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A MACCS2 Single Nuclide Downwind Dose Database for Sandia National Laboratories, Technical Area V

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Abstract

This report documents the database of airborne radiation dose calculations using the MELCOR Accident Consequences Code System, version 1.12 (MACCS2) for the weather and nuclear facilities of Technical Area V (TA-V) of Sandia National Laboratories at Albuquerque, New Mexico. The radiation dose at various distance ranges was calculated and tabulated for a 1.0-curie airborne release of a single radioactive nuclide in the downwind dose database (DWDD) for TA-V. This report discusses the inputs and tabulated doses for the three distributions of the DWDD. Doses for over 120 nuclides for four release conditions of interest to TA-V operations originally calculated in 1997 were tabulated for distribution in 1998. The DWDD was extended in 2000 to 152 nuclide doses with the same inputs as the 1998 distribution and those calculations are also tabulated. Details of the MACCS2 standard input and modeling for the 1998 and 2000 calculations are discussed as well as the possible range of input parameters for selection and implementation in the DWDD calculations of 2002 for 162 nuclides that are also tabulated in this report. The database is intended to facilitate safety analyses of TA-V nuclear facilities and activities by providing an easy to use calculation tool for airborne radiation dose.

Acknowledgements

The author wishes to acknowledge the contributions of others whose information and inputs have made the analysis and writing of this report possible. Specifically, Ken Sabish who started the preparation of a dose versus distance database for Technical Area V using a previous version of the MACCS code and contributed some of the initial dose calculations for the 1998 downwind dose database (DWDD) calculations. In addition, Regina Deola, the Sandia National Laboratories meteorologist, contributed extensive weather data for multiple years and helpful insights on various aspects of meteorology affecting airborne dispersion such as surface roughness. Ed Parma wrote the WINDAT2 Fortran computer code to convert the format of the new weather data so it could be used by the MACCS2 code. Both Ed Parma and Dick Coats provided careful review and helpful comments during the preparation and review of this report that have made it a much clearer and more useful document. Finally, the author wishes to acknowledge the contributions of Robert Matavosian and Louis Restrepo. Robert Matavosian's many concerns for the conservatism of the 1998 and 2000 DWDD calculations focused the need for this report and a 2002 review and update to the DWDD dose calculation inputs. Louis Restrepo's careful review and verification calculations contributed much to finalizing the revised inputs for the 2002 DWDD calculations.

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Acronyms and Abbreviations

ACRR	Annular Core Research Reactor
ACRRF	Annular Core Research Reactor Facility
AHCF	Auxiliary Hot Cell Facility
Bq	becquerel, unit of radioactivity equivalent to 1 disintegration per second
CCDF	complementary cumulative distribution function
Ci	curie, unit of radioactivity equivalent to 3.7×10^{10} becquerel (Bq)
DCF	dose conversion factor
DOE	U. S. Department of Energy
DWDD	downwind dose database
EPA	U. S. Environmental Protection Agency
GIF	Gamma Irradiation Facility
HCF	Hot Cell Facility
ICRP	International Commission on Radiological Protection
m	meter
MACCS	MELCOR Accident Consequence Code System
MACCS2	MACCS version 1.12
MOI	maximally exposed off-site individual
NRC	U. S. Nuclear Regulatory Commission
NWS	National Weather Service
QA	quality assurance
QAPP	Quality Assurance Program Plan
RREP	Sandia Research Reactor and Experimental Programs
s	second
SNL	Sandia National Laboratories
SPRF	Sandia Pulsed Reactor Facility
Sv	seivert, unit of radiation dose equivalent to 100 rem
SVVR	software verification and validation report
TA-V	Technical Area V of Sandia National Laboratories
TEDE	total effective dose equivalent
TMY	Typical Meteorological Year provided by the NWS
W	watt
X/Q	Chi over Q is the airborne concentration of radioactive material at a downwind location per unit source rate of released radioactive material (or time-integrated concentration per unit source) (s/m^3).

A MACCS2 Single Nuclide Downwind Dose Database for Sandia National Laboratories, Technical Area V

INTRODUCTION

This report documents the database of calculated airborne dose at selected distances downwind from Sandia National Laboratories (SNL), Technical Area-V (TA-V) nuclear facilities near Albuquerque, New Mexico for hypothetical releases of a single radioactive nuclide. The database is intended to facilitate safety analysis by estimating the consequences of a radioactive release from a planned or existing operation or facility at TA-V. The database provides an easy to use calculation tool for the airborne dose resulting from a hypothetical release of an inventory of multiple nuclides.

The MELCOR Accident Consequence Code System (MACCS) computer code has been used at TA-V for calculating airborne transport and the resulting dose for analyzing accidental releases of radioactive material. The MACCS code calculates and combines airborne doses from multiple weather histories to characterize the airborne dose for TA-V weather. Unfortunately, the code is difficult to learn and inputs were different for various studies making the results hard to get and hard to duplicate. A simple and consistent airborne dose calculation method was needed for safety analysis at TA-V.

The single nuclide downwind dose database (DWDD) was calculated with a consistent, documented set of inputs for MACCS version 1.12 (MACCS2). Those inputs were specifically chosen for TA-V needs. To compile the database, the dose from 1.0 curie (Ci) of a single radioactive nuclide was calculated at multiple distance ranges for several separate release conditions. The 1.0-Ci dose at the range and condition of interest can be multiplied by the hypothetical released activity of that nuclide to yield its dose. The single nuclide downwind doses allow a user to simply add up doses for the activities of individual nuclides in a released inventory without ever running MACCS2. Thus, the single nuclide DWDD provides the simple and consistent airborne dose calculation tool needed for TA-V.

The DWDD that was distributed in January 1998 included 120 nuclides of interest to operations at the Annular Core Research Reactor (ACRR), the Hot Cell Facility (HCF), and other TA-V facilities. Both whole body and thyroid doses are tabulated for a total of 9600 dose values in spreadsheet form for that original database. The database was extended to a total of 152 nuclides in 2000 and the doses for several nuclides that were originally calculated with MACCS version 1.5.11.1 were recalculated with MACCS2 for consistency. Only whole body doses were retained in the 2000 version of the DWDD.

Additional nuclides can be added to the DWDD since dose conversion factors are available in the Federal Guidance Report series (Eckerman et al. 1989, Eckerman and Ryman 1993) of the U. S. Environmental Protection Agency (EPA) to calculate the 1.0-Ci dose for hundreds of nuclides. Airborne dose calculation for a released inventory can be done using a simple spreadsheet based approach using the doses from the DWDD. The latest DWDD of 162 nuclides was recalculated in 2002 with the revised set of inputs described in this report to make it fully compliant with the dose estimation requirements of DOE-STD-3009, Appendix A (DOE 1994). Release conditions and weather data inputs were also updated.

An independent expert review of the revised inputs for the 2002 DWDD MACCS2 calculations (Restrepo 2002) was obtained by the U. S. Department of Energy (DOE) to assess whether the MACCS2 inputs were appropriate for safety analysis to establish the safety basis for TA-V nuclear facilities. The independent expert review found that the inputs were appropriate to perform the desired calculations and suggested changes to improve the calculation inputs. It is important to note that the DOE transmittal letter for the 2002 DWDD independent review (Zamorski 2002) concluded that, "The results of the review also indicated that the SNL analysis using more conservative input parameters and Omicron's analysis (Restrepo 2002) did not identify any significant differences. OKSO requests that these changes suggested by Omicron be incorporated into the SNL analysis." Those suggested input changes have been incorporated appropriately as described later in this report to perform the MACCS2 dose calculations for the 2002 DWDD. The overall conclusion of this report is that the 2002 DWDD provides "reasonably conservative estimates of the various input parameters" as required by DOE-STD-3009, Appendix A (DOE 1994) to be used in preparation of the 2002 DWDD calculations.

This report provides a brief description of the MACCS2 code. A more extensive discussion of the standard inputs used in the DWDD distributed in 1998 and extended to additional nuclides in 2000 is also provided. The range of possible MACCS2 input values are discussed to document the selection process for the revised inputs that were used for the updated 2002 DWDD. Tabulations of the 1998, 2000, and 2002 versions of the DWDD are included in appendices as are typical input files used in the calculations. The MACCS code is sometimes referred to in this report. In those instances the versions of the MACCS code prior to MACCS2 or all versions of the MACCS code as a generic reference are meant. The distinction between all MACCS code versions and versions prior to MACCS2 should be clear from the context where MACCS is used.

MACCS2 CODE DESCRIPTION

The MELCOR Accident Consequence Code System (MACCS) calculates the transport and dose for airborne releases of radioactive materials. The latest code version 1.12, MACCS2, was used to calculate the doses in the downwind dose database (DWDD) for the versions of 1998, 2000 and 2002. A few of the doses for the 1998 DWDD were calculated with an older version of the code (version 1.5.11.1) and dose conversion factor library using the same input parameters. Both versions of the code and dose conversion factor library gave similar results for the same inputs. The 2002 version of the DWDD provided MACCS2 dose calculations based on a revised set of inputs. This chapter briefly describes the MACCS2 dose code calculation method, the structure of the code and calculation, the dose pathways, the geometry of the dose calculation grid, nuclide inventories and dose conversion factors, and weather data sampling methods. Further details on the MACCS2 code and its inputs can be found in the *User's Guide* (Chanin and Young 1997) or the *Model Description* (Jow et al. 1990).

MACCS2 Dose Calculation Method

MACCS2 models the off-site consequences of postulated accidents that release a plume of radioactive material to the atmosphere. MACCS2 models the transport and deposition of radioactive gases and aerosols into the environment and the potential human health and economic consequences. MACCS2 employs a Gaussian plume model for neutrally buoyant plumes for the atmospheric dispersion.

The amount of radioactive material dispersion during transport is usually given in terms of Chi over Q (X/Q), where Chi (X) is the air concentration of radioactivity at some downwind location, either the instantaneous concentration (e.g., Becquerel/cubic meter [Bq/m^3]) or the time-integrated concentration (e.g., Becquerel seconds/cubic meter [$Bq\text{-}s/m^3$]) and Q is the source rate of release (e.g., Becquerel/second [Bq/s]) or total source strength (e.g., Bq); the units of X/Q are s/m^3 whether the instantaneous or time-integrated releases are considered. Thus, X/Q is the concentration at the receptor per unit source rate (or time-integrated concentration per unit source). The concentration at the receptor is the product of X/Q and the source rate (RFETS 1999). The dose at the receptor is the product of the activity concentration and a dose conversion factor for the specific radionuclide so X/Q has a direct effect on dose.

At a given downwind distance and given atmospheric conditions, the Gaussian model predicts the concentration of the released material at various horizontal and vertical displacements from the centerline of the plume. When the plume is not constrained in the vertical by the ground or the top of the mixed air layer, the basic Gaussian plume equation for determining X/Q is (RFETS 1999 and Jow et al. 1990):

$$\frac{X}{Q} = \frac{1}{2\pi\sigma_y\sigma_z\overline{u}}\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\exp\left(-\frac{(z-h)^2}{2\sigma_z^2}\right) \tag{1}$$

where: X = instantaneous or time integrated air concentration (Bq/m^3 or Bq-s/m^3)
Q = the source release rate or total source (Bq/s or Bq)
X/Q = concentration at the receptor per unit source rate or time-integrated concentration per unit source (s/m^3).
y = the horizontal displacement relative to the plume centerline (m)
z = the vertical displacement from the ground (m)
h = the vertical height of the plume centerline (m)
$\bar{u}$ = the average wind velocity at 10 m height (m/s)
σ_y and σ_z are plume expansion parameters (m) that are functions of downwind distance, x (m).

The last factor in Equation (1) defines the vertical distribution. This factor must be modified to consider the reflection of pollutants between the ground and top of the mixed air layer. This is done mathematically by adding (multiple) mirror exponential source terms to that last factor in Equation (1). The first added term is for reflection from the ground. Subsequent reflections between the ground and top of the mixed air layer are described by a series of terms, one term for each set of reflections. All of the series terms include the height of the top of the mixed layer and the height of the plume, h. The summation is over the number of reflections. The contribution of the summation terms is minor, especially for distances close to the source; also, the higher order terms of the series contribute progressively less and the series is normally terminated after only a few terms. In the MACCS2 code the series is terminated after five terms. The seasonal height of the mixed layer is provided as a user input in MACCS2 (RFETS 1999).

The dose of interest in all the DWDDs is the ground surface dose at the plume centerline because this is the maximum dose received at the ground surface location of the dose receptor (person). By substituting 0 for y and z in Equation (1) and adding the exponential term for reflection from the ground to the last factor in Equation (1), the ground surface, plume centerline release concentration (without the minor contribution of reflection from the mixed layer top) is found:

$$\frac{X}{Q} = \frac{1}{\pi \sigma_y \sigma_z \bar{u}} \exp\left(-\frac{h^2}{2\sigma_z^2}\right) \tag{2}$$

It should be noted that X/Q is inversely proportional to the average wind velocity, $\bar{u}$, so lower wind speeds increase the concentration of released radioactive material at a given range. Also, greater vertical height of the plume centerline (for example, higher release height) reduces the concentration of released radioactive material at a given range by reducing the value of the last factor in Equation (2). For a ground release ($h = 0$) the exponential factor is 1.0 for the maximum X/Q at any distance downwind. As σ_z approaches and exceeds the value of h for an elevated plume centerline, X/Q approaches a value comparable to the ground release value. For $\sigma_z = h$ the value of the exponential factor is 0.607 or more than half of the effect of plume reflection for a ground release.

In MACCS2, the following power law models the plume expansion parameters, σ_y and σ_z:

$$\sigma_y = a_y x^{b_y} \;\; ; \;\; \sigma_z = a_z x^{b_z} \tag{3}$$

where x = the downwind distance from the plume release point in meters (Jow et al. 1990).

Constant values for dimensionless parameters a_y, b_y, and a_z, b_z are provided by the user as a code input. The values for the a_y, b_y, and a_z, b_z parameters are determined by the atmospheric stability class. MACCS2 is used to estimate the radiological doses, health effects, and economic consequences that could result from postulated accidental releases of radioactive materials to the atmosphere. In MACCS2, a table of values for σ_y and σ_z versus downwind distance in the input can be used as an alternative to the power law formulation for the plume expansion parameters, σ_y and σ_z. The Tadmor-Gur parameters (Tadmor and Gur 1969) for a_y, b_y, and a_z, b_z were used for the power law calculation of σ_y and σ_z in the 1998/2000 DWDD and the 2002 DWDD.

The Tadmor-Gur parameters and other parameterizations of σ_y and σ_z are based on observational data of plumes released over flat grassland. The most commonly used curves for representing the observed σ_y and σ_z versus downwind distance relationships are the Pasquill-Gifford curves based on measurements from Project Prairie Grass at O'Neil Nebraska in 1956. Those curves are shown in Figure 1 as taken from (Jow et al. 1990). The σ_y curves are shown in the left half of Figure 1 and the σ_z curves are shown in the right half. Figure 1 shows six curves for σ_y and σ_z that correspond to the six atmospheric stability classes in the Pasquill-Gifford model. Class A is the most unstable and class F is the most stable with class D being neutral atmospheric conditions. The database underlying the empirical curve fits was for distances between approximately 100 m and 1000 m as the range of data collected at Project Prairie Grass was for 50 m to 800 m (Draxler 1984). That is the reason why the Pasquill-Gifford curves of Figure 1 are dashed beyond approximately 1000 m since they represent extrapolations. For distances less than about 100 m, these coefficients do not provide a good fit to the observations and the models are generally not considered valid. The Gaussian assumption of steady state is not true there. It should also be noted that the power law fits to σ_z of Tadmor-Gur are further approximations of the observed data since a power law curve is a straight line on a log-log plot and the six stability class curves for σ_z in the log-log plot of Figure 1 are curved lines instead of straight lines.

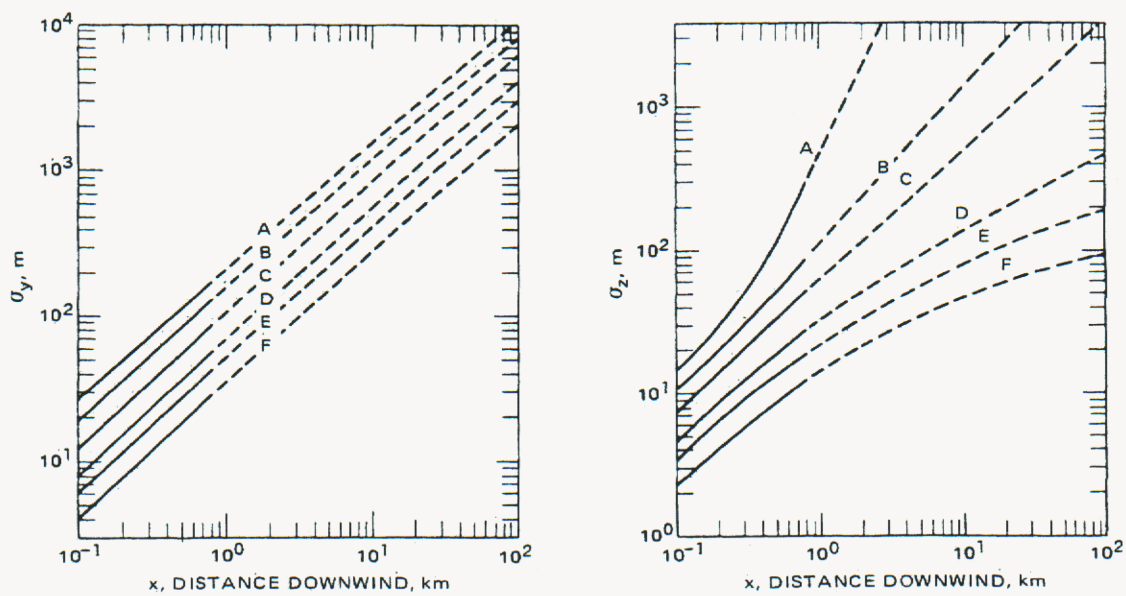

Figure 1. Pasquill-Gifford curves for σ_y and σ_z horizontal and vertical diffusion coefficients

In MACCS2, the values of the dispersion parameters σ_y and σ_z must change continuously although not necessarily smoothly. Since stability class changes discretely, whenever stability class changes, the source distance *x* must be changed in the dispersion parameter of Equation (3) or an input table to some new value that causes dispersion parameter growth to be continuous. The new value of the source distance is called the "virtual source" distance. It will have a different value for σ_y and for σ_z. Although new "virtual source" distances for σ_y and σ_z are calculated every time stability class changes, these distances are used only to calculate growth of σ_y and σ_z. Plume locations are always expressed relative to the release point (Jow et al. 1990).

The specification of the released radioactive material characteristics, designated a "source term," can consist of up to four Gaussian plumes, with these often referred to simply as plumes. For all DWDD calculations, only one plume was used for the source term radioactive material release.

The radioactive materials released are modeled as being dispersed in the atmosphere while being transported by the prevailing wind. During transport, whether or not there is precipitation, particulate material can be modeled as being deposited on the ground, reducing the source for subsequent transport. Radioactive decay of the transported source also reduces the source available for subsequent deposition and dose.

The dose calculation in MACCS2 involves the radioactivity concentration at the downwind receptor location, assumed dose protection factors, dose intake factors, and dose conversion factors (Jow et al. 1990. The MACCS2 code calculates the ground level X/Q (s/m^3) at the receptor location based on meteorological conditions (such as wind speed and stability class). It also calculates the depleted radioactive source Q (Bq) in the plume at the receptor location and the surface concentration of radioactive material on the ground (Bq/m^2) due to removal from the plume at the receptor location. The ground level X/Q and depleted source Q in the plume are used to calculate the dose from immersion in the plume and the dose from inhalation intake of the radioactive material from the plume as illustrated by the following equation:

$$D(x,t) = Q(x,t) * X / Q(x) \; \{ (PF_{IM} DCF_{IM}) + (BR \; PF_{IH} DCF_{IH}) \} \tag{4}$$

where:

$D(x,t)$ = the dose at the receptor location's downwind distance and travel time (seivert [Sv]),
$Q(x,t)$ = the total source depleted by downwind distance and travel time (Bq)
$X/Q(x)$ = time-integrated concentration per unit source at the receptor location distance (s/m^3).
PF_{IM} = protection factor for immersion ($\leq$ 1.0 dimensionless)
PF_{IH} = protection factor for inhalation ($\leq$ 1.0 dimensionless)
BR = breathing rate of the dose receptor for intake of radioactive material (m^3/s)
DCF_{IM} = immersion dose conversion factor from source concentration to dose (Sv/Bq-s/m^3)
DCF_{IH} = inhalation dose conversion factor from source concentration to dose (Sv/Bq)

The dose due to inhalation of ground deposited material that has been resuspended (resuspension dose) is calculated in a similar manner to Equation (4) but with a resuspended radioactive material source. The direct irradiation groundshine dose from material deposited on the ground is calculated using the surface concentration of radioactive material, a dose conversion factor for the groundshine dose rate, and the irradiation time duration (Jow et al. 1990).

MACCS2 Code Modules and Dose Calculation Phases

The MACCS2 code uses three separate calculation modules to perform transport and dose calculations for selected distance ranges downwind from the release point and one output module to present the results in the output. The first module (ATMOS) calculates the dispersion, deposition, and depletion of the airborne radioactive material in the plume as it travels downwind. The second module (EARLY) calculates the dose to the receptor from dose pathways as the radioactive plume passes and for a short emergency phase after plume passage. The third module (CHRONC) calculates the long-term dose due to ingestion and other slow developing dose pathways that are not of interest to dose estimates for safety analysis at Sandia National Laboratories, Technical Area V (TA-V).

Each of the three calculation modules has its own input file for the calculations preformed by that module. Calculations may be directed to terminate after the either of the first two modules with the appropriate output. The output module is automatically run in all MACCS2 calculations and produces the output file based on parameters in the input files for the other modules and the results generated by those modules.

The operation of the code modules is summarized below in Table 1. Timing for each phase of accident response modeled by the MACCS2 code modules begins at radioactive plume arrival at each distance or at the conclusion of the previous phase. Table 1 shows where the accident response and dose is calculated for the accident response phases: emergency, intermediate, and long term.

Table 1. MACCS2 code modules, accident response phases, and dose pathways

Module Name	What Calculated	Accident Response Phases	Dose Pathways Used for Dose Calculation	Used in all DWDD Calculations?
ATMOS	Atmospheric transport, dispersion, deposition, and depletion	N/A	N/A	Yes
EARLY	Dose for the emergency response scenario	Emergency (1-7 days)	Immersion (cloudshine), inhalation, groundshine, and resuspension inhalation	Yes, All four dose pathways for 1998 and 2000, only the first two dose pathways for 2002
CHRONC	Dose for the mitigative actions	Intermediate (0-1 yr) Long-Term (0-30 yr)	Groundshine, resuspension inhalation, and ingestion in food & water	No

Figure 2 below illustrates the progression of a MACCS2 consequence calculation through the code modules including the data and input files. The box marked ATMOS shows the calculation functions of that code module. The box labeled EARLY and CHRONC show the functions of those code modules. Note that CHRONC is really an extension of EARLY with refinements that extend the dose and cost assessments for the chosen mitigative action to a longer duration. CHRONC is not used in the 1998/2000 DWDD or the 2002 DWDD calculations.

The ovals to the left of a box in Figure 2 illustrate the inputs to calculations of that code module. For ATMOS, the source term is defined in the ATMOS input file, as are other parameters that control the calculation (labeled ATMOS Data). The weather data input is a separate file that is identified by name in the disk operation system (DOS) command that executes the MACCS2 code run. For EARLY and CHRONC, a primary input is the ATMOS calculation results as well as the input files for those code modules. Population data may be specified in a separate site data file identified in the DOS execution command or as input information in the EARLY input file. CHRONC requires a separate site data file if it is included in the MACCS2 code run. Dose conversion factor information is provided in a separate file that is specified by name in the EARLY input file. The ATMOS, EARLY, and CHRONC input data files are specified by name in the DOS execution command for that MACCS2 code run. The outputs oval on the right side of the figure illustrates the compilation, processing and printing to a file of all of the MACCS2 calculation results for that code run.

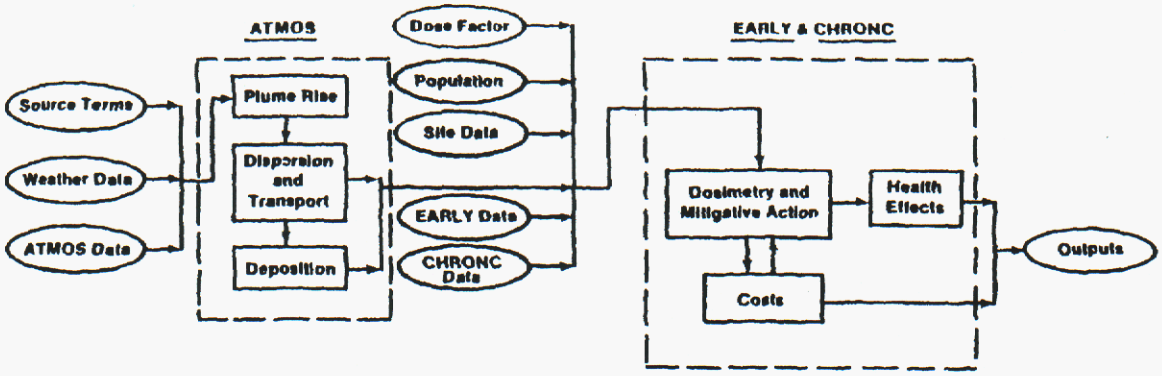

Figure 2. Progression of a MACCS2 consequence calculation

In addition to dose to the receptor, the MACCS2 code can also calculate the effects of evacuation, sheltering, or relocation of an exposed population or withdrawal of land from agricultural production to minimize dose to the public. The input parameters used for all of the DWDDs do not allow such dose minimizing actions in order to calculate the unmitigated dose to the accident dose receptor. Since long-term dose (50-year dose commitment) to an individual is the primary interest, early health effects (deterministic effects), population dose, and number of cancers to be expected (stochastic effects) were not included in the data tabulated in any of the DWDDs.

Only the ATMOS and EARLY modules of the MACCS2 code are used for all of the DWDD calculations. The emergency phase dose period is one day and only the dose pathways for the EARLY module are considered. All four of the dose pathways for the EARLY module were used to contribute dose for the 1998 and 2000 versions of the DWDD. The 2002 version of the DWDD used only plume immersion and inhalation to contribute dose since no deposition of radioactive material was allowed to avoid depletion of the plume and maximize total dose from these two highest dose pathways. Doses from the CHRONC module for longer exposures and ingestion pathways of ground deposition were not considered in any of the DWDD versions as most of the dose from an airborne release is from the initial exposure pathways of inhalation and immersion.

The MACCS2 code allows the consideration of multiple source terms and multiple emergency response strategies in a single run of the code. Multiple source terms for ATMOS and multiple emergency response strategies for EARLY can be specified by the addition of change records positioned at the end of the ATMOS and EARLY input files. Change records specify new values for previously defined source term and multiple emergency response variables. When these change records are encountered, the code's calculations are rerun based on the new values for variables defined in the set of change records and new output is generated. This feature of the code was useful to streamline production of all of the DWDD versions by adding change records to the ATMOS input. The doses for multiple nuclides were calculated in a single run of the code (up to about 30 nuclides for the 1998 and 2000 DWDD and 60 for the 2002 DWDD) by zeroing the activity for the first nuclide and setting the activity for the next nuclide to 1.0 curie (Ci) in each set of change records. No evacuation or other dose mitigation strategies were used in the MACCS2 calculations for any of the DWDD versions so no change records were added to the EARLY input files.

The ATMOS Module

ATMOS calculates the dispersion and deposition of material released to the atmosphere as a function of downwind distance based on the inputs in its input file. It utilizes a Gaussian plume model with Pasquill-Gifford dispersion parameters (Turner 1970) or a table of dispersion parameters in the input. The phenomena that ATMOS treats are (1) building wake effects, (2) buoyant plume rise, (3) plume dispersion during transport, (4) wet and dry deposition, and (5) radioactive decay and ingrowth of initial radioactivity into decay product activity. A detailed discussion of the atmospheric dispersion and deposition models implemented in MACCS2 is provided in Chapter 2 of the MACCS *Model Description* (Jow et al. 1990).

For each spatial interval along the transport path, air and ground concentrations for all of the radionuclides in the released inventory are calculated by ATMOS as well as miscellaneous information about plume size, height, and transport timing. These data are stored for later use by the EARLY and CHRONC modules (not used for any DWDD version). The data may also be printed in the output if directed in the ATMOS input file. The air concentration for each spatial interval is calculated at the plume centerline using the average of the crosswind and vertical standard deviations (σ_y and σ_z) of the concentration distribution for the transported plume material in the interval. The average standard deviations are the average of standard deviations at the spatial interval (distance range) boundaries (Jow et al. 1990). The air concentration at the ground level is calculated by ATMOS from the air concentration at the plume centerline (see Equations (1) and (2)). Ground concentrations of radioactive materials are the result of wet and dry deposition of material from the air concentration, which reduces the air concentration. Thus, both air and ground concentrations of radioactive materials are an average for that spatial interval. The dose for a distance range is the dose defined by the average air and ground concentrations of radioactive material for the range.

Transport and deposition in ATMOS are treated with a one-dimensional model for straight-line Gaussian plume dispersion. Concentration values are calculated only for the plume centerline. There is no calculation in ATMOS of off-centerline concentrations. The adjustment for off-axis locations is handled in the EARLY and CHRONC modules for emergency response strategies (but not used for any DWDD version).

The EARLY Module

The EARLY module calculates dose based on the values specified in its input file and the radioactive material concentrations calculated by the ATMOS module. The doses are calculated for the same distance ranges defined in the ATMOS input file where the radioactive material concentrations were calculated.

The EARLY module models the time period immediately following a radioactive release for dose calculation. This period is commonly referred to as the emergency phase. It may extend up to one week after the arrival of the plume at any downwind spatial interval (distance range). For the all of the DWDD versions, the emergency phase and its dose integration time lasted 24 hours (the minimum allowed duration of the emergency phase). As noted before the CHRONC module treats the subsequent intermediate and long-term periods. CHRONC was not used for the any of the DWDD versions. In the EARLY module the user may specify emergency response scenarios that include evacuation, sheltering, and dose-dependent relocation. In the all of the DWDD versions, no evacuation, sheltering, or dose-dependent relocation was permitted in order to calculate a conservative dose for an individual at that distance range. Receptor dose protection factors for the calculations are discussed in a later section. The emergency response function for EARLY (no evacuation, sheltering, or dose-dependent relocation for any DWDD version) returns the dose for each distance range calculated for each meteorological trial (defined in ATMOS).

EARLY can calculate two kinds of dose: (1) acute dose used for calculating early fatalities and injuries and (2) lifetime dose commitment. The second kind of dose, lifetime dose commitment, was the dose of interest for all of the DWDD versions as the downwind doses for TA-V accidental releases of radioactive material will not generally exceed dose thresholds for any early fatalities or injuries. Assuming that the acute dose will not be important allows using dose conversion factor sets for lifetime dose commitment to be used that include many more nuclides as explained in a following section. The dose of interest in all DWDD versions is the ground surface dose at the plume centerline (centerline dose, result type 6) because this is the maximum dose calculated to be received at the ground surface location of the dose receptor (person). The dose calculated by the EARLY module is the result of multiple dose pathways, as explained in a following section.

Dose Pathways of the Dose Calculation

This section explains the dose pathways used in MACCS2 for all DWDD calculations. The dose calculated for all DWDD versions is a total effective dose equivalent (TEDE) for persons on the ground at the plume centerline (centerline dose). The TEDE contains contributions for direct irradiation from external radioactive material and contributions for committed effective dose equivalent (CEDE) from radioactive material taken into the body and retained there for a long-term dose. The dose pathways with the largest contribution to TEDE are those pathways involving interaction with the passing plume of radioactive material. Other pathways involving material deposited on the ground provide very minor or negligible contributions to TEDE.

The groundshine pathway is direct irradiation of an individual by radioactive material deposited on the ground. Groundshine assumes radiation spread uniformly over an infinite plane but in practice contributions closest to the dose point are most important. Cloudshine is direct irradiation of an individual by immersion in the passing radioactive plume (or cloud). The cloud is assumed to be semi-infinite above the ground plane but contributions closest to the dose point are most important. Another dose pathway, skin dose from material deposited on the skin, is a negligible contributor to lifetime whole body or organ dose other than the skin itself. Skin dose is not considered separately in calculations for any of the DWDD versions.

The inhalation pathway includes the dose from radioactivity inhaled from the cloud as it passes to produce a CEDE. Resuspension inhalation dose is from inhalation of ground deposited material that has been suspended in the air again by some mechanical action such as vehicle traffic. Inhalation dose includes direct irradiation of the body from material while in the lung and the 50-year committed dose of material remaining in the lung or passing into the other parts of the body. The material passing into the body produces a dose in the organs it enters. Thus, the resulting 50-year committed dose is an effective whole body dose that accounts for the damage done by the doses to separate organs for 50 years. The doses calculated by MACCS2 for all DWDD versions included an effective whole body TEDE (EDEWBODY or EFFECTIVE) and separate organ doses for the thyroid, lungs and red marrow from all dose pathways combined. The effective whole body dose is the dose most useful for safety analysis and operations studies and it was the only TEDE tabulated in the DWDD versions of 2000 and 2002. The original DWDD version in 1998 also tabulated the thyroid organ dose.

Doses from cloudshine immersion and cloud inhalation are limited to the time of plume passage. Groundshine and resuspension inhalation doses are limited to the duration of the emergency phase as defined in EARLY module inputs (24 hours for all DWDD versions).

DOE-STD-3009, Appendix A (DOE 1994) considers the airborne dose pathways of inhalation and immersion dose as the primary dose pathways. Groundshine from radioactive material deposited on the ground is an allowable pathway but inhalation dose from resuspension of material deposited on the ground and other slow developing pathways (such as ingestion of contaminated crops) are not allowed. Exceptions are granted in the case of other large dose contributors (such as released water pathways) for particular sites. TA-V has no radioactive material release pathways other than the airborne pathways. The 1998 and 2000 DWDD dose pathways calculated by MACCS2 included inhalation and immersion from the plume passage and groundshine and resuspension inhalation dose from material deposited by the wet and dry deposition processes. Since resuspension inhalation dose is such a miniscule contributor to total dose, resuspension inhalation dose was disabled in the 2002 DWDD calculations. There is no range of parameters suggested in the dose pathways area since resuspension inhalation dose has been removed for 2002 DWDD calculations and it has a negligible impact. Groundshine could be reduced if wet and/or dry deposition of material from the plume was reduced. In any event, groundshine is also a relatively minor contributor to dose and groundshine reduction should be more than compensated by potential increases in inhalation and immersion if plume depletion were reduced.

DOE-STD-3009, Appendix A (DOE 1994) says that the maximally exposed off-site individual (MOI) should be exposed for duration of 2 hours after the plume arrival at that location for the dose estimates. The nominal exposure duration of 2 hours may be extended to 8 hours for those release scenarios that are especially slow to develop. Since the release duration is also the time required for passage of the radioactive section of plume, the exposure duration after plume arrival is also the release duration. The release duration of the 1998 and 2000 DWDD MACCS2 dose calculations was 2 hours but shorter durations were adopted for the 2002 DWDD calculations. The entire airborne activity concentrated in a shorter release would not reduce or increase the dose. In any case, the MOI would be exposed to the entire radioactive section of the facility exhaust plume for the airborne pathways. The MACCS2 calculation of groundshine occurs over a minimum 24-hour emergency period. This overestimate of the groundshine dose pathway contribution (24 hours versus 2 to 8 hours) is an unavoidable though very minor conservative addition to the 1998/2000 DWDD or the 2002 DWDD MACCS2 calculations.

Distance Ranges and Population Information

The region surrounding the location of a hypothetical release of radioactive material is divided into a polar-coordinate grid for dose calculations with the MACCS2 code. A spatial grid was defined for distance ranges of interest to TA-V studies. The source of the radioactive release is located at the center of a 16-sector angular geometry with distance range bins (spatial intervals) defined by radius values. The 16-sector geometry is shown in Figure 3 with the associated compass directions and three spatial intervals. The position of any spatial element on the grid can be identified by its r,θ designation. The listings of spatial intervals that define the distance range bins for the 1998/2000 and 2002 DWDDs are discussed in the next chapter on inputs.

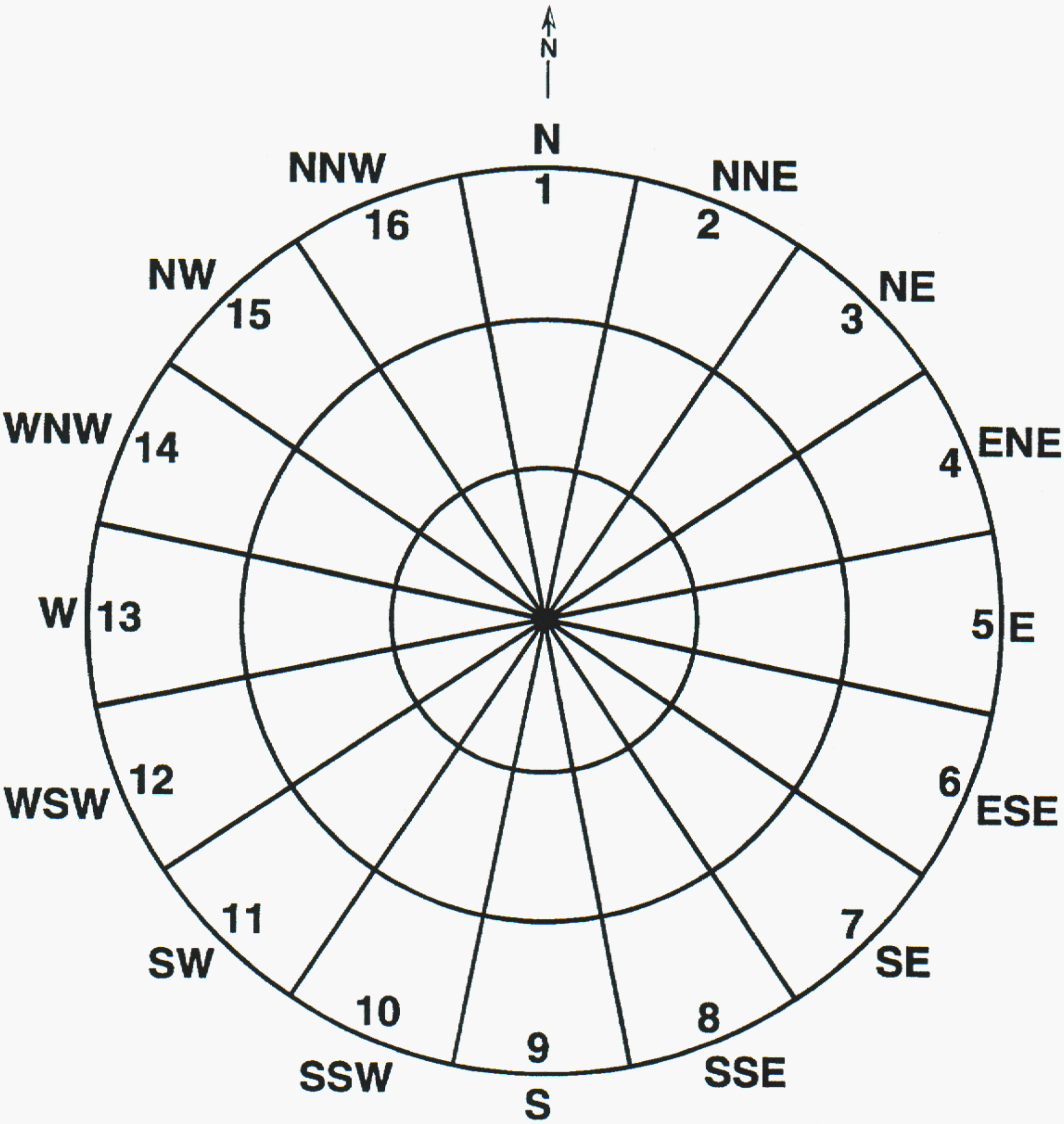

Figure 3. MACCS2 polar-coordinate grid with three radial divisions (The sector numbers on the grid refer to the 16 compass directions.)

