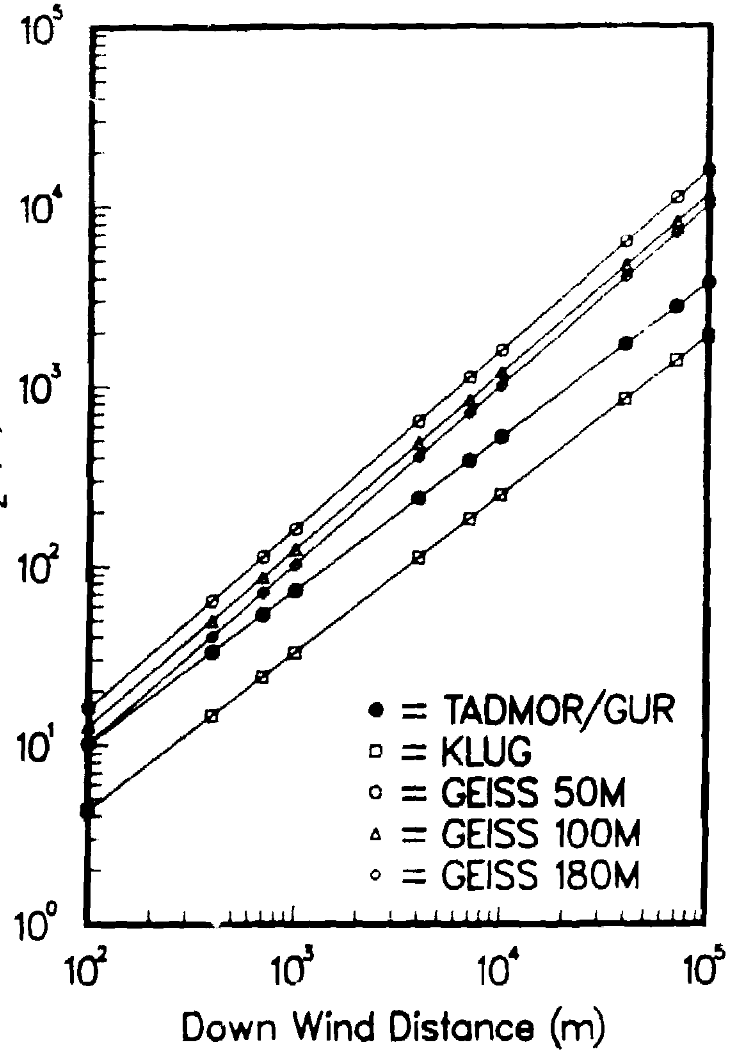


Figure 2-9. Stability Class C: σ_z vs Distance.

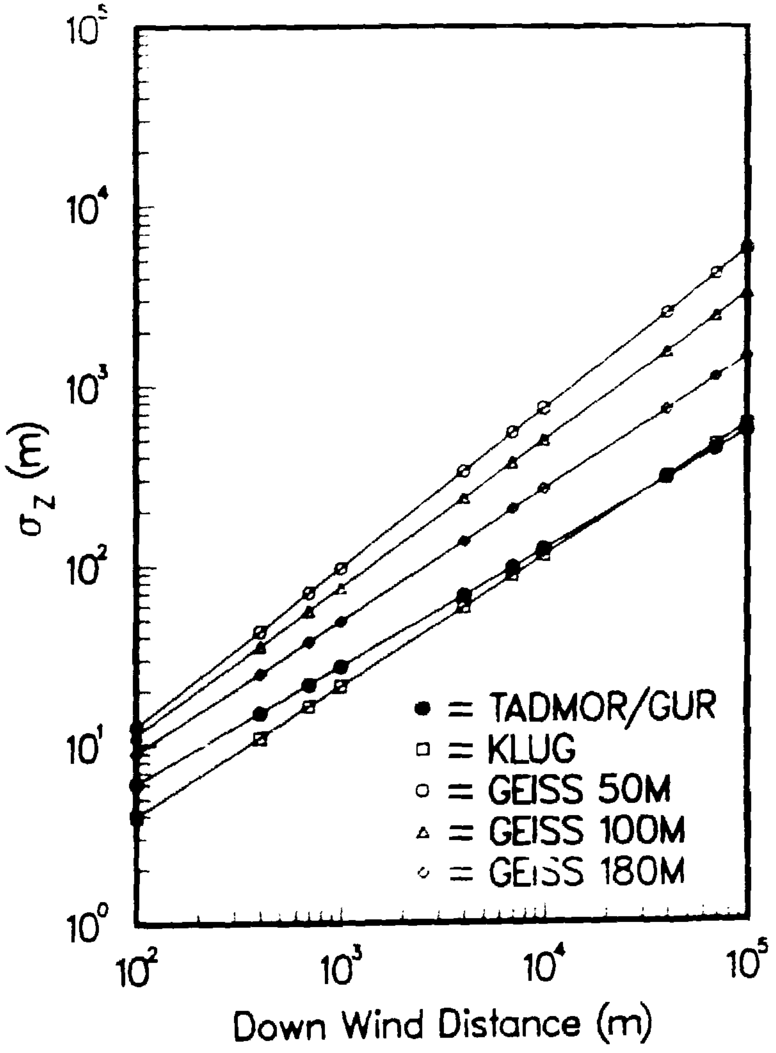


Figure 2-10. Stability Class D: σ_z vs Distance.

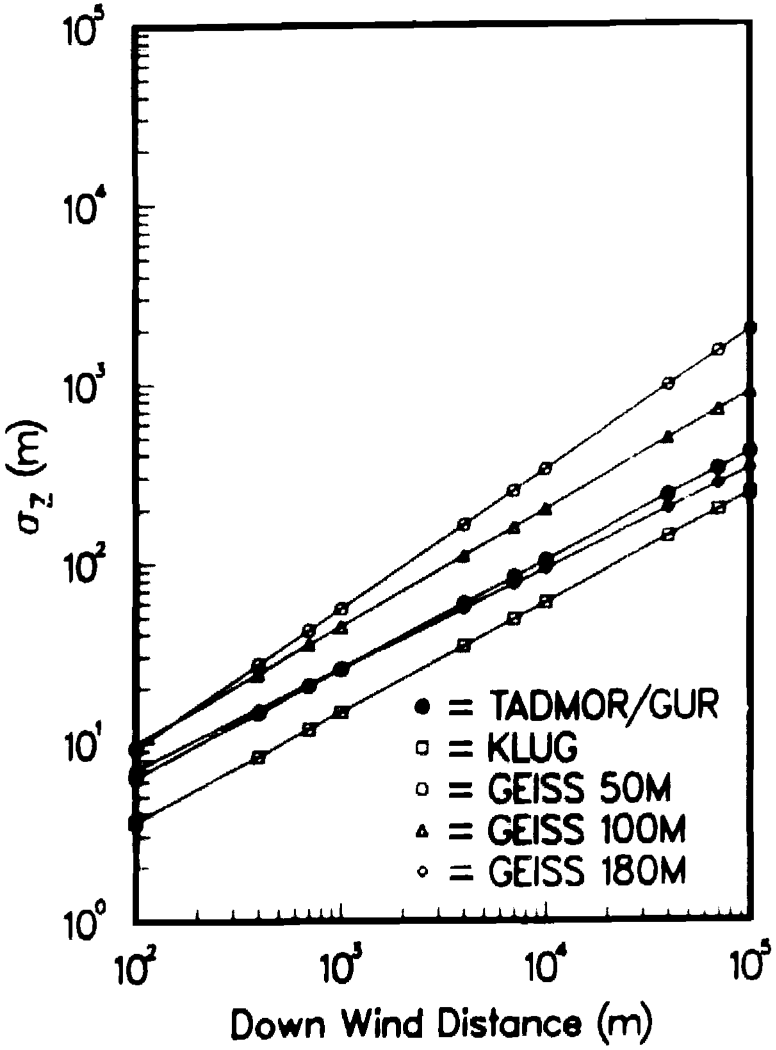


Figure 2-11. Stability Class E: σ_z vs Distance.

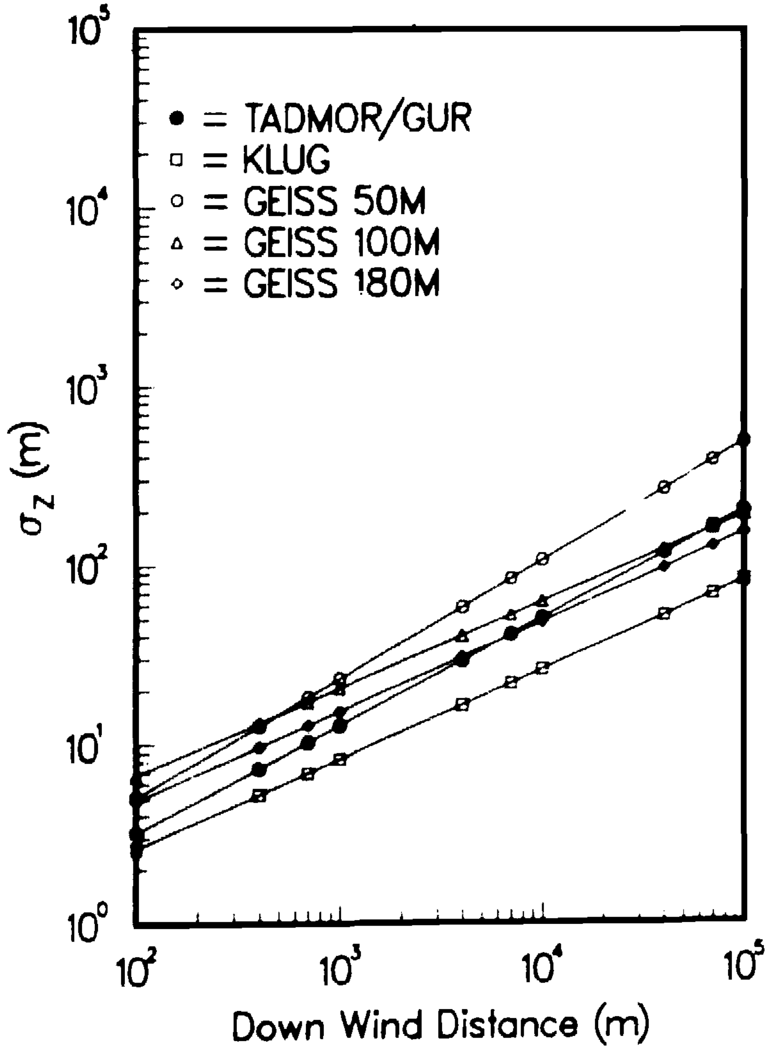


Figure 2-12. Stability Class F: σ_y vs Distance.

2.5 Dry Deposition Velocity

2.5.1 Recommendation

The values in Table 2.6 are recommended for the dry deposition velocity (VDEPOS).

Table 2.6 Dry Deposition Velocity

Variable	Definition	Value	Range
VDEPOS	Dry deposition velosity (cm s^{-1})	0.3	0.03 - 3.0

2.5.1 Discussion

In MACCS, particulate matter is removed from plumes during downwind transport by washout and by dry deposition. Dry deposition is modeled using a mass transfer approach. Thus, the flux (ω) of particles to the ground due to dry deposition is calculated as the product of the ground level air concentration of the particles (χ) and their dry deposition velocity (v_d = VDEPOS), where the dry deposition velocity is an empirical, particle-size dependent parameter that represents the combined effects of diffusion to, impaction on, and settling onto surfaces.

$$\omega = v_d \chi$$

The magnitude of v_d depends on particle size, shape, and density, on atmospheric turbulence (wind speed, stability class), and on surface roughness (z_0) and friction velocity (u_*). Because aerosol size distributions were not developed for NUREG-1150 source terms, a single value for v_d had to be selected for the NUREG-1150 MACCS calculations and the value selected needed to reasonably represent the mean of the range of values that might actually occur.

This discussion of v_d is based on the following assumptions:

Rapid agglomeration of small particles before plume release from containment will largely eliminate particles smaller than 0.5 μm.

Gravitational settling will deplete the distribution of particles larger than 5 μm.

Fission product aerosols will have densities of a few grams per cubic centimeter (1 - 4 g/cm^2).

The value selected for v_d should well represent deposition to suburban areas because most population exposures will occur in suburban areas.

Both theoretical [10,29,30] and experimental [illegible] estimates of the magnitude of v_d are available. A theoretical model that gives v_d as a function of particle diameter, particle density, surface roughness, and friction velocity has been developed by Sehmel and Hodgson [29]. Hobert et al. [30] found that $v_d = 0.0036\ u_*$ with little dependence on particle size. The prevailing windspeed (u), its measurement height (z), surface roughness (z_0), and friction velocity (u_*) are related as follows [10]:

$$u = (u_*/k)\ \ln\ [(z+z_0)/z_0] \qquad (2.5.1)$$

where $k = 0.4$ is von Karman's constant.

Table 2.7 presents values of z_0 and u_* for various surfaces

Table 2.7. Values of z_0 and u_*

Surface	z_0	u_*
Lawns	1	40
Tall Grass, Crops	10 - 15	70
Countryside	30	
Suburbs	100	
Trees, Forests	20 - 200	90
Cities	100 - 300	

If $z_0 = 100$ for suburbs and 5 m/s is a typical windspeed at a measurement height of 10 m, then from Equation 2.5.1 $u_* = 87$ cm/s and $v_d = 0.0036\ u_* = 0.0036$ (87 cm/s) = 0.3 cm/s.

Figure 2.13 presents typical results for the Sehmel and Hodgson model for v_d for $u_* = 50$ cm/s. The figure shows that if $z_0 = 10$ cm, an aerosol distribution with a mean size (particle diameter) of 2 μm and a mean density of 2 g/cm^2 will have $v_d = 0.4$ cm/s. Figures from Sehmel [1] similar to this figure give $v_d = 3.0$ cm/s when $u_* = 100$ cm/s, $z_0 = 100$ cm, $r = 5\ \mu$m, and $\rho = 4$ g/cm^3; and $v_d = 0.03$ cm/s when $u_* = 30$ cm/s, $z_0 = 3$ cm, $r = 0.5\ \mu$m, and $\rho = 1$ g/cm^3.

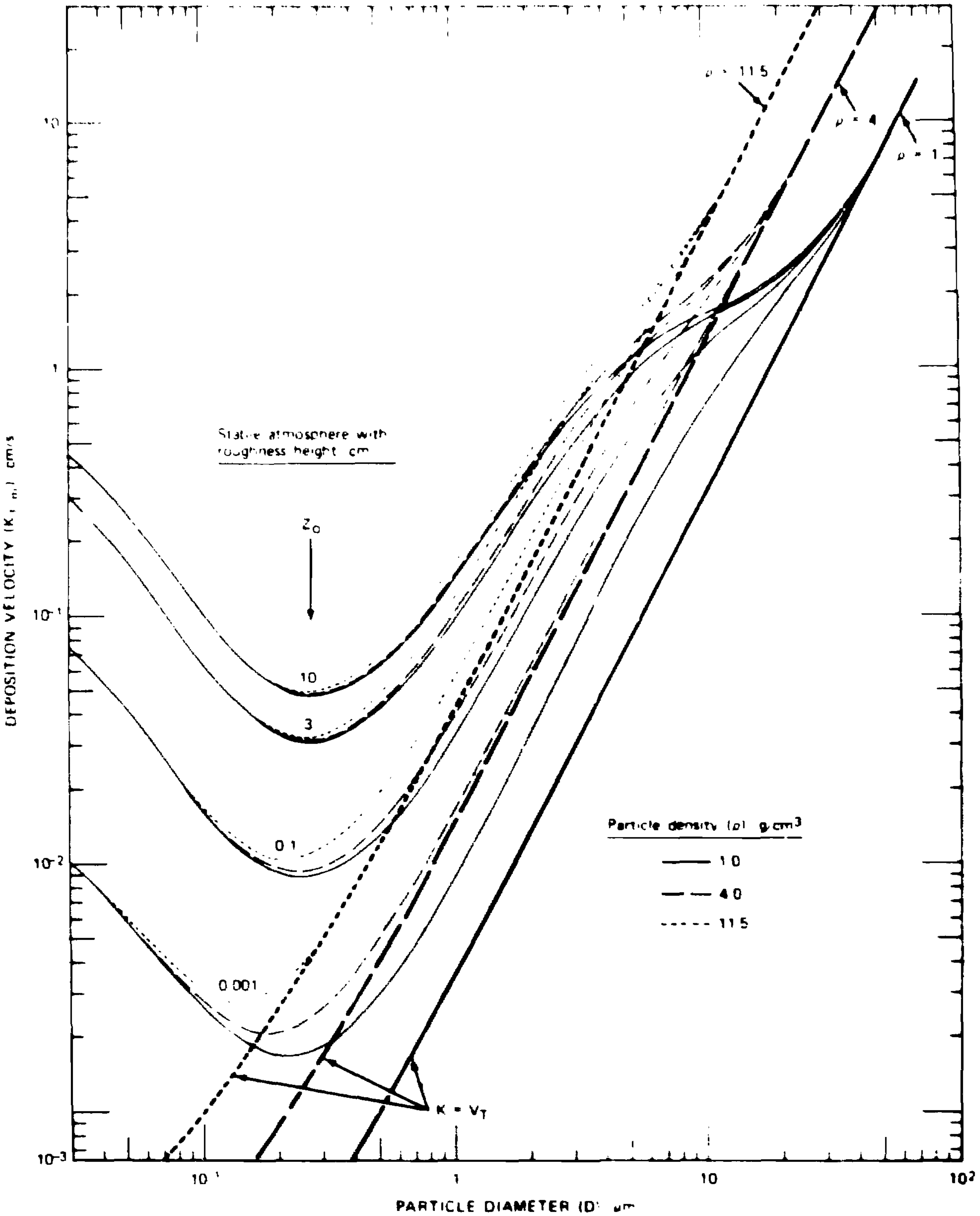


Figure 2.13. Predicted Deposition Velocities at 1 m for u* = 50 cm/s and Particle Densities of 1, 4, and 11.5 g/cm³

Table 2.8 presents experimental values for v_d

Table 2.8. Experimental Values for v_d

Aerosol Composition	Aerosol Size (um)	Deposition Surface	Deposition Velocity Range (cm/s)	Deposition Velocity Arithmatic Mean^a (cm/s)	Reference
--	1	Grass		0.1	[28]
--	1		0.1 -1	0.5	[31]
Various^b		Asphalt	0.01-0.3	0.15	[32]
		Concrete Flagstones	0.005-0.2	0.1	
		Roofs	0.03-0.6	0.3	
		Bare Soils	0.1-0.6	0.3	
		Trees	0.05-1	0.5	
		Forest	0.07-0.9	0.5	
Various^c		Grass	0.03-0.8	0.4	
--	0.1-10	Tall Grass	0.5-2	1.0	[3]
--	0.003-100		0.001-180	0.4^d	[10]

---

[a] Arithmatic mean because for any aerosol size distribution mass will be concentrated amoung the larger particles that will have larger dry deposition velocities.

[b] Aerosols containing Cs-134, Cs-137, I-131, La-140, La-141, Ce-141, Ce-144, Ru-106, Zr-95, and Nb-95.

[c] Aerosols containing Cs-137 and I-131.

[d] Geometric mean because of the large size range

Examination of the table suggests that deposition to roads, lawns, and trees will occur with velocities of about 0.1, 0.3, and 0.5 cm/s. Therefore, if a typical residential suburb has roughly equal amounts of surface area provided by roads, lawns, and canopy (leaves on trees and shrubs), then $v_d = 0.3$. Therefore, since both theory and experiment suggest that v_d = about 0.3 cm/s with a range of 0.03 to 3 cm/s, these values are recommended for use in the MACCS NUREG-1150 calculations.

2.6 Wet Deposition Parameters

2.6.1 Recommendation

The values in Table 2.9 are recommended for use in characterizing plume washout from rainfall.

Table 2.9 Plume Washout from Rainfall

Variable	Summary
CWASH1	Linear coefficient (s^{-1}) in expression defining rate constant for plume washout from rainfall (see Eq. 2.3). Base value: 9.5×10^{-5}. Range: 3×10^{-5} - 3×10^{-4}. Sampling Distribution: Log uniform
CWASH2	Exponential term in expression defining rate constant for plume washout due to rainfall (see Eq. 2.3). Base value: 0.8. Range: 0.2-0.9. Sampling Distribution: Uniform

2.6.2 Rationale

The rain washout model in MACCS is of the form

$$dA/dt = -\lambda A, \quad A(0) = A_0 \qquad (2.2)$$

where

$A(t)$ = amount (Bq/m^2) of a radionuclide in the atmosphere above a region after a period of rainfall of length t (s),

λ = rate constant (s^{-1}) for radionuclide scavenging due to rainfall, and

A_0 = amount (Bq/m^2) of a radionuclide in the atmosphere above a region at the start of a period of rainfall (i.e., at $t = 0$ s).

In turn, λ is assumed to be a function of rainfall intensity. Specifically, λ is defined by

$$\lambda = aR^b \qquad (2.3)$$

where R is the rainfall rate (mm/h) and a = CWASH1 and b = CWASH2 are empirically derived constants.

Additional background on this and other characterizations for rainfall scavenging is available elsewhere [9,33-36].

In MACCS, the constants a and b appearing in Equation 2.3 are used to characterize washout from rainfall. Brenk and Vogt [9] gave the following values for a and b,

$$a = 1.2 \times 10^{-4}, \quad b = 0.5 \tag{2.4}$$

which have been used in past analyses with MACCS. In the NRPB review [33,31], it is concluded that the following ranges characterize values for a and b that are appropriate for use in a reactor accident code that must calculate washout under a variety of conditions:

$$3 \times 10^{-5} \leq a \leq 3 \times 10^{-4}, \quad 0.7 \leq b \leq 0.9 \tag{2.5}$$

For uncertainty studies, the above ranges will be used. Further, the following values at the center of the indicated ranges will be used as base values in the NUREG-1150 consequence analyses:

$$a = 9.5 \times 10^{-5}, \quad b = 0.8 \tag{2.6}$$

2.7 Weathering

2.7.1 Recommendation

The values in Table 2.10 are recommended for characterizing the "weathering" of external exposure in MACCS.

Table 2.10 Weathering of Radionuclides on Ground

Variable	Summary
NGWTRM	Number of different weathering processes selected for consideration. Base Value: 2.
GWCOEF1	Fraction of the deposition undergoing weathering process 1. Base Value: 0.5. Range: 0.25 to 0.75. Sampling Distribution: Uniform
TGWHLF1	Weathering half-life (sec) for fraction of the deposition undergoing weathering process 1. Base Value: 1.6×10^7 s. Range: 7.8×10^6 to 2.3×10^7. Sampling Distribution: Uniform.
GWCOEF2	Fraction of the deposition undergoing weathering process 2. Value: $1-A_1$.
TGWHLF2	Weathering half-life (sec) for fraction of the deposition undergoing weathering process 2. Base Value: 2.8×10^9 s. Range: 1.4×10^9 to 4.2×10^9. Sampling Distribution: Uniform

2.7.2 Rationale

The "weathering" model in MACCS for external exposure to deposited radionuclides is of the form

$$D(t) = D_0 \, e^{-\lambda t} \sum_{i=1}^{n} \left[A_i \, e^{-\lambda_i t} \right] \qquad (2.7)$$

where

$D(t)$ = dose rate (Sv/s) from a ground-deposited radionuclide at time t (s) after its initial deposition.

D_0 = dose rate (Sv/s) at the time of initial deposition (i.e., at $t = 0$ s),

λ = decay constant (s^{-1}) for the radionuclide under consideration,

n = number of different weathering processes selected for consideration (e.g., short term and long term),

A_i = fraction of the deposition undergoing weathering process i (subject to the constraint that $A_1 + \ldots + A_n = 1$), and

λ_i = decay constant (s^{-1}) for the portion of the external dose subject to weathering process i

In turn, the λ_i are defined by

$$\lambda_i = \ln(2)/\tau_i \tag{2.8}$$

where

τ_i = weathering half-life (s), i.e., the time period over which the dose rate subject to weathering process i will decrease by 50%

When only weathering processes are specified (i.e., NGWTRM = 2), then T_1 = TGWHLF1 and T_2 = TGNHLF2.

The use of weathering expressions of the form shown in Equation 2.7 for the assessment of time-dependent external exposure in reactor accident consequence assessments derives from a study by Gale et al. [37]. This study was performed in England and used experimental plots involving five different soil types to estimate the time-dependent external exposure from a deposition of ^{137}Cs. The results of this study lead to the following form of the expression in Equation 2.7:

$$D(t) = D_0 e^{-\lambda t} \left[A_1 e^{-\lambda_1 t} + A_2 e^{-\lambda_2 t} \right] \tag{2.9}$$

where

$A_1 = 0.63$,
$\lambda_1 = \ln(2)/\tau_1 = \ln(2)/0.61 \text{ yr} = 1.13 \text{ yr}^{-1} = 3.65 \times 10^{-8}$ s,
$A_2 = 0.37$, and
$\lambda_2 = \ln(2)/\tau_2 = \ln(2)/92 \text{ yr} = 0.075 \text{ yr}^{-1} = 2.42 \times 10^{-9}$ s.

The relationship in Equation 2.9 was used to estimate dose reduction in WASH-1400 and has also been used in many other reactor accident consequence assessments.

Until recently the study by Gale et al. [37] appears to have been the only study providing any direct information of the time-dependent change in external exposure. However, several additional studies have recently been completed and will be briefly discussed. It is likely that more information on time-dependent weathering will become available in the future as the results of the Chernobyl accident are analyzed.

Warming [38,39] has performed several weathering experiments on impermeable surfaces in Denmark. The 1984 study involved the behavior of ^{86}Rb (an analogue for cesium) on concrete and asphalt surfaces. The following results were obtained. For one-year-old concrete, a maximum of 60% of the contamination (i.e., $A_1 = 0.6$) was weathered away with a half-life of 100 days (i.e., τ_1 = 0.2[illegible] yr). For "young" asphalt, 60% of the contamination (i.e., A_1 = 0.6) is removed with a half life of 60 days (i.e., τ_1 = 0.16 yr). An "old" concrete surface lost 40% (i.e., A_1 = 0.4) with a half life of 100 days (i.e., τ_1 = 0.27 yr). An "old" asphalt surface showed no signs of weathering (i.e., A_1 = [illegible]). The 198[illegible] study involved the behavior of ^{86}Rb, ^{130}Ru, and ^{44}Ba on asphalt surfaces. The combined results of this studied estimated A_1 to be 0.2[illegible] ± [illegible] and τ_1 to be 78 ± [illegible] days = 0.22 ± 0.1[illegible] yr.

Karlberg [illegible] studied the behavior of post-Chernobyl depositions on impermeable surfaces in Sweden. He provides the following summary for his results:

> In general, the different nuclides seem to act in a similar way. The average remaining fraction after 12 months is around 0.[illegible] except for paving stones, where the fraction is 0.8. For ^{103}Ru and ^{110}Ag^{m} on asphalt, the removal also seems to be less than for the other nuclides. A rough estimate of the remaining fraction and half-life times for 'short' weathering gives 0.3 and 104 days, 0.6 and 105 days, and 0.70 and 100 days for paving stones, asphalt, and concrete, respectively.

Thus, for various impermeable surfaces, Karlberg is observing values for A_1 that range from 0.2 to 0.7 and values for τ_1 that range from 0.27 yr to 0.38 yr. Further, Figure 2 in Karlberg's paper suggests that the corresponding values above a grass covered area might be in the area of A_1 = 0.15 and τ_1 < 60 days = 0.16 yr. The depositions considered by Karlberg involved rain during and after the passage of the plume and before the first measurements were made.

Jacob et al. [41] studied the behavior of post-Chernobyl depositions in southern Bavaria. They provide the following summary of their results.

> Surface activities on paved areas have been determined by in situ measurements in Munich after a deposition of radionuclides from Chernobyl by heavy rain. No significant differences were found between asphalt, concrete, and granite pavements. In the first few days, about 50-70% of the caesium was removed by run-off with the depositing rain and by street cleaning. Barium behaved as cesium, about 80% of the ruthenium and about 90% of the iodine were removed. About 70% of the cesium initially retained disappears from the streets and squares with a half-life of about 80 days due to weathering and street cleaning. Cobbled pavement turned out to retain the radionuclides more effectively. In situ measurements on lawns supported the suggestion that the analytical approximation of Gale et al. under-estimates the external exposures from deposited cesium.

Thus, for impermeable surfaces, their results support a value of A_1 in the area of 0.9 and an effective value of τ_1, which is considerably less than 80 days = 0.22 yr when the effects of early runoff are included. Their statement with respect to Gale's equation is not entirely correct. In their comparison, they reduced the initial ground concentration by 30% because of infiltration effects. Such a reduction is not generally done when Gale's equation is used, and if this reduction had been omitted, use of Gale's equation would have provided an upper, rather than lower, bound on the external exposure rates observed by the authors.

Additional discussion of the time dependent decrease in external exposure is given in Appendix C of Ostmeyer and Helton [42].

As can be seen from the studies just discussed, there exists considerable variation in the parameters associated with the Equation 2.[illegible]. This variation is due to many factors, including type of deposition surface, method of deposition, and the action of weather and other processes subsequent to deposition. Further, the uncertainty in these parameters for use in MACCS is compounded by the fact that consequence calculations involve both wet and dry deposition, weathering over a long time period, and environments that are a mixture of many different types of surfaces. With the preceding in mind, it was decided to pick values and ranges for use in MACCS that are representative of the observed values but do not allow any sort of rigorous statistical interpretation. Specifically, the following values are selected:

Table 2.11. MACCS Weathering Values

Parameter	Value	Range	Distribution
n	2		
A_1	0.5	0.25-0.75	uniform
τ_1	0.5 yr	0.25-0.75	uniform
A_2	$1-A_1$		
τ_2	90 yr	45-135	uniform

In picking the preceding values, observed results for permeable surfaces (i.e., grass) were weighted more heavily than those for impermeable surfaces, since permeable surface area typically exceeds impermeable surface area (including in most urban and suburban areas). Because the half lives of the radionuclides involved in external exposure calculations are relatively short (i.e., <30 yr), the parameter τ_2 is not very important.

2.8 Runoff and Washoff

2.8.1 Summary

Table 2.12 summarizes the base values and ranges for the variables for surface-water contamination.

Table 2.12 Base Value and Range for Variables Associated with Surface-Water Contamination

Variable	Summary
NUMWP	Number of radionuclides to be considered in the drinking-water pathway. Base Value: 4.
NAMWPI	Names of radionuclides to be considered in the drinking-water pathway. Selected Radionuclides: ^{89}Sr, ^{90}Sr, ^{134}Cs, ^{137}Cs
WSHFRI1	Initial radionuclide wash-off fraction for ^{89}Sr. Base Value: 0.01. Range: 0.002 to 0.02. Sampling Distribution: Log Uniform
WSHFRI2	Same variable as WSHFRI1 (but for ^{90}Sr)
WSHFRI3	Initial radionuclide wash-off fraction for ^{134}Cs. Base Value: 0.005. Range: 0.001 to [illegible]. Sampling Distribution: Log Uniform
WSHFRI4	Same variable as WSHFRI3 (but for ^{137}Cs)
WSHRTA1	Rate constant (yr^{-1}) for long-term wash-off for ^{89}Sr. Base Value: 0.004. Range: 0.0008 to 0.008. Sampling Distribution: Log Uniform
WSHRTA2	Same variable as WSHRTA1 (but for ^{90}Sr)
WSHRTA3	Rate constant (yr^{-1}) for long-term wash-off for ^{134}Cs. Base Value: 0.001. Range: 0.[illegible] to 0.002. Sampling Distribution: Log Uniform
WSHRTA4	Same variable as WSHRTA3 (but for ^{137}Cs)

Table 2.1[illegible] (cont'd)

Variable	Summary
WINGF1	Water ingestion factor for ^{89}Sr: For Rivers: Base value: 5 x 10^{-6}. Range: 1 x 10^{-6} to [illegible]. Sampling Distribution: Log Uniform. For Large Lakes: Base Value: 2 x 10[illegible]. Range: 1 x 10[illegible] to [illegible] x 10^{-6}. Sampling Distribution: Log Uniform
WINGF2	Water ingestion factor for ^{90}Sr: For Rivers: Same variable as WINGF1. For Large Lakes: Base Value: 2 x 10^{-5}. Range: 1 x 10^{-5} to [illegible]. Sampling Distribution: Log Uniform
WINGF3	Water ingestion factor ^{134}Cs: For Rivers: Base Value: 5 x 10^{-6}. Range: 1 x 10^{-6} to [illegible]. Sampling Distribution: Log Uniform. For Large Lakes: Base value: 2 x 10^{-6}. Range: 1 x 10^{-6} to [illegible]. Sampling Distribution: Log Uniform
WINGF4	Water ingestion factor for ^{13}[illegible]: For Rivers: Same variable as WINGF3. For Large Lakes: Base Value: 4 x 10^{-6}. Range: 2 x 10^{-6} to 2 x 10^{-5}. Take as twice WINGF3 for lakes

2.8.2 Rationale

The radionuclide wash-off model in MACCS is based on the relationship

$$dx/dt = -(\lambda + \lambda_b)\,x, \quad x(0) = (1 - \lambda_a)\,x_0 \qquad (2.10)$$

where

$x(t)$ = amount (bq) of a radionuclide on land surfaces at time t (yr) after an initial deposition at time t = 0,

λ = decay constant (yr^{-1}) for radionuclide,

λ_a = fraction of initial radionuclide deposition that moves from land surfaces to surface-water bodies in a short time period after deposition,

λ_b = rate constant (yr^{-1}) for the long-term [illegible] of the radionuclide from land surfaces to surface-water bodies, and

x_0 = initial radionuclide deposition (bq) on land surfaces.

The quantities λ_a and λ_b are the MACCS input variables WSHFRI and WSHRTA. The quantity x_0 is defined by

$$x_0 = \text{TOTDEP} * \text{FRACLD} \tag{2.11}$$

where

TOTDEP - total deposition (bq) predicted by MACCS for the radionuclide in the region under consideration and

FRACLD - fraction of region under consideration that is land; the remaining fraction 1 FRACLD is assumed to be covered by surface-water bodies.

A single value can be used for FRACLD in a MACCS analysis or FRACLD can be specified for individual grid elements through the use of a Site Data File.

The amount of radionuclide moving from land surfaces to surface-water bodies is given by

$$D_1 = \lambda_a x_0 + \int_0^\infty \lambda_b x(t) dt$$

$$= (\lambda_a \lambda + \lambda_b) x_0/(\lambda + \lambda_b) \tag{2.12}$$

Further, the total deposition directly onto surface-water bodies is given by

$$D_2 = \text{TOTDEP} (1 - \text{FRACLD}) \tag{2.13}$$

Thus, the total amount of a radionuclide entering a surface-water system is given by

$$\text{DTOT} = D_1 + D_2 \tag{2.14}$$

The quantity in Equation 2.14 is then used to determine radionuclide consumption due to water ingestion.

For a given surface-water system, it is assumed that a constant fraction of a radionuclide entering the system will be ultimately consumed via the drinking-water pathway. This fraction is defined by the ratio

$$\text{WINGF} = \text{PTOT}/\text{DTOT} \tag{2.15}$$

where PTOT is the total amount (bq) of radionuclide consumed by the population via the surface-water pathway and DTOT is the total amount of radionuclide entering the surface-water system under consideration (see Equation 2.14).

Some type of analysis/modeling is required to define WINGF. This effort could range from the use of empirical data or simple compartment models to the development/application of quite sophisticated models for surface water systems and their associated public water supply systems. However, in deciding on the amount of effort to invest in determining WINGF, it should be kept in mind that the surface water pathway is probably a small contributor to the total cancer risk from chronic exposure pathways [12,43].

We are interested in values for λ_a = WSHFRI, λ_b = WSHRTA, and WINCF. The quantities λ_a and λ_b are considered first. Table 2.13, which is taken from Helton et al. [12], provides a number of observed values for these quantities. Additional values are given in Table 2.14.

Helton et al. [12] concluded that only four radionuclides, ^{89}Sr, ^{90}Sr, ^{134}Cs, and ^{137}Cs, are needed to treat contamination of surface water bodies. Based on the values for WSHFRI (λ_a) and WSHRTA (λ_b) in Tables 2.14 and 2.15 the following values are recommended for these variables and those nuclides:

Table 2.13 Values for WSHFRI (λ_a) and WSRTH (λ_b)

Isotope	WSHFRI (Range)	WSHRTA (Range)
^{89}Sr	0.01 (0.002 to 0.02)	0.004 (0.0008 to 0.008)
^{90}Sr	0.01 (0.002 to 0.02)	0.004 (0.0008 to 0.008)
^{134}Cs	0.005 (0.001 to 0.01)	0.001 (0.0002 to 0.002)
^{137}Cs	0.005 (0.001 to 0.01)	0.001 (0.0002 to 0.002)

* Considerable subjective judgment was used in selecting these values and ranges.

The development of values for WINCF is now considered. Helton et al. [12] present an exploratory study of the health effects of radionuclide wash-off into surface-water bodies. In that study of wash-off into river systems, WINCF is in effect defined by

$$\text{WINCF} = \text{WT*WC*POP/D} \tag{2.16}$$

where

WT = water treatment factor (i.e., the ratio of radionuclide concentration in water after water treatment to the concentration in water before treatment),

WC = individual water consumption (ℓ/yr-ind),

POP = number of individuals obtaining drinking water from the river under consideration (ind), and

D = river discharge (ℓ/yr).

Two river systems were considered in Reference [12]: the lower Mississippi and Rhein Meuse. Values for WINCF are now calculated using Equation 2.16 and parameter values taken from Reference [12].

Table 2.1[illegible] Removal Rates for Fallout Radionuclides Determined on a Regional Basis (Reference[12], Table 1)

Ref	Nuclide	[illegible]	[illegible]	Location	Comment
Straub et al [44]	^{90}Sr	1.[illegible]*		Continental United States	Three month period
	β emitters	1.[illegible]		Continental United States	Nine month period
	^{90}Sr	[illegible]		Five watersheds in [illegible] Valley	Three month period

*The values for λ_a may be overestimated as λ_a is defined by λ_a=R/D where R and D are the removal in surface water and total deposition, respectively, for each time period considered. No credit is taken for removal of accumulated fallout.

Ref	Nuclide	[illegible]	[illegible]	Location	Comment
Miyake and Tsubota [45]	^{90}Sr		[illegible]	Ten watersheds in Japan	Mean value for [illegible]. The value for [illegible] is estimated as that for direct deposition on water bodies
	^{137}Cs	[illegible]			
Yamagata et al [46]	^{90}Sr	[illegible]	[illegible]	Japan	[illegible] period for λ_a
	^{137}Cs	[illegible]	[illegible]		
Jacobi et al [47]	β emitters	[illegible]	[illegible]	Twenty watersheds in West Germany	[illegible] month period for λ_a Extensive study
Jordan et al [48,49]	^{90}Sr		0.036	Tropical rain forest Puerto Rico	Derives λ_b for stable Sr and uses to predict behavior of ^{90}Sr
Kamada et al [50]	^{90}Sr		0.2–2*	Three watersheds in Japan	

*The values for λ_b may be overestimated as λ_b is defined by λ_b=R/D where R and D are the annual radionuclide removal to surface water and total accumulated deposition, respectively.

Ref	Nuclide	[illegible]	[illegible]	Location	Comment
Miyake et al [51]	^{239}Pu		[illegible] 12	Japan	
Kamada et al [52]	^{90}Sr		[illegible] 2–2	Four watersheds in Japan	
Menzel [53]	^{90}Sr	[illegible]	[illegible]	Eight regions in United States	Two month period for λ_a. Extensive investigation
Simpson et al [54]	^{137}Cs		[illegible]	Hudson River watershed	
Carlsson [55]	^{137}Cs	[illegible]	[illegible] 56	Small watersheds in Sweden	
Sprugel and Bartelt [56]	$^{239,240}Pu$		[illegible] 05	Ohio	
Aarkrog [57]	^{90}Sr	[illegible]	[illegible]	Denmark	Extensive investigation
Linsley et al [58]	^{90}Sr	[illegible]	[illegible]	Upland lake water supplies, England	[illegible] and lake water slightly different [illegible]
	^{90}Sr	[illegible]	[illegible]*	River Thames [illegible]	
	^{137}Cs	[illegible]	[illegible]*	River Thames [illegible]	

Table 2.15 Additional Removal Rates for Radionuclides Determined on a Regional Basis

Ref	Nuclide	100 λ_a	100 λ_b	Comment
[59,60]	^{137}Cs ^{131}I, ^{132}Te, ^{103}Ru	1 4-10		Northern Switzerland and southern Germany in first few weeks following depositions from the Chernobyl accident
[61]	^{137}Cs ^{239}Pu, ^{240}Pu ^{241}Am		0.02 0.02 0.02	Fallout in the Columbia River basin
[62]	^{7}Be ^{137}Cs ^{210}Pb	0.6-2.3	 0.1 0.1	Alpine Rhone watershed in Switzerland. Suggests that value of λ_a for ^{7}Be may also be appropriate for Cs and Pb
[63]	^{239}Pu, ^{240}Pu		0.4	Mississippi drainage basin
[64]	^{210}Pb		0.05	Susquehanna river system
[65]	Pu		0.002-0.08	Modeling study for the continental United States based on the universal soil loss equations

Mississippi for Sr

$$\text{WINGF} = (0.87)\ (370\ \ell/\text{yr-ind})\ (2.9\text{E}6\ \text{ind})/(5.7 \times 10^{14}\ \ell/\text{yr})$$

$$= 1.6 \times 10^{-6} \qquad (2.17)$$

Mississippi for Cs

$$\text{WINGF} = (0.53)\ (370\ \ell/\text{yr-ind})\ (2.9\text{E}6\ \text{ind})/(5.7 \times 10^{14}\ \ell/\text{yr})$$

$$= 1.0 \times 10^{-6} \qquad (2.18)$$

Rhein-Meuse for Sr

$$\text{WINCF} = (1.0)\ (440\ \ell/\text{yr-ind})\ (1.3\text{E}7\ \text{ind})/(8.5 \times 10^{13}\ \ell/\text{yr})$$

$$= 6.7 \times 10^{-5} \qquad (2.19)$$

Rhein-Meuse for Cs

$$\text{WINGF} = (0.1)\ (440\ \ell/\text{yr-ind})\ (1.3 \times 10^{7}\ \text{ind})/(8.5 \times 10^{13}\ \ell/\text{yr})$$

$$= 6.7 \times 10^{-6} \qquad (2.20)$$

Helton et al. [12] also considered the effects of a deposition onto Lake Michigan. The model used in this part of the analysis is equivalent to defining WINGF by

$$\text{WINGF} = \left(\int_0^{\infty} e^{-\lambda t}\, dt/V\right) * WT * WC * POP$$

$$= \frac{WT * WC * POP}{\lambda * V} \qquad (2.21)$$

where V is the volume (ℓ) of the lake, λ is the rate constant (yr^{-1}) for removal from the lake (including radioactive decay, sedimentation, and outflow), and WT, WC, and POP are the same as in Equation 2.16. In turn, λ is defined by

$$\lambda = \ell n(2)/HL \qquad (2.22)$$

where HL is the effective half-life (yr) for the radionuclide under consideration. When Equation 2.21 and Equation 2.23 are combined, the following relationship is obtained:

$$\text{WINGF} = \frac{HL * WT * WC * POP}{\ell n(2) * V} \qquad (2.23)$$

Equation 2.14 and the data in Helton et al. [12] can now be used to estimate WINGF for a release to Lake Michigan.

Lake Michigan for ^{89}Sr

$$\text{WINGF} = \frac{(0.14\ \text{yr})\ (1.0)\ (370\ \ell/\text{yr-ind})\ (1.0 \times 10^{7}\ \text{ind})}{\ell n(2) * (4.87 \times 10^{15}\ \ell)}$$

$$= 1.7 \times 10^{-7} \qquad (2.24)$$

Lake Michigan for ^{90}Sr

$$\text{WINGF} = \frac{(15.4\ \text{yr})\ (1.0)\ (370\ \ell/\text{yr-ind})\ (1.1 \times 10^{7}\ \text{ind})}{\ell n(2) * (4.8 \times 10^{15}\ \ell)}$$

$$= 1.9 \times 10^{-5} \qquad (2.25)$$

Lake Michigan for ^{134}Cs

$$\text{WINGF} = \frac{(0.13\ \text{yr})\ (1.0)\ (370\ \ell/\text{yr-ind})\ (1.1 \times 10^{7}\ \text{ind})}{\ell n(2) * (4.87 \times 10^{15}\ \ell)}$$

$$= 1.6 \times 10^{-6} \qquad (2.26)$$

Lake Michigan for ^{137}Cs

$$\text{WINGF} = \frac{(3.5\ \text{yr})\ (1.0)\ (370\ \ell/\text{yr-ind})\ (1.1 \times 10^{7}\ \text{ind})}{\ell n(2) * (4.87 \times 10^{15}\ \ell)}$$

$$= 4.2 \times 10^{-5} \qquad (2.27)$$

Two additional, very crude calculations are now given for WINGF. The first uses Equation 2.16 and data for the entire United States. Specifically, the following data are used:

WT = 0.87 for Sr, 0.53 for Cs (same as used in Helton et al. [12],

WC = 370 ℓ/yr-ind,

POP = 2.4×10^8 ind * 0.718 = 1.7×10^8 ind, where 2.4×10^8 ind is the population of the United States (<u>Statistical Abstract of the United States 1988</u>) and 0.718 is an approximation of the fraction of the total United States population that receives its water from surface-water bodies (Ref. [66], Table 6-39, p. 345), and

D = $(1,500 \times 10^6$ acre ft/yr) $(1.234 \times 10^6\ \ell$/acre ft) = 1.9×10^{15} ℓ/yr, where $1,500 \times 10^6$ is the annual discharge of rivers in the conterminous United States (Ref. [66], Table 2-2, p. 61)

Then the following approximations to WINGF are obtained

Rivers in Conterminous United States for Sr

$$WINGF = (0.87)(370\ \ell/\text{yr-ind})(1.7 \times 10^{8}\ \text{ind})/(1.9 \times 10^{15}\ \ell/\text{yr})$$

$$= 2.9 \times 10^{-5} \tag{2.28}$$

Rivers in Conterminous United States for Cs

$$WINGF = (0.53)(370\ \ell/\text{yr-ind})(1.7 \times 10^{8}\ \text{ind})/(1.9 \times 10^{15}\ \ell/\text{yr})$$

$$= 1.8 \times 10^{-5} \tag{2.29}$$

The second calculation uses Equation 2.2 and the data for the entire United States. Specifically, the following variable values are assumed

WT = 1 for Sr and Cs,

WC = 370 ℓ/yr-ind,

POP = 1.7×10^{8} ind,

V = 4,500 mi^{3} * 3.38×10^{6} acre ft/mi^{-3} * 1.234×10^{6} ℓ/acre ft

= 1.9×10^{16} ℓ, where 4500 mi^{3} is the volume of freshwater lakes in the conterminous United States (Ref. [66], Table 2-2, p. 61), and

HL = 0.14 yr for ^{89}Sr, 15.4 yr for ^{90}Sr, 1.3 yr for ^{134}Cs, 3.5 yr for ^{137}Cs, where these are the values obtained in Helton et al. [12] for Lake Michigan (values for smaller and/or other lakes could be quite different; e.g., see Santschi et al. [59]).

Then, the following approximations to WINGF are obtained

Lakes in Conterminous United States for ^{89}Sr

$$WINGF = \frac{(0.14\ \text{yr})(1.0)(370\ \ell/\text{yr-ind})(1.7 \times 10^{8}\ \text{ind})}{\ell n(2)\,(1.9 \times 10^{16}\ \ell)}$$

$$= 6.7 \times 10^{-7} \tag{2.30}$$

Lakes in Conterminous United States for ^{90}Sr

$$WINGF = \frac{(15.4\ \text{yr})(1.0)(370\ \ell/\text{yr-ind})(1.7 \times 10^{8}\ \text{ind})}{\ell n(2)\,(1.9 \times 10^{16}\ \ell)}$$

$$= 7.4 \times 10^{-5} \tag{2.31}$$

Lakes in Conterminous United States for ^{134}Cs

$$WINGF = \frac{(1.3\ \text{yr})(1.0)(370\ \ell/\text{yr-ind})(1.7 \times 10^{8}\ \text{ind})}{\ell n(2)\,(1.9 \times 10^{16}\ \ell)}$$

$$= 6.2 \times 10^{-6} \tag{2.32}$$

Lakes in Conterminous United States for ^{137}Cs

$$WINGF = \frac{(3.5\ yr)\ (1.0)\ (370\ \ell/yr\text{-}ind)\ (1.1 \times 10^{[illegible]}\ ind)}{\ell n(2)\ (1.9 \times 10^{16}\ \ell)}$$

$$= 1.[illegible] \times 10^{-5}$$

Several simplistic calculations for WINGF have been given. These calculations are intended to provide only a ballpark estimate of the value of WINGF. The recommendations in Table 2.16 for WINGF are suggested for preliminary assessments of the drinking water pathway.

Table 2.16. Values for WINGF

Isotope	River (Range)	Lake (Range)
^{89}Sr	5×10^{-6} (1×10^{-6} - 1×10^{-5})	2 x [illegible] ([illegible] x 10[illegible] - 1×10^{-5})
^{90}Sr	5×10^{-6} (1×10^{-6} - 1×10^{-5})	2 x 10[illegible] (1 x 10[illegible] - 1 x 10[illegible])
^{134}Cs	5×10^{-6} (1×10^{-6} - 1×10^{-5})	2×10^{-6} (1×10^{-6} - 1×10^{-5})
^{137}Cs	5×10^{-6} (1×10^{-6} - 1×10^{-5})	4×10^{-6} ([illegible] $\times 10^{-6}$ - 2×10^{-5})

The values recommended here for "River" systems are somewhat lower than the screening estimates for WINGF because those calculations probably underestimated effects due to binding to sediments. The values for "Lake" are those obtained for Lake Michigan and they should be used only for a very large lake. The ranges are subjective estimates and are intended to be sampled with a log-uniform distribution.

Note: Although it was obtained too late to use in the development of the parameters presented here, a useful source of information on water use in the United States is Estimated Use of Water in the United States in 1985 by W. B. Solley, C. F. Merk, and R. R. Pierce (USGS Circular 1004, 1988).

2.9 Resuspension

2.9.1 Summary

Table 2.12 summarizes the base values and ranges for the variables for resuspension.

Table 2.12 Base Values and Ranges for Resuspension Variables

Variable	Summary
NRWTRM	Number of resuspension processes under consideration. Base Value: 3
RWCOEF1	Resuspension coefficient for short term resuspension (m^{-1}). Base Value: 10^{-5}. Range: 10^{-6}-10^{-4}. Sampling Distribution: Log Uniform. Rank correlation of 1 with RWCOEF2 and RWCOEF3; rank correlation of -0.75 with TRWHLH1, TRWHLH2 and TRWHLH3.
RWCOEF2	Resuspension coefficient for intermediate term resuspension (m^{-1}). Base Value: 10^{-7}. Range: 10^{-8}-10^{-6}. Sampling Distribution. Log uniform. Correlation same as for RWCOEF1.
RWCOEF3	Resuspension coefficient for long term resuspension (m^{-1}). Base Value: 10^{-9}. Range: 10^{-8}-10^{-10}. Sampling Distribution: Log uniform. Correlations same as for RWCOEF1
TRWHLF1	Half-life (s) for resuspension coefficient RWCOEF1. Base Value: 1.6×10^{7} (~6 mo). Range: 2.6×10^{6}-3.1×10^{7} (~ 1-12 mo). Sampling Distribution. Log uniform. Rank correlation of 1 with TRWHLF2 and TRWHLF3, rank correlation of -0.75 with RWCOEF1, RWCOEF2 and RWCOEF3
TRWHLF2	Half-life (s) for resuspension coefficient RWCOEF2. Base Value. 1.6×10^{8} (~ 5 yr). Range: 3.1×10^{7}-3.1×10^{8} (~ 1-10 yr). Sampling Distribution. Log uniform. Correlations same as for TRWHLF1.
TRWHLF3	Half-life (s) for resuspension coefficient RWCOEF3. Base Value: 1.6×10^{9} (~50 yr). Range: 3.1×10^{8}-3.1×10^{9} (~10-100 yr). Sampling Distribution. Log uniform. Correlations same as for TRWHLF1

Comment. Since RWCOEF1, RWCOEF2, and RWCOEF3 are assumed to have a rank correlation of 1, a single variable can be sampled as a surrogate for all three. The same applies to TRWHLF1, TRWHLF2, and TRWHLF3. Thus, it is necessary to sample only two variables to implement these six variables.

2.9.2 Rationale

The resuspension model in MACCS is based on the resuspension factor approach. The resuspension factor K(t) (m^{-1}) is defined by

$$K(t) = a(t)/s(t) \qquad (2.34)$$

where

a(t) = air concentration (Bq/m^3) of resuspended activity at time t after an initial deposition and

s(t) = initial surface deposition (Bq/m^2) corrected for radioactive decay

Additional discussion is available in a number of reviews [10,42,67,68,69].

In MACCS, K(t) is defined by

$$K(t) = \sum_{i=1}^{n} K_i \exp(-\lambda_i t) \qquad (2.35)$$

where

n = NRWTRM = number of resuspension processes under consideration (e.g., short-term, intermediate-term, and long-term resuspension),

K_i = RWCOEF(i) = resuspension factor (m^{-1}) for the i^{th} resuspension process, and

λ_i = $\ln(2)/\tau_i$ = rate constant (s^{-1}) for the time-dependent reduction in resuspension factor K_i

where

τ_i = TRWHLF(i) = resuspension half-life (s) (i.e., the time period over which the observed air concentration will decrease by 50%)

An excellent review of the data on resuspension is given by Sehmel [10]. As indicated by both the data in this review and statements by the author, there is great uncertainty in characterizing resuspension. For the resuspension model in MACCS, the data in Tables 12.7 and 12.9 of Sehmel will be used to characterize resuspension factors (i.e., the K_i in Equation 2.35). Further, the data in Table 12.8 of Sehmel will be used for guidance with respect to the rate constant λ_i.

Three time periods (i.e., n=3) will be considered in the definition of the resuspension factors: short term (i.e., K_1), intermediate term (i.e., K_2), and long term (i.e., K_3). The short-term and intermediate-term resuspension is assumed to correspond to the larger and intermediate sized factors in Sehmel, Table 12.9. The long-term resuspension corresponds to the values in Sehmel, Table 12.7 and the smaller to values in Sehmel, Table 12.9. Short-, intermediate-, and long-term resuspension is intended to correspond respectively to resuspension which takes place over a few months, a few years, and a few tens of years after deposition.

Table 2.18 shows the values selected for the K_i and the r_i.

Table 2.18 Values for Ki and ri

Variable	Base Value	Range	Comment
K_1	10^{-5}	10^{-6} - 10^{-4}	
r_1	6 mon	1 - 12 mn	1 mon = 2.6 x 10^6 s
K_2	10^{-7}	10^{-8} - 10^{-6}	
r_2	5 yr	1-10 yr	1 yr = 3.1 x 10^7 s
K_3	10^{-9}	10^{-10} 10^{-8}	
r_3	50 yr	10-100 yr	1 yr = 3.1 x 10^7 s

Although the values in Table 2.18 are not inconsistent with the available data, it must be recognized that these quantities are very uncertain.

Changes in environmental conditions are expected to have inverse effects on corresponding values of K_i and ${}_i$, but very similar effects on the set of K_i values, and also on the set of ${}_i$ values. Thus, for sampling purposes, all values of K_i should be assumed to be strongly correlated (e.g., rank correlation of 1), all values of ${}_i$ should be assumed to be strongly correlated (e.g., rank correlation of 1), and corresponding values of K_i and r_i should be assumed to have a moderately strong, negative rank correlation (e.g., -0.75).

For comparison, values for K_i and r_i used in the Reactor Safety Study (i.e., WASH-1400) and suggested in the review by Lassey [67] are listed in Tables 2.19 and 2.20.

Table 2.19. Values in Reactor Safety Study [11]

Variable	Value
K_1	10^{-5}
r_1	1 yr
K_2	10^{-9}
r_2	no decrease with time

Table 2.20 Values in Lassey [67]

Variable	Value
K_1	$9x10^{-5}$
r_1	1.4 mn
K_2	$1x10^{-7}$
r_2	1 yr
K_3	10^{-9}
r_3	no decrease with time

REFERENCES

[1] D. J Hall, and R A Waters *Further Experiments on a Buoyant Emission from a Building*, Warren Spring Laboratory, Stevenage, England, LR 567 (PA), 1986

[2] G. A Briggs, *Plume Rise Predictions*, Environmental Research Laboratories, U S Department of Commerce, National Oceanic and Atmospheric Administration, 1975

[3] S. R. Hanna, G. A. Briggs, and R. P. Hozkers, *Handbook on Atmospheric Diffusion*, DOE/TIC-27601, U.S. Department of Energy, Washington, DC, 1982 (a) p 33, (b) p 375.

[4] U.S. Nuclear Regulatory Commission, *PRA Procedures Guide*, Vol. II, Chapter 9, "Environmental Transport and Consequence Analysis," NUREG/CR-2300, U.S. Nuclear Regulatory Commission, Washington, DC, 1983.

[5] CEC, *Radiation Protection: Methods for Assessing the Off-Site Radiological Consequences of Nuclear Accidents*, EUR 10243 en, Commission of the European Communities, Luxemburg, 1986.

[6] S K. Koa, "Theories of Atmospheric Transport and Diffusion," *Atmospheric Sciences and Power Production*, ed D. Randerson, U.S. Department of Energy, Washington, DC, DOE/TIC-27601, 1984.

[7] G. C. Holzworth, *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States*, AP-101, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1972.

[8] D. B. Turner, *Workbook of Atmospheric Dispersion Estimates*, PSH-999-AP-26, U. S. Department of Health, Education, and Welfare, Washington, DC, 1969.

[9] H. D. Brenk and K. J. Vogt, "The Calculation of W·· Deposition from Radioactive Plumes," *Nuclear Safety*, Vol. 22, pp. 362-371 (1981).

[10] G. A. Sehmel, "Deposition and Resuspension," *Atmospheric Science and Power Production*, ed D Randerson, U.S. Department of Energy, Washington, DC, DOE/TIC-27601, 1984.

[11] U.S. Nuclear Regulatory Commission, *Reactor Safety Study*, Appendix VI, "Calculation of Reactor Accident Consequences," WASH-1400, Washington, DC, 1975.

[12] J. C. Helton, A. B Muller, and A. Bayer, "Contamination of Surface-water Bodies after Reactor Accidents by the Erosion of Atmospherically Deposited Radionuclides," *Health Physics*, Vol 48, pp. 757-771 (1985).

[13] R. P. Hosker, "Flow and Diffusion Near Obstacles," in *Atmospheric Science and Power Production*, ed. D. Randerson, DOE/TIC-27601, U. S. Department of Energy, Washington, DC, 1984, pp 302, 241-326. (a.) p. 302, (b.) pp 241-326.

[14] C. D. Leigh et al., Analyses of Plume Formation, Aerosol Agglomeration and Rainout Following Containment Failure, NUREG/CR-4222, SAND84-2581, Sandia National Laboratories, Albuquerque, NM.

[15] Virginia Electric and Power Co., Final Safety Analysis Report: Surry Nuclear Station.

[16] Tennessee Valley Authority, Final Safety Analysis Report, Sequoyah Nuclear Plant.

[17] Philadelphia Electric Co., Final Safety Analysis Report: Peach Bottom Atomic Power Station, Units 2 & 3.

[18] Mississippi Power and Light Co., Final Safety Analysis Report: Grand Gulf Nuclear Station, Units 1 and 2.

[19] Briggs, G. "Lift Off of Buoyant Gas Initially on the Ground," ADTL Contribution File No. 87, Air Resources Atmospheric Turbulence and Diffusion Laboratory NOAA, Oak Ridge, TN, Nov. 1973.

[20] U.S. Nuclear Regulatory Commission, Onsite Meteorological Programs Safety Guide 23, Regulatory Guide 1.23; Washington, DC, 1972.

[21] H. N. Jow, MELCOR Accident Consequence Code System (MACCS), Volume II, Model Description, NUREG/CR-4691, SAND86-1562, Sandia National Laboratories, Albuquerque NM, 1989, pp. 2-16.

[22] D. H. Slade, Meteorology and Atomic Energy, U.S. Atomic Energy Commission, Washington, DC, 1968, p. 119.

[23] D. Randerson, Atmospheric Science and Power Production, Office of Scientific and Technical Information, U.S. Department of Energy, DOE/TIC-27601, Washington, DC, 1984, p. 375.

[24] M. L. Barad and D. A. Haugen, Project Prairie Grass, Geophysical Research Paper No. 59, Vols. I-III, AFCRC-TR-58-235, Air Force Cambridge Research Center, Bedford, MA, 1958.

[25] F. A. Gifford, "A Review of Turbulent Diffusion Typing Schemes," Nuclear Safety, Vol. 17, p. 68 (1976).

[26] F. A. Gifford, "Atmospheric Dispersion Models for Environmental Pollution Applications," in Lectures on Air Pollution and Environmental Impact Analyses, American Meteorological Society, Boston, MA, 1975, p. 35.

[27] J. Tadmor and Y. Gur, "Analytical Expressions for the Vertical and Lateral Dispersion Coefficients in Atmospheric Diffusion," Atmos. Envir., Vol. 3, p. 688 (1969).

[28] H. D. Brenk et al., "Transport of Radionuclides in the Atmosphere," Radiological Assessment, ed. J. E. Till and H. R. Myer, NUREG/CR-3332, U.S. Nuclear Regulatory Commission, Washington, DC, September 1983.

[29] G. A. Sehmel and W. H. Hodgson, A Model for Predicting Dry Deposition of Particles and Gases to Environmental Surfaces, DOE Rept. PNL-SA-6721, Pacific Northwest Laboratory, NTIS, 1975.

[30] M. Hobert et al., Studies of the Deposition of Aerosols on Vegetation and Other Surfaces, ORNL-tr-4314, Oak Ridge National Laboratory, Oak Ridge, TN, 1976.

[31] J. A. Jones, "The Uncertainty in Dispersion Estimates Obtained from the Working Group Models," The Seventh Report of the Working Group on Atmospheric Dispersion, NRPB-R199, England, 1986.

[32] J. Roed, "Dry Deposition in Rural and in Urban Areas," Presented at the Workshop on the Consequences of an Accidental Contamination of the Urban Environment, Roskilde, Denmark, June 1987.

[33] J. A. Jones, Modelling Wet Deposition from a Short Release, NRPB-R198, National Radiological Protection Board, Chilton, Didcot, Oxon, United Kingdom, 1986.

[34] T. A. McMahon and P. J. Denison, "Empirical Atmospheric Deposition Parameters--A Survey," Atmospheric Environment, Vol. 13, pp. 577-585 (1979).

[35] W. G. N. Slinn, "Precipitation Scavenging," in D. Randerson (ed.), Atmospheric Science and Power Production, U.S. Department of Energy, Office of Scientific and Technical Information, DOE/TIC-27601, pp. 466-532, Washington, DC, 1984.

[36] B. Y Underwood, "Wet Deposition," in B. Y. Underwood, P. J. Cooper, N. J. Holloway, G. D. Kaiser, and W. Nixon, Review of Specific Effects in Atmospheric Dispersion Calculations, Vol. I, EUR8935EN, Commission of the European Communities, Luxembourg, 1984, pp. 3-1 to 3-232.

[37] H. J. Gale, D. L. O. Humphreys, and E. M. R. Fisher, "Weathering of Caesium-137 in Soil," Nature, Vol. 201, pp. 257-261 (1964).

[38] L. Warming, Weathering and Decontamination of Radioactivity Deposited on Asphalt Surfaces, RISO-M-2273, Riso National Laboratory, DK-4000 Roskilde, Denmark, 1982.

[39] L. Warming, Weathering and Decontamination of Radioactivity Deposited on Concrete Surfaces, RISO-M-2473, Riso National Laboratory, DK-4000 Roskilde, Denmark, 1984.

[40] O. Karlberg, "Weathering and Migration of Chernobyl Fall-Out in Sweden," Radiation Protection Dosimetry, Vol. 21, pp. 75-78 (1987).

[41] P. Jacob, R. Meckbach, and H. M. Mueller, "Reduction of External Exposure from Deposited Chernobyl Activity by Run Off, Weathering, Street Cleaning, and Migration in the Soil," Radiation Protection Dosimetry, Vol. 21, pp. 51-57 (1987).

[42] R. M. Ostmeyer and J. C. Helton, Exposure Pathway Models for Accidental Radionuclide Releases, NUREG/CR-5184, SAND88-0620, Sandia National Laboratories, Albuquerque, NM (draft available).

[43] R. B. Codell, "Potential Contamination of Surface Water Supplies by Atmospheric Releases from Nuclear Plants," Health Phys., Vol. 48, pp. 713-730, (1985).

[44] C. P. Straub, L. R. Setter, A. S. Goldin and F. F. Hallbach, "Strontium-90 in Surface Water in the United States," J. Amer. Water Works Assoc., Vol. 59, pp. 756-768 (1960).

[45] Y. Miyake and H. Tsubota, "Estimation of Direct Contribution of Meteoric Water to River Water by Means of Fallout Radiocaesium and Radiostrontium," in Radioisotopes in Hydrology, pp. 425-431 (Vienna: IAEA) (1963).

[46] N. Yamagata, S. Matsuda, and K. Kodaira, "Run-off of Caesium-137 and Strontium-90 from Rivers," Nature, Vol. 200, pp. 668-669 (1963).

[47] W. Jacobi, J. Eichler, and N. Stolterfoht, Korrelation zwischen dem Fallout aus Kernwaffenversuchen und der Spaltproduktaktivitaet in Flusswasser, Hahn-Meitner-Institut fur Kernforschung, Berlin, HMI-B82 (1969).

[48] C. F. Jordan, J. R. Kline, and D. C. Sasscer, "A Simple Model of Strontium and Manganese Dynamics in a Tropical Rain Forest," Health Phys., Vol. 24, pp. 477-489 (1973).