While MACCS2 can calculate and report doses separately for each sector of the grid for a set of weather cases, doses at a given distance range for all directions were combined in all of the DWDD version calculations. The resulting dose approximates an all direction dose distribution based on the variation of meteorological data in the weather cases. The distribution of doses resulting from the variation of meteorological data is discussed further in a following section on weather data. No adjustment to dose for different distances to the exclusion area boundary was required for any of the DWDD versions since the boundary is a circle of constant radius.

The 1998 and 2000 DWDD calculations with MACCS2 and earlier MACCS versions used a site data file (specified with other input files when the code is executed) that listed population in each grid sector. An existing site data file (Albsit.inp) for the 1980 census population information was used. The file was structured for the ten distance ranges that were used for the 1998 and 2000 DWDD calculations. However, current population data is not needed for the downwind dose calculations as the dose receptor for the centerline dose is a phantom uniform density population located at all ranges. For that reason, the 2002 DWDD dose calculations did not use a site data file but instead specified a uniform population density (50 people per square kilometer) in the EARLY input file. Only population dose and cancer risk outputs of the MACCS2 calculations use the population data in a site data file and they were not included in the 2002 DWDD calculations. The CHRONC module, which was not run for any of the DWDD versions, also uses information from the site data file.

Nuclide Inventories and Dose Conversion Factors

The MACCS2 code uses a file of half-life and decay schemes for several hundred nuclides to define decay chains (INDEXR.DAT) that was included with the code distribution package. The chains may be terminated at any radionuclide by defining it as pseudostable. Care was taken in the database calculations to ensure that the direct decay products (daughters) of each nuclide were not defined as pseudostable and thus, allowed to be radioactive (radiate) and contribute to the total dose.

As MACCS2 allows decay of the nuclide inventory during transport to the various distance ranges, some daughter activity could be built up before arrival at the distance range of interest. The initial nuclide inventory for each dose calculation included a 1.0-Ci activity of the nuclide whose dose was being calculated and 0.0 Ci for the daughters. Thus, the dose calculation for each nuclide included dose for the activity of both the nuclide and its daughters that built up during transport to that distance. This approach evaluates the entire dose attributable to that nuclide. The total dose from any activity of a single nuclide can then be calculated by multiplying the activity in curies by the dose for 1 Ci as tabulated in the particular DWDD version.

The MACCS2 code transports, disperses, and deposits the radioactive material in the ATMOS module. Any deposited material provides the source radiation for the groundshine dose pathway and depletes the transported inventory of the radionuclide and its daughters in the calculation. The result is a set of ground and air concentrations for distance ranges along the centerline of the transported plume for each weather trial. The EARLY module uses the concentrations and dose conversion factors (DCFs) for each dose pathway to calculate dose. A few of the calculations in the 1998 DWDD used an old DCF file developed by the DOSFAC code and containing the 60 radionuclides considered important to nuclear power plant analyses. Those few calculations used this DOSFAC set of DCFs for both MACCS versions 1.5.11.1 and MACCS2. The code and DCF set used for each dose calculation is marked on the 1998 DWDD in the appendices.

Another set of DCFs was used with MACCS2 for the majority of 1998 DWDD and all 2000 DWDD and 2002 DWDD calculations. This second set of DCFs was produced by the new FGRDCF preprocessor for MACSS2 that provides the user with access to the DCFs issued by the Environmental Protection Agency (EPA) in Federal Guidance Report (FGR) 11 (Eckerman et al. 1989) and FGR 12 (Eckerman and Ryman 1993). The FGRDCF preprocessor accesses inhalation and ingestion DCFs for over 600 radionuclides, and cloudshine and groundshine DCFs for over 825 radionuclides from the Radiation Shielding Information Center (RSIC 1994). The DCFs provided by FGRDCF are sufficient for MACCS2 lifetime dose calculations but not for the acute dose calculations required for early health effects. None of the DWDD versions include early health effects results. Thus, the FGRDCF DCFs are sufficient for use in all of the DWDD versions.

Some individual radionuclide doses in the database actually contain doses from more than one radionuclide due to the way the FGRDCF DCF library is organized. Nuclides in secular equilibrium are examples of these combined nuclide cases. The radionuclides that include doses from others are shown in each DWDD appendix. Thus, a few nuclides can be eliminated from the dose calculation for a multiple nuclide inventory to avoid double counting of the dose from those daughter activities. In practice, the total dose for a large inventory generally does not increase much with a little double counting. Doses for an inventory of radionuclides should be the same whether calculated by adding up individual nuclide doses or running radionuclides in a combined radionuclide inventory in MACCS2. Nuclide inventories may be developed by the ORIGEN2 code (Croff, 1983) or by other ways suitable to the accident or hazard evaluated.

Weather Data: Weather Bins or Random Sampling

DOE-STD-3009, Appendix A (DOE 1994) requires the 95th percentile of distributed doses to the MOI to be used for comparison against the evaluation guideline. The distribution of dose values is produced by the distribution of weather condition cases used for dose calculations. Variations in the distance to the site boundary as a function of direction (if any) must be considered. Since the distance to the exclusion area boundary for TA-V is constant (3000 m radius), MACCS2 must calculate the all direction distribution of dose. The method of calculating the 95th percentile of dose must be consistent with regulatory position 3 of NRC Regulatory Guide 1.145 (NRC 1982) for calculating the 5 percent overall site *X/Q* value. The MACCS2 code uses a similar method of calculating the 95th percentile of dose for the plume centerline at the ground level as a standard output (type 6 output specified in the EARLY input file).

The pertinent parts of regulatory position 3 of NRC Regulatory Guide 1.145 are quoted below to aid in understanding of the methods used to develop the distribution of doses based on variations of meteorological data in the weather cases chosen for the MACCS2 dose calculations for each of the DWDD versions.

> "The *X/Q* values that are exceeded no more than 5 percent of the total number of hours in the data set around the exclusion area boundary… should be determined as follows:
>
> Using the X/Q values calculated…, an overall cumulative probability distribution for all directions combined should be constructed. A plot of X/Q versus probability of being exceeded should be made, and an upper bound curve should be drawn. The… X/Q value that is exceeded 5 percent of the time should be selected from this curve as representing the dispersion condition indicative of the type of release being considered…. "

The most important points in the regulatory position 3 descriptions are:

- *X/Q* (or dose) values that are exceeded no more than 5 percent of the total number of hours in the (weather) data set.
- An overall cumulative probability distribution (of *X/Q* or dose) for all directions combined should be constructed.
- A plot of X/Q (or dose) versus probability of being exceeded should be made, and an upper bound curve should be drawn.
- X/Q (or dose) value that is exceeded 5 percent of the time should be selected from this curve.

MACCS2 uses this same approach to compiling calculated results such as centerline dose since all results are produced in the form of a complementary cumulative distribution function (CCDF). A one-line summary of the CCDF for each of the requested results is written to the output file as several numerical measures (or metrics) of the distribution. In addition, the user can instruct the code to print the entire CCDF table to the output file (Chanin and Young 1997).

In construction of a CCDF, the MACCS2 code arranges the calculated doses in increasing order with the cumulative frequency of the weather cases that the doses represent. If a certain number of weather cases were taken from all of those available to calculate doses to characterize the variability of dose with weather, they would all have the same frequency. In that case the CCDF could be a simple listing of all of the calculated doses with the cumulative frequency incremented by the frequency of that weather case. If two weather cases (two hours from the NRC Regulatory Guide 1.145 weather data set) have the same calculated dose their individual frequencies are both added to the cumulative frequency. The optional CCDF table listing in a MACCS2 output is shown as the fraction exceeding that dose (1 minus cumulative frequency).

An example of the CCDF tabulation is shown in Table 2 that was taken from the MACCS2 *User's Guide* (Chanin and Young 1997) Figure 2-6. Table 2 is part of the CCDF listing for sample problem A of the MACCS2 code distribution package and represents overall cancer fatalities for the sample calculations modeled after the NUREG-1150 MACCS calculations.

Table 2. CCDF example for cancer fatalities in MACCS2 sample problem A

CCDF Table Listing		CCDF Construction
Consequence Value X	**Probability of Exceeding X**	**Cumulative Frequency of X**
1.00E-04	1.00E+00	3.23E-05
2.00E-04	1.00E+00	6.45E-05
3.00E-04	1.00E+00	9.68E-05
5.00E-04	1.00E+00	1.29E-04
7.00E-04	1.00E+00	1.61E-04
1.00E-03	1.00E+00	1.94E-04
2.00E-03	1.00E+00	2.26E-04
3.00E-03	1.00E+00	2.58E-04
5.00E-03	1.00E+00	2.90E-04
7.00E-03	1.00E+00	3.23E-04
1.00E-02	1.00E+00	3.55E-04
2.00E-02	1.00E+00	3.87E-04
3.00E-02	1.00E+00	4.19E-04
5.00E-02	1.00E+00	4.52E-04
7.00E-02	1.00E+00	4.84E-04
1.00E-01	1.00E+00	5.16E-04
2.00E-01	1.00E+00	5.48E-04
3.00E-01	1.00E+00	5.81E-04
5.00E-01	1.00E+00	6.13E-04
7.00E-01	1.00E+00	6.45E-04
1.00E+00	1.00E+00	6.77E-04
2.00E+00	1.00E+00	7.10E-04
3.00E+00	1.00E+00	7.42E-04
5.00E+00	1.00E+00	7.74E-04
7.00E+00	1.00E+00	8.06E-04
1.00E+01	1.00E+00	8.39E-04
2.00E+01	1.00E+00	8.71E-04
3.00E+01	1.00E+00	9.03E-04
5.00E+01	1.00E+00	9.35E-04
7.00E+01	1.00E+00	9.68E-04
1.00E+02	9.99E-01	1.00E-03
2.00E+02	9.96E-01	4.00E-03
3.00E+02	9.53E-01	4.70E-02
5.00E+02	7.91E-01	2.09E-01
7.00E+02	6.38E-01	3.62E-01
1.00E+03	4.85E-01	5.15E-01
2.00E+03	2.40E-01	7.60E-01
3.00E+03	1.55E-01	8.45E-01
5.00E+03	**7.47E-02**	**9.25E-01**
7.00E+03	**3.40E-02**	**9.66E-01**
1.00E+04	8.40E-03	9.92E-01
2.00E+04	2.85E-04	1.00E+00
2.06E+04	2.85E-04	1.00E+00

Table 2 shows the CCDF listing for sample problem A as the first two columns of the table. The value of the consequence X (overall cancer fatalities in this hypothetical nuclear power plant accident) in increasing order is the first column. The second column is the probability (fraction) of exceeding that value of X shown decreasing from 1.00. The value of X that is exceeded by 5 percent (fraction 5.00E-02) of the weather cases can be estimated by comparing the first two columns. That value of consequence X must be between 5000 and 7000 cancer fatalities as shown in the bold type cells of the table. A sample cumulative frequency for each value of consequence X is also included in Table 2 to demonstrate how the table could have been constructed. Probability of exceeding a value X is 1.0 minus the cumulative frequency. The cumulative frequency for a 5 percent probability of exceeding the value of consequence X is a cumulative frequency of 0.95 (or 95 percent). Thus, the consequence X value exceeded 5 percent of the time is also considered the 95th percentile of consequence X value. In the actual case, the distribution of consequence X values versus cumulative frequency of weather cases was interpolated to make the values shown in the MACCS2 output CCDF table.

Figure 4 is a graph of the data in the first two columns of Table 2. The horizontal axis is the value of consequence X and the vertical axis is the probability of exceeding the value of consequence X. The Figure 4 graphical representation of the MACCS2 CCDF table is the plot of consequence (*X/Q* or dose) versus probability of being exceeded that is required by NRC Regulatory Guide 1.145. The curve of Figure 4 is also an upper bound curve for consequence X since the value can be no more than X for a given frequency (1.0 minus probability of exceeding X) of the number of weather cases (hours in the NRC Regulatory Guide 1.145 data set). More importantly, the curve displays a graphical approximation of the value of consequence X that is only exceeded in that fraction of weather cases. The desired graphical approximation for the value of consequence X exceeded 5 percent of the time is indicated in Figure 4 by the intersection of the dashed 5.00E-02 probability of exceeding line and the plot of consequence versus probability of being exceeded. As indicated, that value of consequence X is also the 95th percentile of consequence X.

The 95th percentile of dose is calculated in MACCS2 by log-linear interpolation of the CCDF of the calculated doses in increasing order with the cumulative frequency of the weather cases the doses represent. The interpolation is logarithmic in cumulative frequency (or probability of exceeding) and linear in dose. The one-line summary of the CCDF for each of the requested results that is written to the output file contains several numerical measures (or metrics) of the distribution. These metrics include the mean, 50th quantile, 90th quantile, 95th quantile, 99th quantile, 99.5th quantile, and the peak consequence. The metrics are called quantiles instead of percentiles in the MACCS2 output because they pertain to the cumulative frequency of the consequence value and not all of the weather cases are of equal frequency in some sampling schemes. But for use in estimating dose to compare to the evaluation guideline of DOE-STD-3009, the 95th quantile is taken as equivalent to the 95th percentile of dose values and the dose value exceeded in 5 percent of the weather hours in the NRC Regulatory Guide 1.145 data set. Thus, the terms 95th quantile and 95th percentile are used interchangeably in this report.

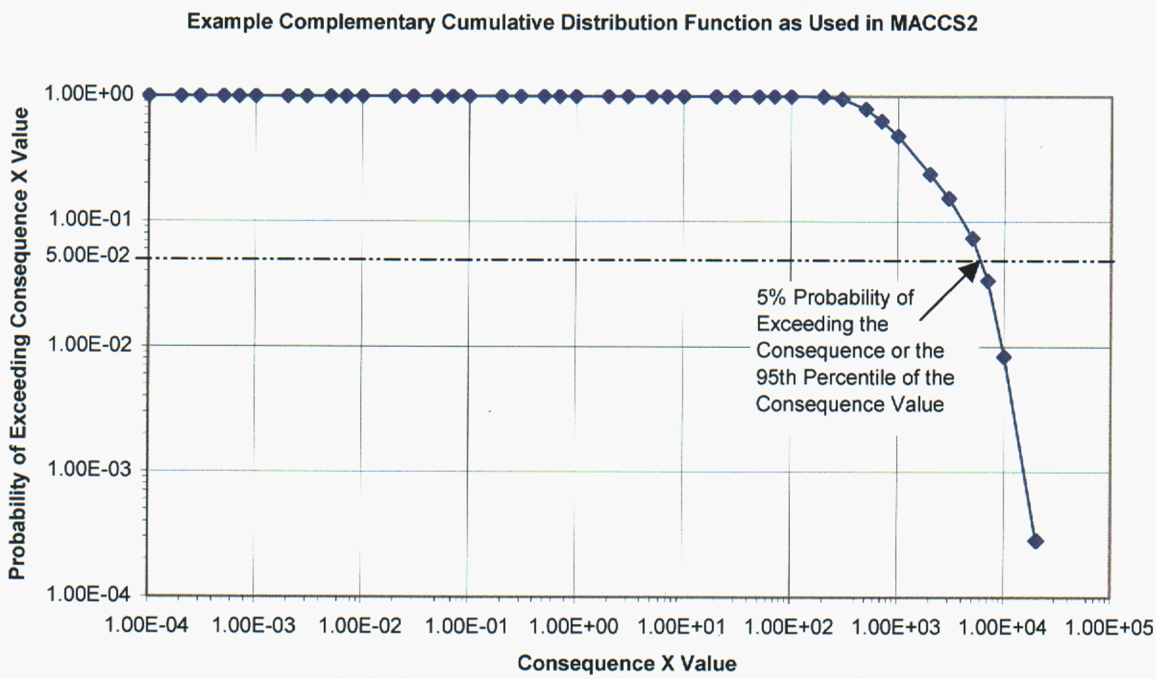

Figure 4. Example CCDF plot of probability of exceeding a consequence value and determination of the 95th percentile of consequence value

In order to approximate an all direction distribution of doses to find the 95th quantile (percentile) of dose, a set of weather cases is needed. These weather cases must be representative of the release site and cover all seasons, times of day, and weather data types needed by the transport and dispersion calculations. The MACCS2 code requires the following weather data for each hour of a full year of weather data (8760 hours) in a prescribed format according to the *User's Guide* (Chanin and Young 1997) as an associated data file. The seasonal mixing heights for each season of the year are also required information in the weather file.

- Julian day of the year (range 1 to 365)
- Hour of the day (range 1 to 24)
- Direction the wind is blowing toward (N to NNW) in the16-sector angular geometry of Figure 3 above (range 1 to 16)
- Wind speed (10ths of meters per second) (range 1 to 300) (Note the values 1-4 are automatically changed to 5 [0.5 m/s] by the code.)
- Stability category (Pasquill class A through G) (range 1 to 7) (Note the value of 7 is automatically changed to 6 by the code.)
- Accumulated precipitation that hour (100ths of inches) (range –1 to 999) (Note some meteorological files use –1 to indicate a trace of precipitation during the hour. MACCS2 assumes these values to be 0.)

Some DOE sites have multiple years of weather observations to analyze for safety studies. It is uncertain whether the cases from a particular year adequately represent the full range of weather conditions. Analysis of multiple years of weather data may call previous studies into question when even worse weather is observed.

Sandia researchers (Aldrich et al. 1982) chose the Typical Meteorological Year (TMY) developed by the National Climatic Center to answer the question of what should constitute representative site weather data. To construct a TMY, representative months are chosen for a particular National Weather Service (NWS) station with approximately 25 years of data available. These months are then combined to produce the TMY of 8760 hourly weather conditions needed to make a year of weather data for MACCS calculations. Using the processes described by Aldrich et al. (1982), a weather-input file was developed from a TMY for the Albuquerque International Airport NWS station data. That file, metalb.inp, had the required wind speed, wind direction, atmospheric stability class, and precipitation for each hour of a typical year (8760 hours) that could be applied to TA-V. According to NWS records the Albuquerque International Airport weather ground station is also at the 10-meter height required by the MACCS code for weather data. The metalb.inp file has been used since the early 1980s by MACCS or its predecessor code CRAC for dose consequence calculations. It was chosen for use by MACCS2 in the 1998 and 2000 DWDD versions in an effort to make those dose results consistent with previous studies.

The 10 CFR 830, Subpart B, (CFR 2001b) Section 202, Safety Basis, requires updating the documented safety analysis for a nuclear facility to keep it current in paragraph (c) (1), (2) and (3) as stated below.

> "(c) In maintaining the safety basis for a hazard category 1, 2, or 3 DOE nuclear facility, the contractor responsible for the facility must:
> (1) Update the safety basis to keep it current and to reflect changes in the facility, the work and the hazards as they are analyzed in the documented safety analysis;
> (2) Annually submit to DOE either the updated documented safety analysis for approval or a letter stating that there have been no changes in the documented safety analysis since the prior submission; and
> (3) Incorporate in the safety basis any changes, conditions, or hazard controls directed by DOE."

This requirement could mandate an annual review of available weather data to determine if a significant change had occurred in the facility in regards to dispersion of airborne releases.

DOE-STD-3009, Appendix A says that NRC Regulatory Guide 1.23 (NRC 1972a) describes acceptable means of generating meteorological data for plume dispersion in dose estimates. Regulatory Guide 1.23 says that the weather data should be gathered locally close to the nuclear power plant site as a full year of 1-hour averaged weather data take at a standard 10 m height. The 1998/2000 DWDD calculations used the TMY for the Albuquerque airport (several miles from TA-V) as the weather data for the MACCS2 calculations. The TMY is typical weather data that is representative of conditions at the airport and not for any particular year. The local TA-V weather tower A36 measures hourly weather data that specifies the local weather history for particular years.

The Sandia National Laboratories meteorologist provided 10 m height hourly weather information from the A36 tower (Deola 2002a, 2002b and 2002c) for seven years (1994 through 2000, 2001 was not available) that was sufficient for conversion to a format readable by the MACCS2 code. Deola initially provided the data with atmospheric stability as determined by the EPA guidelines (EPA 2000) that requires changing the calculated stability class so that it does it vary more than one class per hour. Since NRC Regulatory Guide 1.23 does not require such smoothing of the atmospheric stability data, Deola (2002b and 2002c) recalculated the stability class of each hour in all seven years of weather data to the indicated stability class without smoothing. Calculation of the stability class for each hour was done by the Pasquill-Gifford Sigma Theta criteria (Deola 2000b). The meteorological data provided by Deola were converted to the MACCS2 format for the input file using a simple Fortran code, WINDAT2.

If local weather data is used, the question of which year to use is important. The conservative answer would be the year that gives the highest dose values or the highest dose values for any year available. The concentration (*X/Q*) of the ground level plume centerline at 3000m was used to compare the available years of weather data from the A36 tower to the TMY in ground release and height of release cases. The TMY concentration was greatest in both release height comparisons for all but the highest release heights of TA-V facilities. The year 1994 gave the highest concentrations of the local A36 tower data followed closely by 1999 and 1997 that were essentially identical. The data of 1997 were incomplete and data for a 110-hour period of missing data had to be copied from the previous and following days to make a full year for the comparison. The weather files for the years 1994 through 2000 (2001 was not available) were used for seven independent calculations of the 95th percentile of dose in the 2002 DWDD calculations.

Two basic techniques are possible in MACCS2 for choosing a set of weather data from a weather file as starting points for the dose versus distance calculations: 1) random sampling of the 8760 hours with a specified number of samples per day or 2) weather bin sampling. In weather bin sampling, the 8760 hourly weather data points are sorted into bins by distance range, wind speed, stability class, and precipitation. Then the same number of random samples are taken from each bin to be sure all weather types are sampled. Some bias may be introduced by the way bins are defined.

For random sampling, a sample of one quarter of the total has been shown to give dose results that are representative of the whole year, when six samples are taken from each day for a total of 2190 samples (Chanin and Young 1997). All 8760 samples in a weather year were used in the 2002 DWDD for added conservatism.

For weather bin sampling in the 1998/2000 DWDD calculations, 78 weather cases were selected by taking four random samples from each bin to represent a whole year of hourly weather data. Thus, weather bin sampling provides much faster running calculations. The 1998/2000 DWDD MACCS2 calculations used weather bin sampling to choose the weather cases to save computer calculation time and to be consistent with past MACCS dose calculations in TA-V safety studies. Each weather case consists of 120 hours of weather data that starts at the start time picked by the sampling method. The start times for all 78 weather-bin sampling histories are listed in Table 3 below. The 120-hour weather cases may be reconstructed from those starting dates and times in the TMY site weather data file metalb.inp that is available from the author. Each of the 78 weather histories also show the weather bin number they were drawn from and the frequency (PRBMET) that was assigned to the resulting dose from that weather history. The 95th percentile of dose was calculated by interpolating a complementary cumulative distribution of the calculated doses in increasing order with the cumulative frequency of the weather cases the doses represent (PRBMET totaled). The frequency assigned each weather history in weather bin sampling is derived from the fraction of the all of the weather histories (weather start hours) that the bin represents and the fraction of the bin weather histories that the particular sample represents.

Table 3. The 78 weather histories start times of the TMY that were used for the 1998/2000 DWDD

TRIAL	DAY	HOUR	BIN	PRBMET
1	166	17	32	1.71E-04
2	177	17	8	3.06E-02
3	178	4	16	1.72E-02
4	189	4	14	1.94E-02
5	189	16	27	1.14E-04
6	191	14	1	2.30E-02
7	194	15	5	1.78E-02
8	196	15	36	1.43E-04
9	196	16	32	1.71E-04
10	196	19	21	1.28E-03
11	196	20	20	1.14E-04
12	199	21	11	8.85E-03
13	201	16	7	2.60E-02
14	203	13	36	1.43E-04
15	203	14	36	1.43E-04
16	203	15	32	1.71E-04
17	204	22	17	3.34E-03
18	206	9	31	1.14E-04
19	206	10	30	1.14E-04
20	206	11	27	1.14E-04
21	207	22	18	1.14E-04
22	210	18	10	3.51E-03
23	212	13	2	1.18E-02
24	224	20	6	2.69E-02
25	227	17	4	9.93E-03
26	230	19	11	8.85E-03
27	235	24	12	2.91E-02
28	236	15	7	2.60E-02
29	238	12	2	1.18E-02
30	241	17	32	1.71E-04
31	249	18	21	1.28E-03
32	250	22	17	3.34E-03
33	251	22	22	1.14E-04
34	253	22	15	2.08E-02
35	262	23	12	2.91E-02
36	265	9	6	2.69E-02
37	272	22	16	1.72E-02
38	289	19	22	1.14E-04
39	290	6	17	3.34E-03
40	290	8	22	1.14E-04

Table 3. The 78 weather histories start times of the TMY that were used for the 1998/2000 DWDD (continued)

TRIAL	DAY	HOUR	BIN	PRBMET
41	298	11	1	2.30E-02
42	305	4	15	2.08E-02
43	306	9	21	1.28E-03
44	316	9	2	1.18E-02
45	317	8	5	1.78E-02
46	318	18	4	9.93E-03
47	324	20	14	1.94E-02
48	333	18	10	3.51E-03
49	342	6	8	3.06E-02
50	347	20	11	8.85E-03
51	351	20	12	2.91E-02
52	354	19	15	2.08E-02
53	358	16	4	9.93E-03
54	1	4	16	1.72E-02
55	6	24	14	1.94E-02
56	17	18	10	3.51E-03
57	21	16	1	2.30E-02
58	22	10	7	2.60E-02
59	25	9	5	1.78E-02
60	32	9	1	2.30E-02
61	44	16	6	2.69E-02
62	54	13	4	9.93E-03
63	55	19	20	1.14E-04
64	67	19	14	1.94E-02
65	70	14	36	1.43E-04
66	79	18	12	2.91E-02
67	92	2	15	2.08E-02
68	93	24	8	3.06E-02
69	95	23	16	1.72E-02
70	97	10	2	1.18E-02
71	99	17	6	2.69E-02
72	106	21	7	2.60E-02
73	120	10	8	3.06E-02
74	120	24	21	1.28E-03
75	123	15	5	1.78E-02
76	127	23	11	8.85E-03
77	145	21	17	3.34E-03
78	147	8	10	3.51E-03
				Total = 1

MACCS2 CODE INPUTS

The dose calculations of the Downwind Dose Database (DWDD) documented in January 1998 (Naegeli 1998) and the 2000 DWDD expanded set of dose calculations were made with standard MACCS2 inputs. The MACCS2 inputs for the revised DWDD calculations of 2002 were made with a revised set of standard inputs. Both the original standard inputs and the revised standard inputs for MACCS2 dose calculations are discussed in this chapter.

The approach for defining the inputs for the 1998 and 2000 DWDD was for dose to the public in the same or similar fashion as had been used in U. S. Nuclear Regulatory Commission (NRC) nuclear power reactor safety studies (NRC 1975 and 1989). In those NRC studies the dose from the airborne radioactive material in the released plume was a major contributor to total dose. Some of the airborne radioactive material in the NRC nuclear power reactor safety studies was modeled to deposit on the ground as it was transported downwind. That deposition allowed calculation of long term and slow developing dose pathways for the public such as inhalation dose from the resuspension of deposited material and dose from ingestion of deposited material through food and water. The ingestion pathways were not included in the DWDD of 1998 and 2000 but resuspension inhalation and groundshine dose were included. The 1998 and 2000 DWDD calculations also considered dose to the public by defining such parameters as breathing rate and radiation protection factors based on the average annual experience of the public.

Recent U. S. Department of Energy (DOE) guidance such as DOE-STD-3009 in its Appendix A (DOE 1994) introduced in January 2000 focused dose calculation on a different dose receptor and dose pathway concept than the NRC nuclear power reactor safety studies. DOE-STD-3009, Appendix A established a hypothetical maximally exposed off-site individual (MOI) at the site boundary as the dose receptor for dose estimates to be compared to the evaluation guideline for documented safety analyses. The MOI is assumed to be standing at the site boundary or beyond it if a more distant point provides the maximum exposure. "The dose estimate is that received during a 2-hour exposure to the plume… considering inhalation, direct shine, and groundshine. Other slow-developing release pathways such as ingestion of contaminated food, water supply contamination, or resuspension are not included." DOE-STD-3009, Appendix A allows the exposure duration to be extended to 8 hours for those release scenarios that are especially slow to develop. In regard to dose estimation, DOE-STD-3009 Appendix A also says, "The intent is that calculations be based on reasonably conservative estimates of the various input parameters." Other aspects of the DOE-STD-3009, Appendix A prescriptive guidance on dose estimation (such as calculations of the 95th percentile of dose) are the same or similar to those used in the 1998 and 2000 DWDD dose calculations.

The standard MACCS2 dose calculation inputs for the DWDD versions are summarized in Table 4. Separate columns list the original inputs for the 1998 and 2000 DWDD and the revised inputs for the 2002 DWDD. The inputs are discussed in following subsections to identify the input selected, provide reasons for selection, and identify the candidate range of the input for the 2002 DWDD dose calculations. Table 4 is organized into inputs from the ATMOS and EARLY input files. Input variable names and values are listed for many of the inputs to clarify differences between the DWDDs for 1998/2000 and 2002. The ATMOS inputs characterize the release and transport of radiological material used to calculate the radiological material concentration at each downwind distance range for each weather case calculated. The EARLY inputs characterize the calculation of the resulting radiation dose to receptors from the various dose pathways.

An independent expert review of the revised inputs for the 2002 DWDD MACCS2 calculations (Restrepo 2002) was obtained by DOE to assess whether the revised MACCS2 inputs were appropriate for safety analysis to establish the safety basis for TA-V nuclear facilities. The independent expert review found that the inputs were appropriate to perform the desired calculations and suggested changes to improve the calculations. It is important to note that the DOE transmittal letter for the 2002 DWDD independent review (Zamorski 2002) concluded that, "The results of the review also indicated that the Sandia National Laboratories (SNL) analysis using more conservative input parameters and Omicron's analysis (Restrepo 2002) did not identify any significant differences. OKSO requests that these changes suggested by Omicron be incorporated into the SNL analysis." Those suggested input changes have been incorporated as described later in this SAND report to perform the MACCS2 dose calculations for the 2002 DWDD. The overall conclusion of this SAND report is that the 2002 DWDD provides "reasonably conservative estimates of the various input parameters" as required by DOE-STD-3009, Appendix A (DOE 1994) to be used in preparation of the 2002 DWDD calculations.

Typical input files for the ATMOS and EARLY code modules for the 1998 and 2000 DWDD dose calculations are shown in Appendices A and B. Typical revised input files for the ATMOS and EARLY code modules for the 2002 DWDD are shown in Appendices C and D. These typical input files show how the parameters of Table 4 are implemented for the dose calculations. The dose for the release of 1 curie (Ci) of each single radionuclide was calculated in all of the DWDD versions. Several runs of the MACCS2 code with different ATMOS input files were needed to calculate the dose for all of the radionuclides included in that DWDD version at all downwind distance ranges. Thus, only typical input files are provided for illustration. The reader may find it useful to refer to the input files in the appendices during the discussion of the following sections. The input files are heavily commented to guide the reader in identifying and interpreting the inputs. The comment lines have an asterisk as the first space. Only the lines without asterisks in the first space are read as inputs by the MACCS2 code.

Table 4. Modeling and input parameters used in the 1998 and 2000 DWDD and the 2002 DWDD

Modeling and Input Parameters (Input Variable)	Parameter Value Used in 1998 and 2000 DWDD	Parameter Value Used in 2002 DWDD
ATMOS Input File		
Distance Ranges (NUMRAD)	10 distance ranges	16 distance ranges
Source term inventory and its decay characteristics (NAMSTB, NUCNAM, CORINV)	Decay chains of up to 6 elements include contribution of decay products to dose.	Decay chains of up to 6 elements include contribution of decay products to dose
Wet and dry deposition (WETDEP, DRYDEP)	Applied to all chemical groups but gases (.TRUE. .FALSE.)	No Deposition allowed (all .FALSE.)
Wet deposition parameters (CWASH1, CWASH2)	9.5×10^{-5}, 0.8 (Jon Helton after Jones 1986a)	0.0, 0.8
Dry deposition velocity (VDEPOS)	0.01 m/s (1 particle size group)	0.0 m/s (1 particle size group)
Plume dispersion	Power law (Tadmor and Gur, 1969)	Power law (Tadmor and Gur, 1969)
Surface roughness	10 cm (grassland)	3 cm (flat land)
Linear scaling factor (YSCALE, ZSCALE)	Scaling factors $\sigma_y = 1$, $\sigma_z = 1.27$	Scaling factors $\sigma_y = 1$, $\sigma_z = 1.0$
Plume meander expansion	Expansion for 2 hour release	No meander expansion
Airborne Release data	Single plume	Single plume
Release heights (PLHITE)	Three heights (m): 38.1, 14.3, & 0.0	Seven heights (m): 38.1, 18.0, 16.4, 14.3, 10.0, 4.3, & 0.0
Wake effects	Building wake for the ACRR building for all three release heights and one height (0.0 m) without building wake	Point release modeled with no building wake effects
Release duration (PLUDUR)	7200 seconds (2 hours)	600 seconds (10 minutes)
Buoyant and exit velocity plume rise	No additional plume rise modeled	Plume rise suppressed
Meteorological sampling	Weather bin sampling	Random sampling (All 8760 samples per year)
Weather file	METALB.inp for the Typical Meteorological Year at the Albuquerque airport.	Tower A36 Meteorological Data for years 1994 through 2000

Table 4. Modeling and input parameters used in the 1998 and 2000 DWDD and the 2002 DWDD (continued)

Modeling and Input Parameters	Parameter Value Used in 1998 and 2000 DWDD	Parameter Value Used in 2002 DWDD
EARLY Input File		
Dose conversion factors (DCF_FILE)	FGR 11 and 12 (a few nuclides used an earlier set from DOE/EH-0070 (DOE 1988))	EPA Federal Guidance Reports #11 and #12 (Dosd825.inp)
Population data	Site file ALBSIT.inp listed but same results as uniform population distribution.	Uniform population distribution, no site data file
Dispersion model	Straight line plume	Straight line plume
Protection and exposure factors	Normal activity of the public	MOI standing at the exclusion area boundary
Cloudshine (immersion) factor (CSFACT)	0.75	1.0
Inhalation factor (PROTIN)	0.4	1.0
Groundshine factor (GSHFAC)	0.41	1.0
Breathing rate (BRRATE)	2.66×10^{-4} m^3/s	3.47×10^{-4} m^3/s
Evacuation and sheltering	No evacuation or sheltering	No evacuation or sheltering
Dose and exposure pathways		
During plume passage	Cloudshine and plume inhalation during plume passage (2 hours)	Cloudshine and plume inhalation during plume passage (10 minutes)
During emergency phase	Groundshine and resuspension inhalation dose for 24 hours (minimum emergency period)	No groundshine or resuspension inhalation dose for the emergency period
Dose results calculated	Centerline dose 95th percentile for whole body for all pathways (TEDE)	Centerline dose 95th percentile for whole body for all pathways (TEDE)

ATMOS Module Inputs

Distance Ranges

The distance range bins (spatial intervals) for all DWDD calculations are shown in Table 5 with the facility or feature characterized by the midpoint distance. The DWDD versions for 1998 and 2000 used ten range bins to define the area around TA-V and the 2002 version of the DWDD used 16 range bins. The extra range bins for the 2002 version of the DWDD were used to better define the ranges close to TA-V. The greater number of distance bins also provides smaller radial distance bins of the 100 m minimum width allowed by MACCS2 for distance ranges where the best accuracy in dose calculations was desired. For example, the distance range for 2.9-3.1 km for the 1998 and 2000 DWDD was reduced to 2.95-3.05 km for the 2002 DWDD. That range is of most importance for safety analysis since it represents the TA-V exclusion area boundary, a circle of 3.0-km radius around TA-V nuclear facilities. Dose to an individual at or beyond the exclusion area boundary represents the dose receptor in safety analyses.

MACCS2 input variable names in the ATMOS input file for the distance ranges include:

- NUMRAD for the number of radial bins or distances and
- SPAEND for the distances in kilometers. Since SPAEND is the radial distance, 0.0 is not listed as one of the distances.

A two-letter designator for the section of the input file precedes all of the MACCS2 input variable names and a three number record designation follows the input variable names. Appendix D of the MACCS2 *User's Guide* (Chanin and Young 1997) lists all of the MACCS2 variable names and provided a cross-reference to the section of the users guide that discusses them in more detail.

Source Term Inventory and Decay Characteristics

A source term inventory of radionuclides must be specified for each MACCS2 calculation. Up to 150 radionuclides may be designated for each code run but large inventories require longer running time for dose calculations.

MACCS2 simulates the radioactive decay of the nuclides used in each calculation. The radioactive decay reduces the transported activity of the decaying nuclide. Decay during atmospheric plume transport, as well as any time delay from accident initiation to environmental release can be accounted for in a MACCS2 calculation. For all of the DWDD version dose calculations, the environmental release was assumed to happen immediately upon release from the accident location, thus there was no delay time from accident to environmental release implemented in the calculations.

Table 5. All DWDD version distance ranges and features represented

1998 & 2000 DWDD Ranges		2002 DWDD Ranges		Midpoint of Range for Feature (km)	Features Represented
Range No.	Radial Distance (km)	Range No.	Radial Distance (km)		
1	0.0–0.1	1	0.0–0.05	0.1	TA-V Fenced Area
		2	0.05–0.15		
2	0.1–0.5	3	0.15–0.25	0.3	Collocated Workers in TA-V & TA-III
		4	0.25–0.35		
		5	0.35–0.45		
		6	0.45–0.55		
3	0.5–1.5	7	0.55–0.95		
		8	0.95–1.05		
		9	1.05–1.5		
4	1.5–1.7	10	1.50–1.70	1.6	Kirtland AFB (KAFB) Facility
5	1.7–2.9	11	1.70–2.95		
6	2.9–3.1	12	2.95–3.05	3.0	Exclusion Area Boundary
7	3.1–4.8	13	3.05–4.80		
8	4.8–5.0	14	4.80–5.00		TA-IV
9	5.0–7.0	15	5.00–7.00		KAFB Offices and Housing
10	7.0–20.0	16	7.0–20.0		Albuquerque City Populated Area

The dose for each released radionuclide is calculated in a separate calculation for all of the DWDD versions although multiple radionuclide calculations can be included in one MACCS2 code dose calculation. The activity used for each radionuclide dose calculation is 1.0 Ci so the dose can be scaled to other released activities of the same nuclide. A decay-chain processor used in the ATMOS module of MACCS2 allows contribution to the dose from decay products of the radionuclide. The radionuclide and all of its decay products must be included in the radionuclide inventory established in the ATMOS module input file. Thus, the initial nuclide inventory for each dose calculation included 1.0 Ci activity of the nuclide whose dose was being calculated and 0.0 Ci for the decay products.

The decay-chain processor considers radioactive decay over a maximum of six generations. Six generations means that the sequential list of radionuclides in a decay chain is limited to six members. For species that have progeny spanning more than six generations, the dose due to progeny beyond six generations is ignored. At each step of decay in the chain, branching is allowed with up to three different daughter products, using branch ratios. The decay-chain database was obtained from the Radiation Shielding Information Center (RSIC 1994). It is present in the MACCS2 distribution package as file INDEXR.DAT that was used for all of the DWDD versions (Chanin and Young 1997). MACCS2 automatically refers to a file of that name for the decay chain information.

MACCS2 allows flexibility in selecting the radionuclides to be considered in the radioactive inventory by excluding a list of radionuclides from the calculations. These radionuclides are designated as "pseudostable" and defined in the ATMOS input file. The pseudostable radionuclides are treated by MACCS2 as if they were not radioactive. They do not contribute to doses and they produce no radioactive progeny (Chanin and Young 1997). Designating some radioactive progeny as pseudostable terminates the decay chain and allows removing them from the radionuclide inventory established in the ATMOS module input file. Reducing the inventory reduces the calculation running time for up to the maximum number of 60 separate 1.0 Ci radionuclide dose calculations to be made in a single MACCS2 run.

Care was taken for all of the DWDD versions to ensure that at least the direct daughter decay products were included in the radionuclide inventory for each 1.0 Ci radionuclide dose calculation. In some cases the dose conversion factor that is used to transform the airborne concentration of radionuclide to dose included dose from short half-life daughter decay products in secular equilibrium with the parent radionuclide. In such cases the daughter decay products need not be included in the radionuclide inventory of the ATMOS module input file. In some cases the daughter decay products in secular equilibrium with the parent radionuclide were present in the same inventory for the parent's dose calculation. In those cases the parent dose was conservatively somewhat higher due to the double contribution of the daughter decay products in the inventory and in the dose conversion factor of the parent.

The specification of the nuclide decay characteristics described above does not lend itself to a range of a specific input parameter. Instead, the specification is a reasonably conservative approach since the calculated dose includes contributions from the 1.0 Ci radionuclide release and at least the direct daughter decay products to characterize the dose attributable to that radionuclide.

The ATMOS input variables that define the source term inventory are:

- NUMISO that sets the number of radionuclides in the inventory,
- MAXGRP the number of nuclide groups for defining transport characteristics,
- OTPGRP that identifies the group number for each radionuclide in the inventory,
- NUMSTB that sets the number of pseudostable nuclides,
- NAMSTB that designates the names of the pseudostable nuclides, and
- CORINV that specifies the activity of each radionuclide in the inventory.

The CORINV variable occurs in a later section of the ATMOS input that defines the characteristics of the radioactive material release. CORINV is the variable that is revised by change records to the ATMOS input file to perform multiple subsequent dose calculations in one MACCS2 code run.

Wet and Dry Deposition

In addition to depletion of radioactivity in aerosols and particulate from the plume by decay, MACCS2 allows depletion of the radiological material in the Gaussian plume through wet and dry deposition. The deposition is onto the ground or other surfaces such as skin (skin deposition and other early health effects are not the calculated in any DWDD version). Wet and dry deposition can be turned on or off for different nuclide chemical groups defined in the ATMOS input file. Wet and dry deposition was applied to all of the nine chemical groups in the radionuclides of the 1998 and 2000 DWDD except for noble gases.

- WETDEP is the ATMOS input variable used to turn wet deposition on or off.
- DRYDEP is the ATMOS input variable used to turn dry deposition on or off.

Both wet and dry depositions are addressed as TRUE (on) or FALSE (off) for each nuclide chemical group in the ATMOS input file. The chemical groups are defined in Table 6 below by the typical element for that group.

The radioactive material removed from the plume by wet or dry deposition is not available to contribute to the dose pathways of inhalation or immersion in the radioactive plume (or cloud). Inhalation and immersion are the major contributors to dose in airborne dose calculations. Wet and/or dry deposition is necessary to provide a ground deposited radioactive material source term for direct radiation (groundshine) and inhalation of deposited material that is resuspended (resuspension inhalation). These other dose pathways from ground deposited material are very minor contributors to total dose and will not contribute at all unless wet or dry deposition places the radioactive material on the ground. Thus, less wet and dry deposition provides a more conservative dose calculation estimate (higher dose) due to higher inhalation and immersion dose contributions. The parameters used to control the wet and dry deposition are discussed separately below.

Wet Deposition Inputs

Wet deposition, commonly termed washout, is the removal of aerosols by rainfall or atmospheric precipitation. In MACCS and MACCS2, wet deposition is modeled by applying the method of Brenk and Vogt (1981), and is implemented for each spatial element with the equation:

$$A / A_o = \exp\left(-aI^b \Delta t\right) \qquad (5)$$

where:
A_o = the amount of radioactive material transported into the spatial element,
A = the amount of radioactive material transported out of the element,
Δt = the time that the plume segment takes to cross the spatial element
I = precipitation intensity (mm/hr)
a, b = dimensionless constants, empirically derived.
The dimensionless constants, a and b, were assigned values of 9.5×10^{-5} and 0.8, respectively for the 1998 and 2000 DWDD as suggested in the MACCS2 *User's Guide* (Chanin and Young 1997). These values are the center of the ranges recommended by Jones (1986a) (RFETS 1999).

Table 6. Nuclide chemical groups used in the dose calculations for all DWDD versions

Group #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Typical Element	Xe/Kr	I	Cs	Te	Sr	Ru	La	Ce	Ba

These values for the dimensionless constants in the wet deposition model have been used as standard values in dose calculation applications of the MACCS and MACCS2 codes (Gregory 1999). An earlier discussion of MACCS major input parameters (Sprung et al. 1990) suggested that for uncertainty studies a range of values for *a* and *b* should be used that was reported by the National Radiological Protection Board of the United Kingdom (Jones 1986a, 1986b). The uncertainty parameter range was $3x10^{-5} \leq a \leq 3x10^{-4}$ and $0.7 \leq b \leq 0.9$. Sprung et al. (1990) said that $a = 9.5x10^{-5}$ and $b = 0.8$ would be used in NUREG-1150 (NRC 1989) as it was the center or the range.

The ATMOS input variables that define wet deposition are:

- CWASH1 that is the linear coefficient, *a*, in Equation 5 above, and
- CWASH2 that is the exponential coefficient, *b*, in Equation 5 above.

Wet deposition parameters are uncertain because of changing deposition circumstances but the same mid-range parameters are used to govern it in most dose calculations. Also, precipitation is sparse around TA-V with only a total of 6.85 inches of rain occurring in only 128 of the 8760 total observed weather hours in the Typical Meteorological Year of the weather data for the Albuquerque airport. Wet deposition has a very minor effect on dose in the 1998/2000 DWDD so it could be turned off or left on with negligible impact. Thus, the range of parameter variation is either wet deposition with the MACCS2 parameters discussed above ($a = 9.5x10^{-5}$ and $b = 0.8$) or no wet deposition. No wet deposition could provide slightly higher 95th percentile of dose values for some radionuclides so it is more conservative than wet deposition.

In order to compare the effect of no wet deposition for the 2002 DWDD dose calculations, the ATMOS input file for the 1998 and 2000 DWDD was modified to set WETDEP as FALSE (off) for wet deposition on all nuclide chemical groups. The variable CWASH1 could have been assigned a value of 0.0 as an alternative or additional measure to ensure no wet deposition but it was retained at $9.5x10^{-5}$ for the comparison. The new *X/Q* and 95th percentile of dose was calculated for six nuclides that were chosen to represent noble gases (Kr-88 and Xe-138) and halogens (I-131 and I-133) with short and long half-lives, longer lived fission products (Ce-144), and actinides (Pu-239). Table 7 shows the results of the calculations as ratios of the no wet deposition to the original wet deposition values. The half-lives for each nuclide are shown below its name. There was no increase in *X/Q* or dose for turning off wet deposition with the exception of the dose for Kr-88. This noble gas showed an increase of 13% in its dose with no wet deposition. Since noble gases were not subject to wet deposition in the 1998 and 2000 DWDD standard inputs, this increase cannot be explained by less deposition and may be an artifact of the 95th percentile of dose calculation method. Since there was essentially no impact to turning off wet deposition, the 2002 DWDD revised inputs turn off wet deposition for conservatism.

Table 7. Ratio of *X/Q* and dose for no wet deposition to wet deposition of the 1998/2000 DWDD inputs

		Ratios of 95th Percentile of Dose at 300 m					
Input Variations	***X/Q***	**Kr-88** 2.84 hr	**Xe-138** 14.1 min	**I-131** 8.04 day	**I-133** 20.8 hr	**Ce-144** 284.3 day	**Pu-239** 24,065 yr
No Wet Deposition	1.00	1.13	1.00	1.00	1.00	1.00	1.00

Dry Deposition Inputs

Dry deposition is aerosol removal by diffusion to, impaction on, and gravitational settling onto surfaces. Dry deposition is modeled in MACCS and MACCS2 using Chamberlain's source depletion method (Chamberlain 1953) as described in the MACCS *Model Description* (Jow et al. 1990).

Dry deposition is modeled using a mass transfer approach. Thus, the flux (w) of particles to the ground due to dry deposition is calculated as the product of the ground level air concentration of the particles (X) 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:

$$w = v_d X \tag{6}$$

The magnitude of dry deposition velocity depends on many parameters including: particle size, shape and density, atmospheric turbulence (stability class and wind speed), surface roughness, and friction velocity. MACCS2 has the capability to model particle size distributions for the released material that are defined by user input with a different dry deposition velocity for each size group. Because aerosol size distributions are not developed for accident analysis source terms in TA-V safety analyses and may vary from accident to accident, a single empirical value for v_d had to be selected for the 1998 and 2000 DWDD MACCS2 calculations.

The ATMOS input variable that defines dry deposition velocity is:

- VDEPOS that is the deposition velocity, v_d (m/s), in Equation 6 above.

The value selected to implement dry deposition in the 1998/2000 DWDD calculations was v_d = 0.01 m/s that was used in the WASH-1400, the NRC Reactor Safety Study (NRC 1975) for dose consequence calculations as the average expected dry deposition velocity. WASH-1400, Appendix VI listed a range for v_d from minimum expected (0.001 m/s) to maximum expected (0.1 m/s). The average expected and range of v_d values were based on field experimental data as discussed in WASH-1400.

Other values used for dry deposition velocity include those used in MACCS calculations for NUREG-1150 (Sprung et al. 1990) where both theory and experiment results suggested a single particle size group v_d of about 0.003 m/s with a range of 0.0003 to 0.03 m/s. (Sehmel 1984) is used as the reference for much of the data and theory on v_d in (Sprung et al. 1990).

(Harper et al. 1994) elicited expert opinion on dry deposition velocities for five particle size ranges in the respirable particle size range of aerodynamic equivalent diameter (AED) < 10 micrometer (µm). Expert opinion was based on data and calculations. The elicitation was made to support airborne dose calculation code comparisons between the MACCS and COSYMA codes by characterizing recommended inputs. The average of the eight experts' estimates of dry deposition velocity onto urban and meadow surfaces are shown in Table 8 below. The meadow grass values are most appropriate to TA-V conditions. The expert estimates show the variation of dry deposition velocity with particle size, that is the dry deposition velocity decreases with particle size to about 0.3 µm particle size and then increases. It is evident that these experts would predict a single dry deposition velocity less than the $v_d = 0.01$ m/s used in the DWDD calculations that were distributed in January 1998.

Two other estimates of dry deposition velocity are useful for comparison to the 1998 and 2000 DWDD value. The default deposition velocities used by CAP88-PC are 0.035 m/s for iodine, 0.0018 m/s for particulates and zero for gases (EPA 1992). The MACCS dose calculations to support the Basis for Interim Operation (BIO) safety analysis for the Los Alamos Neutron Science Center (LANSCE) facility used a dry deposition velocity of 0.001 m/s (Gregory 1999).

Based on the information above the parameter range for dry deposition velocity could vary from 0.0003 to 0.03 m/s for a single v_d for all particle sizes. The dry deposition velocity parameter is uncertain because of changing deposition circumstances. Lower dry deposition velocity or dry deposition turned off is conservative (higher dose).

Table 8. Average of expert estimates of dry deposition velocity for five particle sizes

Particle Size (µm)	**0.1**	**0.3**	**1**	**3**	**10**
Average of Experts 50th percentile Urban Dry Deposition Velocity (m/s)	0.00183	0.000867	0.00242	0.00833	0.0258
Average of Experts 50th percentile Meadow Dry Deposition Velocity (m/s)	0.000796	0.000469	0.00140	0.00483	0.0175

In order to compare the effect of varying the deposition velocity and the effect of no dry deposition in the 2002 DWDD dose calculations, the ATMOS input file for the 1998 and 2000 DWDD was modified and MACCS2 calculations were run. To vary the deposition velocity, VDEPOS was set to 0.001 m/s. In a separate comparison DRYDEP was set to FALSE (off) for dry deposition on all nuclide chemical groups and VDEPOS was not changed from the value of 0.01 m/s for the 1998 and 2000 DWDD calculations. The variable VDEPOS could have been assigned a value of 0.0 as an alternative or additional measure to ensure no dry deposition but it was retained at 0.01 for the second comparison. The new *X/Q* and 95th percentile of dose was calculated for same six nuclides that were chosen to represent noble gases (Kr-88 and Xe-138) and halogens (I-131 and I-133) with short and long half-lives, longer lived fission products (Ce-144), and actinides (Pu-239). Table 9 shows the results of the calculations as ratios of the no wet deposition to the original wet deposition values.

There was no increase in *X/Q* for the reduction of dry deposition. The ratios of dose for reducing the dry deposition velocity and for turning off dry deposition produced increases in dose or the same dose for all nuclides other than the noble gases. Since noble gases were not subject to dry deposition in the 1998 and 2000 DWDD standard input calculations, no increase was expected. The lower dose ratio for Xe-138 may be an artifact of the 95th percentile of dose calculation method. There was a large dose increase for turning off dry deposition of about a factor of two for the longer-lived nuclides (several days and longer). Since the intent of DOE-STD-3009, Appendix A is that dose calculations be based on reasonably conservative estimates of the various input parameters, the 2002 DWDD revised inputs turn off dry deposition.

Table 9. Ratio of *X/Q* and dose for reduced deposition velocity and no dry deposition to normal dry deposition of the 1998/2000 DWDD inputs

		Ratios of 95th Percentile of Dose at 3000 m					
Input Variations	***X/Q***	**Kr-88** 2.84 hr	**Xe-138** 14.1 min	**I-131** 8.04 day	**I-133** 20.8 hr	**Ce-144** 284.3 day	**Pu-239** 24,065 yr
Dep. Vel. = 0.001 m/s	1.00	1.00	0.54	1.49	0.94	1.51	1.50
No Dry Deposition	1.00	1.00	0.53	2.28	0.94	2.57	1.73

Plume Dispersion and Surface Roughness

The Gaussian plume model is used for airborne material dispersion in the MACCS2 calculations for all DWDD versions as illustrated in Equations (1) and (2). That model uses both horizontal standard deviation (σ_y) and vertical standard deviation (σ_z) to represent how the plume expands with distance downwind and to calculate the concentration of radioactive material in the plume (*X/Q*). The power law definition of σ_y and σ_z in the Equation (3) is a fit to actual plume expansion data from the Project Prairie Grass dispersion experiments done in the 1956. The fit used in the ATMOS module of the MACCS2 code for the 1998/2000 and the 2002 DWDD is the Tadmor-Gur parameterization of the data in a power law format (Tadmor and Gur 1969).

Constant values for dimensionless parameters a_y, b_y, and a_z, b_z in the power law definition of σ_y and σ_z (see Equation (3)) are provided in the ATMOS input. The values for the a_y, b_y, and a_z, b_z parameters are supplied for each of the six atmospheric stability classes to match the stability class data in every hour of the meteorological data file of one year of weather data. In MACCS2, a table of values for σ_y and σ_z versus downwind distance in the ATMOS input can be used as an alternative to the power law formulation for the plume expansion parameters, σ_y and σ_z.

The ATMOS input variables that define parameters a_y, b_y, and a_z, b_z in the power law definition of σ_y and σ_z are:

- CYSIGA for a_y in Equation (3),
- CYSIGB for b_y in Equation (3),
- CZSIGA for a_z in Equation (3), and
- CZSIGB for b_z in Equation (3).

One ATMOS input that is examined in this report for its impact on dose calculation is the surface roughness of the terrain around TA-V. It affects the calculation of airborne radioactive material concentration (*X/Q*) that is a direct multiplier in the dose calculation. Higher surface roughness of terrain (including the ground and any vegetation or structures) causes increased turbulence of the air in the vertical direction and thus an increase in the standard deviation of the Gaussian plume in the vertical direction (σ_z). This increase in the size of the plume vertically reduces the concentration of the plume and the dose calculated.

Since the Tadmor-Gur parameterization is formulated for a surface roughness of 3 cm, corrections are needed in σ_z for different surface roughness terrain. The MACCS2 code does this by an input that multiplies σ_z by the specified amount that must be calculated by the user with a standard formula provided in the MACCS2 *User's Guide* (Chanin and Young 1997). A multiplier is also provided for σ_y but is not used in inputs for any of the DWDD versions.

The ATMOS input variable that defines the multipliers for σ_y and σ_z is:

- YSCALE for σ_y multiplication, and
- ZSCALE for σ_z surface roughness correction.

The 1998 and 2000 DWDD calculations used a ZSCALE σ_z multiplier of 1.27 for a 10 cm roughness that represents tall grass. The ZSCALE σ_z multiplier for 3 cm roughness is 1.0. The multiplier is not reduced below 1.0 for surface roughness less than 3 cm in the MACCS2 code (Chanin and Young 1997). Since the 10 cm surface roughness of the 1998/2000 DWDD is greater than 3 cm, the 10 cm roughness correction represents a dose reduction from flat, low 3 cm surface roughness terrain. Thus, using 3 cm surface roughness in the 2002 MACCS2 calculations provides a more conservative (higher) dose. The ZSCALE multiplier is calculated with the following equation from the MACCS2 *User's Guide* (Chanin and Young 1997):

$$\text{ZSCALE} = (\text{surface roughness [cm]} / 3\text{ cm})^{0.2} \tag{7}$$

Other parameterizations of the Prairie Grass data have been done but are similar to the Tadmor-Gur parameterization. One such parameterization is the Briggs Open Country parameterization that uses a different formulation than a power law and does not use a surface roughness correction (Briggs 1973). MACCS2 calculations with the Briggs Open Country σ_y and σ_z are modeled with a table of values in the ATMOS input file as explained in the users guide. The concentration and dose from the Briggs Open Country parameterization at 3000 m are intermediate between the Tadmor-Gur parameterization results with surface roughness of 3 cm and with 10 cm.

Surface roughness does not correspond to the actual height of vegetation or other features above the level of the ground. For example, the 10 cm surface roughness corresponds to tall grass that is 60 cm to 70 cm high according to *Atmospheric Science and Power Production*, 1984 (Sehmel 1984), (Priestley 1959) and (Sprung et al. 1990). Sehmel (1984) indicates that aerodynamic surface roughness is about 15% of the vegetation and physical roughness height according to (Plate 1971). The surface roughness for the tall grass was shown to decrease with increasing wind speed in (Sehmel 1984) and (Priestley 1959) so the surface roughness used for slower wind speed weather conditions may not apply to faster wind speed conditions. The highest dose weather conditions will result from low wind speed weather conditions as shown in Equation (2).

Since the TA-V arid terrain has grass 10 to 20 cm high and an occasional scrub bush 30 to 45 cm high, the current 1998/2000 DWDD surface roughness of 10 cm may not be conservative enough to reflect the TA-V terrain. Sandia National Laboratories indicated a surface roughness of 30 cm was appropriate for the desert scrub terrain around TA-V in the documents that provided information for its latest environmental impact statement (Guerrero et al. 1999). The 30 cm surface roughness is consistent with the terrain classification of open flat terrain with grass and few isolated obstacles in Environmental Protection Agency (EPA) guidance (EPA 2000) that is used as a starting point for calculation of surface roughness from special wind measurements at the weather tower of interest. Surface roughness calculations by the Sandia National Laboratories meteorologist (Deola 2002d) using the gustiness method of Wieringa (1993) recommend a minimum surface roughness value of 15 cm for TA-III and TA-V. These calculations of surface roughness used data from weather towers close to TA-V that have the required special instrumentation.

Dose consequence studies of releases to the public would use surface roughness typical of a whole vast area (perhaps 50 mile radius) that reflect the higher surface roughness contributions of the cities, forests, and mountains surrounding TA-V in the Albuquerque area. Since the exclusion area boundary is only 3000 m from TA-V, dose consequence studies for the MOI dose receptor should use conservative local surface roughness such as 3 cm or the Briggs Open Country dispersion parameterization. Such low surface roughness lengths provide a conservative estimate that should be typical of fast as well as slow wind speeds. The range of surface roughness parameters to examine for consideration of revised 2002 DWDD dose calculation inputs for the MACCS2 code should be 3 cm to 30 cm.

In order to compare the effect of varying the surface roughness for the 2002 DWDD dose calculations, the ATMOS input file for the 1998 and 2000 DWDD was modified and MACCS2 calculations were run. Calculations for Briggs Open Country parameterization of σ_y and σ_z and surface roughness of 3, 15, 20, and 30 cm for the Tadmor-Gur parameterization were compared to the 1998/2000 DWDD surface roughness value of 10 cm with Tadmor-Gur parameterization. The new *X/Q* and 95th percentile of dose was calculated for same six nuclides. Table 10 shows the results of the calculations as ratios of the Briggs Open Country and 3 to 30 cm roughness to the 10 cm roughness values.

The comparisons in Table 10 show that Briggs Open Country parameterization provides dose and *X/Q* values that are intermediate between the 3 cm and 10 cm Tadmor-Gur values. Both the Briggs Open Country and 3 cm surface roughness ratios for *X/Q* and dose are relatively small increases for all of the nuclides examined except Kr-88. This larger ratio that is identical for Briggs Open Country and 3 cm surface roughness may be an artifact of the 95th percentile of dose calculation method. The 15, 20, and 30 cm roughness *X/Q* and dose values are small decreases from the 10 cm values except for Pu-239 dose that decreases by 20 to 25 %. Since the 3 cm surface roughness provides only a relatively small increase in dose compared to the 10 cm roughness of the 1998/2000 DWDD, 3 cm was adopted for the 2002 DWDD calculations.

Table 10. Ratio of *X/Q* and dose for Briggs Open Country parameterization and 3 cm surface roughness to the 10 cm surface roughness of the 1998/2000 DWDD inputs

		Ratios of 95th Percentile of Dose at 3000 m					
Input Variations	***X/Q***	**Kr-88** 2.84 hr	**Xe-138** 14.1 min	**I-131** 8.04 day	**I-133** 20.8 hr	**Ce-144** 284.3 day	**Pu-239** 24,065 yr
Roughness 30 cm	0.84	1.00	0.98	0.98	0.95	0.98	0.75
Roughness 20 cm	0.90	1.00	0.98	0.98	0.96	0.98	0.78
Roughness 15 cm	0.94	1.00	0.98	0.99	0.97	0.99	0.79
Briggs Open Country	1.09	1.39	1.02	1.05	1.02	1.05	1.01
Roughness 3 cm	1.18	1.39	1.04	1.12	1.14	1.12	1.02

Plume Meander Expansion Factor

The Prairie Grass experiment dispersion measurements and parameterization schemes for σ_y and σ_z were for short duration plumes. However, plumes tend to meander or change direction slightly. Since a receptor does not move during plume passage, it sees a variation in radioactive material concentration due to plume meander. Release duration of radioactive material in an accident at a nuclear facility determines how long the ventilation system exhaust plume has radioactive material in it that can cause dose to a receptor downwind. The effective radioactive material concentration at a receptor is the average of instantaneous concentrations over the duration of the release. This is always true no matter what happens to the plume during its journey to the receptor. In the straight-line Gaussian plume model of dispersion in the MACCS2 code, the wind direction is ignored and the entire plume is assumed to pass a receptor point no matter how long the release duration. Thus, plume meander is especially important for longer duration releases. For durations over about 10 minutes long, the effective concentration of pollutants in the plume downwind is reduced by the minor direction changes of the wind (plume meandering). The release duration used in the 1998/2000 DWDD was 2 hours. The effect of release duration and plume broadening are implemented in the MACCS2 code by use of a meander expansion factor that serves to widen the plume in the cross-wind direction and reduce *X/Q*. The following shows how the meander factor is calculated in MACCS2.

$$\text{meander factor} = (\text{plume duration / time base})^n \tag{8}$$

where:
plume duration = release duration
time base = 10 minutes
n = an exponent of 0.2 for plume durations of one hour or less and 0.25 for longer durations (Gifford 1975)

The ATMOS input variables that define the meander factor are:

- TIMBAS for the time base (10 minutes),
- BRKPNT for the breakpoint (1 hour) to the higher exponent value in Equation (8),
- XPFAC1 for the exponent (0.2) for times less than BRKPNT, and
- XPFAC2 for the exponent (0.25) for times greater than BRKPNT.

The MACCS2 code compares BRKPNT to the plume duration in the ATMOS module to determine which exponent to use in calculation of the meander factor. If the plume duration is less than or equal to TIMBAS no calculation is done and the meander factor is 1.0 for no plume broadening.

This method produces a meander factor of about 1.86 for the two-hour release duration (1.43 for 1 hour) for dose calculations with constant weather to reduce the radioactive material concentration (and resulting dose). This is a large effect on the dose in the non-conservative direction (long duration lowers dose).

The 1998/2000 DWDD release duration came from earlier dose studies of reactor release accidents that assessed 2 hours as sufficient to clear the released radioactive material from the reactor facility. The TA-V reactor and other facility release accidents are generally shorter in duration of material release from the reactor or other accident source in the facility. Also, ventilation systems in the TA-V nuclear facilities have such a high flow rate through the facility that most released material in an instantaneous or short release is removed from the facility within 10 minutes. Exceptions to the short release and fast ventilation flow rate may occur in the Hot Cell Facility accidents or other situations where the pressure differential is more important for released material confinement than fast flow or in slow evolution of radioactive material from an accident. These exceptions are minor and should not prevent shortening the release duration used in new 2002 DWDD dose calculations to even the most conservative 10-minute release. Justifications of somewhat longer release durations will rely on special conditions in a specific accident so may not be strictly applicable to the 2002 DWDD as a whole.

Some atmospheric models base meander factor on stability class instead of plume duration, as plume meander is more pronounced for low wind speeds and neutral and stable conditions (D through G stability). The NRC incorporated this approach for meander factor into Regulatory Guide 1.145 that recommends not using any meander factor for stability classes A, B, or C (NRC 1982). Since MACCS2 has no provision for changing meander factor by stability class, only meander factor changes due to release duration are addressed in this report and in developing inputs for the 2002 DWDD calculations.

In order to compare the effect of varying the plume broadening for releases shorter than 2 hours in the new 2002 DWDD dose calculations, the ATMOS input file for the 1998 and 2000 DWDD was modified for a release duration of 10 minutes and MACCS2 calculations were run. The plume-broadening model was not altered. The new *X/Q* and 95th percentile of dose was calculated for same six nuclides. Table 11 shows the results of the calculations as ratios of the 1998/2000 DWDD 2-hour release values to the 10-minute release values.

The comparison in Table 11 shows that the 10-minute release increases *X/Q* by approximately the meander factor and increases the dose for all nuclides by approximately 1.4 to 1.5 except for Xe-138 that had a smaller increase. Since the 10-minute release is more typical of the hypothetical accident releases from TA-V nuclear facilities than the 2-hour release of the 1998/2000 DWDD, the 10-minute release was adopted for the 2002 DWDD calculations.

Table 11. Ratio of *X/Q* and dose for the plume broadening from a release duration of 10 minutes versus the 2 hour release duration of the 1998/2000 DWDD inputs

		Ratios of 95th Percentile of Dose at 3000 m					
Input Variations	***X/Q***	**Kr-88** 2.84 hr	**Xe-138** 14.1 min	**I-131** 8.04 day	**I-133** 20.8 hr	**Ce-144** 284.3 day	**Pu-239** 24,065 yr
No Plume Broadening for 10 minute Release	1.84	1.40	1.08	1.49	1.46	1.49	1.46

Plume Rise Data

Two physical processes can propel a neutral buoyancy plume vertically upward to a level higher than that of its initial release, an effect called plume rise or plume lofting. The first process is momentum plume rise where the vertical momentum of the release as it leaves the ventilation system or stack propels the plume upward. The second process is buoyant plume rise that occurs if the temperature of the plume is warmer that that of the ambient air. For either mechanism it is important to account for stack-tip downwash of the plume. Downwash can occur under high wind-speed conditions.

A buoyant plume rise model based on the recommendations of Briggs (1975, 1984) was incorporated into MACCS2. There are three basic components of the model: (1) entrainment of buoyant plumes in a building wake, (2) plume rise under unstable and neutral conditions (classes A to D), and (3) plume rise under stable conditions (classes E to F). There is no provision for plume rise from the vertical momentum of the release in the MACCS2 code. Plume rise from vertical momentum was ignored in the calculation inputs of both 1998/2000 and 2002 DWDD versions since it would result in a higher plume centerline that provides lower ground level concentration and dose values, non-conservative result. See Equations (1) and (2).

The buoyant plume rise component models are described in the MACCS *Model Description* (Jow et al. 1990). The individual numeric coefficients used by these models are fixed in the code. There is no provision for their convenient modification by the user. While it is not possible for the user to vary the individual coefficients utilized by the three components of the plume rise model, it is possible to modify their end results by the specification of linear scaling factors for each of the three basic components of the model.

MACCS2 implements the plume rise entrainment model recommended by Hall and Waters (1986), as described in the MACCS *Model Description*, page 2-6, where the critical wind speed is a function of the height of the building and the thermal power of the plume (ATMOS input variables PLHEAT and BUILDH discussed later). Winds faster than the critical wind speed result in downwash and entrainment of the plume in the building wake. This model is based on wind tunnel experiments for buildings of a size associated with commercial reactors. The MACCS2 formula for calculating the critical wind speed for plume entrainment is:

$$u_C = \left(\frac{9.09F}{L_P} \right)^{1/3} \tag{9}$$

where:
u_c = critical wind speed for plume entrainment (m/s),
L_P = plume scale height (m), the building height (BUILDH) behind which the plume may be entrained, and
F = the buoyancy flux (m^4/s^3) of the plume source that depends of the sensible heat release rate ($q^{\cdot}$) of the plume (sensible heat content divided by the release duration). Note that F = 8.79 x 10^{-6} $q^{\cdot}$ where $q^{\cdot}$ (PLHEAT) is expressed as watts.

The ATMOS input variables that define the linear scaling factors are:

- SCLCRW for the linear scaling factor for the critical wind speed used in determining if buoyant plumes will be trapped in the turbulent wake of a facility building complex,
- SCLADP for the linear scaling factor on the plume rise formula used to determine the amount of plume rise that will occur when unstable or neutral atmospheric conditions occur (classes A through D), and
- SCLEFP for the linear scaling factor on the plume rise formula used to determine the amount of plume rise that will occur when atmospheric conditions are stable (classes E and F).

A value of 1.0 was used for all of these scaling factors in the 1998/2000 DWDD. The 2002 DWDD used a value of 1.0×10^6 for SCLCRW (the maximum allowable value) to suppress entrainment of a buoyant plume in a building wake as recommended by (Restrepo 2002).

Plume rise due to the buoyancy of a higher temperature release and due to the vertical momentum of the release was not desired since they can both produce higher plume centerlines that result in lower ground level concentration of airborne radioactive material and the associated dose as illustrated in Equations (1) and (2), a non-conservative condition. In fact the value of PLHEAT that specifies the rate of sensible heat in the release plume was set to zero to avoid buoyant plume rise for both the 1998/2000 and the 2002 DWDD calculations. PLHEAT is discussed in a later section. The value of BUILDH was set to the building height for the particular release condition in the 1998/2000 DWDD and was set to the minimum allowed value of 1.0 m for the 2002 DWDD calculations. The critical wind speed for plume entrainment is maximized by a minimum building height thus relegating entrainment to higher wind speed weather cases. Thus, setting BUILDH at 1.0 m as well as setting SCLCRW at 1.0×10^6 are designed to preclude plume entrainment.

In order to assess the effect of the variation of the linear scaling factor for critical wind speed, SCLCRW, from the 1998/2000 DWDD value (1.0) to the 2002 DWDD value (1.0×10^6), the doses for all 162 radionuclides were calculated for both values. The other inputs were those chosen for the 2002 DWDD revised standard input with the 1994 A36 weather tower meteorological data. The doses were identical for either SCLCRW value for all of the 162 nuclides. Thus, there was no impact to changing SCLCRW from 1.0 to 1.0×10^6. This result was attributed to the minimum building height (BUILDH) of 1.0 m and 0.0 W for PLHEAT.

Further MACCS2 calculations were performed to assess the impact of varying PLHEAT and BUILDH on plume entrainment for radioactive material ground level concentration (*X/Q*), dose for Pu-239, and resulting plume height all at 3000 m downwind. The concentration, dose, and plume height were all 95th percentile values calculated from the 8760 weather cases for the 1994 A36 tower meteorological data. The rest of the inputs were those chosen for the 2002 DWDD calculations with release height of 14.3 m for the Annular Core Research Reactor Facility (ACRRF). Two values of BUILDH were used for the evaluation, 1.0 and 14.3 m. PLHEAT values used were 0.0 W (standard input for all DWDD versions), 1.1377 x 10^5 W (sensible heat release rate ($q^\cdot$) of burning approximately 0.5 gallons of #2 Diesel fuel in 600 seconds), 1.1377 x 10^6 W ($q^\cdot$ of burning approximately 5 gallons of #2 Diesel fuel in 600 seconds), and 1.1377 x 10^7 W ($q^\cdot$ of burning approximately 50 gallons of #2 Diesel fuel in 600 seconds). Diesel fuel (#2) produces 128,980 Btu/gallon of heat when burned (Norton 1996). For comparison, (RFETS 1999) uses 6.0 x 10^6 W as the sensible heat release rate for a moderate fire at the Rocky Flats Environmental Technology Site. Table 12 shows the results of the MACCS2 calculations.

Table 12. Comparison of concentration, dose and plume height for variation of SCLCRW, PLHEAT, and BUILDH at 3000 m distance

SCLCRW	BUILDH (m)	PLHEAT (W)	*X/Q* (s/m^3)	Pu-239 Dose (rem/Ci)	Plume Height (m)
No Entrainment					
1.0x 10^6	1.0	0.0	7.21 x 10^{-5}	7.53 x 10^0	1.43 x 10^1
1.0x 10^6	1.0	1.1377 x 10^5	3.32 x 10^{-5}	3.56 x 10^0	6.91 x 10^1
1.0x 10^6	1.0	1.1377 x 10^6	1.13 x 10^{-5}	1.15 x 10^0	3.68 x 10^2
1.0x 10^6	1.0	1.1377 x 10^7	2.14 x 10^{-6}	2.16 x 10^{-1}	8.16 x 10^2
Entrainment					
1.0	1.0	0.0	7.21 x 10^{-5}	7.53 x 10^0	1.43 x 10^1
1.0	1.0	1.1377 x 10^5	3.58 x 10^{-5}	4.05 x 10^0	6.91 x 10^1
1.0	1.0	1.1377 x 10^6	1.13 x 10^{-5}	1.15 x 10^0	3.68 x 10^2
1.0	1.0	1.1377 x 10^7	2.14 x 10^{-6}	2.16 x 10^{-1}	8.16 x 10^2
No Entrainment					
1.0x 10^6	14.3	0.0	7.21 x 10^{-5}	7.53 x 10^0	1.43 x 10^1
1.0x 10^6	14.3	1.1377 x 10^5	3.32 x 10^{-5}	3.56 x 10^0	6.91 x 10^1
1.0x 10^6	14.3	1.1377 x 10^6	1.13 x 10^{-5}	1.15 x 10^0	3.68 x 10^2
1.0x 10^6	14.3	1.1377 x 10^7	2.14 x 10^{-6}	2.16 x 10^{-1}	8.16 x 10^2
Entrainment					
1.0	14.3	0.0	7.21 x 10^{-5}	7.53 x 10^0	1.43 x 10^1
1.0	14.3	1.1377 x 10^5	7.04 x 10^{-5}	7.30 x 10^0	1.65 x 10^1
1.0	14.3	1.1377 x 10^6	2.15 x 10^{-5}	2.34 x 10^0	3.57 x 10^2
1.0	14.3	1.1377 x 10^7	6.33 x 10^{-6}	6.94 x 10^{-1}	8.16 x 10^2

The first and third sections of Table 12 represent no entrainment of the plume in building wake. The second and fourth sections of Table 12 represent entrainment of the plume in building wake. Note that for all four sections, the PLHEAT = 0.0 W cases have the same concentration, dose, and plume height results for either value of SCLCRW or BUILDH. Thus, the dose calculations for the 2002 DWDD that have PLHEAT = 0.0 W do not depend on the SCLCRW = $1.0x\ 10^6$ or BUILDH = 1.0 of the 2002 DWDD inputs to ensure the same dose results. Also note that the concentration and dose decrease and the plume height increase for increasing PLHEAT sensible heat release rate. This illustrates that higher plume centerline heights due to plume rise are non-conservative (lower dose than without plume rise). The utility of the no entrainment input of SCLCRW = $1.0x\ 10^6$ is illustrated by noting that the first and third sections of Table 12 have the same values for concentration, dose and plume height for either BUILDH value. Thus, SCLCRW = $1.0x\ 10^6$ and no entrainment are useful for consistency of dose calculation results.