[49] C. F. Jordan and J. R. Kline, "Strontium-90 in a Tropical Rain Forest: 12th-yr Validation of a 32-yr Prediction," Health Phys., Vol. 30, pp. 199-201 (1976).

[50] H. Kamada, M. Yukawa, and M. Saiki, "Studies on Removal of ^{90}Sr in Fall-out from Land to River" (in Japanese), Radioisotopes, Vol. 22, pp. 279-285 (1973).

[51] Y. Miyake, Y. Sugimura, and K. Saruhashi, "Content of Plutonium in River Water in Japan," Pap. Met. Geophys., Vol. 24, pp. 75-78 (1973).

[52] H. Kamada, M. Yukawa, and M. Saiki, "Studies on Removal of Strontium-90, Ruthenium-106, Caesium-137, and Cerium-144 in Land and Fresh Water," in Environmental Surveillance Around Nuclear Installations, Vol. II, pp. 137-146, IAEA, Vienna, 1974.

[53] R. D. Menzel, "Land Surface Erosion and Rainfall as Sources of Strontium-90 in Streams," J. Environ. Quality, Vol. 3, pp. 219-223, (1974).

[54] H. J. Simpson, C. R. Olsen, R. M. Trier, and S. C. Williams, "Man-made Radionuclides and Sedimentation in the Hudson River Estuary," Science, Vol. 194, pp. 179-193 (1976).

[55] S. Carlsson, "A Model for the Movement and Loss of ^{137}Cs in a Small Watershed," Health Phys., Vol. 34, pp. 33-37 (1978).

[56] D. G. Sprugel and G. E. Bartelt, "Erosional Removal of Fallout Plutonium from a Large Midwestern Watershed," J. Environ. Qual., Vol. 7, pp. 175-177 (1978).

[57] A. Aarkrog, Environmental Studies on Radiological Sensitivity and Variability with Special Emphasis on the Fallout Radionuclides ^{90}Sr and ^{137}Cs, Risoe-R 437, Risoe National Laboratory, Roskilde, Denmark, 1979.

[58] G. S. Linsley, S. M. Haywood, and J. Dionian, "The Use of Fallout Data in the Development of Models for the Transfer of Nuclides in Terrestrial and Freshwater Systems," in Migration in the Terrestrial Environment of Long-Lived Radionuclides from the Nuclear Fuel Cycle, pp. 615-634 IAEA, Vienna, 1982.

[59] P. H. Santschi, S. Bollhalder, K. Farrenkothen, A. Lueck, S. Zingg, and M. Sturm, "Chernobyl Radionuclides in the Environment: Tracers for the Tight Coupling of Atmospheric Terrestrial and Aquatic Geochemical Processes," Environmental Science and Technology, Vol. 22, pp. 510-516 (1988)

[60] P. H. Santschi, S. Bollhalder, S. Zingg, A. Lueck, and K. Farrenkothen, "The Self-Cleaning Capacity of Surface Water after Radioactive Fallout. Evidence from European Waters after Chernobyl, 1986-1988," Environmental Science and Technology, Vol. 24, pp. 519-527 (1990).

[61] T. M. Beasley and C. D. Jennings, "Inventories of ^{239,240}Pu, ^{241}Am, ^{137}Cs, and ^{60}Co in Columbia River Sediments from Hanford to the Columbia River Estuary," Environ. Sci. Technol., Vol. 18, pp. 207-212 (1984).

[62] J. Dominik, D. Burrus, and J. P. Vernet, "Transport of the Environmental Radionuclides in an Alpine Watershed," Earth and Planetary Science Letters, Vol. 84, pp. 165-180 (1987).

[63] M. R. Scott, R. J. Rotter, and P. F. Salter, "Transport of Fallout Plutonium to the Ocean by the Mississippi River," Earth and Planetary Science Letters, Vol. 75, pp. 321-326 (1985).

[64] D. M. Lewis, "The Use of ^{210}Pb as a Heavy Metal Tracer in the Susquehanna River System," Geochimica et Cosmochimica Acta, Vol. 41, pp 1557-1564) (1977).

[65] G. R. Foster and T. E. Hakonson, "Predicted Erosion and Sediment Delivery of Fallout Plutonium," J. Environ. Qual., Vol. 13, pp. 595-602 (1984).

[66] D. K. Todd, The Water Encyclopedia, Water Information Center, Port Washington, NY (1970).

[redacted]

[67] K. R. Lassey, "The Possible Importance of Short Term Exposure to Resuspended Radionuclides," *Health Physics*, Vol. 38, pp. 749-761 (1980).

[68] National Council on Radiation Protection, *Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment*, NCRP Report No. 76, National Council on Radiation Protection and Measurements, Bethesda, MD 1984.

[69] W. J. Smith, F. W. Whicker, and H. R. Myer, "Review and Categorization of Saltation, Suspension, and Resuspension Models," *Nuclear Safety*, Vol. 23, pp. 685-699 (1982).

3. EMERGENCY RESPONSE PARAMETERS

3.1 Evacuation Parameters

3.1.1 Recommendation

The values in Table 3.1 for evacuation parameters are recommended for the MACCS NUREG-1150 calculations.

Table 3.1. Recommended Evacuation Parameter Values

Variable	(Units)	Definition	Site	Value	Range[a]
EDELAY	(h)	Evacuation Delay Time	Sur	1.5	1.25 - 3.25
			GG	0.75	0.25 - 1.25
			PB	1.0	0.7 - 1.7
			Seq	1.8	0.5 - 2.0
ESPEED	($m\ s^{-1}$)	Radial Evacuation Speed	Sur	1.8	0.9 - 3.6
			GG	3.7	1.7 - 4.5
			PB	4.8	2.8 - 6.8
			Seq	[illegible].8	1.2 - 6.7

---

[a] All sampling distributions should be uniform over the stated ranges

3.1.2 Data Sources

During 1985, NUS conducted a review for SNL of emergency response plans and estimates of evacuation times prepared for the utilities that run the five NUREG-1150 reactors (Surry, Grand Gulf, Sequoyah, Peach Bottom, and Zion) and, as was appropriate, discussed emergency response assumptions (e.g., evacuation delay period and average evacuation speed) with utility emergency response personnel. NUS submitted the results of this study to SNL in letter reports to which were appended copies of pertinent documentation (e.g., the utility studies of estimated Emergency Protection Zone [EPZ] clearance times) from which the data in the letter reports had been taken. The data presented here were drawn from the NUS reports and supporting documentation.

3.1.3 Surry

The Surry reactor is located on the south side of the James River. On the south side of the river within ten miles of the reactor (i.e., within the EPZ), population densities are low. However, on the north side of the river on the peninsula defined by the James and York rivers, population densities are high because of the presence of three cities: Williamsburg, Newport News, and Hampton. Should a severe accident ever occur at the Surry reactor, evacuation of this peninsula could be difficult because of the high population densities and because only two arteries (I64 and US60) are available to support the evacuation.

Table 3.2 presents EPZ populations for the five counties that neighbor the Surry site and estimates of preevacuation delay periods and average evacuation speeds for a Summer Sunday, a Winter Weekday, and Adverse Weather (winter ice storms).

Table 3.2. Surry Emergency Response Data

County Location	EPZ Pop (x10^-3)	Summer Sunday Delay (h)	Summer Sunday Speed (mph)	Winter Weekday Delay (h)	Winter Weekday Speed (mph)	Adverse Weather Delay (h)	Adverse Weather Speed (mph)
James City	16.5	3.25	4.0			1.25	1.6
Williamsburgh	11.6	2.25	5.7			1.25	2.2
York	8.6	1.25	4.4			1.25	2.5
Newport News	45.3	2.25	3.0			1.25	1.7
Surry/Isle of Wight	4.5	1.25	8.0			1.25	8.0
Total (Population weighted)	86.5	2.3	4.0			1.25	2.2
N of River	82.0	1.25	2.4	1.25	2.7	1.25	1.8
S of River	4.5	1.25	8.0	1.25	8.0	1.25	8.0
Total (Population weighted)	86.5	1.25	2.7	1.25	3.0	1.25	2.1

The population-weighted results for the five counties are probably superior to the population-weighted results for the data for North and South of the river. However, if the county data are used, estimates of the preevacuation delay period and average speed for a Winter Weekday must be developed that are consistent with the county data for a Summer Sunday and Adverse Weather.

The NUS study states that delays in excess of 1.25 h are expected only during the tourist season (summer months). Thus, a preevacuation delay period of 1.25 h should apply to Winter Weekdays, which agrees with the NUS estimates for delays N and S of the river on Winter Weekdays.

The NUS average speed of 3.0 mph estimated from the data for N and S of the river is inconsistent with the population weighted aggregate county data, since the average evacuation speed for the Winter Weekday (3.0 mph) estimated from the data for N and S of the river is lower than the average speed for a Summer Sunday (4.0 mph) estimated from the county data. If the Summer Sunday 4.0 mph speed derived from county data is scaled by the ratio of the Winter Weekday speed (3.0 mph) to the Summer Sunday speed (2.7 mph) developed from the N and S of the river data, then an average evacuation speed of 4.4 mph results.

Two-sevenths of the year are weekend days, and the summer tourist season is about four months long. Therefore, assume that Summer Sunday values apply 30 percent of the time.

$$0.3 = 0.5(2/7 + 4/12)$$

On the coast of Virginia, during the winter (December 21 through March 21) precipitation occurs about 8 percent of the time. If precipitation during the winter is assumed to mean that a severe ice storm has occurred, then during a full year at Surry, adverse weather will occur about 2 percent of the time. Finally, by difference, Winter Weekday values will apply 68 percent of the time.

Yearly average values for the preevacuation delay time and the average evacuation speed at the Surry site may now be estimated using the following equation

$$0.3\ S + 0.68\ W + 0.02\ A = X \qquad (3.1)$$

Table 3.3 presents the yearly average values obtained using this equation.

Table 3.3. Surry Evacuation Parameter Values Estimated from the Seasons and Time of Week

Parameter	Summer Sunday	Winter Weekday	Adverse Weather	Yearly Average
Delay (h)	2.3	1.25	1.25	1.57
Speed (mph)	4.0	4.4	2.2	4.24

Average evacuation speeds for the Surry EPZ can be estimated in at least two other ways. From a map of the peninsula near Williamsburg, one can estimate the following maximum travel distances within the EPZ for population located on the peninsula: maximum travel distance to I64 = 7 mi; and the maximum travel distance on I64 = 5 mi. Therefore, the average evacuation distance within the EPZ is about 6.0 mi = (1/2)(7 + 5). The Surry "Estimation of Evacuation Times" report prepared by PRC Voorhees gives clear time distributions for a Summer Sunday and a Winter Weekday. The distributions show that 50% of the population in the EPZ will be ready to evacuate in 1.0 h and will have cleared the EPZ in 2.6 h. Their average evacuation time is therefore 1.6 h, and their average speed is 3.75 mph = 6.0 mi/1.6 h.

The PRC Voorhees report also presents vehicle capacities (vehicles per hour) for the roads that will be used to exit the EPZ for the counties that neighbor the Surry site, and for the number of vehicles available to support the evacuation in each county. From the number of vehicles available and the total EPZ population of each county, one can estimate that the average evacuating vehicle will be occupied by three people. Thus, from the county EPZ populations and vehicle capacities, one can estimate average evacuation times. Table 3.4 presents these estimates:

Table 3.4. Estimation of Surry Evacuation Times from Vehicle Capacities and Populations

County	EPZ Pop (x10-3)	Vehicle Capacity (x10-3)	Evacuation Time (h)
Surry/Wight	4.5	6.0	0.25
James/Williamsburgh	28.1	7.2	1.3
York	8.6	3.6	0.8
Newport News	45.3	9.6	1.6
Population weighted total	86.5		1.4

Since evacuation of the peninsula will determine average evacuation speeds within the EPZ, that speed can be estimated to be ≈ 4.29 mph = 6.0 mi/1.4 h, where 6.0 is the maximum travel distance within the EPZ on the peninsula

Given the preceding results, a pre-evacuation delay period of 1.5 hours and an average evacuation speed of 4.0 mph (1.8 m s^{-1}) are recommended for NUREG-1150 calculations for the Surry site.

Table 3.5 presents the evacuation delay time and evacuation speed recommended for use at the Surry site and compares the recommended values to those specified by the NRC for use in the first pass NUREG-1150 calculations:

Table 3.5. Values Recommended for Surry Evacuation Parameters

	Recommended Value	NRC
Delay (h)	1.5	1.0
Speed (m s^{-1})	1.8	1.2

3.1.4 Grand Gulf

Evacuation time estimates for the Grand Gulf site are based on a state-of-the-art road network analysis. Data for pre-evacuation delay times and EPZ clearance times (delay time plus evacuation time) were developed for Weekdays, Weekend Days/Nights, and Adverse Weather (severe thunderstorms). Table 3.6 presents the evacuation data.

Table 3.6. Evacuation Data for Grand Gulf

Time/Condition	Average[a] Delay Time (min)	Clear Time (min)	Evacuation Time (min)	Evacuation Time (h)	Maximum Travel Distance (min)	Speed (mph)
Weekday (WD)	45	160	115	1.92	10	5.21
Weekend/Night (WE/N)	45	105	60	1.0	10	10.0
Adverse Weather (A)	45	205	160	2.67	10	3.75

---

[a] Delay times ranged from 15 to 75 minutes, so the average delay time is 45 minutes

At the Grand Gulf site, precipitation at rates in excess of 0.1 in/h occurs about 2 percent of the time. If rain at rates that exceed 0.1 in/h is assumed to mean that a severe thunderstorm is occurring, then adverse weather will also occur at the Grand Gulf site about 2 percent of the time.

Yearly average pre-evacuation times and average evacuation speeds can be calculated from these data using the following equation

$$0.02\ A + 0.98\ [0.5\ N + 0.5(0.71\ WD + 0.29\ WE)] = \bar{X} \tag{3.2}$$

where 0.71 = 2/7, and 0.29 = 5/7. Substitution of the evacuation delay times and speeds listed in the preceding table into this equation yields a yearly average evacuation delay time of 45 min = 0.75 h and a yearly average evacuation speed of 8.2 mph = 3.7 m s^{-1}. Table 3.7 presents the evacuation delay time and evacuation speed recommended for use at the Grand Gulf site and compares the recommended values to those specified by the NRC for use in the first pass NUREG-1150 calculations:

Table 3.7 Values Recommended for Grand Gulf and Evacuation Parameters

Parameter	Recommended Value	NRC
Delay (h)	0.75	1.25[a]
Speed (m s^{-1})	3.7	2.0

[a] where 1.25 h = 75 min, the maximum pre-evacuation delay time.

3.1.4 Peach Bottom

Estimates of total EPZ clearance times and pre-evacuation delay times (expressed in minutes after offsite warning) have been reported by the Philadelphia Electric Company for the five counties (Lancaster, York, Chester, Cecil, and Harford) that neighbor the Peach Bottom site. Values are reported for two types of weather (normal and adverse), two seasons of the year (winter and summer), and two times of day (daytime and nighttime). The estimates were developed using a state-of-the-art road network analysis. Table 3.8 presents estimates of the preevacuation delay time and the evacuation time, where

Evacuation Time = Total EPZ Clearance Time - Pre-evacuation Delay Time

for each county and set of conditions (prevailing weather, season, time of day). Also presented for each county are the distance to the EPZ boundary and the population within the EPZ.

Table 3.8 Peach Bottom Evacuation Data

	County					Population Weighted Average
	Lancaster	York	Chester	Cecil	Harford	
Population						
(0-12 mi x 10^3)	19.2	7.9	2.8	4.2	12.9	47.0
Evacuation Distance (mi)	13	12	15	12	12	12.6
Daytime						
Normal Weather						
Delay Time	85	80	88	75	80	82
Evacuation Time						
Winter	95	80	75	75	90	88
Summer	95	80	75	75	90	88
Adverse Weather						
Delay Time	100	95	98	85	95	96
Evacuation Time						
Winter	100	105	75	75	95	96
Summer	120	105	75	75	105	107
Nighttime						
Normal Weather						
Delay Time	40	40	53	40	40	41
Evacuation Time						
Winter	50	50	40	40	50	49
Summer	60	50	40	40	60	55
Adverse Weather						
Delay Time	40	40	53	40	40	41
Evacuation Time						
Winter	70	70	50	50	80	70
Summer	90	70	50	50	90	81

Yearly average values of pre-evacuation delay times and evacuation times can be calculated from this data using the following equation.

$$0.05[0.25(SDA + WDA + SNA + WNA)] + 0.95[0.25(SDN + WDN + SNN + WNN)] = \bar{X},$$

where

SDA = summer, daytime, adverse weather
WDA = winter, daytime, adverse weather
SNA = summer, nighttime, adverse weather
WNA = winter, nighttime, adverse weather

SDN - summer daytime, normal weather
WDN - winter daytime, normal weather
SNN - summer nighttime, normal weather
WNN - winter nighttime, normal weather

and adverse weather (weather that reduces road capacities by 30%, e.g., snow, ice, rain, fog) is assumed to occur [illegible]% of the time (precipitation occurs during about 8.[illegible]% of the hours in the year at the Peach Bottom site).

Substitution of the pre-evacuation delay times and evacuation times listed in the preceding table into this equation yields a yearly average preevacuation delay time of 62 min = 1.0 h and a yearly average evacuation time of 71 min = 1.18 h. Since the population weighted straight-line evacuation distance is 12.6 mi, this average evacuation time corresponds to an average evacuation speed of 10.7 mph = 4.8 m s^{-1}.

Table 3.9 presents the evacuation delay time and evacuation speed recommended for the Peach Bottom site and compares the recommended values to those specified by the NRC for use in the first pass NUREG-1150 calculations.

Table 3.9 Values Recommended for Peach Bottom Evacuation Parameters

Parameter	Recommended Value	NRC
Delay (h)	1.0	1.25
Speed (m s^{-1})	4.8	2.0

3.1.5 Sequoyah

Estimates of clear times for the Sequoyah site are presented in the Multijurisdictional Emergency Response Plan prepared for that site by the State of Tennessee. That plan divides population into two groups, residents and transients, where transients are primarily people who visit the river to swim or picnic during summer months (June through September). For each of these population groups, and for both together, the plan esimates clear times for each of 28 sectors within the 10-m EPZ. These clear time estimates are presented in Table 3.10.

Table 3.10. Sequoyah Evacuation Data

Sector	**Population**		**Clear Time (h)**					
	Residents	**Transients**	**Residents**		**Transients**		**Both**	
			Normal	**Adverse**	**Normal**	**Adverse**	**Normal**	**Adverse**
A-1	1210	1500	5.25	6.00	2.50	3.25	6.00	6.75
A-2	490	600	5.25	6.00	2.50	3.25	6.00	6.75
A-3	3575		5.25	6.00			6.00	6.75
A-4	660		2.25	3.00			3.00	3.75
A-5	1100		4.25	5.00			5.00	5.75
A-6	1085	1350	3.88	4.63	2.50	3.25	4.63	5.38
B-1	850	2000	2.94	3.69	1.50	2.25	3.69	4.44
B-2	600	1050	2.67	3.42	1.50	2.25	3.42	4.17
B-3	845		2.83	3.58			3.58	4.33
B-4	410	900	2.50	3.25	1.50	2.25	3.25	4.00
B-5	1195		3.17	3.92			3.92	4.67
B-6	160		3.50	4.25			4.25	5.00
B-7	250		2.25	3.00			3.00	3.75
B-8	645		3.50	4.25			4.25	5.00
C-1	1040	750	3.50	4.25	1.50	2.25	4.25	5.00
C-2	1945	3700	3.50	4.25	2.50	3.25	4.25	5.00
C-3	1810		3.00	3.75			3.75	4.25
C-4	750		3.50	4.25			4.25	5.00
C-5	445		2.50	3.25			3.25	4.00
C-6	1670		3.13	3.88			3.88	4.63
C-7	1880	235	3.08	3.83	2.50	3.25	3.83	4.58
C-8	2440	4000	3.50	4.25	2.50	3.25	4.25	5.00
D-1	300	1250	5.25	6.00	2.50	3.25	6.00	6.75
D-2	3585	1500	5.25	6.00	3.88	4.63	6.00	6.75
D-3	3450		4.75	5.50			5.50	6.25
D-4	1650		4.00	4.75			4.75	5.50
D-5	10340		4.50	5.25			5.25	6.00
D-6	2880	5200	5.25	6.00	5.25	6.00	6.00	6.75
Sum	47260	24035						
Population **Weighted Sum**			4.17	4.92			4.90	5.65

The clear time estimates presented in Table 3.10 rest on the following four assumptions:

(1) Whenever the residential population of the full EPZ is evacuated, the delay between notification to evacuate and the actual start of evacuation is 1.75 h.

(2) When the full EPZ is evacuated, adverse weather (snow or flooding) lengthens evacuation times by 45 min.

(3) Clear times for residents are lengthened by 45 min. whenever the recreational transient population evacuates with the residential population.

(4) Delay times are not lengthened by adverse weather

At Knoxville, TN, total yearly precipitation averages 47.29 inches and snow (as snow) averages 12.3 inches. Since the density of water is 1.0 g/cm^3 and the density of snow is about 0.1 g/cm^3, the Knoxville data suggest that about 2.6 percent

$$2.6 = 100(12.3)(0.1)/47.49(1.0)$$

of all precipitation at the Sequoyah site will be snow. At the Sequoyah site, rain occurs during 7 percent of the hours of the year, and intense rain (rain rate greater than 6 mm/h for one h) occurs less than 0.15 percent of the time (during only 13 of 8760 h). If rain at a rate of 6 mm/h is assumed to indicate flooding, then adverse weather (flooding or snowfall) will occur at the Sequoyah site less than 3 percent of the time. Finally, if significant transient population is assumed to be present within the EPZ only on weekend days during the months of June through September, then the fraction of time when both the residential and the transient populations will evacuate together will be 0.1 = (4/12)(2/7).

The following equation can now be used to estimate a yearly average clear time for the entire Sequoyah EPZ:

$$f_A(f_R t_{RA} + f_B t_{BA}) + f_N(f_R t_{RN} + f_B t_{BN}) = \bar{X} \qquad (3.3)$$

where

f_A = fraction time adverse weather prevails = 0.03,

f_N = fraction time normal weather prevails = 0.97,

f_R = fraction time only residential population evacuates = 0.9,

f_B = fraction time both residential and transient population evacuates = 0.1,

t_{RA} = clear time during adverse weather when only the residential population evacuates = 4.90 h,

t_{BA} = clear time during adverse weather when both the residential and the transient population evacuate = 5.65 h,

t_{RA} = clear time during normal weather when only the residential population evacuates = 4.17 h, and

t_{BA} = clear time during normal weather when both the residential and the transient population evacuates = 4.92 h.

Substitution of the parameter values given above now yields an average clear time of 4.27 hours and thus an average evacuation time of 2.52 h = 4.27 h - 1.75 h where 1.75 h is the delay time before evacuation commences. Accordingly, 3.97 mph = 10 mi/2.52 h = 1.8 m s^{-1} is a reasonable estimate of average evacuation speeds within the Sequoyah EPZ when the average is taken over all weather conditions and all evacuating populations. Table 3.11

presents the evacuation delay time and evacuation speed recommended for use at the Sequoyah site and compares the recommended values to those specified by the NRC for use in the first pass NUREG-1150 calculations.

Table 3.11 Values Recommended for Sequoyah Evacuation Parameters

Parameter	Recommended Value	NRC
Delay (h)	1.75	1.7
Speed ($m\ s^{-1}$)	1.8	1.2

3.2 Shielding Factors and Breathing Rate

3.2.1 Recommendation

The shielding factor values and breathing rate in Table 3.12 are recommended for use in MACCS NUREG-1150 calculations. In Table 3.12, BRRATE = breathing rate, CSFACT = cloudshine shielding factor, GSFACT = groundshine shielding factor, PROTIN = inhalation protection factor, and SKPFAC = skin protection factor.

Table 3.12. Recommended Shielding Factor Values

Variable	(Units)	Activity	Site	Value	Range*
BRRATE	(liters/day)	All	All	2.3×10^4	$(0.9\text{-}2.6) \times 10^4$
CSFACT	(unitless)	Evacuation	All	1.0	n/a
		Normal Activity	All	0.75	0.6-0.95
		Active Sheltering	Zion	0.5	0.4-0.6
			GG	0.7	0.6-0.8
			PB	0.5	0.4-0.6
			Sur	0.6	0.5-0.7
			Seq	0.65	0.55-0.75
GSFACT	(unitless)	Evacuation	All	0.5	0.3-0.7
		Normal Activity	All	0.4	0.2-0.75
		Active Sheltering	Zion	0.1	0.03-0.2
			GG	0.25	0.1-0.4
			PB	0.1	0.02-0.2
			Sur	0.2	0.1-0.3
			Seq	0.2	0.1-0.35
PROTIN	(unitless)	Evacuation	All	1.0	n/a
		Normal Activity	All	0.5	0.15-1.0
		Active Sheltering	All	0.2	0.1-0.4
SKPFAC	(unitless)	Evacuation	All	1.0	n/a
		Normal Activity	All	0.5	0.15-1.0
		Active Sheltering	All	0.2	0.1-0.4

---

* All sampling distributions should be uniform over the stated ranges.

9.2.2 Discussion

MACCS requires that shielding factors be specified for people evacuating in vehicles (cars, buses), taking shelter in structures (houses, offices, schools), and continuing normal activities either outdoors, in vehicles, or indoors. Because inhalation doses depend on breathing rate, breathing rates must be specified for people who are continuing normal activities, taking shelter, and evacuating. Since indoor concentrations of gas borne radioactive materials are usually substantially less than outdoor concentrations, MACCS also requires that inhalation and skin protection shielding factors (i.e., indoor/outdoor concentration ratios) be provided.

9.2.2.1 Breathing Rate

Breathing rates depend on activity, sex, and age. Adult men, women, and children who sleep 8 hours per day and engage in light activity when awake breathe respectively about [illegible], 2.1×10^4, and [illegible] liters of air per day [illegible]. Breathing rates for infants are substantially lower. Heavy activity increases breathing rates by about 50 percent. If fear is assumed not to increase the breathing rates of persons taking shelter or evacuating in vehicles, then the age and sex weighted breathing rate for light activity would be a reasonable number to use for persons responding to an accident. If [illegible] percent of the population is assumed to be teenagers and adults (light activity breathing rate = [illegible] liters/day), [illegible] percent [illegible] is preteen children (light activity breathing rate = [illegible] liters/day), and 3 percent [illegible] is babies (waking breathing rate = [illegible] liters/day), the average light activity breathing rate is [illegible] liters/day. Since this value differs little from the daily breathing rate of an adult man (2.3×10^4 liters/day = [illegible] m^3/s) typically used in ex-plant consequence calculations, the value for an adult man is selected for use in the NUREG-1150 calculations. For sensitivity studies, this parameter should be varied over the range [illegible] liters/day (sleeping population) to [illegible] liters/day (light activity).

9.2.2.2 Inhalation and Skin Protection Factors

Penetration of particulate matter into buildings is usually expressed as the ratio of the indoor particulate concentration to the outdoor concentration. Incomplete penetration lowers indoor inhalation and skin doses. Specifically, the indoor dose = (outdoor dose)(indoor/outdoor ratio). Thus, the indoor/outdoor ratio gives the shielding factor [illegible] buildings for inhalation and skin exposures.

Indoor/outdoor ratios of particulate matter in houses and buildings have been determined in several experimental studies [illegible]. These studies show that indoor/outdoor ratios depend strongly on particle size. Table 9.13 summarizes the results of these studies.

Table 3.13 Building Inhalation and Skin Shielding Factors (Indoor/Outdoor Ratios)

Particle Size Range (μm)	Indoor/Outdoor Ratio	Reference
0.05 - 0.2	0.5	[7]
0.1 - 0.65	0.4	[3]
< 1	0.4	[4]
0.1 - 2	0.6	[6]
0.65 - 20	0.2	[3]
> 1	0.2	[4]
?	0.1 - 0.5	[5]

These data suggest that small particles (0.1 - 1 μm) will have an indoor/outdoor ratio of about 0.5, while large particles (1 - 20 μm) will have indoor/outdoor ratios of about 0.2. Since mass and therefore radioactivity will be concentrated in a distribution's large particles, use of a value smaller than 0.5 is indicated.

Indoor/Outdoor inhalation dose ratios have been calculated by Aldrich for a single compartment subject both to infiltration and ventilation [8]. As derived by Aldrich, this ratio is directly proportional to the fraction of the plume that penetrates the compartment (indoor/outdoor concentration ratio). Using best estimate values for model parameters (including a penetration fraction, indoor/outdoor concentration ratio, of 0.85), Aldrich found this dose ratio to have a value of about 0.6. Use of a penetration fraction of 0.3 would lower Aldrich's indoor/outdoor dose ratio to about 0.2.

Opening windows is observed rapidly to increase indoor/outdoor ratios. If windows are assumed to be open during the summer, then a time weighted summation of an indoor/outdoor ratio of 1.0 for the summer (3 months) and 0.2 for the rest of the year (9 months) yields an average indoor/outdoor ratio of 0.4.

Accordingly, for people in buildings, skin and inhalation protection factors of 0.2 (range 0.1 to 0.4) if actively taking shelter and 0.4 (range 0.1 to 1.0) if continuing normal activity are recommended. For people outdoors and evacuating in vehicles, skin and inhalation protection factors of 1.0 (no significant protection) should be assumed.

3.2.2.3 Reference Doses

External radiation doses to individuals are reduced by materials (e.g., hills, buildings, building walls if indoors) that are between the individual and the radiation source. The reduction, which is usually called the "shielding factor," is defined by the following equation:

$$S = D/D_{ref} \qquad (3.4)$$

where S is the shielding factor, D is the dose received, and D_{ref} is the reference dose, which is the groundshine dose that would be received by an individual standing on a contaminated, completely smooth, infinite plane or the cloudshine dose that would be received by an individual immersed in a contaminated infinite cloud (the effects of finite cloud dimensions and off centerline locations on cloudshine doses are treated in MACCS using the semi infinite cloud correction factor)

3.2.2.4 Outdoor Shielding Factors

People outdoors may be partially shielded from a contaminated cloud by buildings and hills. Since this shielding is likely to be pronounced only for people located in urban street canyons, a cloudshine shielding factor of 1.0 for people outdoors is recommended for use in best estimate MACCS calculations.

People who are outdoors are shielded from contaminated ground not only by buildings and hills but also by the roughness of the contaminated ground surfaces (e.g., dirt, lawns, pavement). The average shielding provided by suburban land will depend on how much of that land is typically devoted to houses, lawns, and pavement. Consider a 2000 ft^2 house (45 ft^2) on a quarter acre (10^4 ft^2) lot fronted by a 3-ft-wide sidewalk and half of a 32-ft wide road. If the roof of the house has a surface roughness like that of pavement, then the fraction of suburban land devoted to lawns is about 0.67, and the fraction devoted to pavement is about 0.33.

$$0.67 = \frac{(100)^2 - (45)^2}{100(100 + 3 + 16)} \tag{3.5}$$

Accordingly, using surface roughness shielding factors [9] of 0.8 for lawn and of 0.93 for pavement yields an average surface roughness shielding factor for suburban surfaces of 0.84.

The shielding from groundshine provided by buildings to people located outdoors can be estimated by a view factor calculation. For example, a square house, 45 ft on a side, located at the center of a square quarter acre lot will screen about 36 degrees of the horizon from the view of a person, who is standing at the intersection of the lot sideline with the centerline of the street that fronts the lot. Thus, assuming obstruction of view principally by the four nearest houses, groundshine reduction due to screening by buildings will be about 0.6 = 1 - 4(36/360).

Table 3.14 presents estimates for overall urban and suburban shielding factors for people located outdoors

Table 3.14. Urban and Suburban Skidding Factors for People Located Outdoors

Location	Shielding Factor	Reference
Urban Copenhagen	0.06	[10]
Street canyon	0.1	[11]
Suburban Copenhagen	0.6	[10]
Urban areas	0.3 - 0.7	[12]
Lawns, trees, and streets (after dry deposition)	0.5 - 2.0	[11]
Lawns and streets (deposition during heavy rain, little deposition to tree leaves)	0.2 - 0.5	[11]

If the following three assumptions are made,

(1) the amount of material deposited on tree leaves is about the half the amount deposited on the ground,

(2) the shielding factor for material deposited on tree leaves is 2.0 (this number is larger than 1.0 because the leaves of a tree are a smooth vertical planar source) and the roughness shielding factor for material deposited on suburban surfaces is 0.84, and

(3) buildings and hills reduce exposures to materials deposited on tree leaves and on the ground by a factor of 0.6,

then, in agreement with Ostmeyer and Helton [1a], an overall shielding factor of 0.73 can be calculated for people located oudoors in suburban areas as follows:

$$0.73 = 0.6[0.33(2.0) + 0.67(0.84)] \qquad (3.6)$$

Increasing the fraction of material deposited on tree leaves to 0.5 from 0.33 increases the overall shielding factor to 0.85. Decreasing the fraction deposited on tree leaves to 0.25, lowers the overall shielding factor to 0.68. Accordingly, an overall groundshine shielding factor of 0.7 for people located outdoors is suggested for use in best estimate MACCS calculations. For sensitivity studies a range of 0.2 - 1.0 should be assumed for this factor.

3.2.2.5 Mass Thickness

The shielding provided by a material is directly proportional to its mass thickness, which is the product of the density of the material and its thickness. Densities for typical building materials [13] are presented in Table 3.15.

Table 3.15. Densities of Building Materials

Material	Density (g/cm^3)
aluminum	2.6
asphaltum, tar	1.2
brick	1.8
concrete block	2.3
glass	2.6
gypsum (wallboard)	0.42
insulation	0.05
steel	7.8
Portland cement	3.1
wood (pine)	0.5

From these data, approximate mass thicknesses may be calculated for several types of wall construction typical of U.S. houses.

WOOD FRAME HOUSES FACED WITH WOOD, ALUMINUM, OR STUCCO

0.125" aluminum + 0.5" wood + 3.0" insulation + 0.5" wallboard

$2.54[0.125(2.6) + 0.5(0.5) + 3.0(0.65) + 0.5(0.93)] = 7.6$ g/cm^2

0.5" wood siding + 0.5" wood + 3" insulation + 0.5" wallboard

$2.54[0.5(0.5) + 0.5(0.5) + 3.0(0.65) + 0.5(0.93)] = 7.4$ g/cm^2

0.75" stucco + 0.5" wallboard + 3.0" insulation + 0.5" wallboard

$2.54 [0.75(3.1) + 0.5(0.93) + 3.0(0.65) + 0.5(0.93)] = 13.2$ g/cm^2

BRICK AND CONCRETE BLOCK HOUSES

2.5" brick + 0.5" wallboard + 3.0" insulation + 0.5" wallboard

$2.54[2.5(1.8) + 0.5(0.93) + 3.0(0.65) + 0.5(0.93)] = 18.7$ g/cm^2

0.75" stucco + 3.0" cement + 0.5" wallboard

$2.54[0.75(3.1) + 3.0(2.3) + 0.5(0.93)] = 24.6$ g/cm^2

ROOFS

0.25" asphalt shingles + 0.5" wood + 0.5" wallboard

$2.54[0.25(1.2) + 0.5(0.5) + 0.5(0.93)] = 2.6$ g/cm^2

FLOORS

0.5" wood + 0.5" wallboard

$2.54[0.5(0.5) + 0.5(0.93)] = 1.8$ g/cm^2

In agreement with Ostmeyer and Helton [1b], these qualitative calculations suggest that 10 g/cm^2 is a typical mass thickness for wood frame houses faced with wood siding, aluminum siding, or stucco, and that 20 g/cm^2 is a typical mass thickness for brick or concrete block houses.

3.2.2.6 Vehicular Shielding Factors

An eighth of an inch of steel corresponds to a mass thickness of 2.5 g/cm^2 and an eighth of an inch of glass to a mass thickness of 0.8 g/cm^2, neither of which is sufficient to provide significant shielding from a radioactive plume. Therefore, since the interior space of cars and buses will not exclude a significant fraction of the plume, the value of the cloudshine shielding factor for vehicles should be assumed to be 1.0.

The shielding afforded by vehicles from exposure to contaminated ground has been examined experimentally by comparing the dose rate in the vehicle to the dose rate outside the vehicle [15,16]. Data for cars and buses are presented in Table 3.16.

Table 3.16. Vehicle Groundshine Shielding Factors

Vehicle	Indoor/Outdoor Ratio	Reference
Cars	0.6 - 0.7	[16]
	0.3 - 0.6	[17]
Buses	0.5 - 0.7	[16]
	0.3 - 0.4	[17]

A shielding factor referenced to a contaminated infinite smooth plane may be calculated from these numbers by multiplying by the surface roughness shielding factor for the land surrounding the roadway. Both for countryside and suburbia, the surface roughness shielding factor for grass should be used. Thus, assuming that (1) inside/outside vehicular dose ratios are respectively 0.5 and 0.6 for buses and cars, and that (b) 10 percent of the people in vehicles are in buses and the balance in cars, in agreement with Ostmeyer and Helton [1c], a groundshine shielding factor of 0.5 for vehicles can be calculated as follows:

$$0.5 = 0.8[0.1(0.5) + 0.9(0.6)] \quad (3.7)$$

3.2.2.7 Structure Shielding

The degree of shielding afforded to persons within a structure depends strongly on the nature (construction type) of the structure, the location within the structure of the shielded person, and the amount of radioactive material that infiltrates the structure. Accordingly, the shielding afforded to persons, who actively take shelter in basements or interior rooms with building windows and doors closed, can be significantly greater than that afforded persons who continue normal activities.

Structures shield people from cloudshine because their walls attenuate radiation and because indoor gas-borne concentrations of plume materials are usually substantially less than those in the outdoor plume. Indoor concentrations are lower because infiltration is not complete and deposition to interior surfaces further reduces the gas-borne amounts of those materials that do infiltrate the structure. But the indoor volumes of typical houses will usually be small compared to the volume of the outdoor plume. Therefore, complete plume exclusion from typical houses will produce a reduction in dose of only about 0.95 [1d]. Since complete plume exclusion is unlikely, dose reduction due to plume exclusion can be neglected.

Shielding due to dose attenuation is calculated as the sum of the attenuation factors for the structural elements (walls, roofs, ground if in a basement) that lie between the shielded person and the plume with each attenuation factor weighted by the fraction of the plume shielded by that element. Consider a person standing in the middle of a single story square 2000 ft^2 house enveloped by a hemispherical plume. If approximated by a circle, the house will have a radius of 25 ft. Mensuration formuli for spheres (20) show that the fraction of the hemispherical plume subtended by the walls of the house is given by the ratio of the wall height to the distance from the center of the house to the top of its walls. That distance is about 26 ft, where 26 is the hypotenuse of the right triangle having sides 8 and 25 ft long. Therefore, the walls of the single story square 2000 sq ft house will screen about 0.3 = 8/26 of the hemispherical cloud from a person standing in the middle of the house. The remaining 0.7 of the hemisphere will be screened by the roof of the house. If this single story house has a full basement, then the ground, walls, and roof plus floor of the house will respectively screen the following fractions of the hemispherical cloud: 0.3, 0.3, and 0.4.

If the house has two 1000 ft^2 stories and thus an effective radius of 18 ft, for a person standing in the middle of the first floor, the fractions of the hemispherical plume screened by the walls and the roof will be 0.67 and 0.33. For a person standing in the middle of the second floor, the wall and roof screening fractions are 0.4 and 0.6. If the person is standing in the middle of the basement of the house, the fractions of the hemispherical plume screened by the ground, walls, and roof are 0.4, 0.4, and 0.2. Assuming complete screening by the ground and attenuation factors (16) of 0.7[illegible] for wood frame walls, 0.[illegible]2 for masonry walls, 0.92 for a roof, 0.85 for a roof plus one floor, and 0.81 for a roof plus two floors, now allows the following cloudshine shielding factors to be estimated for houses as in Table 3.17.

Table 3.17. Cloudshine Shielding Factors

House	Construction	Location	Factor
1 story	wood frame	1st floor	[illegible]
		basement	[illegible]
	masonary	1st floor	[illegible]
		basement	[illegible]
2 story	wood frame	2nd floor	[illegible]
		1st floor	[illegible]
		basement	[illegible]
	masonry	2nd floor	[illegible]
		1st floor	[illegible]
		basement	[illegible]

Assuming that most people are downstairs during waking hours and upstairs when sleeping yields overall normal activity cloudshine attenuation factors of 0.80 = 0.67(0.78) + 0.33(0.85) for two story wood frame houses and 0.68 = 0.67(0.64) + 0.33(0.76) for two story masonry houses.

Now consider a two story school or office building with an effective radius of 25 ft. If walls, floors, and roofs all have mass thicknesses of about 20 g/cm^2, then the value of the cloudshine attenuation factor will be 0.52 for people on the second floor and 0.39 for people on the first floor, where

$$0.39 = 0.53(0.52) + 0.47(0.24)$$

The fraction of the cloud subtended by walls is 0.53, and 0.24 is the shielding provided by a roof plus a floor (total mass thickness of 40 g/cm^2). Now if people in the building are evenly distributed between the first and second floors, an overall cloudshine attenuation factor of 0.46 can be calculated for schools and small office buildings. Larger effective building radii and poured concrete (rather than concrete block) walls will reduce this value. Therefore, a cloudshine shielding factor of 0.4 for schools and small office buildings is recommended for use in MACCS. For sensitivity studies, a range of 0.2 (cloudshine shielding factor for large office buildings [18]) to 0.5 (cloudshine shielding factor for single story school or office building) should be assumed.

Structure shielding to cloudshine has been examined by Burson and Profio [18] who assumed different building dimensions and mass thicknesses in their calculations then were assumed above. Table 3.18 presents the shielding factor recommendations of Burson and Profio both as originally developed by those authors (the number not in parentheses) and as obtained using the same mass thicknesses assumed above (the number in parentheses).

Table 3.18 Cloudshine Shielding Factors Recommended by Burson and Profio [18] for People Located in Buildings

Structure	Location	Factor
House		
Wood Frame	Ground Floor	0.9 (0.8)
	Basement	0.6 (0.5)
Masonry	Ground Floor	0.6 (0.[illegible])
	Basement	0.4 (0.45)
Office Building	Interior	0.2 (0.4)

Since cloudshine structure shielding factors are certainly not precise to two significant figures, values in Table 3.19 are recommended for use in MACCS.

Table 3.19 Recommended Cloudshine Shielding Factor for People Located in Buildings

Activity	Structure	Stories	Factor
Normal	Wood Frame House	2	0.8
		1	0.9
	Masonry House	2	0.7
		1	0.8
	School or Office	2	0.4
Sheltering	Wood Frame House	2	0.5
		1	0.6
	Masonry House	2	0.4
		1	0.5
	School or Office	2	0.4

In contrast to cloudshine, where the dose from gas-borne materials that have infiltrated a structure is usually small compared to the dose received from the plume that envelopes the structure, for the groundshine dose received from indoor deposits of infiltrated materials can be important when compared to the groundshine dose received from materials deposited outdoors. The contribution of indoor deposits to total groudshine doses (the dose from all deposited materials whether deposited outdoors or indoors) has been examined by Ostmeyer and Helton [1f] and by Jacob and Meckbach [11]. Jacob and Meckbach note that as structure shielding increases, the dose from indoor deposits becomes increasingly important. For example, in a structure that has a groundshine shielding factor of 0.015, indoor exposures are increased by about a factor of two, if the indoor deposit is 2 percent of the outdoor deposit [11]. In agreement with Ostmeyer and Helton [1g], Jacob and Meckbach [11] also estimate that an indoor deposit that is 10 percent of that outdoors will double the indoor dose if the structure's groundshine shielding factor is 0.07.

The dose from indoor deposits can be indirectly modeled by increasing the value of the groundshine shielding factor as required to produce a total dose equal to that which would result from all deposited materials (both those deposited on outdoor surfaces and those deposited on indoor surfaces). For wood frame houses (mass thickness = 10 g/cm^2) and masonry houses (mass thickness = 20 g/cm^2), Ostmeyer and Helton estimate [1h] that if indoor deposits are half those outdoors, the total indoor dose from all deposited materials (both indoors and outdoors) is well approximated by increasing the structure's groundshine shielding factor 0.1 unit

Groundshine shielding has been reviewed by Burson and Profio [18] and by Ostmeyer and Helton [1f] and recent European studies of groundshine shielding factors have been summarized by Roed [19]. Table 3.20 presents pertinent results from these studies.

Table 3.20 Groundshine Shielding Factors for Buildings

	Houses						School Office			Basement		
	Wood Frame			Masonry								
Ref	L	C	U	L	C	U	L	C	U	L	C	U
O	0.4	0.5	0.6	0.3	0.35	0.4	0.15	0.4	0.5	0.02	0.08	0.08
B	0.2	0.4	0.5	0.04	0.2	0.4	0.01	0.05	0.08	0.02	0.04	0.07
B+d	0.3	0.4	0.6	0.14	0.3	0.5	0.11	0.15	0.18	0.12	0.14	0.17
R		0.44			0.19			0.1				
R+d		0.54			0.29			0.2				

In the table, the shielding factor value in the C column is the central (best) estimate value and the L (lower) and U (upper) values define the estimated range of the factor. In the column labeled Ref. O denotes Ostmeyer and Helton [1a], B Burson and Profio [18], and R Roed [19]. Since the values of Ostmeyer and Helton reflect correction for indoor deposits (i.e. groundshine shielding factor imcremented 0.1 unit to correct for 50 percent infiltration) while those of Burson and Profio and of Roed do not, the table also presents the values of Burson and Profio and of Roed incremented by 0.1 unit (B+d and R+d on the table) to permit comparison to the values of Ostmeyer and Helton. Finally, the values in the table attributed to Roed were calculated assuming mass thicknesses of 10 g/cm^2 (wood frame houses), 20 g/cm^2 (masonry houses), and 35 g/cm^2 (office building with solid concrete walls, i.e., not concrete block) using the following dependence of groundshine shielding factor (S_{gd}) on exterior wall thickness (m_t)

$$S_{gd} = \exp(-0.083\, m_t) \tag{3.8}$$

which was developed from data taken from Roed [19].

Inspection of the preceding table suggests that reasonable values for groundshine shielding factors for normal activity (indoor deposits half those outside) are 0.5 for wood frame houses, 0.3 for masonry houses, 0.3 for schools and small office buildings, and 0.1 for basements. For sheltering, the following values are recommended: 0.4 for wood frame houses, 0.2 for masonry houses, 0.2 for schools and small office buildings, and 0.05 for basements.

Normal Activity. Because people continuing normal activities may be in more than one location, the shielding factor for normal activity, S_N, must be constructed as a weighted sum of the shielding factors for people outdoors, S_O, in vehicles, S_V, and indoors in schools and office buildings, S_B, and in houses, S_H. Thus,

$$S_N = F_O S_O + F_B S_B + F_B S_B + F_H S_H \tag{3.9}$$

where F_O, F_V, F_B, and F_H are the fractions of the population that contine normal activities outdoors, in vehicles, indoors in schools and office buildings, and indoors in houses.

Because differences in dimensions and building materials cause individual house shielding factors to vary significantly, the shielding factor for houses, S_H, must be constructed as a weighted sum over types of houses. Here for simplicity, only two types of houses will be considered:

(1) Wood frame houses faced with wood, aluminum, or stucco

(2) Concrete block houses, and wood frame houses faced with masonry (e.g., brick)

Because the shielding afforded by a structure changes as a person moves about within the structure (walls afford more shielding than windows, basements more than attics), location within structures will affect the value of structure shielding factors. Only two locations, in basements and not in basements, will be considered here. Lastly, because the shielding afforded by structures does not decrease exposures to radioactive materials that penetrate the structure, ventilation and infiltration will increase the values of structure shielding factors. Accordingly

$$S_H = f_W S_W + f_{Wb} S_{Wb} + f_M S_M + f_{Mb} S_{Mb} \qquad (3.10)$$

where f is the fraction of all houses that provide the degree of shielding S, the subscript b indicates a basement, and the subscripts W and M respectively denote wood frame houses not faced by masonry and concrete block and masonry faced houses, respectively.

Since most people performing normal activities in houses are not located in basements, f_{Wb} and f_{Mb} should be set to zero when Equation 3.10 is used to calculate structure shielding factors for normal activity. Since all houses do not have basements, when this equation is used to calculate house shielding factors for people who have taken shelter, nonzero values should be used for f_{Wb} and f_{Mb} that reflect the degree of utilization of available basements.

Values for the fractions F_O, F_V, F_B, and F_H are developed by considering how much time different groups of people spend in different locations. At least three groups of people need to be considered: workers, school age children, and people who spend most of their time at home (i.e., preschool children, homemakers, retired persons, the unemployed). Table 3.21 presents census data for 1986 (2) from which population fractions for these three population groups may be constructed.

Table 3.21. Census Data for Population Groups

Group	Age Range	Number (millions)
Preschool	< 5	18.1
School	5 - 17	45.1
Adult	18 - 64	14[illegible]
Retired	> 64	2[illegible]
All		24[illegible]

In 1986 109.6 million Americans were employed (2). Therefore, about 39.0 million Americans (39.0 = 148.6 - 109.6) between the ages of 18 and 64 must either be homemakers or unemployed, which means that about 86.3 million Americans spend most of their time at home (86.3 = 18.1 + 39.0 + 29.2). Thus, workers constitute 45.5% = 100 (109.6/241.0) of the total 1986 population, school age children 18.7% = 100 (45.1/241.0), and homebodies 35.8% = 100 (86.3/241.0).

Table 3.22 presents plausible estimates of the number of hours in a day on weekdays and weekends during winter and during the rest of the year that individuals in each of the three population groups defined above spend sleeping (N), indoors in houses (I), indoors in schools and office buildings (B), in vehicles (V), and outdoors (O).

Table 3.22 Estimates of Time Spent in Different Locations by Population Groups

Group	Season	Weekdays					Weekends				
		N	I	B	V	O	N	I	B	V	O
Workers	(R) Not Winter	8	6	8	1	1	8	9	0	2	5
	(W) Winter	8	6	8	1	1	8	13	0	1	2
School children	(R) Not Winter	8	5	4	1	6	8	7	0	2	7
	(W) Winter	8	7	6	1	2	8	12	0	1	3
Homebodies	(R) Not Winter	8	12	0	2	2	8	9	0	2	5
	(W) Winter	8	13	0	2	1	8	13	0	1	2

The fraction of the time that the general population spends in houses, in schools or office buildings, in vehicles, or outdoors is now given by

$$F_t = \frac{1}{24} \{0.75[(F_1)(h_{1R}) + (F_2)(h_{2R}) + (F_3)(h_{3R})]$$

$$+ 0.25[(F_1)(h_{1W}) + (F_2)(h_{2W}) + (F_3)(h_{3W})]\} \quad (3.8)$$

where $F_1 = 0.455$, $F_2 = 0.187$, and $F_3 = 0.358$; the subscripts 1, 2, and 3 denote workers, school children, and homebodies, and the subscripts R and W denote "not winter" (that is spring, summer, and fall) and "winter." Substitution of numbers from Table 3.22 yields the values in Table 3.23 for the fractions of time spent by the general population in houses, in schools and offices, in vehicles, and outdoors.

Table 3.23. Time Fractions by Locations for the General Population

Population	Location	Weekday	Weekend	Total
All	Houses	0.67	0.74	0.69
	Buildings	0.19	0.0	0.14
	Vehicles	0.057	0.073	0.06
	Outdoors	0.084	0.19	0.11

Robinson and Converse [20] have developed values for fractions of the time spent in houses, buildings, vehicles, and outdoors by adults less than 65 years old. Since adults less than 65 years old are comprised of 109.6 million workers plus the 39.0 million adult homebodies, the following equation can be used to develop values for time fractions for these adults to compare to the results of Robinson and Converse.

$$F = \frac{1}{24}\{0.75[(F_{1A})(h_{1R}) + (F_{3A})(h_{3R})]$$

$$+ 0.25[(F_{1A})(h_{1W}) + (F_{3A})(h_{3W})]\} \qquad (3.9)$$

where $F_{1A} = 0.74 = 109.6/148.6$ and $F_{3A} = 0.26 = 39.0/148.6$ are the fractions of the adult population that are workers less than 65 years old and homebodies less than 65 years old. Table 3.24 presents time fractions for adults less than 65 years old and compares the values for total time to those of Ref. [20].

Table 3.24. Time Fractions by Location for Working Adults

Population	Location	Weekday	Weekend	Total	Total R&C
Adults < 65	Houses	0.65	0.75	0.68	0.69
	Buildings	0.247	0.0	0.18	0.20
	Vehicles	0.053	0.073	0.06	0.05
	Outdoors	0.05	0.177	0.09	0.06

The good agreement in this table between the calculated results and those of Robinson and Converse suggests that the estimates of hours spent in different locations that were presented in Table 3.22 are reasonable. Thus, the following time fractions for the general population are recommended for use in MACCS: Houses = 0.7, Schools and Office Buildings = 0.15, Vehicles = 0.05, and Outdoors = 0.1.

1983 data on new detached housing (i.e., not apartments) has been published by the FHA [21] and 1980 data on existing housing (single and multiunit structures) have been published by the Department of Commerce [22]. If, as was done by Aldrich [8], it is assumed that the characteristics of new detached housing in a state or metropolitan area applies to all detached houses in that state or area and that most multiunit structures have basements and masonry walls (brick faced or concrete block), then the following formula can be used to estimate the percentage of housing units in a state or metropolitan area that have basements or are constructed with masonry walls:

$$\% X = (\% \text{ houses})(\text{fraction new with } X) + (\% \text{ apartments}) \qquad (3.10)$$

where X is either basements or masonry walls. Table 3.25 presents the FHA [21] and Department of Commerce [22] data needed by Equation 3.10 and the percent masonry housing and percent basements at the five NUREG-1150 sites as calculated using Equation 3.10 and as developed using 1970 and 1971 data either by the Reactor Safety Study [23] or by Aldrich [8].

Table 3.25. Regional Building Data

Site	State/City	% Units at Address one [22]	% Units at Address ≥ one	% Masonry FHA [21]	% Masonry Calc	% Masonry RSS [23]	% Masonry Ch	% Basements FHA [21]	% Basements Calc	% Basements Ald [8]	% Basements Ch
	WI	76	24	16	36	<20		81	86	90	
Zion	Chicago	46	54		61		50				85
	IL	64	36	15	46	40-60		43	64	77	
GG	MS	82	18	56	64	40-60	60	0	18	5	5
PB	PA	77	23	41	55	60-80	55	87	90	89	90
Surry	VA	79	21	14	32	40-60	35	41	53	42	45
Seq	TN	80	20	50	60	40-60	55	12	30	28	30

---

* GG = Grand Gulf, PB = Peach Bottom, Seq = Sequoyah, RSS = Reactor Safety Study [23], Calc = as calculated with Eq. 7, Ald = Aldrich [8], and Ch = choice (recommended value).

Shielding Factors for Normal Activity and for Sheltering. Values for all of the parameters in Equations 3 and 4 have now been selected. Therefore, parameter values can be calculated for persons who contine normal activity (N) and for persons who actively take shelter (S). Values for three shielding factors, cloudshine (C), groundshine (G), and inhalation/skin (I), are calculated for each activity (normal activity and sheltering). For each shielding factor, three values, an upper bound (H), a best estimate (B), and a lower bound (L), are calculated. Because housing stock varies by location, values are calculated for each NUREG-1150 reactor site (Zion, Grand Gulf, Peach Bottom, Surry, and Sequoyah).

Upper and lower bounds are estimated by assuming that the accident occurs at an unfavorable time (after school during the rush hours on a summer weekday) and at a favorable time (during school hours on a winter weekday). For the summer weekday after school during the rush period (the unfavorable upper bound situation), it is assumed that that school children are now outdoors and most office workers are in vehicles commuting to their homes. For the winter weekday with school in session (the favorable lower bound situation), it is assummed that about two-thirds of the population that on average would be outdoors or in vehicles is now indoors in schools or office buildings. These assumptions yield the upper and lower bound values listed in Table 3.26 for the fractions of the general population that are outdoors (F_O), in vehicles (F_V), in buildings (F_B), and in houses (F_H).

Table 3.26. Upper and Lower Bounds for Population Fractions

Scenario	F_O	F_V	F_B	F_H
Upper Bound (H)	0.4	0.15	0.05	0.4
Lower Bound (L)	0.03	0.02	0.3	0.65

[redacted]

The parameter values used to calculate shielding factors for normal activity and for active sheltering are now presented in Table 3.27 and the resulting site specific average shielding values for normal activity and for active sheltering are presented in Table 3.27. In Table 3.27, the column headers are the parameters defined for Equations 3.9 and 3.10. In Table 3.28, <u>Average</u> indicates the average of the site specific values and is given only when the site specific values were quite similar; <u>NRC</u> indicates the value of the indicated shielding factor used in the first pass NUREG-1150 calculations; and <u>Choice</u> indicates the value recommended on the basis of these calculations. In both tables, the line headers are defined as follows: C - cloudshine, G - groundshine, I - inhalation/skin, N - normal activity, S - active sheltering, H - upper bound, B - control estimate, and L - lower bound. Thus, CNH - cloudshine, normal activity, upper bound and the B that comes next - cloudshine, normal activity, central estimate, and so forth.

Table 3.27. Input Data for Calculation of Shielding Factors Using Equations 3.9 and 3.10

Peach Bottom

	F_O	S_O	F_V	S_V	F_B	S_B	F_H	f_W	S_W	f_{Wb}	S_{Wb}	f_M	S_M	f_{Mb}	S_{Mb}
CNH	0.4	1.0	0.15	1.0	0.05	0.5	0.4	0.45	0.95	0.0	0.0	0.55	0.85	0.0	0.0
B	0.1	1.0	0.05	1.0	0.15	0.4	0.7	0.45	0.85	0.0	0.0	0.55	0.75	0.0	0.0
L	0.03	1.0	0.02	1.0	0.3	0.3	0.65	0.45	0.75	0.0	0.0	0.55	0.65	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.5	0.8	0.04	0.95	0.41	0.65	0.05	0.85	0.5	0.55
B	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.04	0.85	0.41	0.55	0.05	0.75	0.5	0.45
L	0.0	0.0	0.0	0.0	0.2	0.3	0.8	0.04	0.75	0.41	0.45	0.05	0.65	0.5	0.35
GNH	0.4	1.0	0.15	0.7	0.05	0.5	0.4	0.45	0.6	0.0	0.0	0.55	0.5	0.0	0.0
B	0.1	0.7	0.05	0.5	0.15	0.3	0.7	0.45	0.5	0.0	0.0	0.55	0.3	0.0	0.0
L	0.03	0.2	0.02	0.2	0.3	0.1	0.65	0.45	0.3	0.0	0.0	0.55	0.15	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.04	0.5	0.41	0.08	0.05	0.4	0.5	0.08
B	0.0	0.0	0.0	0.0	0.2	0.2	0.8	0.04	0.4	0.41	0.05	0.05	0.2	0.5	0.05
L	0.0	0.0	0.0	0.0	0.2	0.01	0.8	0.04	0.2	0.41	0.02	0.05	0.05	0.5	0.02
INH	0.4	1.0	0.15	1.0	0.05	1.0	0.4	0.45	1.0	0.0	0.0	0.55	1.0	0.0	0.0
B	0.1	1.0	0.05	1.0	0.15	0.4	0.7	0.45	0.4	0.0	0.0	0.55	0.4	0.0	0.0
L	0.03	1.0	0.02	0.9	0.3	0.1	0.65	0.45	0.1	0.0	0.0	0.55	0.1	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.04	0.4	0.41	0.4	0.05	0.4	0.5	0.4
B	0.0	0.0	0.0	0.0	0.2	0.2	0.8	0.04	0.2	0.41	0.2	0.05	0.2	0.5	0.2
L	0.0	0.0	0.0	0.0	0.2	0.1	0.8	0.04	0.1	0.41	0.1	0.05	0.1	0.5	0.1

Surry

	F_O	S_O	F_V	S_V	F_B	S_B	F_H	f_W	S_W	f_{Wb}	S_{Wb}	f_M	S_M	f_{Mb}	S_{Mb}
CNH	0.4	1.0	0.15	1.0	0.05	0.5	0.4	0.65	0.95	0.0	0.0	0.35	0.85	0.0	0.0
B	0.1	1.0	0.05	1.0	0.15	0.4	0.7	0.65	0.85	0.0	0.0	0.35	0.75	0.0	0.0
L	0.03	1.0	0.02	1.0	0.3	0.3	0.65	0.65	0.75	0.0	0.0	0.35	0.65	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.5	0.8	0.36	0.95	0.29	0.65	0.19	0.85	0.16	0.55
B	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.36	0.85	0.29	0.55	0.19	0.75	0.16	0.45
L	0.0	0.0	0.0	0.0	0.2	0.3	0.8	0.36	0.75	0.29	0.45	0.19	0.65	0.16	0.35
GNH	0.4	1.0	0.15	0.7	0.05	0.5	0.4	0.65	0.6	0.0	0.0	0.35	0.5	0.0	0.0
B	0.1	0.7	0.05	0.5	0.15	0.3	0.7	0.65	0.5	0.0	0.0	0.35	0.3	0.0	0.0
L	0.03	0.2	0.02	0.2	0.3	0.1	0.65	0.65	0.3	0.0	0.0	0.35	0.15	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.36	0.5	0.29	0.08	0.19	0.4	0.16	0.08
B	0.0	0.0	0.0	0.0	0.2	0.2	0.8	0.36	0.4	0.29	0.05	0.19	0.2	0.16	0.05
L	0.0	0.0	0.0	0.0	0.2	0.01	0.8	0.36	0.2	0.29	0.02	0.19	0.05	0.16	0.02
INH	0.4	1.0	0.15	1.0	0.05	1.0	0.4	0.65	1.0	0.0	0.0	0.35	1.0	0.0	0.0
B	0.1	1.0	0.05	1.0	0.15	0.4	0.7	0.65	0.4	0.0	0.0	0.35	0.4	0.0	0.0
L	0.03	1.0	0.02	0.9	0.3	0.1	0.65	0.65	0.1	0.0	0.0	0.35	0.1	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.36	0.4	0.29	0.4	0.19	0.4	0.16	0.4
B	0.0	0.0	0.0	0.0	0.2	0.2	0.8	0.36	0.2	0.29	0.2	0.19	0.2	0.16	0.2
L	0.0	0.0	0.0	0.0	0.2	0.1	0.8	0.36	0.1	0.29	0.1	0.19	0.1	0.16	0.1

Table 3.27. (Continued)

Zion

	F_O	S_O	F_V	S_V	F_B	S_B	F_H	f_W	S_W	f_{Wb}	S_{Wb}	f_M	S_M	f_{Mb}	S_{Mb}
CNH	0.4	1.0	0.15	1.0	0.05	0.5	0.4	0.5	0.95	0.0	0.0	0.5	0.85	0.0	0.0
B	0.1	1.0	0.05	1.0	0.15	0.4	0.7	0.5	0.85	0.0	0.0	0.5	0.75	0.0	0.0
L	0.03	1.0	0.02	1.0	0.3	0.3	0.65	0.5	0.75	0.0	0.0	0.5	0.65	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.5	0.8	0.08	0.95	0.42	0.65	0.08	0.85	0.42	0.55
B	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.08	0.85	0.42	0.55	0.08	0.75	0.42	0.45
L	0.0	0.0	0.0	0.0	0.2	0.3	0.8	0.08	0.75	0.42	0.45	0.08	0.65	0.42	0.35
GNH	0.4	1.0	0.15	0.7	0.05	0.5	0.4	0.5	0.6	0.0	0.0	0.5	0.5	0.0	0.0
B	0.1	0.7	0.05	0.5	0.15	0.3	0.7	0.5	0.5	0.0	0.0	0.5	0.3	0.0	0.0
L	0.03	0.2	0.02	0.2	0.3	0.1	0.65	0.5	0.3	0.0	0.0	0.5	0.15	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.08	0.5	0.42	0.08	0.08	0.4	0.42	0.08
B	0.0	0.0	0.0	0.0	0.2	0.2	0.8	0.08	0.4	0.42	0.05	0.08	0.2	0.42	0.05
L	0.0	0.0	0.0	0.0	0.2	0.01	0.8	0.08	0.2	0.42	0.02	0.08	0.05	0.42	0.02
INH	0.4	1.0	0.15	1.0	0.05	1.0	0.4	0.5	1.0	0.0	0.0	0.5	1.0	0.0	0.0
B	0.1	1.0	0.05	1.0	0.15	0.4	0.7	0.5	0.4	0.0	0.0	0.5	0.4	0.0	0.0
L	0.03	1.0	0.02	0.9	0.3	0.1	0.65	0.5	0.1	0.0	0.0	0.5	0.1	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.08	0.4	0.42	0.4	0.08	0.4	0.42	0.4
B	0.0	0.0	0.0	0.0	0.2	0.2	0.8	0.08	0.2	0.42	0.2	0.08	0.2	0.42	0.2
L	0.0	0.0	0.0	0.0	0.2	0.1	0.8	0.08	0.1	0.42	0.1	0.08	0.1	0.42	0.1

Grand Gulf

	F_O	S_O	F_V	S_V	F_B	S_B	F_H	f_W	S_W	f_{Wb}	S_{Wb}	f_M	S_M	f_{Mb}	S_{Mb}
CNH	0.4	1.0	0.15	1.0	0.05	0.5	0.4	0.4	0.95	0.0	0.0	0.6	0.85	0.0	0.0
B	0.1	1.0	0.05	1.0	0.15	0.4	0.7	0.4	0.85	0.0	0.0	0.6	0.75	0.0	0.0
L	0.03	1.0	0.02	1.0	0.3	0.3	0.65	0.4	0.75	0.0	0.0	0.6	0.65	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.5	0.8	0.38	0.95	0.02	0.65	0.57	0.85	0.03	0.55
B	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.38	0.85	0.02	0.55	0.57	0.75	0.03	0.45
L	0.0	0.0	0.0	0.0	0.2	0.3	0.8	0.38	0.75	0.02	0.45	0.57	0.65	0.03	0.35
GNH	0.4	1.0	0.15	0.7	0.05	0.5	0.4	0.4	0.6	0.0	0.0	0.6	0.5	0.0	0.0
B	0.1	0.7	0.05	0.5	0.15	0.3	0.7	0.4	0.5	0.0	0.0	0.6	0.3	0.0	0.0
L	0.03	0.2	0.02	0.2	0.3	0.1	0.65	0.4	0.3	0.0	0.0	0.6	0.15	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.38	0.5	0.02	0.08	0.57	0.4	0.03	0.08
B	0.0	0.0	0.0	0.0	0.2	0.2	0.8	0.38	0.4	0.02	0.05	0.57	0.2	0.03	0.05
L	0.0	0.0	0.0	0.0	0.2	0.01	0.8	0.38	0.2	0.02	0.02	0.57	0.05	0.03	0.02
INH	0.4	1.0	0.15	1.0	0.05	1.0	0.4	0.4	1.0	0.0	0.0	0.6	1.0	0.0	0.0
B	0.1	1.0	0.05	1.0	0.15	0.4	0.7	0.4	0.4	0.0	0.0	0.6	0.4	0.0	0.0
L	0.03	1.0	0.02	0.9	0.3	0.1	0.65	0.4	0.1	0.0	0.0	0.6	0.1	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.38	0.4	0.02	0.4	0.57	0.4	0.03	0.4
B	0.0	0.0	0.0	0.0	0.2	0.2	0.8	0.38	0.2	0.02	0.2	0.57	0.2	0.03	0.2
L	0.0	0.0	0.0	0.0	0.2	0.1	0.8	0.38	0.1	0.02	0.1	0.57	0.1	0.03	0.1

Table 3.27. (Concluded)

Sequoyah

	F_O	S_O	F_V	S_V	F_B	S_B	F_H	f_W	S_W	f_{Wb}	S_{Wb}	f_M	S_M	f_{Mb}	S_{Mb}
CNH	0.4	1.0	0.15	1.0	0.05	0.5	0.4	0.45	0.95	0.0	0.0	0.55	0.85	0.0	0.0
B	0.1	1.0	0.05	1.0	0.15	0.4	0.7	0.45	0.85	0.0	0.0	0.55	0.75	0.0	0.0
L	0.03	1.0	0.02	1.0	0.3	0.3	0.65	0.45	0.75	0.0	0.0	0.55	0.65	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.5	0.8	0.31	0.95	0.14	0.65	0.38	0.85	0.17	0.55
B	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.31	0.85	0.14	0.55	0.38	0.75	0.17	0.45
L	0.0	0.0	0.0	0.0	0.2	0.3	0.8	0.31	0.75	0.14	0.45	0.38	0.65	0.17	0.35
GNH	0.4	1.0	0.15	0.7	0.05	0.5	0.4	0.45	0.6	0.0	0.0	0.55	0.5	0.0	0.0
B	0.1	0.7	0.05	0.5	0.15	0.3	0.7	0.45	0.5	0.0	0.0	0.55	0.3	0.0	0.0
L	0.03	0.2	0.02	0.2	0.3	0.1	0.65	0.45	0.3	0.0	0.0	0.55	0.15	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.31	0.5	0.14	0.08	0.38	0.4	0.17	0.08
B	0.0	0.0	0.0	0.0	0.2	0.2	0.8	0.31	0.4	0.14	0.05	0.38	0.2	0.17	0.05
L	0.0	0.0	0.0	0.0	0.2	0.01	0.8	0.31	0.2	0.14	0.02	0.38	0.05	0.17	0.02
INH	0.4	1.0	0.15	1.0	0.05	1.0	0.4	0.45	1.0	0.0	0.0	0.55	1.0	0.0	0.0
B	0.1	1.0	0.05	1.0	0.15	0.4	0.7	0.45	0.4	0.0	0.0	0.55	0.4	0.0	0.0
L	0.03	1.0	0.02	0.9	0.3	0.1	0.65	0.45	0.1	0.0	0.0	0.55	0.1	0.0	0.0
SH	0.0	0.0	0.0	0.0	0.2	0.4	0.8	0.31	0.4	0.14	0.4	0.38	0.4	0.17	0.4
B	0.0	0.0	0.0	0.0	0.2	0.2	0.8	0.31	0.2	0.14	0.2	0.38	0.2	0.17	0.2
L	0.0	0.0	0.0	0.0	0.2	0.1	0.8	0.31	0.1	0.14	0.1	0.38	0.1	0.17	0.1

Table 3.28. Recommended Shielding Factor Values

	Zion	Grand Gulf	Peach Bottom	Surry	Sequoyah	Average	NRC	Choice
CNH	0.94	0.93	0.93	0.94	0.93	0.93		0.95
B	0.77	0.76	0.77	0.78	0.77	0.77	0.75	0.75
L	0.59	0.59	0.59	0.60	0.59	0.59		0.60
SH	0.62	0.80	0.60	0.72	0.74			0.80
B	0.52	0.70	0.50	0.62	0.64			
L	0.42	0.60	0.40	0.52	0.54			0.40
GNH	0.75	0.75	0.75	0.76	0.75	0.75		0.75
B	0.42	0.41	0.41	0.44	0.41	0.42	0.33	0.40
L	0.19	0.18	0.18	0.20	0.18	0.19		0.20
SH	0.19	0.42	0.17	0.31	0.35			0.35
B	0.11	0.25	0.10	0.20	0.21			
L	0.03	0.09	0.02	0.07	0.07			0.02
INH	1.00	1.00	1.00	1.00	1.00	1.00		1.00
B	0.49	0.49	0.49	0.49	0.49	0.49	0.75	0.50
L	0.14	0.14	0.14	0.14	0.14	0.14		0.15
SH	0.40	0.40	0.40	0.40	0.40	0.40		0.40
B	0.20	0.20	0.20	0.20	0.20	0.20		0.20
L	0.10	0.10	0.10	0.10	0.10	0.10		0.10

REFERENCES

[1] R. M. Ostmeyer and J. C. Helton, Exposure Pathways Models for Accidental Radionuclide Releases, NUREG/CR-4184, Sandia National Laboratories, Albuquerque, NM, p. 33, draft available. (a) p. B-17, (b) p. B-13, (c) p. B-23, (d) p. B-22, (e) p. B-21, (f) p. B-10, (g) p. B-16, (h) p. B-11.