Wake Effects Data

As indicated in the previous section, releases from vents and small stacks can be entrained behind a building into its downwind wake or cavity due to the aerodynamic effect of the building on the wind field in which the release occurs. The initial size of the released plume is determined by the width and height of the building wake. The height of the building wake is also used to determine if the plume is entrained in the turbulent region surrounding the building.

The ATMOS input variables that define the wake effects are as follows.

- BUILDH defines the height of the facility building. This value is used in the evaluation of whether a buoyant plume is entrained in the turbulent wake of the building for MACCS2 as discussed in the previous section. The building height, in contrast to MACCS, is no longer used to define the initial value of σ_z for the plume.
- SIGYINIT defines the initial value of σ_y for each of the plumes released.
- SIGZINIT defines the initial value of σ_z for each of the plumes released.

For the purpose of initializing plume dimensions, MACCS, Version 1.5.11.1 the predecessor MACCS2 assumed the release point from a building wake to be at the ground level and in the middle of the downwind face of the building. If plume concentrations at the sides and roofline of the building from which the release occurs are assumed to be 10 percent of plume centerline concentrations (building edges are 2.15 sigma from the plume centerline), then initial values of the horizontal and vertical standard deviations of the Gaussian plume are given by (Jow et al. 1990) as:

$$\sigma_y\ (t = 0) = W_b/4.3 \qquad (10)$$

$$\sigma_z\ (t = 0) = H_b/2.15 \qquad (11)$$

where W_b and H_b are the width and height of the building.

Other methods of calculating σ_y and σ_z are explained in the MACCS2 *User's Guide* (Chanin and Young 1997) but the method described above was used for the 1998/2000 DWDD calculations that modeled wake effects to develop SIGYINIT and SIGZINIT for the particular nuclear facility. The building height of the particular nuclear facility was also used for BUILDH in the 1998/2000 DWDD calculations that modeled wake effects. The 1998/2000 DWDD calculations that did not model wake effects used the minimum allowable values for these inputs so simulate a small or point source. The no wake inputs for the 1998/2000 DWDD calculations were BUILDH = 1.0 m, SIGYINIT = 0.1 m and SIGZINIT = 0.1 m. The 1998/2000 DWDD and the 2002 DWDD wake effects inputs are shown in Table 13 and can be found in the ATMOS input listings of Appendices A and C. Note that the dimensions of the ACRR building were used for all of the wake effects inputs for the building wake release conditions in the 1998/2000 DWDD calculation inputs since the ACRR building is the biggest building in TA-V.

The wake effects inputs chosen for all of the 2002 DWDD calculations were the same no wake inputs used for the 1998/2000 DWDD calculations. These inputs are a conservative assumption since these parameters when set to model point releases will disperse the plume less initially and subsequently to produce higher concentrations and higher doses to the MOI.

The MACCS code matches the plume dispersion calculations to these initial σ_y and σ_z values by calculating a virtual source point and distance from the release point. The distance to this virtual source point is back-calculated from the initial σ_y and σ_z values using the initial wind speed and stability class with the power law dispersion formula of Equation (3). The virtual source point then becomes the starting point for calculating downwind σ_y and σ_z values at the distance ranges from the release point that were established in the ATMOS input. This same technique is used for calculating new downwind σ_y and σ_z values for distance ranges that require more than one hour of transport from the initial release, as was discussed in the previous chapter. The σ_y and σ_z values at the one-hour transport distance are used to calculate a new virtual source point with the next wind speed and stability class from the 120-hour weather history that was randomly selected for that particular dose calculation. This process is repeated until the plume finally gets to all distance ranges (Jow et al. 1990).

The range of the input parameters for the wake effects inputs is from the 1998/2000 DWDD building wake inputs to the 2002 DWDD point source, minimum allowable values. The effect of this range of inputs for an ACRR building release was shown in (Restrepo 2002) and was based on the 2002 DWDD calculation inputs. Restrepo (2002) reported the Sandia National Laboratories dose to the MOI at 3000 m was 7.01 rem for a 1 Ci release of Pu-239. His calculation using the minimum allowable values for the wake effects inputs produced a dose for comparison of 7.33 rem. Thus, the impact of adopting the no wake, minimum allowable values wake effects inputs for the 2002 DWDD was an increase in dose of approximately 5 percent.

The dose calculations for the 1998/2000 DWDD included wake effects. The MACCS2 *User's Guide* (Chanin and Young 1997) says. "The dispersion of a plume of material released in the wake of a large building is subject to a large degree of uncertainty. For that reason, MACCS2 should not be used for estimating doses at distances less than 0.5 km from laboratory or industrial-scale facilities." The 2002 DWDD dose calculations do not include wake effects so the closer distance ranges were included to model doses without considering wake effects.

Table 13. Wake effects inputs for 1998/2000 DWDD and 2002 DWDD calculations

Release Condition	Release Height (m)	BUILDH (m)	SIGYINIT (m)	SIGZINIT (m)
1998/2000 DWDD Inputs				
Hot Cell Facility (HCF) Stack (Wake)	38.1	14.3	3.488	6.651
ACRR Building (Wake)	14.3	14.3	3.488	6.651
Ground (Wake)	0.0	14.3	3.488	6.651
Ground (No Wake)	0.0	1.0	0.1	0.1
2002 DWDD Inputs				
HCF Stack	38.1	1.0	0.1	0.1
Gamma Irradiation Facility (GIF) Stack	18.0	1.0	0.1	0.1
Auxiliary HCF (AHCF) Stack	16.4	1.0	0.1	0.1
ACRR Facility (ACCRF)	14.3	1.0	0.1	0.1
Sandia Pulse Reactor Facility (SPRF)	10.0	1.0	0.1	0.1
GIF Vents	4.3	1.0	0.1	0.1
Ground	0.0	1.0	0.1	0.1

Release Description Data

This section of the ATMOS input provides the inputs that describe the characteristics of the radioactive material release. ATMOS can handle multiple plume segments in order to treat the release of a source term that has a composition that varies with time. The plume segments that comprise a release can be separated by a time gap, they can directly follow the preceding segment, or they can overlap. Different release heights, heat contents, release durations, and initial values for σ_y and σ_z may be assigned to each plume. Only one particle size distribution may be assigned to each chemical element group. Only one plume segment was used in the 1998/2000 DWDD and 2002 DWDD calculations.

MACCS2 incorporates the capability for calculating the consequences from up to 60 different source terms in a single run of the code. This is accomplished by appending change records to the ATMOS input file. The first source term is defined in the main body of the ATMOS input file. Up to 59 additional source terms can be defined through change record sets positioned at the end of the file. The change record sets feature was used extensively in the 1998/2000 DWDD and 2002 DWDD calculations to provide separate dose calculations for 1 Ci of each of many radionuclides.

The purpose of the change record processing in ATMOS is solely to allow modification of the previously specified release description data. If data items from another data block than the release description block appear in the change records, they will be ignored. Each set of change records must include a new value of ATNAM2, a text field describing the source term. Also, each set of change records must specify a change in at least one of the numeric input variables described in this data block. The ATNAM2 text field was used to label the dose calculation results for that particular radionuclide to prevent confusion in extracting the data from the output.

The ATMOS input variables that define the release description data are discussed as follows.

- ATNAM2 identifies the name of the source term being studied. A unique name must be specified for each source term. The single radionuclide for each release was identified with this text field in subsequent change records at the end of the ATMOS input.
- OALARM defines the time at which notification is given to off-site emergency response officials to initiate protective measures for the surrounding population. This time is a function of the accident sequence. It is measured from accident initiation (scram time) and is given in units of seconds. This time has no use in any of the DWDD versions since no evacuation or sheltering strategy was implemented to mitigate dose. A time of 12 seconds was used in both the 1998/2000 DWDD and the 2002 DWDD calculations.
- NUMREL defines the number of plumes that will be released. Only 1 plume was released in both the 1998/2000 DWDD and the 2002 DWDD calculations.
- MAXRIS specifies which plume segment is to be considered risk dominant. The selection of this plume is usually based on its potential for causing early fatalities. Release of the risk-dominant plume always begins at the selected meteorological start time of the weather sequence. Both the 1998/2000 DWDD and the 2002 DWDD calculations used only one plume so MAXRIS was 1.
- REFTIM specifies the representative time point of each plume segment (0.0=leading edge, 0.5=midpoint, 1.0=trailing edge). The characteristics of a plume are uniform along its length. This parameter allows the user to locate the contents of the plume in a bucket of material situated at some point within the plume's length. The radioactive decay, dry deposition, and dispersion calculations are all performed as if the entire contents of the plume segment are located at this point. The user must supply NUMREL values of REFTIM, one for each plume segment. The choice of this parameter will have no impact on the wet deposition calculations since those are performed as if the entire contents of the plume are uniformly distributed along its length. REFTIM was 0.0 for the leading edge of the plume in both the 1998/2000 DWDD and the 2002 DWDD calculations since plume depletion from radioactive decay is minimized, a conservative result.
- PLHEAT specifies the rate of release of sensible heat in each plume segment. This quantity should be calculated as the amount of sensible heat in the plume segment divided by the duration of the plume segment. The value specified here is used to determine the amount of buoyant plume rise that will occur. The user must supply NUMREL values of PLHEAT, one for each plume segment. PLHEAT was 0.0 in both the 1998/2000 DWDD and the 2002 DWDD calculations since plume rise was not desired as discussed in a previous section. This is a conservative assumption since no sensible heat is added to the plume that would loft the plume above its initial release elevation, resulting in lower doses to the MOI.
- PLHITE specifies the height above ground level at which each plume segment is released. The user must supply NUMREL values of PLHITE, one for each plume segment. PLHITE was the release height specified in Table 13 for each release condition for the 1998/2000 DWDD and 2002 DWDD calculations.

- PLUDUR specifies the duration in seconds of each plume segment. The user must supply NUMREL values of PLUDUR, one for each plume segment. In contrast to MACCS, where multiple plume segments were not allowed to overlap each other in time, MACCS2 allows the specification of overlapping plumes. Since one plume was used in both the 1998/2000 DWDD and the 2002 DWDD calculations, only one value of PLUDUR was provided. PLUDUR was 7200 seconds in the 1998/2000 DWDD calculations and 600 seconds in the 2002 DWDD calculations. As discussed in a previous section on Plume Meander Expansion Factor, when the plume meander expansion time base value matches the plume release duration, plume meander is suppressed. The plume meander expansion time base was 600 seconds for both 1998/2000 and the 2002 DWDD input versions. The dose impact of reducing PLUDUR to 600 seconds and the rationale for both values of PLUDUR were discussed in that previous section. Other than the relationship to meander expansion factor, the actual value of the release duration is irrelevant because the dose to the MOI is a time-integrated quantity and does not depend on the duration of the plume release.
- PDELAY specifies the start time of each plume segment in seconds from the time of accident initiation, *e.g.,* reactor scram. The user must supply NUMREL values for PDELAY, one for each plume segment. In contrast to MACCS, where multiple plume segments were not allowed to overlap each other in time, MACCS2 allows the specification of overlapping plumes. Both the 1998/2000 DWDD and the 2002 DWDD calculations used only one plume segment and both used the same value for PDELAY, 0.0 seconds. Any delay in release of the plume would increase plume depletion from radioactive decay so the more conservative no delay option was taken.
- PSDIST defines the fraction of the released material allocated to each of the particle size (deposition velocity) bins. All of the plume segments must use the same distribution of material among these bins. The user must specify one data record for each of the chemical element groups. Nine chemical groups were used in both the 1998/2000 DWDD and the 2002 DWDD calculations and only one particle size group (and deposition velocity so PSDIST was 1.0 for all chemical groups in that one particle size. The chemical groups used for wet and dry deposition were discussed in a previous section.
- CORINV defines the inventory of each radionuclide present in the facility at the time of accident initiation. The inventory is given in units of becquerels (disintegrations/second). All of the radionuclides that have been previously defined in the list of radionuclides (NUCNAM array in the section on Source Term Inventory and Decay Characteristics) must be listed here. The 1998/2000 DWDD and the 2002 DWDD calculations used various inventories as discussed in that previous section. In the main ATMOS input file CORINV list of activities, all activities are shown as 0.0 except for the first radionuclide for dose calculation that has and inventory of 1.0. The CORINV activities are the only thing modified in the change records at the end of the ATMOS input file. The old radionuclide inventory is set to 0.0 and the activity of the next nuclide for dose calculation is set to 1.0. This process continues for up to 60 total source terms (single nuclides) in a MACCS2 code run.

- CORSCA is a linear scaling factor that can be used to adjust the inventory of all the radionuclides defined in the model. The parameter CORSCA may be used to convert the facility inventory from one set of units to another during the input processing phase in order to avoid the tedium of manually converting a set of data from one type of units to another. For example, to convert from curies to becquerels, use a value of 3.7×10^{10} for CORSCA. In the 1998/2000 DWDD calculations, a value of 3.7×10^{10} was used for CORSCA. The dose output of MACCS2 is in sieverts as opposed to rem, which is the usual dose unit used in TA-V. Since there are 100 rem in each sievert, an additional spreadsheet calculation with associated error checking was required to convert the dose to rem for the 1998/2000 DWDD calculations. As a result of the previous experience, CORSCA was changed to 3.7×10^{12} for the 2002 DWDD calculations so the dose could be tabulated directly in rem for the 2002 DWDD without the use of the spreadsheet unit conversion. Thus, activity is entered in curies and dose is output in rem.
- RELFRC defines the release fractions for each of the plume segments. One line must be supplied for each plume and it contains as many values as there are element groups. All components of an element group are released from the facility in the same fraction. The value of 1.0 was used for RELFRC for each of the nine chemical element groups in both the 1998/2000 DWDD and the 2002 DWDD calculations.
- APLFRC specifies how release fractions are applied to ingrowth of decay products produced after accident initiation. PARENT indicates that the code is to handle the release fractions in the same way that they are fixed in previous versions of MACCS. That is, daughter ingrowth products are released in the same proportion as their parent. The new option for MACCS2, PROGENY, indicates that the release fraction applied to daughter ingrowth products is defined by the release fraction for the nuclide group to which the daughter is assigned (variable ISOGRP). Since there is no delay from accident initiation for the one plume segment in both the 1998/2000 DWDD and the 2002 DWDD calculations (PDELAY = 0.0 seconds), no decay and no ingrowth (conversion of initial activity to decay products) will have occurred at the time of release. Thus, PARENT was used in both the 1998/2000 DWDD and the 2002 DWDD calculations since the PROGENY option had no meaning for the 1998/2000 and 2002 DWDD releases.

The values chosen for these inputs for the 1998/2000 DWDD and the 2002 DWDD calculations were as discussed above for the reasons given there. Some of the inputs for this section were discussed in other sections. Ranges for those inputs and the impact of input changes from the 1998/2000 DWDD inputs were discussed in those previous sections.

Output Control Data

Inputs in this section specify program control for the next modules of the code and the output from the ATMOS module execution to print in the output listing. These inputs do not affect the calculation of dose but may assist its interpretation and in debugging execution problems with the code.

The user has the option of looking at tables of dispersion data for all of the trials that are performed. This information includes air and ground concentrations, σ_y and σ_z values, arrival time, and time overhead for each plume segment at each spatial interval. These data are written to the list output file. Details on the data printed and how to specify the data to print are shown in the MACCS2 *User's Guide* (Chanin and Young 1997).

The ATMOS input variables that define the output control data are as follows.

- ENDAT1 is the control flag that allows the user to execute only the ATMOS module. A value of .TRUE. tells the code that EARLY and CHRONC will not be run. When this is done, the user input files for EARLY and CHRONC and a site data file need not be supplied. If the user wishes to skip execution of the CHRONC module, that can be accomplished through the input variable ENDAT2 on the EARLY input file. A value of .FALSE. was used to continue the MACCS2 calculations to the EARLY module.
- IDEBUG specifies the quantity of debug output to be printed. For normal runs, IDEBUG should be set to 0 (i.e., no debug output is printed). If IDEBUG is set to 1 or 2, a print of the atmospheric transport results described below will be generated for each weather trial and each plume segment. If IDEBUG is set to a value of 3 or more, the hourly meteorological data used for each weather trial will also be printed. IDEBUG was usually set to 0 in both of the 1998/2000 DWDD and the 2002 DWDD calculations. An IDEBUG value of –1 was used on some runs in the 2002 DWDD calculations to suppress the printing of the 8760 hours of weather history data for the first source term to reduce the size of output files.
- NUCOUT specifies which radionuclide will appear on the dispersion listing if one is produced. The dispersion listing is only produced if IDEBUG is greater than 0.

Meteorological Sampling

The specification of meteorological sampling for the atmospheric dispersion and source depletion calculations of the ATMOS module is an important consideration. It can affect how representative the ATMOS calculations are of the range of weather conditions experienced near TA-V and thus impact the utility of the doses calculated in the EARLY module. There are five options available to the user for specifying the weather data that will be used by ATMOS. The code can be used to run either a single weather sequence or multiple weather sequences, as described in the following paragraphs. There are three options to run single weather sequences and two options to run multiple weather sequences.

To specify the weather for a single weather sequence, the user must supply a standard weather history of 120 hours in the ATMOS input or state a starting day and hour in a weather data file for the 120-hour weather history. Alternately, constant weather conditions can be specified. Single weather sequences are valuable for understanding the dose responses to certain weather conditions but all DWDD versions rely on the 95th percentile of dose as an unfavorable dose for the public or the MOI. DOE-STD-3009 requires use of the 95th percentile of distributed doses to the MOI for comparison to the evaluation guideline (DOE 1994). The distribution of dose values is produced by the distribution of weather condition cases used for dose calculations. Thus, all DWDD versions require multiple weather sequences to generate a 95th percentile of dose.

A file of hourly weather data covering a period of 1 year (8760 hr) is required if either of the weather sampling options is to be used because these options choose starting times for 120-hour weather history sequences. The two methods of weather sampling are (1) a modified version of the weather bin sampling method used by CRAC2, a predecessor to MACCS (Ritchie et al. 1984) and (2) a stratified purely random sampling approach. The weather bin sampling method sorts weather sequences into categories according to the initial conditions (wind speed and stability class) and the occurrence of rain (intensity and distance) and assigns a probability to each category. The bin probability depends on the number of weather sequences that are sorted into that bin and the total number of weather sequences per year (8760). Because the rain bins depend on rain intensity as well as the downwind distance at which rain occurs, the user is required to supply parameters defining the rain weather bins as part of the ATMOS input file. The definitions of the other, non-rain weather bins, that is, those defined by initial stability class and wind speed, are fixed in the code. A description of the MACCS2 weather-sampling algorithm can be found in the MACCS *Model Description* (Jow *et al.* 1990).

The stratified random sampling method allows the user to sample weather from each day of the year after division of each day into the same number of equal time periods. Each weather sequence selected is considered to have the same probability of occurrence, that is the reciprocal of the total number of samples selected.

The ATMOS input variable that defines the meteorological sampling specification is:

- METCOD that defines the meteorological sampling option with a number as follows.
  - 1 - fixed start time in the weather file (day, hour),
  - 2 - weather bin sampling,
  - 3 - 120 hr of weather supplied by the user,
  - 4 - constant weather conditions (use boundary weather),
  - 5 - stratified random sampling from equally spaced intervals.

The 1998/2000 DWDD calculation inputs used METCOD = 2 for weather bin sampling with the bin characteristics as specified in a later section. The 2002 DWDD calculation inputs used METCOD = 5 for stratified random sampling from equally spaced intervals. The stratified random sampling in the 2002 DWDD inputs ensures that the same number of samples is taken randomly from every day of the one-year weather file so that all weather conditions are sampled. The stratified random sampling method avoids the uncertainty inherent with the bin selection parameters for weather bin sampling since those parameters may not adequately bias the sampling of weather data to make a representative set of weather histories. Weather bin sampling has been used previously in many dose consequence studies for reactor and non-reactor nuclear facilities with the important benefit of reducing the computer running time of the 95th percentile dose calculations. With fast modern computers, this benefit is not as important as avoiding the uncertainty inherent in the choice of bin selection parameters.

Boundary Weather Data

Boundary weather data are required for all possible values of METCOD (meteorological sampling specification). The inputs in this section specify the weather conditions that will be used if 120 hours of recorded weather data do not transport the last plume through the limiting spatial interval for measured weather. The boundary weather data are also used to predict the behavior of the plume at all spatial intervals beyond the limiting spatial interval. For the case of constant weather, METCOD = 4, the boundary weather data in this section define the constant weather conditions that will be used.

Both the 1998/2000 DWDD and the 2002 DWDD calculation inputs used the same boundary weather inputs except for the limiting spatial interval and the atmospheric stability class that are discussed below. Since the exclusion area boundary is a 3000 m radius circle around TA-V, the plume reaches it in only one or two hours in every case. Thus, the boundary weather data for transit times beyond 120 hours is not used in the calculation of the 1998/2000 or the 2002 DWDD dose for the 3000 m range.

The ATMOS input variables that define the boundary weather data are the following.

- LIMSPA is the limiting spatial interval for use of recorded weather data. All spatial intervals beyond this interval will use the boundary weather conditions. LIMSPA ranges from 0 to the total number of special range intervals. LIMSPA was the last spatial interval for the inputs of each DWDD version (10 for 1998/2000 and 16 for 2002 DWD inputs).
- BNDMXH is the mixing layer height in meters that will be used for the boundary weather conditions (2055 m).
- IBDSTB is the stability class that will be used for the boundary weather conditions. The integers 1 through 6 represent Pasquill–Gifford stability classes A through F, respectively. The 1998/2000 DWDD used IBDSTB = 1 (stability class A) and the 2002 DWDD used IBDSTB = 6 (stability class F). Stability class F was recommended by Restrepo (2002) since stability class A is not normally associated with 1 m/s winds (see below) and stability class F is usually associated with this low wind speed. Restrepo (2002) concluded that, "Since the MOI is located well inside the last radial ring where these weather conditions prevail, the different stability class specification doesn't affect the dose to the MOI anyway."
- BNDRAN is the rain rate that will be used for the boundary weather conditions in mm/hour. Both DWDD version inputs used 0.0 mm/hour rain rate.
- BNDWND is the wind speed that will be used for the boundary weather conditions in m/s. Both DWDD version inputs used 1.0 m/s wind speed.

Fixed Start Time

The start time data in this section must be provided for every meteorological sampling specification (METCOD) or an error will terminate code execution. The data are needed for all of these option choices because the food pathway calculations of the CHRONC module depend on the day the accident occurs. The data also provide the 120-hour weather history start time for a dose calculation with only one weather sequence. The ATMOS module checks to ensure the information is provided whether or not the CHRONC module will be run.

The same values were used for both the 1998/2000 DWDD and the 2002 DWDD calculation inputs. Since the data are only used in the CHRONC module and that module is not run for the calculations for either DWDD version, the values chosen have no effect on the dose results.

The ATMOS input variables that define the fixed start time data are the following.

- ISTRDY is the day in the year on which the weather sequence is to begin (day 157).
- ISTRHR is the hour of day on which the weather sequence is to begin (hour 10).

Meteorological Bin Sampling Data

The data in this section must be supplied if the user chooses METCOD = 2 for weather bin sampling. Two of the inputs are also required for METCOD = 5, stratified random sampling. The METCOD = 2 sampling method requires that the meteorological data be sorted into a set of weather bins. The bins are defined to represent rain conditions in different distance intervals downwind from the accident site together with 16 bins for initial conditions (stability class and wind speed) that are fixed in the code. See the MACCS2 *User's Guide* (Chanin and Young 1997) for a description of the initial conditions bins. Definition of the rain intensities and distance intervals that define the rain bins is the responsibility of the user.

This section of the ATMOS input was used for the 1998/2000 DWDD calculation inputs only with the exception of the NSMPLS input (fifth input) and the IRSEED input (sixth input) that are used for stratified random sampling as well.

The ATMOS input variables that define the meteorological bin sampling data are the following.

- NRNINT defines the number of rain distance intervals used in the weather categorization (5 in the 1998/2000 DWDD calculations).
- RNDSTS defines the rain distance interval endpoints to be used for the weather categorization. These distance values must lie within 10% of the spatial interval endpoint distances (in km). The user must supply NRNINT unique values in ascending order (3.1, 4.8, 5.0, 7.0, and 20.0 km for the 1998/2000 DWDD).
- NRINTN defines the number of rain intensity breakpoints to be used for the weather categorization (3 breakpoints were used for the 1998/2000 DWDD).

- RNRATE defines the rain intensity breakpoints in mm/hour. The user must supply NRINTN different values in ascending order (3.0, 4.0, and 6.0 mm/hour were used for the 1998/2000 DWDD).
- NSMPLS defines the number of weather sequences to be chosen from each of the individual weather-category bins (when METCOD = 2), or from each day of the year (when METCOD = 5).

  When METCOD = 2, it is advisable to set a value of at least 4; the more samples that are taken, the more robust is the sampling (Chanin and Young 1997). If the user supplies a value of 0 for NSMPLS, and METCOD = 2, the variables NSBINS, INDXBN, and INWGHT allow the user to specify how many samples are to be chosen from each of the weather-category bins. Since NSMPLS = 0 for was not chosen METCOD = 2, the input variables NSBINS, INDXBN, and INWGHT were not used and are not discussed in this section.

  When METCOD = 5, setting NSMPLS = 24 will have the code sample every hour of the year, a capability that can provide insights into the adequacy of the operation of the weather binning algorithm. In using the METCOD = 5 option, it is advisable to select values for NSMPLS that are divisors of 24 because then each interval is composed of a whole number of hours. That is, NSMPLS should be set to one of the following: 1, 2, 3, 4, 6, 8, 12, or 24. Test calculations by the code developers indicate that taking stratified random samples from each 6-hr interval of the year yields results close to those obtained from sampling all 8760 hr of the year. There may thus be diminishing returns from taking more samples, since calculation time is proportional to the number of samples.

  NSMPLS = 4 was used for METCOD = 2 in the 1998/2000 DWDD calculations. This value was recommended in (Sprung et al. 1990) for the NUREG-1150 source term calculations of risk assessments from severe nuclear reactor accidents.

  NSMPLS = 24 was used for METCOD = 5 in the 2002 DWDD calculations. Restrepo (2002) recommended NSMPLS = 24 for the 2002 DWDD calculations since "the result is a more robust, defensible calculation."
- IRSEED defines the initial seed of the random number generator. Changes to this value will cause different weather sequences to be selected. The random number generator of MACCS2 is included in the FORTRAN source code and therefore runs made on different types of computers should select identical sets of weather sequences. IRSEED = 46 was arbitrarily chosen for both the 1998/2000 DWDD and the 2002 DWDD calculations.

The weather binning process with these inputs resulted in 78 weather history sequences for the 1998/2000 DWDD calculations. Due to interaction of the ranges selected and the site file, several weather bins were empty. Other bins only contained a few weather histories. Several of the other weather bins were quite large with a frequency of approximately 3% for three of them. As a result of these statistics, several fission product nuclides (notably the noble gases) did not have dose values for the 95th percentile of dose. The highest dose values represented a cumulative frequency of 94.2% for that dose value. In the cases where no 95th percentile of dose was available, the highest dose was chosen to represent the 95th percentile of dose.

User Supplied Weather Sequence Data

User supplied weather sequences of 120 hours of weather data were not used in either the 1998/2000 DWDD or the 2002 DWDD calculations so this section of inputs was not used.

CCDFs of Atmospheric Results

In MACCS2, complementary cumulative distribution functions (CCDFs) can be produced for the atmospheric modeling parameters calculated by ATMOS. The ATMOS module will generate CCDFs of ten atmospheric modeling parameters for user-specified distances and plume segments. When the multiple source term looping capability of ATMOS is utilized (i.e., multiple source terms are defined in a single ATMOS input file), these CCDFs may be produced only for the first defined source term.

Air and ground concentrations are reported for the radionuclide specified for the variable NUCOUT. In addition to the results produced for the single specified radionuclide, the total radioactivity on the ground (from all radionuclides) is reported as well. Within a single run of the code, there is no provision in MACCS2 for generating CCDFs of air and ground concentrations for multiple individual radionuclides. The radionuclide chosen for NUCOUT was Ce-144 for the 1998/2000 DWDD inputs and Pu-239 for the 2002 DWDD inputs.

The ATMOS input variables that define the desired CCDF atmospheric results are the following.

- NUM0 specifies how many results of this type are being requested. For each result requested, a block of ten consequence measures is produced in the list output file. Each measure has the CCDF summary for the mean, 50th percentile, 90th percentile, 95th percentile, etc. just as for the dose at a distance range. The ten consequence measures are as follows:
  - (1) Selected Radionuclide Centerline Air Concentration
  - (2) Selected Radionuclide Ground-Level Air Concentration
  - (3) Selected Radionuclide Centerline Ground Concentration
  - (4) Total Centerline Ground Concentration
  - (5) Ground-Level *X/Q* Dispersion Factor
  - (6) Selected Radionuclide Adjusted Source Strength, Q^a
  - (7) Plume σ_y, Crosswind Size
  - (8) Plume σ_z, Vertical Size
  - (9) Plume Centerline Height
  - (10) Plume Arrival Time at Centerpoint

  NUM0 was 10 for the 1998/2000 DWDD and 16 for the 2002 DWDD to match the number of distance ranges.
- INDREL specifies the index of the plume segment for which results are to be generated. Since only one plume segment was used for both DWDD versions, INDREL = 1 was used.
- INDRAD specifies the index of the spatial distance for which results are to be generated. All spatial distance ranges were used for both DWDD versions.

EARLY Module Inputs

The EARLY module models the time period immediately following a radioactive release. This period is commonly referred to as the emergency phase. It may extend up to one week after the arrival of the first plume at any downwind spatial interval. The subsequent intermediate and long-term periods are treated by CHRONC. Only the early exposures of the emergency phase were considered in the 1998/2000 DWDD and the 2002 DWDD dose calculations with the minimum emergency phase duration of one day.

In the EARLY module the user may specify emergency response scenarios that include evacuation, sheltering, and dose-dependent relocation. The EARLY module has the capability for combining results from up to three different emergency response scenarios. This is accomplished by appending change records to the EARLY input file. The first emergency-response scenario is defined in the main body of the EARLY input file. In both the 1998/2000 DWDD and the 2002 DWDD calculations, no evacuation, sheltering or dose-dependent relocation emergency response scenarios were used. Instead, the dose delivered to the dose receptors at the distance ranges was calculated without any mitigation measures. No change records were appended to the EARLY input file for calculations of either DWDD version.

The calculation of radiation doses from early exposure considers five pathways: (1) direct external exposure to radioactive material in the plume (cloudshine), (2) exposure from inhalation of radionuclides in the cloud (cloud inhalation), (3) exposure to radioactive material deposited on the ground (groundshine), (4) inhalation of resuspended material (resuspension inhalation), and (5) skin dose from material deposited on the skin. The first four pathways are used in the 1998/2000 DWDD dose calculations. The 2002 DWDD dose calculations use only the first two pathways. The fifth pathway is not used in either the 1998/2000DWDD or the 2002 DWDD calculations.

Two kinds of doses can be calculated: (1) acute doses used for calculating early fatalities and injuries and (2) lifetime dose commitment used for calculating cancers resulting from the early exposure. Both the 1998/2000 DWDD and the 2002 DWDD calculations are concerned exclusively with lifetime dose commitment and not with acute doses used for calculating early fatalities and injuries. The accumulation of radiation doses from early exposure is strongly dependent on the assumed emergency response, that is, evacuation, sheltering, or early relocation. Even the normal activity of a non-evacuating, non-sheltering, and non-relocating dose receptor population has certain dose protection factors assigned in the EARLY input file for the particular DWDD version calculations. Thus, those inputs play a roll in defining the dose. The conservatism inherent in their selection is discussed in the following sections on the EARLY module inputs. Cloudshine and cloud inhalation exposures are limited to the time of cloud passage. Groundshine and resuspension inhalation doses for early exposure are limited to the duration of the emergency phase.

In general, the dose equation for an early exposure pathway in MACCS2 in a given spatial element is the product of the following quantities: radionuclide concentration, dose conversion factor, duration of exposure, and shielding factor. The quantities used in the dose equations depend on the exposure pathway. For example, for the cloud inhalation exposure pathway, these quantities are the ground-level air concentration at a spatial element, inhalation dose conversion factor, duration of exposure, and inhalation shielding factor.

The EARLY input file was the same for all ATMOS input files for the particular DWDD version. The 2002 DWDD EARLY input file was revised from the 1998/2000 DWDD input file to incorporate certain changes made necessary to support the reasonably conservative inputs for DOE-STD-3009, Appendix A requirements such as the MOI. Separate EARLY input files were developed to use the same run description name as the associated ATMOS input file but the rest of the input parameters were the same for the particular DWDD version.

Dose Conversion Factors and Other Miscellaneous Inputs

The MACCS2 user has a great deal of flexibility in the selection of a dose conversion factor (DCF) file. The MACCS2 package includes a number of sample DCF files of various types. MACCS2 DCF preprocessor programs that are included with the code distribution package can be used to generate additional DCF files.

A few of the calculations for the 1998 DWDD used an old DCF file developed by the DOSFAC code (also included in the MACCS2 code distribution package) and containing the 60 radionuclides considered important to nuclear power plant safety analyses. Those few calculations used this DOSFAC set of DCFs for both MACCS version 1.5.11.1 and MACCS2 code calculations. The code and DCF set used for each dose calculation is marked on the 1998 DWDD listing in Appendix E.

Another set of DCFs was used with MACCS2 for the majority of the 1998 DWDD, all of the 2000 DWDD, and all of the 2002 DWDD calculations. This second set of DCFs was produced by the new FGRDCF preprocessor (also included in the MACCS2 code distribution package), which provides the user with access to the DCFs issued by the EPA in Federal Guidance Report (FGR) 11 (Eckerman et al. 1989) and FGR 12 (Eckerman and Ryman, 1993). The FGRDCF preprocessor accesses inhalation and ingestion DCFs for over 600 radionuclides, and cloudshine and groundshine DCFs for over 825 radionuclides (RSIC 1994). The DCFs provided by FGRDCF are sufficient for MACCS2 lifetime dose calculations but not for acute dose calculations required for early health effects. Thus, the FGRDCF DCFs are sufficient for use in all of the DWDD versions.

The EARLY input variable that defines the desired DCF file is the following.

- DCF_FILE identifies the DCF file to be used for the MACCS2 calculations. This filename can include a directory path; the file need not be in the current directory.

DOSDATA.INP (dated 6/25/92) is the file containing the 60 radionuclides considered important to nuclear power plant safety analyses (the DOSFAC code set of DCFs) that was used for some 1998 DWDD calculations

DOSD825.INP (dated 3/26/97) is the file used for the remainder of the 1998 DWDD, all of the 2000 DWDD and all of the 2002 DWDD calculations. DOSD825.INP was produced by the FGRDCF preprocessor and contains DCFs for over 600 radionuclides provided by the EPA Federal Guidance Reports 11 and 12.

In addition to the specification of a DCF file, the user must supply other miscellaneous input information to identify the run, define the dispersion model option used, define the histogram approximating the crosswind Gaussian distribution, and also supply information describing the handling of the wind rose. It is possible to specify a single wind rose that will override the wind roses that were calculated in ATMOS for each of the weather-category sampling bins. The user must also specify how to treat changes in wind direction.

The EARLY input variables that define the miscellaneous input information are the following.

- EANAM1 identifies a name describing the EARLY calculations. This is printed on all pages of the OUTPUT listing. A name describing the particular emergency response assumption will be requested in addition to this name. The name used for this variable was intended to echo the name adopted for the associated ATMOS input file. This input was generally placed before the DCF_FILE input in the EARLY input file.

- ENDAT2 is the control flag that allows the user to execute only the ATMOS and EARLY modules while skipping execution of the CHRONC module. If CHRONC is to be skipped, there is no need for the user to specify a CHRONC input file. A value of .TRUE. causes MACCS2 to skip the CHRONC module. A value of .FALSE. causes the CHRONC module to be executed. The CHRONC module was not included in any of the DWDD version calculations so the value for this input parameter was always .TRUE.

- IPLUME is the dispersion model option code with values 1-3 as described below.
  1 - Straight-line dispersion model:
  All plume segments travel in the same direction (the radius) out from the origin of the facility release. Each set of modeling results is rotated around the 16 compass directions (population sectors) to yield 16 sets of results for each weather trial. This is the direction independent input used for all of the DWDD versions. DOE-STD-3009, Appendix A requires this option.
  2 - Wind-shift plume dispersion model with rotation:
  Each plume segment in the release travels in the direction that the wind is blowing at the time that its representative time point (REFTIM in the ATMOS input file) leaves the facility. Each set of modeling results is rotated around the 16 compass directions (population sectors) to yield 16 sets of results for each weather trial.
  3 - Wind-shift dispersion model without rotation:
  Each plume segment in the release travels in the direction that the wind is blowing at the time that its representative time point (REFTIM in the ATMOS input file) leaves the facility. No rotation of the wind shift pattern is performed. Each weather trial yields one set of results.

- NUMFIN is the number of fine-grid subdivisions used by the model. A step function is used to approximate the Gaussian distribution of the plume in the crosswind direction. Each of the 22.5-degree sectors is subdivided into NUMFIN fine-grid elements, with doses and risks being uniform in each element. NUMFIN is only used in the calculations performed by EARLY. The same finest grid subdivision number of 7 was used for the 1998/2000 DWDD and the 2002 DWDD dose calculations. This fine-grid subdivision is only useful for calculating dose away from the centerline of the plume radioactive material concentration. Since the dose calculation for all DWDD versions is for the dose on the centerline of the plume, the fine-grid subdivisions are not used in the dose calculations for any of the DWDD versions.
- IPRINT specifies the quantity of debug output that is desired. The higher the value, the more output will be printed. Normal runs should specify a value of 0. All DWDD version calculations specified IPRINT = 0.
- RISCAT specifies whether to print risk contribution tables. If the option of weather-category bin sampling was chosen by the user in the ATMOS input file (METCOD=2), the display of results produced by the OUTPUT module can show the relative contribution of each of the weather-category bins to the mean consequence value. In the calculations for all of the DWDD versions, a value of RISCAT = .FALSE. was used to indicate no risk contribution table printing.
- OVRRID specifies whether the wind rose probabilities are to be supplied by the user. If the weather bin sampling option was chosen in ATMOS (METCOD=2), wind roses for each weather sampling bin have been passed down from ATMOS. Those wind roses will be used if OVRRID = .FALSE. If no wind rose is available, a uniform wind rose will be used, that is, P = 0.0625 in each direction. In the calculations for all of the DWDD versions, a value of OVRRID = .FALSE. was used. For the 1998/2000 DWDD calculations, METCOD = 2 and a wind rose was passed to EARLY from ATMOS. In the 2002 DWDD calculations, METCOD = 5 so no wind roses were passed and a uniform wind roses was used. If OVRRID = .TRUE. the user must supply a new wind rose.
- WINROS is only required if the OVRRID input parameter is set to .TRUE. The values input for this parameter are the probabilities of the wind blowing from the site into each of the 16 compass sectors (rotating clockwise from N to NNW). The sum of these values must be between 0.95 and 1.05. WINROS was not used in the EARLY input files for any of the DWDD versions so it was not included in the files.

Population Data

The user must supply information to define the polar-coordinate population distribution surrounding the site. This information can be supplied from the site data file or a uniform population distribution can be specified by the user.

The EARLY input variables that define the population distribution data are the following.

- POPFLG specifies whether the population is to be defined by the site data file or if it is to be uniform. The value specified must be either FILE or UNIFORM. If a value of UNIFORM is supplied, the program will not attempt to read the site data file. FILE was specified for the 1998/2000 DWDD calculation inputs and UNIFORM was specified for the 2002 DWDD calculation inputs. Uniform population density was chosen for the 2002 DWDD partly because a new site data file would be required for the new spatial interval distance ranges but mostly because the centerline dose output of EARLY does not use or need a population distribution. Thus, a detailed site population distribution is not applicable to dose calculation for the MOI, which is independent of actual population distribution. Other dose and risk outputs of the EARLY module that require detailed actual population distributions were not requested or not tabulated for the 2002 DWDD.
- IBEGIN specifies the spatial interval at which the population begins. Inside of this region there are no people. This allows the modeling of an exclusion zone. This value is only required if POPFLG='UNIFORM'. The value of IBEGIN = 1 for the first spatial interval was used for the 2002 DWDD inputs but as explained under POPFLG above no population distribution is needed for the centerline dose output of EARLY used for the 2002 DWDD dose calculations.
- POPDEN specifies the uniform population density of the region. This value is only required if POPFLG='UNIFORM'. The value of POPDEN = 50 for 50 people per square kilometer was used for the 2002 DWDD inputs but as explained under POPFLG above no population distribution is needed for the centerline dose output of EARLY used for the 2002 DWDD dose calculations.

Organ Definition Data

The body organs referenced in the MACCS2 EARLY and CHRONC input files must be assigned a .TRUE. value for the ORGFLG variable defined in this section.

MACCS2 can calculate two kinds of doses: lifetime dose and effective acute dose. Lifetime dose is utilized to determine the need for mitigative actions and for calculating the cancer induction and population dose results. It represents the 50-year dose commitment. Effective acute doses are used for calculating the acute health effects in the EARLY module. The acute health effects are early fatalities and early injuries. Acute health effects were not considered in the 1998/2000 DWDD or the 2002 DWDD calculations.

If a DCF file generated by FGRDCF is being used for the calculations, the list of available organs is set automatically to the nine organs of FGR 11 and 12. If the header record of that file begins with the characters FGRDCF, the data below for ORGNAM and ORGFLG are not processed by MACCS2 and the list of organs is fixed to the following:

L-GONADS
L-BREAST
L-LUNGS
L-RED MARR
L-BONE SUR
L-THYROID
L-REMAINDER
L-EFFECTIVE
L-SKIN (FGR)

Since most of the 1998 DWDD calculations, all of the 2000 DWDD calculations, and all of the 2002 DWDD calculations used the DOSD825. INP file that is derived from the FGRDCF preprocessor, no list of organs was defined for most of the DWDD calculations with MACCS2.

The EARLY input variables that define the organs for dose calculation are the following.

- ORGNAM defines the list of organs to be included in the calculations. A- indicates an acute dose and L- indicates a 50-year dose commitment. This variable is used to specify the organs included in particular calculation result requests as indicated in a following section. ORGNAM is not used in defining a list of organs for DCF files generated by the FGRDCF preprocessor in this section of the EARLY input file.
- ORGFLG specifies whether each organ on the list is to be used in the calculations. ORGFLG is not used in defining a list of organs for DCF files generated by the FGRDCF preprocessor in this section of the EARLY input file.

Shielding and Exposure Factors

This section defines the shielding factors for exposure to cloudshine, groundshine, inhalation, and deposition to skin for three types of activities (normal activity, evacuation, and sheltering). A breathing rate is also specified for each type of activity. In addition, the resuspension parameters to be used for the emergency phase time period (EARLY), the resuspension coefficient, and resuspension half-life are also defined. Since evacuation and sheltering are not used in either version of the DWDD calculation inputs, only the normal activity values established by the parameters in this section are actually used in all of the DWDD version calculations. The shielding factors used in the particular DWDD version can provide some measure of protection in that factors less than 1.0 reduce the exposure and dose to the receptor.

The EARLY input variables that define the shielding and breathing rate factors are the following.

- CSFACT is the cloudshine shielding factors for the three types of activity.
- PROTIN is the inhalation protection factors for the three types of activity.
- BRRATE is the breathing rates for the three types of activity.
- SKPFAC is the skin protection factors for the three types of activity.
- GSHFAC is the groundshine shielding factors for the three types of activity.

It should be noted that the skin protection factor is not used in calculations for any version of the DWDD as the skin exposure is only of interest as an early health effect. Both of the DWDD versions calculated and tabulated centerline dose and not instances of health effects in their results for use in safety analysis.

DOE-STD-3009, Appendix A introduced a new dose receptor concept for dose consequence estimates that are compared with evaluation guidelines. The dose estimates are to be those received by a hypothetical MOI standing at the site boundary or beyond it if higher doses occur beyond the site boundary. The location of the MOI is to be at the point of maximum dose at or beyond the site boundary. The site boundary for TA-V is the circular exclusion area boundary at a radius of 3000 m from the TA-V nuclear facility of interest. The MOI dose receptor standing at the site boundary is different from the public as dose receptor in the 1998/2000 DWDD. The public spends much of its time in buildings or in cars that provide some protection from inhalation, immersion, and direct irradiation dose and less of its time outdoors. The public also rests and sleeps for a large fraction of each day, decreasing its yearly average breathing rate. The MOI never enters a building or rests so it receives no protection from buildings and its breathing rate never decreases as in sleep.

Shielding Factors

The 1998/2000 DWDD MACCS2 dose calculations employed normal activity shielding factors that were less than 1.0 for the public that reduced the final dose estimated for the public at all distances. These normal activity shielding factors are different from the evacuation and sheltering shielding factors and tactics that can be employed automatically in the MAACS2 code to mitigate dose. Evacuation and sheltering tactics were not used in either version of the DWDD dose calculations. Shielding factors attempt to estimate the usual protection inherent in the dose receptor's experience. The public normal activity shielding factors of the 1998/2000 DWDD were taken from earlier dose consequence studies such as those using the NUREG-1150 source term. The normal activity shielding factors used in the 1998/2000 DWDD were 0.75 for immersion, 0.4 for inhalation, and 0.41 for direct irradiation from radioactive material deposited on the ground (groundshine). Since the MOI never enters a protective structure, the MOI normal activity shielding factors should be 1.0 for no protection. Normal activity shielding factors of 1.0 were used in the 2002 DWDD calculation inputs for that reason.

(Sprung et al. 1990), *Evaluation of Severe Accident Risks: Quantification of Major Input Parameters*, provided an extensive discussion of shielding factors for NRC studies with the MACCS code using the NUREG-1150 source term. (Sprung et al. 1990) provided shielding values for evacuation and normal activity as well as sheltering for several nuclear power plants that were planned for detailed studies.

(Sprung et al. 1990) developed the inhalation and skin protection factors by considering the indoor/outdoor ratios of the concentration of particulate matter in houses and buildings. The experimental studies referenced in (Sprung et al. 1990) showed that the indoor/outdoor ratios depend strongly on particle size. The data from those studies suggest that the small particles (0.1 – 1 micrometer [μm]) that penetrate most deeply into the lung 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. (Sprung et al. 1990) also included an analytical study that considered infiltration and ventilation of the plume into the building and suggested indoor/outdoor ratios of 0.6 to 0.2 depending on the fraction of plume penetration. (Sprung et al. 1990) also considered seasonal differences in ventilation (open windows in summer) to yield an average indoor/outdoor ratio of 0.4.

In conclusion, (Sprung et al. 1990) recommended the following shielding factors for inhalation and skin protection: 1.0 for people outdoors and evacuating in vehicles; 0.2 (range 0.1 to 0.4) if actively taking shelter; and either 0.5 or 0.4 (range of 0.1 to 1.0) for normal activity. The 0.5 value is recommended in a table and 0.4 is recommended in the text.

For the direct radiation exposure shielding factors of cloud immersion (cloudshine) and ground deposited material exposure (groundshine), (Sprung et al. 1990) presents values for normal activity that are for average exposure nation wide and values for active sheltering that are specific to particular nuclear power plants. The shielding factors for a particular location of the public took into account the shielding effectiveness of material in buildings as well as the relative geometry of the placement of people and the radioactive material. In addition, the surface roughness and shadowing of hills and structures were taken into account for groundshine shielding factors.

Table 14 below summarizes the (Sprung et al. 1990) recommended normal activity cloudshine and groundshine shielding factors for use in MACCS by the location of the public and also the fraction of time spent by the public in each such location. Multiplying the shielding factor by the fraction of time spent there and summing over all locations is the basis of the normal activity shielding factor recommendation of (Sprung et al. 1990) for cloudshine and groundshine. The locations are outside, in vehicles, in two types of houses, and in schools or offices. The resulting (Sprung et al. 1990) normal activity shielding factors are approximately 0.75 for cloudshine and 0.4 for groundshine.

Table 14. Sprung et al. (1990) recommended normal activity cloudshine and groundshine shielding factors for the public for use in MACCS dose calculations

Locations	Cloudshine Normal Activity Shielding Factor	Groundshine Normal Activity Shielding Factor	Fraction of Time Public Sends There
Outside	1.0	0.7 (0.2 to 1.0)	0.1
In Vehicles	1.0	0.5	0.05
Wood Frame House	0.9 – 0.8	0.5 (0.4 to 0.6)	0.7
Masonry House	0.8 – 0.7	0.3 (0.3 to 0.4	
School/Office	0.4	0.3 (0.15 to 0.5)	0.15

Table 15 contains to shielding factor values recommended in (Sprung et al. 1990) Table 3.12 for use in MACCS NUREG-1150 calculations. Table 15 also contains the values selected for the NUREG-1150 input files in the appendices of (Sprung et al. 1990), the 1998/2000 DWDD, and 2002 DWDD shielding factors for comparison. In Table 15, CSFACT = cloudshine shielding factor, GSFACT = groundshine shielding factor, PROTIN = inhalation protection factor, and SKPFAC = skin protection factor. The five NUREG-1150 nuclear power reactors shown in Table 15 are Zion, Grand Gulf (GG), Peach Bottom (PB), Surry (Sur), and Sequoyah (Seq).

Table 15. Shielding factors of Sprung et al. (1990), 1998/2000 DWDD, and 2002 DWDD

		(Sprung et al. 1990) Table 3.12 Values			NUREG-1150	1998/2000 DWDD	2002 DWDD
Variable	**Activity**	**Site**	**Shielding Factor**	**Range**	**Shielding Factor**	**Shielding Factor**	**Shielding Factor**
CSFACT	Evacuation	All	1.0	N/A	1.0	1.0	1.0
	Normal Activity	All	0.75	0.6-0.95	0.75	0.75	1.0
	Sheltering	Zion	0.5	0.4-0.6		0.1	1.0
		GG	0.7	0.6-0.8			
		PB	0.5	0.4-0.6	0.5		
		Sur	0.6	0.5-0.7			
		Seq	0.65	0.55-0.75			
GSFACT	Evacuation	All	0.5	0.3-0.7	0.5	0.8	1.0
	Normal Activity	All	0.4	0.2-0.75	0.33	0.4	1.0
	Sheltering	Zion	0.1	0.03-0.2		0.05	1.0
		GG	0.25	0.1-0.4			
		PB	0.1	0.02-0.2	0.1		
		Sur	0.2	0.1-0.3			
		Seq	0.2	0.1-0.35			
PROTIN	Evacuation	All	1.0	N/A	1.0	1.0	1.0
	Normal Activity	All	0.5	0.15-1.0	0.41	0.4	1.0
	Sheltering	All	0.2	0.1-0.4	0.33	0.1	1.0
SKPFAC	Evacuation	All	1.0	N/A	1.0	1.0	1.0
	Normal Activity	All	0.5	0.15-1.0	0.41	0.41	1.0
	Sheltering	All	0.2	0.1-0.4	0.33	0.33	1.0

The values used for the 1998/2000 DWDD normal activity inputs in Table 15 above appear consistent with the (Sprung et al. 1990) Table 3.12 values (including the ranges) and the values used for the NUREG-1150 input files in the appendices of (Sprung et al. 1990) (column labeled NUREG-1150). The 1998/2000 DWDD normal activity shielding factor values were the only ones used in the 1998/2000 DWDD 95th percentile of dose calculations since no evacuation or sheltering were allowed. The 1998/2000 DWDD normal activity shielding factor values originated from values used previously in MACCS calculations done at SNL. It appears clear that the previous work must have been derived from NUREG-1150 MACCS calculations. The final shielding factor values shown in the NUREG-1150 input files in the appendices of (Sprung et al. 1990) (column labeled NUREG-1150) were probably selected by the NRC sponsor of the work. The shielding factors and the particle deposition velocity (see ATMOS inputs) were all attributed to S. Acharya of the NRC in the inputs. A letter from M. A. Cunningham (NRC) to F. T. Harper (SNL) dated August 7, 1990 is a reference for particle deposition velocity in the (Sprung et al. 1990) ATMOS input file and may also be the source of the NRC selection of the shielding factors that are also attributed to S. Acharya of the NRC in the EARLY input file.

The values used for the 2002 DWDD normal activity inputs in Table 15 are the evacuation values (1.0) of the 1998/2000 DWDD or (Sprung et al. 1990) with the exception of the groundshine shielding factor (GSFACT). GSFACT is higher for the 2002 DWDD than the 1998/2000 DWDD, (Sprung et al. 1990) Table 3.12, or the NUREG-1150 input files in the appendices of (Sprung et al. 1990) evacuation shielding factors (1.0 versus 0.8, 0.5, or 0.5 respectively). The rationale for the higher groundshine shielding factor for normal activity in the 2002 DWDD is the same as the rationale for the other shielding factors, DOE-STD-3009, Appendix A requires reasonably conservative input values for dose calculation. In is clear that there could be no more conservative shielding factors than 1.0 so the 2002 DWDD inputs are clearly conservative.

In order to compare the effect of varying the shielding factor values in the 2002 DWDD dose calculations, the EARLY input file for the 1998/2000 DWDD was modified to use shielding factors of 1.0 for CSFACT, GSFACT, PROTIN, and SKPFAC and MACCS2 calculations were run. Shielding factors of 1.0 were used for evacuation, normal activity and sheltering. Thus, the range for variation of shielding factors was from the 1998/2000 DWDD values to 1.0. The new X/Q and 95th percentile of dose was calculated for same six nuclides. Table 16 shows the results of the calculations as ratios of the 1998/2000 DWDD and the shielding factors all 1.0 values.

The comparison in Table 16 shows that making the shielding factors all 1.0 produced the largest increase of any input change proposed for the 2002 DWDD dose calculations. Shielding factors all 1.0 produced larger increases in dose than no plume broadening or no dry deposition. The reason for this large increase is primarily the large increase in the shielding factor for inhalation dose (PROTIN) that increased a factor of 2.5 from 0.4 to 1.0. Since inhalation is the dominant dose pathway for all nuclides except the noble gasses, the large increases in the halogens, Ce-144 and Pu-239 are to be expected. The shielding factor for immersion dose (CSFACT) increased a factor of 1.33 from 0.75 to 1.0 producing dose increases for Kr-88 of a factor of 1.98 and for Xe-138 of a factor of 1.57. Evacuation and sheltering tactics were not used in either the 1998/2000 DWDD or the 2002 DWDD dose calculations.

Table 16. Ratio of *X/Q* and dose for shielding factors all 1.0 as opposed to the shielding factors of the 1998/2000 DWDD inputs

Input Variations	*X/Q*	Ratios of 95th Percentile of Dose at 3000 m					
		Kr-88 2.84 hr	**Xe-138** 14.1 min	**I-131** 8.04 day	**I-133** 20.8 hr	**Ce-144** 284.3 day	**Pu-239** 24,065 yr
Shielding factors all 1.0	1.0	1.98	1.57	2.78	2.48	2.78	1.98

Breathing Rate

The breathing rate of the dose receptor input is a direct contributor to the calculation of inhalation dose, the largest and dominant contributor to airborne dose. If the breathing rate is doubled, the calculated dose is expected to approximately double for a dose calculation with constant weather for the MACCS2 code. This direct relationship between breathing rate and dose is the result of the increased amount of radioactive material taken into the lungs during the passage of the radioactive plume segment. This internally deposited radioactive dust material is absorbed into the body and migrates to other parts of the body to cause dose there as well as in the respiratory system over a long time (calculated as a 50 year dose commitment). The dose continues to develop until the deposited activity is reduced by radioactive decay or eliminated by the removal processes of the body. The long-term dose commitment of inhaled radioactive material causes inhalation dose to be the largest contributor to dose for all radionuclides except the noble gases that have essentially no inhalation dose.

The EARLY input variable that defines the breathing rate is the following.

- BRRATE is the breathing rates for the three types of activity.

The breathing rate for normal activity used in the 1998/2000 DWDD was 2.66×10^{-4} m^3/s. This breathing rate is the daily average rate for adults during all phases of activity, including sleep. It is typical of the public at large and has been used in various nuclear power reactor safety studies that consider long releases as well as long-term dose effects such and ingestion and inhalation dose from deposited material that is resuspended. Sprung et al. (1990) considered breathing rates that depend on activity, sex, and age to develop a breathing rate applicable to all activities (also 2.66×10^{-4} m^3/s) for the NUREG-1150 dose calculations. The 2.66×10^{-4} m^3/s breathing rate was initially developed in ICRP-23 (ICRP 1975), a publication of the International Commission on Radiological Protection (ICRP) and was continued in ICRP-66 (ICRP 1994) that refined assessments of the behavior of the respiratory system for radiological protection.

ICRP-66 refined estimates of breathing rate for various phases of the day such as 3.33×10^{-4} m^3/s for the occupational or work phase (8 hours adult male) and 3.37×10^{-4} m^3/s for the non-occupational or recreational phase (8 hours adult male). Both of these estimates included periods of varying activity from light to heavy to develop the average for that period. ICRP-23 listed the breathing rate for the non-occupational phase as 3.33×10^{-4} m^3/s (adult male).

The 3.33 x 10^{-4} m^3/s breathing rate has been used in at least one calculation of airborne dose for safety analysis that was performed by SNL for Los Alamos National Laboratory and may represent an acceptably more conservative breathing rate (Gregory 1999). Another candidate for a more conservative breathing rate is 3.47 x 10^{-4} m^3/s that was required by the NRC in its Regulatory Guide 1.25 for airborne dose calculation in fuel handling accidents for nuclear power reactors (NRC 1972b). The 1998/2000 DWDD input used breathing rates of 3.47 x 10^{-4} m^3/s for evacuation, 2.66 x 10^{-4} m^3/s for normal activity, and 1.80 x 10^{-4} m^3/s for sheltering where people were assumed to be resting. Of course only the breathing rate for normal activity was used in the dose calculation. The 2002 DWDD input used 3.47 x 10^{-4} m^3/s for all activity levels since that is typical of the higher activity level of the MOI standing at the exclusion area boundary to receive the dose.

In order to compare the effect of varying the breathing rate in the 2002 DWDD dose calculations, the EARLY input file for the 1998/2000 DWDD was modified to use breathing rates of 3.33 x 10^{-4} and m^3/s and 3.47 x 10^{-4} m^3/s and the MACCS2 calculations were run. The higher breathing rates were used for evacuation, normal activity and sheltering. Thus, the range for variation of breathing rates was from 2.66 x 10^{-4} m^3/s to 3.47 x 10^{-4} m^3/s. The new *X/Q* and 95th percentile of dose was calculated for same six nuclides. Table 17 shows the results of the calculations as ratios of the 1998/2000 DWDD and the higher breathing rate values.

The comparison in Table 17 shows that the higher breathing rates had large increases in dose but smaller increases than shielding factors all 1.0, no plume broadening or no dry deposition. The reason for this large increase is primarily the direct impact that breathing rate has on inhalation dose (PROTIN). The higher breathing rates represent increases of 25 % to 30% in the amount of radioactive material inhaled. Since inhalation is the dominant dose pathway for all nuclides except the noble gasses, the increases in the halogens, Ce-144 and Pu-239 are to be expected.

Table 17. Ratio of *X/Q* and dose for higher breathing rates to that of the 1998/2000 DWDD inputs

		Ratios of 95th Percentile of Dose at 3000 m					
Input Variations	***X/Q***	**Kr-88** 2.84 hr	**Xe-138** 14.1 min	**I-131** 8.04 day	**I-133** 20.8 hr	**Ce-144** 284.3 day	**Pu-239** 24,065 yr
BRRATE 3.33x10^{-4} m^3/s	1.0	1.13	1.00	**1.38**	1.16	1.39	1.04
BRRATE 3.47x10^{-4} m^3/s	1.0	1.13	1.00	1.40	1.19	1.40	1.10

Resuspension

The last inputs in this section of the EARLY input file control the amount of ground deposited material that is resuspended subsequent to its deposition during plume passage. Inhalation of this resuspended material contributes to dose.

The EARLY input variables that define resuspension of ground deposited radioactive material are the following.

- RESCON is the initial value for emergency-phase resuspension concentration factor. RESCON has units of seconds/meter.
- RESHAF is the emergency phase resuspension concentration coefficient weathering half-life. RESHAF has units of seconds.

The air concentration of resuspended radioactive material in MACCS2 is defined by the following equation. Note that the air concentration is reduced over time as it "weathers" or settles out of the air again. Initial resuspension may be due to vehicle traffic or other agitation that stirs up the dust on the ground.

$$\text{air concentration} = \text{ground concentration} \bullet \text{RESCON} \bullet \exp(-t \bullet 0.693 / \text{RESHAF}) \qquad (12)$$

If resuspension dose is not desired in a dose calculation, it can be removed by setting RESCON to 0.0 to make the air concentration of radioactive material zero.

The 1998/2000 DWDD calculations used RESCON = 1.0×10^{-4} that is appropriate for mechanical resuspension by vehicles. The 1998/2000 DWDD calculations also used RESHAF = 1.82×10^{5} seconds (2.11 days) that causes air concentration to decay a factor of ten in one week. The 2002 DWDD calculation inputs used RESCON = 0.0 as resuspension dose is not required by the DOE-STD-3009, Appendix A.

Evacuation, Sheltering and Relocation

This section describes the input parameters that control the dose calculations in the regions where sheltering and evacuation or relocation are defined to occur. MACCS2 is structured to allow the analyst a great deal of flexibility in defining emergency response strategies. However, evacuation and sheltering for dose mitigation were not allowed in either the 1998/2000 DWDD or the 2002 DWDD. Relocation after a set threshold dose and residence time is attained is a standard feature of the MACCS and MACCS2 codes. Relocation parameters were designed to ensure the entire dose attributable to the plume passage was received whether or not dose thresholds for relocation were exceeded in either the 1998/2000 DWDD or the 2002 DWDD.

MACCS2 as well as MACCS allows the user to specify up to three emergency-response scenarios. The population data associated with each of these scenarios may be defined in either of two ways: (1) with a single population data block (as with MACCS) or (2) a separate population data block for each of the emergency-response scenarios. If multiple population distributions are defined, the user is then unable to define fraction-of-the-people or fraction-of-the-time weighting factors for summation of the overall results. In that case, the various results are simply added in reporting the CCDF summary tables generated by the code. Both the 1998/2000 DWDD and the 2002 DWDD use a single population data block. That population data was a site data file for the 1998/2000 DWDD and uniform population distribution for the 2002 DWDD.

As was the case with MACCS, evacuation and sheltering actions for MACCS2 may be modeled in the region surrounding the release point. The evacuation and sheltering actions are preplanned as defined in the input. Outside the evacuation and sheltering region, dose-dependent relocation actions may take place using the hot-spot and normal relocation dose criteria.

In the MACCS2 code's modeling of the evacuation and sheltering region, the user explicitly defines the reference time to be used for initiation of the action as being either the alarm time (input variable OALARM of the ATMOS input) associated with the source term or the arrival time of the first plume reaching the downwind location. When evacuation and sheltering are not selected, as was the case for the 1998/2000 DWDD and the 2002 DWDD, no reference time is required. In the region beyond the evacuation and sheltering region, that is, the relocation zone, the reference time point for actions is the plume arrival time.

The evacuation and sheltering region is user specified to extend a given radial distance (i.e., radial spatial interval). For each radial distance in this region, the user specifies a sheltering period (which may have a zero duration) that occurs prior to the initiation of the evacuation. By allowing the delay times to vary for each ring of the polar grid, a staged evacuation may be modeled in which the evacuation delay time increases as a function of distance. During the sheltering phase, shielding factors appropriate for sheltered activity are used to calculate doses for the individuals in contaminated areas. When evacuation and sheltering are not desired, as was the case for the 1998/2000 DWDD and the 2002 DWDD, the outer boundary of the evacuation and sheltering region is defined as the zero spatial interval indicating there is no such region.

At the termination of the sheltering phase, the resident individuals start their travel out of the region. Travel speed is assigned by the EARLY input. During evacuation, shielding factors appropriate for evacuation activity (travel) are used to calculate doses for the individuals as they traverse contaminated areas. In each of the scenarios chosen, the user defines whether evacuation is to follow radial paths (as in MACCS) or follow complex paths defined as a network (for MACCS2).

Evacuation and Sheltering Inputs

The EARLY input variables that define preplanned evacuation and sheltering are the following. Other variables may be used in MACCS2 but were unnecessary for either of the DWDD versions since preplanned evacuation and sheltering was not used in any DWDD version. The zero value of the variable LASMOV turns off evacuation and sheltering for both DWDD versions.

- EANAM2 identifies the name of the emergency response scenario being studied. This name will be printed on all pages of the output listing. A unique name must be specified for each emergency response. In both the 1998/2000 DWDD and the 2002 DWDD inputs, for the one emergency response EANAM2 was "WORST CASE NO EVACUATION".
- WTNAME defines the type of weighting to be used in generating the overall weighted sum of results. In both the 1998/2000 DWDD and the 2002 DWDD inputs, WTNAME was "PEOPLE". The value of PEOPLE is the appropriate weighting factor (as opposed to TIME) since no evacuation or sheltering time is used in either DWDD version.
- WTFRAC is the weighting fraction to be applied to the results from this emergency response scenario. The OUTPUT module uses this value in combining results for the overall weighted sum. The weighting can be done for either fraction-of-the-people or fraction-of-the-time as determined by the input variable WTNAME. In both the 1998/2000 DWDD and the 2002 DWDD inputs, WTFRAC was "1.0" indicating that the single population distribution was to be given 100% of the weight in combining results There was only one set of results since there was only one response scenario and one population distribution in the 1998/2000 DWDD and the 2002 DWDD.
- LASMOV is the outermost spatial interval of the evacuation movement zone. This is the distance after which evacuees are assumed to disappear from the early health effects model and receive no further dose. Early health effects are not included in either DWDD version. In both the 1998/2000 DWDD and the 2002 DWDD inputs, LASMOV was "0" indicating no evacuation since the 0 spatial interval is the innermost distance of 0.0 km. This parameter prevents any evacuation and sheltering strategy from mitigating dose to the public or the MOI.

Relocation Inputs

Outside the evacuation and sheltering region, relocation actions may take place after a set threshold dose and residence time through use of the hot-spot and normal relocation dose criteria. If either dose criteria is exceeded in a spatial grid element, the population of the element is considered relocated and receives no further dose after the associated residence time following plume arrival. The dose for comparison to the relocation dose criteria is the calculated result of exposure during the entire emergency phase (ENDEMP variable discussed below) while engaging in normal activity (normal activity shielding factor applies).

Even if either dose threshold is exceeded for the 1998/2000 DWDD or the 2002 DWDD calculations, the dose receptor is kept in place until the entire dose attributable to plume passage has been accumulated through the residence time selected for each relocation dose criteria. Thus, the largest dose pathway contributors to dose, inhalation dose and cloudshine, provide their full dose to the public or MOI receptor. Unfortunately, some of the groundshine and resuspension inhalation dose accumulated subsequent to relocation may be lost if the calculated dose exceeds a threshold. Both groundshine and resuspension inhalation dose are very minor contributors to dose and are not included for the 2002 DWDD dose calculations.

The EARLY input variables that define relocation in response to dose thresholds and residence time for the DWDD versions are the following. These variables must be used or MACCS2 will not execute a calculation. The values chosen for these variables were necessary since relocation was not intended to mitigate dose in either DWDD version.

- ENDEMP defines the duration of the emergency-phase period in seconds. EARLY only calculates doses that would be received during the emergency-phase time period. Doses at each spatial interval are cut off at ENDEMP seconds after the arrival of the first plume segment to reach the spatial interval. This cutoff applies to all individuals, no matter where they are located. In both the 1998/2000 DWDD and the 2002 DWDD inputs, ENDEMP was "86400" seconds or one day, the minimum duration of the emergency phase. Groundshine and resuspension inhalation doses are accumulated during this time in addition to the inhalation dose and cloudshine dose attributable to the time of plume passage. The 1998/2000 DWDD doses included contributions from groundshine and resuspension inhalation dose but the 2002 DWDD did not. Other 2002 DWDD inputs ensured that there was no source of ground deposited material to cause those doses.

- CRIORG defines the critical organ for relocation decisions during the emergency-phase period considered by EARLY. In order to determine whether people can remain in the relocation zone, the total committed dose to the critical organ of an individual who remained in place for the entire emergency phase is calculated. The critical organ must be found on the list of organs, ORGNAM, as described in a previous section. In both the 1998/2000 DWDD and the 2002 DWDD inputs, CRIORG was "L-EFFECTIVE" for the whole body TEDE.

- TIMHOT defines the hot-spot relocation action time in seconds after plume arrival. Hot-spot relocation can only occur for individuals residing outside of the emergency-response zone (the whole spatial grid for both DWDD versions). That is, doses to people awaiting evacuation or protected in shelters will not be affected by the hot-spot relocation model. In both the 1998/2000 DWDD and the 2002 DWDD inputs, TIMHOT was "7200" seconds or 2 hours. This time equals or exceeds the plume duration for both the 1998/2000 DWDD and the 2002 DWDD.

- TIMNRM defines the normal relocation action time in seconds after plume arrival. Normal relocation can only occur for individuals residing outside of the emergency-response zone (the whole spatial grid for both DWDD versions). That is, doses to people awaiting evacuation or protected in shelters will not be affected by the normal relocation model. In both the 1998/2000 DWDD and the 2002 DWDD inputs, TIMNRM was "7200" seconds or 2 hours. This time equals or exceeds the plume duration for both the 1998/2000 DWDD and the 2002 DWDD.

- DOSHOT defines the hot-spot relocation dose threshold in sieverts. If the total dose commitment to individuals outside of the evacuation and sheltering zones who remained stationary for the entire emergency phase period would exceed DOSHOT, those people are relocated (removed) at the hotspot relocation time (TIMHOT). In both the 1998/2000 DWDD and the 2002 DWDD inputs, DOSHOT was "0.5" sieverts (50 rem).
- DOSNRM defines the normal relocation dose threshold in sieverts. If the total dose commitment to individuals outside of the evacuation and sheltering zones who remained stationary for the entire emergency phase period exceeds DOSNRM, those people are relocated (removed) at the normal relocation time TIMNRM. In both the 1998/2000 DWDD and the 2002 DWDD inputs, DOSNRM was "0.25" sieverts (25 rem).

Dose results from both the 1998/2000 DWDD and the 2002 DWDD were examined to assess the possible impact of triggering the relocation dose criteria on the tabulated doses. First, the 1998/2000 DWDD doses were examined. The 1998/2000 DWDD doses include groundshine and resuspension inhalation dose so relocation had the potential to slightly reduce the total dose by terminating their accumulation if the relocation criteria were exceeded. The 1998/2000 DWDD tabulated doses in rem were converted from the sieverts doses reported in the MACCS2 output listings. Thus, the two relocation dose criteria of 0.5 and 0.25 sieverts are 50 and 25 rem in the 1998/2000 DWDD listings.

The only radionuclides with doses exceeding the dose criteria for some of the spatial internals in the 1998/2000 DWDD were 12 of the 20 actinides and daughters. These radionuclides exceeded the dose criteria in only one or two of the closest spatial intervals to TA-V for the ground release height. Two radionuclides exceeded the dose criteria for the Annular Core Research Reactor (ACRR) release height in only the closest spatial interval. None of the radionuclides exceeded the dose criteria at the 3000 m spatial interval for the 1998/2000 DWDD. Since the groundshine and resuspension inhalation dose are such minor contributors to total dose and only a relative few of the radionuclides may have had slightly reduced calculated dose at only the closest spatial intervals, the use of the combined relocation dose criteria thresholds and residence times was judged acceptable for the 1998/2000 DWDD calculations.

Next the 2002 DWDD dose results were examined for the ACRR release height in the 1994 weather year calculations (the highest X/Q value year and highest dose year in almost all cases). The variable CORSCA in the ATMOS input was set to 3.7×10^{12} so the dose in the MACCS2 output would be in rem not sieverts for the 2002 DWDD. Thus, the two relocation dose criteria of 0.5 and 0.25 sieverts would be dose values 0.5 and 0.25 rem in the 2002 DWDD listings. Again, the only radionuclides with doses that exceeded the relocation dose criteria were the actinides and daughters but now most of the spatial intervals were above the dose criteria. Fortunately, the 2002 DWDD does not include groundshine and resuspension inhalation dose accumulated during the emergency phase so terminating their accumulation would not reduce the total dose.

To verify that exceeding the relocation dose criteria in the 2002 DWDD calculations would not reduce the total dose, two test calculations were run to calculate the dose for the actinides and daughters with the ACRR release height and the 1994 weather data. The first test calculation increased the residence time after exceeding the relocation dose criteria to ensure the entire potential dose was accumulated. The second increased the relocation dose criteria to avoid exceeding it and triggering relocation. Both test calculations produced exactly the same doses for the actinides and daughters for all spatial intervals as had been calculated with the original 2002 DWDD inputs for relocation dose criteria and residence time. Thus, the use of these combined relocation dose criteria thresholds and residence times was judged acceptable for the 2002 DWDD calculations.

Early Fatality, Early Injury and Latent Cancer Effects

The risk of prompt fatality, early injury and various cancers is modeled in MACCS2. The inputs to make those calculations are discussed in the MACCS2 *User's Guide* (Chanin and Young 1997). The 1998/2000 DWDD and the 2002 DWDD do not calculate the risk of early health effects (fatality and injury) since both DWDD versions are intended to calculate the unlikely ground level centerline dose (95^{th} percentile of dose) for dose receptors located at various distances downwind from a hypothetical airborne radioactive material release from TA-V nuclear facilities or activities. The 1998/2000 DWDD inputs included instructions to calculate the risk for various types of cancer but those results were never tabulated or used in the 1998/2000 DWDD. For further details on the cancer risk calculation inputs in the 1998/2000 DWDD EARLY inputs, the reader is directed to Appendix B for a copy of a typical EARLY input file and to the MACCS2 *User's Guide*. The 2002 DWDD inputs did not include instructions to calculate the risk for various types of cancer.

Dose Consequence Results

Under the control of parameters supplied by the user on the EARLY input file, the EARLY module can calculate a variety of different consequence measures to portray the impact of a facility accident on the surrounding region. The user has total control over the results that will be produced. By choosing appropriate values in the user input file, the user can ensure that the code does not perform unnecessary calculations. This affords a great deal of flexibility but it also requires that the user anticipate which results will be of interest. If any are omitted, it is necessary to correct the user input and rerun the program.

A result can only be produced if the model needed for its calculation has been previously defined in the appropriate section. If any results pertaining to health effects are requested, risk factors for that model must have been supplied in the sections entitled Early Fatality (EF), Early Injury (EI), and Latent Cancer (LC). Inputs for results of latent cancer were included in 1998/2000 DWDD EARLY input file but are not included for the 2002 DWDD EARLY input files.

EARLY can produce ten different types of results (result types 1-8, A, and B). These result types are summarized in Table 18 with the input variable names required to define each type. Also included in the table is use of that type of result in the two versions of DWDD inputs.

Table 18. Ten consequence results produced by the EARLY module

EARLY Consequence Measures by Result Type	Variables	In 1998/2000 DWDD Calculation?	In 2002 DWDD Calculation?
1. Cases of a Given Health Effect	NUM1, NAME, I1DIS1, I2DIS1	Yes	No
2. Early Fatality Radius	NUM2, RISTHR	Yes	No
3. Population Exceeding a Dose Threshold	NUM3, NAME, DISTH3	Yes	No
4. Average Individual Risk	NUM4, I1DIS4, NAME	No	No
5. Population Dose	NUM5, NAME I1DIS5	Yes	No
6. Centerline Dose Versus Distance	NUM6, ORGNAM, PATHNM, I1DIS6, I2DIS6	Yes	Yes
7. Centerline Risk Versus Distance	NUM7, NAME, I1DIS7, I2DIS7	Yes	No
8. Population-Weighted Risk	NUM8, NAME, I1DIS8, I2DIS8	Yes	No
A. Peak Dose at a Distance	NUMA, NAME, I1DISA, I2DISA	Yes	No
B. Peak Dose at an (r,θ) Location	NUMB, NAME, IRAD_B, IANG_B	No	No

EARLY does not generate complementary cumulative distribution functions (CCDFs) of the results that it calculates. As EARLY generates the requested consequence measures, those numbers are written to binary files for later processing into CCDFs.

The OUTPUT module of MACCS2 generates CCDFs. It reads the binary files of consequence measures and automatically combines the results in a predetermined way. The user has no direct control over the OUTPUT module other than through the EARLY data blocks that control the generation of consequence measures.

The CCDF is an estimate of the distribution of consequence magnitudes. The variability of consequence values in MACCS2 CCDFs is due solely to the uncertainty of the weather conditions existing at the time of the accident. One of the CCDFs is the 95th percentile used as the measure of the dose consequence of interest in both DWDD versions, the ground level centerline dose.

Result Type 6 Centerline Dose Versus Distance

Since result type 6, centerline dose versus distance, was used in both the 1998/2000 DWDD and the 2002 DWDD inputs and since it provides the dose tabulated for both DWDD versions, inputs for result type 6 will be discussed in more detail.