[2] Statistical Abstract of the United States, 108th Edition, 1988, summary insert.

[3] J. Alzona et al., Atmos. Environment, Vol. 13, No 55 (1979)

[4] A. F. Cohen and B. L. Cohen, Infiltration of Particulate Matter into Buildings, NUREG/CR-1151, Sandia National Laboratories, Albuquerque, NM, November 1979.

[5] J. Roed and R. J. Cannell, Radiation Protection Dosimetry, Vol. 21, No. 107 (1987).

[6] H. D. Brenk and H. de Witt, Radiation Protection Dosimetry, Vol 21, No. 117 (1987).

[7] G. C. Christensen and R. Mustonen, Radiation Protection Dosimetry, Vol. 21, No. 125 (1987).

[8] D. C. Aldrich and D. M. Ericson, Public Protection Strategies in the Event of a Nuclear Reactor Accident: Multicompartment Ventilation Model for Shelters, SAND77-1555, Sandia National Laboratories, Albuquerque, NM, January 1978.

[9] Office of Civil Defense, Shelter Design and Analysis, Vol 1, Fallout Radiation Shielding, TR-20-(Vol. 1), Department of Defense, 1968.

[10] P. H. Jensen, Shielding Factors for Gamma Radiation from Activity Deposited on Structures and Ground Surfaces, Riso National Laboratory, Riso-M-2270, DK-4000 Roskilde, Denmark, 1982

[11] P. Jacob and R. Meckbach, Radiation Protection Dosimetry, Vol 21, No. 79 (1987).

[12] M. O. Cohen, Calculations of Dose Rates Arising from Radioactive Fallout Upon an Urban Environment, MR-7027, Mathematical Applications Group, Inc., 1975.

[13] T. Baumeister, ed., Marks' Handbook for Mechanical Engineers, McGraw-Hill, New York, 1978, pp. 6-7.

[15] Z. G. Burson, Health Physics, Vol. 16, No. 42 (1974)

[16] B. Lauridsen and P. H. Jensen, Shielding Factors for Vehicles to Gamma Radiation Deposited on Structures and Ground Surfaces, Riso-M-2339, Riso National Laboratory, DK-4000 Roskilde, Denmark, 1982

[17] R. H. Perry and C. H. Chilton, Chemical Engineers' Handbook, Fifth Edition, McGraw-Hill, New York, 1973, pp. 2-7.

[18] Z. G. Burson and A. E. Profio, Structure Shielding from Cloud and Fallout Gamma Ray Sources for Assessing the Consequences of Reactor Accidents, EG&G, EGG-1183-1670, 1975.

[19] J. Roed, "Parameters Used in Consequence Calculations for an Urban Area," Recent Advances in Reactor Accident Consequence Assessment, CSNI Rpt. 145, OECD, Paris, February 1988, p. 103.

[20] J. P. Robinson and P. E. Converse, Summary of U.S. Time Use Survey, Institute for Social Relations, University of Michigan, Ann Arbor, MI, 1966.

[21] U.S. Department of Housing and Urban Development, 1983 FHA Homes, Data for States and Selected Areas, 1983.

[22] U.S. Department of Commerce, 1980 Census of Housing, General Housing Characteristics, 1982.

[23] U.S. Nuclear Regulatory Commission, Reactor Safety Study, Appendix VI, Calculation of Reactor Accident Consequences, WASH-1400, October 1975, pp. 11-26.

4. MACCS FOOD PATHWAY INPUT PARAMETERS

4.1 Introduction

Within the MACCS code, of the consequences from the ingestion of food contaminated by radionuclides deposited onto farmland following an accidental release are measured. These consequences can be divided into two general categories:

(1) societal dose received from the ingestion of contaminated food and the health effects from that dose, and

(2) economic costs from the mitigative actions to limit the dose to some user-defined level of acceptability.

In addition, a further distinction is made within the MACCS code between the dose received via the food pathway from crops being grown at the time of the release (i.e., the growing season submodel) and the dose received subsequent to the current growing season from food grown on land contaminated by the release (i.e., the long-term submodel). This distinction becomes evident in the preparation of the food pathway input parameters. Doses are calculated and mitigative actions determined for each of these submodels.

In general, the following model is used to determine the dose received via the food pathway. The dose received by organ k from the ingestion of nuclide i found in food arising from crop j, $D_{i,j,k}$, can be expressed as

$$D_{i,j,k} = GC_i \cdot A \cdot FA_j \cdot TF_{i,j} \cdot DF_{i,k}$$

where

GC_i = ground concentration of nuclide i (Bq/m^2),

A = farmland area (m^2),

FA_j = fraction of farmland used to grow crop j (unitless),

$TF_{i,j}$ = transfer factor, i.e., the fraction of deposited material incorporated onto or into the edible portion of crop j and ultimately eaten by man (unitless), and

$DF_{i,k}$ = dose received by organ k from ingested nuclide i (Sv/Bq).

The resulting dose to organ k from ingested nuclide i becomes

$$D_{i,k} = CC_i \quad \cdot \quad DF_{i,k} \cdot \sum_j (A \cdot FA_j \cdot TF_{i,j}) \tag{4.1}$$

Equation 4.1 is used both to project the potential dose for the determination of necessary mitigative actions and to determine the societal health effects resulting from the actual dose received.

The food pathway parameters will be discussed in three major groups. Section 4.1 describes the general parameters to define the food pathway model, i.e., information about the nuclides to be considered and the crop categories to be used. Section 4.2 discusses the components of the transfer factor, $TF_{i,j}$, in Equation 4.1. In Section 4.3, the input parameters specifically required in determining the necessary mitigative actions are discussed. The input parameters within each section are presented in alphabetical order for ease of location. Each parameter is described as well as its recommended values. Because there is uncertainty inherent in the derivation of the input parameter values, most tables containing the recommended values will also contain a range of possible parameter values. This range for the input parameters will be enclosed in parentheses or, in some cases, indicated explicitly The recommended values for each parameter are followed by a discussion of the methodology used and the assumptions made in deriving the values currently recommended.

4.2 Food Pathway Definition Input Parameters

Several input parameters are required for the definition of the MACCS food pathway model. The values selected for some of these parameters will determine the dimensions for all subsequent food pathway input parameters.

4.2.1 NFICRP

NFICRP = number of crop categories to be used

The recommended value for NFICRP is 7.

Discussion

The recommended crop categories are listed in Table 4.1 with the major crops included within each category.

Table 4.1. Crop Categories

Pasture	Stored Forage	Grain	Legumes & Nuts	Leafy Green Veg	Roots & Tubers	Other Food
Various grasses	Alfalfa	Wheat	Soybeans	Lettuce	Potatoes	Fruits:
	Clover	Oats	Peanuts	Cabbage	Carrots	Apples
	Sorghum	Barley	Snap beans	Broccoli	Beets	Grapes
		Corn (incl. sweet corn)	Dried beans	Spinach	Sugar	Citrus Fruits
		Sorghum	Peas	Celery	Onion	Oranges
			Nuts	Cauliflower		Grapefruits
				Greens		Lemons
						Vegetables:
						Tomatoes
						Cucumbers
						Peppers

Several factors were considered in dividing the crops into the seven distinct categories in Table 4.1. The evaluation of the input parameters for the food pathway in the MACCS code tends to be somewhat labor intensive, so the intent was to keep the derivation of input parameters as simple and straightforward as possible.

The first factor considered was the harvesting pattern for the various crop categories. Pasture is the only crop for which harvesting is considered continuous. It is also assumed that all radioactive material deposited onto pastureland during a given growing season will be consumed by grazing animals before the end of that growing season. In addition, it is assumed that the rate at which the pasture is harvested is constant over the entire season. In contrast, harvest is assumed to be a discrete process for all nonpasture crops. This significant difference in harvesting patterns served as the basis for the first major subdivision into crop categories, that is,

(1) Pasture, and
(2) Nonpasture crops.

To make an additional distinction between the nonpasture crops, consideration was given to how the edible portion of the nonpasture crops becomes contaminated during deposition. In certain crops, the edible portion is not exposed to the environment, and contamination occurs only by the translocation of the radioactive material deposited onto plant surfaces into the edible portion of the plant. Examples of this type of crop are grains, legumes, nuts, roots, and tubers. For all other nonpasture crops, the edible portion of the plant is directly exposed to the radioactive material during deposition. These crops include stored forage and all fruits and vegetables. By differentiating between nonpasture crops in which the edible portion is directly contaminated and those in which the edible portion is not subject to direct contamination, the crops were then further subdivided into the following categories:

(1) Pasture
(2) Nonpasture
    Indirect contamination of the edible portion
      (grains, legumes, nuts, roots, and tubers)
    Direct contamination of the edible portion
      (stored forage, fruits, and vegetables)

Within each of these broad groups of nonpasture crops, a further distinction can be made when consideration is given to the plant surface characteristics. For all crops, an increased roughness of the plant surfaces directly affects the efficiency with which the plant retains the radioactive material until the time of harvest.

For crops in which the edible portion is not exposed to the environment, an increase in the amount of material retained on the plant surfaces increases the translocation that can occur. The beard structure of grains further enhances the efficiency of the translocation process. The plant surfaces of legumes, nuts, roots, and tubers are similar and characteristically have less surface roughness than the plant surfaces of grains.

For crops in which the edible portion is exposed to the outside environment, an increased roughness in the plant surfaces will increase the amount of material physically retained on those surfaces until the crop is harvested. A distinction was thus made between green leafy vegetables and stored forage, in which the edible portion has significant surface roughness, and all other fruits and vegetables for which the edible portion has a relatively smooth surface or a "rind" that will be removed during preparation.

By considering the differences in the surface roughness of both plants and their edible portions, the crops categories were further refined as follows:

(1) Pasture
(2) Nonpasture
    Indirect contamination of the edible portion
      High plant surface roughness
        (grains)
      Low plant surface roughness
        (legumes, nuts, roots, tubers)
    Direct contamination of the edible portion
      High surface roughness of the edible portion
        (stored forage, green leafy vegetables)
      Low surface roughness of the edible portion
        (fruits and vegetables)

Finally, two additional factors were given consideration in arriving at the crop categories currently being used. The first, biological dissimilarity of the edible portion of the plant, led to a distinction between seeds (legumes and [illegible]) and roots (roots and tubers). The second factor, crop utilization, gave rise to the distinction being made between stored forage (consumed only by animals) and green leafy vegetables (consumed only by man).

By giving consideration to these distinctions between crop types, the following crop categories evolved:

1) Pasture
2) Nonpasture
   - Indirect contamination of the edible portion
     - High plant surface roughness
       - (grains)
     - Low plant surface roughness
       - Reproductive plant part
         - (legumes and nuts)
       - Absorptive or energy storing plant part
         - (roots and tubers)
   - Direct contamination of the edible portion
     - High plant surface roughness
       - Consumed only by animals
         - (stored forage)
       - Consumed only by man
         - (green leafy vegetables)
     - Low plant surface roughness
       - (other food)

Of the crop categories, pasture crops and stored forage are eaten by animals that in turn are food for man, but they are not eaten by man directly. On the other hand, green leafy vegetables, roots, tubers, and "other" crops are not consumed by animals, but are consumed directly by man. Grains and legumes and nuts are consumed by both man and animals, which is important in evaluating the input parameters for the food pathway.

4.2.2 NFIISO

NFIISO = number of nuclides for which data will be specified for the food pathway

The recommended value for NFIISO is 6.

Discussion

When NFIISO = 6, the recommended food pathway nuclides are Sr-89, Sr-90, Cs-134, Cs-137, I-131, and I-133. It is expected that these radionuclides will dominate the food pathway doses across the entire spectrum of potential reactor accident scenarios [1:40].

4.2.3 NTTRM

NTTRM = Number of terms used in the growing crop retention model that describes the weathering loss mechanism

The recommended value for NTTRM is 2.

Discussion

The growing season crop retention model calculates the fraction of the radioactive material deposited onto the surface of growing plants that will be retained following an exponential weathering loss resulting from exposure of the plant to the environment. By using two terms in the growing crop retention model, it is possible to separate the deposited material into the portion that will weather rapidly with a relatively short half-life and the remaining material that will adhere more stubbornly to the plant surfaces and weather more slowly.

The fractions of the material weathering with each pattern and the half-lives associated with each weathering pattern are supplied by the input parameters CTCOEF and CTHALF as described in Section 4.3.

4.2.4 TGSBEG and TGSEND

$TGSBEG_j$ = day of the year marking the start of the growing season for crop j

$TGSEND_j$ = day of the year marking the end of the growing season for crop j

Table 4.10 gives recommended values for $TGSBEG_j$ and $TGSEND_j$.

Discussion

Since the fraction of radioactive material deposited directly onto growing crops that remains on the crop at the time of harvest is time dependent, it must be determined when during the growing season the deposition occurred. The elapsed time before harvest, T_e, is then the difference between the day on which the crop is harvested, TGSEND, and the day on which deposition, T_a, (i.e., the day on which the accidental release occured). Therefore,

$$T_e = TGSEND - T_a$$

This elapsed time is used within the MACCS code to determine the amount of radioactive material deposited onto plant surfaces that will be weathered away before the crop is harvested.

The values recommended for TGSBEG and TGSEND are summarized in Table 4.2.

Table 4.2 Values for TGSBEG and TGSEND

Crop	$TGSBEG_j$	$TGSEND_j$	(Dates)
Pasture	90	270	(3/31-9/27)
Stored Forage	150	240	(5/30-8/28)
Grains	150	240	
Legumes & Nuts	150	240	
Leafy Green Vegetables	150	240	
Root Vegetables	150	240	
Other Food	150	240	

4.3 Transfer Factor Component Input Parameters

Calculation of the dose to organ k from nuclide i, $D_{i,k}$ in Equation 4.1, requires the determination of the transfer factors, $TF_{i,j}$, which define the fraction of nuclide i deposited onto cropland used to grow crop j that is incorporated into the edible portion of the crop and ultimately consumed by man.

Figure 4.1 depicts the overall transfer of deposited radionuclides to man as modeled by MACCS. Each transfer path is labeled using the MACCS input parameters that either define the transfer along the path or, as in the case of CTCOEF and CTHALF, calculate within the MACCS code the fraction of the available material transferred at that segment of the pathway. Tables 4.3 to 4.6 give the recommended values.

Two submodels within the MACCS food pathway model describe the transfer of deposited radioactive material to the edible portion of the crop. The first of these, the growing season submodel, describes the transfer of radionuclides deposited directly onto the surfaces of crops growing at the time of the release. The second, the long-term submodel, describes the transfer of radionuclides deposited onto soil that will subsequently enter the food chain via root uptake by plants or by direct ingestion of the contaminated soil by grazing animals. Within each of these submodels, crops are considered to enter the food chain in one of three ways: (1) the crop may be consumed directly by man, (2) it may be consumed by meat-producing animals with the meat in turn being consumed by man, or (3) it may be consumed by milk-producing animals with the milk in turn being consumed by man.

The derivation of values for each of the input parameters depicted in Figure 4.1 is discussed fully in the remainder of this section. These input parameters are considered in alphabetical order.

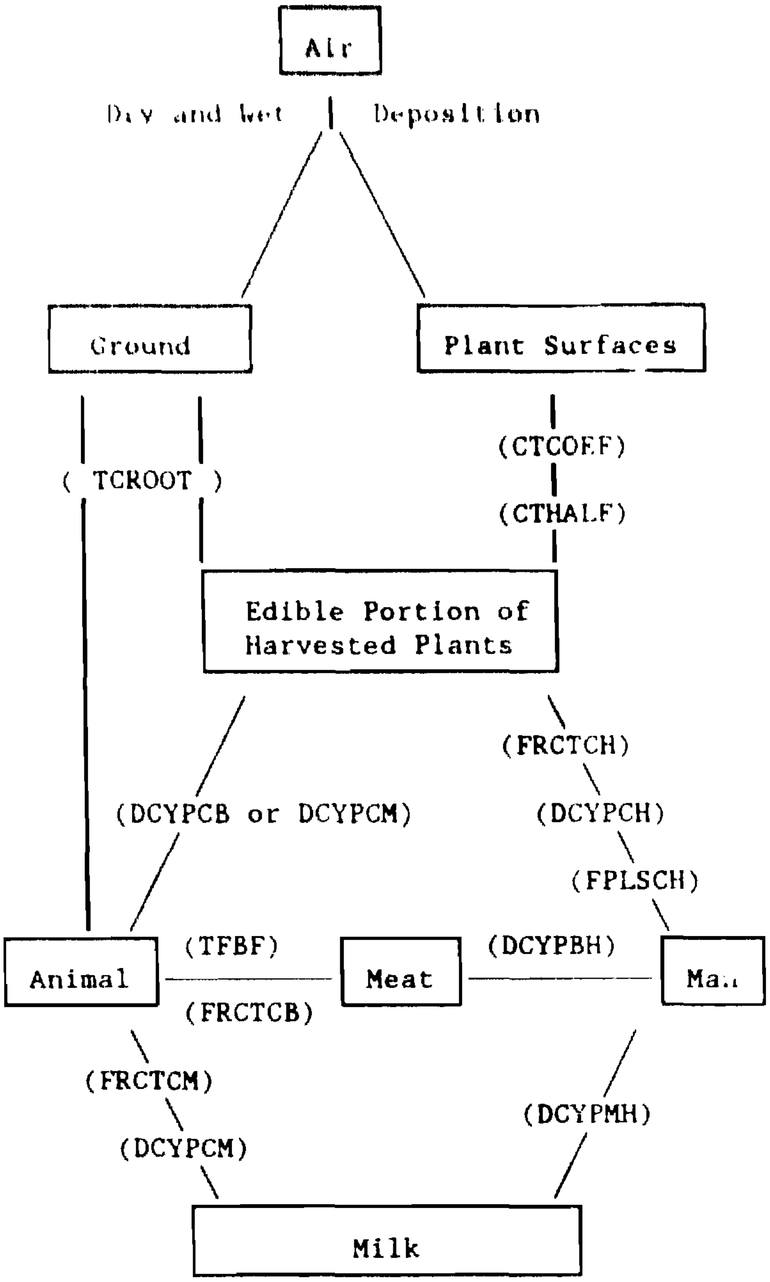


Figure 4.1 Transfer of Released Radionuclides to Man Via the Food Pathway as Depicted in the MACCS Code.

4.3.1 CTCOEF and CTHALF

$CTCOEF_n$ = fraction of material weathering with a half-life $CTHALF_n$

$CTHALF_n$ = half-life for the nth exponential term of the weathering model

Table 4.3. Recommended Values for CTCOEF$_1$

Crop	Strontium	Cesium	Iodine
Pasture	0.30 (0.23-0.38)	0.30 (0.23-0.38)	0.30 (0.23-0.38)
Stored Forage	0.20 (0.15-0.24)	0.20 (0.15-0.24)	0.20 (0.15-0.24)
Grain	0.010 (0.0075-0.013)	0.050 (0.038-0.063)	0.0
Legumes	0.0050 (0.0038-0.0063)	0.010 (0.0075-0.013)	0.0
Green Leafy Vegetables	0.24 (0.18-0.30)	0.24 (0.18-0.30)	0.24 (0.18-0.30)
Roots & Tubers	0.0006 (0.00045-0.00075)	0.025 (0.019-0.031)	0.0
Other Food	0.020 (0.15-0.24)	0.020 (0.15-0.24)	0.020 (0.15-0.24)

Table 4.4. Recommended Values for CTHALF$_1$*

Crop	Strontium	Cesium	Iodine
Pasture	1.2096×10^6	1.2096×10^6	1.2096×10^6
Stored Forage	1.2096×10^6	1.2096×10^6	1.2096×10^6
Grain	3.1536×10^{13}	3.1536×10^{13}	1.0
Legumes	3.1536×10^{13}	3.1536×10^{13}	1.0
Green Leafy Vegetables	1.2096×10^6	1.2096×10^6	1.2096×10^6
Roots & Tubers	3.1536×10^{13}	3.1536×10^{13}	1.0
Other Food	1.2096×10^6	1.2096×10^6	1.2096×10^6

---

* Half-lives in seconds: 14 days = 1.2096×10^6
1 million years = 3.153×10^{13}.

Table 4.5. **Recommended Values for** CTCOEF$_2$

Crop	Strontium	Cesium	Iodine
Pasture	0.076 (0.058-0.096)	0.076 (0.058-0.096)	0.076 (0.058-0.096)
Stored Forage	0.050 (0.038-0.063)	0.050 (0.038-0.063)	0.050 (0.038-0.063)
Grain	0.0	0.0	0.0
Legumes	0.0	0.0	0.0
Green Leafy Vegetables	0.060 (0.046-0.076)	0.060 (0.046-0.076)	0.060 (0.046-0.076)
Roots & Tubers	0.0	0.0	0.0
Other Food	0.050 (0.038-0.063)	0.050 (0.038-0.063)	0.050 (0.038-0.063)

Table 4.6. **Recommended Values for** CTHALF$_2$*

Crop	Strontium	Cesium	Iodine
Pasture	$4.3200\text{x}10^6$	$4.3200\text{x}10^6$	$4.3200\text{x}10^6$
Stored Forage	$4.3200\text{x}10^6$	$4.3200\text{x}10^6$	$4.3200\text{x}10^{66}$
Grain	1.0	1.0	1.0
Legumes	1.0	1.0	1.0
Green Leafy Vegetables	$4.3200\text{x}10^6$	$4.3200\text{x}10^6$	$4.3200\text{x}10^6$
Roots & Tubers	1.0	1.0	1.0
Other Food	$4.3200\text{x}10^6$	$4.3200\text{x}10^6$	$4.3200\text{x}10^6$

---

* Half-lives in seconds: 50 days = $4.3200\text{x}10^6$.

A uniform sampling distribution is recommended for all CTCOEF and CTHALF. Recall that the numbers within the parentheses represent the possible range of values for each parameter value.

Discussion

Between the time of deposition of radioactive material onto plant surfaces and the time when the plants are harvested, part of the radioactive material will be lost from the plant surfaces by the following processes (1) weathering, (2) radioactive decay, (3) translocation to interior portions of the plant, and (4) harvesting.

The fraction of the radioactive material initially deposited onto plant surfaces that remains in or on the edible portions of the harvested plant is called the direct deposition transfer factor.

The magnitude of the direct deposition transfer factor depends on the time during the growing season when the accident (deposition) occurs. For crops in which the edible portion is exposed to the outside environment, the losses from weathering and decay will increase with time. Therefore, decreasing the time between deposition and harvest will result in an increase in the direct deposition transfer factor.

It is assumed that pasture undergoes continuous harvesting throughout the growing season. Deposition early in the pasturing season will increase both the time available for nuclide loss from weathering and decay and will also increase the time available for the consumption of contaminated pasture by grazing animals. Since consumption of nuclides by grazing is faster than the removal by either weathering or radioactive decay, the size of the direct deposition transfer factor will increase as the time available for grazing increases.

Weathering has been observed to cause a loss of radioactive material on plant surfaces due to the simultaneous occurrence of several exponential processes. Therefore, the removal of radioactivity from plant surfaces by weathering can be treated as a sum of terms that have the following form:

$$\sum_{n} \{CTCOEF_n \cdot EXP[-(\ln 2/CTHALF_n)]\} \qquad (4.2)$$

where

$CTCOEF_n$ = fraction of material deposited per unit area of cultivated field that is removed by weathering with a half-life $CTHALF_n$

In addition,

$$CTCOEF_n = IF \cdot AF_n$$

where

IF - interception fraction, i.e., the fraction of the material deposited onto the field that is intercepted by crop surfaces

AF_n - availability fraction, i.e., the fraction of the material deposited onto crop surfaces from which the material is removed by weathering with the half-life $CTHALF_n$

and

$$\sum_n AF_n = 1$$

The edible portion of some crops is not exposed to the outside environment. For these crops, the retention of radioactivity in the edible portions will be determined by translocation of the material from plant surfaces to the edible portion. When this is the case, the weathering model as described above will not be applicable. Instead, an empirical transfer factor is used that has been derived from fallout studies. The empirical transfer factor represents the combined effects of interception, weathering, and translocation to the edible portion of the plant. For convenience, this empirical factor can be input as a value of $CTCOEF_n$. Since this empirical value includes the effects of weathering, the exponential part of weathering decay expression associated with this empirical value for $CTCOEF_n$ is reduced to a value of unity by setting $CTHALF_n$, in Equation 4.2, equal to one million years (i.e., 3.1536×10^{13} seconds). In addition, all but the first term of the weathering equation are set to zero by setting $CTCOEF_n$ for $n > 1$ equal to 0.0 and letting the associated value of $CTHALF_n$ for $n > 1$ be 1 second. In effect, this transforms the exponential equation into a constant (i.e., $CTCOEF_1$) for those crops in which the edible portion is not exposed to the outside environment.

Finally, the removal of radioactivity is treated explicitly for all crops. It is currently assumed that there are two exponential weathering terms for all crop categories with appropriate adjustments made for the crops in which the edible portion is not exposed to the outside environment. When using a two exponential term weathering model, it becomes necessary to derive two values for each crop/nuclide combination that indicates the $CTCOEF_n$ for each exponential expression. In addition, each of these terms will also require a value of $CTHALF_n$ that describes the weathering half-life for that nuclide/crop combination for that component of the weathering process.

The following crops have edible portions that are exposed to the outside environment: pasture, stored forage, green leafy vegetables, and "other food." Given that the "other food" crop category consists primarily of fruits and vegetables in the light of per capita consumption data [2], the entire category will be treated as though the edible portion is exposed to the outside environment. As previously stated, CTCOEF$_n$ is the product of the interception fraction and the availability fraction. In addition, a half-life will be needed for each of the two exponential terms in the weathering equation. Based on studies by Simmonds and Linsley [3,4], the following values and associated ranges recommended for the interception fraction, availability fraction, and weathering half-lives are as summarized in Table 4.7. The higher interception fractions for pasture and spinach seems to be justified by Vuori's [5] study of fallout data following the Chernobyl accident.

Table 4.7 Interception Fraction, Availability Fraction, and Half-Lives

Variable	Value	Range of Values
Interception fraction		
Pasture	0.38	0.29-0.48
Stored Forage	0.25	0.20-0.28
Green Leafy Vegetables	0.30	0.23-0.38
Other Food	0.25	0.20-0.28
Availability fraction for short-term weathering	0.80	0.75-0.85
Availability fraction for long-term weathering	0.20	0.15-0.25
Half-life for short-term weathering (day)	14.0	13.0-19.0
Half-life for long-term weathering (day)	50.0	13.0-19.0

These data lead to the values in Table 4.8 for the variables CTCOEF and CTHALF for all nuclides being treated in the MACCS code. The remaining crop categories (i.e., grains, legumes, and roots and tubers) have edible portions not exposed to the environment, and the values for CTCOEF$_1$ will therefore represent empirical transfer factors as derived from fallout data. To ensure that MACCS will treat these factors as constants, the other related

Table 4.8. Values for CTCOEF and CTHALF*

	Pasture	Stored Forage	Green Leafy Vegetables	Other Food
$CTCOEF_1$	0.30	0.20	0.24	0.20
$CTCOEF_2$	0.076	0.05	0.060	0.05
$CTHALF_1$	14 d.	14 d.	14 d.	14 d.
$CTHALF_2$	50 d.	50 d.	50 d.	14 d.

---

* These values are converted to seconds for use in the MACCS code.

input variables take on the following values:

$CTHALF_1$ = 1 million years (i.e., 3.154×10^{13} s),
$CTCOEF_2$ = 0.0
$CTHALF_2$ = 1 s

Since the iodine isotopes considered have very short half-lives, it has been assumed that these isotopes will not be found in the edible portion of the plant at the time of harvest. Therefore, the value for $CTCOEF_1$ for both I-131 and I-133 will be 0.0.

In a review of the available data on direct deposition transfer factors to be used for $CTCOEF_1$, Ostmeyer and Helton [1] arrived at empirical direct deposition transfer factors for grain and legumes. Coughtrey and Thorne [6] discussed the analogous empirical direct deposition transfer factor for roots and tubers. For each of these transfer factors, a range of possible values for each element/crop combination was chosen by assuming a 25% uncertainty range.

A summary of these empirical transfer factors and the associated range of possible values is given in Table 4.9.

Table 4.9. Summary of Empirical Transfer Factors

	Empirical Transfer Factors	
Crop	Strontium	Cesium
Grain	0.010 (0.0075-0.013)	0.050 (0.038-0.063)
Legumes	0.005 (0.0038-0.0063)	0.010 (0.0075-0.013)
Roots & Tubers	0.00060 (0.00045-0.00075)	0.025 (0.019-0.031)

4.3.2 DCYPBH

$DCYPBH_i$ - Fraction of radionuclide i present in meat at the time of slaughter that is retained and consumed by man (accounts for losses from both decay and processing).

Table 4.10 shows the recommended values for $DCYPBH_i$.

Table 4.10. Recommended Values for $DCYPBH_i$

Nuclide	DCYPBH
Sr-89	0.77 (0.58-0.96)
Sr-90	1.0
Cs-134	1.0
Cs-137	1.0
I-131	0.18 (0.14-0.23)
I-133	0.0

A uniform sampling distribution is recommended for $DCYPBH_i$.

Discussion

$DCYPBH_i$ can be expressed as

$$DCYPBH_i = \frac{FINAL_i}{INITIAL_i},$$

where

$FINAL_i$ - Concentration of radionuclide i in the feed at the time of consumption by the animal (Ci/kg) (accounts for both decay and processing losses)

$INITIAL_i$ - Concentration of radionuclide i in the meat at the time of slaughter (Ci/kg)

A value for DCYPBH is obtained for each nuclide i by evaluating the following expression:

$$\mathrm{DCYPBH}_i = \mathrm{EXP}\,(-[\,(\ln 2/\mathrm{THALF}_i)\cdot \mathrm{TDELAY}\,]) \tag{4.3}$$

where

THALF_i = radiological half-life of isotope i

TDELAY = delay time between the production and consumption of the food product

The values for DCYPBH_i were obtained using Equation 4.3 with two assumptions. The first assumption is that 20 days elapse between the time of production and the consumption of meat and meat products as recommended in the Regulatory Guide 1.109 [7: Table E-15]. That delay time seems reasonable for all meat products purchased fresh by the consumer. The second assumption is that there is no significant difference in the delay time between production and consumption of beef, pork, and poultry; therefore, the loss from decay will be basically the same for all meat products.

In finding the range of values for this variable, it was assumed that the estimated value would most probably be accurate to 25%

4.3.3 DCYPCB and DCYPCM

$\mathrm{DCYPCB}_{i,j}$ and $\mathrm{DCYPCM}_{i,j}$ give the fraction of radionuclide i present in crop j at the time of harvest that is ingested respectively by meat-producing or milk-producing animals.

$\mathrm{DCYPCB}_{i,j}$ = Transfer factor for meat-producing animals

$\mathrm{DCYPCM}_{i,j}$ = Transfer factor for milk-producing animals

Because dairy and beef cattle have similar consumption patterns for different crop types, $\mathrm{DCYPCB}_{i,j}$ and $\mathrm{DCYPCM}_{i,j}$ have the same values. The recommended values are presented in Tables 4.11 and 4.12. Since there are no processing losses between harvest and consumption by cattle, $\mathrm{DCYPCB}_{i,j}$ and $\mathrm{DCYPCM}_{i,j}$ treat only losses resulting from radioactive decay.

A uniform sampling distribution is recommended for $\mathrm{DCYPCB}_{i,j}$ and $\mathrm{DCYPCM}_{i,j}$.

Discussion

Because $\mathrm{DCYPCB}_{i,j}$ and $\mathrm{DCYPCM}_{i,j}$ have the same values for any nuclide/crop pair, they are both denoted in the following discussion by $\mathrm{DCYPCA}_{i,j}$.

Table 4.11. Recommended Values for $DCYPCB_{i,j}$ and $DCYPCM_{i,j}$ for Crops Consumed by Cattle

Nuclide	Pasture	Stored Forage	Grains	Legumes and Nuts
Sr-89	1.0	0.37 (0.28-0.46)	0.20 (0.15-0.25)	0.20 (0.15-0.25)
Sr-90	1.0	0.99	0.99	0.99
Cs-134	1.0	0.92 (0.69-1.0)	0.85 (0.64-1.0)	0.85 (0.64-1.0)
Cs-137	1.0	0.99	0.99	0.99
I-131	1.0	0.063 (0.047-0.079)	0.032 (0.024-0.040)	0.032 (0.024-0.040)
I-133	1.0	0.0068 (0.0051-0.0085)	0.0034 (0.0025-0.0043)	0.0034 (0.0025-0.0043)

Table 4.12. Recommended Values for All Nuclides for Crops Not Consumed by Cattle

Nuclide	Leafy Green Vegetables	Roots & Tubers	Other Food
All	0.0	0.0	0.0

Thus,

$$DCYPCA_{i,j} = \frac{CONSUMED_{i,j}}{HARVEST_{i,j}}$$

where

$CONSUMED_{i,j}$ = concentration (Ci/kg) of radionuclide i in crop j when consumed by animals (accounts for losses because of radioactive decay) and

$HARVEST_{i,j}$ = concentration (Ci/kg) of radionuclide i in crop j at harvest.

Crops used to feed livestock will generally follow the same storage pattern regardless of whether the animal that consumes the crop is a milk- or beef-producing animal. For this reason, these two variables will have the same value for any nuclide/crop pair.

The values derived are based on the assumption that the consumption patterns for the crops in each crop category are similar from year to year. Three the crop categories have no significant consumption by animals, Leafy Green Vegetables, Roots and Tubers, and Other Food, and therefore are assigned a transfer factor of 0.0.

For pasture, grazing is the method of harvesting, and there is therefore no delay time between harvesting and consumption. Since herds are usually sized to the fields on which they graze, all radionuclides deposited onto the pasture grass are assumed to be consumed by the end of the pasturing season. For this reason, for pasture the value for the ratio of the amount of the nuclide consumed to the amount of the nuclide present at the time of harvest is 1.0 for all nuclides.

It is assumed that stored forage will be used on a continuous basis during the time when the animals are not grazing on pasture. The length of time over which this continuous feeding takes place is the difference between 365 days and the length of the pasturing season (growing season) for pasture. If FT_s is the time period over which the feeding of stored forage takes place, then letting the length of the growing season for pasture be 180 days (see TGSBEG and TGSEND), $FT_s = 365 - 180 = 185$ days.

For both grains and legumes, it is assumed that harvest occurs once a year, and the crops will be fed to animals in a continuous manner throughout the year until their next harvest. Accordingly, if the time over which grain and legumes are fed is denoted by FT_g, then $FT_g = 365$ days.

For a crop that is not harvested continuously (single harvest time), if an exact delay time (TDELAY) between harvest and consumption can be assigned the transfer factor, $TF_{i,j}$, for a given crop j for nuclide i is evaluated as follows:

$$TF_{i,j} = EXP\ (-[(\ln 2/THALF_i) \cdot TDELAY_j]) \qquad (4.4)$$

where

$THALF_i$ = radiological decay half-life for nuclide i and

$TDELAY_j$ = time delay between harvest and consumption of crop j by animals.

$TF_{i,j}$ represents the fraction of the radioactive material present in the crop at the time of harvest that remains when the crop is consumed. The losses of radioactive material over that period of time is the result of radioactive decay.

For a crop that is continuously consumed, the transfer factor, $TF_{i,j}$, is calculated as the product of the consumption rate for the crop and the integral of the rate of transfer over the entire period of time the crop is being consumed. The transfer factor for a given crop category for a specific nuclide is then calculated using the following expression:

$$TF_{i,j} = CR_j \cdot \int_0^{T_j} EXP\{-[(\ln 2/THALF_i) \cdot t]\}\, dt$$

where

CR_j = consumption rate for crop j (day^{-1})

$THALF_i$ = radiological decay half-life for nuclide i

T_j = length of overall period during which crop j is consumed

If it is assumed that consumption takes place at a constant rate over the designated period, T_j, then $CR_j = 1/T_j$, and the expression for the transfer factor becomes

$$TF_{i,j} = DCYPCA_{..j}$$

$$= \frac{1}{T_j} \cdot \int_0^{T_j} EXP\{-[(\ln 2/THALF_i) \cdot t]\}\, dt$$

$$= \frac{1 - EXP\{-[(\ln 2/THALF_i) \cdot T_j]\}}{T_j \cdot (\ln 2/THALF_i)} \qquad (4.5)$$

For the period of consumption, T_j, the values FT_s and FT_g were used. That is,

$T_j = FT_s$ = 185 days for Stored Forage

$= FT_g$ = 365 days for Grains, Legumes, and Seeds

The range of possible values in each case was arrived at by assuming that the best estimate values are probably accurate to 25%

4.3.4 DCYPCH

$DCYPCH_{i,j}$ = fraction of radionuclide i present in crop j at the time of harvest remains in food at the time of consumption by man (accounts for losses from radioactive decay)

The transfer factor, $DCYPCH_{i,j}$, accounts only for losses of radioactive material attributable to radioactive decay. Losses of material which occurs during the processing of food before it is eaten is accounted for by the transfer factor $FPLSCH_{i,j}$. Table 4.13 summarizes the recommended values of $DCYPCH_{i,j}$ for crops consumed by man, and Table 4.14 summarizes the values for crops not consumed by man.

Table 4.13. Recommended Values of $DCYPCH_{i,j}$ for Crops Consumed by Man

Nuclides	Grains	Legumes and Nuts	Green Leafy Vegetables	Roots & Tubers	Other Food
Sr-89	0.18 (0.14-0.22)	0.18 (0.14-0.22)	0.67 (0.50-0.84)	0.18 (0.14-0.22)	0.21 (0.16-0.26)
Sr-90	0.99 (0.97-1.0)	0.99 (0.97-1.0)	1.0	0.99 (0.97-1.0)	0.99 (0.97-1.0)
Cs-134	0.84 (0.63-1.0)	0.84 (0.63-1.0)	0.96 (0.76-1.0)	0.84 (0.63-1.0)	0.85 (0.64-1.0)
Cs-137	0.99 (0.77-1.0)	0.99 (0.77-1.0)	1.0	0.99 (0.77-1.0)	0.99 (0.77-1.0)
I-131	0.0099 (0.0074-0.012)	0.0099 (0.0074-0.012)	0.21 (0.052-0.37)	0.0099 (0.0074-0.012)	0.024 (0.017-0.030)
I-133	0.0	0.0	0.0	0.0	0.0

Table 4.14. Recommended Values for $DCYPCH_{i,j}$ for Crops Not Consumed by Man

Nuclide	Pasture	Stored Forage
All	0.0	0.0

The uniform sampling sampling distribution is recommended for $DCYPCH_{i,j}$.

Discussion

$DCYPCH_{i,j}$ can be defined as

$$DCYPCH_{i,j} = \frac{INTAKE_{i,j}}{HARVEST_{i,j}} .$$

where

$INTAKE_{i,j}$ = concentration (Ci/kg)of radionuclide i in crop j when consumed by man

$HARVEST_{i,j}$ = concentration (Ci/kg) of radionuclide i in crop j at harvest

For the variable $DCYPCH_{i,j}$, it is necessary to determine a value for each crop category and radionuclides considered.

Since neither Pasture nor Stored Forage is consumed directly by man, a value of 0.0 is assigned to the variable DCYPCH for these crop categories over all the nuclides considered.

The values derived by Ostmeyer and Helton [1] were based on the assumption that there was a 14-day delay between harvest and consumption of all crops except grain. Grain was assumed to be put into storage upon harvest and then continuously released for consumption over the course of the year prior to the next harvest.

The revised values were derived by taking a more comprehensive look at the current marketing practices for each crop category. It is acknowledged that processing (canning and freezing) as well as storage will considerably change the delay time from harvest to consumption. A brief discussion follows of the observed practices and the assumptions made for each crop category.

Grains are harvested once a year and placed in storage to be released continuously to produce the edible products. It was assumed that the harvest of any given year would be completely depleted by the time of harvest the following year. This is considered a conservative model for grain usage, since the current stores would indicate that the actual delay time before consumption may well be considerably longer than the assumed delay time. Sweet corn has been included in the grain category to allow using similar transfer factors for the concentration of radionuclides found in the edible portion. This does not disrupt the model for crop usage, since sweet corn represents only 1.5% of the total grains consumed by man. In addition, only 30% of the sweet corn is consumed fresh, and the remaining 70% is processed [2:Table 213]. In effect, processing allows for the same continuous consumption over the year that is used in the model for all grain. It has been further assumed that there is a minimum processing and delivery time of 14 days before the grain products would be available for consumption.

The model used for grains was also used for two other categories of crops: (1) Legumes and Nuts and (2) Roots and Tubers. Continuous consumption for crops in these categories is assumed to begin 14 days after the crop is harvested and extends until the next year's harvest is ready for consumption, that is, until 14 days after the next harvest. The total time over which consumption of these crops occurs is therefore 365 days.

Storage and consumption patterns for the crop categories Green Leafy Vegetables and Other Food fall into three broad categories. Some produce is delivered fresh to market and consumed within 14 days. Some produce is placed in refrigerated storage for up to 6 months. Finally, some produce is undergoes additional processing (i.e., freezing, canning, or drying), which significantly increases its shelf life. For the processed produce, it has been assumed that the processing and delivery to the consumer will require 14 days and that the supply of processed products will be consumed continuously over the course of the next year.

By surveying agricultural data, it can be shown that 70% of the Green Leafy Vegetables will be consumed fresh after approximately a 14-day delay to the consumer. Another 25% of the crop will be placed in refrigerated storage and used over the course of six months. The final 5% will undergo additional processing and be used continuously until the time of the next harvest a year later. This information can be found in Ref. [2]: Table 161, p. 218; Table 244, p. 178; Table 205, p. 152; Table 209, p. 154; Table 246, p. 180.

For the Other Food crop category, a review of agricultural data [2: Tables 246, 258, 277, and 295] shows that 5% will be consumed fresh (after 14 days), while 95% undergoes additional processing that allows continuous utilization over the course of the year prior to the next harvest. This information is taken from Ref. [2]: Table 258, p. 189; Table 295, p 211; Table 277, p. 199; Table 246, p. 180.

The information on consumption patterns for the various crop categories is summarized in Table 4.15. These percentages are used to evaluate a weighted average for the fraction of radionuclide i present in crop j at harvest that will be consumed by man, $DCYPCH_{i,j}$. Therefore, $DCYPCH_{i,j}$ will be derived as follows:

$$DCYPCH_{i,j} = FF_j \cdot TFF_i + FR_j \cdot TFR_i + FP_j \cdot TFP_i, \qquad (4.6)$$

where

FF_j = fraction of crop j consumed fresh within 14 days of harvest

FR_j = fraction of crop j refrigerated and consumed continuously over a 6-month time period beginning 14 days after harvest,

FP_j = fraction of crop j processed and continuously consumed over a 1-year time period beginning 14 days after harvest,

TFF_i = transfer factor that represents the fraction of radionuclide i present at harvest that would ultimately be consumed by man if the entire crop is consumed as fresh produce

TFR_i = transfer factor that represents the fraction of radionuclide i present at harvest that would ultimately be consumed by man if the entire crop has been refrigerated and then is consumed continuously over 6 months

TFP_i = transfer factor that represents the fraction of radionuclide i present at harvest that would ultimately be consumed by man if the entire crop undergoes further processing and then is consumed continuously over a period of 1 year

Table 4.15. Consumption Patterns

Crop	Fresh (% eaten after 14-day delay)	Refrigerated (% eaten over 6 mo)	Processed (% eaten over 1 yr)
Grains	0	0	100
Legumes & Nuts	0	0	100
Green Leafy Vegetables	70	25	5
Roots & Tubers	0	0	100
Other Food	5	0	95

All transfer factors that are part of Equation 4.5 are used to describe the fraction of radioactive material present in the edible portion of the crop at the time of harvest and retained following radioactive decay. As was noted earlier, the losses from the processing of food are handled by the parameter FPLSCH.

If an exact delay time between harvest and consumption can be assigned, as has been done for TFF_i, the fraction of radionuclide i present at harvest that is consumed by man would be calculated as follows:

$$TFF_i = EXP\ (-[(\ln 2/THALF_i) \cdot TDELAY]) \qquad (4.7)$$

where

$THALF_i$ - radiological decay half-life for the nuclide i (day^{-1})

TDELAY - time delay between harvest and consumption (day)

If a portion of the crop is stored or preserved for utilization over an extended period, the consumption is considered to be continuous. The transfer factors, TFR and TRP, will be the product of the daily consumption rate of the food and the integral of the rate of transfer over the entire period of time the crop is being consumed. If it is assumed that consumption of the crop occurs at a constant rate over a given time period, T_j, then the consumption rate for crop j, CR_j, is

$$CR_j = 1 \ / \ T_j \quad (day^{-1})$$

Then the transfer factors TFR and TFP can be calculated using the following equation.

$$TRF_{i,j} = TRP_{i,j} = CR_j \int_{T_1}^{T_2} EXP(-[(\ln 2/THALF_i \cdot t]) \, dt$$

$$= \frac{1}{T_j} \cdot \int_{T_1}^{T_2} EXP(-[(\ln 2/THALF_i) \cdot t]) \, dt$$

$$= \frac{THALF_i}{T_j \cdot \ln 2} \cdot \left[EXP\left[-\frac{\ln 2}{THALF_i} \cdot T_2 \right] - EXP\left[-\frac{\ln 2}{THALF_i} \cdot T_1 \right] \right] \quad (4.8)$$

where

T_j - length of the consumption period (day)

CR_j - consumption rate for crop j (day^{-1}) $= \dfrac{1}{T_j} = \dfrac{1}{T_2 - T_1}$

$THALF_i$ - radiological decay half-life for nuclide i (day)

T_1 - the shortest time after harvest that crop j will be consumed (days)

T_2 - the longest time after harvest that the crop will be consumed (days)

The values of T_j, T_1, and T_2 used for the various consumption patterns are given in Table 4.16.

Table 4.16. Values for Time Variables

Time	Foods Consumed Fresh	Foods Refrigerated and Consumed Over 6 Months	Foods Processed and Consumed Over 1 Year
T_1	0	14	14
T_2	14	197	379
T_j	14	183	365

The range of possible values in each case was arrived at by assuming that the best estimate values being used are most probably accurate to within 25% of their actual value.

4.3.5 DCYPMH

$DCYPMH_i$ - fraction of radionuclide i present in milk at the time of production that is retained in the milk until the time of consumption by man (accounts for losses from both radioactive decay and processing)

The recommended values for $DCYPMH_i$ are as in Table 4.17.

Table 4.17. Recommended Values for $DCYPMH_i$

Nuclide	DCYPMH	Range of Values
Sr-89	0.66	0.50-0.83
Sr-90	1.0	
Cs-134	1.0	
Cs-137	1.0	
I-131	0.28	0.21-0.35
I-133	0.002	0.0015-0.0025

The uniform sampling distribution is recommended for DCYPMH.

Discussion

$DCYPMH_i$ can be defined as

$$DCYPMH_i = \frac{FINAL_i}{INITIAL_i}$$

where

$FINAL_i$ = concentration (Ci/L) of radionuclide i in milk at the time of consumption by man

$INITIAL_i$ = concentration (Ci/L) of radionuclide i in milk at the time it is produced

Values for this variable are found for each nuclide treated by the food pathways model by evaluating the following expression

$$DCYPMH_i = EXP\{-[(\ln 2/THALF_i) \cdot TDELAY]\}$$

where

$THALF_i$ = radiological half-life of nuclide i (days)

TDELAY = delay time between the production and consumption of the dairy product (days)

The values first used for this variable were obtained by the assuming that all milk produced was consumed as fluid. Furthermore, a delay time (TDELAY) of four days was used as recommended in the Regulatory Guide 1.109 [7:Table E-15].

An investigation of the utilization of milk ir the United States [2:Table 480] showed that milk products could by divided into three groups according to their shelf-life. These groups, the milk products included in each group, and the percentage of the total amount of milk that is accounted for by each group are shown in Table 4.18.

Since the products with the long shelf-life represent such a small percentage of the total milk produced, it was decided to combine it with those products having an intermediate shelf-life and to consider the entire group as having an intermediate shelf-life.

The derivation of the values for $DCYPMH_i$ now takes the form:

$$DCYPMH_i = FR_s \cdot EXP\left[-\frac{\ln 2}{THALF_i} \cdot T_s\right] + FR_l \cdot EXP\left[-\frac{\ln 2}{THALF_i} \cdot T_l\right] \quad (4.9)$$

where

FR_s = fraction of milk production used in products with a short shelf-life

FR_I = fraction milk production used in products with an intermediate shelf-life (including long shelf-life products)

T_s = delay time between production of milk and consumption of those products with a short shelf-life (days)

T_I = delay between production of milk and consumption of those products with an intermediate shelf-life (days)

$THALF_i$ = as defined previously (days)

Delay times needed to be established for the two groups. Milk consumed as a fluid accounts for nearly 80% of those products with a short shelf-life. Therefore, milk was assumed to be representative of short-shelf life products. It was found through the Associated Milk Producers that 2 or 3 days are required to get the milk to the shelf, and that a freshness date of at least 2 weeks is applied at the time of packaging, 1 or 2 days following production. Based on this information, the 4-day delay time originally used to calculate DCYPMH seemed somewhat short for this product group. A modified delay time of 7 days was, therefore, used to derive the current values of DCYPMH. Still, it seems likely that even the revised delay time may be too short.

Cheese and butter dominate the product group with intermediate shelf-life (which now also includes canned and dehydrated products). Cheese accounts for

Table 4.18. U.S. Milk Utilization

Group	Products	Total Production (%)
Short Shelf-Life	Fluid Milk Cottage Cheese Bulk Condensed Milk Ice Cream	49
Intermediate Shelf-Life	Cheese American Other Butter	49
Long Shelf-Life	Canned Milk Dry Milk Other Dehydrated Products	2

59% of the milk used for these products, and butter accounts for 37%. After curing for at least 60 days, cheese is given a freshness date of 60 days at the time of packaging. Butter, on the other hand, takes 5 or 6 days to produce, is readily frozen, which greatly enhances its shelf-life, and is given a freshness date of 60 days at the time of packaging. Using this information, it was decided to use value for the delay time for these products of 65 days.

In summary, the data in Table 4.19 were used to determine the value of the variable $DCYPMH_i$ for each nuclide i using Equation 4.9.

Table 4.19 Consumption Intervals for Milk Products

Product Group	Milk Production (%)	Delay Time (Days)*
Short Shelf-Life	50	7
Intermediate Shelf-Life	50	65

* Time from production to consumption.

It has been assumed for the nuclides with relatively long half-lives that the entire amount of radioactivity present at the time of production will in fact be consumed.

The range of possible values for DCYPMH was derived based on the estimate that the actual value would probably lie within 25% of the calculated value.

4.3.6 FPLSCH

$FPLSCH_{i,j}$ = fraction of radionuclide i present in crop j at harvest that is retained until consumption by man (does not account for losses from radioactive decay, which are handled separately by the parameter DCYPCH)

The recommended values for FPLSCH are summarized in Tables 4.20 and 4.21. A uniform sampling distribution is recommended for FPLSCH.

Discussion

The variable $FPLSCH_{i,j}$ can be defined as follows:

$$FPLSCH_{i,j} = \frac{FINAL_{i,j}}{INITIAL_{i,j}}$$

where

$FINAL_{i,j}$ = concentration (Ci/kg) of radionuclide i in the edible portion of crop j at consumption by man when there are no losses caused by radioactive decay

$INITIAL_{i,j}$ = concentration (Ci/kg) of radionuclide i in the edible portion of crop j at harvest

Since neither pasture nor stored forage is consumed by man, each of these crops are assigned a processing retention factor of 0.0 over all nuclides. Processing loss factors for crops consumed by man were developed using data compiled by Boone et al. [8].

Table 4.20. Recommended Values for $FPLSCH_{i,j}$ for Crops Consumed by Man

Nuclide	Grains	Legumes & Nuts	Green Leafy Vegetables	Roots & Tubers	Other Food
Sr-89	0.25 (0.19-0.31)	0.8 (0.6-1.0)	0.5 (0.38-0.63)	0.8 (0.6-1.0)	0.71 (0.53-0.89)
Sr-90	0.25 (0.19-0.31)	0.8 (0.6-1.0)	0.5 (0.38-0.63)	0.8 (0.6-1.0)	0.71 (0.53-0.89)
Cs-134	0.25 (0.19-0.31)	0.8 (0.6-1.0)	0.5 (0.38-0.63)	0.8 (0.6-1.0)	0.71 (0.53-0.89)
Cs-137	0.25 (0.19-0.31)	0.8 (0.6-1.0)	0.5 (0.38-0.63)	0.8 (0.6-1.0)	0.71 (0.53-0.89)
I-131	0.33 (0.25-0.41)	0.8 (0.6-1.0)	0.5 (0.38-0.63)	0.8 (0.6-1.0)	0.71 (0.53-0.89)
I-133	0.33 (0.25-0.41)	0.8 (0.6-1.0)	0.5 (0.38-0.63)	0.8 (0.6-1.0)	0.71 (0.53-0.89)

Table 4.21. Recommended Value of $FPLSCH_{i,j}$ for Crops Not Consumed by Man

	Pasture	Stored Forage
All nuclides	0.0	0.0

The retention factor for grain is quite low because of the high degree of refinement of grains during the production of the refined products that dominate the per capita consumption of grain. This retention factor may be expected to increase as eating patterns change toward whole grain products as witnessed recently.

On the other hand, in the processing of legumes and nuts, the edible portion is consumed without such refinement. Therefore, all crops in this category except snap beans have a retention factor of 1.0. The edible pod of the snap bean is exposed to the environment during the growing season and will therefore be contaminated directly, and the bean itself will be contaminated by translocation. According to Boone et al. [10], only 50% of the radioactive material present at harvest will be retained in the bean after processing. Snap bean consumption accounts for approximately 40% of the human intake from this crop category. A weighted averaging approach was used in arriving at the overall retention factor for the legume and nut crops. That is,
FPLSCH = (0.60)(1.0) + (0.40)(0.50) = 0.80

For green leafy vegetables, translocation is not an important factor in the contamination resulting from direct deposition. Furthermore, half the radioactive material present on the edible portions of green leafy vegetables will be removed during washing and cooking.

Part of the contamination of the roots and tubers is from direct contact with contaminated soil, but translocation transfers an even greater amount of radioactive material from above-ground plant parts into the roots. Washing and peeling will remove the material in the skin of these vegetables, but processing will not decrease the amount of translocated material.

The Other Food category consists primarily of a wide variety of fruits and vegetables that can be grouped into three broad subcategories, each of which has a characteristic retention factor for radioactivity after processing:

(1) Foods that have a rind or peel not considered to be edible and therefore removed before consumption. Examples are citrus fruits and melons. The contamination in the edible portion of the plant consists of material translocated to the flesh of the fruit. Retention fraction = 0.80

(2) Fruits and vegetables that are contaminated by direct deposition and also contain radioactive material translocated to the interior portion of the fruit. The entire harvested portion of the crop is edible (for example, apples, pears, etc.). Since the skin is smooth and the fruit will be washed before consumption, much of the radioactive material present at the time of harvest will be removed. Retention fraction = 0.50

(3) Tomatoes are especially susceptible to translocation to all edible portions, including the seeds. Therefore, even though their skin is smooth and easily washed, the retention fraction is greater than for the fruits and vegetables in subgroup 2. Retention fraction = 0.80

Approximately 70% of the crops in this category have a retention factor of 0.80, while the other 30% have a retention factor of 0.50. By weighting these two groups appropriately, an overall retention factor can be calculated as FPLSCH = 0.70 (0.80) + 0.30 (0.50) = 0.7.

The ranges of values were found by assuming that the calculated value is most probably correct to 25%.

4.3.7 FRCTCB, FRCTCH, FRCTCM

$FRCTCB_j$ = fraction of crop j consumed by meat-producing animals,

$FRCTCH_j$ = fraction of crop j consumed by man,

$FRCTCM_j$ = fraction of crop j consumed by milk-producing animals.

The recommended values for FRCTCH, FRCTCM, and FRCTCB are as given in Table 4.22. When sampling is to be done over the range of possible values, it is recommended that a uniform sampling distribution be assumed.

Table 4.22. Values for FRCTCH, FRCTCM, and FRCTCB

Crop	FRCTCH	FRCTCM	FRCTCB
Pasture	0.0	0.10 (0.075-0.125)	0.90 (0.875-0.925)
Stored Forage	0.0	0.13 (0.098-0.16)	0.87 (0.84-0.902)
Grain	0.35 (0.26-0.44)	0.040 (0.030-0.050)	0.61 (0.51-0.71)
Legumes and Nuts	0.24 (0.18-0.30)	0.046 (0.035-0.058)	0.714 (0.642-0.785)
Green Leafy Veg.	1.0	0.0	0.0
Roots & Tubers	1.0	0.0	0.0
Other Food	1.0	0.0	0.0

The recommended values were derived by analyzing current agricultural statistics [2] and using the summary of livestock ingestion rates as summarized by Boone et al [8] as adapted from Ng [9]. A partial list of the reference tables [1] used to compile the data for the various crops and animals is given in Table 4.23. Since the health effects in MACCS are considered in the societal sense, the products exported are also included in defining the amounts of each crop category consumed by man and by animals. With the exception of soybeans, it has been assumed that utilization of the part of the crop exported follows the same pattern as domestic utilization. On the other hand, the utilization pattern for domestic use versus the

Table 4.23. Crop Utilization Patterns

	Domestic		Export			
Crop	Food (lbs)	Feed (lbs)	Food (lbs)	Feed (lbs)	Ref. 1 Table	Ref. 1 Page
Wheat	3.75×10^{10}	2.70×10^{10}	4.87×10^{10}	3.53×10^{10}	5	4
Rye	1.96×10^{8}	8.40×10^{8}	1.06×10^{7}	4.54×10^{7}	19	16
Barley	8.35×10^{9}	1.33×10^{10}	1.70×10^{9}	2.66×10^{9}	58	44
Sorghum	5.60×10^{8}	2.18×10^{10}	3.50×10^{8}	1.32×10^{10}	67	51
Oats	2.50×10^{9}	1.49×10^{10}	8.96×10^{6}	5.50×10^{7}	50	39
Rice	5.58×10^{9}	0.0	6.50×10^{9}	0.0	28	20
Corn	2.73×10^{10}	1.09×10^{11}	1.04×10^{10}	4.14×10^{10}	41	31
Sweet Corn	2.89×10^{9}	0.0	0.0	0.0	213	157
Soybeans	7.18×10^{9}	6.46×10^{10}	1.89×10^{10}	3.52×10^{10}	170	127
Peanuts	1.52×10^{9}	5.81×10^{8}	7.26×10^{7}	2.82×10^{7}	160	121
Snap beans	1.27×10^{9}	0.0	0.0	0.0	204	151
Peas	3.65×10^{8}	0.0	0.0	0.0	223	163
Dried beans	1.55×10^{9}	0.0	0.0	0.0	376	255
Nuts	5.19×10^{8}	0.0	0.0	0.0	343	237
					345	237
					348	238
					351	240

utilization pattern for exported soybeans is significantly different. According to the American Soybean Association the patterns of soybean utilization are as indicated in Table 4.24

Table 4.24 Crop Utilization

Market	Food (%)	Feed (%)
Domestic	10	90
Export	35	65

These utilization patterns for soybeans have been incorporated into Table 4.22, the summary table of crop utilization.

Using the summary data for crop utilization within the general categories of Grains and Legumes & Nuts, overall utilization can be summarized as in Table 4.25.

Table 4.25. Utilization of Grains, Legumes, and Nuts

Crop Category	Food (%)	Feed (%)
Grains	35	65
Legumes & Nuts	24	76

Boone et al. [8] compiled a summary of the daily consumption rates of various animals for a variety of crops. The rates for cattle, hogs, chickens, and dairy cattle from this summary are given below. In addition, a consumption rate for turkeys has been added, since they are being considered as part of the crop-meat-man pathway. To obtain a daily consumption rate for turkeys, the following assumptions were made:

(1) Turkeys and chickens have similar biological and metabolic characteristics.
(2) Similar amounts of feed will produce a similar weight-gain in both types of poultry.
(3) The diet of both chickens and turkeys are similar in content.

As a result of these assumptions and the use of weight-at-slaughter statistics, it was determined that the daily consumption of a turkey is 2.6 times the daily consumption of a chicken. This factor was then used to determine the daily consumption rate for turkeys of the various crops based on the daily consumption by chickens. An overall summary of the daily consumption rates (lbs/day) is summarized in Table 4.26.

Table 4.26 Daily Consumption Rates of Feeds by Animals in Pounds per Day

	Cattle				
Feed	Dairy	Beef	Hogs	Chickens	Turkeys
Pasture	8.55	8.55	0.0	0.0	0.0
Hay	14.90	10.80	0.0	0.0	0.0
Corn Silage	5.84	4.54	0.0	0.0	0.0
Sorghum Silage	1.33	0.966	0.0	0.0	0.0
Wheat	0.0509	0.0375	0.0675	0.00126	0.00328
Oats	0.131	0.0970	0.175	0.00328	0.00854
Rye	0.0888	0.0653	0.118	0.00232	0.00603
Barley	0.0372	0.0274	0.492	0.000922	0.00240
Sorghum	0.0599	0.0441	0.0794	0.00149	0.00387
Corn	4.48	3.30	5.92	0.111	0.289
Soybeans	1.06	0.783	1.41	0.0265	0.688
Peanuts	0.00992	0.00729	0.00131	0.000246	0.000640

Since the consumption rates for the different types of animals are given on a daily basis, it is necessary to determine how many of each type of animal there are on any given day to determine the total daily consumption by all such animals. For dairy cows and beef cattle, statistical data [2] provide those numbers. However, in the case of hogs and poultry, the age of the animal at the time of slaughter is less than one year. Therefore, for hogs and poultry, the "standing crop" (i.e., the number extant) on any given day is less than the total number produced during the year and is found by dividing the total number produced annually by the "number of crops per year", where

$$\text{Number of crops per year} = \frac{12 \text{ months}}{\text{Age at time of slaughter (mo)}}$$

A summary of the "standing crop" for each type of food-producing animal is given in Table 4.27.

By multiplying the daily consumption rate for a particular species of animal by the "standing crop" of that species, the total daily consumption of that crop by that type of animal can be found. With this total daily consumption for each crop category, it is then possible to determine the percentage of each crop category consumed by each species of food-producing animal. The percentages obtained are given in Table 4.28. Finally, by using Table 4.25 in conjunction with Table 4.28, it is possible to arrive at the fraction of the crop which is consumed by man, dairy animals, and meat producing animals.

The range of possible values was derived by assuming that the smallest fraction would most probably not vary by more than 25% of its calculated value. The variation for the larger fractions was then calculated such that

Table 4.27. "Standing Crops" (Animals)

Animal	Total No. During Year	Age at Slaughter (mo)	Number of "Crops"	Standing Crop	Table	Page
Cattle						
Dairy	1.114×10^7	24	1.0	1.114×10^7	388	261
Beef	1.029×10^8	96	1.0	1.029×10^8	388	261
Hogs	9.847×10^7	6	2.4	4.103×10^7	402	276
Chickens	4.415×10^9	3	4.0	1.104×10^9	508	358
					511	360
Turkeys	1.698×10^8	6	2.0	8.490×10^7	524	367

Table 4.28. Crop Consumption by Animal

Crop Category	Cattle Dairy (%)	Cattle Beef (%)	Hogs (%)	Chickens (%)	Turkeys (%)
Pasture	10	90	0	0	0
Stored Forage	13	87	0	0	0
Grain	6	42	30	15	6
Legumes & Nuts	6	43	31	16	4
Green Leafy Vegetables	0	0	0	0	0
Roots & Tubers	0	0	0	0	0
Other Food	0	0	0	0	0

the ranges would be proportional to their sizes, but would not allow the total consumption of any crop to exceed 100%.

4.3.8 TCROOT

$TCROOT_{i,j}$ - fraction of the nuclide i deposited onto soil used to grow crop j that will ultimately be consumed by man as a result of the long-term uptake by plant roots or by direct consumption of the soil by grazing animals.

Table 4.29 shows the recommended values for $TCROOT_{i,j}$ for the Sr and Cs nuclides and Table 4.30 shows the recommended values for $TCROOT_{i,j}$ for the I nuclides.

Table 4.29. Recommended Values for $TCROOT_{i,j}$ for Sr and Cs Nuclides

Crop	Sr-89	Sr-90	Cs-134	Cs-137
Pasture	0.00041 (0.00030- 0.00051)	0.026 (0.014- 0.049)	0.0013 (0.0010- 0.0016)	0.0069 (0.0047- 0.0102)
Stored Forage	0.0013 (0.00095- 0.0016)	0.090 (0.05- 0.17)	0.00071 (0.00048- 0.0010)	0.0015 (0.00092- 0.0027)
Grain	0.000043 (0.000033- 0.000053)	0.0033 (0.0019- 0.0063)	0.000035 (0.000024- 0.000051)	0.000076 (0.000046- 0.00013)
Legumes	0.00037 (0.00028- 0.00047)	0.028 (0.016- 0.054)	0.000093 (0.000062 0.00014)	0.00020 (0.00012- 0.00035)
Green Leafy Vegetables	0.00017 (0.00013- 0.00021)	0.013 (0.0071- 0.024)	0.000014 (0.0000094- 0.000020)	0.000030 (0.000018- 0.000051)
Roots & Tubers	0.00011 (0.000083- 0.00014)	0.0084 (0.0047- 0.0016)	0.000056 (0.000038- 0.000080)	0.00012 (0.000072- 0.00021)
Other Food	0.000008 (0.0000063- 0.00041)	0.00066 (0.00036- 0.0013)	0.00011 (0.000071- 0.00015)	0.00023 (0.00014- 0.00041)

Table 4.30 **Recommended Values for $TCROOT_{i,j}$ for I Nuclides**

Crop	I-131	I-133
Pasture	0.000016	0.0000017
All others	0.0	0.0

A uniform sampling distribution is recommended for $TCROOT_{i,j}$

Discussion

$$TCROOT_{i,j} = IRU_{i,j} + ISI_{i,j} \tag{4.10}$$

where

$IRU_{i,j}$ = time-integrated root uptake rate for nuclide i deposited onto soil used to grow crop j

$ISI_{i,j}$ = time-integrated soil ingestion rate for nuclide i deposited onto pasture

The principal mechanism by which nuclides are transferred from soil to plants is via root uptake. Transfer to plant surfaces may also occur by rainsplash and by the deposition of materials resuspended from surface soil. A rate at which nuclides are transferred from the soil to plants via each of these mechanisms can be established. The overall transfer rate is then just the weighted sum of these individual rates.

For the pasture, an additional term is used in deriving the data for TCROOT. To account for the fact that grazing cattle will ingest a certain amount of soil along with the plant material they consume, a time-integrated soil ingestion factor is added to the time-integrated root uptake rate. It is assumed that pasture undergoes continuous harvest (grazing by animals) and that all nuclides deposited onto pasture will be consumed by the end of the growing season. Therefore, the transfer factors (DCYPCB and DCYPCM) for nuclides deposited onto pasture and consumed by meat- or milk-producing animals is unity. The overall transfer factor for soil ingestion by grazing animals can be obtained by treating the ingestion of soil by grazing animals as though the ingested soil was first transferred to the surface of pasture grass then and consumed. The soil ingestion component, ISI, of the transfer factor TCROOT will be 0.0 for all crops except pasture.

According to Ostmeyer and Helton [1], the rate of transfer from soil to plants by either rainsplash or resuspension is negligible compared the rate of transfer via root uptake. The values for TCROOT were thus derived using only root uptake transfer factors.

If the nuclides deposited onto the soil were to remain at a constant level over time, the long-term transfer factor would simply be the product of the annual uptake rate and the length of time being considered. However, in actuality, the availability of the deposited material decreases over time. This decrease is a reflection of the following physical and chemical processes: (1) radioactive decay, (2) percolation of material to the region below the root zone, (3) irreversible chemical binding of the nuclides to components of the soil, (4) previous root uptake of nuclides, and (5) soil ingestion by grazing animals.

Because the availability of the material does not remain constant, it is necessary to integrate the uptake rate over time. If an exponential depletion rate is assumed, then the time-integrated root uptake transfer factor, IRU, can be expressed as

$$IRU_{i,j} = RU_{i,j} \cdot \int_0^T EXP\{-[(RU_{i,j} + RD_i + RP_i + RB_i + RSI_{i,j}) \cdot t]\}\, dt \quad (4.11)$$

where

$RU_{i,j}$ - rate at which nuclide i is corporated into the edible portion of crop j via root uptake from the soil (yr^{-1})

RD_i - radiological decay rate for nuclide i (yr^{-1})

RP_i - rate at which nuclide i percolates to a region below the root zone (yr^{-1})

RB_i - rate at which nuclide i chemically binds irreversibly with soil components (yr^{-1})

$RSI_{i,j}$ - rate at which nuclide i is removed via soil ingestion from the soil used to grow crop j (yr^{-1})

T - the time period of interest for the transfer of deposited nuclides via root uptake from the soil to the edible portion of the plant (yr)

The time-integrated soil ingestion factor is obtained in an analogous manner with several differences. Soil ingestion occurs only from the surface soil, and therefore, the unavailability of material for ingestion by grazing cattle relates to the "loss" of the material from surface soil. Several factors contribute to the unavailabilty of material for ingestion. They are radiological decay, percolation of the nuclides out of the surface soil, removal of material via root uptake, and removal of material via ingestion by grazing animals.

Even though irreversible chemical binding may occur to the soil in the surface soil compartment (the top 1 cm), this irreversibly bound material is still available to be ingested. Therefore, the rate at which chemical binding occurs does not appear in the derivation of the transfer factor, ISI. ISI can be derived as follows:

$$ISI_{i,j} = RSI_{i,j} \cdot \int_{0}^{T} EXP[-[(SRU_{i,j} + RD_i + SRP_i + RSI_{i,j}) \cdot t]]\, dt \qquad (4.12)$$

where

$RSI_{i,j}$ = rate at which nuclide i is removed via soil ingestion from the surface soil compartment on land used to grow crop j (yr^{-1})

$SRU_{i,j}$ = rate at which nuclide i is corporated into the edible portion of crop j via root uptake from the surface soil compartment (yr^{-1})

RD_i = radiological decay rate for nuclide i (yr^{-1})

SRP_i = rate at which nuclide i percolates to a region below the surface soil compartment (yr^{-1})

T = the time period of interest for the transfer of deposited nuclides via soil ingestion of soil on which pasture is grown (yr)

When the time period of concern for the long-term doses arising from the food pathway is taken to be all time following the accident (i.e., letting $T = \infty$), $TCROOT_{i,j}$ will be evaluated as follows:

$$TCROOT_{i,j} = IRU_{i,j} + ISI_{i,j}$$

and

$$TCROOT_{i,j} = \frac{RU_{i,j}}{RU_{i,j} + RD_i + RP_i + RB_i + RSI_{i,j}} + \frac{RSI_{i,j}}{SRU_{i,j} + RD_i + SRP_i + RSI_{i,j}} \qquad (4.13)$$

The values for $RU_{i,j}$ are derived from fallout data. Root uptake by plants is usually described using an empirical concentration ratio (CR) defined as

$$CR = \frac{\text{Radionuclide activity per unit mass (dry) of plant (bq/kg)}}{\text{Radionuclide activity per unit mass (dry) of soil (bq/kg)}}$$

The root uptake rate, RU, is then defined as

$$RU_{i,j} = CR_{i,j} \cdot \frac{CM_j}{SM}$$

where

CM_j = annual yield of crop j (kg yr^{-1} /m^2)

SM = soil mass in root uptake compartment (kg/m^2)

The soil mass (SM) is taken to be an average value of 240 kg/m^2.

A summary of concentration ratios can be found in Till and Meyer [10, Table 5.17], and a summary of crop yield values can be found in Boone et al. [8]. A value for CM for each crop category is obtained by a weighted average over the predominant crops in each category. The values used for CR and CM for Sr and Cs nuclides are given in Table 4.31. The CR values for the short-lived I nuclides are assumed to be 0.0, which in turn implies that the IRU values for the I nuclides is 0.0 for all crops.

Table 4.31. Values for Concentration Ratios (CR) and Crop Yield Values (CM)

Crop	CR		CM
	Strontium	Cesium	(kg/yr·m^2)
Pasture	2.0	0.01	0.175
Stored Forage	3.0	0.2	0.50
Grains	0.2	0.02	0.25
Legumes	2.0	0.06	0.22
Green Leafy Veg.	2.0	0.02	0.10
Roots & Tubers	0.5	0.03	0.26
Other Foods	0.2	0.03	0.05

By using these values for CR and CM, the corresponding values for RU were established. These RU values are summarized in Table 4.32. The range of values derived by assuming that the correct value would lie within 25% of the value estimated for RU.

Table 4.32. Values for Root Uptake (RU)

	RU		
Crop	Strontium	Cesium	Iodine
Pasture	0.0015 (0.0011-0.0019)	0.0000073 (0.0000054-0.0000091)	0.0
Stored Forage	0.0063 (0.0047-0.0079)	0.00042 (0.00032-0.00053)	0.0
Grain	0.00021 (0.00016 0.00026)	0.000021 (0.000016-0.000026)	0.0
Legumes	0.0018 (0.0014-0.0023)	0.000055 (0.000041-0.000069)	0.0
Green Leafy Vegetables	0.00083 (0.00062-0.0010)	0.0000083 (0.0000062-0.000010)	0.0
Roots & Tubers	0.00054 (0.00041-0.00068)	0.000033 (0.000025-0.000041)	0.0
Other Foods	0.000042 (0.000031-0.000053)	0.000063 (0.000047-0.000079)	0.0

The rate at which nuclide i becomes unavailable for root uptake from radioactive decay, RD_i, can be defined as

$$RD_i = \ln 2 / THALF_i$$

where

$THALF_i$ = radiological half-life of nuclide i (yr)

Because radioactive half-lives are precisely known, no range of values has been established for RD_i. The values of RD_i are summarized in Table 4.33.

The percolation rate is strongly dependent on soil characteristics; therefore, these values are quite uncertain. The range of possible values was established by assuming that the actual value would most likely lie within 25% of the predicted value. The half-lives of the iodine isotopes considered are so short that radioactive decay is the primary mechanism by which these nuclides become unavailable for root uptake. Thus, no percolation rate has been established for iodine nuclides.

Table 4.33. Values for Radioactive Decay

Nuclide	RD
Sr-89	4.860
Sr-90	0.024
Cs-134	0.340
Cs-137	0.023
I-131	31.500
I-133	292.000

The percolation rates, RP, for strontium and cesium established by Hoffman and Baes [11] are summarized in Table 4.34.

Table 4.34. Percolation Rate for Sr and Cs

Element	RP
Strontium	0.0021
Cesium	0.0096

In addition, the derived values for RP apply to the entire root zone (the top 15 cm of soil compartment). Since the surface soil compartment is assumed to reach a depth of 1 cm, the value of SRP, the percolation rate for the surface soil compartment, could be assumed to be one-fifteenth of the value RP established for the root zone. This does not seem too unreasonable, since the percolation distance would be one critical factor in the percolation rate. Still, this approximation may be somewhat conservative, since the surface soil compartment is much more susceptible to weathering than is the root uptake soil compartment.

Table 4.35 gives a summary of the values for RP, the percolation rate from the root uptake zone, and SRP, the percolation rate from the surface soil compartment.

Table 4.35. Values for ITF and ISI

	ITF	ISI
Element	RP	SRP
Strontium	0.0096 (0.0072-0.012)	0.14 (0.11-0.18)
Cesium	0.0021 (0.0016-0.0026)	0.032 (0.024-0.040)

Ostmeyer and Helton [1] established the rate of soil ingestion, RSI, for all nuclides for pasture. Since no soil ingestion occurs during the harvest of the nonpasture crops, the corresponding values of RSI is 0.0 yr^{-1}. Table 4.36 shows the values for RSI for all nuclides.

Table 4.36. Values for RSI for All Nuclides

Crop	RSI
Pasture	0.0005 (0.0004-0.0006)
Nonpasture	0.0

The range of possible values for the soil ingestion rate was established by assuming the actual value would most probably lie within 25% of the estimated value.

4.3.9 TFBF

$TFBF_i$ = fraction of the daily consumption of nuclide i by meat-producing animals that remains in the meat at the time of slaughter

Table 4.37 shows the recommended values for $TFBF_i$. A uniform sampling distribution is recommended for $TFBF_i$.

Discussion

$$TFBF_i = \frac{OUTPUT_i}{EATEN_i}$$

Table 4.37. Recommended Values for $TFBF_i$

Nuclide	TFBF	Range of Values
Sr-89	0.00022	0.000094 - 0.00038
Sr-90	0.00022	0.000094 - 0.00038
Cs-134	0.023	0.020 - 0.035
Cs-137	0.024	0.020 - 0.035
I-131	0.0024	0.00082 - 0.0037
I-133	0.0011	0.00041 - 0.0013

where

$OUTPUT_i$ = amount of radionuclide i in meat produced by meat animals (Ci)

$EATEN_i$ = amount of radionuclide i in feed consumed by meat animals (Ci)

The value of this transfer factor is derived by evaluating the following expression:

$$TFBF_i = TR \cdot M \cdot ETF_i ,$$

where

TR = fraction of animals slaughtered per day (day^{-1})

M = quantity of meat produced by those animals at slaughter (kg)

ETF_i = equilibrium transfer factor to meat for the radionuclide i (day/kg)

Previously, $TFBF_i$ was calculated using only beef in the calculations. By using recent agricultural data [2:Tables 455 and 516], it can be shown that beef accounts for only 42% of the meat produced, pork an additional 29%, and poultry the final 29%. The amount of poultry produced is composed of 84% chicken and 16% turkey. In light of these data, it was decided to consider all three meat sources (beef, pork, and poultry) in deriving a value for TFBF.

A transfer factor is obtained for each of these meat sources and an overall transfer is developed by taking a weighted average of these animal-specific transfer factors. That is,

$$TFBF_i = FB \cdot TFB_i + FPK \cdot TFPK_i + FC \cdot TFC_i + FT \cdot TFT_i$$

where

FB = fraction of meat produced that is beef (i.e., 0.42)

FPK = fraction of meat produced that is pork (i.e., 0.29)

FC = fraction of meat produced that is chicken (i.e., 0.24)

FT = fraction of meat produced that is turkey (i.e., 0.05)

TFB_i = transfer factor for nuclide i by beef

$TFPK_i$ = transfer factor for nuclide i by pork

TFC_i = transfer factor for nuclide i by chicken

TFT_i = transfer factor for nuclide i by turkey

Equilibrium transfer factors (ETF_i) for Sr, Cs, and I were derived by Ng et al. [12] and are presented in Table 4.38.

Table 4.38. Equilibrium Transfer Factors (ETFs)

Element	Animal Product	ETF	Range of Values*
Sr	Beef	0.00030	0.000064 - 0.00057
	Pork	0.0029	0.0012 - 0.0040
	Poultry	0.032	0.018 - 0.080
Cs	Beef	0.020	0.0072 - 0.093
	Pork	0.30	0.26 - 0.38
	Poultry	4.4	4.3 - 4.5
I	Beef	0.0072	0.0072 - 0.020
	Pork	0.027	0.0010 - 0.027
	Poultry	0.20	0.0080 - 0.20

* The range of possible values was established by Ng.

Due to the physiological similarity between different poultry types, the ETF_i values established by Ng for chicken have been used for both chicken and turkey.

These ETF_i values were derived for stable strontium and cesium and for I-131, and therefore represent biological losses for strontium and cesium but not radioactive decay losses. For iodine, the radioactive decay constant for I-131 has been included. For I-133, it is therefore necessary to adjust value of TF to reflect the significantly shorter half-life of this isotope.

To find an adjusted ETF value to incorporate specific radioactive decay rates, it is possible to begin with the assumption that

$$\frac{dQ_i(t)}{dt} = \frac{R_i}{M} - \lambda_i \cdot Q_i(t) \tag{4.14}$$

where

$Q_i(t)$ = concentration of the nuclide i in the meat at time t (Ci/kg)

R_i = ingestion rate for nuclide i (Ci/day)

M = the total weight of the meat in an animal at the time of slaughter (kg)

λ_i = decay constant reflecting both radiological decay and biological losses of nuclide i (day^{-1})

Therefore,

$$\frac{dQ_i(t)}{\lambda_i Q_i(t) - \frac{R_i}{M}} = - dt \tag{4.15}$$

By letting $u = \frac{R_i}{M} - \lambda_i Q_i(t)$ then $\frac{du}{dQ_i(t)} = - \lambda_i$ and $\frac{du}{- \lambda_i} = dQ_i(t)$

Therefore, by subsitution into Equation 4.15

$$\frac{du}{\lambda_i u} = - dt \quad \text{and} \quad \frac{\ln(\lambda_i u)}{\Lambda_i} = -t + C \quad \text{and} \quad \ln(\lambda_i u) = - \lambda_i t + C$$

then $\lambda_i u = e^{-\lambda t + C} = e^C e^{-\lambda t}$ and $u = \dfrac{e^C}{\lambda_i} e^{-\lambda t}$

Therefore,

$$\frac{R_i}{M} - \lambda_i Q_i(t) = \frac{e^C}{\lambda_i} e^{-\lambda t} \quad \text{and} \quad Q_i(t) = \frac{R_i}{\lambda_i M} + \frac{e^C}{\lambda_i^2} e^{-\lambda t}$$

and in the equilibrium state

$$ETF_i = \lim_{t \to \infty} Q_i(t) = \frac{R_i}{\lambda_i M} \qquad (4.16)$$

Since

$$ETF_i = \frac{Q_i(t)}{R_i} = \frac{\text{Concentration of nuclide i in meat (Ci/kg)}}{\text{Daily ingestion rate of nuclide i by the animal (Ci/day)}}$$

in the equilibrium state, it follows from Equation 4.16 that

$$ETF_i = \frac{Q_i(t)}{R_i} = \frac{\frac{R_i}{\lambda_i M}}{R_i} = \frac{1}{\lambda_i M} \qquad (4.17)$$

For ETF_i as derived by Ng et al. [12], λ_i represents the biological decay constant for both strontium and cesium and represents the sum of the biological decay constant and the I-131 radiological decay constant for the iodine ETF_i. The revised $RETF_i$ can be defined as

$$RETF_i = \frac{1}{M\,(\lambda_{b,i} + \lambda_{d,i})} \ \text{(day/kg)} \qquad (4.18)$$

$\lambda_{b,i}$ = biological decay constant for nuclide i for the animal being considered (day^{-1})

$\lambda_{d,i}$ = radiological decay constant for nuclide i (day^{-1})

To derive the revised $RETF_i$ for a specific nuclide i, it will be assumed that the the Ng value, ETF_i, is based on nuclide with the radiological decay rate, λ_1. Therefore,

$$ETF_i = \frac{1}{M\ (\lambda_1 + \lambda_{b,i})} \tag{4.19}$$

To establish the $RETF_i$, the biological decay rate will be needed. By solving Equation 4.19 for $\lambda_{b,i}$, we find

$$\lambda_{b,i} = \frac{1}{M \cdot ETF_i} - \lambda_1$$

Therefore, by Equation 4.17,

$$RETF_i = \frac{1}{M\ (\lambda_{b,i} + \lambda_{d,i})}$$

$$= \frac{1}{M \left[\left(\frac{1}{M \cdot ETF_i} - \lambda_1 \right) + \lambda_{d,i} \right]}$$

$$= \frac{1}{M \left[\frac{1 - \lambda_1 \cdot M \cdot ETF_i + \lambda_{d,i} \cdot M \cdot ETF_i}{M \cdot ETF_i} \right]}$$

$$= \frac{ETF_i}{1 + [M \cdot ETF_i \cdot (\lambda_{d,i} - \lambda_1)]}$$

where

ETF_i - original equilibrium transfer factor as established by Ng (day/kg)

M - amount of meat produced by animals at time of slaughter (kg)

λ_i - radioactive decay constant of used to establish the original ETF_i (day^{-1})

$\lambda_{d,i}$ - radioactive decay constant for nuclide i (day^{-1})

It has been noted that the ETF for strontium and cesium were established using the stable elements. This implies that λ_i for both these cases would be nearly zero, and the expression for $RETF_i$ would simplify for strontium and cesium isotopes and becomes

$$RETF_i = \frac{ETF_i}{1 + (\lambda_{d,i} * M * ETF_i)} \tag{4.20}$$

The ETF for iodine was established using data for I-131, and therefore, in Equation 4.19,

$$\lambda_i = \frac{\ln 2}{8.04}$$

Therefore, for any other isotope of iodine

$$RETF_i = \frac{ETF_i}{1 + \left[M \cdot ETF_i \cdot \left(\lambda_{d,i} - \frac{\ln 2}{8.04} \right) \right]} \tag{4.21}$$

Using Equations 4.20 and 4.21 and the values and ranges of ETF_i established by Ng et al. [12], the values and associated ranges for the revised equilibrium factors, $RETF_i$, were established and are summarized in Table 4.39. These values for $RETF_i$ were in turn used in deriving the transfer factor $TFBF_i$ for each nuclide i.

The variable M, the amount of meat produced by the animal at the time of slaughter, is needed both in the calculation of $RETF_i$ and the calculation of $TFBF_i$. Based on agricultural data [2:Tables 444 and 516], the values for M summarized in Table 4.40 were used.

Table 4.39. Values for Revised Equilibrium Transfer Factors

Nuclide	Cattle	Hog	Chicken	Turkey
Sr-89	0.00030 (0.000064-0.00057)	0.0029 (0.0012-0.0040)	0.032 (0.018-0.079)	0.032 (0.018-0.079)
Sr-90	0.00030 (0.000064-0.00057)	0.0029 (0.0012-0.0040)	0.032 (0.018-0.080)	0.032 (0.018-0.080)
Cs-134	0.020 (0.0072-0.091)	0.29 (0.26-0.37)	4.4 (4.3-4.5)	4.3 (4.2-4.4)
Cs-137	0.20 (0.0072-0.093)	0.30 (0.26-0 38)	4.4 (4.3-4.5)	4.4 (4.3-4.5)
I-131	0.0072 (0.0072-0.020)	0.027 (0.0010-0.027)	0.20 (0.0080-0.20)	0.20 (0.0080-0.20)
I-133	0.0033 (0.0033-0.0047)	0.011 (0.00095-0.011)	0.17 (0.0079-0.17)	0.11 (0.077-0.11)

Table 4.40. Meat Produced at Slaughter

Animal	Dressed Weight (kg)	Cutting Losses (%)	Edible Products Weight (kg) *
Cattle	269.0	15	229.0
Hogs	84.02	10	70.62
Chickens	1.34	10	1.188
Turkeys	6.96	10	6.183

Also needed for the calculation of $TFBF_i$ are values for the variable TR, the fraction of animals slaughtered per day. By using agricultural data on meat production [2:Tables 388, 398, 406, 407, 415, 502, 511, 516, 521, and 523], the values for TR in Table 4.41 were derived.

Recently there has been fallout data being made available following the Chernobyl accident. These data were reviewed by Nair and Iijima [13] and estimates were made for several ETF_i. For Cs-137, they found an ETF of 0.02 day/kg for beef and a factor of 0.3 day/kg for pork, both of which closely agree with the ETFs as established by Ng [12].

A range of values for the equilibrium transfer factors was given by Ng. These ranges were used to determine the possible ranges for the variable $TFBF_i$.

Table 4.41. Values for the Fraction of Animals Slaughtered per Day (TR)

			Poultry	
	Beef	Pork	Chicken	Turkey
TR (day^{-1})	0.0011	0.0024	0.0026	0.0026

4.3.10 TFMLK

$TFMLK_i$ = fraction of the amount of radionuclide i present in the feed consumed by milk-producing animals that is present in the milk produced

Table 4.42 gives the recommended values for $TFMLK_i$. A uniform sampling distribution is recommended for $TFMLK_i$.

Table 4.42. Recommended Values for $TFMLK_i$

Nuclide	$TFMLK_i$	Range of Values
Sr-89	0.022	(0.0072-0.061)
Sr-90	0.022	(0.0072-0.061)
Cs-134	0.11	(0.040-0.26)
Cs-137	0.11	(0.040-0.26)
I-131	0.13	(0.036-0.46)
I-133	0.062	(0.018-0.22)

Discussion

$$TFMLK_i = \frac{OUTPUT_i}{EATEN_i}$$

where

$OUTPUT_i$ = amount of nuclide i in milk produced

$EATEN_i$ = amount of nuclide i in feed consumed

This variable is evaluated in the following manner for each nuclide i:

$$TFMLK_i = ETF_i \cdot MP$$

where

ETF_i = equilibrium transfer coefficient for nuclide i into milk (day/L)

MP = average daily total milk production (L/day)

Using recent agricultural data it was found the the average daily production is 16.01 L/day/cow [2:Table 471]. Therefore a value of MP = 16 was used for these calculations.

The equilibrium transfer factor, ETF_i, for the nuclide i is given below as summarized by Ng [12]. It is expected that there will be considerable variation in all ETF values. A summary of the possible range of values for the ETF for each of the elements is given below as adapted from Hoffman and Baes [11] by Ng [12].

Table 4.43. ETF for Nuclides

Element	ETF (L/day)	Range of Values
Strontium	0.0014	(0.00045-0.0038)
Cesium	0.0071	(0.0025-0.016)
Iodine	0.0099	(0.0027-0.035)

These values for ETF are based on stable element concentrations in associated milk and feed. Radioactive decay within the animal has an important impact on the ETF values for the short-lived radionuclides. The ETF values to be used for the I-131 and I-133 were adjusted to reflect these losses. The transfer coefficient can be thought of as the time-integrated transfer fraction for a unit nuclide intake by an animal [12]. In a development of the model used to describe the crop-animal-milk pathway, Ostmeyer and Helton [1] conclude that when intake is considered to be constant with time the intake-to-milk equilibrium transfer coefficient can be derived as follows:

$$ETF_i = \sum_{k=1}^{n} \frac{A_k}{\lambda_{b,k} + \lambda_i} \qquad (4.22)$$

where

A_k - concentration coefficient associated with a single acute exposure (L^{-1})

$\lambda_{b,k}$ - biological decay constant for the associated concentration coefficient A_k (day^{-1})

λ_i - radiological decay constant for the nuclide i (day^{-1})

This formulation accounts for the decrease in elemental concentration patterns over time from radioactive decay. Ng et al. [12] gave the values for stable iodine in Table 4.44.

Table 4.44. Values for Stable Iodine

k	A_k	BDC_k
1	0.0055	0.69
2	0.00017	0.088

Using the λ_i values of 0.086 and 0.80 for I-131 and I-133 respectively, the adjusted ETF_i values for these two nuclides are then as shown in Table 4.45.

Table 4.45. Adjusted ETF Values

Nuclide	Adjusted ETF Value
I-131	0.0081 (0.0022-0.029)
I-133	0.0039 (0.0011-0.014)

The range of possible values for ETF as noted above served as the basis for determining the adjusted range of values for ETF. This was accomplished by using similar ratios between the ETF values for stable iodine and the adjusted ETF value for each nuclide.

The values and ranges used in determining the values of the variable $TFMLK_i$ for each nuclide i are summarized in Table 4.46.

Table 4.46. ETF Values for $TFMLK_i$

Nuclide	ETF Value (L/d)	Range of Value
Sr-89	0.0014	(0.00045-0.0038)
Sr-90	0.0014	(0.00045-0.0038)
Cs-134	0.0071	(0.0025-0.016)
Cs-137	0.0071	(0.0025-0.016)
I-131	0.0081	(0.0022-0.029)
I-133	0.0039	(0.0011-0.014)

In a review of fallout data following the Chernobyl accident by Nair and Iijima [13], an equilibrium transfer factor of 0.002 d/L was suggested for I-131, which is somewhat less than the transfer factor derived here. This may be a notable development, since milk is the primary means within the food pathway by which iodine may be ingested. If this value is correct, the value of TFMLK for I-131 would then become 0.032.

4.4 Mitigative Action Input Parameters

Within the MACCS code, the dose received by society is restricted by user-established dose criteria. For the food pathway model, two distinct criteria can be established: one for the growing season submodel and one for the long-term submodel. Various mitigative action options are available within the code for each of these submodels within the code. Each of the mitigative actions are designed to attenuate the societal dose received following an accidental release.

Several input parameters are required by the MACCS code to assure that the dose to be received via the food pathway will remain below the criteria. These input parameters are discussed in this section.

4.1 GCMAXR, PSCMLK, and PSCOTH

$GCMAXR_i$ maximum allowable concentration for ground on which crops are grown that assures the lifetime dose criteria will be met (Bq/m^2)

$PSCMLK_i$ - maximum allowable concentration for ground on which crops are grown that assures the emergency dose criteria will be met without milk disposal (Bq/m^2)

$PSCOTH_i$ - maximum allowable concentration for ground on which crops are grown that assures the emergency dose criteria will be met without crop disposal (Bq/m^2)

Table 4.47 gives the recommended values for $GCMAXR_i$, $PSCMLK_i$, and $PSCOTH_i$.

Table 4.47. Recommended Values for $GCMAXR_i$, $PSCMLK_i$, and $PSCOTH_i$

Nuclide	GCMAXR	PSCMLK	PSCOTH
Sr-89	$1.79x10^{8}$	$2.16x10^{7}$	$2.16x10^{7}$
Sr-90	$3.67x10^{4}$	$2.41x10^{5}$	$2.41x10^{5}$
Cs-134	$4.07x10^{6}$	$2.18x10^{5}$	$2.18x10^{6}$
Cs-137	$1.76x10^{6}$	$2.66x10^{5}$	$2.66x10^{10}$
I-131	$1.00x10^{20}$	$1.34x10^{6}$	$7.9510x^{6}$
I-137	$1.00x10^{20}$	$1.05x10^{10}$	$1.02x10^{11}$

It can be assumed the actual value for these variables will most probably lie within 25% of the calculated value. This assumption served as the basis for deriving a possible range of values for each nuclide/parameter pair.

Discussion

To assure that the dose received by individual remains below the user-defined dose criterion, the dose equation (i.e., Equation 4.1) is solved to find a maximum allowable ground concentration that would ensure the dose limit would not be exceeded. That is,

$$GCMAXR_i = \frac{DL_{i,k}}{DF_{i,k} \cdot \sum_j (A \cdot FA_j \cdot TF_{i,j})} \qquad (4.23)$$

To determine these maximum allowable ground concentrations, a dose limit for a maximally exposed individual was used. That is, the ground concentration was calculated for an individual whose entire intake of food was assumed to originate on contaminated ground. The maximally exposed individual can be either an infant whose food intake consists entirely of milk or an adult whose intake of food is based on a "typical" market basket.

Since the dose is being limited for an individual, parameters in Equation 4.23 assume the following definitions:

$DL_{i,k}$ = dose limit for the maximally exposed individual (Sv)

$DF_{i,k}$ = dose conversion factor for the target organ k arising from the ingestion of nuclide i (Sv/Bq)

A = total cropland area required to grow crops to provide the food for the annual market basket for a maximally exposed individual (m^2)

FA_j = fraction of area A needed to grow crop j (unitless)

$TF_{i,j}$ = fraction of the amount of nuclide i deposited following the release that will ultimately be consumed by man (unitless)

Separate maximum allowable ground concentrations are derived for the long-term and growing season food pathway submodels. Associated with each of these submodels is an allowable dose (user input dose criterion).

$GCMAXR_i$ is the maximum allowable ground concentration established for nuclide i to meet the lifetime exposure criteria. It is applied to the long-term food pathway submodel.

For the growing season food pathway submodel, two maximum allowable ground concentrations are established. $PSCMLK_i$ is applied to the crop-milk-man pathway and assures that a maximally exposed infant (i.e., an infant drinking milk only from animals raised and fed on contaminated ground). $PSCOTH_i$ assures that the maximally exposed individual would not exceed the allowable dose when the nonmilk portion of his annual intake is added to the milk consumed when the ground concentration for milk production is $PSCMLK_i$.

Each of these allowable ground concentrations is determined for each nuclide is considered in the food pathway model. They are used within the MACCS code to determine mitigative action to assure the individual dose received as a result of the release of radioactive material will remain within the preestablished exposure criteria.

$PSCMLK_i$ is used to determine the necessity of disposing of the milk being produced on contaminated ground. No disposal of milk is deemed to be necessary if the following condition is met:

$$\sum_i \frac{PSCMLK_i}{GC_i} \leq 1 \qquad (4.24)$$

where

GC_i = the actual ground concentration of nuclide i following the release (Bq/m^2)

Analogously, $PSCOTH_i$ is used to determine the necessity of disposing of crops contaminated by direct deposition of radioactive material onto the plant surfaces following the release. No crop disposal is deemed necessary if the following condition is met:

$$\sum_i \frac{PSCOTH_i}{GC_i} \leq 1 \qquad (4.25)$$

The parameter $GCMAXR_i$ is used to ensure that the lifetime exposure from radionuclides ingested via the food pathway will meet the established criteria. No mitigative actions will be required if the following condition is met:

$$\sum_i \frac{GCMAXR_i}{GC_i} \leq 1 \qquad (4.26)$$

If the ground concentration following the release is too high for this criteria to be met, several mitigative actions are evaluated for effectiveness in reducing the projected dose to within allowable standards. The first of the mitigative actions evaluated is decontamination of the cropland. If decontamination alone is insufficient to produce the required results, it is determined whether restricting crop production to allow natural depletion of the radioactive material would bring the dose received to within the lifetime criteria. Currently a maximum of eight years is permitted for interdiction of crop growth.

To calculate the effectiveness of an interdiction of crops for t years, the ground concentration following decontamination is attenuated by an overall annual depletion rate, $QROOT_i$, and the dose is again projected to determine whether the lifetime criteria have been fulfilled. That is,

$$GCI_{i,t} = GCD_i \cdot EXP\ (-\ QROOT_i \cdot t)$$

where

$GCI_{i,t}$ = ground concentration of nuclide i following t years of interdiction (Bq/m^2)

GCD_i = ground concentration of nuclide i following decontamination (Bq/m^2)

$QROOT_i$ = annual natural depletion rate for nuclide i (i.e., the depletion resulting from radioactive decay, percolation from the root zone, irreversible chemical binding with the soil, previous loss from the root zone from root uptake, and the loss from soil ingestion by grazing animals) (yr^{-1})

t = number of years over which interdiction is being considered (yr)

Following the calculation of the ground concentration following each additional year of interdiction (up to a maximum of eight years), a check is made to see whether the lifetime dose criteria are met, that is,

$$\sum_{k=1}^{n} \frac{GCMAXR_i}{GCI_{i,k}} \leq 1 \qquad n \leq 8$$

If eight years proves to be insufficient for natural depletion to bring ground concentrations to within acceptable levels, the farmland will be condemned. That is, it will be purchased and restricted from production.

A complete discussion of the derivation of the values used for the input parameters $GCMAXR_i$, $PSCOTH_i$, and $PSCMLK_i$ is given in Appendix C of the MACCS Model Description [14]. Because of the lengthy discussion needed to describe these calculations adequately, that discussion will not be repeated in this document.

4.4.2 QROOT

$QROOT_i$ = annual depletion rate of nuclide i from the root zone

Table 4.48 gives the recommended values for QROOT for each nuclide i. A uniform sampling distribution is recommended for $QROOT_i$.

Table 4.48. Recommended Values for QROOT

Nuclide	QROOT	Range of Possible Values
Sr-89	4.9	
Sr-90	0.065	(0.041-0.090)
Cs-134	0.59	(0.51-0.69)
Cs-137	0.28	(0.19-0.38)
I-131	32.0	
I-133	290.0	

Discussion

$$QROOT_i = RRU_i + RD_i + RP_i + RB_i \tag{4.27}$$

where

$QROOT_i$ = annual rate of depletion of nuclide i from the root zone (yr^{-1})

RRU_i = annual rate of depletion from root uptake of the nuclide from the root zone (yr^{-1})

RD_i = annual rate of depletion from radioactive decay (yr^{-1})

RP_i = annual rate of depletion from percolation into soil below root zone (yr^{-1})

RB_i = annual rate of depletion from irreversible chemical binding of the nuclide with soil components (yr^{-1})

A single value of this variable is derived for each nuclide considered in the food pathway.

The annual rate at which plants remove strontium and cesium from the root zone via root uptake for the various crop categories is discussed and summarized by Ostmeyer and Helton [1] whose recommended values are presented in Table 4.49.

Table 4.49. Root Uptake (RU) by Crop and Element

Crop	Rate of Root Uptake Sr	Rate of Root Uptake Cs
Pasture	0.0017	0.000083
Stored Forage	0.0042	0.00021
Grains	0.00021	0.000021
Leafy Vegetables	0.0013	0.000013
Other Foods	0.00083	0.000042

Even though not all the crop categories considered were included in this summary, the cross section is wide enough that a weighted average of these values was used to determine the annual rate of depletion from soil via root uptake. As a result, the following values given for RU in Table 4.50 were obtained.

Table 4.50. Values for Root Uptake (RU)

Element	RU	Range of Values
Strontium	0.0016	(0.00021-0.0042)
Cesium	0.000074	(0.000013-0.00021)

No value for RU was derived for iodine isotopes because their short half-lives mean that these isotopes do not contribute significantly to the root uptake dose.

The annual rate at which a nuclide i disappears from the root zone due to radioactive decay (RD_i) is dependent on its radiological half-life. RD_i can be defined as follows:

$$RD_i = \frac{\ln 2}{THALF_i}$$

where

$THALF_i$ = radiological half-life of nuclide i (yr)

Values for RD_i are given in Table 4.51.

Table 4.51. Values for Radioactive Decay, RD_i (yr^{-1})

Nuclide	RD
Sr-89	4.86
Sr-90	0.024
Cs-134	0.34
Cs-137	0.023
I-131	31.5
I-133	292.0

Because radioactive half-lives are precisely known, no ranges are given for the values of RD_i.

The percolation rate for strontium and cesium have been established by Hoffman and Baes [11]. For strontium, this rate is given as 0.0021 yr^{-1}, and for cesium, it is given as 0.0096 yr^{-1}. The percolation rate is strongly dependent on soil characteristics; therefore, these values represent an approximate rate and are quite uncertain. A range of possible values was established by assuming that the actual value would most likely lie within 25% of the estimated value. No value for RP was derived for the iodine isotopes being considered since their depletion rate is dominated almost totally by radioactive decay. The values and possible ranges of values used for RP are summarized as in Table 4.52.

Table 4.52. Values for Rate of Percolation (RP_i)

Element	DRP	Range of Values
Strontium	0.0096	(0.0072-0.012)
Cesium	0.0021	(0.0016-0.0026)

When attempting to establish the rate of depletion from the root zone because of irreversible chemical binding with the soil, it becomes apparent that the binding rates for both strontium and cesium are strongly dependent on soil characteristics. Based on investigations by Squire [15], Squire and Middleton [16], and Lassey [17], and a discussion by Coughtrey and Thorne [8], it seems reasonable to assume that 10-20% of the strontium in the soil will become chemically bound to the soil particles at a rate of about 1-5% per year. Cesium reacts even more dramatically with clay, and approximately 85-95% will become chemically bound to the clay particles and this binding will essentially be complete in three years. Chemical binding is not an important consideration for the iodine isotopes being considered, since radioactive decay is the primary mechanism by which they are depleted from the environment.

Based on this information, the values and ranges in Table 4.53 were established for the annual rate at which the nuclides become unavailable for root uptake because of irreversible binding with the soil.

Table 4.53. Values for Binding Rate, RB

Element	RB	Range of Values
Strontium	0.030	(0.01-0.05)
Cesium	0.25	(0.17-0.32)

Using the indicated derived values and ranges for the depletion rates from root uptake, radioactive decay, percolation out of the root zone, and chemical binding with the soil, the recommended values for the total depletion rates were found as the sum of the component parts as indicated in Equation 4.23

REFERENCES

[1] R. M. Ostmeyer and J. C. Helton, Exposure Pathways Models for Accidental Radionuclide Releases, NUREG/CR-4148, SAND85-0520, Sandia National Laboratories, Albuquerque, NM (unpublished but available upon request).

[2] Agricultural Statistics 1984, United States Department of Agriculture, Washington, DC, 1984.

[3] J. R. Simmonds and G. S. Linsley, "A Dynamic System for Transfer of Radioactivity in Terrestrial Food Chains," Nuclear Safety, pp. 766-777, 1981.

[4] J. R. Simmonds and G.S. Linsley, "Parameters for Modelling the Interception and Retention of Deposits from the Atmosphere by Grain and Green Leafy Vegetables," Health Physics, pp. 679-691, 1982.

[5] S. Vuori, Radionuclide Transfer to Foodstuffs Via Plant in View of the Data Available After the Chrenobyl Accident, Technical Report, OECD/NEA Group of Experts on Accident Consequences (GRECA), Helsinki, Finland, 1988.

[6] P. J. Coughtrey and M. C. Thorne, Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems: A Critical Review of Data, A. A. Balkema, Rotterdam, Netherlands, 1983.

[7] USNRC, Regulatory Guide 1.109; Calculation of Annual Dose from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50 Appendix I. U.S. Nuclear Regulatory Commission, Washington, DC, 1977.

[8] F. W. Boone, Y. C. Ng, and J. M. Palms, "Terrestrial Pathways of Radionuclide Particulates," Health Physics, Vol. 41, pp. 735-747, 1981.

[9] Y. C. Ng, Methodology for Assessing Dose Commitment to Individuals and to the Population from Ingestion of Terrestrial Foods Contaminated by Emissions from a Nuclear Fuel Reprocessing Plant at the Savannah River Plant, Report UCID-17743, University of California, 1978.

[10] J. E. Till, and H. R. Meyer, eds. Radiological Assessment: A Textbook On Environmental Dose Analysis. U.S. Nuclear Regulatory Commission, Washington, DC, 1983.

[11] F. O. Hoffman and C. F. Baes III, A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides, NUREG/CR-1004, July 1979.

[12] Y. C. Ng, C. S. Colsher, D. J. Quinn, and S. E. Thompson, Transfer Coefficients for the Prediction of the Dose to Man via the Forage-Cow-Milk Pathway from Radionuclides Released to the Biosphere, UCRL-51939, Lawrence Livermore National Laboratory, Livermore, California, 1977.

[13] S. Nair and T. Iijima "GRECA Review of Chernobyl Data on Transfer to Animal Products" in Proceedings of Joint OECD (NEA)/CEC Workshop on Recent Advances in Reactor Accident Consequence Assessments, vol. 1, Rome, January 25-29, 1988, pp. 169-99, OECD Nuclear Energy Agency, Paris, 1988.

[14] H-N Jow, J. L. Sprung, J. A. Rollstin, L. T. Ritchie, D. I. Chanin, MELCOR Accident Consequence Code System (MACCS): Model Description, NUREG/CR-4691, SAND86-1562, Sandia National Laboratories, 1990.

[15] H. M. Squire, "Long Term Studies of Sr-90 in Soils and Pastures," Radiation Botany, pp. 49-67, 1966.

[16] H. M. Squire and L. J. Middleton, "Behaviour of Cs-137 in Soils and Pastures, A Long Term Experiment," Radiation Botany, pp 413-423, 1966.

[17] K. Lassey, "The Transfer of Radiostrontium and Radiocesium from Soil to Diet: Models Consistent with Fallout Analysis, Health Physics, pp. 557-573, 1979.

5 ECONOMIC PARAMETERS

5.1 Nonfarm Parameters: Recommended Values

Table 5.1 lists the values of nonfarm economic parameters recommended for use in MACCS.

Table 5.1. Economic Parameter Values for MACCS

Variable	(Units)	Site	Value	Range*	Definition
DPRATE	(per yr)	All	0.2	0.1 - 0.3	Property depreciation rate
DSRATE	(per yr)	All	0.12	0.7 - 0.17	Investment rate of return
EVACST	($/day)	All	$27	$25 - $30	Per diem living expenses for evacuees
FRNFIM		All	0.8	0.7 - 0.9	Nonfarm
POPCST	($)	All	$5000	$3500 - $7500	Relocation costs for owners of interdicted property
RELCST	($/day)	All	$27	$25 - $30	Per diem living expenses for relocated population
VALWNR	($)	Grand Gulf	$53K	$43K - $63K	Per capita value of nonfarm wealth
		Peach Bottom	$79K	$69K - $89K	
		Surry	$84K	$74K - $94K	
		Sequoyah	$66K	$56K - $76K	
		Zion	$76K	$66K - $86K	
		US	$80K	$60K - $100K	

---

* All sampling distributions should be uniform over the stated ranges.

5.2 Nonfarm Parameters: Discussion

Most of the data presented in the following discussion were taken from Statistical Abstract of the United States for 1988. A few figures were taken from Fortune (April 25, 1988) and Forbes (January 11, 1989, June 27, 1988) magazines.

The economic model in the MACCS code treats following costs:

(1) Daily food and lodging costs per person for short-term relocation of people who evacuate or relocate during the emergency phase of the accident (e.g., the first seven days after the accident),

(2) Decontamination costs for property that can be returned to use,

(3) Economic losses incurred while property is temporarily interdicted so that a period of decay following maximum decontamination can reduce yearly doses to acceptable levels (e.g., 5 5 rem in eight years), and

(4) Economic losses from the permanent interdiction of property.

The model divides economic costs into two groups, farm costs and nonfarm costs. Farm costs are always calculated per hectare of farmland (worth of farmland and improvements per hectare, crop worth per hectare). Nonfarm costs are always calculated per person (temporary and permanent relocation costs per person, tangible worth of nonfarm property per person, decontamination costs of nonfarm property per person), where nonfarm property includes residential, commercial, and public land, improvements, equipment, and possessions.

5.2.1 Relocation Costs

Burke [1] estimated per diem relocation costs (housing, food, transportation) per person to be $23.70 in 1982 dollars. Correction to 1986 (1986 CPI = 328; 1982 CPI = 289; ratio = 1.13) gives $26.90 per day per person. Fifty dollars per night for a four-person motel room, and $3.50, $4.50, and $7.00 per person for breakfast, lunch, and dinner plus $1.50 per day for public transportation, gives $29.00 per day per person. Burke estimated that mass care per diem costs would be about half the cost of commercial care (hotels and restaurants) and that about one fifth of all relocated persons would be accommodated in mass care facilities. If per diem costs are $29 per person for 80 per cent of the relocated population and $14.50 per person for the remaining 20 per cent, an average per diem relocation cost of $26 per person results, which agrees well with Burke's result after correction to 1986 dollars. Therefore, a per diem relocation cost of $27 per person is recommended for use in the final NUREG-1150 calculations.

5.2.2 Decontamination Costs

The MACCS decontamination model assumes that for both farm and nonfarm property several (no more than three) decontamination methods will be available. For each decontamination method, the model requires a cost (per hectare for farm property and per person for nonfarm property) and a decontamination factor, F_D, where

$$F_D = C_i/C_f$$

and C_i and C_f are the surface contamination levels before and after the decontamination step. Although the costs of the decontamination methods for farm and nonfarm property need not be the same, the set of decontamination factors used for farm property must be the same as the set used for nonfarm property.

5.2.3 Temporary Interdiction Losses

When property is temporarily interdicted, three costs are incurred for nonfarm property and two for farm property. For nonfarm property, the three costs are lost wages per person moved, lost return on investment on the interdicted property, and the cost of the repairs required to return the property to use once the interdiction period ends. For farm property, the second and third costs apply but the first does not (because only the nonfarm economic model treats people).

Burke [1] examined the relocation costs that would be incurred by a person forced to relocate because his home had been interdicted. Since most of his possessions have been contaminated, Burke concluded that moving costs would be small when compared to lost wages, which he estimated to total about $4000 based on the assumption that each worker relocated would be out of work for 100 to 180 days. Since per capita income in 1986 was $14,600, if 140 days of lost wages are assumed (the average duration of unemployment from 1972 through 1986 was 15 weeks or 105 days, Reactor Safety Study [2] assumed that interdicted businesses would require about six months to reopen in a new location) and lost wages per person relocated would be $5600. Correction of Burke's estimate of $4000 based on 1982 data to 1986 yields $4500. Accordingly, a moving cost of $5000 is recommended for use in the final NUREG-1150 calculations.

Assume that all property (land, buildings, equipment, etc.) can be viewed as an investment that yields a rate of return, r, and depreciates at a rate, p, if left untended for some length of time, t. If, for example, the property is interdicted for t years, then two costs are incurred: (1) lost return on investment and (2) repair costs.

Consider a property composed of land (present value L) and improvements (present value I). The total present value of the property is $L + I = V$, and the fraction of the total present value that is improvements is $I/V = f$. If this property is now interdicted for t years, the lost return on investment is $V_t - V$, where $V_t = V\,e^{rt}$ and the repair costs that will be incurred at the end of the interdiction period are $I - I_t$, where $I_t = I\,e^{-pt}$. Therefore,

$$\text{Loss on Investment} = V_t - V = V\,e^{rt} - V = V\,(e^{rt} - 1)$$

$$\text{Repair Costs} = I - I_t = I - I\,e^{-pt} = I\,(1 - e^{-pt})$$

Let the present values of the lost return on investment and the repair costs be V' and I'. Then

$$V'\,e^{rt} = V_t - V = V\,(e^{rt} - 1)$$

$$V' = V\,(1 - e^{-rt})$$

$$I'\,e^{rt} = I - I_t = I\,(1 - e^{-pt})$$

$$I' = I\,e^{-rt}\,(1 - e^{-pt})$$

and C', the present value of the total losses incurred during the interdiction period (t), is

$$C' = V' + I' = V\,(1 - e^{-rt}) + I\,e^{-rt}\,(1 - e^{-pt})$$

$$= V - e^{rt}\,[V\,(1 - f + f\,e^{-pt})]$$

which agrees with Burke et al. [1] and with the Reactor Safety Study [2].

To apply the preceding model, values for V, f, r, and p are needed. Since MACCS calculates farm costs on a per hectare basis and nonfarm costs on a per person basis, the values of V needed are the value of farm property per hectare (per acre) and of nonfarm property per person. State and national data for farm property are available from Statistical Abstract of the United States [3] and are discussed in other data packages. A value for the per person worth of nonfarm residential, commercial, and public property can be estimated from the following data, which were taken from Ref. [3]:

Reproducible Tangible Wealth = $\$1.98 \times 10^{13}$
Urban and Built-Up Land = 4.64×10^{4} acres
Total Farm Assets = $\$7.89 \times 10^{11}$
Farm Land = $\$5.54 \times 10^{11}$
Farm Household Possessions = $\$3.05 \times 10^{10}$
1987 U.S. Population = 2.44×10^{8}

Now assuming that nonfarm land costs about $90,000 per acre (typical suburban residential lots are 0.2 acre, land usually constitutes about one fifth of the cost of a house, and the 1986 median value of houses was $92,000), the per person worth of nonfarm residential, commercial, and public property, that is V, is given by

$$
\begin{aligned}
V = [&\text{reproducible tangible wealth} \\
&+ \text{value of suburban land} \\
&- \text{value of farm assets} \\
&+ \text{value of farm household possessions}]/[\text{U.S. population}] \\
= [&\$1.98 \times 10^{13} \\
&+ (4.64 \times 10^{4} \text{ acres})(\$9 \times 10^{4} \text{ acre}^{-1}) \\
&- \$7.89 \times 10^{11} \\
&+ \$3.05 \times 10^{10}]/[2.44 \times 10^{8} \text{ people}] \\
= \$&7.8 \times 10^{4}
\end{aligned}
$$

Therefore, V is about $80,000 per person.

The value of V is likely to vary significantly by state. This variation can be approximated by multiplying the $80,000 value by the ratio of a state's per capita income to the national per capita income. The pertinent data are given in Table 5.2.

Table 5.2. Value to Region

Reactor	Region	($1000) Per Capita Income	V ($1000)
	US	$14.6	$80
Seq	TN	12.0	66
	AL	11.3	62
Zion	WI	13.9	76
	Chicago	13.2	72
	IL	15.6	85
GG	MI	9.7	53
	LA	11.2	61
PB	PA	14.2	79
	MD	16.9	93
Sur	VA	15.4	84

Since investment property is usually purchased by borrowing money (mortgages, equipment loans), r, the total rate of return on any property must be calculated as the dollar weighted sum of the property owner's rate of return on equity (r_E) and the debt holder's rate of return on debt (r_D). Specifically,

$$r = fr_E + (1-f)r_D,$$

where $f = E/V$, E is the owner's equity in the property, V is the total value of the property, and $V - E = D$ is the debt on the property (for all manufacturing companies, $D/E = 1.8$ and thus $f = 0.36$, for the Fortune 500 companies, $D/E = 1.2$ and $f = 0.45$).

Several measures of the rate of return on debt or equity are given in Table 5.3:

Table 5.3. Rates of Return

Measure	Percent
Conventional Mortagage Rate (1970 - 1986)	11.9
Return on Equity	
Forbes Stock Fund Composite (1977 - 1987)	16.4
Standard and Poors 500 (1977 - 1987)	16.9
Fortune 500 (1977 - 1987)	12.2
Fortune 500 (1983 - 1987)	12.8
Fortune 500 (1986)	11.6
Fortune 500 (1987)	12.2
All Manufacturing (1985)	11.6
All Manufacturing (1986)	11.6

These data suggest that 12% is a representative rate of return on both mortagages and equity. Therefore, r equals 12%, which is the value of r used in Reactor Safety Study [2], where r was viewed as the carrying cost (expressed as a percent of value) for interdicted residential property (mortgage rate of 9% plus real estate tax rate of 3%).

Finally, no data on depreciation rates (p) for untended property are available. Reactor Safety Study assumed a value of 20% per year for p after noting that depreciation rates for property that is maintained are typically 3% to 5% per year.

5.3 Farm Parameters: Recommended Values

Table 5.4 gives the recommended values for VALUE and FRFIM.

Table 5.4. Recommended Values for VALWF and FRFIM

Site	VALWF ($/ha)	FRFIM ($/ha)
Grand Gulf (Mississippi)	1824	0.30
Peach Bottom (Pennsylvania)	4469	0.25
Sequoyah (Tennessee)	2708	0.27
Surry (Virginia)	2952	0.25
Zion (Wisconsin)	1754	0.49

VALWF - Value of farm wealth in region (includes all improvements belonging to both public and private sector)

FRFIM - Fraction of farm wealth in region from improvements (includes buildings, equipment, infrastructure (such as roads, utilities, etc.)

5.3.1 Discussion

The total value of farm machinery and implements in 1988 is 84.5 billion dollars according to the U.S. Department of Commerce [4:Table 1086]. Since there are 1002 million acres of farmland in the U.S. [4:Table 1057], the value of machinery and implements per acre is $84.3 or $208.2 per/hectare.

The value of farm land and buildings in 1988 [4:Table 1066] in the states being considered can be summarized as in Table 5.5.

Table 5.5. Value of Farm Land and Buildings (1988)

State	Value of Land & Buildings ($/ha)
Mississippi	654
Pennsylvania	1725
Tennessee	1012
Virginia	1111
Wisconsin	626

The data in Table 5.5 were used to determine the value of the variable VALWF for each of the states considered in Table 5.6.

Table 5.6. Values for VALWF by State

State	Value of Land & Buildings ($/ha)	VALWF($/ha)
Mississippi (Grand Gulf)	1615	1824
Pennsylvania (Peach Bottom)	4261	4469
Tennessee (Sequoyah)	2500	2708
Virginia (Surry)	2744	2952
Wisconsin (Zion)	1546	1754

Based on information from the USDA for 1984 [4:Table 543], Table 5.7 shows the value that was determined for the percentage of the total value of the farm that is accounted for by the buildings for each state being considered.

Table 5.7. Value of Buildings

State	Value of Land and Buildings*	Value of Buildings	Total Value Represented by Buildings (%)
Mississippi	13814	1975	14.3
Pennsylvania	12015	3196	26.6
Tennessee	12743	2829	22.0
Virginia	10192	2140	21.0
Wisconsin	17436	4830	27.7

* in millions of dollars

This percentage was then used with the values derived for VALWF to determine the current value of buildings/acre, as well as the total value of buildings and equipment/hectare as in Table 5.8.

Table 5.8. Value of Buildings per Acre

State	Value of Buildings ($/ac)	Value of Buildings ($/ha)	Value of Buildings & Equipment ($/ha)
Mississippi	138	341	549
Pennsylvania	367	906	1114
Tennessee	211	521	729
Virginia	218	538	746
Wisconsin	265	655	863

The values of FRFIM in Table 5.9 were derived as the fraction of VALWF that is represented by improvements (buildings and equipment).

Table 5.9. Values of FRFIM

State	FRFIM
Mississippi (Grand Gulf)	0.30
Pennsylvania (Peach Bottom)	0.25
Tennessee (Sequoyah)	0.27
Virginia (Surry)	0.25
Wisconsin (Zion)	0.49

REFERENCES

[1] R. P. Burke et al., Economic Risks of Nuclear Power Reactor Accidents, NUREG/CR-3673, Sandia National Laboratories, Albuquerque, NM 1984.

[2] U.S. Nuclear Regulatory Commission, Reactor Safety Study, Appendix VI, "Calculation of Reactor Accident Consequences," WASH-1400, Washington, DC, 1975.

[3] Statistical Abstract of the United States, 1988, U.S. Department of Commerce.

[4] Agricultural Statistics 1984, United States Department of Agriculture, Washington, DC, 1984.