If the straight-line plume model was chosen (IPLUME=1), the code can keep track of the centerline dose between a range of distances for the various pathways. The centerline dose at each distance is treated as a separate result and OUTPUT will generate a set of results for each of the radial spatial intervals within the specified range. The user must specify the organ doses and exposure pathways for which type 6 results are calculated with one organ dose and exposure pathway for each result requested.

The EARLY input variables that define result type 6 calculations for the 1998/2000 DWDD and the 2002 DWDD are the following.

- NUM6 is the number of results of this type to be calculated. This result is only available when straight-line plume dispersion (IPLUME=1) is used, as it is in both of the DWDD input versions. NUM6 = 4 for both the 1998/2000 DWDD and 2002 DWDD inputs.
- ORGNAM defines the names of the organs for which centerline doses are to be reported. These organs must be found in the list of organs, ORGNAM, discussed in a previous section. The list of organs is in the dose conversion factor (DCF) file, DOSD825.inp, that was generated by the DCF preprocessor FGRDCF. No other organ list was provided for most of the calculations of the 1998/2000 DWDD and all of the calculations of the 2002 DWDD. The user must supply NUM6 values in column 1 of the data block for type 6 results.
- PATHNM defines the names of the pathways for which centerline doses are to be reported. The name of each pathway must be on the list of pathways. The user must supply NUM6 values in column 2 of the data block.
- I1DIS6 defines the inner spatial interval of the region of interest for this result. The user must supply NUM6 values in column 3 of the data block.
- I2DIS6 defines the outer spatial interval of the region of interest for this result. The user must supply NUM6 values in column 4 of the data block.

The actual type 6 data block used in the 2002 DWDD EARLY input file is shown in Figure 5 below for illustration of the application of these input variables.

```
*
TYPE6NUMBER     4
*
*              ORGNAM           PATHNM       I1DIS6   I2DIS6
*
TYPE6OUT001   'L-EFFECTIVE'    'TOT LIF'       1        16       * CCDF
TYPE6OUT002   'L-LUNGS'        'TOT LIF'       1        16
TYPE6OUT003   'L-THYROID'      'TOT LIF'       1        16
TYPE6OUT004   'L-RED MARR'     'TOT LIF'       1        16
```

Figure 5. Result type 6, centerline dose versus distance, input data block

The “TYPE6NUMBER 4” line in Figure 5 indicates that NUM6 = 4 for four centerline dose results. Both the 1998/2000 DWDD and the 2002 DWDD inputs requested the same four centerline dose results but in different order. Each of the four lines of requested results have an ORGNAM, a PATHNM, and an inner and outer spatial interval. Note that all 16 spatial intervals were requested for the 2002 DWDD inputs as all 10 spatial intervals were for the 1998/2000 DWDD

The first requested result output in the data block of Figure 5 is identified as “TYPE6OUT001” for the ORGNAM “'L-EFFECTIVE'” and the PATHNM “'TOT LIF'”. The “'L-EFFECTIVE'” organ is the lifetime whole body TEDE and corresponds to the EDEWBODY label on whole body dose in the 1998/2000 DWDD dose tabulation. Thus, the dose to the whole body is requested for the dose pathway “'TOT LIF'”. The “'TOT LIF'” pathway is defined as the total dose from all direct exposure pathways (Lifetime). This PATHNM includes inhalation, cloudshine, groundshine, and inhalation dose from resuspended radioactive material that was deposited on the ground. As noted previously, the 2002 DWDD calculations do not include groundshine and resuspension inhalation dose since there is no depletion of the plume through wet or dry deposition to provide a ground deposited radiation source. Instead, all of the radioactive material is available to produce dose in the recipient through the inhalation and cloudshine dose pathways that provide a higher dose contribution than the other dose pathways.

The other three requested results in Figure 5 are the PATHNM “'TOT LIF'” dose pathway for three separate organs, the lungs, the thyroid, and the red marrow of the bones respectively. These individual organ doses are not tabulated in the 2002 DWDD dose listings but are available in the calculation output listings should they be needed in the future. The 1998/2000 DWDD tabulates dose to the thyroid in its dose listings as well as the whole body TEDE.

An addition input “* CCDF” is shown at the end of the first requested result in Figure 5. The “*” indicates the input is to be considered as only a comment and not an actual direction for program execution. The “CCDF” input requests a more extensive CCDF output than the standard one line output for each spatial interval. The standard one line CCDF output is shown in Figure 6 for the Pu-239 centerline dose with the ACRR release height and the 1994 weather data.

Figure 6 shows a one line CCDF of the centerline dose for each of the 16 the spatial intervals of the 2002 DWDD. Each line shows that the organ and dose pathway is “L-EFFECTIVE TOT LIF” and the distance for that one line CCDF output. The next column shows the probability of getting a non-zero result (essentially 1 for certainty). Then the columns show measures of the dose data in the cumulative distribution. The first column is the mean value (expected value) of the dose. The next five columns show various “quantiles” of the dose data in the cumulative distribution. The underlying data used to generate the quantiles are those shown in the CCDF tables, and interpolation is used to estimate the fixed quantiles of the one-line summaries. The interpolation technique used to estimate the quantiles is log-linear (logarithmic on probability, linear on consequence). Thus, the quantiles are not statistically gathered and analyzed percentiles but they do represent an estimate of the probability of that dose result. The 95th quantile (also called percentile in this report) of dose value is the dose value that is only expected to be exceeded 5% of the time as discussed in the last chapter. The last three columns show the peak dose, the probability (or frequency) of that peak dose, and the trial that produced it.

SOURCE TERM 1 OF 21:
PAC3 SAR -Random Sampling Meteorological Conditions- Pu-239

RESULTS FOR A SINGLE EMERGENCY RESPONSE COHORT WITHOUT ANY WEIGHTING FRACTIONS BEING APPLIED

COHORT 1 = WORST CASE NO EVACUATION

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CENTERLINE DOSE AT SOME DISTANCES (Sv)		PROB NON-ZERO	MEAN	QUANTILES 50TH	90TH	95TH	99TH	99.5TH	PEAK CONS	PEAK PROB	PEAK TRIAL
L-EFFECTIVE TOT LIF	0-0.1 km	0.9999	4.43E-04	7.46E-09	2.06E-06	3.73E-03	7.65E-03	9.37E-03	2.79E-02	1.14E-04	8122
L-EFFECTIVE TOT LIF	0.1-0.2 km	0.9999	1.22E+01	1.03E+01	2.59E+01	3.32E+01	5.32E+01	6.28E+01	1.55E+02	1.14E-04	8122
L-EFFECTIVE TOT LIF	0.2-0.3 km	0.9999	1.88E+01	1.42E+01	3.42E+01	4.53E+01	7.28E+01	8.67E+01	1.88E+02	3.42E-04	6210
L-EFFECTIVE TOT LIF	0.3-0.4 km	0.9999	1.62E+01	1.15E+01	3.11E+01	3.96E+01	6.30E+01	7.34E+01	1.56E+02	3.42E-04	6210
L-EFFECTIVE TOT LIF	0.4-0.5 km	0.9999	1.38E+01	9.88E+00	3.01E+01	3.69E+01	5.79E+01	6.89E+01	1.23E+02	3.42E-04	6210
L-EFFECTIVE TOT LIF	0.5-0.6 km	0.9999	1.19E+01	7.51E+00	2.87E+01	3.61E+01	5.66E+01	6.68E+01	9.83E+01	3.42E-04	6210
L-EFFECTIVE TOT LIF	0.6-1.0 km	0.9999	8.54E+00	4.61E+00	2.26E+01	3.27E+01	5.42E+01	6.33E+01	9.13E+01	1.37E-03	486
L-EFFECTIVE TOT LIF	1.0-1.1 km	0.9999	6.39E+00	3.03E+00	1.76E+01	2.57E+01	4.39E+01	5.29E+01	7.70E+01	1.37E-03	486
L-EFFECTIVE TOT LIF	1.1-1.5 km	0.9999	4.88E+00	2.16E+00	1.31E+01	2.16E+01	3.68E+01	4.43E+01	6.27E+01	1.37E-03	486
L-EFFECTIVE TOT LIF	1.5-1.7 km	0.9999	3.70E+00	1.53E+00	1.08E+01	1.61E+01	2.97E+01	3.53E+01	4.97E+01	1.26E-03	486
L-EFFECTIVE TOT LIF	1.7-3.0 km	0.9999	2.24E+00	9.04E-01	7.26E+00	1.06E+01	1.52E+01	1.78E+01	3.25E+01	1.14E-04	8323
L-EFFECTIVE TOT LIF	3.0-3.1 km	0.9999	1.53E+00	6.10E-01	5.10E+00	7.53E+00	1.13E+01	1.29E+01	2.33E+01	4.57E-04	485
L-EFFECTIVE TOT LIF	3.1-4.8 km	0.9999	9.85E-01	4.00E-01	3.19E+00	5.06E+00	6.79E+00	7.87E+00	1.64E+01	1.14E-04	8322
L-EFFECTIVE TOT LIF	4.8-5.0 km	0.9999	6.82E-01	2.86E-01	2.14E+00	3.28E+00	5.00E+00	5.80E+00	1.20E+01	3.42E-04	5237
L-EFFECTIVE TOT LIF	5.0-7.0 km	0.9999	4.76E-01	2.01E-01	1.25E+00	2.25E+00	3.70E+00	4.40E+00	6.75E+00	1.14E-04	676
L-EFFECTIVE TOT LIF	7.0-20.0 km	0.9999	1.01E-01	4.62E-02	2.52E-01	3.74E-01	7.52E-01	9.53E-01	1.49E+00	1.14E-04	6024

Figure 6. One line CCDF output for Pu-230 centerline dose with the ACRR release height and the 1994 weather data

DISCUSSION OF RESULTS AND CONCLUSIONS

1998/2000 DWDD and 2002 DWDD Tabulations

The calculated 95th percentile (quantile) of dose is tabulated in Appendix E for the 1998 DWDD, in Appendix F for the 2000 DWDD, and in Appendix G for the 2002 DWDD. The doses calculated are the total effective dose equivalent (TEDE) for a hypothetical airborne release of radioactive material from Technical Area V (TA-V) nuclear facilities or activities. As explained previously, the 1998/2000 DWDD calculations used the original standard inputs for the MACCS2 calculations and the 2002 DWDD used a revised set of standard inputs. The 1998 DWDD contained downwind doses for a hypothetical release of 1 curie (Ci) of a single radionuclide for 120 nuclides. The 2000 DWDD expanded the nuclide doses to 155 nuclides and the 2002 DWDD included doses for 162 nuclides. The radionuclides included mostly fission products with actinides and daughters and activation products for materials of interest for reactors and experiment apparatus.

The 1998 DWDD in Appendix E includes doses for ten distance ranges (spatial intervals) including the doses for the 2.9 to 3.1 km range corresponding to the 3000 m radius exclusion area boundary for TA-V. Doses from four release conditions are tabulated for each nuclide and include dose for the thyroid organ as well as the TEDE. The dose conversion factor (DCF) preprocessor and MACCS code version used to calculate each dose in the 1998 DWDD is indicated in Appendix E. The 2000 DWDD in Appendix F includes TEDE doses for only the 2.9 to 3.1 km range although the downwind doses for the same ten distance ranges of the 1998 DWDD and were calculated and are available from the author if needed for TA-V safety analysis. The 2000 DWDD used the EPA Federal Guidance Reports # 11 and # 12 DCFs (Eckerman et al. 1989, Eckerman and Ryman 1993) provided through the FGRDCF preprocessor and the MACCS version 1.12 (MACCS2) to calculate the doses in Appendix F. Both the 1998 DWDD and the 2000 DWDD used the Albuquerque airport weather Typical Meteorological year (METALB.inp) for the 95th percentile dose calculations.

The 2002 DWDD in Appendix G includes TEDE doses for only the 2.95 to 3.05 km range although the downwind doses for the full 16 distance ranges were calculated and are available from the author if needed for TA-V safety analysis. The 2002 DWDD also used the EPA Federal Guidance Reports # 11 and # 12 DCFs provided through the FGRDCF preprocessor and MACCS2 to calculate the doses in Appendix G. The 2002 DWDD used seven years (1994 through 2000, 2001 was unavailable) of meteorological data measured at the TA-V local weather tower A36 for the dose calculations. Since it was possible for the 95th percentile of dose to vary from year to year, the dose calculations were repeated for all seven sets of one-year meteorological data and the highest dose for each nuclide was compiled in the 2002 DWDD. The 1994 weather year doses were the highest in every case except for several fission products and two actinides and daughters that had slightly higher calculated doses from other weather years. The doses that did not come from the 1994 weather year calculations are shown as bold text in Appendix G.

In comparing the 1998/2000 DWDD to the 2002 DWDD calculated doses, it is evident that the 2002 DWDD doses are higher. Table 19 compares the doses calculated for the same six nuclides and the concentration (*X/Q*) for the 2002 DWDD revised standard input and weather file (1994 tower A36) to the 1998/2000 DWDD standard input and weather file (TMY file METALB) as a measure of the dose increase. The ACRRF release height was used for the calculations of Table 19 as it was for the input change comparisons of the last chapter. The 1994 weather file was used with the 2002 DWDD inputs for this comparison since it had the highest *X/Q* of any of the local tower A36 weather files. The same ratios of calculated dose are also shown for the 2002 DWDD inputs with the METALB weather file in Table 19 for assessing the effect of changing from Albuquerque airport TMY weather to the A36 tower local weather.

The ratios in Table 19 are all greater than one indicating that the dose increased for each these radionuclides from the 2002 DWDD as opposed to the 1998/2000 DWDD values. In the first row of the table for the A36-94 weather file, the *X/Q* value also increased by the ratio 1.54. The noble gas nuclides had the lowest dose increase with ratios of approximately 2 (200%). Both of these noble gas nuclides had half-lives of less than a few hours. The nuclides with the longest half-lives (longer than a few days) showed the highest dose increases with ratios of approximately 11 to 13 (1100% to 1300%). The large dose increases indicate the substantial increase in conservatism in the 2002 DWDD revised standard inputs with local weather data in accordance with the requirements of DOE-STD-3009, Appendix A (DOE 1994). The second row of Table 19 shows the effect of the TMY weather (METALB file) on the dose and *X/Q* ratios. The ratios are very similar even though *X/Q* is somewhat higher for the TMY weather in all but the highest release heights.

Table 19. Ratio of *X/Q* and dose for the 2002 DWDD inputs and weather to that of the 1998/2000 DWDD inputs and weather

		Ratios of 95th Percentile of Dose at 3000 m					
Input Variations	***X/Q***	**Kr-88** 2.84 hr	**Xe-138** 14.1 min	**I-131** 8.04 day	**I-133** 20.8 hr	**Ce-144** 284.3 day	**Pu-239** 24,065 yr
2002 DWDD Inputs and Weather File A36-94	1.54	1.92	1.52	11.04	5.91	13.12	10.74
2002 DWDD Inputs and Weather File METALB	1.74	1.72	1.72	11.48	7.40	11.77	11.68

The variation of *X/Q* with downwind distance affects the variation of calculated dose with downwind distance. DOE-STD-3009, Appendix A (DOE 1994) indicates that for purposes of comparison to the safety analysis evaluation guideline dose, the maximally exposed off-site individual (MOI) dose receptor is assumed to be standing at the site boundary or beyond it "if a buoyant or elevated plume is not a ground level at the DOE site boundary. In such cases, the calculation location is taken at the point of maximum exposure." Neither the 1998/2000 DWDD or the 2002 DWDD inputs consider buoyant plumes but some of the TA-V facilities provide an elevated release for potential releases of radiological material. Thus, the possibility of higher doses beyond the site boundary (the exclusion area boundary of radius 3000 m for TA-V) must be considered in assessing the dose outputs of the MACCS2 calculations. Fortunately for that assessment, the *X/Q* concentration of released material and the resulting dose decreases for spatial internals beyond 3000 m in the 1998/2000 DWDD and the 2002 DWDD results.

Figures 7 and 8 show the variation of 95th percentile of ground level *X/Q* with downwind distance for all of the TA-V facility release heights as calculated by MACCS2. Figure 7 shows the *X/Q* variation for the 2002 DWDD inputs and Figure 8 shows the *X/Q* variation for the 1998/2000 DWDD inputs for the same range of *X/Q*. Both figures show the calculated *X/Q* at the center of the spatial interval (range bin) for the same maximum distance. The 2002 DWDD has more and smaller spatial intervals close to the TA-V facility than the 1998/2000 DWDD. The range of release height is the same for both figures but the 2002 DWDD has more release heights. The 2002 DWDD release height calculations are without building wake while most of the 1998/2000 DWDD release height calculations included building wake.

The behavior with distance is very similar for the two figures but Figure 7 for the 2002 DWDD has higher *X/Q* values as expected due to the shorter release duration. The lowest release height (ground release, 0.0 m) is the top curve with highest *X/Q* in both figures while the highest release height (HCF stack, 38.1 m) is the bottom curve with the lowest *X/Q* values. All of the curves continue to decrease in *X/Q* value beyond 3000 m indicating that the associated dose should decrease as well. The lower release height curves approach each other closely at or slightly beyond 2000 m while the highest release height does not approach the others until approximately 6000 m. The values *X/Q* of the lower release heights are very close at 3000 m and beyond. This different behavior is explained by the effect of the reflection from the ground of the radiological material concentration in an elevated plume. A ground release has full reflection from its first release while the material in an elevated release must expand until in can be reflected in sufficient concentration to approach the ground level concentration in the fully reflected ground release. The point of comparable reflection is when σ_z expands to approximate the release height as was discussed in the second chapter of this report on the MACCS2 code and described by Equation (2). Since the highest release height is more than twice the height of the next shorter release height, the plume from it requires more expansion time and downwind distance to provide sufficient ground reflection to for *X/Q* to approach the ground release value.

Figures 9-11 confirm that the 95th percentile of dose decreases beyond 3000 m allowing the 2002 DWDD tabulation in Appendix G to reflect only the 3000 m dose for each nuclide at the different release heights. Figures 9-11 show the variation of 2002 DWDD 95th percentile of TEDE dose with downwind distance for the SPRF release height (10 m). Figures 9-11 are the dose for the actinides and daughters, activation products, and fission products respectively.

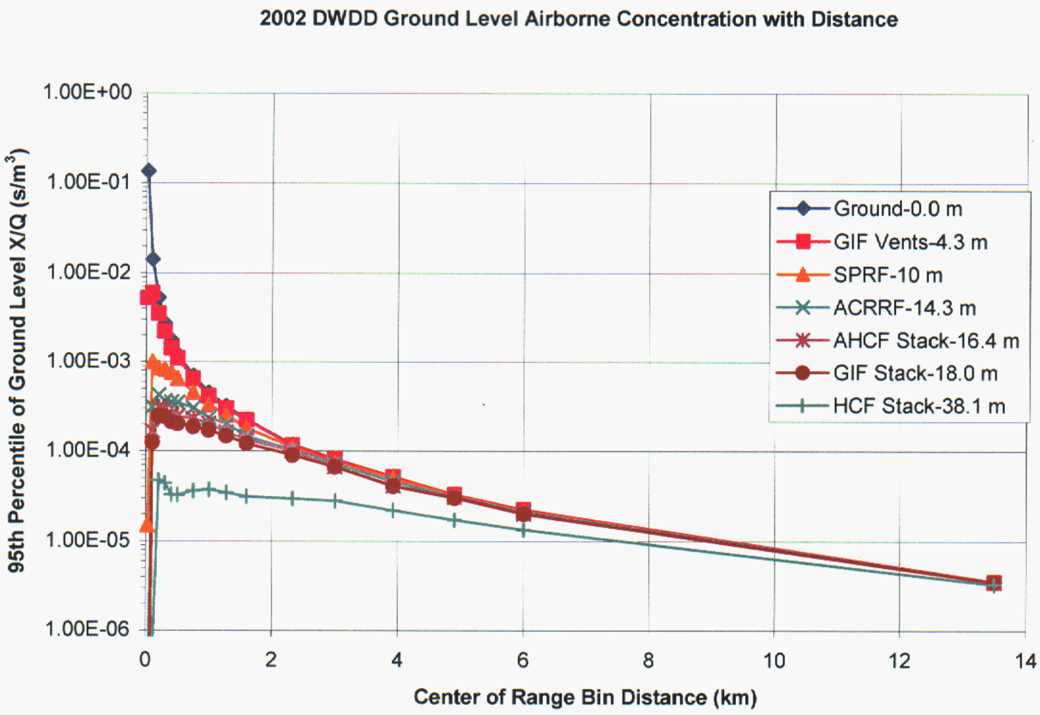

Figure 7. 2002 DWDD ground level airborne concentration (*X/Q*) with distance

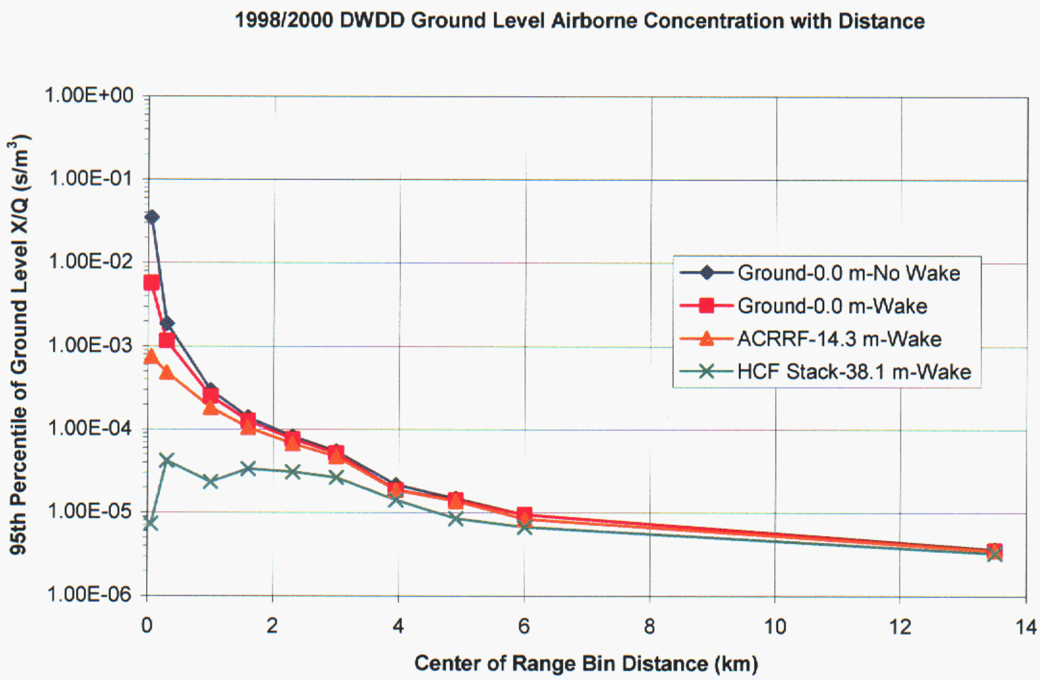

Figure 8. 1998/2000 DWDD ground level airborne concentration (*X/Q*) with distance

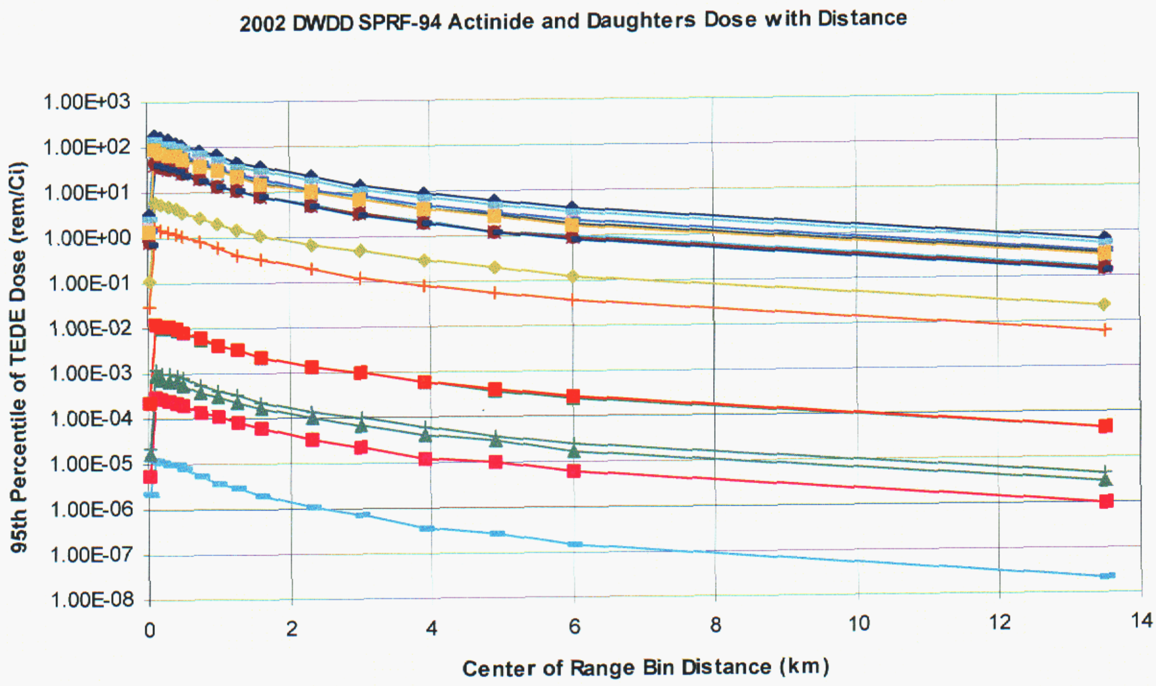

Figure 9. 2002 DWDD actinides and daughters dose with distance for SPRF, 1994 weather

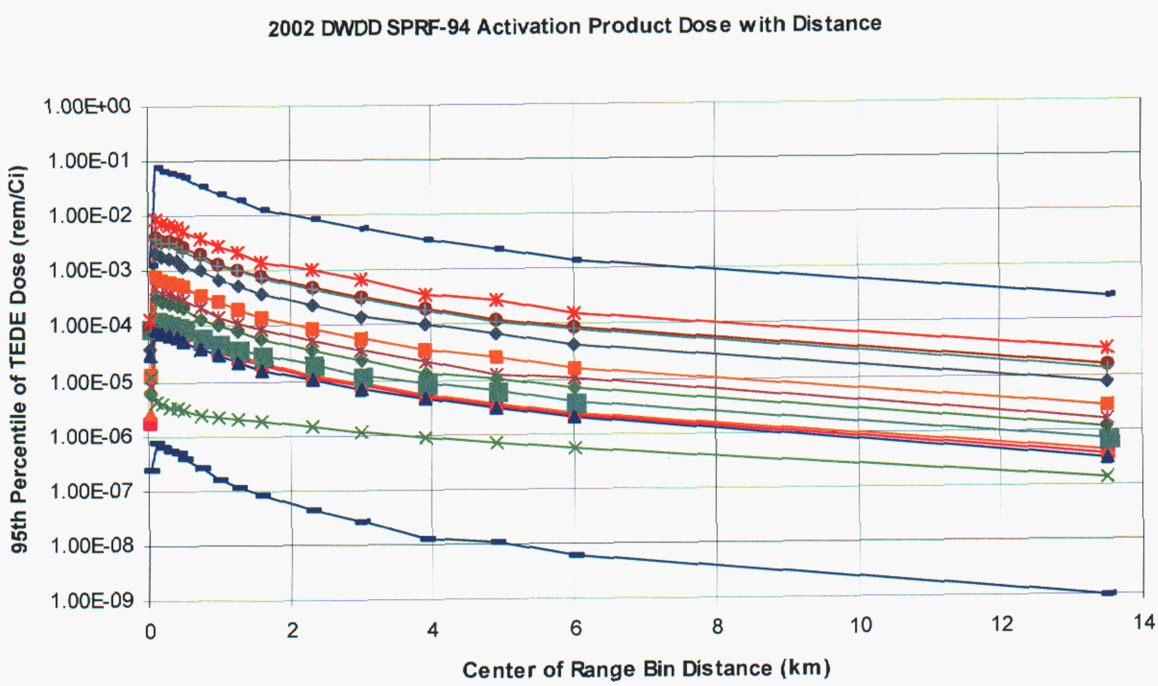

Figure 10. 2002 DWDD activation products dose with distance for SPRF, 1994 weather

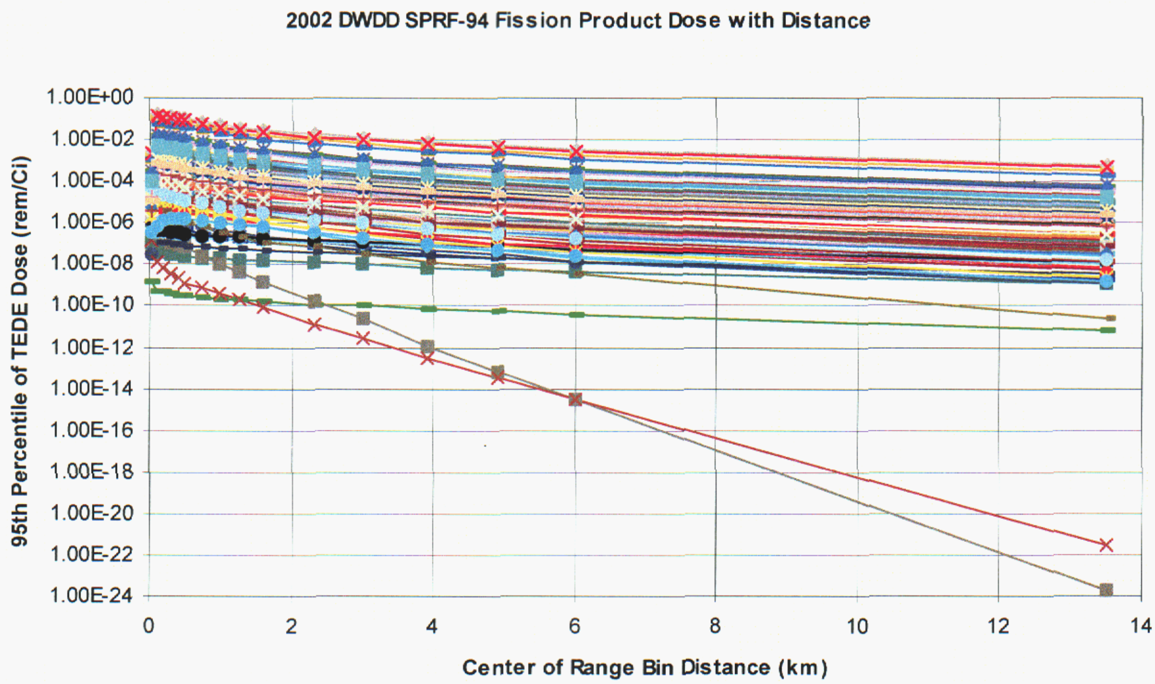

Figure 11. 2002 DWDD fission products dose with distance for SPRF, 1994 weather

In Figure 9 the dose with distance for the actinides and daughters falls off with almost the same profile that is characteristic of the *X/Q* reduction with distance for the SPRF release height. All of the actinides and daughters have long half-lives so their airborne activity is not diminished appreciably with travel time. Ten of the actinides and daughters have doses greater than 1 rem/Ci at 3000 m since they decay by alpha emission or spontaneous fission.

In Figure 10 most of the activation products follow the same *X/Q* reduction profile for the SPRF release height but the two lowest nuclide dose curves appear to follow a slightly different profile with distance. Again most of the activation products have relatively long half-lives with the exception of Co-60m (10.47 minute half-life), the lowest dose curve. Co-60 is the decay product of Co-60m and is the highest dose curve in the figure. The reader should recall that the decay products of each nuclide whose dose was calculated were allowed to radiate and contribute to the total dose in the MACCS2 calculations. It appears that Co-60m may be decaying quickly to Co-60 and the resulting smaller activity of Co-60 may be responsible for the dose profile at distances greater than about 4000 m. For Xe-125, the second lowest dose curve, the dose is being augmented by dose from its decay product I-125 that is the second highest dose curve in the figure. The much higher dose per Ci of I-125 increases the dose with distance of Xe-125 as it continues to be produced, the reverse of dose reduction with distance by fast decay. All of the activation products have doses less than 0.01 rem/Ci at 3000 m.

Most of the fission products of Figure 11 follow the same dose profile with distance but a few of them decay faster and reduce dose faster with distance. All of the fission products have doses less than or equal to approximately 0.01 rem/Ci at 3000 m for the SPRF release height.

Conservatism in 2002 DWDD Inputs

This section examines changes from the 1998/2000 DWDD standard inputs as incorporated in the 2002 DWDD revised standard inputs to identify the resulting additional conservatism in the dispersion calculations of the 2002 DWDD. Part of the rationale in developing revised inputs for the 2002 DWDD and incorporating description of those inputs in this report was the need to ensure adequate conservatism in the dose calculated by the 2002 DWDD. Another reason was to ensure the requirements of DOE-STD-3009, Appendix A were reflected in the dose calculations used for TA-V nuclear facility safety analysis.

Recent DOE guidance in DOE-STD-3009 (DOE 1994), Appendix A introduced in January 2000 focused dose calculation on a different dose receptor and dose pathway concept than the NRC nuclear power reactor safety studies. DOE-STD-3009, Appendix A established a hypothetical MOI standing at the site boundary as the dose receptor for dose estimates to be compared to the evaluation guideline for documented safety analyses. In regard to dose estimation, DOE-STD-3009, Appendix A also says, "The intent is that calculations be based on reasonably conservative estimates of the various input parameters." Other aspects of the DOE-STD-3009, Appendix A prescriptive guidance on dose estimation (such as calculations of the 95th percentile of dose) are the same or similar to those used in the 1998 and 2000 DWDD dose calculations.

The MACCS2 inputs for the ATMOS and EARLY modules of the code are listed in Table 20 with an explanation of added conservatism introduced by changed inputs. Some of the comments in Table 20 were taken from the review of the 2002 DWDD inputs (Restrepo 2002). Added conservatism as discussed in the table usually means that the 2002 DWDD input would result in a larger dose than the 1998/2000 DWDD input. Also, some comments indicated that the choice was a conservative assumption or resulted in a more robust, defensible calculation. While those input choices were advantageous for those reasons, they may not have added conservatism in the sense of increasing calculated dose for the 2002 DWDD.

Input changes for the 2002 DWDD in Table 20 that added conservatism (increased dose) for the ATMOS input file were: 1) eliminating dry deposition that added a relatively large amount of conservatism (See Table 9.), 2) adjusting the σ_z linear scaling factor to 1.0 for surface roughness of 3 cm that added a relatively small amount of conservatism (See Table 10.), 3) suppressing plume meander expansion by matching the time base and release duration to 600 seconds added a medium amount of conservatism (See Table 11.), and 4) setting building wake effects parameters to the minimum allowable values to model a point source added a small amount of conservatism (Restrepo 2002). For the EARLY input file input changes in Table 20, setting the cloud shielding factor and the inhalation protection factor to 1.0 added a relatively large amount of conservatism to the 2002 DWDD calculations (See Table 16.). Increasing the breathing rate added a medium amount of conservatism (See Table 17.).

The overall conclusion evident from a review of Table 20 is that the 2002 DWDD provides "reasonably conservative estimates of the various input parameters" as required by DOE-STD-3009, Appendix A. Restrepo (2002) and DOE (Zamorski 2002) concurred.

Table 20. MACCS2 input changes from 1998/2000 DWDD to 2002 DWDD and the additional conservatism incorporated in dose calculations

Modeling and Input Parameters	Value Used in 1998/2000 DWDD	Value Used in 2002 DWDD	Added Conservatism in 2002 DWDD
ATMOS Inputs			
Radial grid specification	10 radial rings, ranging from 100 m to 20 km. Range of interest for dose to the public is the annular ring bounded by 2900 m and 3100 m.	16 radial rings, ranging from 50 m to 20 km. Range of interest for dose to the MOI is the annular ring bounded by 2950 m and 3050 m.	Minimum distance between radial rings is 100 m. Specification of 2950 m and 3050 m radial distances provides the finest resolution for estimating doses to the MOI at the 3000 m site boundary. No added conservatism.
Source term inventory characteristics • Number of Nuclides • Number and names of pseudostable nuclides • Number and identification of nuclides by group	The number of nuclides and the number and names of pseudostable nuclides vary between calculations but direct decay products are always included for contribution to dose	The number of nuclides and the number and names of pseudostable nuclides vary between calculations but direct decay products are always included for contribution to dose	The source term characterization was not changed. No added conservatism.
Wet and dry deposition Flags	FALSE for noble gases and TRUE for all other groups	FALSE for all nuclide groups	Conservative assumption, nuclides are not removed from the plume by wet or dry deposition for the full inhalation and immersion dose. Added conservatism is large for no dry deposition. No added conservatism for no wet deposition.
Wet deposition coefficients	Washout coefficient linear factor set to 9.5E-05 and exponential factor set to 0.8	Washout coefficient linear factor set to 0.0 and exponential factor set to 0.8	Conservative assumption, does not allow wet deposition, even if deposition flag is set to TRUE. No added conservatism.
Dry deposition velocity	Set to 0.01 m/s	Set to 0.0 m/s	Conservative assumption, does not allow dry deposition, even if deposition flag is set to TRUE. No added conservatism.

Table 20. MACCS2 input changes from 1998/2000 DWDD to 2002 DWDD and the additional conservatism incorporated in dose calculations (continued)

Modeling and Input Parameters	Value Used in 1998/2000 DWDD	Value Used in 2002 DWDD	Added Conservatism in 2002 DWDD
Plume dispersion parameters	Power law calculation (Tadmor and Gur 1969) of σ_y and σ_z for the Gaussian plume airborne concentration	Power law calculation (Tadmor and Gur 1969) of σ_y and σ_z for the Gaussian plume airborne concentration	Conservative assumption, based on measurements over flat terrain covered with grass. No added conservatism.
σ_y linear scaling factor	1.0	1.0	Original Tadmor and Gur dispersion parameters without scaling is a conservative assumption
σ_z linear scaling factor	1.27 (for 10 cm surface roughness)	1.0 (for 3 cm surface roughness)	Original Tadmor and Gur dispersion parameters, with conservative implication that the TA-V average surface roughness length is 3 cm (smooth, flat surface). Added conservatism is small for 3 cm surface roughness. Recent meteorological analysis indicates a minimum surface roughness of 15 cm for area surrounding TA-V.
Plume meander expansion factor • Timebase • Breakpoint time • Expansion factor formula exponents	 600 s 3600 s 0.2 and 0.25	 600 s 3600 s 0.2 and 0.25	Specification of these parameters determines the plume meander expansion factor. Assumption of timebase equal to the plume release duration (600 s) for the 2002 DWDD suppresses plume meander expansion. Added conservatism is medium for no plume meander expansion.
Plume rise data • Critical wind speed scaling factor • Scaling factors for A-D and E-F stability plume rise formula	 1.0 1.0 and 1.0	 1.0E+06 1.0 and 1.0	Critical wind speed scaling factor was conservatively set to the maximum allowable value to suppress entrainment of a buoyant plume in a building wake. No added dose or conservatism since plume heat content assumed (0.0 W) also prevents entrainment of a buoyant plume.