APPENDIX A: Sample NUREG-1150 MACCS Input Files

Page

A.1 ATMOS A-2
A.2 EARLY A-11
A.3 CHRONC A-19
A.4 DOSDATA A-29
A.5 SITE A-43
  Surry A-44
  Sequoyah A-48
  Peach Bottom A-52
  Grand Gulf A-56

```
******************** ***********************************************     **********  *********
* FILE NAME [illegible]
*
* [illegible] THE [illegible]
*
RIATNAM1 [illegible] FINAL NUREG 1150 CALC[illegible]
*
* FLA[illegible] IS [illegible] PROGRAM IN [illegible]
*
OVERNA[illegible] THIS VALUE [illegible] TRUE. TO SKI[illegible]
***************************************************************************************
* GEOMETRY DATA [illegible] LOADED BY INPGEO, STORED IN [illegible]
*
* NUMBER [illegible] SPATIAL ELEMENTS
*
GEN[illegible]RAD[illegible]
*
* SPATIAL END[illegible] DISTANCES IN MILES
*
*     END[illegible]1    [illegible]          [illegible]5        0.[illegible]5       1.0        1.[illegible]
*     END[illegible]2    [illegible]          2.5        3.0        3.5        [illegible]
*     END[illegible]3    [illegible]          10         13         16         [illegible]
*     END004     [illegible]        30         40         50         [illegible]
*     END[illegible]5    1[illegible]       1[illegible]       200        350        [illegible]
*     END[illegible]6    1[illegible]
*
* SPATIAL END[illegible] DISTANCES IN KILOMETERS
*
*     SITE                              GG     LS     PB     SE[illegible]   [illegible]    ZION
*     EXCLUSION ZONE DISTANCE (MI)   0.432  0.320  0.51[illegible]  0.364  [illegible]  0.[illegible]49
*     EXCLUSION ZONE DISTANCE (KM)   0.696  0.515  0.8[illegible]  [illegible]  [illegible]  .4[illegible]
*     EXCLUSION ZONE + 1.0 MI (KM)   2.305  2.124  2.4[illegible]  2.[illegible]  [illegible]  2.[illegible]
*
*GESPAEND001      .4[illegible]        .80        1.21        1.61        2.41    * STANDARD GRID
*GESPAEND001      .4[illegible]        .70        1.21        1.61        2.3[illegible]    * GRAND GULF
*GESPAEND001      .16        .52        1.21        1.61        [illegible]    * LA SALLE
*GESPAEND001      .4[illegible]        .82        1.21        1.61        2.4[illegible]    * PEACH BOTTOM
*GESPAEND001      .[illegible]6        .59        1.21        1.61        [illegible]    * SEQUOYAH
*GESPAEND001      .[illegible]        .52        1.21        1.61        [illegible]    * SURRY
*GESPAEND001      .4[illegible]        .80        1.21        1.61        [illegible]    * ZION
*
*  PEACH BOTTOM
*
GESPAEND001       .4[illegible]        82        1.21        1.61        [illegible].4[illegible]
GESPAEND002      3.2[illegible]       4.02        4.83        5.63        8.[illegible]
GESPAEND003     11.[illegible]       16.09       20.92       25.75       [illegible]
GESPAEND004     40.2[illegible]      48.28       64.37       80.47      11[illegible]
GESPAEND005    160.[illegible]      241.14      321.87      563.27      804.[illegible]
GESPAEND006   1609.34
*******************************************************************************************
* NUCLIDE DATA BLOCK, LOADED BY INPISO, STORED IN /ISOGRP/, [illegible]
*
* NUMBER OF NUCLIDES
*
ISNUMISO001 6[illegible]
*
* NUMBER OF NUCLIDE GROUPS
*
ISMAXGRP001  9
*
* WET AND DRY DEPOSITION FLAGS FOR EACH NUCLIDE GROUP
*
*                 WETDEP      DRYDEP
*
ISDEPFLA[illegible]      .FALSE.     .FALSE.
ISDEPFLA[illegible]      [illegible]      .TRUE.
```

```
ISDEPFLA003      .TRUE.     .TRUE.
ISDEPFLA004      .TRUE      .TRUE.
ISDEPFLA005      .TRUE      .TRUE.
ISDEPFLA006      .TRUE.     .TRUE
ISDEPFLA007      .TRUE.     .TRUE.
ISDEPFLA008      .TRUE.     .TRUE.
ISDEPFLA009      .TRUE.     .TRUE.
*
* NUCLIDE GROUP DATA FOR 9 NUCLIDE GROUPS
*
*                NUCNAM     PARENT    IGROUP        HAFLIF
*
ISOTPGRP001      CO 58       NONE       6        6.160E+06
ISOTPGRP002      CO 60       NONE       6        1.660E+08
ISOTPGRP003      KR-85       NONE       1        3.386E+08
ISOTPGRP004      KR-85M      NONE       1        1.613E+04
ISOTPGRP005      KR-87       NONE       1        4.560E+03
ISOTPGRP006      KR-88       NONE       1        1.008E+04
ISOTPGRP007      RB-86       NONE       3        1.611E+06
ISOTPGRP008      SR-89       NONE       5        4.493E+06
ISOTPGRP009      SR-90       NONE       5        8.865E+08
ISOTPGRP010      SR-91       NONE       5        3.413E+04
ISOTPGRP011      SR-92       NONE       5        9.756E+03          NEW
ISOTPGRP012      Y-90       SR-90       7        2.307E+05
ISOTPGRP013      Y-91       SR-91       7        5.080E+06
ISOTPGRP014      Y-92       SR-92       7        1.274E+04          NEW
ISOTPGRP015      Y-93        NONE       7        3.636E+04          NEW
ISOTPGRP016      ZR-95       NONE       7        5.659E+06
ISOTPGRP017      ZR-97       NONE       7        6.048E+04
ISOTPGRP018      NB-95      ZR-95       7        3.033E+06
ISOTPGRP019      MO-99       NONE       6        2.377E+05
ISOTPGRP020      TC-99M     MO-99       6        2.167E+04
ISOTPGRP021      RU-103      NONE       6        3.421E+06
ISOTPGRP022      RU-105      NONE       6        1.598E+04
ISOTPGRP023      RU-106      NONE       6        3.188E+07
ISOTPGRP024      RH-105     RU-105      6        1.278E+05
ISOTPGRP025      SB-127      NONE       4        3.283E+05
ISOTPGRP026      SB-129      NONE       4        1.562E+04
ISOTPGRP027      TE-127     SB-127      4        3.366E+04
ISOTPGRP028      TE-127M     NONE       4        9.418E+06
ISOTPGRP029      TE-129     SB-129      4        4.200E+03
ISOTPGRP030      TE-129M     NONE       4        2.886E+06
ISOTPGRP031      TE-131M     NONE       4        1.080E+05
ISOTPGRP032      TE-132      NONE       4        2.808E+05
ISOTPGRP033      I-131      TE-131M     2        6.947E+05
ISOTPGRP034      I-132      TE-132      2        8.226E+03
ISOTPGRP035      I-133       NONE       2        7.488E+04
ISOTPGRP036      I-134       NONE       2        3.156E+03
ISOTPGRP037      I-135       NONE       2        2.371E+04
ISOTPGRP038      XE-133      I-133      1        4.571E+05
ISOTPGRP039      XE-135      I-135     .1        3.301E+04
ISOTPGRP040      CS-134      NONE       3        6.501E+07
ISOTPGRP041      CS-136      NONE       3        1.123E+06
ISOTPGRP042      CS-137      NONE       3        9.495E+08
ISOTPGRP043      BA-139      NONE       9        4.986E+03          NEW
ISOTPGRP044      BA-140      NONE       9        1.105E+06
ISOTPGRP045      LA-140     BA-140      7        1.448E+05
ISOTPGRP046      LA-141      NONE       7        1.418E+04          NEW
ISOTPGRP047      LA-142      NONE       7        5.724E+03          NEW
ISOTPGRP048      CE-141     LA-141      8        2.811E+06    PARENT ADDED
ISOTPGRP049      CE-143      NONE       8        1.188E+05
ISOTPGRP050      CE-144      NONE       8        2.457E+07
ISOTPGRP051      PR-143     CE-143      7        1.173E+06
ISOTPGRP052      ND-147      NONE       7        9.495E+05
ISOTPGRP053      NP-239      NONE       8        2.030E+05
ISOTPGRP054      PU 238     CM 242      8        2.809E+09
```

```
ISOTPGRP055     PU-239     NP-239        8          7.700E+11
ISOTPGRP056     PU-240     CM-244        8          2.133E+11
ISOTPGRP057     PU-241       NONE        8          4.608E+08
ISOTPGRP058     AM-241     PU-241        7          1.366E+10
ISOTPGRP059     CM-242       NONE        7          1.408E+07
ISOTPGRP060     CM-244       NONE        7          5.712E+08
*****************************************************************************
* WET DEPOSITION DATA BLOCK, LOADED BY INPWET, STORED IN /WETCON/
*
* WASHOUT COEFFICIENT NUMBER ONE, LINEAR FACTOR
*
WDCWASH1001  9.5E-5   (HELTON AFTER JONES, 1986)
*
* WASHOUT COEFFICIENT NUMBER TWO, EXPONENTIAL FACTOR
*
WDCWASH2001  0.8      (HELTON AFTER JONES, 1986)
*****************************************************************************
* DRY DEPOSITION DATA BLOCK, LOADED BY INPDRY, STORED IN /DRYCON/
*
* NUMBER OF PARTICLE SIZE GROUPS
*
DDNPSGRP001    1
*
* DEPOSITION VELOCITY OF EACH PARTICLE SIZE GROUP (M/S)
*
DDVDEPOS001    0.01   (VALUE SELECTED BY S. ACHARYA, NRC)*
*****************************************************************************
* DISPERSION PARAMETER DATA BLOCK, LOADED BY INPDIS, STORED IN /DISPY/, /DISPZ/
*
* SIGMA = A X ** B  WHERE A AND B VALUES ARE FROM TADMOR AND GUR (1969)
*
* LINEAR TERM OF THE EXPRESSION FOR SIGMA-Y, 6 STABILITY CLASSES
*
* STABILITY CLASS: A        B        C        D        E        F
*
DPCYSIGA001    0.3658   0.2751   0.2089   0.1474   0.1046   0.0722
*
* EXPONENTIAL TERM OF THE EXPRESSION FOR SIGMA-Y, 6 STABILITY CLASSES
*
* STABILITY CLASS: A        B        C        D        E        F
*
DPCYSIGB001     .9031    .9031    .9031    .9031    .9031    .9031
*
* LINEAR TERM OF THE EXPRESSION FOR SIGMA-Z, 6 STABILITY CLASSES
*
* STABILITY CLASS: A        B        C        D        E        F
*
DPCZSIGA001    2.5E-4   1.9E-3      .2       .3       .4       .2
*
* EXPONENTIAL TERM OF THE EXPRESSION FOR SIGMA-Z, 6 STABILITY CLASSES
*
* STABILITY CLASS; A        B        C        D        E        F
*
DPCZSIGB001     2.125    1.6021     .8543    .6532    .6021    .6020
*
*  LINEAR SCALING FACTOR FOR SIGMA-Y FUNCTION, NORMALLY 1
*
DPYSCALE001     1.
*
*  LINEAR SCALING FACTOR FOR SIGMA-Z FUNCTION,
*  NORMALLY USED FOR SURFACE ROUGHNESS LENGTH CORRECTION.
*  (Z1 / Z0) ** 0.2,    FROM CRAC2 WE HAVE  (10 CM / 3 CM) ** 0.2 = 1.27
*
DPZSCALE001     1.27
*****************************************************************************
* EXPANSION FACTOR DATA BLOCK, LOADED BY INPEXP, STORED IN /EXPAND/
```

***See letter from M.A. Cunningham (NRC) to F.T. Harper (SNL) dated Aug. 7, 1990 filed in NRC Public Document Room.**

```
*
* TIME BASE FOR EXPANSION FACTOR (SECONDS)
*
PMTIMBAS001    60 .    (10 MINUTES)
*
* BREAK POINT FOR FORMULA CHANGE (SECONDS)
*
PMBRKPNT001    3600.    (1 hour)
*
* EXPONENTIAL EXPANSION FACTOR NUMBER 1
*
PMXPFAC1001       0.2
*
* EXPONENTIAL EXPANSION FACTOR NUMBER 2
*
PMXPFAC2001       0.25
***********************************************************************
* PLUME RISE DATA BLOCK, LOADED BY INPLRS, STORED IN /PLUMRS/
*
* SCALING FACTOR FOR THE CRITICAL WIND SPEED FOR ENTRAINMENT OF A BOUYANT PLUME
* (USED BY FUNCTION CAUGHT)
*
PRSCLCRW001    1.
*
* SCALING FACTOR FOR THE A-D STABILITY PLUME RISE FORMULA
* (USED BY FUNCTION PLMRIS)
*
PRSCLADP001    1.
*
* SCALING FACTOR FOR THE E-F STABILITY PLUME RISE FORMULA
* (USED BY FUNCTION PLMRIS)
*
PRSCLEFP001    1.
***********************************************************************
* WAKE EFFECTS DATA BLOCK, LOADED BY INPWAK, STORED IN /BILWAK/
*
*    SITE         GG   PB   SEQ  SUR
*    WIDTH  (M)   40   50   40   40
*    HEIGHT (M)   60   50   40   50
*
* BUILDING WIDTH (METERS)
*
WEBUILDW001    50.   *  PEACH BOTTOM
*
* BUILDING HEIGHT (METERS)
*
WEBUILDH001    50.   *  PEACH BOTTOM
***********************************************************************
* RELEASE DATA BLOCK, LOADED BY INPREL, STORED IN /RELEAS/
*
* SPECIFIC DESCRIPTIVE TEXT DESCRIBING THIS PARTICULAR SOURCE TERM
*
RDATNAM2001 'NUREG-1150 PEACH BOTTOM SOURCE TERM PB-15-1'
*
* TIME (SECONDS) AFTER ACCIDENT INITIATION WHEN THE ACCIDENT REACHES GENERAL
* EMERGENCY CONDITIONS (AS DEFINED IN NUREG-0654), OR WHEN PLANT PERSONNEL
* CAN RELIABLY PREDICT THAT GENERAL EMERGENCY CONDITIONS WILL BE ATTAINED.
*
RDOALARM001    1.40E4
*
* SELECTION OF RISK DOMINANT PLUME
*
RDMAXRIS001    1
*
* NUMBER OF PLUME SEGMENTS THAT ARE RELEASED
*
```

```
RDNUMREL    2
*
* REFERENCE TIME POINT FOR DISPERSION AND RADIOACTIVE DECAY
*
RDREFTIM 1              0.5    (CORRESPONDING TO HEAD AND MIDDLE OF WEATHER)
*
* HEAT CONTENT OF THE RELEASE SEGMENTS (WATTS)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLHEAT 1    1.4[illegible]     1.49E6  *  6.0E8 CAL 240 SEC, [illegible] CAL 1.4E4 SEC
*                                  4.184 CAL/SEC = 1.0 WATT
*
* HEIGHT OF THE PLUME SEGMENTS AT RELEASE (METERS)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLHITE 1   30.    30.
*
* DURATION OF THE PLUME SEGMENTS (SECONDS)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPLUDUR 1  240.    1.40E4
*
* TIME OF RELEASE FOR EACH PLUME (SECS FROM SCRAM)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
*
RDPDELAY001  2.51E4  2.58E4
*
* RELEASE FRACTIONS FOR NUCLIDE GROUPS IN RELEASE
*
* GENERIC SOURCE TERM A
*
*     GROUP:  XE KR   I        CS       TE      SR       RU        LA        CE       BA
*
RDRELFRC001    0.66  8.5E-3  9.4E-3  0.019  0.026  3.5E-[illegible]  [illegible]  5.4E-[illegible]  0.026
RDRELFRC002    0.34  0.49    0.54    0.61   0.72   9.3E-[illegible]  [illegible]  0.12     0.62
*
* 3578 MWTH BWR CORE INVENTORY, 80 O/O CAPACITY, 3/3 SHUTDOWN INVENTORY
*                    SUPPLIED BY D.E. BENNETT, 6/17/86
*
*                 NUCNAM        CORINV(BQ)
*
RDCORINV001     CO-58         2.024E+16
RDCORINV002     CO-60         2.423E+16
RDCORINV003     KR-85         3.317E+16
RDCORINV004     KR-85M        1.206E+18
RDCORINV005     KR-87         2.193E+18
RDCORINV006     KR-88         2.960E+18
RDCORINV007     RB-86         1.856E+15
RDCORINV008     SR-89         3.673E+18
RDCORINV009     SR-90         2.599E+17
RDCORINV010     SR-91         4.771E+18
RDCORINV011     SR-92         4.984E+18
RDCORINV012     Y-90          2.783E+17
RDCORINV013     Y-91          4.482E+18
RDCORINV014     Y-92          5.004E+18
RDCORINV015     Y-93          5.690E+18
RDCORINV016     ZR-95         5.899E+18
RDCORINV017     ZR-97         6.073E+18
RDCORINV018     NB-95         5.581E+18
RDCORINV019     MO-99         6.436E+18
RDCORINV020     TC-99M        5.554E+18
RDCORINV021     RU-103        4.877E+18
RDCORINV022     RU-105        3.254E+18
RDCORINV023     RU-106        1.327E+18
RDCORINV024     RH-105        2.429E+18
RDCORINV025     SB-1[illegible]        3.0[illegible]E+1[illegible]
```

```
RDCORINV026     SB-1[illegible]     1.[illegible]8E+18
RDCORINV027     TE-12[illegible]    2.9[illegible]9E+17
RDCORINV028     TE-[illegible]M     4.010E+16
RDCORINV029     T[illegible]        1.00[illegible]E+18
RDCORINV030     TE-[illegible]9M    2.634E+17
RDCORINV031     TE-1[illegible]1M   5.0[illegible]8E+17
RDCORINV032     TE-132      4.944E+18
RDCORINV033     I-131       4.41[illegible]E+18
RDCORINV034     I-132       5.[illegible]20E+18
RDCORINV035     I-133       [illegible].1[illegible]2E+18
RDCORINV036     I-134       [illegible].850E+18
RDCORINV037     I-135       [illegible].[illegible]51E+18
RDCORINV038     XE-133      [illegible].182E+18
RDCORINV039     XE-13[illegible]    1.[illegible]0[illegible]E+18
RDCORINV040     CS-134      5.596E+17
RDCORINV041     CS-136      1.501E+17
RDCORINV042     CS-137      3.350E+17
RDCORINV043     BA-139      6.612E+18
RDCORINV044     BA-140      6.522E+18
RDCORINV045     LA-140      6.655E+18
RDCORINV046     LA-141      6.145E+18
RDCORINV047     LA-142      5.912E+18
RDCORINV048     CE-141      5.922E+18
RDCORINV049     CE-143      5.[illegible]6[illegible]E+18
RDCORINV050     CE-144      3.841E+18
RDCORINV051     PR-143      5.643E+18
RDCORINV052     ND-147      2.522E+18
RDCORINV053     NP-239      [illegible].516E+19
RDCORINV054     PU-238      5.226E+15
RDCORINV055     PU-239      1.325E+15
RDCORINV056     PU-240      1.659E+15
RDCORINV057     PU-241      2.856E+17
RDCORINV058     AM-241      2.903E+14
RDCORINV059     CM-242      [illegible].667E+16
RDCORINV060     CM-244      4.13[illegible]E+15
*
*  SCALING FACTOR TO ADJUST THE CORE INVENTORY
*
*     REACTOR                PWR   BWR   [illegible]   LS    PB    [illegible]   [illegible]   [illegible]
*     TYPE                               B     B     B     [illegible]     [illegible]     [illegible]
*     POWER LEVEL (MWTH) 3412  3578  383[illegible]  32[illegible].  [illegible]   [illegible]   [illegible]   [illegible]
*     SCALING FACTOR     1.0   1.0   1.0[illegible]1 0.92[illegible] 0.[illegible]   [illegible]   [illegible]   [illegible]
*
RDCORSCA001   0.920  *  PEACH BOTTOM
*
* PARTICLE SIZE DISTRIBUTION OF EACH NUCLIDE GROUP
* YOU MUST SPECIFY A COLUMN OF DATA FOR EACH OF THE [illegible]
*
RDPSDIST001       1.
RDPSDIST002       1.
RDPSDIST003       1.
RDPSDIST004       1.
RDPSDIST005       1.
RDPSDIST006       1
RDPSDIST007       1
RDPSDIST008       1.
RDPSDIST009       1.
***************************************************************************
* OUTPUT CONTROL DATA BLOCK [illegible]
*
OCIDEBUG001   0
*
* NAME OF THE NUCLIDE TO BE [illegible] THE [illegible]
*
OCN[illegible]
************************************************************************  * *
```

```
* METEOROLOGICAL SAMPLING DATA BLOCK
*
* METEOROLOGICAL SAMPLING OPTION CODE:
*
* METCOD = 1  USER SPECIFIED DAY AND HOUR IN THE YEAR ([illegible]).
*          2  WEATHER CATEGORY BIN SAMPLING.
*          3  120 HOURS OF WEATHER SPECIFIED ON THE ATM[illegible] USER INPUT FILE
*          4  CONSTANT MET (BOUNDARY WEATHER USED FROM [illegible])
*          5  STRATIFIED RANDOM SAMPLES FOR EACH DAY OF THE YEAR
*
M1METCOD001  2
*
* LAST SPATIAL INTERVAL FOR MEASURED WEATHER
*
M1LIMSPA001  1[illegible]
*
*      BOUNDARY WEATHER, NO RAIN, WIND SPEED = 0.5 M/S, A STABILITY
*      MIXING HEIGHT = 1000 M, APPLIES TO THE LAST SPATIAL INTERVAL
*      ([illegible] - 1000 MILES)
*
* BOUNDARY WEATHER MIXING LAYER HEIGHT
*
M2BNDMXH001  1000.  (METERS)
*
* BOUNDARY WEATHER STABILITY CLASS INDEX
*
M2IBDSTB001  1        (A STABILITY)
*
* BOUNDARY WEATHER RAIN RATE
*
M2BNDRAN001  0.       (0 MM / HOUR = NO RAIN)
*
* BOUNDARY WEATHER WIND SPEED
*
M2BNDWND001  0.5      (M / S)
*
* NUMBER OF SAMPLES PER BIN
*
M4NSMPLS001  4  (THIS NUMBER SHOULD BE SET TO 4 FOR RI - ASSESSMENT
*
* NUMBER OF BINS TO BE SAMPLED (WHEN NSMPLS = 0)
*
*M4NSBINS001  6
*
*           BIN NUMBER     SAMPLE SIZE
*             INDXBN          INWGHT
*M4SMPLDF001  3               8
*M4SMPLDF002  4              16
*M4SMPLDF003  5              12
*M4SMPLDF004  6               4
*M4SMPLDF005  7               4
*M4SMPLDF006  8               4
*
* NUMBER OF RAIN DISTANCE INTERVALS FOR BINNING
*
M4NRNINT001  6
*
* ENDPOINTS OF THE RAIN DISTANCE INTERVALS (KILOMETERS
*
* NOTE: THESE MUST BE CHOSEN TO MATCH THE SPATIAL ENDPOINTS [illegible]
*       SPECIFIED FOR THE ARRAY SPAEND (1) * ERROR IN [illegible]
*
*   [illegible]   1[illegible]   [illegible]
*
M4RNDI[illegible]  [illegible]  4  [illegible]  4  [illegible]
*
```

[redacted]

```
* NUMBER OF RAIN INTENSITIY BREAKPOINTS
*
M4NRININ001    3
*
* RAIN INTENSITY BREAKPOINTS FOR WEATHER BINNING (MILLIMETER PER HOUR)
*
M4RNRATE001    1.   2.   3.
*
* INITIAL SEED FOR RANDOM NUMBER GENERATOR
*
M4IRSEED001    1
.
```

```
************************************************************************
* FILE NAME: [illegible]
*
* GENERAL DESCRIPTIVE TITLE DESCRIBING THIS "EARLY" INPUT FILE
*
MIENAM1001 'EARLY INPUT FOR FINAL NUREG-1150 CALCULATIONS'
*
* FLAG TO INDICATE THAT THIS IS THE LAST PROGRAM IN THE SERIES TO BE RUN
*
MIENDAT2001 .FALSE.      (SET THIS VALUE TO .TRUE. TO SKIP CHRONC)
*
* THE FIRST NUMBER IS MODEL OPTION CODE:  1  =  STRAIGHT LINE
*                                         2  =  WIND SHIFT WITH ROTATION
*                                         3  =  WIND SHIFT WITHOUT ROTATION
*
MIIPLUME001  2
*
* NUMBER OF FINE GRID SUBDIVISIONS USED BY THE MODEL
*
MINUMFIN001          (3, 5 OR 7 ALLOWED)
*
* LEVEL OF DEBUG OUTPUT REQUIRED. NORMAL RUNS SHOULD SPECIFY ZERO
*
MIIPRINT001  0
*
* FLAG INDICATING IF WIND-ROSES FROM ATMOS ARE TO BE OVERRIDDEN
*
MIOVRRID001  .FALSE.  (USE THE WIND ROSE CALCULATED FOR EACH WEATHER BIN)
*
* LOGICAL FLAG SIGNIFYING THAT THE BREAKDOWN OF RISK BY WEATHER CATEGORY
* BIN ARE TO BE PRESENTED TO SHOW THEIR RELATIVE CONTRIBUTIONS TO THE MEAN
*
*              RISBIN
*
MIRISCAT001   .FALSE.
************************************************************************
* POPULATION DISTRIBUTION DATA BLOCK, LOADED BY INPOPU, STORED IN /POPDAT/
*
PDPOPFLG001  FILE
*
*PDPOPFLG001  UNIFORM
*PDIBEGIN001  1   (SPATIAL INTERVAL AT WHICH POPULATION BEGINS)
*PDPOPDEN001  50. (POPULATION DENSITY (PEOPLE PER SQUARE KILOMETER))
************************************************************************
* ORGAN DEFINITION DATA BLOCK, LOADED BY INORGA, STORED IN /EARDIM/ AND /ORGNAM/
*
* NUMBER OF ORGANS DEFINED FOR HEALTH EFFECTS
*
ODNUMORG001    9
*
* NAMES OF THE ORGANS DEFINED FOR HEALTH EFFECTS
*
ODORGNAM001 'SKIN', 'EDEWBODY', 'LUNGS', 'RED MARR', 'LOWER LI', 'STOMACH',
ODORGNAM002 'THYROIDH', 'BONE SUR', 'BREAST'
*ODORGNAM003 'EMBRYO', 'FETAL BONE', 'FETAL OTHR', 'GONADS',
************************************************************************
* SHIELDING AND EXPOSURE FACTORS, LOADED BY INDFAC, STORED IN [illegible]
*
* THREE VALUES OF EACH PROTECTION FACTOR ARE SUPPLIED
* ONE FOR EACH TYPE OF ACTIVTY:
*
* ACTIVITY TYPE:
*      1    EVACUEES WHILE MOVING
*      2    NORMAL ACTIVITY IN SHELTERING AND EVACUATION ZONES
*      3    SHELTERED ACTIVITY
*
```

```
* CLOUD SHIELDING FACTOR
*
*     SITE          GG    PB    SEQ    SUR   ZION
*     SHELTERING          0.5   0.65   0.6   0.5
*
*                 EVACUEES  NORMAL   SHELTER
*
SECSFACT001        1          0.75         0.5      *    PEACH BOTTOM SHELTERING VALUE
*
* PROTECTION FACTOR FOR INHALATION
*
SEPROTIN001        1.         0.41         0.33     *    VALUES FOR NORMAL ACTIVITY
*                                                        AND SHELTERING SELECTED
*                                                        BY S. ACHARYA, NRC.
*
* BREATHING RATE (CUBIC METERS PER SECOND)
*
SEBRRATE001   2.66E-4   2.66E-4   2.66E-4
*
* SKIN PROTECTION FACTOR
*
SESKPFAC001        1.         0.41         0.33     *    VALUES FOR NORMAL ACTIVITY
*                                                        AND SHELTERING SELECTED
*                                                        BY S. ACHARYA, NRC.
*
* GROUND SHIELDING FACTOR
*
*     SITE          GG    PB    SEQ   SUR   ZION
*     SHELTERING   0.25  0.1   0.2   0.2   0.1
*
SEGSHFAC001        0.5        0.33         0.1      *    VALUE FOR NORMAL ACTIVITY
*                                                        SELECTED BY S. ACHARYA, NRC;
*                                                        PEACH BOTTOM SHELTERING VALUE.
*
* RESUSPENSION INHALATION MODEL CONCENTRATION COEFFICIENT (/METER)
*
*   RESCON = 1.E-4 IS APPROPRIATE FOR MECHANICAL RESUSPENSION BY VEHICLES.
*   RESHAF = 2.11 DAYS CAUSES 1.E-4 TO DECAY IN ONE WEEK TO 1.E-5, THE VALUE
*   OF RESCON USED IN THE FIRST TERM OF THE LONG-TERM RESUSPENSION EQUATION
*   USED IN CHRONC.
*
SERESCON001    1.E-4      (RESUSPENSION IS TURNED ON)
*
* RESUSPENSION CONCENTRATION COEFFICIENT HALF-LIFE (SEC)
*
SERESHAF001    1.82E5     (2.11 DAYS)
***************************************************************************************
* EVACUATION ZONE DATA BLOCK, LOADED BY EVNETW, STORED IN /NETWOR/,  EOPTIO.
*
* SPECIFIC DESCRIPTION OF THE EMERGENCY RESPONSE STRATEGY BEING USED
*
EZEANAM001 'EVACUATION TO 10 MILES WITH HOT SPOT AND NORMAL RELOCATION'
*
* THE TYPE OF WEIGHTING TO BE APPLIED TO THE EMERGENCY RESPONSE SCENARIOS
*    YOU MUST SUPPLY A VALUE OF 'TIME' OR 'PEOPLE'
*
EZWTNAME001   'PEOPLE'
*
* WEIGHTING FRACTION APPLICABLE TO THIS SCENARIO
*
EZWTFRAC001      1.0          (100% OF THE PEOPLE WITHIN 10 MILES EVACUATE)
*
* LAST RING IN THE MOVEMENT ZONE
*
EZLASMOV001      15           (EVACUEES ARE DIRECTED AWAY FROM THE PATH OF
*                              THE RELEASE AFTER TRAVELLING 10-20 MILES)
```

```
*
* FIRST SPATIAL INTERVAL IN THE EVACUATION ZONE
*
EZINIEVA001     1             (NO INNER SHELTER ZONE)
*
* OUTER BOUNDS OF THE 3 EVACUATION ZONES (0 MEANS THE [illegible]
*
EZLASEVA001     [illegible]  0  11  (EVACUATION FROM A SINGLE ZONE [illegible]
*
*        SITE              GG    PB    SEQ   SUR
*        EDELAY  (HR)  1.25 1.5   [illegible]   2.0
*        ESPEED  (M/S)  3.7   4.8   1.8   1.8
*
*        EDELAY  = CLDELAY + 0.5 HR
*
*        CLDELAY = DELAY BETWEEN WARNING OF PUBLIC TO BEGIN
*                  EVACUATION AND TIME EVACUATION ACTUALLY BEGINS.
*                  VALUES USED ARE DEVELOPED FROM SITE SPECIFIC
*                  CLEAR TIME STUDIES
*
*        0.5 HR  = MEAN (EXPECTED) TIME FROM OCCURENCE GENERAL EMERGENCY
*                  CONDITIONS TO WARNING OF PUBLIC (SYREN/ BROADCAST)
*
* EVACUATION DELAY TIMES (SECONDS) FOR THE 3 EVACUATION ZONES
*
EZDELAY001      0.   0.   5400.   *  PEACH BOTTOM
*
* RADIAL EVACUATION SPEED (METERS / SECOND)
*
EZESPEED001    4.8   *   PEACH BOTTOM
*
**************************************************************************
* EMERGENCY RESPONSE DEFINITION, LOADED BY INPEMR, STORED IN [illegible]  PHASE
*
* TIME TO TAKE SHELTER IN THE INNER SHELTER ZONE (SECONDS FROM ALARM)
*
SRTTOSH1001      0.   (THIS ZONE IS NULL BECAUSE INIEVA
*
* SHELTER TIME IN THE INNER SHELTER ZONE (SECONDS)
*
SRSHELT1001      0.   (THIS ZONE IS NULL BECAUSE INIEVA-1)
*
* LAST RING OF THE OUTER SHELTER ZONE
*
SRLASHE2001      0    (THIS ZONE IS NULL)
*
* TIME TO TAKE SHELTER IN THE OUTER SHELTER ZONE (SECONDS FROM ALARM)
*
SRTTOSH2001      0.   (THIS ZONE IS NULL)
*
* SHELTER TIME IN THE OUTER SHELTER ZONE (SECONDS)
*
SRSHELT2001      0.   (THIS ZONE IS NULL)
*
* DURATION OF THE EMERGENCY PHASE (SECONDS FROM PLUME ARRIVAL)
*
SRENDEMP001   604800.   (ONE WEEK)
*
* CRITICAL ORGAN FOR RELOCATION DECISIONS
*
SRCRIORG001 'EDEWBODY'
*
* HOT SPOT RELOCATION TIME (SECONDS FROM PLUME ARRIVAL)
*
SRTIMHOT001   43200.        (ONE HALF DAY)
*
```

```
* NORMAL RELOCATION TIME [illegible] FROM [illegible] ARRIVAL
*
CRTIMNRM001  86400.           ONE DAY.
*
* HOT SPOT RELOCATION DOSE CRITERION THRESHOLD (SIEVERT)
*
SRDOSHOT001  [illegible]     (PROJECTED WHOLE BODY DOSE OF [illegible] IN [illegible] WEEK TRIGGERS
*                             RELOCATION AT ONE HALF DAY)
*
* NORMAL RELOCATION DOSE CRITERION THRESHOLD (SIEVERT)
*
SRDOSNRM      [illegible]    (PROTECTED WHOLE BODY DOSE OF [illegible] IN [illegible] WEEK TRIGGERS
*                             RELOCATION AT ONE DAY)
*****************************************************************************
* EARLY FATALITY MODEL PARAMETERS, LOADED BY INEFAT, STORED IN  EFATAL
*
* NUMBER OF EARLY FATALITY EFFECTS
*
EFNUMEFA001    3
*                                                          [illegible]
*                ORGNAM      EFFACA    EFFACB    EFFTHE    1  [illegible] 14 [illegible]
*
EFATAGRP001 'RED MARROW'      4.         6.      1.5      4      8 10
EFATAGRP002 'LUNGS'          10.0        [illegible]   [illegible]   2    16     [illegible]
EFATAGRP003 'LOWER LI'       15.        10.      [illegible]   1[illegible]
*
* NOTE: LUNG PARAMETERS TAKEN FROM LETTER FROM B. SCOTT TO J. WALL DATED
*         [illegible] 87, SHAPE FACTOR OF [illegible] IS APPROPRIATE FOR EXTERNAL AND INTERNAL
*         DOSE DELIVERED AT THE SAME TIME.
*****************************************************************************
* EARLY INJURY MODEL PARAMETERS, LOADED BY INEINJ, STORED IN  EINJUR
*
* NUMBER OF EARLY INJURY EFFECTS
*
EINUMEIN001   7
*                                                                  Dose vs t
*              EINAME             ORGNAM    EISUSC EITHRE EIFACA EIFACB  1   [illegible]  10 21
*
EINJUGRP001 'PRODROMAL VOMIT'   'STOMACH'   1.      .5      [illegible]      3.     2  5
EINJUGRP002 'DIARRHEA'          'STOMACH'   1.      1.      3.      [illegible]    3  6
EINJUGRP003 'PNEUMONITIS'       'LUNGS'     1.      5.      [illegible]      [illegible]     - DEATH
EINJUGRP004 'SKIN ERYTHEMA'     'SKIN'      1.      3.      [illegible]      [illegible]     6    20
EINJUGRP005 'TRANSEPIDERMAL'    'SKIN'      1.     10.      [illegible]      5.    [illegible]   80
EINJUGRP006 'THYROIDITIS'       'THYROIDH'  1.     40.    24.      2.               240
EINJUGRP007 'HYPOTHYROIDISM'    'THYROIDH'  1.      2.      [illegible]      1.3               60
*EINJUGRP008 'FETAL DEATH'       'EMBRYO'   0.012  0.1     [illegible]      [illegible]   TO 270d
*EINJUGRP009 'MENTAL RETARD'     'EMBRYO'   0.0048 0.      [illegible]      1.    TO 175d
*EINJUGRP010 'MICROCEPHALY'      'EMBRYO'   0.0053 0.0     [illegible]      [illegible].4   TO 119d
*
*  NOTE: THYROIDH ACUTE DOSE CONVERSION FACTORS ARE USED TO CALCULATE
*         THYROID INJURIES.  WHEN THESE DOSE FACTORS WERE CALCULATED,
*         INHALATION DOSE FACTORS FOR IODINE ISOTOPES WERE REDUCED BY A
*         FACTOR OF FIVE TO ACCOUNT FOR THE REDUCED EFFECTIVENESS OF DOSE FROM
*         IODINE ISOTOPES.  0.0048 = 0.012 X 0.4; 0.0053 = 0.012 X ([illegible]X[illegible])/270.
*****************************************************************************
* ACUTE EXPOSURE CANCER PARAMETERS, LOADED BY INACAN, STORED IN  ACANCR
*
* NUMBER OF ACUTE EXPOSURE CANCER EFFECTS
*
ACNUMACA001  [illegible]
*
* DOSE THRESHOLD FOR LINEAR DOSE RESPONSE (SV)
*
ACTHRE001  [illegible]
*
*              ACNAME                 ORGNAM   ACSUSC  DOSEFA  DOSEFB  CFRISK  CIRISK
```

```
*
LCANCERS001 'LEUKEMIA'          'RED MARR'     1.     .39     .61  [illegible]E [illegible]  [illegible]E [illegible]
LCANCERS002 'BONE'              'BONE SUR'     1.     .39     .61  1.5E 4   1.5E 4
LCANCERS003 'BREAST'            'BREAST'       1.     1.      0.   6.0E [illegible]   1.[illegible]E 2
LCANCERS004 'LUNG'              'LUNGS'        1.     .39     .61  5.1E 3   5.7E 3
LCANCERS005 'THYROID'           'THYROIDH'     1.     1.      0.   [illegible].2E 4   [illegible].2E [illegible]
LCANCERS006 'GI'                'LOWER LI'     1.     .39     .61  1.5E 2   2.5E 2
LCANCERS007 'OTHER'             'LOWER LI'     1.     .39     .61  [illegible].5E 3   1.3E [illegible]
*LCANCERS008 'SKIN'              'SKIN'         1.     1.      0.   0.0      6.[illegible]E [illegible]
*LCANCERS009 'LEUK UTERO'        'FETAL BONE'   0.012 0.4     0.[illegible]  [illegible].0E 2   3.0E 2
*LCANCERS010 'OTHR UTERO'        'FETAL OTHR'   0.012 0.4     [illegible]  3.0E 2   [illegible].0E 2
*LCANCERS011 'DOMINANT'          'GONADS        1.     0.5     0.5  0.0      1.4E [illegible]
*LCANCERS012 'X LINKED'          'GONADS'       1.     0.[illegible]     [illegible]  [illegible]      4.4E [illegible]
*LCANCERS013 'ANEUPLOIDY'        'GONADS'       1.     1.      0.   0.0      [illegible]E 4
*LCANCERS014 'TRANSLOCAT'        'GONADS'       1.     0.      [illegible]  [illegible]      [illegible].9E 3
*LCANCERS015 'M-FACT'            'GONADS'       1.     0.[illegible]     0.5  0.0      1.4E 2
*LCANCERS016 'PREG LOSS'         'GONADS'       1.     0. 4    0.26 0.0      [illegible].5E 2
*
*  NOTE: THYROIDH LIFETIME DOSE CONVERSION FACTORS ARE USED TO CALCULATE
*        THYROID CANCERS.  WHEN THESE DOSE FACTORS WERE CALCULATED, INHALATION
*        AND INGESTION DOSE FACTORS FOR IODINE ISOTOPES WERE REDUCED BY A
*        FACTOR OF THREE TO ACCOUNT FOR THE REDUCED EFFECTIVENESS OF DOSE FROM
*        IODINE ISOTOPES.  0.74 = (17 + 9)/(17 + 9 + 9) AND 0.26 = 1.0 - 0.74.
*        GONADS DOSE FACTOR = (TESTES DOSE FACTOR + OVARIES DOSE FACTOR) 2.
*        SKIN CANCER IS ASSUMED TO BE LINEAR (SEE NUREG CR 4214 PAGE II-1[illegible]2).
*        GENETIC EFFECTS ARE INTEGRATED OVER ALL FUTURE GENERATIONS (SEE
*        HARVARD REPORT FOR FRACTIONS IN EACH GENERATION).
**************************************************************************
* RESULT 1 OPTIONS BLOCK, LOADED BY INOUT1, STORED IN [illegible]
* TOTAL NUMBER OF A GIVEN EFFECT (LATENT CANCER, EARLY DEATH, EARLY INJURY)
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE1NUMBER     3[illegible]
*
TYPE1OUT001     'ERL FAT TOTAL'                     1  26   ([illegible] TO [illegible] MILES)
TYPE1OUT002     'ERL INJ/PRODROMAL VOMIT'           1  26
TYPE1OUT003     'ERL INJ/DIARRHEA'                  1  26
TYPE1OUT004     'ERL INJ/PNEUMONITIS'               1  26
TYPE1OUT005     'ERL INJ/THYROIDITIS'               1  26
TYPE1OUT006     'ERL INJ/HYPOTHYROIDISM'            1  26
TYPE1OUT007     'ERL INJ/SKIN ERYTHEMA'             1  26
TYPE1OUT008     'ERL INJ/TRANSEPIDERMAL'            1  26
TYPE1OUT009     'CAN FAT/TOTAL'                     1  26
TYPE1OUT010     'CAN FAT/LUNG'                      1  26
TYPE1OUT011     'CAN FAT/THYROID'                   1  26
TYPE1OUT012     'CAN FAT/BREAST'                    1  26
TYPE1OUT013     'CAN FAT/GI'                        1  26
TYPE1OUT014     'CAN FAT/LEUKEMIA'                  1  26
TYPE1OUT015     'CAN FAT/BONE'                      1  26
TYPE1OUT016     'CAN FAT/OTHER'                     1  26
TYPE1OUT017     'CAN INJ/TOTAL'                     1  26
TYPE1OUT018     'ERL FAT/TOTAL'                     1  19   ([illegible] TO [illegible] MILES)
TYPE1OUT019     'ERL INJ/PRODROMAL VOMIT'           1  19
TYPE1OUT020     'ERL INJ/DIARRHEA'                  1  19
TYPE1OUT021     'ERL INJ/PNEUMONITIS'               1  19
TYPE1OUT022     'ERL INJ/THYROIDITIS'               1  19
TYPE1OUT023     'ERL INJ/HYPOTHYROIDISM'            1  19
TYPE1OUT024     'ERL INJ/SKIN ERYTHEMA'             1  19
TYPE1OUT025     'ERL INJ/TRANSEPIDERMAL'            1  19
TYPE1OUT026     'CAN FAT/TOTAL'                     1  19
TYPE1OUT027     'ERL FAT/TOTAL'                     1  1[illegible]   ([illegible] TO [illegible] MILES)
TYPE1OUT028     'ERL INJ/PRODROMAL VOMIT'           1  1[illegible]
TYPE1OUT029     'ERL INJ/DIARRHEA'                  1  1[illegible]
TYPE1OUT030     'ERL INJ/PNEUMONITIS'               1  1[illegible]
TYPE1OUT031     'ERL INJ/THYROIDITIS'               1  1[illegible]
```

```
TYPE1OUT002     'ERL INJ/HYPOTHYROIDISM'        1  12
TYPE1OUT003     'ERL INJ/SKIN ERYTHEMA'         1  12
TYPE1OUT004     'ERL INJ/TRANSEPIDERMAL'        1  12
TYPE1OUT005     'CAN FAT/TOTAL'                 1  12
*************************************************************************
* RESULT 2 OPTIONS BLOCK, LOADED BY INOUT2, STORED IN  /INOUT2/.
* FURTHEST DISTANCE AT WHICH A GIVEN RISK OF EARLY DEATH IS EXCEEDED.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE2NUMBER   1
*
*              FATALITY RISK THRESHOLD
*
TYPE2OUT01   0.
**************************************************************************
* RESULT 3 OPTIONS BLOCK, LOADED BY INOUT3, STORED IN  /INOUT3/
* NUMBER OF PEOPLE WHOSE ACUTE DOSE TO A GIVEN ORGAN EXCEEDS A GIVEN THRESHOLD.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE3NUMBER   2
*
*                 ORGAN NAME   DOSE THRESHOLD (SV)
*
TYPE3OUT001     'RED MARR'          1.5
TYPE3OUT002     'LUNGS'             5.0
**************************************************************************
* RESULT 4 OPTIONS BLOCK, LOADED BY INOUT4, STORED IN  /INOUT4
* 360 DEGREE AVERAGE RISK OF A GIVEN EFFECT AT A GIVEN DISTANCE.
*
* POSSIBLE TYPES OF EFFECTS ARE:
*
*    'ERL FAT/TOTAL'
*    'ERL INJ/INJURY NAME'
*    'CAN FAT/CANCER NAME'
*    'CAN FAT/TOTAL'
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE4NUMBER   5
*
*              RADIAL INDEX   TYPE OF EFFECT
*
TYPE4OUT001         1           'ERL FAT/TOTAL'
TYPE4OUT002         2           'ERL FAT/TOTAL'
TYPE4OUT003         3           'ERL FAT/TOTAL'
TYPE4OUT004         4           'ERL FAT/TOTAL'
TYPE4OUT005         5           'ERL FAT/TOTAL'
**************************************************************************
* RESULT 5 OPTIONS BLOCK, LOADED BY INOUT5, STORED IN  /INOUT5/
*
* TOTAL POPULATION DOSE TO A GIVEN ORGAN BETWEEN TWO DISTANCES.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE5NUMBER        3
*
*                ORGAN            I1DIS5           I2DIS5
*
TYPE5OUT001 'EDEWBODY'              1                12      (0-10 MILES)
TYPE5OUT002 'EDEWBODY'              1                19      (0-50 MILES)
TYPE5OUT003 'EDEWBODY'              1                26      (0-1000 MILES)
**************************************************************************
* RESULT 6 OPTIONS BLOCK, LOADED BY INOUT6, STORED IN  /INOUT6/
*
```

```
* CENTERLINE DOSE TO AN ORGAN VS DIST BY PATHWAY, PATHWAY NAME [illegible]
*
* PATHWAY NAMES
*       'CLD'          CLOUDSHINE
*       'GRD'          GROUNDSHINE
*       'INH ACU'      "ACUTE DOSE EQUIVALENT" FROM DIRECT INHALATION OF THE CLOUD
*       'INH LIF'      "LIFETIME DOSE COMMITMENT" FROM DIRECT INHALATION OF THE CLOUD
*       'RES ACU'      "ACUTE DOSE EQUIVALENT" FROM RESUSPENSION INHALATION
*       'RES LIF'      "LIFETIME DOSE COMMITMENT" FROM RESUSPENSION INHALATION
*       'TOT ACU'      "ACUTE DOSE EQUIVALENT" FROM ALL PATHWAYS
*       'TOT LIF'      "LIFETIME DOSE COMMITMENT" FROM ALL PATHWAYS
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE6NUMBER       0
*
*               ORGNAM          PATHNM          I1DIS6    I2DIS6
*
*TYPE6OUT001  'RED MARR'     'TOT ACU'          1         19      (0-50 MILES)
*TYPE6OUT002  'LUNGS'        'TOT ACU'          1         19      (0-50 MILES)
*TYPE6OUT003  'EDEWBODY'     'TOT LIF'          1         26      (0-1000 MILES)
**********************************************************************************
* RESULT 7 OPTIONS BLOCK, LOADED BY INOUT7, STORED IN /INOUT7/
*
* CENTERLINE RISK OF A GIVEN EFFECT VS DISTANCE
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE7NUMBER    0
*
*                     NAME             I1DIS7         I2DIS7
*
*TYPE7OUT001      'ERL FAT/TOTAL'         1              13         (0-[illegible] MILES)
*TYPE7OUT002      'CAN FAT/TOTAL'         1              26         (0-1000 MILES)
**********************************************************************************
* RESULT 8 OPTIONS BLOCK, LOADED BY INOUT8, STORED IN /INOUT8/
*
* POPULATION WEIGHTED FATALITY RISK BETWEEN 2 DISTANCES
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE8NUMBER    2
*
*                     NAME             I1DIS8         I2DIS8
*
TYPE8OUT001      'ERL FAT/TOTAL'         1               5         (0-EXCL ZONE + 1 MI)
TYPE8OUT002      'CAN FAT/TOTAL'         1              12         (0-10 MILES)
.
```

```
**********************************************************************
* FILE NAME: [illegible]
*
* GENERAL DESCRIPTIVE TITLE DESCRIBING THIS "CHRONC" INPUT FILE
*
CHCHNAM001 'CHRONC INPUT FOR FINAL NUREG 1150 CALCULATION'
**********************************************************************
* EMERGENCY RESPONSE COST DATA BLOCK
*
* EVACUATION COST (DOLLARS/PERSON-DAY)
*
CHEVACST001  [illegible]
*
* RELOCATION COST (DOLLARS/PERSON-DAY)
*
CHRELCST001  [illegible]
****** ***************************************************************
* LONG TERM PROTECTIVE ACTION DATA BLOCK
*
* END OF THE INTERMEDIATE PHASE PERIOD (SECONDS FROM ACCIDENT INITIATION)
*
CHTMIPND001  604800.              (7 DAYS, NO INTERMEDIATE PHASE)
*
* ACTION PERIOD (PROJECTION PERIOD) FROM THE START OF THE LONG TERM PHASE TO
* THE POINT AT WHICH THE LONG TERM DOSE CRITERION IS EVALUATED (SECONDS)
*
CHTMPACT001   1.58E8              (5 YEARS)
*
* DOSE CRITERION FOR INTERMEDIATE PHASE RELOCATION (SV)
*
CHDSCRTI001   1.0E5               (NO INTERMEDIATE PHASE RELOCATION)
*
* DOSE CRITERION FOR LONG TERM PHASE RELOCATION (SV)
*
CHDSCRLT001   0.04   (2 REM IN FIRST YEAR, 0.5 REM PER YEAR FOR YRS 2 - 5)
*
* CRITICAL ORGAN NAME FOR LONG-TERM ACTIONS
*
CHCRTOCR001 'EDEWBODY'
*
**********************************************************************
* DECONTAMINATION PLAN DATA BLOCK
*
* NUMBER OF LEVELS OF DECONTAMINATION
*
CHLVLDEC001  2
*
* DECONTAMINATION TIMES (SECONDS) CORRESPONDING TO THE LVLDEC LEVELS
* OF DECONTAMINATION
*
CHTIMDEC001   5.184E6  1.0368E7     (60, 120 DAYS)
*
* DOSE REDUCTION FACTORS CORRESPONDING TO THE LVLDEC LEVELS OF DECONTAMINATION
*
CHDSRFCT001   3.       15.
*
* COST OF FARM DECONTAMINATION PER UNIT AREA (DOLLARS/HECTARE)
* FOR THE VARIOUS LEVELS OF DECONTAMINATION
*
CHCDFRM0001   562.5   1250
*
* COST OF NONFARM DECONTAMINATION PER PERSON (DOLLARS/PERSON)
* FOR THE VARIOUS LEVELS OF DECONTAMINATION
*
CHCDNFRM001  [illegible]
```

```
*
* FRACTION OF FARMLAND DECONTAMINATION COST DUE TO LABOR
* FOR THE VARIOUS DECONTAMINATION LEVELS
*
CHFRFLC001  0.3          0.35
*
* FRACTION OF NON FARM DECONTAMINATION COST DUE TO LABOR
* FOR THE VARIOUS DECONTAMINATION LEVELS
*
CHFRNFL001  0.7          0.5
*
* FRACTION OF TIME WORKERS IN FARM AREAS SPEND IN DECONTAMINATION WORK
* FOR THE VARIOUS DECONTAMINATION LEVELS
*
CHTFWKF001  0.10         0.33
*
* FRACTION OF TIME WORKERS IN NON FARM AREAS SPEND IN DECONTAMINATION WORK
* FOR THE VARIOUS DECONTAMINATION LEVELS
*
CHTFWKNF001  0.33        0.33
*
* AVERAGE COST OF DECONTAMINATION LABOR (DOLLARS/MAN YEAR)
*
CHDLBCST001    35000
*****************************************************************************
* INTERDICTION COST DATA BLOCK
*
* DEPRECIATION RATE DURING INTERDICTION PERIOD (PER YEAR)
*
CHDPRATE001     0.20
*
* SOCIETAL DISCOUNT RATE DURING INTERDICTION PERIOD (PER YEAR)
*
CHDSRATE001     0.1
*
* URBAN POPULATION REMOVAL COST (DOLLARS/PERSON)
*
CHPOPCST001   5000
*****************************************************************************
* GROUNDSHINE WEATHERING DEFINITION DATA BLOCK
*
* NUMBER OF TERMS IN THE GROUNDSHINE WEATHERING RELATIONSHIP (EITHER 1 OR 2)
*
CHNGWTRM001   2
*
* GROUNDSHINE WEATHERING COEFFICIENTS
*
CHGWCOEF001   0.5    0.5               (GAYLE'S EQUATION)
*
* HALF LIVES CORRESPONDING TO THE GROUNDSHINE WEATHERING COEFFICIENTS (S)
*
CHTGWHLF001   1.6E7  2.8E9             (GAYLE'S EQUATION)
*****************************************************************************
* RESUSPENSION WEATHERING DEFINITION DATA BLOCK
*
* NUMBER OF TERMS IN THE RESUSPENSION WEATHERING RELATIONSHIP
*
CHNRWTRM001     3
*
* RESUSPENSION CONCENTRATION COEFFICIENTS (/ METER)
* RELATIONSHIP BETWEEN GROUND CONCENTRATION AND INSTANTANEOUS AIR CONC.
*
CHRWCOEF001  1.0E-5   1.0E-7   1.0E-9
*
* HALF LIVES CORRESPONDING TO THE RESUSPENSION CONCENTRATION COEFFICIENTS (S)
*
```

```
[illegible]                                    (6 MONTHS, [illegible]
***********************************************************************
* [illegible] REGION DEFINITION DATA BLOCK
*
* FRACTION OF AREA THAT IS LAND IN THE REGION
*
CHFRACLD001   1.0E+00     (VALUE NOT USED SINCE SITE FILE IS USED)
*
* FRACTION OF LAND DEVOTED TO FARMING IN THE REGION
*
CHFRCFRM001   1.0E+00     (VALUE NOT USED SINCE SITE FILE IS USED)
*
* AVERAGE VALUE OF ANNUAL FARM PRODUCTION IN THE REGION (DOLLARS/HECTARE
*   (CASH RECEIPTS FROM FARMING PLUS VALUE OF HOME CONSUMPTION)/LAND IN FARMS
*
CHFRMPRD001   0.          (VALUE NOT USED SINCE SITE FILE IS USED)
*
* FRACTION OF FARM PRODUCTION RESULTING FROM DAIRY PRODUCTION IN THE REGION
*   (VALUE OF MILK PRODUCED)/(CASH RECEIPTS FROM FARMING PLUS VALUE OF HOME [illegible]
*
CHFFFRCT001   0.          (VALUE NOT USED SINCE SITE FILE IS USED)
*
* VALUE OF FARM WEALTH (DOLLARS/HECTARE):  AVERAGE VALUE OF FARM LAND
* AND BUILDINGS PER HECTARE TO 100 MILES
*
*  SITE                 GG    LS    PB    SEQ   SUR   ZION
*  VALWF ($/HECTARE)   2561  3305  3421  1855  [illegible]  [illegible]
*
CHVALWF0001   3421.  *  PEACH BOTTOM
*
* FRACTION OF FARM WEALTH IN IMPROVEMENTS FOR THE REGION
*
*  SITE    GG    LS    PB    SEQ    SUR   ZION
*  FRFIM  0.3   0.19  0.25  0.2[illegible]  0.25  0.49
*
CHFRFIM0001   0.25  *  PEACH BOTTOM
*
* NON FARM WEALTH, PROPERTY AND IMPROVEMENTS FOR THE REGION (DOLLARS/PERSON,
* THE VALUE OF ALL RESIDENTIAL, BUSINESS, AND PUBLIC ASSETS WHICH WOULD BE
* LOST IN THE EVENT OF PERMANENT INTERDICTION OF THE AREA
*
*  SITE            GG   PB   SUR  SEQ  ZION
*  VALWNF ($K)     53   78   84   66   76
*
CHVALWNF001   78000.  *  PEACH BOTTOM
*
* FRACTION OF NON FARM WEALTH IN IMPROVEMENTS FOR THE REGION
*
CHFRNFIM001   0.8
***********************************************************************
* SPECIAL OPTIONS DATA BLOCK
*
* DETAILED PRINT OPTION CONTROL SWITCHES, LOOK AT THE CODE BEFORE TURNING ON
*          (KCEPNT, KDFPNT, KDTPNT, KGCPNT, KLTPNT, KWTPNT, KSWRSK, KSWESC)
*
CHKSWTCH001   0 0 0 0 0 0 0 0 0 0 0 0
***********************************************************************
* WATER PATHWAY NUCLIDE DEFINITIONS FOR CHRONC
*
* NUMBER OF NUCLIDES IN THE WATER INGESTION PATHWAY MODEL
*
CHNUMWFI001     4
*
* TABLE OF NUCLIDE DEFINITIONS IN THE WATER INGESTION PATHWAY MODEL
* WATER PATHWAY NUCLIDES MUST BE A SUBSET OF THE [illegible] MODEL.
*
```

```
* IF A SITE DATA FILE IS DEFINED, THE DATA DEFINING THE WATER INGESTION
* FACTOR IS SUPERSEDED BY THE CORRESPONDING DATA IN THE SITE DATA FILE
*
       WINGF VALUES BY DRAINAGE SYSTEM
*  NUCLIDE      SR 89    SR 90    CS 134   CS 137
*  RIVER        5.0E [illegible]  [illegible]  [illegible]  [illegible]
*  GREAT LAKE   2.0E [illegible]  2.0E [illegible]  2.0E-6   4.0E 6
*  OCEAN        0.0      0.0      0.0      0.0
*
*  ALL NUREG 1150 SITES HAVE RIVER DRAINAGE SYSTEMS EXCEPT [illegible]
*
*                       INITIAL      ANNUAL     INGESTION FACTOR
*            WATER      WASHOFF      WASHOFF     (BQ INGESTED
*           NUCLIDE     FRACTION      RATE        (BQ IN WATER
*
*           NAMWFI      WSHFRI       WSHRTA          WINGF
CHWTRISO001  SR-89       0.01         0.004        [illegible]
CHWTRISO002  SR-90       0.01         0.004        [illegible]
CHWTRISO003  CS-134      0.005        0.001        [illegible]
CHWTRISO004  CS-137      0.005        0.001        [illegible]
******************************************************************
* CROP PATHWAY DEFINITIONS FOR CHRONC
*
* MODIFIED 14 OCT 88, BY JLS. VALUES CHANGED TO THOSE DEVELOPED BY [illegible]
*
* NUMBER OF DEFINED CROPS IN THE CHRONC FOOD INGESTION MODEL
*
CHNFICRP001    7     (UP TO 10 ALLOWED)
*
* NOTE TO USER: THE CODE MAKES SPECIAL TREATMENT OF CROP NAMES BEGINNING WITH
* 'PASTURE' DUE TO THE CONTINUOUS NATURE OF THE HARVESTING PROCESS
*
* IF THE USER WISHES TO DEFINE A NEW CROP CATEGORY FOR RANGELAND PASTURE
* IT SHOULD BE CALLED 'PASTURE-RANGE' OR 'PASTURE-DR[illegible]
*
* TABLE OF CROP DEFINITIONS FOR THE CHRONC FOOD INGESTION MODEL
*
*                                  FRACTION OF CROP CONSUMED BY
*
*                                            DAIRY    MEAT
*              CROP NAME               MAN  ANIMALS  ANIMALS
*
*              NAMCRP                FRCTCH  FRCTCM  FR[illegible]
CHCRPTBL001 'PASTURE               ' 0.0     0.1     0.[illegible]
CHCRPTBL002 'STORED FORAGE         ' 0.0     0.13    0.[illegible]
CHCRPTBL003 'GRAINS                ' 0.35    0.040   0.[illegible]
CHCRPTBL004 'GRN LEAFY VEGETABLES' 1.0     0.0     0.[illegible]
CHCRPTBL005 'OTHER FOOD CROPS      ' 1.0     0.0     0.[illegible]
CHCRPTBL006 'LEGUMES AND SEEDS     ' 0.24    0.046   0.[illegible]4
CHCRPTBL007 'ROOTS AND TUBERS      ' 1.0     0.0     0.[illegible]
******************************************************************
* CHRONC INGESTION PATHWAY NUCLIDE DEFINITIONS
*
* NUMBER OF NUCLIDES IN THE CHRONC FOOD INGESTION MODEL
*
CHNFIISO001  6  (UP TO 10 ALLOWED, BEWARE THAT DAUGHTER BUILD [illegible] TREATED.)
*
* TABLE OF NUCLIDE DEFINITIONS IN THE CHRONC INGESTION PATHWAY MODEL.
*
* NUCLIDES THAT WERE DEFINED IN THE WATER PATHWAY DATA ARE [illegible] BE
* A SUBSET OF THE CHRONC INGESTION FOOD PATHWAY NUCLIDES. THE WATER
* PATHWAY NUCLIDES MUST BE LISTED FIRST IN THIS DATA BLOCK AND IN THE
* SAME ORDER AS THEY WERE LISTED IN THE WATER PATHWAY DATA B. *
*
*                                              TRANSFER FACTOR
*                        RETENTION FACTORS     (BQ TRANSFER
```

```
*              INGESTION   PROCESSING AND DECAY       (BQ INGESTED
*              NUCLIDE     MILK/MAN  MEAT/MAN          MILK      MEAT
*
*               NAMIPI       DCYPMH     DCYPBH          TFMLK     TFBF
CHISODEF001   SR 89         0.66       0.[illegible]   0.022     [illegible]
CHISODEF002   SR 90         1.0        1.0             0.022     [illegible]
CHISODEF003   CS 134        1.0        1.0             0.11      [illegible]
CHISODEF004   CS 137        1.0        1.0             0.11      [illegible]
CHISODEF005   I 131         0.28       0.18            0.13      [illegible]
CHISODEF006   I 133         0.062      0.0             0.062     [illegible]
*************************************************************************
* TRANSFER FACTOR FROM SOIL TO PLANT BY ROOT-UPTAKE (AND BY SOIL INGESTION FOR
* GRAZING ON PASTURE) INTEGRATED OVER ALL TIME [(BQ TRANSFERRED) (BQ DEPOSITED)]
*
*                                                  GREEN   OTHER   LEGUMES  ROOTS
*                                  STORED          LEAFY   FOOD    AND      AND
*              NUCLIDE  PASTURE   FORAGE  GRAINS  VEG     CROPS   SEEDS    TUBERS
*
*              NAMISO   TCROOT    TCROOT  TCROOT  TCROOT  TCROOT  TCROOT   TCROOT
CHTCROOT001   SR 89    4.1E-4    1.3E-3  4.3E-5  1.7E-4  [illegible]  [illegible]E-4  1.1E-4
CHTCROOT002   SR-90    2.6E-2    9.0E-2  3.3E-3  1.3E-2  [illegible]  [illegible]E-2  8.4E-3
CHTCROOT003   CS-134   1.3E-3    7.1E-4  3.5E-5  1.4E-5  [illegible]  9.[illegible]E-5  [illegible]
CHTCROOT004   CS-137   6.9E-3    1.5E-3  7.6E-5  3.0E-5  [illegible]  [illegible]E-4  1.2E-4
CHTCROOT005   I-131    1.6E-4      0.0     0.0     0.0   [illegible]  [illegible]  [illegible]
CHTCROOT006   I-133    1.7E-6      0.0     0.0     0.0   [illegible]  [illegible]  [illegible]
*************************************************************************
*  RADIOACTIVE DECAY RETENTION FACTORS (I.E., 1 - F WHERE F = FRACTION OF
*  RADIOACTIVITY LOST BY DECAY) FOR NUCLIDES IN CROPS FROM TIME OF HARVEST
*  TO TIME OF CONSUMPTION BY HUMANS (FRACTION RETAINED).
*
*                                                  GREEN   OTHER   LEGUMES  ROOTS
*                                  STORED          LEAFY   FOOD    AND      AND
*              NUCLIDE  PASTURE   FORAGE  GRAINS  VEG     CROPS   SEEDS    TUBERS
*
*              NAMISO   DCYPCH    DCYPCH  DCYPCH  DCYPCH  DCYPCH  DCYPCH   DCYPCH
CHDCYPCH001   SR-89       0.0      0.0    0.18    0.67   [illegible]  0.18   0.18
CHDCYPCH002   SR-90       0.0      0.0    0.99    1.0    [illegible]  [illegible]  [illegible]
CHDCYPCH003   CS-134      0.0      0.0    0.84    0.96   [illegible]  0.84   0.84
CHDCYPCH004   CS-137      0.0      0.0    0.99    1.0    [illegible]  [illegible]  0.99
CHDCYPCH005   I-131       0.0      0.0    0.0099  0.21   [illegible]  [illegible]  [illegible]
CHDCYPCH006   I-133       0.0      0.0    0.0     0.0    [illegible]  [illegible]  [illegible]
*************************************************************************
*  CROP PROCESSING AND PREPARATION RETENTION FACTORS FOR NUCLIDES IN FOOD
*  CROPS CONSUMED BY HUMANS (FRACTION RETAINED).  FACTORS REFLECT LOSS OF
*  NUCLIDES FROM FOODS DUE TO PROCESSING (E.G., WASHING OF FRUIT, PEELING
*  OF POTATOES, LOSSES DURING CANNING) AND FOOD PREPARATION (COOKING) FROM
*  THE TIME OF PROCESSING OF THE HARVESTED CROP TO THE TIME OF CONSUMPTION
*  BY HUMANS.  FACTORS DO NOT REFLECT LOSSES DUE TO RADIOACTIVE DECAY.
*
*                                                  GREEN   OTHER   LEGUMES  ROOTS
*                                  STORED          LEAFY   FOOD    AND      AND
*              NUCLIDE  PASTURE   FORAGE  GRAINS  VEG     CROPS   SEEDS    TUBERS
*
*              NAMISO   FPLSCH    FPLSCH  FPLSCH  FPLSCH  FPLSCH  FPLSCH   FPLSCH
CHFPLSCH001   SR-89       0.0      0.0    0.25    0.5    [illegible]  [illegible]  0.8
CHFPLSCH002   SR-90       0.0      0.0    0.25    0.5    [illegible]  [illegible]  0.8
CHFPLSCH003   CS-134      0.0      0.0    0.25    0.5    [illegible]  [illegible]  [illegible]
CHFPLSCH004   CS-137      0.0      0.0    0.25    [illegible]  [illegible]  [illegible]  [illegible]
CHFPLSCH005   I-131       0.0      0.0    0.33    [illegible]  [illegible]  [illegible]  [illegible]
CHFPLSCH006   I-133       0.0      0.0    0.33    [illegible]  [illegible]  [illegible]  [illegible]
*************************************************************************
*  RETENTION FACTORS FOR NUCLIDES IN CROPS FROM TIME OF HARVEST TO TIME OF
*  CONSUMPTION BY MILK PRODUCING ANIMALS (FRACTION RETAINED).  FACTOR REFLECTS
*  LOSSES DUE TO RADIOACTIVE DECAY.
*
*                                                  GREEN   OTHER   LEGUMES  ROOTS
```

```
*                                STORED             LEAFY    FOOD     AND       AND
*             NUCLIDE  PASTURE   FORAGE   GRAINS    VEG      CROPS    SEEDS     TUBERS
*
*              NAMISO   DCYPCM   DCYPCM   DCYPCM    DCYPCM   DCYPCM   DCYPCM    DCYPCM
CHDCYPCM001   SR-89       1.0     0.37     0.20       0.0      0.0     0.20       0.0
CHDCYPCM002   SR-90       1.0     0.99     0.99       0.0      0.0     0.99       0.0
CHDCYPCM003   CS-134      1.0     0.92     0.85       0.0      0.0     0.85       0.0
CHDCYPCM004   CS-137      1.0     0.99     0.99       0.0      0.0     0.99       0.0
CHDCYPCM005   I-131       1.0     0.063    0.032      0.0      0.0     0.032      0.0
CHDCYPCM006   I-133       1.0     0.0068   0.0034     0.0      0.0     0.0034     0.0
*************************************************************************************
*   RETENTION FACTORS FOR NUCLIDES IN CROPS FROM TIME OF HARVEST TO TIME OF
*   CONSUMPTION BY MEAT-PRODUCING ANIMALS (FRACTION RETAINED).  FACTOR REFLECTS
*   LOSSES DUE TO RADIOACTIVE DECAY.
*
*                                                   GREEN    OTHER    LEGUMES   ROOTS
*                                STORED             LEAFY    FOOD     AND       AND
*             NUCLIDE  PASTURE   FORAGE   GRAINS    VEG      CROPS    SEEDS     TUBERS
*
*              NAMISO   DCYPCB   DCYPCB   DCYPCB    DCYPCB   DCYPCB   DCYPCB    DCYPCB
CHDCYPCB001   SR-89       1.0     0.37     0.20       0.0      0.0     0.20       0.0
CHDCYPCB002   SR-90       1.0     0.99     0.99       0.0      0.0     0.99       0.0
CHDCYPCB003   CS-134      1.0     0.92     0.85       0.0      0.0     0.85       0.0
CHDCYPCB004   CS-137      1.0     0.99     0.99       0.0      0.0     0.99       0.0
CHDCYPCB005   I-131       1.0     0.063    0.032      0.0      0.0     0.032      0.0
CHDCYPCB006   I-133       1.0     0.0068   0.0034     0.0      0.0     0.0034     0.0
*************************************************************************************
* DEFINE THE DIRECT DEPOSITION TO CROPS TRANSFER FUNCTION
*
* NUMBER OF TERMS IN THE DIRECT DEPOSITION TO CROPS TRANSFER FUNCTION
*
CHNTRTRM001     2
*
* LOSSES DUE TO WEATHERING FROM PLANT SURFACES AND DURING TRANSLOCATION
* FROM PLANT SURFACES TO INTERIOR EDIBLE PORTIONS OF PLANTS ARE MODELLED
* USING THE FOLLOWING EQUATION:
*
* FRACTION RETAINED = CTCOEF1*EXP(-LN2/CTHALF1) + CTCOEF2*EXP(-LN2/CTHALF2)
*
* FOR PASTURE, STORED FORAGE, GREEN LEAFY VEGETABLES, AND OTHER FOOD CROPS,
* THIS EQUATION IS USED AS A TWO TERM WEATHERING EQUATION.  FOR GRAINS,
* LEGUMES AND SEEDS, AND ROOTS AND TUBERS WHERE RADIOACTIVITY IS CONSUMED
* ONLY IF TRANSLOCATED TO EDIBLE PORTIONS OF THE PLANT, THIS EQUATION IS
* REDUCED TO A TRANSLOCATION TRANSFER FACTOR BY SETTING CTCOEF2 TO ZERO,
* CTHALF2 TO ONE SECOND, AND CTHALF1 TO ABOUT ONE MILLION YEARS (1E13
* SECONDS).  WHEN USED TO MODEL TRANSLOCATION, THE VALUE OF THE TRANSLOCATION
* TRANSFER FACTOR IS DEVELOPED FROM FALLOUT DATA AND IS INPUT AS THE VALUE
* OF CTCOEF1.
*
* TWO TIME PERIODS ARE USED FOR WEATHERING, THE FIRST IS 14 DAYS LONG (1.21E6
* SECONDS) AND THE SECOND IS 50 DAYS LONG (4.32E6 SECONDS)
*
* DIRECT DEPOSITION TRANSFER COEFFICIENTS [(BQ TRANSFERRED)/(BQ DEPOSITED)]
* BY CHRONC INGESTION MODEL NUCLIDE
*
*                                                   GREEN    OTHER    LEGUMES   ROOTS
*                                STORED             LEAFY    FOOD     AND       AND
*  TERM 1    NUCLIDE  PASTURE    FORAGE   GRAINS    VEG      CROPS    SEEDS     TUBERS
CHCTCOEF101   SR-89       0.3       0.2     0.01    0.24     0.0      0.0006   0.0006
CHCTCOEF102   SR-90       0.3       0.2     0.01    0.24     0.0      0.0006   0.0006
CHCTCOEF103   CS-134      0.3       0.2     0.05    0.24     0.0      0.01     0.025
CHCTCOEF104   CS-137      0.3       0.2     0.05    0.24     0.0      0.01     0.025
CHCTCOEF105   I-131       0.3       0.2     0.0     0.24     0.0      0.0      0.0
CHCTCOEF106   I-133       0.3       0.2     0.0     0.24     0.0      0.0      0.0
*  TERM 2
CHCTCOEF201   SR-89     [illegible] [illegible] [illegible] [illegible]     [illegible]
```

```
[illegible]                              0.05     0.0      0.06
[illegible]              [illegible]     0.05     0.0      0.06
[illegible]                              0.05     0.0      0.06
[illegible]              I 131           0.05     0.0      0.06
[illegible]              I 133           0.05     0.0      0.06
*
*   [illegible] TRANSFER HALF LIVES BY CHRONIC INGESTION MODEL NUCLIDE (SECONDS)
*
*                                                       GREEN     OTHER     LEGUMES    ROOTS
*                                  STORED               LEAFY     FOOD      AND        AND
*   TERM 1     NUCLIDE   PASTURE   FORAGE   GRAINS     VEG       CROPS     SEEDS      TUBERS
CHCTHALF101   SR 89     1.21E6    1.21E6      1E13    1.21E6    1.21E6        1E13       1E13
CHCTHALF102   SR 90     1.21E6    1.21E6      1E13    1.21E6    1.21E6        1E13       1E13
CHCTHALF103   CS 134    1.21E6    1.21E6      1E13    1.21E6    1.21E6        1E13       1E13
CHCTHALF104   CS 137    1.21E6    1.21E6      1E13    1.21E6    1.21E6        1E13       1E13
CHCTHALF105   I 131     1.21E6    1.21E6       1.0    1.21E6    1.21E6         1.0        1.0
CHCTHALF106   I 133     1.21E6    1.21E6       1.0    1.21E6    1.21E6         1.0        1.0
*   TERM.
CHCTHALF201   SR 89     4.32E6    4.32E6       1.0    4.32E6    4.32E6         1.0        1.0
CHCTHALF202   SR 90     4.32E6    4.32E6       1.0    4.32E6    4.32E6         1.0        1.0
CHCTHALF203   CS 134    4.32E6    4.32E6       1.0    4.32E6    4.32E6         1.0        1.0
CHCTHALF204   CS 137    4.32E6    4.32E6       1.0    4.32E6    4.32E6         1.0        1.0
CHCTHALF205   I 131     4.32E6    4.32E6       1.0    4.32E6    4.32E6         1.0        1.0
CHCTHALF206   I 133     4.32E6    4.32E6       1.0    4.32E6    4.32E6         1.0        1.0
*****************************************************************************************
* TABLE OF CROP DATA (GROWING SEASON AND FARMLAND SHARE) IN THE REGION.
*
* IF A SITE DATA FILE IS BEING USED (AS SPECIFIED ON THE EARLY USER INPUT FILE),
* THEN DATA FROM THE SITE FILE (AND NOT THE DATA BELOW) IS USED FOR THE
* CALCULATION OF DOSES AND COSTS FROM THE AGRICULTURE MODEL AND THE NUMBERS
* BELOW ARE IGNORED.
*
* IF A SITE DATA FILE IS NOT BEING USED, THE DATA BELOW IS USED IN ITS STEAD.
*
*        FARMLAND SHARE VALUES (FRCTFL) BY SITE AND CROP CATEGORY
*
*    SITE                       GG        LS        PB        SEQ       SUR       ZION
*
*    PASTURE                    0.70      0.47      0.38      0.69      0.41      0.45
*    STORED FORAGE              0.05      0.10      0.13      0.006     0.13      0.11
*    GRAINS                     0.18      0.26      0.23      0.16      0.21      0.26
*    GRN LEAFY VEGETABLES       0.0005    0.0003    0.002     0.0007    0.002     0.0004
*    OTHER FOOD CROPS           0.004     0.001     0.004     0.005     0.004     0.001
*    LEGUMES AND SEEDS          0.13      0.13      0.16      0.15      0.15      0.13
*    ROOTS AND TUBERS           0.0008    0 002     0.004     0.001     0.003     0.002
*
*                                     GROWING
*                                  SEASON (DAYS) FARMLAND
*             CROP NAME             START  END    SHARE
*
*              NAMCRP              TGSBEG  TGSEND  FRCTFL
CHCRPRGN001 'PASTURE              '  90.   270.    0.38
CHCRPRGN002 'STORED FORAGE        ' 150.   240.    0.13
CHCRPRGN003 'GRAINS               ' 150.   240.    0.23
CHCRPRGN004 'GRN LEAFY VEGETABLES' 150.   240.    0.002
CHCRPRGN005 'OTHER FOOD CROPS     ' 150.   240.    0.004
CHCRPRGN006 'LEGUMES AND SEEDS    ' 150.   240.    0.16
CHCRPRGN007 'ROOTS AND TUBERS     ' 150.   240.    0.004
*****************************************************************************************
* PROTECTIVE ACTION GUIDES FOR THE DIRECT DEPOSITION PATHWAY TO
* MILK AND ITS PRODUCTS AND TO OTHER CROPS AND THEIR PRODUCTS
* BY FOOD INGESTION MODEL NUCLIDE (PERMISSIBLE SURFACE
* CONCENTRATION IN BECQUERELS PER SQUARE METER)
*
* PERMISSIBLE SURFACE CONCENTRATIONS WERE DERIVED BY INVERTING
* THE FOOD PATHWAY MODEL THEREBY MAKING THE DOSE TO AN ORGAN THE
```

```
* [illegible] ALLOWABLE [illegible] ON INGESTION [illegible]
* [illegible] CONCENTRATIONS WERE [illegible]
* A [illegible] WATER [illegible]
* [illegible] REM [illegible] THYROID AND 5 REM [illegible]
* [illegible] ALL WATER DOSES IN [illegible]
* [illegible] 1.5 REM TO THYROID AND [illegible]
* AND [illegible]
*
*                           MILK AND    OTHER CROP
*               NUCLIDE     PRODUCTS    AND PRODUCTS
*
*               NAMIEI      PSCMLK      PSCOTH
CHPAGM[illegible]  SR 89    2.1E06      [illegible]
CHPAGM[illegible]  SR 90    4.6E?4      5.1E04
CHPAGM[illegible]  CS 134   1.4E0?      9.6E04
CHPAGM[illegible]  CS 137   1.9E0?      1.3E0?
CHPAGM[illegible]  I 131    1.0E0?      9.2E06
CHPAGM[illegible]6 I 133    1.2E09      1.0E20     1.0E[illegible]  [illegible] LIMIT
***************************************************************************
* PROTECTIVE ACTION GUIDES FOR LONG TERM TRANSFER TO FARM CROPS
* FROM ROOT AND OTHER SOIL UPTAKE FROM SURFACE CONTAMINATION
* BY CHRONIC INGESTION MODEL NUCLIDE (PERMISSIBLE SURFACE
* CONCENTRATION IN BEQUERELS PER SQUARE METER) AND THE ASSOCIATED
* ANNUAL DEPLETION RATE FOR THE NUCLIDE IN THE SOIL.
*
*                         PERMISSIBLE      ANNUAL
*                           SURFACE       DEPLETION
*               NUCLIDE   CONCENTRATION     RATE
*
*               NAMIEI      GCMAXR        QROOT
CHPAGLTS001     SR 89       8.3E0?        4.9
CHPAGLTS002     SR 90       4.0E0?        0.06?
CHPAGLTS003     CS 134      1.1E05        0.59
CHPAGLTS004     CS 137      1.2E05        0.28
CHPAGLTS005     I 131       2.1E0?       32.0
CHPAGLTS006     I 133       1.6E12      290.0
***************************************************************************
* DEFINE THE TYPE 9 RESULTS
*
* LONG TERM POPULATION DOSE IN A GIVEN REGION BROKEN DOWN BY THE 12 PATHWAYS
*
* NUMBER OF RESULTS OF THIS TYPE THAT ARE BEING REQUESTED
* FOR EACH RESULT YOU REQUEST, THE CODE WILL PRODUCE A SET OF 12
*
TYPE9NUMBER    2       (UP TO 10 ALLOWED)
*
*               ORGNAM          INNER      OUTER
*
TYPE9OUT001    'EDEWBODY'        1          26     (0-1000 MILES)
TYPE9OUT002    'EDEWBODY'        1          19     (0-50 MILES)
***************************************************************************
* ECONOMIC COST RESULTS IN A REGION BROKEN DOWN BY 12 TYPES OF COSTS
*
* NUMBER OF RESULTS OF THIS TYPE THAT ARE BEING REQUESTED
* FOR EACH RESULT YOU REQUEST, THE CODE WILL PRODUCE A SET OF 12
*
TYP10NUMBER    2       (UP TO 10 ALLOWED)
*
*               INNER       OUTER
*
TYP10OUT001       1           26     (0-1000 MILES)
TYP10OUT002       1           19     (0-50 MILES)
***************************************************************************
* DEFINE A FLAG THAT CONTROLS THE PRODUCTION OF THE ACTION DISTANCE RESULTS
*
* SPECIFYING A VALUE OF .TRUE. TURNS ON ALL 8 OF THE ACTION DISTANCE RESULTS
```

[redacted]

```
* A VALUE OF .FALSE. WILL ELIMINATE THE ACTION DISTANCE EFFECT FROM THE RESULT
*
TYP1   AG11   .TRUE.
******************************************************************************
* IMPACTED AREA/POPULATION RESULTS IN A REGION BROKEN DOWN BY [illegible] TYPES OF IMPACTS
*
* NUMBER OF RESULTS OF THIS TYPE THAT ARE BEING REQUESTED
* FOR EACH RESULT YOU REQUEST, THE CODE WILL PRODUCE A SET OF [illegible]
*
TYP1NUMBER    2        (UP TO 10 ALLOWED)
*
*                 INNER       OUTER
*
TYP1OUT001        1            26     (0-1000 MILES)
TYP1OUT002        1            19     (0-50 MILES)
.
```

```
MACCS DOSE CONVERSION FILE:  MOD SER #32,  1-NOV 88, 1 [illegible]
SANDIA NATIONAL LABORATORIES           J. JOHNSON
        12 ORGANS DEFINED IN THIS FILE:
STOMACH
SMALL IN
LUNGS
RED MARR
THYROID
LOWER LI
BONE SUR
BREAST
TESTES
OVARIES
EDEWBODY
THYROIDH
        60 NUCLIDES DEFINED IN THIS FILE:
CO-58
CO-60
KR-85
KR-85M
KR-87
KR-88
RB-86
SR-89
SR-90
SR-91
SR-92
Y-90
Y-91
Y-92
Y-93
ZR-95
ZR-97
NB-95
MO-99
TC-99M
RU-103
RU-105
RU-106
RH-105
SB-127
SB-129
TE-127
TE-127M
TE-129
TE-129M
TE-131M
TE-132
I-131
I-132
I-133
I-134
I-135
XE-133
XE-135
CS-134
CS-136
CS-137
BA-139
BA-140
LA-140
LA-141
LA-142
CE-141
CE-143
CE-144
```

```
PR 143
ND 147
NP 239
PU 238
PU 239
PU 240
PU 241
AM 241
CM 242
CM 244
           CLOUDSHINE  GROUND     GROUND     GROUND     INHALED    INHALED   INGESTION
                       SHINE 8HR SHINE 7DAY SHINE RATE ACUTE      CHRONIC
CO 58
STOMACH     3.520E-14 1.979E-11 4.024E-10 6.881E-16 1.558E-10 1.394E-09 3.853E-10
SMALL IN    3.203E-14 1.796E-11 3.652E-10 6.247E-16 3.307E-10 7.495E-10 1.130E-09
LUNGS       3.805E-14 2.143E-11 4.356E-10 7.452E-16 1.039E-09 1.601E-08 8.510E-11
RED MARR    3.869E-14 2.179E-11 4.430E-10 7.579E-16 1.577E-10 9.228E-10 2.601E-10
THYROID     4.788E-14 2.690E-11 5.469E-10 9.354E-16-1.000E+00 8.704E-10 6.308E-11
LOWER LI    3.456E-14 1.942E-11 3.948E-10 6.754E-16 9.144E-10 1.989E-09 3.962E-09
BONE SUR    4.249E-14 2.389E-11 4.857E-10 8.308E-16-1.000E+00 6.926E-10 1.252E-10
BREAST      4.566E-14 2.571E-11 5.228E-10 8.942E-16-1.000E+00 9.367E-10 1.788E-10
TESTES      5.074E-14 2.845E-11 5.784E-10 9.894E-16-1.000E+00 1.060E-10 1.614E-10
OVARIES     3.456E-14 1.942E-11 3.948E-10 6.754E-16-1.000E+00 6.166E-10 1.041E-09
EDEWBODY    4.398E-14 2.459E-11 5.000E-10 8.553E-16-1.000E+00 3.088E-09 8.206E-10
THYROIDH    4.788E-14 2.690E-11 5.469E-10 9.354E-16 6.142E-11 8.704E-10 6.308E-11
CO 60
STOMACH     9.132E-14 4.602E-11 9.655E-10 1.598E-15 3.840E-10 2.726E-08 1.611E-09
SMALL IN    8.530E-14 4.301E-11 9.022E-10 1.494E-15 8.077E-10 7.046E-09 3.591E-09
LUNGS       9.862E-14 4.986E-11 1.046E-09 1.731E-15 5.186E-09 3.448E-07 8.768E-10
RED MARR    9.957E-14 5.032E-11 1.055E-09 2.747E-15 3.986E-10 1.718E-08 1.311E-09
THYROID     1.230E-13 6.219E-11 1.305E-09 2.159E-15-1.000E+00 1.615E-08 7.843E-10
LOWER LI    9.069E-14 4.575E-11 9.597E-10 1.589E-15 2.386E-09 7.916E-09 1.113E-08
BONE SUR    1.056E-13 5.333E-11 1.119E-09 1.852E-15-1.000E+00 1.353E-08 9.415E-10
BREAST      1.164E-13 5.872E-11 1.232E-09 2.039E-15-1.000E+00 1.843E-08 1.100E-09
TESTES      1.297E-13 6.548E-11 1.373E-09 2.274E-15-1.000E+00 1.697E-09 1.075E-09
OVARIES     8.879E-14 4.484E-11 9.406E-10 1.557E-15-1.000E+00 4.753E-09 3.187E-09
EDEWBODY    1.125E-13 5.666E-11 1.189E-09 1.968E-15-1.000E+00 5.948E-08 2.839E-09
THYROIDH    1.230E-13 6.219E-11 1.305E-09 2.159E-15 1.465E-10 1.615E-08 7.843E-10
KR 85
STOMACH     7.674E-17 0.000E+00 0.000E+00 0.000E+00 6.757E-14 7.007E-14 0.000E+00
SMALL IN    6.881E-17 0.000E+00 0.000E+00 0.000E+00 6.781E-14 7.007E-14 0.000E+00
LUNGS       8.340E-17 0.000E+00 0.000E+00 0.000E+00 4.672E-13 4.708E-13 0.000E+00
RED MARR    8.562E-17 0.000E+00 0.000E+00 0.000E+00 6.808E-14 7.007E-14 0.000E+00
THYROID     1.037E-16 0.000E+00 0.000E+00 0.000E+00-1.000E+00 7.007E-14 0.000E+00
LOWER LI    7.484E-17 0.000E+00 0.000E+00 0.000E+00 6.781E-14 7.007E-14 0.000E+00
BONE SUR    9.767E-17 0.000E+00 0.000E+00 0.000E+00-1.000E+00 7.007E-14 0.000E+00
BREAST      1.037E-16 0.000E+00 0.000E+00 0.000E+00-1.000E+00 7.007E-14 0.000E+00
TESTES      1.123E-16 0.000E+00 0.000E+00 0.000E+00-1.000E+00 7.007E-14 0.000E+00
OVARIES     7.484E-17 0.000E+00 0.000E+00 0.000E+00-1.000E+00 7.007E-14 0.000E+00
EDEWBODY    2.315E-16 0.000E+00 0.000E+00 0.000E+00-1.000E+00 1.180E-13 0.000E+00
THYROIDH    1.037E-16 0.000E+00 0.000E+00 0.000E+00 6.689E-14 7.007E-14 0.000E+00
KR 85M
STOMACH     5.232E-15 0.000E+00 0.000E+00 0.000E+00 6.098E-14 6.101E-14 0.000E+00
SMALL IN    4.566E-15 0.000E+00 0.000E+00 0.000E+00 6.101E-14 6.104E-14 0.000E+00
LUNGS       5.771E-15 0.000E+00 0.000E+00 0.000E+00 4.804E-13 4.804E-13 0.000E+00
RED MARR    5.549E-15 0.000E+00 0.000E+00 0.000E+00 6.369E-14 6.372E-14 0.000E+00
THYROID     7.737E-15 0.000E+00 0.000E+00 0.000E+00-1.000E+00 5.532E-14 0.000E+00
LOWER LI    5.105E-15 0.000E+00 0.000E+00 0.000E+00 5.912E-14 5.915E-14 0.000E+00
BONE SUR    8.467E-15 0.000E+00 0.000E+00 0.000E+00-1.000E+00 6.103E-14 0.000E+00
BREAST      8.593E-15 0.000E+00 0.000E+00 0.000E+00-1.000E+00 5.722E-14 0.000E+00
TESTES      7.959E-15 0.000E+00 0.000E+00 0.000E+00-1.000E+00 5.514E-14 0.000E+00
OVARIES     4.630E-15 0.000E+00 0.000E+00 0.000E+00-1.000E+00 5.995E-14 0.000E+00
EDEWBODY    7.222E-15 0.000E+00 0.000E+00 0.000E+00-1.000E+00 1.110E-13 0.000E+00
THYROIDH    7.737E-15 0.000E+00 0.000E+00 0.000E+00 5.529E-14 5.532E-14 0.000E+00
KR 87
STOMACH     3.161E-14 0.000E+00 0.000E+00 0.000E+00 2.218E-13 2.218E-13 0.000E+00
```

```
SMALL IN    [illegible] 14 [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
LUNGS       [illegible] 14 [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
RED MARR    [illegible] 14 [illegible] [illegible] 0.000E+00 [illegible] [illegible] [illegible]
THYROID     4.[illegible] 14 [illegible] [illegible] 0.000E+00 [illegible] [illegible] [illegible]
LOWER LI    [illegible] 14 [illegible] [illegible] 0.000E+00 [illegible] [illegible] [illegible]
BONE SUR    [illegible] 14 0.000E+00 [illegible] 0.000E+00 [illegible] [illegible] [illegible]
BREAST      [illegible] 14 [illegible] [illegible] 0.000E+00 [illegible] [illegible] [illegible]
TESTES      4.4[illegible] 14 [illegible] [illegible] 0.000E+00 [illegible] [illegible] [illegible]
OVARIES     [illegible] 14 [illegible] [illegible] 0.000E+00 [illegible] [illegible] [illegible]
EDEWBODY    [illegible] 14 [illegible] [illegible] [illegible] [illegible] 4.8[illegible] [illegible]
THYROIDH    4.[illegible] 14 [illegible] [illegible] 0.000E+00 [illegible] [illegible] [illegible]
RB [illegible]
STOMACH     [illegible] [illegible] [illegible] 0.000E+00 [illegible] [illegible] 0.000E+00
SMALL IN    [illegible] [illegible] [illegible] 0.000E+00 [illegible] [illegible] 0.000E+00
LUNGS       [illegible] [illegible] [illegible] 0.000E+00 [illegible] [illegible] [illegible]
RED MARR    [illegible] [illegible] [illegible] 0.000E+00 [illegible] [illegible] [illegible]
THYROID     [illegible] [illegible] 0.000E+00 0.000E+00 [illegible] [illegible] 0.000E+00
LOWER LI    [illegible] 0.000E+00 0.000E+00 0.000E+00 [illegible] [illegible] 0.000E+00
BONE SUR    [illegible] 0.000E+00 0.000E+00 0.000E+00 [illegible] [illegible] 0.000E+00
BREAST      [illegible] [illegible] [illegible] 0.000E+00 [illegible] [illegible] 0.000E+00
TESTES      [illegible] 0.000E+00 0.000E+00 0.000E+00 [illegible] [illegible] 0.000E+00
OVARIES     [illegible] 14 0.000E+00 0.000E+00 0.000E+00 [illegible] [illegible] 0.000E+00
EDEWBODY    [illegible] 14 0.000E+00 0.000E+00 0.000E+00 [illegible] 8.4[illegible] 0.000E+00
THYROIDH    [illegible] 0.000E+00 0.000E+00 0.000E+00 [illegible] [illegible] 0.000E+00
RB [illegible]
STOMACH     [illegible] 1.866E 12 3.361E 11 6.410E [illegible] [illegible] [illegible] [illegible]
SMALL IN    [illegible] 1.6[illegible] 12 3.108E 11 5.835E [illegible] [illegible] 1.34[illegible] 2.16[illegible] 09
LUNGS       3.[illegible] 15 1.[illegible] 12 3.6[illegible] 11 6.818E [illegible] [illegible] [illegible] 2.13[illegible] 09
RED MARR    3.8[illegible] 15 1.9[illegible] 12 3.6[illegible] 11 6.913E [illegible] [illegible] [illegible] [illegible] 09
THYROID     4.[illegible] 15 2.466E 12 4.5[illegible] 11 8.593E [illegible] [illegible] 1.[illegible] 09 [illegible] 09
LOWER LI    [illegible] 15 1.788E 12 3.[illegible] 11 6.247E [illegible] [illegible] 1.[illegible] 09 2.16[illegible] 09
BONE SUR    4.[illegible] 15 2.11[illegible] 12 3.9[illegible] 11 [illegible] [illegible] 4.[illegible] 6.841E 09
BREAST      4.439E 15 2.30[illegible] 12 4.290E 11 8.054E [illegible] [illegible] 1.[illegible] 09 2.142E 09
TESTES      4.947E 15 2.[illegible] 12 4.[illegible] 11 9.006E [illegible] [illegible] 1.346E 09 [illegible].160E 09
OVARIES     3.[illegible] 15 1.[illegible] 12 3.293E 11 6.183E [illegible] [illegible] 1.332E 09 2.13[illegible] 09
EDEWBODY    4.[illegible] 15 3.909E 12 7.2[illegible]E-11 1.36[illegible]E-16 [illegible] 1.8[illegible] 09 2.545E 09
THYROIDH    4.[illegible] [illegible] 2.466E 12 4.5[illegible] 11 8.593E [illegible] [illegible] 1.[illegible] 09 2.13[illegible] 09
SR 89
STOMACH     [illegible] 18 2.[illegible] 15 5.50[illegible] 14 9.545E-20 [illegible] 5.[illegible] 10 9.321E 10
SMALL IN    4.[illegible] 18 2.497E 15 5.011E 14 8.689E 20 [illegible] 6.284E [illegible] 1.433E 09
LUNGS       [illegible] 18 2.952E 15 5.[illegible]E-14 1.027E-19 [illegible] [illegible] 2.584E 10
RED MARR    5.[illegible] 18 2.998E 15 6.01[illegible]E-14 1.043E-19 9.360E [illegible] 5.651E 09 3.261E-09
THYROID     6.849E 18 3.72[illegible] 15 7.480E 14 1.297E 19 [illegible] 4.4[illegible] 10 2.584E 10
LOWER LI    4.942E 18 2.697E 15 5.413E-14 9.386E-20 [illegible] 3.[illegible]86E 09 2.063E 08
BONE SUR    5.961E-18 3.245E 15 6.492E 14 1.126E 19 [illegible] 8.3[illegible]5E 09 4.820E-09
BREAST      6.4[illegible] 18 3.508E 15 7.041E-14 1.221E 19 [illegible] 4.4[illegible] 10 2.584E 10
TESTES      7.196E 18 3.909E 15 7.846E 14 1.360E-19 [illegible] 4.4[illegible] 10 2.584E 10
OVARIES     4.943E 18 2.688E-15 5.395E 14 9.354E 20 [illegible] 4.4[illegible] 10 2.584E-10
EDEWBODY    3.[illegible] 16 1.457E 12 2.924E 11 5.069E 17 [illegible] 1.[illegible]E-09 2.503E-09
THYROIDH    6.849E 18 3.727E 15 7.480E 14 1.297E 19 [illegible] 4.4[illegible] 10 2.584E 10
SR 90
STOMACH     0.000E+00 0.000E+00 0.000E+00 0.000E+00 [illegible] 10 2.365E 09 1.570E 09
SMALL IN    0.000E+00 0.000E+00 0.000E+00 0.000E+00 [illegible] 10 2.402E 09 1.802E-09
LUNGS       0.000E+00 0.000E+00 0.000E+00 0.000E+00 [illegible] 3.422E 09 1.333E-09
RED MARR    0.000E+00 0.000E+00 0.000E+00 0.000E+00 [illegible] 3.051E-0[illegible] 1.752E-07
THYROID     0.000E+00 0.000E+00 0.000E+00 0.000E+00 [illegible] 2.328E 09 1.333E-09
LOWER LI    0.000E+00 0.000E+00 0.000E+00 0.000E+00 1.611E [illegible] [illegible]133E 09 1.943E-08
BONE SUR    0.000E+00 0.000E+00 0.000E+00 0.000E+00 [illegible] 6.[illegible] 3.881E-07
BREAST      0.000E+00 0.000E+00 0.000E+00 0.000E+00 [illegible] 2.328E 09 1.333E-09
TESTES      0.000E+00 0.000E+00 0.000E+00 0.000E+00 [illegible] [illegible]328E 09 1.333E-09
OVARIES     0.000E+00 0.000E+00 0.000E+00 0.000E+00 [illegible] 2.328E 09 1.333E-09
EDEWBODY    9.5[illegible] [illegible] 2.464E 13 3.113E 11 5.000E 18 [illegible] [illegible] 08 [illegible]518E 08
THYROIDH    0.000E+00 0.000E+00 0.000E+00 0.000E+00 [illegible] 2.329E 09 1.333E 09
SR 91
STOMACH     [illegible] 14 1.456E 11 3.4[illegible] 11 6.938E 16 [illegible] [illegible] 10 [illegible]
SMALL IN    [illegible] 14 1.324E 11 3.11[illegible] 11 6.305E 16 [illegible] [illegible] [illegible]
```

```
LUNGS      [illegible] 14 [illegible] 11 [illegible] 11 [illegible] 10 [illegible] 9.243E 10 3.289E 11
RED MARR   [illegible] 14 [illegible]99E 11 [illegible] 11 [illegible] 10 [illegible] 2.446E 10 1.233E 10
THYROID    4.8[illegible] 14 1.[illegible]1E 11 4.633E 11 9.388E 10 1.000E+00 4.434E 11 2.641E 11
LOWER LI   [illegible] 14 1.425E 11 3.350E 11 6.[illegible]87E 10 [illegible] 10 6.234E 10 3.929E 09
BONE SUR   4.[illegible] 14 1.[illegible]56E 11 4.133E 11 8.[illegible]5E 10 1.000E+00 1.424E 10 9.812E 11
BREAST     4.[illegible] 14 1.895E 11 4.459E 11 9.034E 10 1.000E+00 4.814E 11 5.224E 11
TESTES     5.130E 14 2.089E 11 4.914E 11 9.957E 10 1.000E+00 4.335E 11 4.141E-11
OVARIES    [illegible] 14 1.42[illegible] 11 [illegible] 11 6.[illegible]87E 10 1.000E+00 6.[illegible]3E 11 2.120E 10
EDEWBODY   [illegible]160E 14 1.464E 11 3.184E 11 6.435E 10 [illegible] 2.615E 10 6.[illegible] 10
THYROIDH   4.869E 14 1.9[illegible]1E 11 4.633E 11 9.388E 10 [illegible]E 11 4.434E 11 2.641E-11
SR 9[illegible]
STOMACH    4.88[illegible] 14 1.1[illegible]E 11 1.422E 11 8.403E 10 [illegible]E 10 1.108E 10 5.294E 10
SMALL IN   4.[illegible] 14 1.081E 11 1.3[illegible]E 11 7.864E 10 [illegible] 10 1.861E 10 1.081E 09
LUNGS      5.264E 14 1.2[illegible]E 11 1.539E 11 9.101E-10 [illegible] [illegible]E 10 1.948E 11
RED MARR   5.3[illegible]E 14 1.266E 11 1.556E 11 9.196E 10 4.114E [illegible] 4.213E 11 4.225E-11
THYROID    6.532E 14 1.556E 11 1.913E 11 1.129E 1[illegible] 1.000E+00 2.288E 11 1.418E-11
LOWER LI   4.8[illegible] 14 1.1[illegible]2E 11 1.415E 11 8.321E 10 [illegible] 3.369E 10 2.179E-09
BONE SUR   [illegible]644E 14 1.343E 11 1.653E 11 9.735E-10 1.000E+00 5.591E-11 3.874E-11
BREAST     6.[illegible]E 14 1.481E-11 1.821E 11 1.075E 1[illegible] 1.000E+00 2.549E 11 2.743E-11
TESTES     6.923E 14 1.643E 11 2.020E 11 1.192E-1[illegible] 1.000E+00 [illegible]176E-11 1.903E-11
OVARIES    4.[illegible]5E 14 1.123E 11 1.381E-11 8.149E-10 1.000E+00 [illegible]134E-11 8.079E-11
EDEWBODY   6.019E 14 1.536E-11 1.953E 11 1.043E-1[illegible] 1.000E+00 1.[illegible]41E-10 4.451E-10
THYROIDH   6.532E 14 1.556E 11 1.913E-11 1.129E-1[illegible] [illegible]241E 11 2.288E 11 1.418E-11
Y 9[illegible]
STOMACH    0.[illegible]0E+00 0.000E+00 0.000E+00 0.000E+0[illegible] 3.[illegible]4[illegible]E 10 4.263E 10 1.060E-09
SMALL IN   0.000E+00 0.000E+00 0.000E+00 0.000E+0[illegible] [illegible]13E 10 1.022E 09 2.557E-09
LUNGS      0.000E+00 0.000E+00 0.000E+00 0.000E+0[illegible] [illegible]546E [illegible] 9.309E 09 1.264E-14
RED MARR   0.000E+00 0.000E+00 0.000E+00 0.000E+0[illegible] [illegible]68E 12 1.50[illegible]E 11 3.664E-13
THYROID    0.000E+00 0.000E+00 0.000E+00 0.000E+0 1.000E+00 5.183E-13 1.264E-14
LOWER LI   0.000E+00 0.000E+00 0.000E+00 0.000E+0[illegible] [illegible]544E 09 1.262E 08 3.145E-08
BONE SUR   0.000E+00 0.000E+00 0.000E+00 0.000E+0 1.000E+00 1.50[illegible]E 11 3.664E-13
BREAST     0.000E+00 0.000E+00 0.000E+00 0.000E+0 1.000E+00 5.184E 13 1.268E-14
TESTES     0.000E+00 0.000E-00 0.000E+00 0.000E+0 1.000E+00 5.183E 13 1.264E-14
OVARIES    0.000E+00 0.000E+00 0.000E+00 0.000E+0[illegible] 1.000E+00 5.191E 13 1.438E-14
EDEWBODY   6.308E-16 2.379E-12 2.404E 11 8.623E-1 1.000E+00 2.281E-09 2.905E-09
THYROIDH   0.000E+00 0.000E+00 0.000E+00 0.000E+0 3.15[illegible]E-13 5.183E 13 1.264E-14
Y 91
STOMACH    1.316E 16 6.690E-14 1.351E 12 2.328E-18 [illegible]4[illegible]E 10 3.431E 10 6.914E-10
SMALL IN   1.224E 16 6.234E-14 1.259E-12 2.169E-18 6.656E 10 8.421E-10 1.737E-09
LUNGS      1.424E-16 7.246E-14 1.463E 12 2.521E-18 6.923E 09 9.836E-08 2.017E-13
RED MARR   1.436E 16 7.310E-14 1.476E-12 2.543E-18 2.[illegible]98E 11 3.174E-10 6.562E-12
THYROID    1.782E 16 9.060E-14 1.830E-12 3.152E-18 1.000E+00 8.479E 12 1.288E-13
LOWER LI   1.306E 16 6.644E-14 1.342E-12 2.312E-18 6.908E 09 1.455E 08 3.027E-08
BONE SUR   1.528E 16 7.765E-14 1.568E-12 2.702E-18 1.000E+00 3.166E-10 6.108E-12
BREAST     1.677E-16 8.540E-14 1.725E-12 2.971E-18 1.000E+00 8.908E-12 5.545E-13
TESTES     1.874E-16 9.570E-14 1.933E-12 3.330E-18 1.000E+00 6.404E-12 4.137E-13
OVARIES    1.284E 16 6.535E-14 1.320E-12 2.274E-18 1.000E+00 8.190E-12 3.532E-12
EDEWBODY   5.509E 16 1.594E-12 3.218E-11 5.544E-1 1.000E+00 1.312E 08 2.571E-09
THYROIDH   1.782E-16 9.060E-14 1.830E-12 3.152E-18 6.243E 13 8.479E-12 1.288E-13
Y-92
STOMACH    9.229E 15 2.473E-12 3.125E-12 1.700E-16 1.703E 10 1.705E 10 1.420E-09
SMALL IN   8.498E 15 2.274E-12 2.875E-12 1.563E-16 2.382E 10 2.390E-10 2.000E-09
LUNGS      9.989E 15 2.671E-12 3.376E-12 1.836E-16 1.242E-09 1.249E-09 1.393E-12
RED MARR   1.012E-14 2.708E-12 3.423E-12 1.861E-16 2.061E 12 2.079E-12 4.930E-12
THYROID    1.249E-14 3.344E-12 4.227E-12 2.299E-16 1.000E+00 1.054E 12 1.776E-13
LOWER LI   9.132E 15 2.440E-12 3.084E-12 1.677E-16 1.959E 10 2.090E-10 1.749E-09
BONE SUR   1.088E 14 2.920E-12 3.691E-12 2.007E 16 1.000E+00 1.512E 12 1.754E-12
BREAST     1.186E 14 3.178E-12 4.017E-12 2.185E-16 1.000E+00 1.503E-12 3.564E-12
TESTES     1.316E 14 3.529E-12 4.460E-12 2.426E-16 1.000E+00 3.494E 13 1.399E-12
OVARIES    9.006E 15 2.413E-12 3.049E-12 1.658E-16 1.000E+00 2.628E 12 1.971E-11
EDEWBODY   1.238E 14 5.018E-12 6.342E-12 3.449E-16 1.000E+00 2.125E 10 5.153E-10
THYROIDH   1.249E-14 3.344E 12 4.227E-12 2.299E-16 1.049E [illegible] 1.054E 12 1.776E-13
Y 93
STOMACH    3.36[illegible] 15 1.321E-12 3.127E 12 5.961E-1 [illegible]810E 10 [illegible]846E 10 1.280E-09
SMALL IN   3.1[illegible] 15 1.[illegible]23E 12 2.895E 12 5.518E-1 [illegible] [illegible]11E 10 2.524E-09
LUNGS      3.64[illegible] 15 1.427E 12 3.377E 12 6.437E-1 [illegible] [illegible]524E [illegible] 8.661E-13
```

```
RED MAR   [illegible]
THYROID   [illegible]
LOWER LI  [illegible]
BONE SUR  [illegible]
BREAST    [illegible]
TESTES    [illegible]
OVARIES   [illegible]
EDEWBODY  [illegible]
THYROIDH  [illegible]
ZR 9
STOMACH   [illegible] 1.[illegible] [illegible] 5.[illegible]E-16 1.[illegible]
SMALL IN  [illegible] 1.[illegible]E-11 2.94[illegible]E-10 4.[illegible]E-16 [illegible]
LUNGS     2.8[illegible]E-14 1.628E-11 [illegible]E-10 5.644E-16 1.5[illegible]
RED MARR  2.924E-14 1.6[illegible]E-11 [illegible] 5.[illegible]40E-16 2.84[illegible]
THYROID   3.615E-14 2.049E-11 4.425E-10 7.10[illegible]E-16 1.0[illegible]
LOWER LI  2.60[illegible]E-14 1.4[illegible]E-11 3.181E-10 5.105E-16 1.5[illegible]
BONE SUR  3.203E-14 1.821E-11 3.910E-10 6.279E-16 1.0[illegible]
BREAST    3.456E-14 1.948E-11 4.207E-10 6.754E-16 1.0[illegible]
TESTES    3.837E-14 2.159E-11 4.661E-10 7.484E-16 1.0[illegible]
OVARIES   2.616E-14 1.482E-11 3.199E-10 5.137E-16 1.0[illegible]
EDEWBODY  3.299E-14 1.873E-11 4.043E-10 6.493E-16 1.0[illegible]
THYROIDH  3.615E-14 2.049E-11 4.425E-10 7.103E-16 6.14[illegible]
ZR 9
STOMACH   5.527E-14 2.431E-11 9.498E-11 1.083E-15 [illegible]
SMALL IN  5.004E-14 2.202E-11 8.599E-11 9.807E-16 [illegible].834E[illegible]
LUNGS     5.975E-14 2.626E-11 1.026E-10 1.170E-15 2.83[illegible]
RED MARR  6.084E-14 2.673E-11 1.044E-10 1.191E-15 1.0[illegible]
THYROID   7.481E-14 3.301E-11 1.290E-10 1.471E-15-1.0[illegible] [illegible]44E-11 [illegible]
LOWER LI  5.419E-14 2.38 E-11 9.324E-11 1.063E-15 2.6[illegible]
BONE SUR  6.691E-14 2.949E-11 1.153E-10 1.315E-15-1.0[illegible] [illegible] 4.[illegible]E-11
BREAST    7.210E-14 3.172E-11 1.240E-10 1.414E-15-1.0[illegible] [illegible]94E-11 8.094E-11
TESTES    7.937E-14 3.496E-11 1.366E-10 1.558E-15-1.0[illegible] 2.986E-12 5.200E-11
OVARIES   5.415E-14 2.380E-11 9.302E-11 1.061E-15-1.0[illegible] [illegible].696E-10 6.219E-1[illegible]
EDEWBODY  8.623E-15 5.200E-12 1.857E-11 2.118E-16-1.0[illegible] 1.06 E-0[illegible] 2.288E-09
THYROIDH  7.481E-14 3.301E-11 1.290E-10 1.471E-15 2.788E-11 [illegible].744E-11 2.662E-12
NB 95
STOMACH   2.778E-14 1.557E-11 3.063E-10 5.422E-16 1.[illegible] 6.362E-10 2.796E-1[illegible]
SMALL IN  2.515E-14 1.411E-11 2.776E-10 4.915E-16 2.888E-1[illegible] 5.201E-10 9.116E-10
LUNGS     3.000E-14 1.684E-11 3.314E-10 5.866E-16 7.399E-10 8.319E-09 2.743E-1[illegible]
RED MARR  3.051E-14 1.711E-11 3.367E-10 5.961E-16 1.[illegible]E-10 4.425E-10 1.993E-10
THYROID   3.773E-14 2.121E-11 4.173E-10 7.388E-16-1.0[illegible] 4.582E-10 1.184E-11
LOWER LI  2.724E-14 1.529E-11 3.009E-10 5.327E-16 9.234E-10 1.928E-09 4.009E-09
BONE SUR  3.330E-14 1.866E-11 3.672E-10 6.501E-16-1.000E+00 [illegible].161E-10 2.965E-10
BREAST    3.583E-14 2.012E-11 3.959E-10 7.008E-16-1.000E+00 4.062E-10 1.074E-10
TESTES    3.995E-14 2.230E-11 4.388E-10 7.769E-16-1.000E+00 6.507E-11 9.664E-11
OVARIES   2.730E-14 1.529E-11 3.009E-10 5.327E-16-1.000E+00 4.310E-10 8.030E-10
EDEWBODY  3.449E-14 1.937E-11 3.812E-10 6.748E-16-1.000E+00 1.652E-09 7.029E-10
THYROIDH  3.773E-14 2.121E-11 4.173E-10 7.388E-16 4.2[illegible]E-11 4.582E-10 1.184E-11
MO-99
STOMACH   5.518E-15 3.820E-12 5.368E-11 1.100E-16 1.894E-10 2.325E-10 5.135E-10
SMALL IN  4.978E-15 3.408E-12 4.751E-11 9.894E-17 4.221E-10 5.189E-10 1.249E-09
LUNGS     5.993E-15 4.163E-12 5.884E-11 1.192E-16 1.592E-09 4.292E-09 1.506E-11
RED MARR  6.057E-15 4.111E-12 5.687E-11 1.202E-16 3.096E-11 5.074E-11 7.972E-11
THYROID   7.579E-15 5.376E-12 7.737E-11 1.513E-16-1.000E+00 1.516E-11 1.034E-11
LOWER LI  5.422E-15 3.740E-12 5.251E-11 1.078E-16 2.860E-09 5.516E-09 1.367E-08
BONE SUR  6.913E-15 5.189E-12 7.849E-11 1.386E-16-1.000E+00 4.290E-11 6.669E-11
BREAST    7.388E-15 5.483E-12 8.176E-11 1.487E-16-1.000E+00 2.748E-11 3.422E-11
TESTES    7.991E-15 5.622E-12 8.026E-11 1.595E-16-1.000E+00 1.210E-11 2.719E-11
OVARIES   5.359E-15 3.624E-12 4.483E-11 1.065E-16-1.000E+00 9.503E-11 2.174E-10
EDEWBODY  7.164E-15 5.694E-12 7.867E-11 1.667E-16 1.000E+00 1.075E-09 1.362E-09
THYROIDH  7.579E-15 5.376E-12 7.737E-11 1.513E-16 5.884E-12 1.516E-11 1.034E-11
TC-99M
STOMACH   4.154E-15 1.731E-12 2.875E-12 9.196E-17 1.43 E-11 1.519E-11 [illegible].169E-11
SMALL IN  3.583E-15 1.498E-12 2.489E-12 7.959E-17 3.[illegible] [illegible] 2.227E-11
LUNGS     4.698E-15 1.928E-12 3.203E-12 1.024E-16 2.[illegible] [illegible] 3.1[illegible]E-12
RED MARR  4.[illegible] 1.[illegible]E-12 2.91[illegible]E-12 9.323E-17 2.[illegible]
```

```
[illegible]  [illegible]  [illegible]  4.412E-12  [illegible]  [illegible]  [illegible]  8.449E-11
[illegible]  [illegible]  [illegible]  [illegible]  8.924E-1[illegible]  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  [illegible]  1.620E-16  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  [illegible]  1.433E-16  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  [illegible]  1.285E-16  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  [illegible]  1.411E-16  [illegible]  [illegible]  8.449E-11

[illegible]  [illegible]  [illegible]  [illegible]  3.426E-16  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  [illegible]  3.806E-16  [illegible]  [illegible]  1.666E-10
[illegible]  [illegible]  [illegible]  2.638E-10  4.635E-16  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  1.914E-10  3.363E-16  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  2.493E-1[illegible]  4.381E-16  [illegible]  [illegible]  9.661E-11
[illegible]  [illegible]  [illegible]  [illegible]  4.694E-16  [illegible]  [illegible]  1.200E-10
[illegible]  [illegible]  [illegible]  2.859E-10  5.023E-16-1.[illegible]  [illegible]  1.220E-10
[illegible]  [illegible]  [illegible]  1.896E-10  3.331E-16-1.[illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  2.476E-10  4.351E-16  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  2.638E-10  4.635E-16  [illegible]  [illegible]  [illegible]
[illegible]
STOMACH    [illegible]  [illegible]  1.410E-11  5.581E-16  [illegible]  [illegible]  4.980E-10
SMALL IN   [illegible]  [illegible]  [illegible]  5.010E-16  [illegible]  [illegible]  [illegible]
[illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
RED MARR   [illegible]  [illegible]  [illegible]  6.152E-16  [illegible]  [illegible]  [illegible]
THYROID    [illegible]  [illegible]  1.919E-11  7.579E-16-1[illegible]  4.145E-12  1.813E-12
LOWER LI   [illegible]  [illegible]  1.379E-11  5.454E-16  [illegible]  [illegible]  [illegible]
BONE SUR   [illegible]  [illegible]  [illegible]  6.944E-16-[illegible]  [illegible]  6.893E-12
BREAST     [illegible]  [illegible]  1.893E-11  [illegible]  [illegible]  [illegible]  [illegible]
TESTES     [illegible]  [illegible]  2.045E-11  8.054E-16-[illegible]  [illegible]  [illegible]
OVARIES    [illegible]  8.994E-12  1.365E-11  5.422E-16-[illegible]  [illegible]  [illegible]
REMAINDR   [illegible]  1.210E-11  1.848E-11  7.292E-16  [illegible]  [illegible]  2.868E-10
THYROID    [illegible]  1.258E-11  1.919E-11  [illegible]  [illegible]  4.145E-12  [illegible]
RU [illegible]
STOMACH    [illegible]  [illegible]  [illegible]  1.452E-16  [illegible]  [illegible]  [illegible]
SMALL IN   [illegible]  [illegible]  [illegible]  1.310E-16  [illegible]  [illegible]  [illegible]
LUNG       [illegible]  [illegible]  9.469E-11  1.576E-16  [illegible]  [illegible]  [illegible]
RED MARR   [illegible]  4.622E-12  9.660E-11  1.608E-16  [illegible]  [illegible]  [illegible]
THYROID    [illegible]  [illegible]  1.181E-10  1.966E-16  [illegible]  [illegible]  1.432E-09
LOWER LI   [illegible]  4.093E-12  8.555E-11  1.424E-16  [illegible]  [illegible]  [illegible]
BONE SUR   [illegible]  [illegible]  1.084E-10  1.804E-16-[illegible]  1.620E-09  1.445E-09
BREAST     [illegible]  [illegible]  1.160E-10  1.931E-16-[illegible]  [illegible]  [illegible]
TESTES     [illegible]  [illegible]  1.265E-10  2.106E-16-1[illegible]  [illegible]  1.474E-09
OVARIES    [illegible]  [illegible]  8.517E-11  1.417E-16-1[illegible]  [illegible]  1.656E-09
REMAINDR   [illegible]  [illegible]  1.885E-10  3.137E-16-1[illegible]  [illegible]  [illegible]
THYROID    [illegible]  [illegible]  1.181E-10  1.966E-16  [illegible]  [illegible]  1.432E-09
RH [illegible]
STOMACH    [illegible]  1.488E-12  9.870E-12  5.581E-17  [illegible]  7.262E-11  1.946E-10
SMALL IN   [illegible]  1.327E-12  8.604E-12  4.978E-17  [illegible]  1.578E-10  4.427E-10
LUNG       2.841E-15  1.631E-12  1.082E-11  6.120E-17  [illegible]  9.569E-10  3.847E-12
RED MARR   [illegible]  1.682E-12  1.116E-11  6.310E-17  [illegible]  7.746E-12  1.463E-11
THYROID    [illegible]  2.071E-12  1.374E-11  7.769E-17-1.000E+00  2.878E-12  2.894E-12
LOWER LI   [illegible]  1.462E-12  9.701E-12  5.486E-17  [illegible]  1.347E-09  3.781E-09
BONE SUR   [illegible]  2.088E-12  1.385E-11  7.832E-17-1.000E+00  4.441E-12  [illegible]
BREAST     [illegible]  2.189E-12  1.452E-11  8.213E-17-1.000E+00  [illegible]  8.959E-12
TESTES     [illegible]  2.206E-12  1.464E-11  8.276E-17-[illegible]  [illegible]  [illegible]
OVARIES    [illegible]  [illegible]  9.197E-12  5.200E-17-[illegible]  [illegible]  5.798E-11
REMAINDR   [illegible]  [illegible]  1.335E-11  7.546E-17-[illegible]  [illegible]  3.980E-10
THYROID    [illegible]  2.071E-12  1.374E-11  7.769E-17  [illegible]  [illegible]  2.894E-12
SR [illegible]
STOMACH    [illegible]  [illegible]  1.623E-10  4.693E-16  [illegible]  [illegible]  [illegible]
SMALL IN   [illegible]  [illegible]  1.459E-10  4.217E-16  [illegible]  [illegible]  [illegible]
LUNG       [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
RED MARR   [illegible]  [illegible]  [illegible]  5.200E-16  [illegible]  [illegible]  [illegible]
THYROID    [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]  [illegible]
```

```
[illegible]
[illegible]
BREA[illegible]    [illegible]
TE[illegible]    [illegible]
OVARIE[illegible]    [illegible] 4.[illegible]
ELSEWHE[illegible]    [illegible] 14 [illegible]
THYROID[illegible]    [illegible] 4 [illegible]4E 11 [illegible] 4E 16 2.44[illegible] .44[illegible] 4 [illegible]41E-1[illegible]
SR-[illegible]
STOMACH    [illegible]14[illegible] 14 [illegible] 11 [illegible] 11 [illegible] 16 [illegible] 4 E [illegible]
SMALL IN   4.[illegible] 14 1.[illegible]E 11 [illegible] 11 [illegible] 16 [illegible] 4 [illegible]
LUNGS      [illegible] 14 1.[illegible]E 11 [illegible] 11 [illegible] 1 8.[illegible]4[illegible]
RED MARR   [illegible]E 14 1.81[illegible]E 11 [illegible]4[illegible] 11 [illegible]
THYROID    [illegible]4E 14 [illegible] 11 [illegible]E-11 [illegible]4E 1[illegible] 4[illegible]4E [illegible]
LOWER LI   [illegible] 14 1.[illegible].4E 11 2.[illegible]E 11 [illegible] 16 [illegible]
BONE SUR   [illegible].4[illegible] 14 1.9[illegible]E 11 [illegible]4E 11 1.1[illegible] 1[illegible] 4[illegible]
BREAST     [illegible] 14 [illegible]14[illegible]E 11 [illegible] 11 1.[illegible] 1[illegible]
TESTES     [illegible] 14 [illegible] 1[illegible] [illegible]-1[illegible]E-11 1.4[illegible] 1[illegible] 4.[illegible]
OVARIES    [illegible] 14 1.[illegible]8E 11 2.251E 1[illegible] [illegible] 4[illegible] 4E
ELSEWHERE  [illegible] 14 [illegible]129E-11 2.498E-11 1.[illegible] 4 [illegible] 4[illegible]
THYROID    [illegible]4E 14 [illegible] 1 [illegible]13.E-11 1.[illegible]4E 1[illegible] 4[illegible]
IF[illegible]
STOMACH    1.[illegible]E 16 [illegible]9E 14 1.[illegible]E-1[illegible] [illegible].4[illegible] 1[illegible] 4 [illegible] 4. [illegible]
SMALL IN   1.46.E 16 6.[illegible]E-14 1.[illegible]E-13 4.[illegible]2E 1[illegible]
LUNGS      1.[illegible]E 16 8.19[illegible]E 14 1.83[illegible]E-1[illegible]
RED MARR   1.8[illegible]E 16 8.4[illegible]E-14 1.8[illegible]E 13
THYROID    2.4[illegible]E 16 1.[illegible]E-13 2.310E-1[illegible] 4
LOWER LI   1.[illegible]E 16 [illegible]E 14 1.[illegible]4E-1[illegible]
BONE SUR   2.191E 16 1.06[illegible]E 1[illegible] 2.24[illegible]E-1[illegible] 4.[illegible]
BREAST     2.[illegible]E 16 1.0[illegible]E-1[illegible] 2.[illegible]E 1[illegible] 4
TESTES     2.41[illegible]E 16 1.1[illegible]9E-1[illegible] 2.4[illegible]E 1[illegible]
OVARIES    1.5[illegible]E 16 [illegible]E 13 1.66[illegible]E 1[illegible]
ELSEWHERE  0.[illegible]E+0[illegible] 0.000E+0[illegible] 0.0[illegible]E+[illegible]
THYROID    2.24[illegible]E 16 1.[illegible]E 1[illegible] [illegible]E 1[illegible] 4
TE-1[illegible]M
STOMACH    4.[illegible]E 1[illegible] [illegible]4E-14 2.9[illegible]E 1[illegible] 1.[illegible]
SMALL IN   [illegible]E 1[illegible] [illegible]E 14 2.40[illegible]E [illegible]
LUNGS      6.24[illegible] 3.[illegible]E 13 [illegible]E 1[illegible]
RED MARR   2.632E 1[illegible] [illegible].643E-14 2.[illegible]E 1[illegible] 4[illegible]
THYROID    1.2[illegible]E 16 1.862E 13 5.6[illegible]E 12
LOWER LI   4.[illegible]9E-1[illegible] [illegible].121E 14 2.[illegible]E 12 1.[illegible]E 1[illegible]
BONE SUR   1.[illegible]9E 16 1.61[illegible]E 13 5.126E 12 4.[illegible]
BREAST     3.[illegible]E 16 4.141E-1[illegible] 1.[illegible]42E 12 1.[illegible]
TESTES     1.8[illegible]E 16 2.688E-13 7.518E-12 8.[illegible] 1[illegible]
OVARIES    4.5[illegible]3E 1[illegible] [illegible]E 14 2.865E 12 1.[illegible] 1[illegible]
ELSEWHERE  1.412E 16 1.[illegible]8E 13 3.61[illegible]E 12 [illegible] 1[illegible]
THYROID    1.2[illegible]E 16 [illegible]E-13 5.663E 12 [illegible] 1[illegible]
TE-129
STOMACH    1.[illegible]4.E 1[illegible] [illegible]E 1[illegible] 2.29[illegible]E-1[illegible] [illegible] 1
SMALL IN   1.[illegible]E 1[illegible] [illegible]E-1[illegible] 2.044E-1[illegible] [illegible] 1
LUNGS      2.[illegible]E 1[illegible] 2.482E 13 2.503E 13 4.1[illegible]4[illegible] 1
RED MARR   2.[illegible]42E 1[illegible] 2.[illegible]1E 13 2.522E 1[illegible] 4.1[illegible] 1
THYROID    2.[illegible]E 1[illegible] 3.145E 13 3.172E 1[illegible] [illegible]48E 1
LOWER LI   1.8[illegible]4E 1[illegible] 2.21[illegible]E-13 2.235E 1[illegible] 4 [illegible] 1
BONE SUR   2.[illegible]E 1[illegible] [illegible]6E 1[illegible] 2.981E 1[illegible] 4 [illegible] 1
BREAST     2.[illegible]E 1[illegible] 3.334E 1[illegible] 3.363E 1[illegible] [illegible] 1
TESTES     2.[illegible]E 1[illegible] [illegible]4.[illegible]9E 1[illegible] 4.456E 1[illegible] [illegible]4[illegible] 1
OVARIES    1.[illegible]82E 1[illegible] 2.198E 13 2.216E 1[illegible] [illegible] 1
ELSEWHERE  [illegible]E 1[illegible] [illegible]E 1[illegible] 5.5[illegible]2E 1[illegible] [illegible]4[illegible]E 1
THYROID    [illegible]E 1[illegible] 3.145E-13 3.1[illegible]E 1[illegible] [illegible]4E 1
TE-1[illegible]M
STOMACH    [illegible] 2.[illegible]40E 1[illegible] 2.[illegible]E 11 [illegible]
SMALL IN   [illegible] 2.[illegible]4E 1[illegible] 2.4[illegible]E 11 [illegible]
LUNGS      [illegible] 2.96[illegible]E 11 [illegible]
RED MARR   [illegible]44E 1[illegible] [illegible]94 E 1[illegible] [illegible]
THYROID    [illegible]
LOWER LI   [illegible]
```