Table 20. MACCS2 input changes from 1998/2000 DWDD to 2002 DWDD and the additional conservatism incorporated in dose calculations (continued)

Modeling and Input Parameters	Value Used in 1998/2000 DWDD	Value Used in 2002 DWDD	Added Conservatism in 2002 DWDD
Building wake effects • Building height (m) • Initial plume σ_y (m) • Initial plume σ_z (m)	 14.3 and 1.0 3.488 and 0.1 6.651 and 0.1	 1.0 0.1 0.1	Conservative assumption, parameters set to minimum allowable values to model a point release. This will disperse the plume less initially and will result in higher doses to the MOI. The resulting added dose and conservatism were small.
Release description, • Number of releases	1 plume	1 plume	A single release is consistent with TA-V safety analysis.
Release description, • Rate of release of sensible heat	0.0 W	0.0 W	Conservative assumption, no sensible energy added to plume that would loft the plume above its initial release elevation, resulting in lower doses to the MOI. No added dose or conservatism.
Release description, • Plume release height	0.0, 14.3 and 38.1 m	0.0, 4.3, 10.0, 14.3, 16.4, 18.0, and 38.1 m	Specific facility release heights allow more accurate dose estimates for hypothetical releases from different facilities. No added conservatism.
Release description, • Release duration	7200 s	600 s	When the plume meander expansion factor time base value matches the plume release duration, plume meander is suppressed. Otherwise, the actual value of the release duration is irrelevant because the dose to the MOI is a time-integrated quantity and does not depend on the duration of the plume release. See plume meander expansion factor row for discussion of the large added conservatism for no plume meander expansion
Release description, • Radionuclide inventory released	1.0 Ci for the first nuclide dose calculation and 0.0 Ci for all others listed	1.0 Ci for the first nuclide dose calculation and 0.0 Ci for all others listed	Dose for other nuclides calculated by change records listed at the end of the ATMOS file. No change and no added conservatism.

Table 20. MACCS2 input changes from 1998/2000 DWDD to 2002 DWDD and the additional conservatism incorporated in dose calculations (continued)

Modeling and Input Parameters	Value Used in 1998/2000 DWDD	Value Used in 2002 DWDD	Added Conservatism in 2002 DWDD
Meteorological sampling	Weather bin sampling with 78 weather histories per dose calculation	Stratified random sampling with 24 samples per day for 8760 weather histories per dose calculation	24 samples per day results in every hour of an entire year being used. The result is a more robust, defendable dose calculation.
Meteorological data	The single typical meteorological year (TMY) for the Albuquerque airport	TA-V local weather tower A36 meteorological data for seven one year sets of data (1994-2000, 2001 not available)	Local meteorological data is required by DOE-STD-3009. Seven one-year sets of weather data allow calculation and comparison of seven doses to use the highest dose. The result is a more robust, defendable dose calculation.
Last spatial interval for meteorological data	Mixing layer height = 2055 m Rain rate 0.0 mm/hr Wind speed = 1.0 m/s Stability class = A	Mixing layer height = 2055 m Rain rate 0.0 mm/hr Wind speed = 1.0 m/s Stability class = F	All inputs are identical between the two DWDD input versions except the stability class. Stability class A, unstable conditions, is not normally associated with 1 m/s winds. Stability class F is usually associated with this low wind speed for boundary weather specification. Since the MOI is located well inside the last radial ring where these weather conditions prevail, the different stability class specification doesn't affect the dose to the MOI anyway. No added conservatism.

Table 20. MACCS2 input changes from 1998/2000 DWDD to 2002 DWDD and the additional conservatism incorporated in dose calculations (continued)

Modeling and Input Parameters	Value Used in 1998/2000 DWDD	Value Used in 2002 DWDD	Added Conservatism in 2002 DWDD
EARLY Inputs			
Dose conversion factors	EPA Federal Guidance Reports #11 and #12 (a few nuclides used DOE/EH-0070 1988)	EPA Federal Guidance Reports #11 and #12 (Dosd825.inp)	The EPA Federal Guidance Reports #11 and #12 provide dose conversion factors for hundreds of nuclides. No added conservatism.
Population data file	Site file ALBSIT.inp gave same results as uniform population distribution.	Uniform population distribution, no site data file	There was no change in calculated dose since the centerline dose does not depend on population. No added conservatism.
Dispersion model	Straight line plume	Straight line plume	No added conservatism.
Cloud shielding factor	0.75 normal activity	1.0 all activity classes	Results in conservative dose estimate because effect of cloud shielding is zero. Added conservatism is large.
Inhalation protection factor	0.4 normal activity	1.0 all activity classes	Results in conservative dose estimate because effect of inhalation protection factor is zero. Added conservatism is large.
Skin protection factor	0.41 normal activity	1.0 all activity classes	Results in conservative dose estimate because effect of skin protection factor is zero. However, skin dose is not assessed in either version of DWDD dose calculations so no added conservatism.
Ground shielding factor	0.4 normal activity	1.0 all activity classes	Results in conservative dose estimate because effect of ground shielding is zero. However, no groundshine dose is included in the 2002 DWDD calculations since there was no wet or dry deposition and hence no ground radiation source. No added conservatism.
Breathing rate	2.66×10^{-04} m^3/s for normal activity	3.47×10^{-04} m^3/s for normal activity	Results in conservative dose estimate because inhalation dose is proportional to breathing rate. Added conservatism is medium.
Evacuation, sheltering and relocation	Not used in either DWDD version	Not used in either DWDD version	No added conservatism.

QUALITY ASSURANCE

This chapter describes the quality assurance (QA) efforts for the 2002 Downwind Dose Database (DWDD) calculations as required by the Technical Area V (TA-V) QA program. The calculations for the 1988 and 2000 DWDD used the MACCS2 airborne dose computer code and an existing weather data file. The 2002 DWDD used the MACCS2 code and a new data conversion computer program (WINDAT2) to convert the format of local TA-V weather data to the format required by MACCS2. WINDAT2 was developed specifically for the 2002 DWDD calculation inputs.

The same approach for QA of the dose calculated by MACCS2 was used for all of the 1998/2000 DWDD and the 2002 DWDD. That approach consisted of (1) running the standard calculations supplied with the MACCS2 code and checking that the calculated outputs agreed with the standard calculation outputs that were distributed with the MACCS2 code and (2) an independent review of the calculation input files. Running and checking the standard calculations was done on every computer used for any version of the DWDD calculations as part of MACCS2 code installation. Independent review of inputs was done for the two sets of standard inputs for the 1998/2000 DWDD and for the 2002 DWDD.

For QA of the weather data conversion of the new WINDAT2 computer code, input was compared to output for a sample of the weather data converted to verify that the conversion was performed correctly. Other QA requirements were applied to the WINDAT2 development. The sections below describe the MACCS2 code installation check of standard calculation outputs, independent review of the 1998/2000 DWDD and the 2002 DWDD input files, and QA for the new WINDAT2 computer code. Other sections below describe the spreadsheet method of extracting and comparing the calculated doses from MACCS2 outputs and the QA verification of the calculations and analysis of the 2002 DWDD by independent review.

The Sandia Research Reactor and Experimental Programs (RREP) Quality Assurance Program Plan (QAPP) (SNL 2002) establishes quality assurance (QA) requirements for the MACCS2 2002 DWDD calculations for TA-V nuclear facility safety analyses. The TA-V QA program is designed in conformance with applicable Department of Energy (DOE) requirements, including 10 CFR 830 Subpart A, "Quality Assurance Requirements," (CFR 2001a). Analyses and calculations used to support safety bases for TA-V facilities are accomplished in accordance with QA procedures relating to Software Quality Assurance and Control and Verification of Analyses and Calculations as per 10 CFR 830.122, Quality Assurance Criteria (CFR 2001a). The TA-V RREP QAPP (SNL 2002) and its procedures RREP 3-2, Computer Software Control (SNL 2001a), and RREP 3-3, Control and Verification of Analyses and Calculations (SNL 2001b), are used to implement the 10 CFR 830.122 criteria.

RREP 3-2, Computer Software Control (SNL 2001a), describes quality assurance controls to be followed for the development, modification, and use of computer software for the users of the RREP at Sandia National Laboratories (SNL). RREP 3-2 controls apply to computer programs previously developed or being developed for use in the design of items or processes for nuclear facilities and experiments in TA-V. The goal of the RREP 3-2 controls is to provide a rigorous software quality program to ensure that reliable software is developed and the validity of the results is traceable, retrievable, reproducible, and defensible.

MACCS2 falls into the category of existing software in RREP 3-2 and its QA requirements are prescribed by completion of an Existing Software Qualification Form (Appendix A of RREP 3-2). The Existing Software Qualification Form for the MACCS2 code is included in Appendix H of this report. The Existing Software Qualification Form requires a software verification and validation report (SVVR) that is also included in Appendix H. The SVVR examined independent reviews of the 1998/2000 DWDD standard inputs and the 2002 DWDD revised standard inputs. Those independent reviews are included in Appendix I.

RREP 3-2 uses a graded approach to apply requirements depending on the source, use, and importance to safety (as defined in the RREP QAPP) of the software and application. Computer programs outside of the scope of RREP 3-2 include:

- Software that is solely intended for use with a given calculation and is validated in related documents or reports,
- Application of software that is used solely for scoping calculations, where results of computer runs may guide the analysis but are not used to support conclusions for the analysis,
- Commercial products that have no potential for altering design data, and
- Data acquisition and reduction software whose performance is adequately confirmed via calibration and testing procedures defined in a Project/Experiment Quality Plan.

WINDAT2 falls under the first exclusion from the full RREP 3-2 requirements so its validation is described in this report. Certain code description and development details are included in addition to the validation efforts. A summary document was prepared for a QA record as well as the discussion in this report. The WINDAT2 summary document is included in Appendix J. That document and the validation effort are described in a following section on the WINDAT2 code.

The calculated downwind doses were extracted from the MACCS2 output files by using a commercial spreadsheet computer program (Microsoft® Excel) for the 2002 DWDD. The same spreadsheet program was used to compile the downwind doses for the various nuclides for each weather year and release height and to compare the doses for the 3000 m range to find the highest dose for each nuclide. The use of that spreadsheet program for these purposes is also discussed as an exception to the requirements of RREP 3-2 in a following section and detailed description is provided in Appendix K.

RREP 3-3, Control and Verification of Analyses and Calculations (SNL 2001b), identifies the actions and responsibilities of persons who perform analyses or calculations in support of RREP activities and establishes controls for technical review of such analyses and calculations. RREP 3-3 uses a graded approach similar to RREP 3-2 to apply requirements. In addition to other requirements, RREP 3-3 requires verification or validation of the analysis or calculation by individual(s) other that those that created or developed the analysis or calculation. QA records were prepared to document that verification for the 2002 DWDD MACCS2 calculations and are included in Appendix L. QA for the 2002 DWDD calculations is discussed in the final section of this chapter.

MACCS2 Code Installation

A separate software test plan was not written to justify the use of MACCS2 as existing software for QA. Instead, the sample problems provided with the code distribution package were run after code installation using the procedure detailed by the MACCS2 *User's Guide* (Chanin and Young 1997) in its Appendix B and the outputs were compared to the sample problem outputs provided in the code distribution package. Comparing the outputs of the sample problems was suggested as a means to verify correct MACCS2 operation in the users guide. The results of the comparison are discussed below and documented in the SVVR of Appendix H. The quality assurance documentation of the existing externally developed MACCS2 code was not examined in conjunction with the sample problem comparison. Specific inputs for either version of the DWDD calculations performed with the MACCS2 code on this computer were not examined as part of the sample problem comparison.

The criteria used for the output file comparison were as follows. The output of the sample problems calculated on the computer used must match the output of the sample problems distributed with the code package. Minor mismatches such as changed dates that the calculation was run are allowable for successful code performance validation.

The sample problem calculations were performed on a Dell Optiplex GX1 computer with Pentium® III processor running at 550 MHz with SNL property number S824741. This was the same computer that was used for the 2002 DWDD calculations. The outputs of the sample problems had been compared before the calculations were run as well as after they were completed. The MACCS2 calculations were run in a DOS window of the Microsoft® Windows® 2000 Professional operating system. The comparison of the calculated and distribution output files was done using Microsoft® Word 97 on another computer. The Compare Documents function of Track Changes was used to identify changes in the calculated output files from the distribution output files. The outputs for all 14 of the sample problems were compared. The only differences found by examining the two sets of output files were different dates for execution. This was an expected difference. The calculated doses were exactly the same for each pair of output files (calculated and distributed). Thus, there were no discrepancies and no issues for resolution in the sample output testing. It is concluded that the MACCS2 code was installed correctly and calculated radionuclide concentrations and doses correctly for the inputs used.

1998/2000 and 2002 DWDD Input Independent Reviews

Independent expert reviews of the standard inputs for the 1998/2000 DWDD (Liscum-Powell 1997) and the 2002 DWDD (Restrepo 2002) MACCS2 calculations were obtained to assess whether the MACCS2 inputs were appropriate for safety analysis to establish the safety basis for TA-V nuclear facilities. Both independent expert reviews found that the inputs were appropriate to perform the desired calculations and both reviews suggested changes to improve the calculations.

It is important to note that the DOE transmittal letter for the 2002 DWDD independent review (Zamorski 2002) concluded that, "The results of the review also indicated that the SNL analysis using more conservative input parameters and Omicron's analysis (Restrepo 2002) did not identify any significant differences. OKSO requests that these changes suggested by Omicron be incorporated into the SNL analysis."

The independent review documents for both versions of the MACCS2 DWDD standard inputs are included in Appendix I to this report. That independent review documentation includes (Liscum-Powell 1997) for the 1998/2000 DWDD and (Zamorski 2002) and (Restrepo 2002) for the 2002 DWDD MACCS2 calculations.

The changes suggested by the independent reviews were compared against the available documentation of the 1998/2000 DWDD (Naegeli 1998) and the 2002 DWDD MACCS2 dose calculations (a draft of this report) to see if the suggested changes had been incorporated into the standard input files for those sets of calculations. Those comparisons are discussed in the SVVR of Appendix H. Almost all of the suggested changes had been incorporated in the inputs. A few changes that were not included would not impact the calculation of dose or were not consistent with the intent of the MACCS2 calculations. An example of the later type of suggestion that was not incorporated was the (Liscum-Powell 1997) suggestion that the 1998/2000 DWDD MACCS2 calculation inputs be changed from centerline dose to use type B results of the peak dose on a spatial grid location. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145 (NRC 1982) and later DOE-STD-3009 (DOE 1994) required the 95th percentile of dose at or beyond the site boundary as the dose of interest for safety basis dose estimation and not the peak dose. Thus, no issues from the independent expert reviews or their implementation were raised that would make the inputs for the 1998/2000 DWDD or the 2002 DWDD questionable.

The MACCS2 software was accepted for use in 2002 DWDD dose calculation "as is" in the QA review of Appendix H and no further software development or input development is needed. The MACCS2 sample problems must be run on each new computer installation of the software and the calculated output files compared to the output files that were distributed with the software to ensure the code is operating correctly. No further benchmark or other testing is required to accept the calculated dose results since correct operation of the code is verified by comparison of sample problem results and since no appropriate experimental measurements of the software calculated values are available for direct comparison. Thus, the appropriateness of the code inputs for the 2002 DWDD was confirmed by independent expert reviews of the inputs.

WINDAT2 Meteorological Data Conversion Program

The WINDAT2 computer program was written to convert hourly meteorological data for TA-V weather tower A36 from the format provided by the SNL meteorologist to the format read by the MACCS2 code for use in the 2002 DWDD calculations. Changing safety basis requirements mandated the change from weather data of the Typical Meteorological Year at the Albuquerque, NM airport that was considered typical of all years to yearly weather data measured at a local TA-V weather tower (tower A36) for specific years.

The weather files provided by the SNL meteorologist for tower A36 included multiple years and more types of data for each hour than were required by the MACCS2 code weather input file. One year of hourly weather data (8760 hours) is needed by MACCS2 for airborne radioactive material dose calculations. Since seven years of weather data were available from the SNL meteorologist, seven separate specific year weather files were required to calculate the dose from all of the years so the most conservative dose (highest dose) could be used for the 2002 DWDD. Thus, a separate computer code was needed to read the multiple year SNL meteorologist weather file, convert the format of the data for the year of interest, and write a one year weather file in the MACCS2 format. WINDAT2 was written to fill that need. A more detailed summary of WINDAT2 requirements, description, use and testing is included in Appendix J. This section and Appendix J provide documentation of the validation of the WINDAT2 code that is intended solely for use with the 2002 DWDD calculation inputs as required by RREP 3-2.

The MACCS2 code does extensive error checking on its inputs such as the meteorological file. MACCS2 will terminate its run and write an error message for diagnosis if the input data are in the wrong range or inconsistent with other input data (Chanin and Young 1997). Thus, requirements for error checking are greatly eased for WINDAT2 due to the extensive error checking of MACCS2. MACCS2 confirmed the 110 hours of missing weather data in December of the 1997 weather file by stopping its execution. The SNL meteorologist said the data were missing when that A36 tower input file was supplied. Data from the days just before and just after the missing section were copied to the corresponding hour locations to make the present 1997 weather file that runs correctly in MACCS2.

The accuracy of weather data conversion was verified by checking multiple hours of weather data in some of the output files to ensure the conversion was done correctly. The hours checked included samples throughout the range of data for each of the input data types. The WINDAT2 weather data conversion was correct in every sample checked.

Spreadsheet Application for 2002 DWDD Dose Extraction and Comparison

The Microsoft® Excel 2000 commercial spreadsheet program was used for 2002 DWDD dose extraction from the MACCS2 output files and for comparing the doses to find the highest dose for each nuclide for each release height. This section discusses the two types of spreadsheets used for the extraction of dose results from MACCS2 output files (input-year files) and for the compilation and comparison of nuclide downwind dose for a release height (DWDD-height files). A more detailed description is provided in Appendix K.

The first spreadsheet file type (input-year files) was essentially a spreadsheet version of the text MACCS2 output file. In the calculated results section of the input-year spreadsheet file, the atmospheric modeling parameters and the calculated dose outputs for each nuclide were organized in spreadsheet columns that greatly eased the extraction of downwind dose for each of the 16 distance ranges for each nuclide. Each output file and its associated input-year file could contain doses for up to a maximum of 60 individual nuclides. The 95th percentile of dose column for each nuclide could then be extracted by coping to a compilation spreadsheet file for that release height (DWDD-height file) for later comparison to find the highest dose for each nuclide at that release height. All of the files for each release height were kept in a separate subdirectory on the processing computer's hard drive for positive organization and identification of the input and output files.

No data scaling or alteration of the dose data columns was done in the process of dose extraction from the input-year files to the associated DWDD-height file for the 2002 DWDD except for transposition of the dose data from a column to a row format. The dose versus distance columns of the input-year file became a row in the DWDD-height file. Copying and transposition were accomplished manually using the Paste Special function of Excel for some of the initial weather years in the first two release heights analyzed. The process was later automated through the use of formulas in a separate sheet of the input-year spreadsheet workbook file for the last years and the other release heights. Correct operation of the formulas in the design of the input-year automated dose extraction workbook file was verified with a special test output file and testing that verified the automated selection of the correct dose data for each nuclide in the input-year file dose output section. The same testing confirmed error indications and how to extract the correct nuclide dose information for each nuclide in the input-year file. Thus, the input-year automated dose extraction workbook file provides a built in error detection feature to preclude extracting erroneous dose data from the MACCS2 output files.

The second file type, a spreadsheet workbook file (DWDD-height files) was used for compilation and comparison of nuclide downwind dose for each release height. Each DWDD-height workbook file had seven sheets of nuclide dose data for the seven years (1994-2000) of weather data files used in the MACCS2 dose calculations and an eighth sheet for comparison of nuclide dose at the 3000 m exclusion area boundary distance from all of the weather year sheets so that the maximum dose for a given nuclide could be selected from the seven candidates.

This laborious process of calculating the downwind doses for all 162 nuclides seven times for the different weather years and then comparing the seven doses at 3000 m for each nuclide was undertaken solely to ensure that the most conservative 95th percentile dose (highest dose) was selected for each nuclide at that release height. The 1994 weather file produced the highest doses at 3000 m for the vast majority of nuclides at all of the release heights but the MACCS2 calculations were repeated for the other six weather year files to find the few cases when the calculated dose was slightly higher than the 1994 weather dose.

No data scaling or alteration of the dose data was done in the process of dose compilation and comparison within DWDD-height workbook file for any release height of the 2002 DWDD. The comparison process required calculation of ratios of dose data to facilitate comparison by inspecting the dose ratios. The comparison process did not scale or alter the dose data of the 2002 DWDD. Thus, the application of commercial spreadsheet software for extraction, compilation and comparison of the downwind dose data of the 2002 DWDD are outside of the scope of RREP 3-2 as a commercial software product that has no potential for altering design data and the requirements of RREP 3-2 for software quality assurance do not apply.

Quality Assurance of the Calculations and Analysis for the 2002 DWDD

RREP 3-3 requires independent verification or validation of analyses or calculations performed for RREP activities. The QA review documentation for the 2002 DWDD calculations is included in Appendix L. The review included the use of MACCS2 in the 2002 DWDD.

The verification documentation included specification of the calculation objectives, inputs, literature searches or other background data, and assumptions. Since a computer program (MACCS2) was used for the calculations, the appropriateness of the application and the adequacy of verification and validation of the code were evaluated. Finally, the independent reviewer evaluated the calculations for their inputs, assumptions computer program mathematical model, literature searches, reasonableness of results in relation to inputs and defined objectives, and the adequacy of documents to produce the same results.

In conclusion, the quality assurance of the 2002 DWDD calculations, their inputs, and results have been examined and accepted through the TA-V QA system of the RREP QAPP. The MACCS2 code was accepted for use as existing software without additional testing or verification requirements. The independent expert reviews of the inputs for the 1998/2000 DWDD and the 2002 DWDD agreed that the inputs were adequate to accomplish the intended dose calculations. The few suggested improvements to inputs have been incorporated or disregarded as not affecting dose or not accomplishing the intended purpose of that version of the DWDD calculations. The WINDAT2 code has been documented as a code written specifically for the 2002 DWDD calculation inputs and the accuracy of its data format conversions have been verified. The commercial spreadsheet applications used for dose extraction, compilation, and comparison provide built in error detection and do not scale or alter the dose data of the 2002 DWDD calculations. Finally, the QA review independently verified the 2002 DWDD calculation activity by evaluating its component activities.

REFERENCES

(Aldrich et al. 1982) Aldrich, D.C., J.L. Sprung, D.J. Alpert, K. Diegert, R.M. Ostmeyer, L.T. Ritchie, and D.R.Strip, *Technical Guidance for Siting Criteria Development*, SAND81-1549, NUREG/CR-2239, Sandia National Laboratories, Albuquerque, NM, December 1982.

(Brenk and Vogt 1981) H. D. Brenk and K. J. Vogt, The Calculation of Wet Deposition from Radioactive Plumes, *Nuclear Safety,* Vol. 22, p. 362-371, 1981.

(Briggs 1973) G. A. Briggs, *Diffusion Estimation for Small Emissions*, Atmospheric Turbulence and Diffusion Laboratory Contribution File No. 79, Oak Ridge TN, 1973.

(Briggs 1975) G. A. Briggs, Plume Rise Predictions, in *Lectures on Air Pollution and Environmental Impact Analysis,* Workshop proceedings, American Meteorological Association, Boston, MA, 1975.

(Briggs 1984) G. A. Briggs, Plume Rise and Buoyancy Effects, (Chapter 8), *Atmospheric Science and Power Production*, editor D. Randerson, DOE/TIC-27601, Department of Energy, Washington, DC, 1984.

(CFR 2001a) U.S. Code of Federal Regulations Title 10, *Energy,* Part 830, Subpart A, *Quality Assurance Requirements*, U.S. Department of Energy, Office of the Federal Register, Washington, DC, January 10, 2001.

(CFR 2001b) U.S. Code of Federal Regulations Title 10, *Energy,* Part 830, Subpart B, *Safety Basis Requirements*, U.S. Department of Energy, Office of the Federal Register, Washington, DC, January 10, 2001.

(Chamberlain 1953) A. C. Chamberlain, *Aspects of Travel and Deposition of Aerosol and Vapour Clouds,* British Report AERE-HP/R 1261, Atomic Energy Research Establishment, Harwell, United Kingdom, 1953.

(Chanin and Young 1997) D.I. Chanin, and M.L. Young, *Code Manual for MACCS2: Volume 1, User's Guide*, SAND97-0594, Sandia National Laboratories, Albuquerque, NM, March 1997.

(Croff 1983) A. G. Croff, ORIGEN2: A Versatile Computer Code for Calculating the Nuclide Compositions and Characteristics of Nuclear Materials, *Nuclear Technology*, 62, p. 335, 1983.

(Deola 2002a) R. A. Deola, Seasonal Mixing Heights, Sandia National Laboratories, Albuquerque, NM memorandum to R. E. Naegeli, July 25, 2002.

(Deola 2002b) R. A. Deola, A36 modeling file, Sandia National Laboratories, Albuquerque, NM e-mail to R. E. Naegeli, July 30, 2002 (includes 1996-2000 meteorological data).

(Deola 2002c) R. A. Deola, A36 1994/5 data, Sandia National Laboratories, Albuquerque, NM e-mail to R. E. Naegeli, August 14, 2002.

(Deola 2002d) R. A. Deola, Minimum Surface Roughness at TA-III and TA-V, Sandia National Laboratories, Albuquerque, NM e-mail to R. E. Naegeli, November 19, 2002 (includes a white paper as attachment, Site-Specific Roughness Lengths for Use in TA-III and TA-V).

(DOE 1988) U.S. Department of Energy (DOE), DOE/EH-0070, *External Dose-Rate Conversion Factors for Calculation of Dose to the Public*, U.S. Department of Energy, Washington, DC, 1988.

(DOE 1994) U.S. Department of Energy (DOE), DOE-STD-3009-94, (Change Notice 2, April 2002), *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, U.S. Department of Energy, Washington, DC, July 1994.

(Draxler 1984) R. R. Draxler, Diffusion and Transport Experiments, (Chapter 9), *Atmospheric Science and Power Production*, editor D. Randerson, DOE/TIC-27601, U. S. Department of Energy, Washington, DC, 1984.

(Eckerman et al. 1989) K.F., Eckerman, A.B. Wolbarst, and A.C.B. Richardson, *Limiting Values for Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, Federal Guidance Report 11*, EPA 520/1-88-020, second printing with corrections, Environmental Protection Agency, Washington, DC, 1989.

(Eckerman and Ryman 1993) K.F. Eckerman, and J.C. Ryman, *External Exposure to Radionuclides in Air, Water, and Soil, Federal Guidance Report 12*, EPA 402-R-93-081, Environmental Protection Agency, Washington, DC, 1993.

(EPA 1992) *Users Guide for CAP88-PC*, Version 1.0, 402-B-92-001, U.S. Environmental Protection Agency (EPA), Las Vegas, NV, March 1992.

(EPA 2000) *Meteorological Monitoring Guidance for Regulatory Modeling Applications*, EPA-454/R-99-005, U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, February 2000.

(Gregory 1999) J. J. Gregory, *The Use of MACCS in a Non-Reactor Application*, SAND99-1982C, Sandia National Laboratories, Albuquerque, NM, 1999.

(Gifford 1975) F. Gifford, Atmospheric Dispersion Models for Environmental Pollution Applications, in *Lectures on Air Pollution and Environmental Impact Analysis*, D. A. Haugen, ed., American Meteorological Society, 1975.

(Guerrero et al. 1999) J. V. Guerrero, K. A. Kuzio, W. H. Johns, L. S. Bayliss, and B. Bailey White, *Sandia National Laboratories/New Mexico Environmental Information Document*, SAND99-2022/1, Sandia National Laboratories, Albuquerque, NM, September 1999.

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

(Harper et al 1994) F. T. Harper, S. C. Hora, M. L. Young, L. A. Miller, C. H. Lui, M. D. McKay, J. C, Helton, L. H. J. Goossens, R. M. Cooke, J. Pasler-Sauer, B. Kraan, and J. A. Jones, *Probabilistic Accident Consequence Uncertainty Analysis, Dispersion and Deposition Uncertainty Assessment*, SAND94-1453, NUREG/CR-6244, EUR 15855EN, Vol. 1, 2, & 3, Sandia National Laboratories, Albuquerque, NM, 1994.

(ICRP 1975) International Commission on Radiological Protection (ICRP), Task Group on Reference Man, *Report of the Task Group on Reference Man*, a Report Prepared by a Task Group of Committee 2 of the International Commission on Radiological Protection, ICRP Publication 23, Pergamon Press Ltd., Oxford England, 1975.

(ICRP 1994) International Commission on Radiological Protection (ICRP), *Human Respiratory Tract Model for Radiological Protection: a Report of a Task Group of the International Commission on Radiological Protection*, ICRP Publication 66, Pergamon, Elsevier Science Ltd., Oxford England, 1994.

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

(Jones 1986b) J. A. Jones, The Uncertainty in Dispersion Estimates Obtained from the Working Group Models, *The Seventh Report of the Working Group on Atmospheric Deposition,* NRPB-R199, National Radiological Protection, Board Chilton, Didcot, Oxon, United Kingdom, 1986.

(Jow et al. 1990) H-N Jow, J. L. Sprung, J. A. Rollstin, L. T. Ritchie, and D. I. Chanin, *MELCOR Accident Consequence Code System (MACCS), Model Description*, NUREG/CR-4691, SAND86-1562, Vol. 2, Sandia National Laboratories, Albuquerque, NM, February 1990.

(Liscum-Powell 1997) J. Liscum-Powell, Review of MACCS2 Input Files, Sandia National Laboratories, Albuquerque, NM internal memorandum to R. Naegeli, June 18, 1997.

(Naegeli 1998) R. E. Naegeli, Transmittal of MACCS2 Single Isotope Airborne Dose Versus Distance Database, Memorandum to Distribution, Sandia National Laboratories, Albuquerque, NM, January 9, 1998.

(Norton 1996) P. Norton, The Right Way to Calculate Fuel Cost Conversions, *Natural Gas Fuels*, August 1996.

(NRC 1972a) U.S. Nuclear Regulatory Commission (NRC), *Onsite Meteorological Programs*, Regulatory Guide 1.23, U.S. Nuclear Regulatory Commission, Washington DC, February 1972.

(NRC 1972b) U.S. Nuclear Regulatory Commission (NRC), *Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors*, Regulatory Guide 1.25, U.S. Nuclear Regulatory Commission, Washington DC, March 1972.

(NRC 1975) U.S. Nuclear Regulatory Commission (NRC), *Reactor Safety Study*, WASH-1400, NUREG-75/014, U. S. Nuclear Regulatory Commission, Washington, DC, October 1975.

(NRC 1982) U.S. Nuclear Regulatory Commission (NRC), *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, Regulatory Guide 1.145, Revision 1 (Reissued February 1983), U.S. Nuclear Regulatory Commission, Washington DC, November 1982.

(NRC 1989) U. S. Nuclear Regulatory Commission (NRC), *Severe Accident Risks: An Assessment for Five U. S. Nuclear Power Plants*, NUREG-1150, June 1989.

(Plate 1971) E. J. Plate, *Aerodynamic Characteristics of Atmospheric Boundary Layers*, TID-25465, U. S. Atomic Energy Commission, NTIS, 1971.

(Priestley 1959) C. H. B. Priestley, *Turbulent Transfer in the Lower Atmosphere*, University of Chicago Press, Chicago, IL, 1959.

(Restrepo 2002) L. Restrepo, Letter Report on TA-V MACCS2 Input Files to William T. Mullen, DOE/OKSO, Omicron Safety and Risk Technologies, Albuquerque, NM, October 18, 2002.

(RFETS 1999) J. W. Marr, V. L. Peterson, R. G. Colwell, R. L. Dickey, D. W. Mondragon, S. W. Fong, H. Jordan, G. F. Larson, S. L. Nicolosi, and K. K. Taylor, *Safety Analysis and Risk Assessment Handbook (SARAH)*, RFP-5098, Revision No. 2, Kaiser-Hill Company, Safety Analysis Group, Nuclear Engineering Department, Rocky Flats Environmental Technology Site (RFETS), December 6, 1999.

(Ritchie et al. 1984) T. Ritchie, D. J. Alpert, R. P. Burke, J. D. Johnson, R. M. Ostmeyer, D. C. Aldrich, and R. M. Blond, *CRAC2 Model Description*, NUREG/CR-2552, SAND82-0342, Sandia National Laboratories, Albuquerque, NM, 1984.

(RSIC 1994) Radiation Shielding Information Center (RSIC), *FGR-DOSE: Dose Coefficients from Federal Guidance Reports 11 and 12*, DLC-167, Oak Ridge National Laboratory, Oak Ridge, TN, 1994.

(Sehmel 1984) G. A. Sehmel, Deposition and Resuspension, (Chapter 12), *Atmospheric Science and Power Production*, editor D. Randerson, DOE/TIC-27601, U. S. Department of Energy, Washington, DC, 1984.

(SNL 2001a) RREP 3-2, *Computer Software Control*, Revision 04, Sandia National Laboratories, Albuquerque, NM, June 25, 2001.

(SNL 2001b) RREP 3-3, *Control and Verification of Analysis and Calculations*, Revision 02, Sandia National Laboratories, Albuquerque, NM, June 25, 2001.

(SNL 2002) *Sandia Research Reactor and Experimental Programs (RREP) Quality Assurance Program Plan (QAPP)*, Revision 11, Sandia National Laboratories, Albuquerque, NM, October 10, 2002.

(Sprung et al. 1990) J. L. Sprung, J. A. Rollstin, J. C. Helton, and H-N Jow, *Evaluation of Severe Accident Risks: Quantification of Major Input Parameters*, NUREG/CR-4551, SAND86-1309, Vol. 2, Rev.1, Part 7, Sandia National Laboratories, Albuquerque, NM, December 1990.

(Tadmor and Gur 1969) J. Tadmor and Y. Gur, Analytical Expressions for the Vertical and Lateral Dispersion Coefficients in Atmospheric Diffusion, *Atmospheric Environment*, Vol. 3, pp. 688-689, 1969.

(Turner 1970) D.B. Turner, *Workbook of Atmospheric Dispersion Estimates*, PSH-999-AP-26, Department of Health, Education, and Welfare, Washington, DC, 1970.

(Wieringa 1993) J. Wieringa, Representative Roughness Parameters for Homogeneous Terrain, *Boundary Layer Meteorology*, 63, pp. 323-363, 1993.

(Zamorski 2002) M. J. Zamorski, TA-V Nuclear Facilities Dispersion and Consequence Analysis Actions, DOE/AOO Memorandum to Tom Blejwas, Director of Nuclear and Risk Technologies, at SNL/NM, Department of Energy, National Nuclear Security Administration, Albuquerque Operations Office, Albuquerque, NM. October 31, 2002.