BONE SUR	1.443E [illegible]	[illegible]	5.446E 11	3.022E-1[illegible]	[illegible]	[illegible].149E 09	8.103E 09
BREAST	[illegible]	[illegible]	4.203E 11	3.869E-1[illegible]	1.90[illegible]E	1.684E 1[illegible]	1.657E 10
TESTES	1.754E [illegible]	1.942E 12	4.207E 11	3.773E-1[illegible]	1.00[illegible]E+0[illegible]	1.399E 10	1.604E-10
OVARIES	1.138E [illegible]	1.209E 12	2.649E 11	2.318E-1[illegible]	1.000E+0[illegible]	1.783E 10	2.407E-10
EDEWBODY	1.644E [illegible]	2.813E 1[illegible]	6.196E 11	5.035E-1[illegible]	1.000E+00	6.466E 09	2.685E-09
THYROIDH	1.613E [illegible]	[illegible]	3.829E 11	3.393E-1[illegible]	[illegible]	1.555E 1[illegible]	1.566E 10
TE 129M							
STOMACH	5.52[illegible]E 14	2.[illegible]E 11	1.[illegible]E 10	1.048E-1[illegible]	[illegible]E 1[illegible]	2.[illegible]8E 1[illegible]	6.617E-10
SMALL IN	5.016E 14	2.504E 11	1.594E 10	9.528E-1[illegible]	3.920E-10	4.928E-1[illegible]	1.600E-09
LUNGS	5.966E 14	2.979E 11	1.845E 10	1.133E-1[illegible]	1.244E 09	[illegible].231E 09	6.208E-11
RED MARR	6.028E 14	3.011E 11	1.918E 10	1.145E-1	9.441E 11	1.386E 10	2.393E-10
THYROID	[illegible].492E 14	3.[illegible]E-11	2.[illegible]E 10	1.430E-1[illegible]	[illegible]E-0[illegible]	5.280E 08	3.908E-08
LOWER LI	5.424F 14	2.[illegible]E 11	1.[illegible]E 10	1.031E-1[illegible]	1.333E 09	2.367E 09	8.102F-09
BONE SUR	6.713E 14	3.366E 11	2.1[illegible]E 10	1.281E-1[illegible]	1.000E+0[illegible]	[illegible].608E 10	3.698E-10
BREAST	7.245E 14	3.646E 11	2.332E 10	1.387E-1[illegible]	1.000E+0[illegible]	9.204E-11	1.342E-10
TESTES	7.928F 14	3.970E 11	2.5[illegible]9E 10	1.511E-1[illegible]	1.00[illegible]E+0	4.542E-11	9.816E-11
OVARIES	5.350E 14	2.671E 11	1.695E-10	1.016E-1[illegible]	1.000E-0	2.335E-1[illegible]	7.370F 10
EDEWBODY	6.458E 14	3.243F 11	2.0[illegible]0E 10	1.227E-1[illegible]	1.000F+0	1.634E-09	2.355E 09
THYROIDH	7.492E 14	3.[illegible]7E 11	2.390E-10	1.430E-1[illegible]	6.429E-0[illegible]	5.285F 08	3.908E 08
TE 132							
STOMACH	6.976E-15	3.219E 1[illegible]	5.4[illegible]1E-10	1.551E-1[illegible]	[illegible]2F 1[illegible]	4.076E-10	4.855E-10
SMALL IN	6.1[illegible]1F 1[illegible]	2.912E-1[illegible]	4.9[illegible]7F 10	1.364E-1[illegible]	[illegible]E 1[illegible]	5.081E 10	7.662F-10
LUNGS	[illegible]E-15	3.493E 11	5.930E 10	1.7[illegible]2E-1[illegible]	[illegible].740F 1[illegible]	1.641E-09	2.937E-10
RED MARR	7.642E-15	3.531E-11	6.006F 10	1.681E-1[illegible]	[illegible]	3.951F-10	4.064F 10
THYROID	1.021E 14	4.414F 11	7.469E 10	2.308E-1[illegible]	[illegible]F+0[illegible]	[illegible].284E-08	4.695E-08
LOWER LI	6.849E-15	3.154F-11	5.362E 10	1.519E 1[illegible]	8.[illegible]E 1[illegible]	1.574E 09	3.764E-09
BONE SUR	1.075E 14	4.624E 11	6.752E 10	2.419E-1[illegible]	[illegible]F+0[illegible]	[illegible].249F-10	8.537E-10
BREAST	1.164F 14	4.369F 11	7.321E 10	2.686E-1[illegible]	[illegible]F+[illegible]	3.312E 10	3.126E-10
TESTES	1.[illegible]8E-14	4.683E 11	[illegible].922E 10	2.461E 1[illegible]	[illegible]F-[illegible]	[illegible].374F 10	3.256E 10
OVARIES	6.247E-1[illegible]	3.114E-11	5.313E 10	1.395E 1[illegible]	[illegible]E-0[illegible]	3.866E-10	5.058F-10
EDEWBODY	9.502E-1[illegible]	4.131E-11	6.992E-10	2.153E-1[illegible]	[illegible]F+0[illegible]	2.229E-09	2.132E-09
THYROIDH	1.021E 14	4.414E-11	7.469E 1[illegible]	2.308E-1[illegible]	[illegible]F 08	[illegible].284F-08	4.695E-08
I 131							
STOMACH	1.291E 14	7.742E-12	1.748E 10	2.727E-1[illegible]	[illegible]E 11	[illegible].516E-11	3.059E-10
SMALL IN	1.154F 14	6.914F-12	1.196E-1[illegible]	2.435E-1[illegible]	1.572F 11	[illegible]42E 11	4.471E 11
LUNGS	1.408F 14	8.444E 12	1.951F 10	2.974E-1[illegible]	4.616F 11	6.565E-10	1.016E-10
RED MARR	1.449E 14	8.678E 12	1.388E 10	3.057E 1[illegible]	[illegible]	6.26[illegible]E-11	9.444F-11
THYROID	1.776E 14	1.062F-11	1.699E 10	3.742E 1[illegible]	[illegible]	[illegible].911F 0[illegible]	4.753E 07
LOWER LI	1.261F 14	[illegible].189E 12	1.114E 10	2.673E-1[illegible]	1.4[illegible]F 11	2.593E 11	4.239E 11
BONE SUR	1.[illegible]F 14	1.044E-11	1.671E-10	3.678E-1[illegible]	[illegible]E-	[illegible]18E-11	8.699F 11
BREAST	1.83[illegible]E 14	1.098E-11	1.[illegible]7E 10	3.869E-1[illegible]	[illegible]E+0[illegible]	[illegible].861F 11	1.209E 10
TESTES	1.899F 14	1.143F 11	1.829E-1[illegible]	4.027E-1[illegible]	[illegible]E-0[illegible]	2.312E 11	3.777E-11
OVARIES	1.224E 14	7.337E-12	1.174E-10	2.584E-1[illegible]	1.000F+00	[illegible].533E-11	4.067E-11
EDEWBODY	1.66[illegible]E 14	1.009E 11	1.614E 10	3.553E-1[illegible]	1.00[illegible]F+0[illegible]	6.872E 09	1.434E-08
THYROIDH	1.776E 14	1.062E 11	1.699E 10	3.742E-1[illegible]	[illegible]F 08	6.694E 09	1.583E-07
I 132							
STOMACH	8.[illegible]F 14	1.738E 11	1.949E 11	1.598E-1	[illegible]F 11	[illegible].896E 11	6.320E 10
SMALL IN	[illegible]4[illegible] 14	1.[illegible]9E 11	1.[illegible]E 11	1.452E-1[illegible]	1.[illegible]4[illegible]F 11	1.245E 11	3.160E 11
LUNGS	8.9[illegible]4E 14	1.879F 11	2.065E 11	1.728E-1[illegible]	[illegible]	[illegible]E 10	2.643E 11
RED MARR	9.132E 14	1.910E 11	2.099E 11	1.757E-1	[illegible]4[illegible]F 11	1.4[illegible]F 11	2.450E 11
THYROID	1.126E 1[illegible]	2.352F-11	2.584E 11	2.163E-1[illegible]	[illegible]	[illegible]E 09	3.842E-09
LOWER LI	8.149E-14	1.703E 11	1.871E 11	1.566E [illegible]	[illegible]E 11	[illegible]F-11	2.750E-11
BONE SUR	9.989F-14	2.0[illegible]9E 11	2.296E 11	1.922E-1[illegible]	[illegible]F+0[illegible]	[illegible].242E 11	2.190E-11
BREAST	1.078E 1[illegible]	2.259E 11	2.481E-11	2.077E-1[illegible]	[illegible]E-0[illegible]	1.412F 11	2.511E-11
TESTES	1.192E-1[illegible]	2.493F 11	2.[illegible]49E 11	2.293E-1[illegible]	[illegible]F+0[illegible]	4.901F 12	2.220E-11
OVARIES	8.118F 14	1.700E-11	1.868E 11	1.563E-1[illegible]	1.00[illegible]E+0[illegible]	4.900F 12	2.340E-11
EDEWBODY	1.0[illegible]E 1[illegible]	2.203E 11	2.420E 11	2.025E-1[illegible]	[illegible]F+0[illegible]	1.020E 1[illegible]	1.814E-10
THYROIDH	1.1[illegible]E 1[illegible]	2.352E 11	2.584E 11	2.163E [illegible]	[illegible]44[illegible]F 1[illegible]	[illegible]48E 1[illegible]	1.279E-09
I 133							
STOMACH	2.1[illegible]E 14	1.[illegible]6E 11	4.[illegible]20F 11	4.249E-1[illegible]	[illegible]	[illegible].046F 1[illegible]	5.533E-10
SMALL IN	1.[illegible]E 14	4.[illegible]3F-12	4.2[illegible]2E 11	3.837E [illegible]	[illegible]E 11	[illegible]E 11	4.041E 11
LUNGS	2.[illegible]F 14	1.[illegible]2F 11	5.158F 11	4.610E [illegible]	[illegible]	[illegible]E 1[illegible]	4.518E 11
RED MARR	[illegible] 14	1.[illegible]F 11	[illegible]F 11	4.[illegible]5E [illegible]	[illegible]	[illegible]F 11	4.[illegible]E-11
THYROID	[illegible]	1.462F 11	6.492F 11	[illegible]E	[illegible]	[illegible]	9.102E 08
LOWER LI	[illegible] 14	1.[illegible]F 11	4.[illegible]E 11	4.1[illegible]4E [illegible]	[illegible]	[illegible]4[illegible] 1[illegible]	3.884F 11
BONE SUR	[illegible] 14	1.[illegible]F 11	6.[illegible]41F 11	[illegible]	[illegible]	[illegible]	4.[illegible] 11

```
BREAST    [illegible]
TESTES    [illegible] 14 [illegible] 6.[illegible]E 11 6.[illegible]E 16 [illegible]
OVARIES   [illegible] 14 [illegible]E 11 4.[illegible]02E 11 4.1[illegible]4E 16 1 [illegible]
EDEWBODY  [illegible] 14 [illegible] 11 6.312E 11 5.[illegible]E 16 1 [illegible]
THYROIDH  [illegible] 14 [illegible]E 11 6.49[illegible] 11 [illegible]1E 16 4 [illegible]
I-134
STOMACH   9.[illegible] 14 [illegible] 11 8.24[illegible]E 11 1.812E 15 [illegible]
SMALL IN  8.[illegible]4[illegible]E 14 [illegible]4E 11 [illegible]E 11 1.6[illegible]E 15 [illegible]
LUNGS     1.[illegible]4[illegible]E 14 8.8[illegible]E 11 8.9[illegible]E 11 1.9[illegible]E 15 1.4[illegible]
RED MARR  1.[illegible]E 14 [illegible]E 11 9.[illegible]E 11 1.[illegible]2E 15 [illegible]
THYROID   1.[illegible]E 14 [illegible]114E 11 1.110E 11 2.4[illegible]1E 15 1[illegible]
LOWER LI  9.[illegible]E 14 8.1[illegible]E 11 8.11[illegible]E 11 1.[illegible]82E 15 4.[illegible]
BONE SUR  1.14[illegible]E 14 [illegible]E 11 [illegible]8 4E 11 [illegible]53E 15 1 [illegible]
BREAST    1.[illegible]E 14 1.[illegible]1E 11 1.06[illegible]E 11 2.[illegible]84E 15 1 [illegible]
TESTES    1.[illegible]E 14 1.[illegible]E 11 1.1[illegible]E 11 1.[illegible]84E 15 1 [illegible]
OVARIES   9.41[illegible] 14 [illegible]8E 11 8.04[illegible]E 11 1.[illegible]6E 15 1 [illegible]
EDEWBODY  1.[illegible]4E 14 [illegible]4.[illegible]E 11 1.044E 11 2.[illegible]92E 15 1 [illegible]
THYROIDH  1.[illegible]E 14 [illegible]114E 11 1.110E 11 2.4[illegible]1E 15 [illegible]
I-135
STOMACH   6.[illegible]E 14 [illegible]E 11 4.26[illegible]E 11 1.0[illegible]E 15 9.[illegible]
SMALL IN  [illegible]E 14 [illegible]E 11 [illegible].951E 11 9.932E 16 1.[illegible]
LUNGS     6.[illegible]E 14 [illegible]E 11 4.[illegible]E 11 1.1[illegible]4E 15 4.[illegible]
RED MARR  6.[illegible]E 14 [illegible]E 11 4.[illegible]E 11 1.1[illegible]E 15 [illegible]
THYROID   8.[illegible]E 14 [illegible]E 11 [illegible]E 11 1.4[illegible]E 15 1 [illegible]
LOWER LI  6.[illegible]E 14 [illegible]4E 11 4.[illegible]E 11 1.[illegible]E 15 1 [illegible]
BONE SUR  [illegible]E 14 [illegible]E 11 [illegible]E 11 1.4[illegible]E 15 1 [illegible]
BREAST    [illegible]E 14 [illegible]E 11 [illegible]E 11 1.[illegible]E 15 [illegible]
TESTES    8.[illegible]E 14 [illegible]4E 11 6.[illegible]E 11 1.[illegible]14E 15 [illegible]
OVARIES   5.[illegible]E 14 [illegible]E 11 4.[illegible]E 11 1.[illegible]E 15 [illegible]
EDEWBODY  [illegible]E 14 2.[illegible]E 11 [illegible]E 11 1.[illegible]E 15 [illegible]
THYROIDH  8.[illegible]E 14 [illegible]E 11 [illegible]E 11 1.4[illegible]E 15 [illegible]
XE-133
STOMACH   9.4[illegible]E 1[illegible] [illegible]E+00 0.[illegible]E+00 0.[illegible]E+00 [illegible]
SMALL IN  7.9[illegible]E 1[illegible] [illegible]E+00 0.[illegible]E+00 0.[illegible]E+00 1 [illegible]
LUNGS     1.11[illegible]E 1[illegible] [illegible]E+00 0.[illegible]E+00 0.[illegible]E+00 [illegible]
RED MARR  7.2[illegible]E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 1 [illegible]
THYROID   1.[illegible]E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 1 [illegible]
LOWER LI  8.[illegible]E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 1 [illegible]
BONE SUR  1.[illegible]E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 1 [illegible]
BREAST    2.[illegible]E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 1 [illegible]
TESTES    1.814E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 1 [illegible]
OVARIES   8.[illegible]4[illegible]E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 1 [illegible]
EDEWBODY  1.[illegible]1E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 1 [illegible]
THYROIDH  1.[illegible]19E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 1 [illegible]
XE-135
STOMACH   8.[illegible]E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 2 [illegible]
SMALL IN  7.[illegible]E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 2 [illegible]
LUNGS     9.[illegible]E 1[illegible] [illegible]E+00 0.000E+00 0.000E+00 [illegible]
RED MARR  9.228E 1[illegible] 0.000E+00 0.000E+00 0.000E+00 2 [illegible]
THYROID   1.16[illegible]E 14 0.000E+00 0.000E+00 0.000E+00 1 [illegible]
LOWER LI  8.118E 1[illegible] 0.000E+00 0.000E+00 0.000E+00 2 4 [illegible]
BONE SUR  1.202E 14 0.000E+00 0.000E+00 0.000E+00 1 [illegible]
BREAST    1.2[illegible]3E 14 0.000E+00 0.000E+00 0.000E+00 1 [illegible]
TESTES    1.22[illegible]E 14 0.000E+00 0.000E+00 0.000E+00 1 [illegible]
OVARIES   7.51[illegible]E 1[illegible] 0.000E+00 0.000E+00 0.000E+00 1 [illegible]
EDEWBODY  1.1[illegible]3E 14 0.000E+00 0.000E+00 0.000E+00 1 [illegible]
THYROIDH  1.16[illegible]E 14 0.000E+00 0.000E+00 0.000E+00 2 [illegible]
CS-134
STOMACH   5.[illegible]E 14 3.1[illegible]9E 11 6.61[illegible]E 10 1.09[illegible]E 15 3 [illegible]
SMALL IN  5.04[illegible]E 14 2.858E 11 [illegible].984E 10 9.92[illegible]E 16 3 [illegible]
LUNGS     6.[illegible]E 14 3.424E 11 7.169E 10 1.189E 15 1 [illegible]
RED MARR  6.[illegible]E 14 3.4[illegible]8E 11 7.303E 10 1.211E 15 9 [illegible]
THYROID   [illegible]9E 14 4.[illegible]E 11 8.986E 10 1.49[illegible]E 15 1 [illegible]
LOWER LI  5.4[illegible]4[illegible] 14 [illegible]E 11 6.481E 10 1.[illegible]E 15 3 [illegible]
BONE SUR  6.[illegible]E 14 4.[illegible]44E 11 8.049E 10 1.3[illegible]5E 15 1 [illegible]
BREAST    [illegible]E 14 4.[illegible]6E 11 8.[illegible]1E 10 1.43[illegible]E 15 1 [illegible]
```

```
TESTES    [illegible]E-14 4.[illegible] [illegible] [illegible] [illegible] [illegible] [illegible]
OVARIES   [illegible]4.4E-14 [illegible] [illegible] 1.[illegible]E-15 [illegible] [illegible] [illegible]
EDEWBODY  [illegible]E-14 [illegible]E-11 8.[illegible]4E-10 1.3[illegible]E-15 1.000E+[illegible] [illegible]E-08 [illegible]E-08
THYROIDH  [illegible]E-14 4.[illegible]E-11 8.[illegible]E-10 1.4[illegible]E-15 4.[illegible]36E-1[illegible] [illegible] [illegible]4E-08
[illegible]
STOMACH   [illegible]4E-14 4.[illegible]E-11 [illegible]E-10 1.4[illegible]E-1[illegible] [illegible] [illegible] [illegible]4E-09
SMALL IN  [illegible]E-14 [illegible]84E-11 6.88[illegible]E-10 1.[illegible]E-15 [illegible] [illegible]4E-0[illegible] [illegible]E-0[illegible]
LUNGS     [illegible]4[illegible]E-14 4.[illegible]8E-11 8.16[illegible]E-10 1.[illegible]14E-15 [illegible]04[illegible]E-1[illegible] [illegible] [illegible]61[illegible]E-09
RED MARR  [illegible]E-14 4.6[illegible]E-11 8.24[illegible]E-10 1.[illegible]E-15 [illegible]018E-1[illegible] [illegible] 2.9[illegible]2E-09
THYROID   1.[illegible]E-1[illegible] [illegible]84[illegible]E-11 1.03[illegible]E-09 2.042E-15 1.000E+[illegible] [illegible]E-09 2.[illegible]36E-09
LOWER LI  [illegible]E-14 4.191E-11 [illegible].42[illegible]E-10 1.466E-15 [illegible].61[illegible]E-1[illegible] [illegible]E-09 [illegible].404E-09
BONE SUR  [illegible].4[illegible]E-14 [illegible]1[illegible]E-11 9.1[illegible]E-10 1.814E-15 1.000E+[illegible] [illegible] [illegible]E-09
BREAST    [illegible]E-14 [illegible]6[illegible]4E-11 9.[illegible]0E-10 1.96[illegible]E-15 1.000E+[illegible] [illegible]E-09 2.6[illegible]E-09
TESTES    [illegible]12[illegible]E-14 [illegible].129E-11 1.086E-09 [illegible]14[illegible]E-15 1.000E+[illegible] 1.[illegible]E-09 3.[illegible]4E-09
OVARIES   [illegible]64[illegible]E-14 4.146E-11 7.347E-10 1.452E-15-1.000E+[illegible] 1.[illegible]E-09 2.699E-09
EDEWBODY  [illegible]E-14 [illegible]E-11 9.4[illegible]E-10 1.86[illegible]E-15 1.00[illegible]E+[illegible] 1.4[illegible]E-09 [illegible]E-09
THYROIDH  1.[illegible]E-14 [illegible].83[illegible]E-11 1.0[illegible]3E-09 2.042E-15 [illegible].58[illegible]E-1[illegible] 1.[illegible]E-09 2.[illegible]36E-09
CS 13[illegible]
STOMACH   [illegible]E-14 1.149E-11 2.4[illegible]E-10 4.0[illegible]E-16 2.2[illegible]E-1[illegible] 8.[illegible]E-09 1.390E-08
SMALL IN  1.812E-14 1.03[illegible]E-11 2.194E-10 3.670E-16 1.956E-1[illegible] 9.[illegible]43E-09 1.436E-08
LUNGS     [illegible]78E-14 1.243E-11 2.630E-10 4.350E-16 9.53[illegible]E-1[illegible] 8.[illegible]49E-09 1.266E-08
RED MARR  2.217E-14 1.260E-11 2.666E-10 4.410E-16 5.62[illegible]E-1[illegible] 8.295E-09 1.316E-08
THYROID   [illegible]30E-14 1.560E-11 3.301E-10 5.460E-16-1.000E+[illegible] [illegible]919E-09 1.257E-08
LOWER LI  1.968E-14 1.125E-11 2.376E-10 3.930E-16 1.95[illegible]E-1[illegible] [illegible]6[illegible]3E-09 1.439E-08
BONE SUR  2.46[illegible]E-14 1.40[illegible]E-11 2.974E-10 4.9[illegible]0E-16-1.00[illegible]E+[illegible] [illegible]933E-09 1.2[illegible]8E-08
BREAST    2.64[illegible]E-14 1.509E-11 3.192E-10 [illegible]28[illegible]E-16 1.00[illegible]E+[illegible] [illegible]8[illegible]E-09 1.240E-08
TESTES    1.904E-14 1.6[illegible]5E-11 3.500E-10 [illegible]79[illegible]E-16-1.00[illegible]E+[illegible] [illegible]7[illegible]E-09 1.390E-08
OVARIES   1.[illegible]4E-14 1.12[illegible]E-11 2.376E-10 [illegible]E-16 1.00[illegible]E+[illegible] [illegible]10[illegible]E-09 1.286E-08
EDEWBODY  [illegible]2[illegible]E-14 1.45[illegible]E-11 3.085E-10 5.104E-16 1.00[illegible]E+[illegible] 8.629E-09 1.355E-08
THYROIDH  2.[illegible]30E-14 1.560E-11 3.301E-10 5.460E-16 2.96[illegible]E-1[illegible] [illegible]919E-09 1.257E-08
BA 1[illegible]
STOMACH   1.157E-15 1.742E-13 1.775E-13 2.467E-17 9.184E-11 9.184E-11 6.880E-10
SMALL IN  1.024E-15 1.539E-13 1.567E-13 2.178E-17 7.42[illegible]E-11 [illegible].425E-11 5.560E-10
LUNGS     1.278E-15 1.928E-13 1.964E-13 2.730E-17 2.52[illegible]E-10 2.[illegible]29E-10 4.450E-13
RED MARR  1.227E-15 1.841E-13 1.875E-13 2.60[illegible]E-17 4.351E-12 4.351E-12 9.610E-13
THYROID   1.709E-15 2.598E-13 2.646E-13 3.678E-17 1.00[illegible]E+00 2.905E-12 3.210E-13
LOWER LI  1.138E-15 1.711E-13 1.743E-13 2.423E-17 1.57[illegible]E-11 1.[illegible]73E-11 1.000E-10
BONE SUR  1.826E-15 2.77[illegible]E-13 2.829E-13 3.932E-17-1.00[illegible]E+[illegible] 4.554E-12 6.40[illegible]E-13
BREAST    1.887E-15 2.911E-13 2.966E-13 4.122E-17-1.00[illegible]E+[illegible] [illegible].047E-12 5.700E-13
TESTES    1.763E-15 2.68[illegible]E-13 2.737E-13 3.805E-17-1.00[illegible]E+[illegible] 2.67[illegible]E-12 3.620E-13
OVARIES   1.034E-15 1.554E-13 1.583E-13 2.201E-17-1.00[illegible]E+[illegible] [illegible]054E-12 1.610E-12
EDEWBODY  2.164E-15 8.125E-13 8.276E-13 1.150E-16-1.00[illegible]E+00 4.686E-11 1.080E-10
THYROIDH  1.709E-15 2.598E-13 2.646E-13 3.678E-17 2.905E-12 2.905E-12 3.210E-13
BA 140
STOMACH   6.405E-15 6.623E-12 5.941E-10 1.332E-16 1.416E-1[illegible] [illegible].561E-10 5.836E-10
SMALL IN  5.708E-15 6.025E-12 5.512E-10 1.189E-16 2.874E-10 [illegible].526E-10 1.691E-09
LUNGS     6.976E-15 [illegible].294E-12 6.438E-10 1.455E-16 9.581E-1[illegible] 1.678E-09 6.920E-11
RED MARR  7.0[illegible]1E-15 [illegible].296E-12 6.525E-10 1.471E-16 4.734E-1[illegible] 1.221E-09 4.219E-10
THYROID   8.752E-15 9.019E-12 7.951E-10 1.842E-16-1.00[illegible]E+00 2.721E-10 5.583E-11
LOWER LI  6.247E-15 6.515E-12 5.891E-10 1.300E-16 2.334E-09 4.364E-09 2.630E-08
BONE SUR  8.340E-15 8.317E-12 7.069E-10 1.754E-16-1.00[illegible]E+00 [illegible].317E-09 5.331E-10
BREAST    8.942E-15 9.129E-12 7.788E-10 1.918E-16-1.00[illegible]E+00 [illegible].025E-10 1.609E-10
TESTES    9.418E-15 9.696E-12 8.495E-10 1.991E-16-1.00[illegible]E+00 [illegible].908E-10 1.467E-10
OVARIES   6.152E-15 6.374E-12 5.705E-10 1.284E-16-1.000E+00 4.480E-10 9.877E-10
EDEWBODY  8.333E-15 8.930E-12 7.628E-10 1.875E-16-1.00[illegible]E+00 1.020E-09 2.545E-09
THYROIDH  8.752E-15 9.019E-12 7.951E-10 1.842E-16 6.83[illegible]E-11 2.721E-10 5.583E-11
LA 14[illegible]
STOMACH   8.657E-14 4.02[illegible]E-11 2.954E-10 1.447E-15 3.5[illegible]E-1[illegible] 4.664E-10 1.086E-09
SMALL IN  8.086E-14 3.754E-11 2.754E-10 1.395E-15 7.48[illegible]E-1[illegible] [illegible]E-10 2.968E-09
LUNGS     9.354E-14 4.354E-11 3.198E-10 1.620E-15 2.04[illegible]E-0[illegible] 4.21[illegible]E-09 4.000E-11
RED MARR  9.481E-14 4.419E-11 3.242E-10 1.643E-15 1.44[illegible]E-1[illegible] [illegible].124E-1[illegible] [illegible].816E-10
THYROID   1.148E-1[illegible] [illegible].366E-11 3.936E-10 1.995E-15 1.0[illegible]E+[illegible] [illegible]E-11 6.386E-12
LOWER LI  8.593E-14 4.[illegible]E-11 2.935E-10 1.487E-15 2.94[illegible] [illegible].4[illegible]E-09 1.750E-08
BONE SUR  1.008E-1[illegible] 4.[illegible]E-11 3.467E-10 1.7[illegible]E-15-1.0[illegible]E+[illegible] [illegible]4[illegible]E-1[illegible] 9.[illegible]E-11
BREAST    [illegible]E-1[illegible] [illegible]21[illegible]E-11 3.824E-10 1.937E-15 1.0[illegible]E+[illegible] [illegible]4[illegible]E-10 1.[illegible]0E-10
TESTES    [illegible]E-1[illegible] [illegible]E-11 4.193E-10 2.128E-15 1.[illegible] [illegible]E-11 [illegible]E-1[illegible]
```

```
OVARIES   [illegible]
EDEWBODY  [illegible]                                1.809E
THYROIDH  [illegible]                                1.995E
LA 14[illegible]
STOMACH   [illegible]
SMALL IN  [illegible]
LUNGS     [illegible]
RED MARR  [illegible]
THYR [illegible]  [illegible]
LOWER LI  [illegible]                                                                  1.448E
BONE SUR  [illegible]
BREAST    [illegible]
TESTES    [illegible]
OVARIES   [illegible]
EDEWBODY  [illegible]
THYROIDH  [illegible]
LA 14[illegible]
STOMACH   [illegible]                     1.744E
SMALL IN  [illegible]
LUNGS     [illegible]
RED MARR  [illegible]                     1.899E
THYR [illegible]  [illegible]  1.849E
LOWER LI  [illegible]
BONE SUR  [illegible]
BREAST    [illegible]
TESTES    [illegible]
OVARIES   [illegible]         1.338E
EDEWBODY  [illegible]         1.810E
THYROIDH  [illegible]
CE 14[illegible]
STOMACH   [illegible]
SMALL IN  [illegible]   4.6[illegible]
LUNGS     [illegible]
RED MARR  [illegible]
THYR [illegible]  [illegible]  8.4[illegible]
LOWER LI  [illegible]                                                       8.641E
BONE SUR  4.[illegible]  [illegible]  9.418E
BREAST    4.[illegible]  [illegible]  9.830E                                1.105E
TESTES    [illegible]  4.864E
OVARIES   [illegible]  4.[illegible]
EDEWBODY  [illegible]  4.364E
THYROIDH  [illegible]  8.403E
CE 143
STOMACH   8.[illegible]  4.[illegible]  1.858E 16  [illegible]  10
SMALL IN  [illegible]  4.[illegible]  1.[illegible]  4.914E 10  1.365E
LUNGS     [illegible]  3.403E 11  2.045E 16  [illegible]  09  3.[illegible]
RED MARR  [illegible]  2.010E 16  [illegible]  11  [illegible]
THYROIDH  1.234E 14  [illegible]  12  4.449E 11  2.673E 16  [illegible]  12  4.[illegible]
LOWER LI  8.498E  [illegible]  1.867E 16  [illegible]  09  1.1[illegible]
BONE SUR  1.19[illegible] 14  [illegible]  4.[illegible]  2.600E 16  [illegible]  11  1.610E 11
BREAST    [illegible] 14  [illegible]  4.81[illegible]  2.89[illegible] 16  [illegible]  11  [illegible]
TESTES    [illegible]  [illegible]  4.[illegible]  [illegible]  16  [illegible]  12  1.5[illegible]
OVARIES   8.[illegible]  4.6[illegible]  [illegible]  16  [illegible]  11  [illegible]
EDEWBODY  [illegible] 14  [illegible]  4.6[illegible]  [illegible]  16  [illegible]  10  1.[illegible]
THYROIDH  1.234E 14  [illegible]  12  4.449E 11  2.6[illegible] 16  [illegible]  12  4.3[illegible]
CE 144
STOMACH   [illegible]  2.00[illegible] 11  3.34[illegible]  [illegible]  09  1.1[illegible]
SMALL IN  [illegible]  4.[illegible]  1.81[illegible] 11  [illegible]  3.[illegible]
LUNGS     1.9[illegible]  [illegible]  6.[illegible]14E
RED MARR  [illegible]  3.4[illegible]
THYR [illegible]  [illegible]  2.88[illegible]  4.81[illegible]
LOWER LI  [illegible]  1.96[illegible]
BONE SUR  [illegible]  4.[illegible]  [illegible]  1.394E
BREAST    [illegible]
TESTES    [illegible]
OVARIES   [illegible]
```

```
[illegible]
[illegible]
[illegible]
[illegible]                                   1.41E [illegible]
[illegible]
NB 94
ST MA [illegible]    4. [illegible]  4. [illegible]    [illegible]  1.41 [illegible]
SMALL IN  [illegible]  4.646E 11 [illegible]
LUNGS     4. [illegible]  [illegible]  1.046E 16 [illegible]
RED MARR  [illegible]
THYR IN   [illegible]  [illegible] 6.868E 11 1.405E 16 [illegible]
LOWER LI  4. [illegible]  4.4 [illegible] 11 9.006E [illegible]
BONE SUR  [illegible]  6.868E 11 1.405E 16 1.00 [illegible]
BREAST    [illegible]  1.5 [illegible] 16 [illegible]
TESTES    [illegible]  1.509E 16 [illegible]
OVARIE    4. [illegible]  4.356E 11 8.971E [illegible]
EDEWB [illegible]  6.847E 11 1.400E 16 1. [illegible]
THYR [illegible]  6.969E 11 1.475E 16 4. [illegible]
NB 95
ST MA [illegible]  1.180E 16 1. [illegible]
SMALL IN  4. [illegible]  1.077E 16 2.41 [illegible]
LUNGS     [illegible]  1.316E 16 9.580 [illegible]
RED MARR  [illegible]  1.208E 16 7.94 [illegible]   4. [illegible]
THYR IN   [illegible]  4. [illegible] 11 1.791E 16 1.00 [illegible]
LOWER LI  [illegible]  1.144E 16 1. [illegible]
BONE SUR  [illegible]  1.982E 16 1. [illegible]
BREAST    [illegible]  7.629E 11 2.198E 16 1.00 [illegible]
TESTES    [illegible]  4.801E 11 1.8 4E 16 1.00 [illegible]
OVARIE    4 [illegible]  2.70 E 11 1.056E 16 1.50 [illegible]
EDEWB [illegible]  4.290E 11 1.66 E 16 1.00 [illegible]
THYR [illegible]  4.590E 11 1.792E 16 4.1 [illegible]
PU 238
STOMA [illegible]  1. [illegible] 14 4.852E 20 2.7 [illegible]
SMALL IN  4. [illegible] 4. [illegible] 16 8.930E [illegible] 1.478E 20 6.38 [illegible]
LUNGS     [illegible]  6.348E 14 1.050E 19 1.4 [illegible]
RED MARR  4. [illegible]  2.34 E 14 3.869E 20 2.5 [illegible] 14
THYR IN   1.46 [illegible]  7.825E 14 1.294E 19 1.00 [illegible] 14
LOWER LI  6. [illegible]  3. 49E 14 6.183E 20 6.6 [illegible]
BONE SUR  [illegible]  1.063E 13 1.75 E 19 1.00 [illegible]
BREAST    [illegible]  2.110E 13 3.488E 18 1.00 [illegible] 4. [illegible] 1.804E [illegible]
TESTE     [illegible]  14 3.913E 13 6.469E 19 1.0 [illegible]
OVARIE    [illegible]  3.6 6E 14 5.961E 20 1.00 [illegible]
EDEWB [illegible]  4 [illegible] 14 4.8 9E 13 .951E 19 1.00 [illegible]
THYROID [illegible]  .4 [illegible]  7.825E 14 1.294E 19 1.4 [illegible] 14
PU 239
STOMA [illegible]  2.9 9E 14 [illegible] 169E 20 [illegible]
SMALL IN  1.4 [illegible]  1.881E 14 3.425E 20 5.9 [illegible]
LUNGS     [illegible]  4.40 E 14 [illegible] 4E 20 1.3 [illegible] 4 [illegible] 14
RED MARR  [illegible]  2.665E 14 4. 88E 20 2.4 [illegible]
THYR [illegible]  14 9.98 E 20 1.0 [illegible] 14
LOWER LI  [illegible]  3.18 [illegible] 14 3.61 E 20 6.1 [illegible]
BONE [illegible]  14 1.26 E 19 1. [illegible]
BREAST    [illegible]  14 8.344E 13 1.380E 18 1. [illegible]
TESTE     [illegible]  13 2.9 E 19 [illegible]
OVARIE    [illegible]
EDEWB     [illegible]  4.4 4E 19 1. [illegible]
```

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]								
STOMACH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SMALL IN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LUNGS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RED MARR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
THYROID	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LOWER LI	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BONE SUR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BREAST	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TESTES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OVARIES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EDEWBODY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
THYROIDH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PU 241								
STOMACH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SMALL IN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LUNGS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RED MARR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
THYROID	[illegible]	1.4[illegible]E 18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LOWER LI	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BONE SUR	[illegible]	1.615E 18	5.9[illegible]0E 16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BREAST	[illegible]	1.866E 18	6.852E 16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TESTES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OVARIES	[illegible]	[illegible]	2.915E-16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EDEWBODY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
THYROIDH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AM 241								
STOMACH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SMALL IN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LUNGS	[illegible]	[illegible]	1.041E-11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RED MARR	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
THYROID	9.418E 16	[illegible]	1.645E-11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LOWER LI	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BONE SUR	[illegible]	[illegible]	1.914E-11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BREAST	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TESTES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OVARIES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EDEWBODY	8.264E 16	[illegible]	[illegible]	2.616E-1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
THYROIDH	[illegible]	[illegible]	1.645E 11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CM 242								
STOMACH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SMALL IN	[illegible]	[illegible]	8.949E-15	1.500E 20	[illegible]	[illegible]	[illegible]	[illegible]
LUNGS	[illegible]	[illegible]	[illegible]	1.230E-1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RED MARR	[illegible]	1.296E-15	2.684E 14	4.503E-20	[illegible]	[illegible]	[illegible]	[illegible]
THYROID	[illegible]	[illegible]	9.48[illegible]E 14	1.592E-1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LOWER LI	[illegible]	2.090E 1[illegible]	4.328E-14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BONE SUR	[illegible]	[illegible]	1.219E 13	2.045E-1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BREAST	[illegible]	[illegible]	2.192E-12	3.678E-1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TESTES	[illegible]	[illegible]	4.498E-13	7.547E-1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OVARIES	[illegible]	[illegible]	[illegible]	7.008E-2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EDEWBODY	[illegible]	2.482E 14	5.139E 13	8.623E 1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
THYROIDH	[illegible]	[illegible]	9.48 E-14	1.592E-1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CM 244								
STOMACH	[illegible]	[illegible]	2.914E-14	4.820E-2	[illegible]	[illegible]	[illegible]	[illegible]
SMALL IN	[illegible]	[illegible]	6.480E-15	1.072E-2	[illegible]	[illegible]	[illegible]	[illegible]
LUNGS	[illegible]	[illegible]	6.404E 14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RED MARR	[illegible]	[illegible]	2.301E 14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
THYROID	[illegible]	[illegible]	8.244E-14	1.364E-1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LOWER LI	[illegible]	[illegible]	[illegible]	6.215E 2	[illegible]	[illegible]	[illegible]	[illegible]
BONE SUR	[illegible]	[illegible]	1.064E-13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BREAST	[illegible]	[illegible]	1.994E 12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TESTES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OVARIES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EDEWBODY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
THYROIDH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

```
MACCS SITE DATA FILE FOR SURRY (JLS, 11/10/88)
SECPOP POP DISTRIBUTION FROM 1980 CENSUS DATA ALTERED [illegible] NRC DATA
 26 SPATIAL INTERVALS
 16 WIND DIRECTIONS
  7 CROP CATEGORIES
  4 WATER PATHWAY ISOTOPES
  2 WATERSHEDS
 59 ECONOMIC REGIONS
SPATIAL DISTANCES
      0.16      0.52        1.21      1.61       2.13    [illegible]    4.[illegible]   4.83
      5.63      8.05       11.27     16.09      20.92    [illegible]   32.19     40.23
     48.28     64.37       80.47    112.65     160.93     241.14     321.8     563.27
    804.67   1609.34
POPULATION
        0.        0.          0.        0.         0.          0         4.         5.
        6.       25.       3341.     7107.      2173.         0.      1305.       474.
     2252.     2945.       5403.    20169.    112004.   3431368.   1355706.   2742710.
   248346.   104331.
        0.        0.          0.        0.         1.         2.         9.        13.
       15.       63.       1667.     3550.      1330.      1272.      4198.      2425.
      515.     9469.       5317.     7120.     13586.    198786.   1058044.  20508438.
  3290082.   830354.
        0.        0.          0.        0.         0.   [illegible] [illegible]     6.
        8.       31.        822.     1752.      4543.      1214.  [illegible]     1296.
     6535.     1775.          0.     8555.     48596.   [illegible] [illegible] [illegible]
   620003.  1169436.
        0.        0.          0.        0.         0.   [illegible]       1.         1.
        2.       11.        543.     1157.      3620.      3622.      5461.        0.
        0.      129.       6679.    11858.         0.   [illegible] [illegible]      0.
        0.        0.
        0.        0.          0.        0.         0.   [illegible] [illegible]      0.
        0.        0.       4798.    10202.     10348.      1541.  [illegible]        0.
        0.      231.       1756.        0.         0.   [illegible] [illegible]      0.
        0.        0.
        0.        0.          0.        0.         0.   [illegible]       1.         1.
        1.        7.       8316.    17684.     16340.   [illegible] [illegible]   4998.
    24195.    80412.       5747.        0.         0.   [illegible] [illegible]      0.
        0.        0.
        0.        0.          0.        0.         0.   [illegible] [illegible] [illegible]
        0.        0.          0.        0.      1722.   [illegible] [illegible] [illegible]
   126203.   372471.      68327.     8599.      6339.   [illegible]       0.         0.
        0.        0.
        0.        0.          0.        0.         0.         0.         2.         2.
        3.       13.        127.      273.      1649.      4571.      5441.      7848.
    11747.    19019.       3360.    36387.     10447.      2249.  [illegible]        0.
        0.        0.
        0.        0.          5.        4.         8.        23.        14.        20.
       23.       93.        301.      650.         0.         0.      1264.      4067.
     1106.    14665.       4071.    18006.     37417.      8599.     81616.         0.
        0.        0.
        0.        0.          0.        0.         0.         0.        19.        25.
       29.      117.         45.      105.         0.       510.       951.      1521.
     1223.    17636.       4926.    30765.     53265.    289674.    216165.    479431.
   280809.  8801784.
        0.        0.          0.        0.         1.         2.        14.        20.
       23.       93.        155.      338.       125.      1079.         0.      1355.
     2765.      154.       5296.    21409.     62228.    523804.    479188.   1538059.
  1526840.  3099458
        0.        0.          0.        0.         1.         1.        14.        20.
       23.       93.        110.      240.      1056.   [illegible]      50.      1396.
      915.     3153.       4132.    16295.     35596.     23071.  [illegible]   294590.
  3957581. 10560254.
        0.        0.          0.        0.         0.         0.        27.        33.
       38.      154.         30.       70.       450.   [illegible]      980.  [illegible]
      155.    66531.      40902.     9557.     44818.    194811.  [illegible]  1492286.
  2250273. 12145932.
```

```
                          0.          0.          0.          0.                      9.
    .          4          31          69          0.        385.        281.        445.
[illegible] [illegible] [illegible] [illegible] 40369. [illegible]    94113.     132898.
[illegible]  [illegible]
                          0.          0.          0.          0.          0.          0.
               1        225.          4.          0.       1020.        609.       2575.
[illegible] [illegible]   9665.     107328.      47585.     154826.     101785.    415263.
[illegible]     966 [illegible]
                          0.          0.          0.          0.         15.         20.
   25          9.       2503.       5326.       3508.       1826        1884.       275.
  4967.       2084.      6270.      10765.     103787.     970679.     472558.    1396088.
 1969210      3968.
LAND FRACTION
1.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.80 1.00 1.00 0.95 0.75 0.70 0.85
1.00 0.85 0.70 0.75 0.55 0.70 0.60 1.00 1.00 0.95
1.00 1.00 1.00 1.00 0.90 0.70 0.40 0.00 0.00 0.45 1.00 0.95 0.40 0.60 1.00 1.00
0.90 0.45 0.60 0.20 0.50 0.50 0.30 0.25 0.50 0.60
1.00 1.00 1.00 1.00 1.00 1.00 0.00 0.00 0.00 0.05 1.00 1.00 0.20 1.00 0.70 0.30
0.85 0.20 0.00 0.20 0.00 0.00 0.00 0.00 0.00 0.00
1.00 1.00 1.00 1.00 1.00 0.80 0.10 0.00 0.00 0.00 1.00 1.00 0.75 0.30 0.40 0.00
0.15 [illegible] 0.45 0.30 0.00 0.00 0.00 0.00 0.00 0.00
1.00 1.00 1.00 1.00 1.00 0.60 0.00 0.00 0.00 0.00 0.95 1.00 1.00 0.70 0.40 0.10
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
1.00 1.00 1.00 1.00 1.00 0.70 0.00 0.00 0.00 0.80 0.90 [illegible] 0.85 1.00 1.00 0.70
0.35 [illegible] 0.25 0.00 0.00 0.00 0.00 0.00 0.00 0.00
1.00 1.00 1.00 1.00 1.00 1.00 0.55 0.50 0.25 0.15 0.00 0.20 0.00 0.10 0.50 0.60
0.85 1.00 1.00 0.40 0.45 [illegible] 0.00 0.90 0.00 0.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.90 0.30 0.40 0.85 1.00 1.00 1.00
1.00 1.00 1.00 1.00 0.90 0.20 0.00 0.00 0.00 0.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 0.85 0.40 0.00 0.00 0.20
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.70 0.50 0.45
1.00 1.00 0.70 0.40 0.20 0.70 0.95 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 0.95 1.00 1.00 1.00 1.00 0.80
1.00 1.00 1.00 1.00 0.70 0.30 0.05 0.70 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 0.95 0.95 1.00 1.00 1.00 1.00
1.00 1.00 0.05 0.00 [illegible] 0.00 0.90 0.15 0.70 0.90 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.20 0.50 0.40 0.30 0.25 0.75 0.80 0.85
0.85 0.95 1.00 1.00 1.00 1.00 1.00 1.00 0.90 0.85
1.00 1.00 0.90 0.00 0.00 0.00 0.00 0.15 0.80 0.75 0.80 0.85 0.95 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.50 0.45
1.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.90 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 0.95 0.80 0.85 1.00 1.00 0.55 0.95
REGION INDEX
44445050505050504444444444444444444444441818 7283054
44444444444444505044444444444444444444444418 728301917
4444444444445050504444444444444444444450441850505050
4444444444444450505044444444444504450444450505050500
4444444444445050505044444444444450445050505050505050
44444444444450505044444444444444444444505050505050
44444444444444444444504450444444444444443131505050
44444444444444444444444444444444444444313131505050
4444444444444444444444444444444444443131313131315050 8
444444444444444444444444444444444444443131313138 9 8
44444444444444444444444444444444444444431313138 9 1
44445050505044444444444444444444444444444444444314040
4444505050505044444444444444444444444444444444461511
4444505050505050444444444444444444444444444444463347
44445050505050504444444444444444444444444444365320
444450505050505050504444444444444444444444444181836305
WATERSHED INDEX
1 1 2 2 2 2 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 2 2 2     1 1 2 1 1 1 1 1 1 2 2 2 2 2 1
1 1 1 1 1 1 1   1     1 1 1 1 2 1 2 2 2 2 2 2 2 2 2
```

```
.       . . . . .   . 1 1 . . 2 2 2 . . 2 2 . . 2 .
.   . . . 1 . . . . . 1 1 1 2 . 2 . . . 2 2 . . 2 .
. . . 1 1 2 . . . . 1 1 1 1 1 2 . 2 2 . . . . . 2 .
. . . . . . . . 2 . . . 2 2 . 1 1 1 1 . 2 2 . . 2 .
. . . . . . . 1 . . . . 1 1 . 1 1 1 . 1 1 2 . . 2 .
. . . . 1 1 1 . . 1 1 1 1 1 1 . 1 1 1 1 1 1 2 2 2 .
. . . . . 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 .
. . . . .   1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 1 1 1 1 1
. . . . . . . 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
. . . . . . . . 1 1 1 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1
1 1 . 2 2 2 2 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 . . 2 2 2 . 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
. 1 . 2 2 . 2 . 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
CROP SEASON AND SHARE
   1 PASTURE                90. 270.    0.41
   2 STORED FORAGE         150. 240.    0.13
   3 GRAINS                150. 240.    0.21
   4 GRN LEAFY VEGETABLES 150. 240.    0.002
   5 OTHER FOOD CROPS      150. 240.    0.004
   6 LEGUMES AND SEEDS     150. 240.    0.15
   7 ROOTS AND TUBERS      150. 240.    0.003
WATERSHED DEFINITION         INITIAL AND ANNUAL WASHOFF AND INGESTION FACTORS
   1 [illegible] 89                            5.0E 6   0.0
   2 [illegible] 90                            5.0E 6   0.0
   3 [illegible] 144                           5.0E 6   0.0
   4 [illegible] 1[illegible]                  [illegible]0E 6   0.0
REGIONAL ECONOMIC DATA
   1 ALA               [illegible] .040       [illegible]       1624.      [illegible]
   2 ARIZ              .510 .104      [illegible]        682.      [illegible]
   3 ARK               .483 .041       466.       2049.      [illegible]
   4 CALIF             [illegible] .144      [illegible]       4394.      [illegible]
   5 COLO              .522 .048       211.       [illegible]      [illegible]
   6 CONN              .160 .294      [illegible]       4980.      [illegible]
   7 DEL               [illegible] .042      [illegible]       3428.      [illegible]
   8 FLA               [illegible] .080       [illegible]      3341.      [illegible]
   9 GA                .363 [illegible]       613.       1885.      [illegible]
  10 IDAHO             [illegible] .144       343.       1562.      [illegible]
  11 ILL               .806 .044       [illegible]      3900.      [illegible]
  12 IND               .713 [illegible]       611.       3283.      [illegible]
  13 IOWA              .938 [illegible]       695.       3133.      [illegible]
  14 KANS              [illegible] .035       281.       1204.      [illegible]
  15 KY                [illegible] .112       482.       1838.      [illegible]
  16 LA                .354 [illegible]       459.       3284.      61000.
  17 MAINE             .079 .260       662.       1133.      70000.
  18 MD                .429 .216       956.       4489.      93000.
  19 MASS              .136 .249      1349.       2563.      97000.
  20 MICH              .313 .247       658.       2187.      81000.
  21 MINN              .597 .223       516.       2111.      82000.
  22 MISS              .470 .054       403.       2084.      53000.
  23 MO                .703 .102       322.       1647.      76000.
  24 MONT              .657 .030        61.        563.      65000.
  25 NEBR              .962 .031       318.       1148.      75000.
  26 NEV               .127 .139        63.        601.      84000.
  27 N.H.              .096 .482       518.       2018.      87000.
  28 N.J.              .203 .129      1399.       6477.     102000.
  29 N.MEX             .590 .144        53.        473.      63000.
  30 N.Y.              .310 .589       711.       1378.      94000.
  31 N.C.              .352 [illegible]       860.       2658.      68000.
  32 N.DAK             .924 .048       164.        948.      69000.
  33 OHIO              .602 .175       581.       2686.      76000.
  34 OKLA              .751 .060       204.       1508.      67000.
  35 OREG              .292 .111       236.       1203.      [illegible]
  36 PA                .303 .447       855.       2534.      78000.
  37 R.I.              .108 .213      1062.       6438.      80000.
  38 S.C.              .290 .084       472.       1843.      62000.
  39 S.DAK             [illegible] [illegible]       145.        587.      [illegible]
```

[redacted]

```
 40 TENN        .[illegible] .153      360.      1850.      [illegible]
 41 TEX         .816 .064      164.      1492.      [illegible]
 42 UTAH        .225 .259      123.      1286.      [illegible]
 43 VT          .286 .[illegible]      628.      1472.      [illegible]
 44 VA          .382 .198      371.      2075.      [illegible]
 45 WASH        .3[illegible] .154      476.      1948       [illegible]
 46 W.VA        .246 .224      150.      1728.      [illegible]
 47 WIS         .517 .591      723.      1751.      [illegible]
 48 WYO         .561 .028       43.       380.      [illegible]
 49 BRIT COL    .377 .154      476.      1948.      [illegible]
 50 OCEAN       .000 .000        0.         0.           0
 51 SASKAT      .657 .030       61.       563.      [illegible]
 52 MANITOBA    .924 .048      164.       948.      [illegible]
 53 ONTARIO     .597 .223      516.      2111.      [illegible]
 54 QUEBEC      .310 .589      711.      1378.      60000.
 55 NOVA SCOT   .079 .260      662.      1133.      [illegible]
 56 BAJA CAL    .330 .144     1022.      4394.      [illegible]
 57 SONORA      .516 .104      110.       682.      [illegible]
 58 CHIHUAHUA   .590 .144       53.       473.      [illegible]
 59 COAHUILA    .816 .064      164.      1492.      [illegible]
END
```

```
MACCS SITE DATA FILE FOR SEQUOYAH (JLS, 11/10/88)
SECPOP POP DISTRIBUTION FROM 1980 CENSUS DATA ALTERED USING NRC 0-10 MI DATA
 26 SPATIAL INTERVALS
 16 WIND DIRECTIONS
  7 CROP CATEGORIES
  4 WATER PATHWAY ISOTOPES
  2 WATERSHEDS
 59 ECONOMIC REGIONS
SPATIAL DISTANCES
     0.16       0.59       1.21      1.61       2.20       3.22       4.02       4.83
     5.63       8.05      11.27     16.09      20.92      25.75      32.19      40.23
    48.28      64.37      80.47    112.65     160.93     241.14     321.87     563.27
   804.67    1609.34
POPULATION
       0.         0.         1.        2.         3.         9.        17.        23.
      27.       108.        94.      205.      1723.      2650.      2143.      3115.
       0.      3480.     11182.    17930.     28763.    115019.    418223.   5029591.
 4226619.   4488368.
       0.         0.         0.        0.         0.         0.        20.        26.
      31.       123.       113.      247.       139.         0.      5298.      1568.
    2201.      7260.      7325.    32422.     30166.    160847.    199147.   1890643.
 6355716.   4462791.
       0.         0.         0.        0.         0.         0.        10.        13.
      15.        62.       100.      219.      1268.         0.       842.      1545.
    4148.      8158.     13530.    64005.    402619.    112881.    264818.   1337697.
 4212858.  16777882.
       0.         0.         2.        2.         4.        12.        21.        29.
      34.       139.       137.      303.      1791.        84.      2410.      1760.
    3279.     25166.     14663.    20036.     90922.    166500.    427081.   1708718.
 2761967.  33429318.
       0.         0.         4.        3.         6.        17.        19.        26.
      31.       125.       109.      241.      8099.      4329.      4865.      3644.
    1631.      4373.      5694.    10190.     40504.    307919.    679113.   2706447.
 1836035.     61860.
       0.         0.        10.        8.        15.        42.        30.        39.
      46.       185.       284.      616.     14472.     17775.      2090.         0.
    2584.      1342.     11514.    18499.     39805.    264994.    248066.   1611099.
  158953.         0.
       0.         0.        28.       21.        43.       108.        19.        26.
      31.       124.       221.      479.      1696.      3491.      3673.       573.
    2284.      1781.      5016.    12098.    124573.    247313.    116761.    926895.
   20508.         0.
       0.         0.        10.        8.        15.        42.        30.        39.
      46.       185.       317.      683.      4433.      1428.      1116.      4812.
    8921.     35672.      8113.    18140.    440744.   1509163.    332123.    724766.
 1849557.   7058200.
       0.         0.        13.       11.        21.        55.        34.        42.
      51.       201.       350.      750.      3423.     13902.      1593.     10103.
    5243.     23950.      9798.    83659.     74015.    179136.    445749.    722824.
   88247.         0.
       0.         0.        10.        8.        15.        42.        24.        33.
      38.       155.      1388.     2964.     18490.     16715.     47757.     20708.
   13611.     14501.     10374.    25951.     87033.    219844.    165903.    817257.
  727568.         0.
       0.         0.         0.        0.         0.         0.        20.        26.
      31.       123.      1035.     2207.     11021.     32871.     58191.     25162.
    5119.     10063.      8404.    43649.     85136.    336315.    718998.    539129.
 2939755.   2621959.
       0.         0.         6.        6.        10.        28.       187.       229.
     270.      1064.      1598.     3402.     25316.      8121.      4311.       247.
    2740.     13641.      9228.     7319.    198972.    203432.    153718.    737715.
  929605.  11056743.
       0.         0.         6.        6.        10.        28.        63.        78.
      93.       366.       928.     1979.         0.       496.         0.      4192.
    2202.      5408.      6558.    45279.     45072.   [illegible]   [illegible]   1566084.
 1144300.   4699268.
```

```
          0.          0.          4.          3.          6.         17.        100.        124.
        148.        582.       1596.       3404.          0.        148.       1389.       2780.
       1346.       6102.       1913.      27190.     109653.     372482.     105699.     775542.
     952215.    4577283.
          0.          0.          9.          8.         15.         38.         61.         76.
         90.        355.       1437.       3063.        170.        549.        806.       1180.
        438.        977.      10997.      34763.      56460.     458043.     255865.     988566.
    3299217.    5212747.
          0.          0.         13.         11.         21.         55.         25.         33.
         38.        154.        317.        683.        165.          0.       1108.       1298.
       3963.       3087.       4143.      45483.      42869.     162004.     191306.    1389826.
    8653033.    9372618.
 LAND FRACTION
 1.00 1.00 0.75 0.90 0.60 0.35 1.00 0.45 0.30 0.80 0.90 0.95 0.95 1.00 1.00 1.00
 1.00 1.00 1.00 1.00 0.95 1.00 1.00 1.00 0.80 0.50
 1.00 0.50 0.40 0.00 0.00 0.40 0.75 0.75 0.95 0.50 0.50 0.55 0.60 0.50 0.70 0.80
 1.00 0.75 0.90 1.00 1.00 1.00 1.00 1.00 0.95 0.70
 1.00 0.20 0.10 0.00 0.00 0.40 0.90 1.00 1.00 1.00 1.00 1.00 0.95 0.50 1.00 1.00
 0.95 1.00 1.00 0.95 0.95 1.00 1.00 1.00 1.00 0.55
 1.00 0.50 0.00 0.00 0.10 0.90 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.80 0.70 1.00
 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.95 0.00
 1.00 1.00 0.00 0.00 0.60 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
 1.00 1.00 1.00 0.95 1.00 1.00 1.00 1.00 0.40 0.00
 1.00 1.00 0.00 0.00 0.95 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
 0.90 1.00 1.00 0.95 0.95 1.00 0.95 0.90 0.00 0.00
 1.00 1.00 0.00 0.10 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.95 0.50 0.15
 1.00 1.00 0.00 0.00 1.00 1.00 1.00 1.00 1.00 1.00 0.95 1.00 1.00 1.00 1.00 1.00
 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.80 0.10
 1.00 0.50 0.00 0.00 1.00 1.00 1.00 1.00 1.00 0.70 1.00 1.00 1.00 1.00 1.00 1.00
 1.00 1.00 1.00 0.80 1.00 1.00 0.95 0.85 0.00 0.00
 1.00 0.50 0.30 0.00 0.20 0.80 1.00 1.00 1.00 0.80 0.65 1.00 1.00 1.00 1.00 1.00
 1.00 1.00 1.00 1.00 1.00 0.95 1.00 1.00 0.75 0.00
 1.00 0.90 0.80 0.40 0.00 0.20 0.55 0.30 0.20 0.25 0.60 0.75 0.85 0.90 0.95 1.00
 1.00 1.00 1.00 0.95 0.90 0.90 1.00 1.00 1.00 0.20
 1.00 1.00 0.15 0.75 0.25 0.45 0.55 0.90 0.80 0.45 0.90 1.00 1.00 1.00 0.90 0.95
 0.90 0.95 1.00 1.00 1.00 0.95 1.00 1.00 1.00 1.00
 1.00 1.00 0.70 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
 1.00 1.00 1.00 0.80 1.00 1.00 0.95 1.00 1.00 1.00
 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
 1.00 1.00 1.00 1.00 1.00 1.00 0.75 1.00 1.00 1.00
 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
 1.00 1.00 1.00 0.95 0.95 1.00 1.00 1.00 1.00 1.00
 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.60 0.50 0.80 1.00 1.00 1.00 1.00 1.00
 1.00 1.00 1.00 1.00 0.95 1.00 1.00 1.00 0.75 0.50
 REGION INDEX
40404040404040404040404040404040404040401515333320
40404040404040404040404040404040404040401515153330
40404040404040404040404040404040404040404040464436
40404040404040404040404040404040404040403131313150
40404040404040404040404040404040404031313838383150
404040404040404040404040404040404040 9 9 9 9385050
404040404040404040404040404040 9 9 9 9 9 9 9 9 8 8
40404040404040404040404040 9 9 9 9 9 9 9 9 9 9 8 8
40404040404040404040404040 9 9 9 9 9 9 1 1 1 15050
40404040404040404040404040 9 9 9 9 9 1 1 1 1 11650
404040404040404040404040404040 9 9 1 1 1 1 1221641
4040404040404040404040404040404040 1 1 1 12222 341
40404040404040404040404040404040404040404040 3 334
40404040404040404040404040404040404040404040232314
40404040404040404040404040404040404040404015111113
4040404040404040404040404040404040404040151512114
 WATERSHED INDEX
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

```
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
CROP SEASON AND SHARE
  1 PASTURE                90. 270.   0.69
  2 STORED FORAGE         150. 240.   0.006
  3 GRAINS                150. 240.   0.16
  4 GRN LEAFY VEGETABLES  150. 240.   0.0007
  5 OTHER FOOD CROPS      150. 240.   0.005
  6 LEGUMES AND SEEDS     150. 240.   0.15
  7 ROOTS AND TUBERS      150. 240.   0.001
WATERSHED DEFINITION  --  INITIAL AND ANNUAL WASHOFF AND INGESTION FACTORS
  1 SR-89                             5.0E-6  0.0
  2 SR-90                             5.0E-6  0.0
  3 CS-134                            5.0E-6  0.0
  4 CS-137                            5.0E-6  0.0
REGIONAL ECONOMIC DATA
  1 ALA                .354 .040     459.      1824.     62000.
  2 ARIZ               .516 .104     110.       682.     74000.
  3 ARK                .483 .041     466.      2049.     61000.
  4 CALIF              .330 .144    1022.      4394.     93000.
  5 COLO               .522 .048     211.       971.     83000.
  6 CONN               .160 .294    1605.      4980.    107000.
  7 DEL                .534 .042    1723.      3428.     82000.
  8 FLA                .375 .080     832.      3341.     80000.
  9 GA                 .363 .060     613.      1885.     73000.
 10 IDAHO              .279 .144     343.      1562.     61000.
 11 ILL                .806 .044     709.      3963.     86000.
 12 IND                .713 .079     611.      3283.     72000.
 13 IOWA               .938 .060     695.      3133.     73000.
 14 KANS               .917 .035     281.      1204.     81000.
 15 KY                 .571 .112     482.      1838.     61000.
 16 LA                 .354 .074     459.      3284.     61000.
 17 MAINE              .079 .260     662.      1133.     70000.
 18 MD                 .429 .216     956.      4489.     93000.
 19 MASS               .136 .249    1349.      2563.     97000.
 20 MICH               .313 .247     658.      2187.     81000.
 21 MINN               .597 .223     516.      2111.     82000.
 22 MISS               .470 .054     403.      2084.     53000.
 23 MO                 .703 .102     322.      1647.     76000.
 24 MONT               .657 .030      61.       563.     65000.
 25 NEBR               .962 .031     318.      1148.     75000.
 26 NEV                .127 .139      63.       601.     84000.
 27 N.H.               .096 .482     518.      2018.     87000.
 28 N.J.               .203 .129    1399.      6477.    102000.
 29 N.MEX              .590 .144      53.       473.     63000.
 30 N.Y.               .310 .589     711.      1378.     94000.
 31 N.C.               .352 .065     860.      2658.     68000.
 32 N.DAK              .924 .048     164.       948.     69000.
 33 OHIO               .602 .175     581.      2686.     76000.
 34 OKLA               .751 .060     204.      1508.     67000.
 35 OREG               .292 .111     236.      1203.     73000.
 36 PA                 .303 .447     855.      2534.     78000.
 37 R.I.               .108 .213    1062.      6438.     80000.
 38 S.C.               .290 .084     472.      1843.     6[illegible]
 39 S.DAK              .915 .091     145.       587.     6[illegible]
```

[redacted]

```
 40 TENN            .509 .153     360.     1850.     66000.
 41 TEX             .816 .064     164.     1492.     74000.
 42 UTAH            .225 .259     123.     1286.     60000.
 43 VT              .286 .789     628.     1472.     73000.
 44 VA              .382 .198     371.     2075.     84000.
 45 WASH            .377 .154     476.     1948.     82000.
 46 W.VA            .246 .224     150.     1728.     58000.
 47 WIS             .517 .591     723.     1751.     76000.
 48 WYO             .561 .028      43.      380.     70000.
 49 BRIT COL        .377 .154     476.     1948.     60000.
 50 OCEAN           .000 .000       0.        0.         0.
 51 SASKAT          .657 .030      61.      563.     60000.
 52 MANITOBA        .924 .048     164.      948.     60000.
 53 ONTARIO         .597 .223     516.     2111.     60000.
 54 QUEBEC          .310 .589     711.     1378.     60000.
 55 NOVA SCOT       .079 .260     662.     1133.     60000.
 56 BAJA CAL        .330 .144    1022.     4394.     10000.
 57 SONORA          .516 .104     110.      682.     10000.
 58 CHIHUAHUA       .590 .144      53.      473.     10000.
 59 COAHUILA        .816 .064     164.     1492.     10000.
END
```

```
MACCS SITE DATA FILE FOR PEACH BOTTOM (JLS, 11/10/88)
SECPOP POP DISTRIBUTION FROM 1980 CENSUS DATA ALTERED USING NRC 0-10 MI DATA
  26 SPATIAL INTERVALS
  16 WIND DIRECTIONS
   7 CROP CATEGORIES
   4 WATER PATHWAY ISOTOPES
   2 WATERSHEDS
  59 ECONOMIC REGIONS
SPATIAL DISTANCES
      0.40      0.82      1.21      1.61      2.43      3.22      4.02      4.83
      5.63      8.05     11.27     16.09     20.92     25.75     32.19     40.23
     48.28     64.37     80.47    112.65    160.93    241.14    321.87    563.27
    804.67   1609.34
POPULATION
        0.        0.        0.        0.        0.        0.       20.       26.
       31.      122.      406.      867.     2212.     5557.    68185.    42610.
    36746.    25232.    43251.    88038.   210634.   215849.   547385.  1124293.
    25330.        0.
        0.        0.        1.        1.        3.        7.       19.       26.
       30.      123.      455.      977.     5385.     1870.     9336.    12012.
    13500.    29877.   188747.    79915.   174604.   430572.   162914.  1349066.
   393839.        0.
        0.        0.        1.        2.        4.        8.       24.       32.
       37.      151.      413.      889.     1602.     2235.     3231.    10573.
    14456.    22521.    91474.   220858.   495439.  1870811.  1387490.  5663616.
  1201796.   326019.
        0.        0.        0.        1.        2.        4.       31.       39.
       48.      187.      325.      700.     2912.     1710.     3207.     3038.
    26164.    90241.   164108.  2425058.   987201. 10635304.  3591517.  4107688.
    32847.        0.
        0.        0.        6.        5.       14.       21.       32.       41.
       49.      195.      323.      698.     1871.     4260.     5207.     9780.
    37964.   241423.   217733.   745625.   219373.   268826.        0.        0.
        0.        0.
        0.        0.        0.        0.        0.        0.       32.       39.
       46.      183.      354.      755.     4439.      760.     4691.    11312.
    40619.    35254.    18393.   113077.   188361.    49837.        0.        0.
        0.        0.
        0.        0.        0.        0.        0.        0.       28.       36.
       43.      169.      406.      870.     3309.     3109.     5776.     1130.
     3899.    10750.    14771.    72422.    79583.     9233.        0.        0.
        0.        0.
        0.        0.        1.        2.        4.        8.       37.       46.
       56.      219.      702.     1498.     1005.     4019.    24424.     5722.
      856.     8539.     9246.    26850.    83286.   119486.      706.        0.
        0.        0.
        0.        0.        4.        4.       11.       17.       14.       20.
       23.       93.     1048.     2238.     4653.     5262.     9826.    24736.
     5216.     3830.     3556.    39680.    50491.    79486.   699284.   908098.
    91529.        0.
        0.        0.        8.        6.       20.       28.       16.       23.
       27.      109.      476.     1024.     2497.    11148.     9730.    20245.
    77714.   765820.   262612.   524192.   713496.   142725.   773884.  1665003.
  1818021.  9939781.
        0.        0.        5.        5.       13.       19.      178.      219.
      259.     1019.      510.     1090.     2522.     2254.     7890.    10533.
    48267.   370900.   155161.   804528.  1197119.   135990.   265587.  2040215.
  3539979. 10361091.
        0.        0.        4.        4.       11.       16.       30.       39.
       46.      185.      317.      683.     1074.     2423.     1931.     3281.
     4610.    26679.    45421.    93784.   130701. [illegible]   106204.  1206559.
  2351412. 10208089.
        0.        0.        9.        7.       21.       30.       49.       62.
       73.      291.      475.     1019.     3353. [illegible] [illegible]     9756.
     4223.    44975.    27904.    69133.   177306. [illegible] [illegible] [illegible]
  5452104. 13054765.
```

```
        0.        0.        6.        6.       16.       22.       31.       38.
       46.      183.      322.      691.     1940.     1080.     6848.    31792.
    83510.    44075.    21768.    73783.    45512.   395828.  1156228.  5822832.
  7781776. 19209774.
        0.        0.       10.        8.       23.       34.       25.       34.
       40.      162.      277.      601.        0.     1973.     2991.    15791.
    23371.    47987.   222390.    93214.    73488.   171388.   178662.   598201.
   349209.   682187.
        0.        0.        6.        6.       16.       22.       10.       14.
       17.       69.      344.      741.      925.     3322.    15194.    35881.
    19668.    33274.    82407.    38728.   153958.   173734.   178396.  2242777.
        0.        0.
LAND FRACTION
0.00 0.00 0.00 0.00 0.00 0.00 0.05 1.00 1.00 1.00 0.95 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
0.00 0.00 0.00 0.00 0.00 0.80 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.95 0.70
0.00 0.00 0.00 0.05 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 0.75 0.65 0.45 0.00 0.15
0.00 0.00 0.00 0.40 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.80 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 0.15 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.20 0.80 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 0.90 0.80 0.90 0.95 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.25 0.60 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
0.90 0.75 0.40 0.80 0.15 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.25 0.75 1.00 0.95 0.95 0.90 0.90 0.75 0.50
0.50 1.00 1.00 0.70 1.00 0.45 0.00 0.00 0.00 0.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.80 1.00 1.00 1.00 0.90 0.40
0.25 0.95 1.00 1.00 0.60 0.20 0.10 0.20 0.00 0.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.80
0.40 0.25 0.15 0.20 0.65 0.80 0.80 1.00 0.50 0.10
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
0.95 0.80 0.75 0.95 1.00 1.00 1.00 1.00 1.00 0.95
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
0.80 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
0.90 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.90 0.95 0.90
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.50 0.60 0.50
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.75 0.80 1.00 0.95 0.95 0.90
0.95 0.95 1.00 1.00 1.00 1.00 1.00 0.70 0.50 0.90
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.25 0.25 0.40 1.00 1.00 0.80 0.95 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 0.95 0.70 1.00 0.90
 REGION INDEX
363636363636363636363636363636363636363636303030 5454
3636363636363636363636363636363636363636362830271717
3636363636363636363636363636363636363636282830 65055
3636363636363636363636363636363636363636282850505050
36363636363636363636363636363636 7 72828285050505050
3636363636363636363618181818181818 72828285050505050
36363636363636363618181818181818181818 7 7 71850505050
363636363636363618181818181818181818181818 7 744445050
36363636363636181818181818181818181818181818444444313 1 8
3636363636363636181818181818181818181818184444443138 9
36363636363636363618181818181818181818184444444440 1
363636363636363636181818181818181818181818464646152
3636363636363636363636363636363636363636363636333311
3636363636363636363636363636363636363636363636362047
3636363636363636363636363636363636363636363636305353
3636363636363636363636363636363636363636363030535 4
 WATERSHED INDEX
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

```
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
CROP SEASON AND SHARE
  1 PASTURE                 90. 270.    0.38
  2 STORED FORAGE          150. 240.    0.13
  3 GRAINS                 150. 240.    0.23
  4 GRN LEAFY VEGETABLES   150. 240.    0.002
  5 OTHER FOOD CROPS       150. 240.    0.004
  6 LEGUMES AND SEEDS      150. 240.    0.16
  7 ROOTS AND TUBERS       150. 240.    0.004
WATERSHED DEFINITION  --  INITIAL AND ANNUAL WASHOFF AND INGESTION FACTORS
  1 SR-89                               5.0E-6  0.0
  2 SR-90                               5.0E-6  0.0
  3 CS-134                              5.0E-6  0.0
  4 CS-137                              5.0E-6  0.0
REGIONAL ECONOMIC DATA
  1 ALA               .354 .040      459.      1824.     62000.
  2 ARIZ              .516 .104      110.       682.     74000.
  3 ARK               .483 .041      466.      2049.     61000.
  4 CALIF             .330 .144     1022.      4394.     93000.
  5 COLO              .522 .048      211.       971.     83000.
  6 CONN              .160 .294     1605.      4980.    107000.
  7 DEL               .534 .042     1723.      3428.     82000.
  8 FLA               .375 .080      832.      3341.     80000.
  9 GA                .363 .060      613.      1885.     73000.
 10 IDAHO             .279 .144      343.      1562.     61000.
 11 ILL               .806 .044      709.      3900.     86000.
 12 IND               .713 .079      611.      3283.     72000.
 13 IOWA              .938 .060      695.      3133.     73000.
 14 KANS              .917 .035      281.      1204.     81000.
 15 KY                .571 .112      482.      1838.     61000.
 16 LA                .354 .074      459.      3284.     61000.
 17 MAINE             .079 .260      662.      1133.     70000.
 18 MD                .429 .216      956.      4489.     93000.
 19 MASS              .136 .249     1349.      2563.     97000.
 20 MICH              .313 .247      658.      2187.     81000.
 21 MINN              .597 .223      516.      2111.     82000.
 22 MISS              .470 .054      403.      2084.     53000.
 23 MO                .703 .102      322.      1647.     76000.
 24 MONT              .657 .030       61.       563.     65000.
 25 NEBR              .962 .031      318.      1148.     75000.
 26 NEV               .127 .139       63.       601.     84000.
 27 N.H.              .096 .482      518.      2018.     87000.
 28 N.J.              .203 .129     1399.      6477.    102000.
 29 N.MEX             .590 .144       53.       473.     63000.
 30 N.Y.              .310 .589      711.      1378.     94000.
 31 N.C.              .352 .065      860.      2658.     68000.
 32 N.DAK             .924 .048      164.       948.     69000.
 33 OHIO              .602 .175      581.      2686.     76000.
 34 OKLA              .751 .060      204.      1508.     67000.
 35 OREG              .292 .111      236.      1203.     73000.
 36 PA                .303 .447      855.      2534.     78000.
 37 R.I.              .108 .213     1062.      6438.     80000.
 38 S.C.              .290 .084      472.      1843.     62000.
 39 S.DAK             .915 .091      145.       587.     65000.
```

[redacted]

```
 40 TENN            .509 .153       360.      1850.     66000.
 41 TEX             .816 .064       164.      1492.     74000.
 42 UTAH            .225 .259       123.      1286.     60000.
 43 VT              .286 .789       628.      1472.     73000.
 44 VA              .382 .198       371.      2075.     84000.
 45 WASH            .377 .154       476.      1948.     82000.
 46 W.VA            .246 .224       150.      1728.     58000.
 47 WIS             .517 .591       723.      1751.     76000.
 48 WYO             .561 .028        43.       380.     70000.
 49 BRIT COL        .377 .154       476.      1948.     60000.
 50 OCEAN           .000 .000         0.         0.         0.
 51 SASKAT          .657 .030        61.       563.     60000.
 52 MANITOBA        .924 .048       164.       948.     60000.
 53 ONTARIO         .597 .223       516.      2111.     60000.
 54 QUEBEC          .310 .589       711.      1378.     60000.
 55 NOVA SCOT       .079 .260       662.      1133.     60000.
 56 BAJA CAL        .330 .144      1022.      4394.     10000.
 57 SONORA          .516 .104       110.       682.     10000.
 58 CHIHUAHUA       .590 .144        53.       473.     10000.
 59 COAHUILA        .816 .064       164.      1492.     10000.
END
```

```
MACCS SITE DATA FILE FOR GRAND GULF (JLS, 11/10/88)
SECPOP POP DISTRIBUTION FROM 1980 CENSUS DATA ALTERED USING NRC 0-10 MI DATA
 26 SPATIAL INTERVALS
 16 WIND DIRECTIONS
  7 CROP CATEGORIES
  4 WATER PATHWAY ISOTOPES
  2 WATERSHEDS
 59 ECONOMIC REGIONS
SPATIAL DISTANCES
     0.40      0.70      1.21      1.61      2.31      3.22      4.02      4.83
     5.63      8.05     11.27     16.09     20.92     25.75     32.19     40.23
    48.28     64.37     80.47    112.65    160.93    241.14    321.87    563.27
   804.67   1609.34
POPULATION
        0.        0.        4.        3.        7.       16.        0.        1.
        2.       12.       30.       70.        0.        0.       67.     1304.
        0.       74.      743.    15484.    83209.    72162.   120923.   541090.
  3057152.  9822912.
        0.        0.        1.        2.        3.        9.        1.        3.
        4.       17.       45.      105.        0.     4637.        0.    15004.
    21111.     2866.      604.    10875.    31683.   110002.   126487.  1603453.
  1595033. 24970756.
        0.        0.        0.        0.        0.        0.        5.        6.
        8.       31.       95.      205.      713.        0.     1658.     4373.
      757.     3527.     3814.    12032.    35282.    62550.   175379.  1020222.
  2240248. 21211502.
        0.        0.        0.        0.        1.        4.       11.       16.
       19.       79.       85.      190.        0.      413.        0.      853.
     2232.     3387.    49094.   247241.    33956.    99583.    73501.  1699378.
  3829756. 18370806.
        0.        0.        1.        2.        3.        9.       13.       18.
       22.       87.       61.      139.      401.      327.        0.        0.
      893.     5713.    10673.    16982.    31249.   133852.    75589.   888587.
  1460466.  1943140.
        0.        0.        1.        0.        3.        6.       51.       65.
       77.      307.      109.      241.        0.      751.       63.        0.
     1185.     5028.     7940.    15118.    33308.   130847.   390071.   714008.
   368763.  8028641.
        0.        0.        1.        0.        3.        6.      201.      249.
      293.     1157.     1149.     2451.        0.      851.        0.      222.
      858.     1203.    21095.    19956.    49172.    94458.   284438.      656.
        0.   754387.
        0.        0.        0.        0.        1.        4.       14.       20.
       23.       93.      170.      370.      201.        0.     1430.        0.
       13.     3396.     1567.    22369.    42828.   544166.   811964.    11629.
        0.        0.
        0.        0.        1.        2.        3.        9.        6.        9.
       12.       48.      128.      282.        0.        0.     1492.     3370.
        0.     1858.     2341.     9365.    67097.   515206.   208032.        0.
        0.        0.
        0.        0.        0.        0.        1.        4.        3.        6.
        8.       33.      101.      224.        0.      927.        0.     1091.
       65.    28282.     3770.     5243.    35077.   369254.    56437.        0.
        0.        0.
        0.        0.        1.        0.        2.        2.        0.        0.
        0.        0.       79.      171.        0.        0.        0.     1339.
        0.    23126.     3047.     4072.    41214.   100210.   217276.   879780.
   399582.   639306.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.       63.      137.     1716.      465.        0.      525.
      663.     1298.     2246.    16476.   123117.    79084.    75399.  2976832.
  2081941.   284505.
        0.        0.        0.        0.        0.        0.        0.        0.
        0.        0.       25.       55.        0.        0.      117.      313.
        0.     5945.     2397.    10843.    28920.    64335.   236712.  2130706.
  1744285.  1801823
```

```
         0.         0.         0.         0.         1.         4.         0.         1.
         2.        12.        22.        53.      1473.        87.         0.       855.
         0.      4689.     14121.     53864.     93558.    102537.    291271.    781001.
   1506956.   2162785.
         0.         0.         1.         2.         3.         4.         0.         0.
         0.         0.        32.        68.         0.         0.       107.         0.
         0.      2793.      6767.     20193.     50650.     73872.     97972.    481302.
   1452393.   3444556.
         0.         0.         7.         5.        14.        24.         0.         0.
         0.         0.        24.        51.         0.         0.         0.       515.
     11703.      2097.      2389.     12027.     17138.     62950.    248012.    811364.
    989294.   5604039.
LAND FRACTION
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.90 0.90 1.00 0.90 0.80 1.00 1.00 0.90
0.85 0.90 0.90 0.95 0.95 0.95 1.00 1.00 1.00 0.75
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.95 1.00 1.00 0.90 0.90
0.95 0.95 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.85
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.95 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 0.90 0.95 1.00 1.00 1.00 1.00 0.55
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.90 0.20
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 0.95 0.20 0.05 0.40
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 0.20 0.05 0.00 0.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 0.70 0.95 0.00 0.00 0.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 0.50 0.00 0.00 0.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 0.95 0.95 1.00 1.00 1.00 0.75 0.00 0.10
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.65 0.60 0.60 0.80
0.85 0.85 0.95 1.00 1.00 1.00 0.60 0.50 0.30 0.85
1.00 1.00 1.00 1.00 1.00 1.00 0.85 0.60 0.50 0.70 0.75 0.85 0.70 0.90 1.00 1.00
1.00 1.00 1.00 0.95 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 0.50 0.10 0.80 1.00 1.00 1.00 1.00 0.80 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 0.20 0.60 1.00 0.80 0.70 0.85 0.95 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 0.95 1.00 1.00 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 0.70 0.30 0.80 0.65 0.90 0.95 0.90 0.85 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 0.95 1.00
1.00 1.00 1.00 1.00 1.00 1.00 0.80 0.50 0.75 0.60 0.75 0.80 0.80 1.00 1.00 1.00
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
REGION INDEX
22222222222222222222221622161616222222222 3 3 32311
2222222222222222222222222222222222222222222222401533
2222222222222222222222222222222222222222222222 14044
22222222222222222222222222222222222222222222 1 1 938
222222222222222222222222222222222222222222220101 9 8
2222222222222222222222222222222222222222222222 8 8 8
2222222222222222222222222222222222222222221616165050
2222222222222222222222222222222222222222161616505050
2222222222222222222222222222222222222222161616505050
2222222222222222222222222222222222222222161616505059
2222222222222222222222222222222216161616161616414159
2222222222222222222222221616161616161616161616414141
2222222222221616161616161616161616161616161616414141
22222222222216161616161616161616161616161616 3343441
222222222222222222161616161616161616161616 3 3 33414
2222222222222222221616161616161616161616 3 3 3 32313
WATERSHED INDEX
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

```
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
CROP SEASON AND SHARE
  1 PASTURE               90. 270.   0.70
  2 STORED FORAGE        150. 240.   0.05
  3 GRAINS               150. 240.   0.18
  4 GRN LEAFY VEGETABLES 150. 240.   0.0005
  5 OTHER FOOD CROPS     150. 240.   0.004
  6 LEGUMES AND SEEDS    150. 240.   0.13
  7 ROOTS AND TUBERS     150. 240.   0.0008
WATERSHED DEFINITION  --  INITIAL AND ANNUAL WASHOFF AND INGESTION FACTORS
  1 SR-89                            5.0E-6  0.0
  2 SR-90                            5.0E-6  0.0
  3 CS-134                           5.0E-6  0.0
  4 CS-137                           5.0E-6  0.0
REGIONAL ECONOMIC DATA
  1 ALA               .354 .040     459.      1824.    62000.
  2 ARIZ              .516 .104     110.       682.    74000.
  3 ARK               .483 .041     466.      2049.    61000.
  4 CALIF             .330 .144    1022.      4394.    93000.
  5 COLO              .522 .048     211.       971.    83000.
  6 CONN              .160 .294    1605.      4980.   107000.
  7 DEL               .534 .042    1723.      3428.    82000.
  8 FLA               .375 .080     832.      3341.    80000.
  9 GA                .363 .060     613.      1885.    73000.
 10 IDAHO             .279 .144     343.      1562.    61000.
 11 ILL               .806 .044     709.      3900.    86000.
 12 IND               .713 .079     611.      3283.    72000.
 13 IOWA              .938 .060     695.      3133.    73000.
 14 KANS              .917 .035     281.      1204.    81000.
 15 KY                .571 .112     482.      1838.    61000.
 16 LA                .354 .074     459.      3284.    61000.
 17 MAINE             .079 .260     662.      1133.    70000.
 18 MD                .429 .216     956.      4489.    93000.
 19 MASS              .136 .249    1349.      2563.    97000.
 20 MICH              .313 .247     658.      2187.    81000.
 21 MINN              .597 .223     516.      2111.    82000.
 22 MISS              .470 .054     403.      2084.    53000.
 23 MO                .703 .102     322.      1647.    76000.
 24 MONT              .657 .030      61.       563.    65000.
 25 NEBR              .962 .031     318.      1148.    75000.
 26 NEV               .127 .139      63.       601.    84000.
 27 N.H.              .096 .482     518.      2018.    87000.
 28 N.J.              .203 .129    1399.      6477.   102000.
 29 N.MEX             .590 .144      53.       473.    63000.
 30 N.Y.              .310 .589     711.      1378.    94000.
 31 N.C.              .352 .065     860.      2658.    68000.
 32 N.DAK             .924 .048     164.       948.    69000.
 33 OHIO              .602 .175     581.      2686.    76000.
 34 OKLA              .751 .060     204.      1508.    67000.
 35 OREG              .292 .111     236.      1203.    73000.
 36 PA                .303 .447     855.      2534.    78000.
 37 R.I.              .108 .213    1062.      6438.    80000.
 38 S.C.              .290 .084     472.      1843.    62000.
 39 S.DAK             .915 .091     145.       587.    65000.
```

[redacted]

```
 40 TENN           .509 .153      360.      1850.     66000.
 41 TEX            .816 .064      164.      1492.     74000.
 42 UTAH           .225 .259      123.      1286.     60000.
 43 VT             .286 .789      628.      1472.     73000.
 44 VA             .382 .198      371.      2075.     84000.
 45 WASH           .377 .154      476.      1948.     82000.
 46 W.VA           .246 .224      150.      1728.     58000.
 47 WIS            .517 .591      723.      1751.     76000.
 48 WYO            .561 .028       43.       380.     70000.
 49 BRIT COL       .377 .154      476.      1948.     60000.
 50 OCEAN          .000 .000        0.         0.         0.
 51 SASKAT         .657 .030       61.       563.     60000.
 52 MANITOBA       .924 .048      164.       948.     60000.
 53 ONTARIO        .597 .223      516.      2111.     60000.
 54 QUEBEC         .310 .589      711.      1378.     60000.
 55 NOVA SCOT      .079 .260      662.      1133.     60000.
 56 BAJA CAL       .330 .144     1022.      4394.     10000.
 57 SONORA         .516 .104      110.       682.     10000.
 58 CHIHUAHUA      .590 .144       53.       473.     10000.
 59 COAHUILA       .816 .064      164.      1492.     10000.
END
```

DISTRIBUTION:

Frank Abbey
U. K. Atomic Energy Authority
Wigshaw Lane, Culcheth
Warrington, Cheshire, WA3 4NE
ENGLAND

Kiyoharu Abe
Department of Reactor Safety
Research
Nuclear Safety Research Center
ToKai Research Establishment
JAERI
Tokai-mura, Naga-gun
Ibaraki-ken,
JAPAN

Ulvi Adalioglu
Nuclear Engineering Division
Cekmece Nuclear Research and
Training Centre
P.K.1 Havaalani
Istanbul
TURKEY

Bharat Agrawal
USNRC-RES/AEB
MS: NL/N-344

Kiyoto Aizawa
Safety Research Group
Reactor Research and Development
Project
PNC
9-13m 1-Chome Akasaka
Minatu-Ku
Tokyo
JAPAN

Oguz Akalin
Ontario Hydro
700 University Avenue
Toronto, Ontario
CANADA M5G 1X6

David Aldrich
Science Applications International
Corporation
1710 Goodridge Drive
McLean, VA 22102

Agustin Alonso
University Politecnica De Madrid
J Gutierrez Abascal, 2
28006 Madrid
SPAIN

Christopher Amos
Science Applications International
Corporation
2109 Air Park Road SE
Albuquerque, NM 87106

Richard C. Anoba
Project Engr., Corp. Nuclear Safety
Carolina Power and Light Co.
P. O. Box 1551
Raleigh NC 27602

George Apostolakis
UCLA
Boelter Hall, Room 5532
Los Angeles, CA 90024

Argonne National Laboratory
Attn: Mr. S. Y. Chen
Mr. Kou-John Hong
Mr. Brad Micklich
9700 S. Cass Avenue
Argonne, IL 60439

Mr. Ephraim Asculai
Division of Nuclear Safety
Wagramestrasse, 5
P.O. Box 100
A-1400 Wien
AUSTRIA

James W. Ashkar
Boston Edison Company
800 Boylston Street
Boston, MA 02199

Donald H. Ashton
Bechtel Power Corporation
P.O. Box 2166
Houston, TX 77252-2166

J. de Assuncao
Gabinete de Proteccao e Seguranca
Nuclear
Secretario de Estado de Energia
Ministerio da Industria
av. da Republica, 45-6°
1000 Lisbon
PORTUGAL

Mark Averett
Florida Power Corporation
P.O. Box 14042
St. Petersburg, FL 33733

Raymond O. Bagley
Northeast Utilities
P.O. Box 270
Hartford, CT 06141-0270

Juan Bagues
Consejo de Seguridad Nucleare
Sarangela de la Cruz 3
28020 Madrid
SPAIN

George F. Bailey
Washington Public Power Supply
System
P. O. Box 968
Richland, WA 99352

H. Bairiot
Belgonucleaire S A
Rue de Champ de Mars 25
B-1050 Brussels
BELGIUM

Louis Baker
Reactor Analysis and Safety
Division
Building 207
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439

H-P. Balfanz
TUV-Norddeutschland
Grosse Bahnstrasse 31,
2000 Hamburg 54
FEDERAL REPUBLIC OF GERMANY

Patrick Baranowsky
USNRC-NRR/OEAB
MS: 11E-22

H. Bargmann
Dept. de Mecanique
Inst. de Machines Hydrauliques
et de Mecaniques des Fluides
Ecole Polytechnique de Lausanne
CH-1003 Lausanne
M.E. (ECUBLENS)
CH. 1015 Lausanne
SWITZERLAND

Robert A. Bari
Brookhaven National Laboratory
Building 130
Upton, NY 11973

Richard Barrett
USNRC-NRR/PRAB
MS: 10A-2

Kenneth S. Baskin
S. California Edison Company
P.O. Box 800
Rosemead, CA 91770

J. Basselier
Belgonucleaire S A
Rue du Champ de Mars 25, B-1050
Brussels
BELGIUM

Werner Bastl
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

Anton Bayer
BGA/ISH/ZDB
Postfach 1108
D-8042 Neuherberg
FEDERAL REPUBLIC OF GERMANY

Ronald Bayer
Virginia Electric Power Co.
P. O. Box 26666
Richmond, VA 23261

Eric S. Beckjord
Director
USNRC-RES
MS: NL/S-007

Bruce B. Beckley
Public Service Company
P.O. Box 330
Manchester, NH 03105

William Beckner
USNRC-RES/SAIB
MS: NL/S-324

Robert M. Bernero
Director
USNRC-NMSS
MS: 6A-4

Ronald Berryman
Virginia Electric Power Co.
P. O. Box 26666
Richmond, VA 23261

Robert C. Bertucio
NUS Corporation
1301 S. Central Ave, Suite 202
Kent, WA 98032

John H. Bickel
EG&G Idaho
P.O. Box 1625
Idaho Falls, ID 83415

Peter Bieniarz
Risk Management Association
2309 Dietz Farm Road, NW
Albuquerque, NM 87107

Adolf Birkhofer
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

James Blackburn
Illinois Dept. of Nuclear Safety
1035 Outer Park Drive
Springfield, IL 62704

Dennis C. Bley
Pickard, Lowe & Garrick, Inc.
2260 University Drive
Newport Beach, CA 92660

Roger M. Blond
Science Applications Int. Corp.
20030 Century Blvd., Suite 201
Germantown, MD 20874

Simon Board
Central Electricity Generating
Board
Technology and Planning Research
Division
Berkeley Nuclear Laboratory
Berkeley Gloucestershire, GL139PB
UNITED KINGDOM

Mario V. Bonace
Northeast Utilities Service Company
P.O. Box 270
Hartford, CT 06101

Mr. Alfredo Bottino
ENEA/DISP
Via Vitaliano Brancati, 48
00144 Roma EUR
ITALY

Mr. Stephen Boult
Electrowatt Engineering Services
(UK) Ltd.
Grandford House
16 Carfax, Horsham
West. Sussex RH12 1UP
ENGLAND

Gary J. Boyd
Safety and Reliability Optimization
Services
9724 Kingston Pike, Suite 102
Knoxville, TN 37922

Robert J. Breen
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Charles Brinkman
Combustion Engineering
7910 Woodmont Avenue
Bethesda, MD 20814

K. J. Brinkmann
Netherlands Energy Res. Fdtn.
P.O. Box 1
1755ZG Petten NH
NETHERLANDS

Allan R. Brown
Manager, Nuclear Systems and
Safety Department
Ontario Hydro
700 University Ave.
Toronto, Ontario
CANADA M5G1X6

Robert G. Brown
TENERA L.P.
1340 Saratoga-Sunnyvale Rd.
Suite 206
San Jose, CA 95129

Sharon Brown
EI Services
1851 So. Central Place, Suite 201
Kent, WA 98031

Ben Buchbinder
NASA, Code QS
600 Maryland Ave. SW
Washington, DC 20546

R. H. Buchholz
Nutech
6835 Via Del Oro
San Jose, CA 95119

Robert J. Budnitz
Future Resources Associates
734 Alameda
Berkeley, CA 94707

Gary R. Burdick
USNRC-RES/DSR
MS: NL/S-007

Mr. Bruce Burnett
CDRH (HFZ-60)
U.S. Department of Health and
Human Services
Food and Drug Administration
5600 Fishers Lane
Rockville, MD 20857

Arthur J. Buslik
USNRC-RES/PRAB
MS: NL/S-372

M. Bustraan
Netherlands Energy Res. Fdtn.
P.O. Box 1
1755ZG Petten NH
NETHERLANDS

Nigel E. Buttery
Central Electricity Generating
Board
Booths Hall
Chelford Road, Knutsford
Cheshire, WA168QG
UNITED KINGDOM

Jose I. Calvo Molins
Probabilistic Safety Analysis
Group
Consejo de Seguridad Nuclear
Sor Angela de la Cruz 3, Pl. 6
28020 Madrid
SPAIN

J. F. Campbell
Nuclear Installations Inspectorate
St. Peters House
Balliol Road, Bootle
Merseyside, L20 3LZ
UNITED KINGDOM

Kenneth S. Canady
Duke Power Company
422 S. Church Street
Charlotte, NC 28217

Mr. Leonel Canelas
New Universit 5 of Lisbon
Quinta de Torre
2825 Monte da Caparica
PORTUGAL

Mr. Harold Careway
General Electric Co., M/C 754
175 Cartner Ave.
San Jose, CA 95129

Lennart Carlsson
IAEA A-1400
Wagramerstrasse 5
P.O. Box 100
Vienna, 22
AUSTRIA
Annick Carnino
Electricite de France
32 Rue de Monceau 8EME
Paris, F5008
FRANCE

G. Caropreso
Dept. for Envir. Protect. & Hlth.
ENEA Cre Casaccia
Via Anguillarese, 301
00100 Roma
ITALY

James C. Carter, III
TENERA L.P.
Advantage Place
308 North Peters Road
Suite 280
Knoxville, TN 37922

Eric Cazzoli
Brookhaven National Laboratory
Building 130
Upton, NY 11973

John G. Cesare
SERI
Director Nuclear Licensing
5360 I-55 North
Jackson, MS 39211

S. Chakraborty
Radiation Protection Section
Div. De La Securite Des Inst. Nuc.
5303 Wurenlingen
SWITZERLAND

Sen-I Chang
Institute of Nuclear Energy
Research
P.O. Box 3
Lungtan, 325
TAIWAN

J. R. Chapman
Yankee Atomic Electric Company
1671 Worcester Road
Framingham, MA 01701

Mr. S. Y. Chen
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439

Mr. Mike Cheok
NUS
910 Clopper Road
Gaithersburg, MD 20878

Robert F. Christie
Tennessee Valley Authority
400 W. Summit Hill Avenue, W10D190
Knoxville, TN 37902
T. Cianciolo
BWR Assistant Director
ENEA DISP TX612167 ENEUR
Rome
ITALY

Thomas Cochran
Natural Resources Defense Council
1350 New York Ave. NW, Suite 300
Washington, D.C. 20005

Frank Coffman
USNRC-RES/HFB
MS: NL/N-316

Frank Congel
USNRC-NRR/DREP
MS-10E4

Larry Conradi
NUS Corporation
16835 W. Bernardo Drive
Suite 202
San Diego, CA 92127

Donald Cool
USNRC-RES/RPHEB
MS-NL139

Peter Cooper
U.K. Atomic Energy Authority
Wigshaw Lane, Culcheth
Warrington, Cheshire, WA3 4NE
UNITED KINGDOM

C. Allin Cornell
110 Coquito Way
Portola Valley, CA 94025

Michael Corradini
University of Wisconsin
1500 Johnson Drive
Madison, WI 53706

E. R. Corran
Nuclear Technology Division
ANSTO Research Establishment
Lucas Heights Research Laboratories
Private Mail Bag 7
Menai, NSW 2234
AUSTRALIA

James Costello
USNRC-RES/SSEB
MS: NL/S-217A

George R. Crane
1570 E. Hobble Creek Dr.
Springville, UT 84663

Mat Crawford
SERI
5360 I-55 North
Jackson, MS 39211

Michael C. Cullingford
Nuclear Safety Division
IAEA
Wagramerstrasse, 5
P.O. Box 100
A-1400 Vienna
AUSTRIA

Garth Cummings
Lawrence Livermore Laboratory
L-91, Box 808
Livermore, CA 94526

Lemoine Cunningham
USNRC-NRR/PRAB
MS-11D23

Mark A. Cunningham
USNRC-RES/PRAB
MS: NL/S-372

James J. Curry
7135 Salem Park Circle
Mechanicsburg, PA 17055

Peter Cybulskis
Battelle Columbus Division
505 King Avenue
Columbus, OH 43201

Mr. M. Daggupaty
Environnment Canada
4905 Dufferin Street
Downsview
Ontario,
CANADA M3H 5T4

Mr. Jack Dallman
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, ID 83415

Peter R. Davis
PRD Consulting
1935 Sabin Drive
Idaho Falls, ID 83401

Jose E. DeCarlos
Consejo de Seguridad Nuclear
Sor Angela de la Cruz 3, Pl. 8
28016 Madrid
SPAIN

M. Marc Decreton
Department Technologie
CEN/SCK
Boeretang 200
B-2400 Mol
BELGIUM

Richard S. Denning
Battelle Columbus Division
505 King Avenue
Columbus, OH 43201

Vernon Denny
Science Applications Int. Corp.
5150 El Camino Real, Suite 3
Los Altos, CA 94303

Mr. Lennart Devell
Studsvik Nuclear
Studsvik Energiteknik AB
S-611 82 Nykoping
SWEDEN

J. Devooget
Faculte des Sciences Appliques
Universite Libre de Bruxelles
av. Franklin Roosevelt
B-1050 Bruxelles
BELGIUM

R. A. Diederich
Supervising Engineer
Environmental Branch
Philadelphia Electric Co.
2301 Market St.
Philadelphia, PA 19101

Raymond DiSalvo
Battelle Columbus Division
505 King Avenue
Columbus, OH 43201

Mr. Chuck Dobbe
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, ID 83415

Mary T. Drouin
Science Applications International
Corporation
2109 Air Park Road S.E.
Albuquerque, NM 87106

Andrzej Drozd
Stone and Webster
Engineering Corp.
243 Summer Street
Boston, MA 02107

Duke Power Co.
Design Engineering
Attn: Mr. Duncan Brewer
Mr. Steve Deskevich
422 South Church Street
Charlotte, NC 28242

EG&G Idaho, Inc. (4)
Attn: Mr. Jack Dallman
Mr. Chuck Dobbe
Mr. Darrel Knudson
Mr. John Tolli

P.O. Box 1625
Idaho Falls, ID 83415

Mr. Bill Eakin
Northeast Utilities
Box 270
Hartford, CT 06141-0270

N. W. Edwards
NUTECH
145 Martinville Lane
San Jose, CA 95119

Ward Edwards
Social Sciences Research Institute
University of Southern California
Los Angeles, CA 90089-1111

Joachim Ehrhardt
Kernforschungszentrum Karlsruhe/INR
Postfach 3640
D-7500 Karlsruhe 1
FEDERAL REPUBLIC OF GERMANY

Adel A. El-Bassioni
USNRC-NRR/PRAB
MS: 10A-2

J. Mark Elliott
International Energy Associates,
Ltd., Suite 600
600 New Hampshire Ave., NW
Washington, DC 20037

Farouk Eltawila
USNRC-RES/AEB
MS: NL/N-344

Mike Epstein
Fauske and Associates
P. O. Box 1625
16W070 West 83rd Street
Burr Ridge, IL 60521

Malcolm L. Ernst
USNRC-RGN II

F. R. Farmer
The Long Wood, Lyons Lane
Appleton, Warrington
WA4 5ND
UNITED KINGDOM

P. Fehrenback
Atomic Energy of Canada, Ltd.
Chalk River Nuclear Laboratories
Chalk River Ontario
CANADA K0J1P0

P. Ficara
ENEA Cre Casaccia
Department for Thermal Reactors
Via Anguillarese, 301
00100 ROMA
ITALY

A. Fiege
Kernforschungszentrum
Postfach 3640
D-7500 Karlsruhe
FEDERAL REPUBLIC OF GERMANY

John Flack
USNRC-RES/SAIB
MS: NLS-324

Karl N. Fleming
Pickard, Lowe & Garrick, Inc.
2260 University Drive
Newport Beach, CA 92660

Terry Foppe
Rocky Flats Plant
P. O. Box 464, Building T886A
Golden, CO 80402-0464

Richard D. Fowler
Idaho Nat. Engineering Laboratory
P.O. Box 1625
Idaho Falls, ID 83415

Joseph R. Fragola
Science Applications International
Corporation
274 Madison Avenue
New York, NY 10016

Wiktor Frid
Swedish Nuclear Power Inspectorate
Division of Reactor Technology
P. O. Box 27106
S-102 52 Stockholm
SWEDEN

James Fulford
NUS Corporation
910 Clopper Road
Gaithersburg, MD 20878

Urho Fulkkinen
Technical Research Centre of
Finland
Electrical Engineering Laboratory
Otakaari 7 B
SF-02150 Espoo 15
FINLAND

J. B. Fussell
JBF Associates, Inc.
1630 Downtown West Boulevard
Knoxville, TN 37919

John Garrick
Pickard, Lowe & Garrick, Inc.
2260 University Drive
Newport Beach, CA 92660

John Gaunt
British Embassy
3100 Massachusetts Avenue, NW
Washington, DC 20008

Jim Gieseke
Battelle Columbus Division
505 King Avenue
Columbus, OH 43201

Frank P. Gillespie
USNRC-NRR/PMAS
MS: 12G-18

Ted Ginsburg
Department of Nuclear Energy
Building 820
Brookhaven National Laboratory
Upton, NY 11973

James C. Glynn
USNRC-RES/PRAB
MS: NL/S-372

Mr. Robert Gobel
Clark University
Center for Technology,
Environment and Development
950 Main St.
Worcester, MA 01610-1477

P. Govaerts
Departement de la Surete Nucleaire
Association Vincotte
avenue du Roi 157
B-1060 Bruxelles
BELGIUM

George Greene
Building 820M
Brookhaven National Laboratory
Upton, NY 11973

Carrie Grimshaw
Brookhaven National Laboratory
Building 130
Upton, NY 11973

H. J. Van Grol
Energy Technology Division
Energieonderzoek Centrum Nederland
Westerduinweg 3
Postbus 1
NL-1755 Petten ZG
NETHERLANDS

Sergio Guarro
Lawrence Livermore Laboratories
P. O. Box 808
Livermore, CA 94550

Sigfried Hagen
Kernforschungzentrum Karlsruhe
P. O. Box 3640
D-7500 Karlsruhe 1
FEDERAL REPUBLIC OF GERMANY

L. Hammar
Statens Karnkraftinspektion
P.O. Box 27106
S-10252 Stockholm
SWEDEN

Stephen Hanauer
Technical Analysis Corp.
6723 Whittier Avenue
Suite 202
McLean, VA 22101

Brad Hardin
USNRC-RES/TRAB
MS: NL/S-169

R. J. Hardwich, Jr.
Virginia Electric Power Co.
P O. Box 26666
Richmond, Va 23261

Michael R. Haynes
UKAEA Harwell Laboratory
Oxfordshire
Didcot, Oxon., OX11 0RA
ENGLAND

Michael J Hazzan
Stone & Webster
3 Executive Campus
Cherry Hill, NJ 08034

A. Hedgran
Royal Institute of Technology
Nuclear Safety Department
Bunellvagen 60
10044 Stockholm
SWEDEN

Sharif Heger
UNM Chemical and Nuclear
Engineering Department
Farris Engineering
Room 209
Albuquerque, NM 87131

Jon C. Helton
Dept. of Mathematics
Arizona State University
Tempe, AZ 85287

Robert E. Henry
Fauske and Associates, Inc.
16W070 West 83rd Street
Burr Ridge, IL 60521

P. M. Herttrich
Federal Ministry for the
Environment, Preservation of
Nature and Reactor Safety
Husarenstrasse 30
Postfach 120629
D-5300 Bonn 1
FEDERAL REPUBLIC OF GERMANY

F. Heuser
Giesellschaft Fur Reaktorsicherheit
Forschurgsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

E. F. Hicken
Giesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

D. J. Higson
Radiological Support Group
Nuclear Safety Bureau
Australian Nuclear Science and
Technology Organisation
P.O. Box 153
Rosebery, NSW 2018
AUSTRALIA

Ms. Marion Hill
National Radiological Protection
Board
Chilton
Didcot
Oxon. OX11 ORQ
UNITED KINGDOM

Daniel Hirsch
University of California
A. Stevenson Program on
Nuclear Policy
Santa Cruz, CA 95064

H. Hirschmann
Hauptabteilung Sicherheit und
Umwelt
Swiss Federal Institute for
Reactor Research (EIR)
CH-5303 Wurenlingen
SWITZERLAND

Mike Hitchler
Westinghouse Electric Corp.
Savanna River Site
Aiken, SC 29808

Richard Hobbins
EG&G Idaho
P. O. Box 1625
Idaho Falls, ID 83415

Lars Hoegberg
Office of Regulation and Research
Swedish Nuclear Power Inspectorate
P. O. Box 27106
S-102 52 Stockholm
SWEDEN

Lars Hoeghort
IAEA A-1400
Wagranerstraase 5
P.O. Box 100
Vienna, 22
AUSTRIA

Edward Hofer
Giesellschaft Fur Reaktorsicherheit
Forschurgsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

Peter Hoffmann
Kernforschingszentrum Karlsruhe
Institute for Material
Und Festkorperforsching I
Postfach 3640
D-7500 Karlsruhe 1
FEDERAL REPUBLIC OF GERMANY

N. J. Holloway
UKAEA Safety and Reliability
Directorate
Wigshaw Lane, Culcheth
Warrington, Cheshire, WA34NE
UNITED KINGDOM

Mr. Kou-John Hong
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439

Mr. William Hopkins
Bechtel Power Corporation
15740 Shady Grove Road
Gaithersburg, MD 20877-1454

Stephen C. Hora
University of Hawaii at Hilo
Division of Business Administration
and Economics
College of Arts and Sciences
Hilo, HI 96720-4091

J. Peter Hoseman
Swiss Federal Institute for
Reactor Research
CH-5303, Wurenlingen
SWITZERLAND

Thomas C. Houghton
KMC, Inc.
1747 Pennsylvania Avenue, NW
Washington, DC 20006

Dean Houston
USNRC-ACRS
MS: P-315

Der Yu Hsia
Taiwan Atomic Energy Council
67, Lane 144, Keelung Rd.
Sec. 4
Taipei
TAIWAN

Alejandro Huerta-Bahena
National Commission on Nuclear
Safety and Safeguards (CNSNS)
Insurgentes Sur N. 1776
Col. Florida
C. P. 04230 Mexico, D.F.
MEXICO

Kenneth Hughey [2]
SERI
5360 I-55 North
Jackson, MS 39211

Won-Guk Hwang
Kzunghee University
Yongin-Kun
Kyunggi-Do 170-23
KOREA

Michio Ichikawa
Japan Atomic Energy Research
Institute
Dept. of Fuel Safety Research
Tokai-Mura, Naka-Gun
Ibaraki-Ken, 319-1
JAPAN

Mr. Hanspeter Isaak
Abteilung Strahlenschutz
Hauptabteilung fur die Sicherheit
der Kernanlagen (HSK)
CH-5303 Wurenlingen
SWITZERLAND

Sanford Israel
USNRC-AEOD/ROAB
MS: MNBB-9715

Krishna R. Iyengar
Louisiana Power and Light
200 A Huey P. Long Avenue
Gretna, LA 70053

Jerry E. Jackson
USNRC-RES
MS: NL/S-302

Michael Jamgochian
USNRC-RES/SAIB
MS-NLS324

R. E. Jaquith
Combustion Engineering, Inc.
1000 Prospect Hill Road
M/C 9490-2405
Windsor, CT 06095

S. E. Jensen
Exxon Nuclear Company
2101 Horn Rapids Road
Richland, WA 99352

Kjell Johannson
Studsvik Energiteknik AB
S-611 82, Nykoping
SWEDEN

Richard John
SSM, Room 102
927 W. 35th Place
USC, University Park
Los Angeles, CA 90089-0021

D. H. Johnson
Pickard, Lowe & Garrick, Inc.
2260 University Drive
Newport Beach, CA 92660

James Johnson
USNRC-RES/PRAB
MS-NL372

W. Reed Johnson
Department of Nuclear Engineering
University of Virginia
Reactor Facility
Charlottesville, VA 22901

Jeffery Julius
NUS Corporation
1301 S. Central Ave, Suite 202
Kent, WA 98032

H. R. Jun
Korea Adv. Energy Research Inst.
P.O. Box 7, Daeduk Danju
Chungnam 300-31
KOREA

Peter Kafka
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

Geoffrey D. Kaiser
Science Application Int. Corp.
1710 Goodridge Drive
McLean, VA 22102

William Kastenberg
UCLA
Boelter Hall, Room 5532
Los Angeles, CA 90024

Walter Kato
Brookhaven National Laboratory
Associated Universities, Inc.
Upton, NY 11973

Mr. Paul Kayser
Division de la Radioprotection
1, Avenue des Archiducs
L-1135 Luxembourg-Belair
LUXEMBOURG

M. S. Kazimi
MIT, 24-219
Cambridge, MA 02139

Ralph L. Keeney
101 Lombard Street
Suite 704W
San Francisco, CA 94111

Mr. Ken Keith
TVA
W 10 D 201
400 West Summit Hill
Knoxville, TN 37902

Mr. G. Neale Kelly
Nuclear Safety Research
Commission of the European
Communities
Rue de la Loi, 200
B-1049 Bruxelles
BELGIUM

Henry Kendall
Executive Director
Union of Concerned Scientists
Cambridge, MA

Frank King
Ontario Hydro
700 University Avenue
Bldg. H11 G5
Toronto
CANADA M5G 1X6

Oliver D. Kingsley, Jr.
Tennessee Valley Authority
1101 Market Street
GN-38A Lookout Place
Chattanooga, TN 37402

Stephen R Kinnersly
Winfrith Atomic Energy
Establishment
Reactor Systems Analysis Division
Winfrith, Dorchester
Dorset DT2 8DH
ENGLAND

Ryohei Kiyose
University of Tokyo
Dept. of Nuclear Engineering
7-3-1 Hongo Bunkyo
Tokyo 113
JAPAN

George Klopp
Commonwealth Edison Company
P.O. Box 767, Room 35W
Chicago, IL 60690

Knolls Atomic Power
Laboratory (2)
Attn: Mr. Ken McDonough
Mr. Dominic Sciaudone
Box 1072
Schenectady, NY 12301-1072

Mr. Darrel Knudson
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, ID 83415

Klaus Koberlein
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

E. Kohn
Atomic Energy Canada Ltd.
Candu Operations
Mississauga
Ontario
CANADA L5K 1B2

Alan M. Kolaczkowski
Science Applications International
Corporation
2109 Air Park Road, S.E.
Albuquerque, NM 87106

Mr. John G. Kollas
Institute of Nuclear Technology and
Radiation Protection
N.R.C.P.S. "Demokritos"
P.O. Box 60228
GR-153 10 Aghia Paraskevi
Attiki
GREECE

S. Kondo
Department of Nuclear Engineering
Facility of Engineering
University of Tokyo
3-1, Hongo 7, Bunkyo-ku
Tokyo
JAPAN

Robert Kornasiewicz
USNRC-RES/WMB
MS-NLS260

Herbert J. C. Kouts
Brookhaven National Laboratory
Building 179C
Upton, NY 11973

W. Kroger
Institut fur Nukleare
Sicherheitsforschung
Kernforschungsanlage Julich GmbH
Postfach 1913
D-5170 Julich 1
FEDERAL REPUBLIC OF GERMANY

Greg Krueger [3]
Philadelphia Electric Co.
2301 Market St.
Philadelphia, PA 19101

Bernhard Kuczera
Kernforschungzentrum Karlsruhe
LWR Safety Project Group (PRS)
P. O. Box 3640
D-7500 Karlsruhe 1
FEDERAL REPUBLIC OF GERMANY

Jeffrey L. LaChance
Science Applications International
Corporation
2109 Air Park Road S.E.
Albuquerque, NM 87106

Les Lancaster
USNRC-RES/PRAB
MS-NL372

H. Larsen
Riso National Laboratory
Postbox 49
DK-4000 Roskilde
DENMARK

Wang L. Lau
Tennessee Valley Authority
400 West Summit Hill Avenue
Knoxville, TN 37902

Lawrence Livermore National
Laboratory (4)
Attn: Ms. Sandra Brereton
Mr. Marvin Dickerson
Mr. George Greenly
Mr. Rolf Lange
Livermore, CA 94550

Timothy J. Leahy
EI Services
1851 South Central Place, Suite 201
Kent, WA 98031

John C. Lee
University of Michigan
North Campus
Dept. of Nuclear Engineering
Ann Arbor, MI 48109

Mr. Shengdar Lee
Yankee Atomic Electric Company
580 Main St.
Bolton, MA 01740

Tim Lee
USNRC-RES/RPSB
MS: NL/N-353

Mark T. Leonard
Science Applications International
Corporation
2109 Air Park Road, SE
Albuquerque, NM 87106

Leo LeSage
Director, Applied Physics Div.
Argonne National Laboratory
Building 208, 9700 South Cass Ave.
Argonne, IL 60439

Joe Levine
USNRC-NRR/PRPB
MS-11D23

Milton Levenson
Bechtel Western Power Company
50 Beale St.
San Francisco, CA 94119

Librarian
NUMARC/USCEA
1776 I Street NW, Suite 400
Washington, DC 80006

Eng Lin
Taiwan Power Company
242, Roosevelt Rd., Sec. 3
Taipei
TAIWAN

N. J. Liparulo
Westinghouse Electric Corp.
P. O. Box 355
Pittsburgh, PA 15230

Y. H. (Ben) Liu
Department of Mechanical
Engineering
University of Minnesota
Minneapolis, MN 55455

Bo Liwnang
IAEA A-1400
Swedish Nuclear Power Inspectorate
P.O. Box 27106
S-102 52 Stockholm
SWEDEN

J. P. Longworth
Central Electric Generating Board
Berkeley Gloucester
GL13 9PB
UNITED KINGDOM

Mr. D. Eugenio Gil Lopez
Consejo de Seguridad Nuclear
Calle Justo Dorado, 11
E-28040 Madrid
SPAIN

Walter Lowenstein
Electric Power Research Institute
3412 Hillview Avenue
P. O. Box 10412
Palo Alto, CA 94303

William J. Luckas
Brookhaven National Laboratory
Building 130
Upton, NY 11973

Hans Ludewig
Brookhaven National Laboratory
Building 130
Upton, NY 11973

Robert J. Lutz, Jr.
Westinghouse Electric Corporation
Monroeville Energy Center
EC-E-371, P. O. Box 355
Pittsburgh, PA 15230-0355

Phillip E. MacDonald
EG&G Idaho, Inc.
P.O. Box 1625
Idaho Falls, ID 83415

Jim MacKenzie
World Resources Institute
1735 New York Ave. NW
Washington, DC 20006

Tom McKenna
USNRC-AEOD/IRB
MS-3206

Richard D. Fowler
Idaho Nat. Engineering Laboratory
P.O. Box 1625
Idaho Falls, ID 83415

Giuseppe Mancini
Commission European Comm.
CEC-JRC Eraton
Ispra Varese
ITALY

Mr. Daniel Manesse
IPSN
Boite Postale 6
F-92265 Fontenay-aux-Roses CEDEX
FRANCE

Mr. Fred Mann
Westinghouse Hanford Co.
W/A-53
P.O. Box 1970
Richland, WA 99352

Tim Margulies
USNRC-RES/WMB
MS-NLS260

Ms. Nadia Soido Falcao Martins
Comissao Nacional de Energia
Nuclear
R General Severiano 90 S/408-A
Rio de Janeiro
BRAZIL

Mr. Hideo Matsuzuru
Tokai Research Establishment
Tokai-mura
Maka-gun
Ibaraki-ken, 319-11
JAPAN

Lasse Mattila
Technical Research Centre of
Finland
Lonnrotinkatu 37, P. O. Box 169
SF-00181 Helsinki 18
FINLAND

Roger J. Mattson
SCIENTECH Inc.
11821 Parklawn Dr.
Rockville, MD 20852

Mr. Jim Mayberry
Ebasco Services
160 Chubb Ave.
Lyndhurst, NJ 07071

Donald McPherson
USNRC-NRR/DONRR
MS: 12G-18

Ms. Zen Mendoza
SAIC
5150 El Camino Real
Suite C31
Los Altos, CA 94022

Jim Metcalf
Stone and Webster Engineering
Corporation
245 Summer St.
Boston, MA 02107

Mr. Jim Meyer
Scientech
11821 Parklawn Dr.
Suite 100
Rockville, MD 20852

Mary Meyer
A-1, MS F600
Los Alamos National Laboratory
Los Alamos, NM 87545

Ralph Meyer
USNRC-RES/AEB
MS: NL/N-344

Charles Miller
8 Hastings Rd.
Momsey, NY 10952

Mr. Brad Micklich
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439

Joseph Miller
Gulf States Utilities
P. O. Box 220
St. Francisville, LA 70775

William Mims
Tennessee Valley Authority
400 West Summit Hill Drive.
W10D199C-K
Knoxville, TN 37902

Jocelyn Mitchell
USNRC-RES/SAIB
MS: NL/S-324

Kam Mohktarian
CBI Na-Con Inc.
800 Jorie Blvd.
Oak Brook, IL 60521

James Moody
P.O. Box 641
Rye, NH 03870

S. Mori
Nuclear Safety Division
OECD Nuclear Energy Agency
38 Blvd. Suchet
75016 Paris
FRANCE

Walter B. Murfin
P.O. Box 550
Mesquite, NM 88048

Joseph A. Murphy
USNRC-RES/DSR
MS: NL/S-007

Mr. Shankaran Nair
Central Electricity Generating
Board
Berkeley Nuclear Laboratories
Berkeley
Gloucestershire GL13 9PB
UNITED KINGDOM

V. I. Nath
Safety Branch
Safety Engineering Group
Sheridan Park Research Community
Mississauga, Ontario
CANADA L5K 1B2

Mr. Ray Ng
NUMARC
1776 Eye St, NW
Suite 300
Washington, DC 20006-2496

Susan J. Niemczyk
1545 18th St. NW, #112
Washington, DC 20036

Mr. William Nixon
AEA/SRD
Wigshaw Lane
Culcheth
Warrington
Cheshire WA3 4NE
UNITED KINGDOM

Pradyot K. Niyogi
USDOE-Office of Nuclear Safety
Washington, DC 20545

Paul North
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, ID 83415

Oak Ridge National Laboratory (3)
Attn: George F. Flanagan
Steven Hodge
A. P. Malinauskas
P. O. Box Y
Oak Ridge, TN 37831

Oak Ridge National Laboratory (2)
Attn: Mr. Keith F. Eckerman
Mr. Robert W. Roussin
P.O. Box 2008
Oak Ridge, TN 37831

Mr. Ken O'Brien
University of Wisconsin
Nuclear Engineering Dept.
153 Engineering Research Bldg
Madison, WI 53706

Edward P. O'Donnell
Ebasco Services, Inc.
2 World Trade Center, 89th Floor
New York, NY 10048

David Okrent
UCLA
Boelter Hall, Room 5532
Los Angeles, CA 90024

Mr. Kevin O'Kula
Savannah River Laboratory
Aiken, SC 29808

Robert L. Olson
Tennessee Valley Authority
400 West Summit Hill Rd.
Knoxville, TN 37902

Simon Ostrach
Case Western Reserve University
418 Glenman Bldg.
Cleveland, OH 44106

D. Paddleford
Westinghouse Electric Corporation
Savanna River Site
Aiken, SC 29808

Robert L. Palla, Jr.
USNRC-NRR/PRAB
MS: 10A-2

Chang K. Park
Brookhaven National Laboratory
Building 130
Upton, NY 11973

Michael C. Parker
Illinois Department of Nuclear
Safety
1035 Outer Park Dr.
Springfield, IL 62704

Gareth Parry
NUS Corporation
910 Clopper Road
Gaithersburg, MD 20878

J. Pelce
Departement de Surete Nucleaire
IPSN
Centre d'Estudes Nucleaires du CEA
B.P. no. 6, Cedex
F-92260 Fontenay-aux-Roses
FRANCE

Harold Peterson
USNRC-RES/RPHEB
MS-NLS139

G. Petrangeli
ENEA Nuclear Energy ALT Disp
Via V. Brancati, 48
00144 Rome
ITALY

Marty Plys
Fauske and Associates
16W070 West 83rd St.
Burr Ridge, IL 60521

Edward Podolak
USNRC-NRR/PEPB
MS-10D4

Mike Podowski
Department of Nuclear Engineering
and Engineering Physics
RPI
Troy, NY 12180-3590

Robert D. Pollard
Union of Concerned Scientists
1616 P Street, NW, Suite 310
Washington, DC 20036

R. Potter
UK Atomic Energy Authority
Winfrith, Dorchester
Dorset, DT2 8DH
UNITED KINGDOM

William T. Pratt
Brookhaven National Laboratory
Building 130
Upton, NY 11973

M. Preat
Chef du Service Surete Nucleaire et
Assurance Qualite
TRACTEBEL
Bd. du Regent 8
B-100 Bruxells
BELGIUM

David Pyatt
USDOE
MS: EH-332
Washington, DC 20545

William Raisin
NUMAEC
1726 M St. NW
Suite 904
Washington, DC 20036

Joe Rashid
ANATECH Research Corp.
3344 N. Torrey Pines Ct.
Suite 1320
La Jolla, CA 90237

Dale M. Rasmuson
USNRC-RES/PRAB
MS: NL/S-372

Ingvard Rasmussen
Riso National Laboratory
Postbox 49
DK-4000, Roskilde
DENMARK

Norman C. Rasmussen
Massachusetts Institute of
Technology
77 Massachusetts Avenue
Cambridge, MA 02139

John W. Reed
Jack R. Benjamin & Associates, Inc.
444 Castro St., Suite 501
Mountain View, CA 94041

David B. Rhodes
Atomic Energy of Canada, Ltd.
Chalk River Nuclear Laboratories
Chalk River, Ontario
CANADA K0J 1P0

Dennis Richardon
Westinghouse Electric Corporation
P.O. Box 355
Pittsburgh, PA 15230

Doug Richeard
Virginia Electric Power Co.
P.O.Box 26666
Richmond, VA 23261

John Ridgely
USNRC-RES/SAIB
MS-NLS324

Robert Ritzman
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94304

Richard Robinson
USNRC-RES/PRAB
MS: NL/S-372

Ms. Judy Rollstin
GRAM, Inc .
1709 Moon NE
Albuquerque, NM 87112

Jack E. Rosenthal
USNRC-AEOD/ROAB
MS: MNBB-9715

Denwood F. Ross
USNRC-RES
MS: NL/S-007

Frank Rowsome
9532 Fern Hollow Way
Gaithersburg, MD 20879

Wayne Russell
SERI
5360 I-55 North
Jackson, MS 39211

Chris Ryder
USNRC-RES/PRAB
MS-NL372

SAIC (3)
Attn: Mr. Chris Amos
Mr. Jay Johnson
Mr. Paul Mattingly
2109 Air Park Rd. SE
Albuquerque, NM 87106

Jorma V. Sandberg
Finnish Ctr. Rad. Nucl. and Safety
Department of Nuclear Safety
P.O. Box 268
SF-00101 Helsinki
FINLAND

G. Saponaro
ENEA Nuclear Engineering Alt.
Zia V Brancati 4B
00144 ROME
ITALY

M. Sarran
United Engineers
P. O. Box 8223
30 S 17th Street
Philadelphia, PA 19101

Marty Sattison
EG&G Idaho
P. O. Box 1625
Idaho Falls, ID 83415

George D. Sauter
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Jorge Schulz
Bechtel Western Power Corporation
50 Beale Street
San Francisco, CA 94119

B. R. Sehgal
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Subir Sen
Bechtel Power Corp.
15740 Shady Grove Road
Location 1A-7
Gaithersburg, MD 20877

S. Serra
Ente Nazionale per l'Energia
Electtrica (ENEL)
via G. B. Martini 3
Rome
ITALY

Bonnie J. Shapiro
Science Applications International
Corporation
360 Bay Street
Suite 200
Augusta, GA 30901

H. Shapiro
Licensing and Risk Branch
Atomic Energy of Canada Ltd
Sheridan Park Research Community
Mississauga, Ontario
CANADA L5K 1B2

Dave Sharp
Westinghouse Savannah River Co
Building 773-41A, P O Box 616
Aiken, SC 29802

John Sherman
Tennessee Environmental Council
1719 West End Avenue, Suite 22[illegible]
Nashville, TN 37203

Brian Sheron
USNRC-RES/DSR
MS: NL/N-007

Rick Sherry
JAYCOR
P. O. Box 85154
San Diego, CA 92138

Steven C. Sholly
MHB Technical Associates
1723 Hamilton Avenue, Suite K
San Jose, CA 95125

Louis M. Shotkin
USNRC-RES/RPSB
MS: NL/N-353

M. Siebertz
Chef de la Section Surete' des
Reacteurs
CEN/SCK
Boeretang, 200
B-2400 Mol
BELGIUM

Melvin Silberberg
USNRC-RES/DE/WNB
MS: NL/S-260

Frank Skopec
USNRC-NRR/PRPB
MS-11D23

Gary Smith
SERI
5360 I-55 North
Jackson, MS 39211

Gary L. Smith
Westinghouse Electric Corporation
Hanford Site
Box 1970
Richland, WA 99352

Lanny N. Smith
Science Applications International
Corporation
2109 Air Park Road SE
Albuquerque, NM 87106

K. Soda
Japan Atomic Energy Res. Inst.
Tokai-Mura Naka-Gun
Ibaraki-Ken 319-11
JAPAN

Leonard Soffer
USNRC-RES/SAIB
MS-NLS324

David Sommers
Virginia Electric Power Company
P. O. Box 26666
Richmond, VA 23261

Herschel Spector
New York Power Authority
123 Main Street
White Plains, NY 10601

Themis P. Speis
USNRC-RES
MS: NL/S-007

Mr. Desmond Stack
Los Alamos National Laboratory
Analysis and Assessment Division
Los Alamos, NM 87545

Klaus B. Stadie
OECD-NEA, 38 Bld. Suchet
75016 Paris
FRANCE

Mr. Eli Stern
Isreal AEC Licensing Div.
P.O. Box 7061
Tel-Aviv 61070
ISRAEL

John Stetkar
Pickard, Lowe & Garrick, Inc.
2216 University Drive
Newport Beach, CA 92660

Wayne L. Stiede
Commonwealth Edison Company
P.O. Box 767
Chicago, IL 60690

William Stratton
Stratton & Associates
2 Acoma Lane
Los Alamos, NM 87544

Mr. Dennis Strenge
Pacific Northwest Laboratory
RTO /125
P.O. Box 999
Richland, WA 99352

Soo-Pong Suk
Korea Advanced Energy Research
Institute
P. O. Box 7
Daeduk Danji, Chungnam 300-31
KOREA

W. P. Sullivan
GE Nuclear Energy
175 Curtner Ave., M/C 789
San Jose, CA 95125

Tony Taig
U.K. Atomic Energy Authority
Wigshaw Lane, Culcheth
Warrington, Cheshire, WA3 4NE
UNITED KINGDOM

John Taylor
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Harry Teague
U.K. Atomic Energy Authority
Wigshaw Lane, Culcheth
Warrington, Cheshire, WA3 4NE
UNITED KINGDOM

Technadyne Engineering
Consultants, Inc, (2)
Attn: Mr. Burt Newmark
Mr. David Chanin
P.O. Box 13928
Albuquerque, NM 87192

Technical Library
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94304

Mark I. Temme
General Electric, Inc.
P.O. Box 3508
Sunnyvale, CA 94088

T. G. Theofanous
University of California, S.B.
Department of Chemical and Nuclear
Engineering
Santa Barbara, CA 93106

David Teolis
Westinghouse-Bettis Atomic Power
Laboratory
P. O. Box 79, ZAP 34N
West Mifflin, PA 15122-0079

Ashok C. Thadani
USNRC-NRR/SAD
MS: 7E-4

Garry Thomas
L-499 (Bldg. 490)
Lawrence Livermore National
Laboratory
7000 East Ave.
P.O. Box 808
Livermore, CA 94550

Gordon Thompson
Institute for Research and
Security Studies
27 Ellworth Avenue
Cambridge, MA 02139

Grant Thompson
League of Women Voters
1730 M. Street, NW
Washington, DC 20036

Mr. Soren Thykier-Nielsen
Riso National Laboratory
Postbox 49
DK-4000 Roskilde
DENMARK

Arthur Tingle
Brookhaven National Laboratory
Building 130
Upton, NY 11973

Rich Toland
United Engineers and Construction
30 S. 17th St., MS 4V7
Philadelphia, PA 19101

Brian J. R. Tolley
DG/XII/D/1
Commission of the European
Communities
Rue de la Loi, 200
B-1049 Brussels
BELGIUM

Mr. John Tolli
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, ID 83415

Mr. R. Toossi
Physical Research, Inc.
25500 Hawthorne Blvd.
Torrance, CA 90505-6828

David R. Torgerson
Atomic Energy of Canada Ltd.
Whiteshell Nuclear
Research Establishment
Pinawa, Manitoba
CANADA ROE 1L0

Alfred F. Torri
Pickard, Lowe & Garrick, Inc.
191 Calle Magdalena, Suite 290
Encinitas, CA 92024

Klau Trambauer
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FERERAL REPUBLIC OF GERMANY

Nicholas Tsoulfanidis
Nuclear Engineering Dept.
University of Missouri-Rolla
Rolla, MO 65401-0249

Chao-Chin Tung
c/o H.B. Bengelsdorf
ERC Environmental Services Co.
P. O. Box 10130
Fairfax, VA 22030

Brian D. Turland
UKAEA Culham Laboratory
Abingdon, Oxon OX14 3DB
ENGLAND

Mr. Ulf Tveten, Head
Environmental Physics Section
Institutt for Energiteknikk
Postboks 40
N-2007 Kjeller
NORWAY

U.S. Department of Energy (3)
Attn: Mr. Sarbes Acharya
Mr. Ed Branagan (EH332)
Mr. Ken Murphy (EH351)
Washington, D.C. 20545

U.S. Environmental Protection
Agency (2)
Office of Radiation Programs
Environmental Analysis Division
Attn: Mr. Allen Richardson
Mr. Joe Logsdon
Washington, D.C. 20460

Takeo Uga
Japan Institute of Nuclear Safety
Nuclear Power Engineering Test
Center
3-6-2, Toranomon
Minato-ku, Tokyo 108
JAPAN

Stephen D. Unwin
Battelle Columbus Division
505 King Avenue
Columbus, OH 43201

A. Valeri
DISP
ENEA
Via Vitaliano Brancati, 48
I-00144 Rome
ITALY

Harold VanderMolen
USNRC-RES/PRAB
MS: NL/S-372

Mr. Jan Van der Steen
KEMA Laboratories
Utrechtseweg, 310
Postbus 9035
NL-6800 ET Arnhem
Netherlands

G. Bruce Varnado
ERC International
1717 Louisiana Blvd. NE, Suite 202
Albuquerque, NM 87110

Jussi K. Vaurio
Imatran Voima Oy
Loviisa NPS
SF-07900 Loviisa
FINLAND

William E. Vesely
Science Applications International
Corporation
2929 Kenny Road, Suite 245
Columbus, OH 43221

J. I. Villadoniga Tallon
Div. of Analysis and Assessment
Consejo de Seguridad Nuclear
c/ Sor Angela de la Cruz, 3
28020 Madrid
SPAIN

Willem F. Vinck
Kapellestract 25
1980
Tervuren
BELGIUM

R. Virolainen
Office of Systems Integration
Finnish Centre for Radiation and
Nuclear Safety
Department of Nuclear Safety
P.O. Box 268
Kumpulantie 7
SF-00520 Helsinki
FINLAND

Raymond Viskanta
School of Mechanical Engineering
Purdue University
West Lafayette, IN 47907

S. Visweswaran
General Electric Company
175 Curtner Avenue
San Jose, CA 95125

Truong Vo
Pacific Northwest Laboratory
Battelle Blvd.
Richland, WA 99352

Richard Vogel
Electric Power Research Institute
P. O. Box 10412
Palo Alto, CA 94303

G. Volta
Engineering Division
CEC Joint Research Centre
CP No. 1
I-21020 Ispra (Varese)
ITALY

Mr. Seppo Vuori
Technical Research Centre of
Finland (VTT)
Nuclear Engineering Laboratory
(YDI)
Lonnrotinkatu 37
P.O. Box 169
SF-00181 Helsinki 18
FINLAND

Ian B. Wall
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Adolf Walser
Sargent and Lundy Engineers
55 E. Monroe Street
Chicago, IL 60603

Edward Warman
Stone & Webster Engineering Corp.
P.O. Box 2325
Boston, MA 02107

Norman Weber
Sargent & Lundy Co.
55 E. Monroe Street
Chicago, IL 60603

Lois Webster
American Nuclear Society
555 N. Kensington Avenue
La Grange Park, IL 60525

Wolfgang Werner
Gesellschaft Fur Reaktorsicherheit
Forschungsgelande
D-8046 Garching
FEDERAL REPUBLIC OF GERMANY

Don Wesley
IMPELL
1651 East 4th Street
Suite 210
Santa Ana, CA 92701

Westinghouse Electric Co.
Energy Center East
Attn: Mr. Griff Holmes
Mr. John Iacovino
Bldg. 371
P.O. Box 355
Pittsburgh, Pa 15230

Charles Willis
NRR/DREP
MS-10E4

Detlof von Winterfeldt
Institute of Safety and Systems Management
University of Southern California
Los Angeles, CA 90089-0021

Mr. Keith Woodard
Pickard, Low, and Garrick
Suite 730
1615 M. Street
Washington, DC 20036

Pat Worthington
USNRC-RES/AEB
MS: NL/N-344

John Wreathall
Science Applications International Corporation
2929 Kenny Road, Suite 245
Columbus, OH 43221

D. J. Wren
Atomic Energy of Canada Ltd.
Whiteshell Nuclear Research Establishment
Pinawa, Manitoba
CANADA ROE 1L0

Roger Wyrick
Inst. for Nuclear Power Operations
1100 Circle 75 Parkway, Suite 1500
Atlanta, GA 30339

Shlomo Yaniv
USNRC-RES/RPHEB
MS-NLS139

Mr. M. K. Yeung
University of Hong Kong
Mechanical Engineering Dept.
Pokfulam
HONG KONG

Kun-Joong Yoo
Korea Advanced Energy Research Institute
P. O. Box 7
Daeduk Danji, Chungnam 300-31
KOREA

Faith Young
Energy People, Inc.
Dixon Springs, TN 37057

Jonathan Young
R. Lynette and Associates
15042 Northeast 40th St.
Suite 206
Redmond, WA 98052

C. Zaffiro
Division of Safety Studies
Directorate for Nuclear Safety and Health Protection
Ente Nazionale Energie Alternative
Via Vitaliano Brancati, 48
I-00144 Rome
ITALY

Mike Zentner
Westinghouse Hanford Co.
P. O. Box 1970
Richland, WA 99352

X. Zikidis
Greek Atomic Energy Commission
Agia Paraskevi, Attiki
Athens
GREECE

Bernhard Zuczera
Kernforschungszentrum
Postfach 3640
D-7500 Karlsruhe
FEDERAL REPUBLIC OF GERMANY

1521	J. R. Weatherby
3141	S. A. Landenberger [5]
3151	W. I. Klein
3212	H. N. Jow
5214	D. B. Clauss
6344	E. D. Gorham
6001	D. D. Carlson
6001	R. J Breeding
6001	D. M. Kunsman
6216	D. J. Alpert
6216	J. L. Sprung
6400	D. J. McCloskey
6410	D. A. Dahlgren
6412	A. L. Camp
6412	S. L. Daniel
6412	T. M. Hake

6412	L. A. Miller
6412	D. B. Mitchell
6412	A. C. Payne, Jr.
6412	T. T. Sype
6412	T. A. Wheeler
6412	D. W. Whitehead
6413	K. G. Adams
6413	T. D. Brown
6413	F. T. Harper [20]
6415	R. M. Cranwell
6415	W. R. Cramond
6415	R. L. Iman
6418	J. E. Kelly
6418	K. J. Maloney
6419	M. P. Bohn
6419	J. A. Lambright
6422	D. A. Powers
6424	K. D. Bergeron
6424	J. J. Gregory
6424	D. R. Bradley
6424	D. C. Williams
6425	S. S. Dosanjh
6453	J. S. Philbin
6460	J. V. Walker
6463	M. Berman
6463	M. P. Sherman
6471	L. D. Bustard
6573	W. A. von Riesemann
7254	L. T. Ritchie
8524	J. A. Wackerly

NRC FORM 335
(2 89)
NRCM 1102
3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

1. REPORT NUMBER
(Assigned by NRC. Add Vol., Supp., Rev., and Addendum Numbers, if any.)

NUREG/CR-4551
SAND86-1309
Vol. 2, Rev. 1, Part 7

2. TITLE AND SUBTITLE

Evaluation of Severe Accident Risks:
Quantification of Major Input Parameters

MACCS Input

3. DATE REPORT PUBLISHED

MONTH	YEAR
December	1990

4. FIN OR GRANT NUMBER
A1853

5. AUTHOR(S)

J.L. Sprung, J.A. Rollstin,* J.C. Helton**, H-N Jow

* GRAM, Inc.
** Arizona State University

6. TYPE OF REPORT

Technical

7. PERIOD COVERED *(Inclusive Dates)*

8. PERFORMING ORGANIZATION — NAME AND ADDRESS *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

Sandia National Laboratories
Albuquerque, NM 87185

9. SPONSORING ORGANIZATION — NAME AND ADDRESS *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)*

Division of Systems Research
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

Estimation of offsite accident consequences is the customary final step in a probabilistic assessment of the risks of severe nuclear reactor accidents. Recently, the Nuclear Regulatory Commission reassessed the risks of severe accidents at five U.S. power reactors (NUREG-1150). Offsite accident consequences for NUREG-1150 source terms were estimated using the MELCOR Accident Consequence Code System (MACCS). Before these calculations were performed, most MACCS input parameters were reviewed, and for each parameter reviewed, a best-estimate value was recommended. This report presents the results of these reviews. Specifically, recommended values and the basis for their selection are presented for MACCS atmospheric and biospheric transport, emergency response, food pathway, and economic input parameters. Dose conversion factors and health effect parameters are not reviewed in this report.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

Accidents, Atmospheric Dispersion, Dosimetry, Economic Costs, Emergency Response, Evacuation, MACCS Computer Code, Mitigative Actions, Nuclear, Offsite Consequences, Radiation, Radioactive Releases, Reactor Accidents, Relocation, Sheltering

13. AVAILABILITY STATEMENT
Unlimited

14. SECURITY CLASSIFICATION
(This Page)
Unclassified
(This Report)
Unclassified

15. NUMBER OF PAGES

16. PRICE