APPENDIX A, TYPICAL 1998/2000 DWDD ATMOS INPUT FILE

```
* HCF SINGLE ISOTOPE ACCIDENT SCENARIO RELEASE AT SANDIA AREA V "ATMOS" INPUT
* Executed under MACCS2 input format, Use with "New" COMIDA2-Based Food Model
* of CHRONC
*
RIATNAM1001 'BTFG3AC.INP, FGRDCFs, Miscellaneous, (HCF), ATMOS INPUT'
*
*  SANDIA NAT.LAB., R. E. NAEGELI, DIV 9361. (8/13/97)
*     ***** ACRR RELEASE, ACRR WAKE, 0.0W BOUYANT PLUME RISE DUE TO HEAT*****
*     ***** Single RADIONUCLIDES BEING MODELED****
*     ***** RELEASE FRACTIONS ALL SET TO 1.0 ****
*     ***** WEATHER BIN SAMPLING ****
********************************************************************************
* GEOMETRY DATA BLOCK, LOADED BY INPGEO, STORED IN /GEOM/
*
* NUMBER OF RADIAL SPATIAL ELEMENTS
*
GENUMRAD001  10
*
*  SANDIA
*
GESPAEND001  0.10  0.50  1.50  1.70  2.90  3.10
GESPAEND002  4.80  5.00  7.00  20.0
*
*
********************************************************************************
* NUCLIDE DATA BLOCK, LOADED BY INPISO, STORED IN /ISOGRP/, /ISONAM/
*
* NUMBER OF NUCLIDES, NO NEW RADIONUCLIDES HAVE BEEN ADDED
* --------------------------------
ISNUMISO001    148          NUMBER OF ISOTOPES = CORE INVENTORY
* --------------------------------
* NUMBER OF NUCLIDE GROUPS
*
ISMAXGRP001  9
*
* WET AND DRY DEPOSITION FLAGS FOR EACH NUCLIDE GROUP
*
*              WETDEP     DRYDEP
*
ISDEPFLA001    .FALSE.   .FALSE.
ISDEPFLA002    .TRUE.    .TRUE.
ISDEPFLA003    .TRUE.    .TRUE.
ISDEPFLA004    .TRUE.    .TRUE.
ISDEPFLA005    .TRUE.    .TRUE.
ISDEPFLA006    .TRUE.    .TRUE.
ISDEPFLA007    .TRUE.    .TRUE.
ISDEPFLA008    .TRUE.    .TRUE.
ISDEPFLA009    .TRUE.    .TRUE.
```

```
*
* Number of pseudostable nuclides (used to truncate the decay chains)
*
ISNUMSTB001      18
*
* List of pseudostable nuclides
*
*                          NAMSTB
ISNAMSTB001      I-129    (daughter of Te-129 and Te-129m)       CHRONC
* ISNAMSTB002     Te-129    (daughter of Te-129m)         CHRONC
* ISNAMSTB002      Xe-131m  (daughter of I-131)         CHRONC
* ISNAMSTB003      Xe-133m  (daughter of I-133)
* ISNAMSTB004      Xe-135m  (daughter of I-135)
ISNAMSTB002      Cs-135   (daughter of Xe-135 and Xe-135m)       CHRONC
ISNAMSTB003      Sm-147   (daughter of Pm-147)          CHRONC
* ISNAMSTB005      U-234    (daughter of Pu-238)
* ISNAMSTB006      U-235    (daughter of Pu-239)
* ISNAMSTB007      U-236    (daughter of Pu-240)
* ISNAMSTB008      U-237    (daughter of Pu-241)
* ISNAMSTB004      Np-237   (daughter of Am-241)          CHRONC
ISNAMSTB004      Rb-87    (daughter of Kr-87)           CHRONC
* ISNAMSTB007      Ba-137m  (daughter of Cs-137)
* ISNAMSTB014      Rb-88    (daughter of Kr-88)
* ISNAMSTB015      Y-91m    (daughter of Sr-91)
ISNAMSTB005      Zr-93    (daughter of Y-93)            CHRONC
ISNAMSTB006      Nb-93m   (daughter of Zr-93)           CHRONC
* ISNAMSTB008      Nb-95m   (daughter of Zr-95)         CHRONC
* ISNAMSTB019      Nb-97    (daughter of Zr-97 and Nb-97m)
* ISNAMSTB020      Nb-97m   (daughter of Zr-97)
ISNAMSTB007      Tc-99    (daughter of Mo-99)           CHRONC
* ISNAMSTB011      Pu-239   (daughter of Np-239)
* ISNAMSTB010      Th-230  (daughter of U-234)          CHRONC
ISNAMSTB008      Th-232  (daughter of U-236)            CHRONC
ISNAMSTB009      Pa-231  (daughter of Th-231)           CHRONC
* ISNAMSTB015      Rh-103m  (daughter of Ru-103)          CHRONC
* ISNAMSTB016      Rh-106   (daughter of Ru-106)          CHRONC
* ISNAMSTB024     Te-131    (daughter of Te-131m)
* ISNAMSTB017      Pr-144   (daughter of Ce-144 and Pr-144m)       CHRONC
* ISNAMSTB013      Pr-144m  (daughter of Ce-144)           CHRONC
* ISNAMSTB017      Pm-147   (daughter of Nd-147)
ISNAMSTB010      Th-234
ISNAMSTB011      Th-229
ISNAMSTB012      Pa-233
ISNAMSTB013      Pa-234
ISNAMSTB014      Pa-234m
ISNAMSTB015      Ra-226
ISNAMSTB016      Rn-222
ISNAMSTB017      U-233
ISNAMSTB018      In-115
*
* NUCLIDE GROUP DATA FOR 9 NUCLIDE GROUPS
*
*                     NUCNAM       IGROUP
*
* FISSION PRODUCTS
*
ISOTPGRP001      H-3       3
```

ISOTPGRP002	Ge-77	4		
ISOTPGRP003	As-77	4		
ISOTPGRP004	Br-82	2		
ISOTPGRP005	Br-83	2	* Dosd825	
ISOTPGRP006	Kr-83m	1	* Dosd825	
ISOTPGRP007	Br-84	2	* Dosd825	
ISOTPGRP008	Kr-85m	1		
ISOTPGRP009	Kr-85	1		
ISOTPGRP010	Rb-86	3		
ISOTPGRP011	Kr-87	1		
ISOTPGRP012	Kr-88	1		
ISOTPGRP013	Rb-88	3	* Dosd825	
ISOTPGRP014	Rb-89	3	* Dosd825	
ISOTPGRP015	Sr-89	5	* CHRONC	
ISOTPGRP016	Sr-90	5	* CHRONC	
ISOTPGRP017	Y-90	7	* CHRONC	
ISOTPGRP018	Sr-91	5		
ISOTPGRP019	Y-91	7		
ISOTPGRP020	Y-91m	7	* Dosd825	Retain, implicit daughter
ISOTPGRP021	Sr-92	5		
ISOTPGRP022	Y-92	7		
ISOTPGRP023	Y-93	7		
ISOTPGRP024	Y-94	7	* Dosd825	
ISOTPGRP025	Y-95	7	* Dosd825	
ISOTPGRP026	Zr-95	7		
ISOTPGRP027	Nb-95	7		
ISOTPGRP028	Nb-95m	7		
ISOTPGRP029	Nb-96	7		
ISOTPGRP030	Zr-97	7		
ISOTPGRP031	Nb-97	7	* Dosd825	
ISOTPGRP032	Nb-97m	7	* Dosd825	Retain, implicit daughter
ISOTPGRP033	Mo-99	6		
ISOTPGRP034	Tc-99m	6		
ISOTPGRP035	Mo-101	6	* Dosd825	
ISOTPGRP036	Tc-101	6	* Dosd825	
ISOTPGRP037	Ru-103	6	* CHRONC	
ISOTPGRP038	Rh-103m	6	* Dosd825	Retain, implicit daughter
ISOTPGRP039	Tc-104	6	* Dosd825	
ISOTPGRP040	Ru-105	6		
ISOTPGRP041	Rh-105	6		
ISOTPGRP042	Ru-106	6	* CHRONC	
ISOTPGRP043	Rh-106	6	* Dosd825	
ISOTPGRP044	Ag-109m	4		
ISOTPGRP045	Ag-111	4		
ISOTPGRP046	Ag-112	4		
ISOTPGRP047	Cd-115	4		
ISOTPGRP048	Cd-115m	4		
ISOTPGRP049	In-115m	4		
ISOTPGRP050	Sn-119m	4		
ISOTPGRP051	Sn-121	4		
ISOTPGRP052	Sn-123	4		
ISOTPGRP053	Sn-125	4		
ISOTPGRP054	Sb-125	4		
ISOTPGRP055	Xe-125	1		
ISOTPGRP056	I-125	2		
ISOTPGRP057	Te-125m	4		
ISOTPGRP058	Sb-126	4		

ISOTPGRP059	I-126	2		
ISOTPGRP060	Xe-127	1		
ISOTPGRP061	Sb-127	4		
ISOTPGRP062	Te-127	4	* CHRONC	
ISOTPGRP063	Te-127m	4	* CHRONC	
ISOTPGRP064	Sn-128	4	* Dosd825	
ISOTPGRP065	Sb-128a	4	* Dosd825	
ISOTPGRP066	Xe-129m	1		
ISOTPGRP067	Sb-129	4		
ISOTPGRP068	Te-129	4	Retain, implicit daughter	
ISOTPGRP069	Te-129m	4	* CHRONC	
ISOTPGRP070	Xe-131m	1		
ISOTPGRP071	Sb-131	4	* Dosd825	
ISOTPGRP072	Te-131	4	* Dosd825	Retain, implicit daughter
ISOTPGRP073	Te-131m	4		
ISOTPGRP074	I-131	2	* CHRONC	
ISOTPGRP075	Te-132	4	* CHRONC	
ISOTPGRP076	I-132	2	* CHRONC	
ISOTPGRP077	Te-133	4	* Dosd825	
ISOTPGRP078	Te-133m	4	* Dosd825	
ISOTPGRP079	I-133	2	* CHRONC	
ISOTPGRP080	Xe-133	1	* CHRONC	
ISOTPGRP081	Xe-133m	1	* Dosd825	CHRONC
ISOTPGRP082	Te-134	4	* Dosd825	
ISOTPGRP083	I-134	2		
ISOTPGRP084	Cs-134	3	* CHRONC	
ISOTPGRP085	I-135	2		
ISOTPGRP086	Xe-135	1		
ISOTPGRP087	Xe-135m	1	* Dosd825	Retain, implicit daughter
ISOTPGRP088	Cs-137	3	* CHRONC	
ISOTPGRP089	Ba-137m	9	* Dosd825	
ISOTPGRP090	Xe-138	1	* Dosd825	
ISOTPGRP091	Cs-138	3	* Dosd825	
ISOTPGRP092	Ba-139	9		
ISOTPGRP093	Ba-140	9	* CHRONC	
ISOTPGRP094	La-140	7	* CHRONC	
ISOTPGRP095	Ba-141	9	* Dosd825	
ISOTPGRP096	La-141	7		
ISOTPGRP097	Ce-141	8		
ISOTPGRP098	Ba-142	9	* Dosd825	
ISOTPGRP099	La-142	7		
ISOTPGRP100	La-143	7	* Dosd825	
ISOTPGRP101	Ce-143	8		
ISOTPGRP102	Pr-143	7		
ISOTPGRP103	Ce-144	8	* CHRONC	
ISOTPGRP104	Pr-144	7	* Dosd825	Retain, implicit daughter
ISOTPGRP105	Pr-144m	7		
ISOTPGRP106	Pr-145	7	* Dosd825	
ISOTPGRP107	Pr-147	7	* Dosd825	
ISOTPGRP108	Nd-147	7		
ISOTPGRP109	Pm-147	7	* Dosd825	
ISOTPGRP110	Pm-148	7	* Dosd825	
ISOTPGRP111	Pm-148m	7		
ISOTPGRP112	Nd-149	7	* Dosd825	
ISOTPGRP113	Pm-149	7	* Dosd825	
ISOTPGRP114	Pm-151	7	* Dosd825	
ISOTPGRP115	Sm-151	7	* Dosd825	

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ISOTPGRP116     Sm-153        7          * Dosd825
ISOTPGRP117     Eu-155        7
ISOTPGRP118     Eu-156        7
*
* ACTINIDES
*
ISOTPGRP119     Th-230         8
ISOTPGRP120     Th-231         8             * Dosd825     CHRONC
ISOTPGRP121     U-234         8            * Dosd825      CHRONC
ISOTPGRP122     U-235         8            * Dosd825      CHRONC
ISOTPGRP123     U-236         8             * Dosd825     CHRONC
ISOTPGRP124     U-237         8             * Dosd825     CHRONC
ISOTPGRP125     U-238         8
ISOTPGRP126     U-239         8             * Dosd825
ISOTPGRP127     Np-237         8
ISOTPGRP128     Np-238         8               * Dosd825
ISOTPGRP129     Np-239         8
ISOTPGRP130     Pu-238        8             *  CHRONC
ISOTPGRP131     Pu-239         8              * CHRONC
ISOTPGRP132     Pu-240        8             *  CHRONC
ISOTPGRP133     Pu-241        8             *  CHRONC
ISOTPGRP134     Am-241       7              * CHRONC
ISOTPGRP135     Cm-242       7             *  CHRONC
ISOTPGRP136     Cm-244       7             *  CHRONC
*
* ACTIVATION PRODUCTS
*
ISOTPGRP137     P-32           4
ISOTPGRP138     S-35           4
ISOTPGRP139     Cr-51           6           * Dosd825
ISOTPGRP140     Mn-56           6            * Dosd825
ISOTPGRP141     Fe-55           6           * Dosd825
ISOTPGRP142     Fe-59           6           * Dosd825
ISOTPGRP143     Co-58           6
ISOTPGRP144     Co-60           6           * Dosd825
ISOTPGRP145     Co-60m           6           * Dosd825
ISOTPGRP146     Ni-59           6
ISOTPGRP147     Ni-63           6            * Dosd825
ISOTPGRP148     Ni-65           6            * Dosd825
*
********************************************************************************
* WET DEPOSITION DATA BLOCK, LOADED BY INPWET, STORED IN /WETCON/
*
* WASHOUT COEFFICIENT NUMBER ONE, LINEAR FACTOR
*
WDCWASH1001  9.5E-5   (JON HELTON AFTER JONES, 1986)
*
* WASHOUT COEFFICIENT NUMBER TWO, EXPONENTIAL FACTOR
*
WDCWASH2001  0.8      (JON HELTON AFTER JONES, 1986)
**********************************************************************************
* DRY DEPOSITION DATA BLOCK, LOADED BY INPDRY, STORED IN /DRYCON/
*
* NUMBER OF PARTICLE SIZE GROUPS
*
DDNPSGRP001   1
*
```

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* DEPOSITION VELOCITY OF EACH PARTICLE SIZE GROUP (M/S), ASSUMED TO BE
* ONE MICRON AMAD.
*
DDVDEPOS001   0.01
* DDVDEPOS001   0.003   (RSAC-5 default value)
********************************************************************************
* 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
*
* USE OF OPTIONAL DISPERSION TABLES INSTEAD OF THE POWER-LAW MODEL
*
NUM_DIST001  0  (dispersion tables are not being supplied, use power-law)
********************************************************************************
*  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   (value intended to be used with Tadmor and Gur parameters)
********************************************************************************
* EXPANSION FACTOR DATA BLOCK, LOADED BY INPEXP, STORED IN /EXPAND/
*
* TIME BASE FOR EXPANSION FACTOR (SECONDS)
*
PMTIMBAS001    600.   (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
*
* BUILDING HEIGHT (METERS) This is now used just for plume rise entrainment.
*
* WEBUILDH001   1.0     * Ground Release
WEBUILDH001  14.3     *  9.4 ACRR + 4.9 PENTHOUSE (ACRR) (HCF too)
* WEBUILDH001   10.     *  SPR KIVA
*
* Initial Value for Plume Sigma-y (m) due to wake effects
*
* SIGYINIT001  9.302  (initial sigma-y=W/4.3 for MACCS, 40-m wide bldg.)
SIGYINIT001  3.488  (initial sigma-y=W/4.3 for MACCS, 15-m wide ACRR SPR & HCF)
* SIGYINIT001  0.1    (initial sigma-y=W/4.3 for no wake)
*
* Initial Value for Plume Sigma-z (m) due to wake effects
*
* SIGZINIT001  23.26  (initial sigma-z=W/2.15 for MACCS, for 50-m high bldg.)
SIGZINIT001  6.651  (initial sigma-z=W/2.15 for MACCS, 14.3-m high ACRR & HCF)
* SIGZINIT001  4.651  (initial sigma-z=W/2.15 for MACCS, for 10-m high SPR KIVA)
* SIGZINIT001  0.1    (initial sigma-z=W/2.15 for no wake)
*
*******************************************************************************
* RELEASE DATA BLOCK, LOADED BY INPREL, STORED IN /ATNAM2/, /MULREL/
*
* Specific Descriptive Text Describing This Particular Source Term
*
RDATNAM2001 'HCF & ACRR SAR-Weather Bin METEOROLOGICAL CONDITIONS- I-133'
*
* TIME 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      12.
*
* NUMBER OF PLUME SEGMENTS THAT ARE RELEASED
*
RDNUMREL001          1
*
* SELECTION OF RISK DOMINANT PLUME
*
RDMAXRIS001          1
*
* REFERENCE TIME FOR DISPERSION & RADIOACTIVE DECAY (LEADING EDGE OF THE PLUME)
*
RDREFTIM001       0.0
*
* HEAT CONTENT OF THE RELEASE SEGMENTS (W)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
* NO HEAT CONTENT HAVE BEEN ASSUMED TO PREVENT PLUME RISE
*
RDPLHEAT001    0.0
*
* HEIGHT OF THE PLUME SEGMENTS AT RELEASE (M)
*
* RDPLHITE001    0.0      PARKING LOT
RDPLHITE001    14.3     ACRR/SNL
* RDPLHITE001    10.0     SPR/KIVA
* RDPLHITE001    38.1     HCF STACK
*
* DURATION OF THE PLUME SEGMENTS (S)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
* A MAXIMUM OF TWO HOUR RELEASE IS ASSUMED SINCE OVER
* 99.99% OF THE MATERIAL THAT IS TO BE RELEASED FROM THE
* BUILDING HAS BEEN RELEASED ALREADY - SEE MELCOR RESULTS
*
RDPLUDUR001      7200.
*
* TIME OF RELEASE FOR EACH PLUME (S AFTER SCRAM)
* A VALUE SPECIFIED FOR EACH OF THE RELEASE SEGMENTS
* SINCE ALL THE BUILDING SOURCE TERM HAVE BEEN DECAYED
* FOR A PERIOD OF 30 MINUTES, NO ADDITIONAL DECAY IS ASSUMED
*
RDPDELAY001      0.
*
* PARTICLE SIZE DISTRIBUTION OF EACH NUCLIDE GROUP
* YOU MUST SPECIFY A COLUMN OF DATA FOR EACH OF THE PARTICLE SIZE GROUPS
*
*                             0.01   DEPOSITION VELOCITY FOR EACH PARTICLE SIZE
GROUP (M/S)
*
RDPSDIST001      1.
RDPSDIST002      1.
RDPSDIST003      1.
RDPSDIST004      1.
RDPSDIST005      1.
RDPSDIST006      1.
RDPSDIST007      1.
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RDPSDIST008      1.
RDPSDIST009      1.
*
* CORE INVENTORY INFORMATION
*
* Dosd825    CHRONC
*
*                      NUCNAM    INVENTORY(Ci)
*
* FISSION PRODUCTS
*
RDCORINV001    H-3       0.000E+00
RDCORINV002    Ge-77       0.000E+00
RDCORINV003    As-77       0.000E+00
RDCORINV004    Br-82       0.000E+00
RDCORINV005    Br-83       0.000E+00          * Dosd825
RDCORINV006    Kr-83m      0.000E+00            * Dosd825
RDCORINV007    Br-84       0.000E+00            * Dosd825
RDCORINV008   Kr-85m     0.000E+00
RDCORINV009   Kr-85     0.000E+00
RDCORINV010   Rb-86     0.000E+00
RDCORINV011   Kr-87     0.000E+00
RDCORINV012   Kr-88     0.000E+00
RDCORINV013    Rb-88     0.000E+00            * Dosd825
RDCORINV014    Rb-89     0.000E+00            * Dosd825
RDCORINV015   Sr-89     0.000E+00           *  CHRONC
RDCORINV016   Sr-90     0.000E+00           *  CHRONC
RDCORINV017   Y-90      0.000E+00           *  CHRONC
RDCORINV018   Sr-91     0.000E+00
RDCORINV019   Y-91      0.000E+00
RDCORINV020    Y-91m     0.000E+00            * Dosd825    Implicit daughter
RDCORINV021   Sr-92     0.000E+00
RDCORINV022   Y-92      0.000E+00
RDCORINV023   Y-93      0.000E+00
RDCORINV024    Y-94    0.000E+00          * Dosd825
RDCORINV025    Y-95    0.000E+00          * Dosd825
RDCORINV026   Zr-95     0.000E+00
RDCORINV027   Nb-95     0.000E+00
RDCORINV028   Nb-95m     0.000E+00
RDCORINV029   Nb-96     0.000E+00
RDCORINV030   Zr-97     0.000E+00
RDCORINV031    Nb-97     0.000E+00          * Dosd825
RDCORINV032    Nb-97m     0.000E+00          * Dosd825    Implicit daughter
RDCORINV033   Mo-99    0.000E+00
RDCORINV034   Tc-99m    0.000E+00
RDCORINV035    Mo-101     0.000E+00          * Dosd825
RDCORINV036    Tc-101     0.000E+00          * Dosd825
RDCORINV037   Ru-103    0.000E+00            *  CHRONC
RDCORINV038    Rh-103m     0.000E+00         * Dosd825    Implicit daughter
RDCORINV039    Tc-104      0.000E+00          * Dosd825
RDCORINV040   Ru-105    0.000E+00
RDCORINV041   Rh-105    0.000E+00
RDCORINV042   Ru-106    0.000E+00            *  CHRONC
RDCORINV043   Rh-106    0.000E+00         * Dosd825
RDCORINV044   Ag-109m    0.000E+00
RDCORINV045   Ag-111    0.000E+00
RDCORINV046   Ag-112    0.000E+00
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RDCORINV047   Cd-115     0.000E+00
RDCORINV048   Cd-115m     0.000E+00
RDCORINV049   In-115m     0.000E+00
RDCORINV050   Sn-119m     0.000E+00
RDCORINV051   Sn-121     0.000E+00
RDCORINV052   Sn-123     0.000E+00
RDCORINV053   Sn-125     0.000E+00
RDCORINV054   Sb-125     0.000E+00
RDCORINV055   Xe-125     0.000E+00
RDCORINV056   I-125      0.000E+00
RDCORINV057   Te-125m     0.000E+00
RDCORINV058   I-126     0.000E+00
RDCORINV059   Sb-126     0.000E+00
RDCORINV060   Xe-127     0.000E+00
RDCORINV061   Sb-127     0.000E+00
RDCORINV062   Te-127     0.000E+00          *  CHRONC
RDCORINV063   Te-127m    0.000E+00          *  CHRONC
RDCORINV064    Sn-128    0.000E+00         * Dosd825
RDCORINV065    Sb-128a    0.000E+00         * Dosd825
RDCORINV066    Xe-129m     0.000E+00
RDCORINV067    Sb-129     0.000E+00
RDCORINV068   Te-129     0.000E+00     * Implicit daughter unless no Te-129m
RDCORINV069   Te-129m    0.000E+00          *  CHRONC
RDCORINV070    Sb-131     0.000E+00         * Dosd825
RDCORINV071    Te-131     0.000E+00         * Dosd825    Implicit daughter
RDCORINV072   Te-131m     0.000E+00
RDCORINV073   Xe-131m     0.000E+00
RDCORINV074   I-131     0.000E+00           *  CHRONC
RDCORINV075   Te-132     0.000E+00           *  CHRONC
RDCORINV076   I-132     0.000E+00           *  CHRONC
RDCORINV077   Te-133     0.000E+00         * Dosd825
RDCORINV078   Te-133m     0.000E+00         * Dosd825
RDCORINV079   I-133     1.000E+00           *  CHRONC
RDCORINV080   Xe-133     0.000E+00          *  CHRONC
RDCORINV081    Xe-133m     0.000E+00           *  CHRONC
RDCORINV082    Te-134     0.000E+00         * Dosd825
RDCORINV083   I-134     0.000E+00
RDCORINV084   Cs-134     0.000E+00           * CHRONC
RDCORINV085   I-135     0.000E+00
RDCORINV086   Xe-135     0.000E+00
RDCORINV087    Xe-135m     0.000E+00     * Implicit daughter unless I-135 is zero
RDCORINV088   Cs-137     0.000E+00           *  CHRONC
RDCORINV089    Ba-137m     0.000E+00          * Dosd825    Implicit daughter
RDCORINV090    Xe-138     0.000E+00
RDCORINV091    Cs-138     0.000E+00
RDCORINV092   Ba-139     0.000E+00
RDCORINV093   Ba-140     0.000E+00           *  CHRONC
RDCORINV094   La-140     0.000E+00           *  CHRONC
RDCORINV095    Ba-141     0.000E+00         * Dosd825
RDCORINV096   La-141     0.000E+00
RDCORINV097   Ce-141     0.000E+00
RDCORINV098    Ba-142     0.000E+00         * Dosd825
RDCORINV099   La-142     0.000E+00
RDCORINV100    La-143     0.000E+00         * Dosd825
RDCORINV101   Ce-143     0.000E+00
RDCORINV102   Pr-143     0.000E+00
RDCORINV103   Ce-144     0.000E+00           *  CHRONC
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RDCORINV104    Pr-144     0.000E+00          * Dosd825   Implicit daughter
RDCORINV105    Pr-144m    0.000E+00
RDCORINV106    Pr-145     0.000E+00          * Dosd825
RDCORINV107    Pr-147     0.000E+00          * Dosd825
RDCORINV108    Nd-147     0.000E+00
RDCORINV109    Pm-147     0.000E+00          * Dosd825
RDCORINV110    Pm-148     0.000E+00          * Dosd825
RDCORINV111    Pm-148m    0.000E+00
RDCORINV112    Nd-149     0.000E+00          * Dosd825
RDCORINV113    Pm-149     0.000E+00          * Dosd825
RDCORINV114    Pm-151     0.000E+00          * Dosd825
RDCORINV115    Sm-151     0.000E+00          * Dosd825
RDCORINV116    Sm-153     0.000E+00          * Dosd825
RDCORINV117    Eu-155     0.000E+00
RDCORINV118    Eu-156     0.000E+00
*
* ACTINIDES
*
RDCORINV119     Th-230    0.000E+00          *  CHRONC
RDCORINV120     Th-231    0.000E+00          *  CHRONC
RDCORINV121     U-234     0.000E+00          *  CHRONC
RDCORINV122     U-235     0.000E+00          *  CHRONC
RDCORINV123     U-236     0.000E+00          *  CHRONC
RDCORINV124     U-237     0.000E+00          *  CHRONC
RDCORINV125     U-238     0.000E+00
RDCORINV126     U-239     0.000E+00
RDCORINV127     Np-237    0.000E+00
RDCORINV128     Np-238    0.000E+00
RDCORINV129     Np-239    0.000E+00
RDCORINV130    Pu-238     0.000E+00          *  CHRONC
RDCORINV131    Pu-239     0.000E+00          *  CHRONC
RDCORINV132    Pu-240     0.000E+00          *  CHRONC
RDCORINV133    Pu-241     0.000E+00          *  CHRONC
RDCORINV134    Am-241     0.000E+00          *  CHRONC
RDCORINV135    Cm-242     0.000E+00          *  CHRONC
RDCORINV136    Cm-244     0.000E+00          *  CHRONC
*
* ACTIVATION PRODUCTS
*
RDCORINV137     P-32      0.000E+00
RDCORINV138     S-35      0.000E+00
RDCORINV139     Cr-51     0.000E+00
RDCORINV140     Mn-56     0.000E+00
RDCORINV141     Fe-55     0.000E+00
RDCORINV142     Fe-59     0.000E+00
RDCORINV143     Co-58     0.000E+00
RDCORINV144     Co-60     0.000E+00
RDCORINV145     Co-60m    0.000E+00
RDCORINV146     Ni-59     0.000E+00
RDCORINV147     Ni-63     0.000E+00
RDCORINV148     Ni-65     0.000E+00
*
*  SCALING FACTOR TO ADJUST UNITS FROM CURIES TO BEQUERELS
*
RDCORSCA001   3.7E10  * UNITS
*
*  RELEASE FRACTION APPLICATION TO INGROWTH DECAY PRODUCTS
```

```
*  PRODUCED AFTER ACCIDENT INITIATION
*
RDAPLFRC001    PARENT   (apply release fractions at time of accident, as prior)
*RDAPLFRC001    PROGENY   (apply release fractions at time of release)
*
* RELEASE FRACTIONS FOR ISOTOPE GROUPS IN RELEASE
*
* ISOTOPE GROUPS:
*
*           XE/KR    I     CS     TE     SR     RU     LA     CE     BA
*
RDRELFRC001   1.0      1.0   1.0    1.0    1.0    1.0    1.0    1.0    1.0
************************************************************************
* OUTPUT CONTROL DATA BLOCK, LOADED BY INPOPT, STORED IN /STOPME/, /ATMOPT/
*
* FLAG TO INDICATE THAT THIS IS THE LAST PROGRAM IN THE SERIES TO BE RUN
*
OCENDAT1001  .FALSE. (SET THIS VALUE TO .TRUE. TO SKIP EARLY AND CHRONC)
*
* SPECIFIES THE QUANTITY OF DEBUG OUTPUT TO BE PRINTED.
* 0 = no debug output.
* 1 or 2 = atmospheric transport results.
* 3 or more = also hourly meteorological data used for each weather trial.
*
OCIDEBUG001  0  (REQUESTS NO DEBUG DATA BE PRINTED)
*OCIDEBUG001  1  (REQUESTS A TRACE OF ATMOSPHERIC DISPERSION)
*
* NAME OF THE NUCLIDE TO BE LISTED ON THE DISPERSION LISTINGS
* Only required if OCIDEBUG001 > zero
*
OCNUCOUT001  Ce-144
************************************************************************
* METEOROLOGICAL SAMPLING DATA BLOCK
*
* METEOROLOGICAL SAMPLING OPTION CODE:
*
* METCOD = 1, USER SPECIFIED DAY AND HOUR IN THE YEAR (FROM MET FILE),
*          2, WEATHER CATEGORY BIN SAMPLING,
*          3, 120 HOURS OF WEATHER SPECIFIED ON THE ATMOS USER INPUT FILE,
*          4, CONSTANT MET (BOUNDARY WEATHER USED FROM THE START),
*          5, STRATIFIED RANDOM SAMPLES FOR EACH DAY OF THE YEAR.
*
M1METCOD001   2   (WEATHER BIN SAMPLING)
*
************************************************************************
* LAST SPATIAL INTERVAL FOR MEASURED WEATHER
*
M2LIMSPA001  10
*
* BOUNDARY WEATHER MIXING LAYER HEIGHT
*
M2BNDMXH001 2055.  (METERS)
*
* BOUNDARY WEATHER STABILITY CLASS INDEX
*
M2IBDSTB001  1   (A-STABILITY)
*
```

```
* BOUNDARY WEATHER RAIN RATE
*
M2BNDRAN001  0.      (MM/HR)
*
* BOUNDARY WEATHER WIND SPEED
*
M2BNDWND001  1.0      (M/S)
*
*******************************************************************************
*  START DAY IN THE YEAR FOR THE SINGLE WEATHER SEQUENCE
*  Not required for METCOD=2 (meteorological bin sampling)
*  and METCOD=5 (stratified random sampling).
*
*  M3ISTRDY001  157    (START TIME FOR PEAK ECONOMIC COST)
*
*  START HOUR IN THE DAY FOR THE SINGLE WEATHER SEQUENCE
*  Not required for METCOD=2 (meteorological bin sampling)
*  and METCOD=5 (stratified random sampling).
*
*  M3ISTRHR001  10     (START TIME FOR PEAK ECONOMIC COST)
*
*******************************************************************************
*  Data in this section are required for METCOD=2 (meteorological bin sampling)
*  NUMBER OF RAIN DISTANCE INTERVALS FOR BINNING
*
M4NRNINT001   5
*
*  ENDPOINTS OF THE RAIN DISTANCE INTERVALS (KILOMETERS)
*
*  NOTE: MUST BE CHOSEN TO MATCH THE SPATIAL ENDPOINT DISTANCES
*       SPECIFIED FOR THE ARRAY SPAEND (10% ERROR IS ALLOWED).
*
M4RNDSTS001  3.1   4.8   5.0   7.0   20.0
*
*  NUMBER OF RAIN INTENSITY BREAKPOINTS
*
M4NRINTN001   3
*
*  RAIN INTENSITY BREAKPOINTS FOR WEATHER BINNING (MM PER HOUR)
*
M4RNRATE001   3.  4.  6.
*
*  NUMBER OF SAMPLES PER WEATHER BIN
*
M4NSMPLS001    4    (a value of 4 was used with NUREG-1150)
*
*  INITIAL SEED FOR RANDOM NUMBER GENERATOR
*
M4IRSEED001  46
***************************************************************************
* CCDFs OF ATMOSPHERIC RESULTS
*
*            NUMO
*TYPEONUMBER   0   (request no CCDF results)
TYPEONUMBER   10   (request 10 CCDF results)*
*
*  How many & what kind of CCDF results
```

```
*
*              INDREL   INDRAD
TYPE0OUT001       1          1
TYPE0OUT002       1          2
TYPE0OUT003       1          3
TYPE0OUT004       1          4
TYPE0OUT005       1          5
TYPE0OUT006       1          6
TYPE0OUT007       1          7
TYPE0OUT008       1          8
TYPE0OUT009       1          9
TYPE0OUT010       1         10
*TYPE0OUT001    1        10          CCDF  (full results)
*
.
RDATNAM2001 'HCF & ACRR SAR-Weather Bin METEOROLOGICAL CONDITIONS- I-132'
RDCORINV079   I-133    0.000E+00              *  CHRONC
RDCORINV076   I-132    1.000E+00              *  CHRONC
.
RDATNAM2001 'HCF & ACRR SAR-Weather Bin METEOROLOGICAL CONDITIONS- I-135'
RDCORINV076   I-132    0.000E+00              *  CHRONC
RDCORINV085   I-135    1.000E+00
.
RDATNAM2001 'HCF & ACRR SAR-Weather Bin METEOROLOGICAL CONDITIONS- I-131'
RDCORINV085   I-135    0.000E+00
RDCORINV074   I-131    1.000E+00              *  CHRONC
.
RDATNAM2001 'HCF & ACRR SAR-Weather Bin METEOROLOGICAL CONDITIONS- I-134'
RDCORINV074   I-131    0.000E+00              *  CHRONC
RDCORINV083   I-134    1.000E+00
.
RDATNAM2001 'HCF & ACRR SAR-Weather Bin METEOROLOGICAL CONDITIONS- BR-82'
RDCORINV083   I-134    0.000E+00
RDCORINV004    Br-82       1.000E+00
.
RDATNAM2001 'HCF & ACRR SAR-Weather Bin METEOROLOGICAL CONDITIONS- BR-83'
RDCORINV004    Br-82       0.000E+00
RDCORINV005    Br-83       1.000E+00         * Dosd825
.
RDATNAM2001 'HCF & ACRR SAR-Weather Bin METEOROLOGICAL CONDITIONS- BR-84'
RDCORINV005    Br-83       0.000E+00         * Dosd825
RDCORINV007    Br-84       1.000E+00           * Dosd825
.
```

APPENDIX B, TYPICAL 1998/2000 DWDD EARLY INPUT FILE

```
* HOT CELL SINGLE ISOTOPE ACCIDENT SCENARIO RELEASE AT SNL AREA V "EARLY" INPUT
* Executed under MACCS2 input format, Use with "New" COMIDA2-Based Food Model
* when CHRONC Called
*
* GENERAL DESCRIPTIVE INFORMATION FOR "EARLY" INPUT FILE
*
MIEANAM1001 'BTNG2_EC.INP, FGRDCFs, Combined Isotopes, (HCF), EARLY INPUT'
*
* SANDIA NAT. LAB., R. E. NAEGELI, DIV 9361. (8/13/97)
* DCF file identification and location
*
DCF_FILE001  'D:\MACCS2\DOSDATA\Dosd825.inp'    *(DCF file of FGR 11 & 12)
*
* FLAG TO INDICATE THIS IS THE LAST PROGRAM IN THE SERIES TO BE RUN
*
* MIENDAT2001  .FALSE.    (SET THIS VALUE TO .TRUE. TO SKIP CHRONC)
MIENDAT2001  .TRUE.    (SET THIS VALUE TO .TRUE. TO SKIP CHRONC)
*
* DISPERSION MODEL OPTION CODE:  1  *  STRAIGHT LINE
*                                2  *  WIND-SHIFT WITH ROTATION
*                                3  *  WIND-SHIFT WITHOUT ROTATION
*
MIIPLUME001  1    (STRAIGHT LINE PLUME)
* MIIPLUME001  2    (WIND-SHIFT WITH ROTATION)
*
* NUMBER OF FINE GRID SUBDIVISIONS USED BY THE MODEL
*
MINUMFIN001  7    (3, 5 OR 7 ALLOWED)
*
* LEVEL OF DEBUG OUTPUT REQUIRED, NORMAL RUNS SHOULD SPECIFY ZERO
*
MIIPRINT001  0    (TURN OFF THE DEBUG PRINT)
*
* LOGICAL FLAG SIGNIFYING THAT THE BREAKDOWN OF RISK BY WEATHER CATEGORY
* BIN ARE TO BE PRESENTED TO SHOW THEIR RELATIVE CONTRIBUTION TO THE MEAN
*
*            RISBIN
*
MIRISCAT001   .FALSE.
*
* FLAG INDICATING IF WIND-ROSES FROM ATMOS ARE TO BE OVERRIDDEN
*
MIOVRRID001  .FALSE.  (USE THE WIND ROSE CALCULATED FOR EACH WEATHER BIN)
*******************************************************************************
* 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))
*
********************************************************************************
* SHIELDING AND EXPOSURE FACTORS, LOADED BY INDFAC, STORED IN /EADFAC/
*
* 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 ZONE
*      3 - SHELTERED ACTIVITY
*
* CLOUD SHIELDING FACTOR
*
*    SITE                GG   PB   SEQ  SUR  ZION
*    SHELTERING  0.7   0.5   0.65   0.6   0.5
*
*            EVACUEES  NORMAL  SHELTER
*
SECSFACT001    1.0     0.75     0.1   *  SNL SHELTERING VALUES
*
* PROTECTION FACTOR FOR INHALATION
*
SEPROTIN001     1.0     0.4      0.1  * VALUES FOR NORMAL ACTIVITY AND
*                                         SHELTERING SELECTED BY NRC STAFF
*
* BREATHING RATE (CUBIC METERS PER SECOND)
*
SEBRRATE001  3.47E-4  2.66E-4  1.8E-4
* SEBRRATE001  3.47E-4  3.47E-4  3.47E-4      *  1994 HCF SAR values
*
* SKIN PROTECTION FACTOR
*
SESKPFAC001  1.0      0.41     0.33    * VALUES FOR NORMAL ACTIVITY AND
*                                        SHELTERING SELECTED BY NRC STAFF
*
* GROUND SHIELDING FACTOR
*
*    SITE        GG   PB   SEQ  SUR  ZION
*    SHELTERING  0.25 0.1  0.2  0.2  0.1
*
SEGSHFAC001      0.8    0.4    0.05   * SHIELDING FACTORS J.SPRUNG & NRC STAFF
*
* RESUSPENSION INHALATION MODEL CONCENTRATION COEFFICIENT (SECOND/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 SCENARIO BEING USED
*
EZEANAM2001  'WORST CASE NO EVACUATION '
*
* 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 ARE EFFECTED)
*
* LAST RING IN THE MOVEMENT ZONE
*
EZLASMOV001     0    (NO EVACUATION)
*
* FIRST SPATIAL INTERVAL IN THE EVACUATION ZONE
*
* EZINIEVA001      1     (NO INNER SHELTER ZONE)
*
* OUTER BOUNDS ON 3 EVACUATION ZONES (ZERO MEANS THE ZONE IS NOT DEFINED)
*
* EZLASEVA001      0   0   10  (SINGLE EVACUATION ZONE OUT TO 10 MILES)
*
* EVACUATION DELAY TIMES FOR THE 3 EVACUATION ZONES
* THIS IS THE DELAY TIME FROM OALARM (ATMOS) TO WHEN PEOPLE START MOVING
*
* EZEDELAY001     0.  0.  7200.  (SURRY)
*
* RADIAL EVACUATION SPEED (M/S)
*
* EZESPEED001    1.8             (SURRY)
*******************************************************************
* SHELTER AND RELOCATION ZONE DATA BLOCK, LOADED BY INPEMR,
*                                         STORED IN /INPSRZ/, /RELOCA/
*
* DURATION OF THE EMERGENCY PHASE (SECONDS FROM PLUME ARRIVAL)
*
SRENDEMP001  86400.   (ONE DAY)
* SRENDEMP001  172800.   (2 DAYS)
* SRENDEMP001  259200.   (3 DAYS)
* SRENDEMP001  345600.   (4 DAYS)
* SRENDEMP001  432000.   (5 DAYS)
* SRENDEMP001  518400.   (6 DAYS)
* SRENDEMP001  604800.   (ONE WEEK)
*
* CRITICAL ORGAN FOR RELOCATION DECISIONS
*
SRCRIORG001    'L-EFFECTIVE'
*
* HOT SPOT RELOCATION TIME (SECONDS FROM PLUME ARRIVAL)
*
```

```
SRTIMHOT001  7200.    (NO RELOCATION)
*
* NORMAL RELOCATION TIME (SECONDS FROM PLUME ARRIVAL)
*
SRTIMNRM001 7200.    (NO RELOCATION)
*
* HOT SPOT RELOCATION DOSE CRITERION THRESHOLD (SIEVERTS)
*
SRDOSHOT001  0.5    (50 REM DOSE TO WHOLE BODY IN 1 WEEK TRIGGERS RELOCATION)
*
* NORMAL RELOCATION DOSE CRITERION THRESHOLD (SIEVERTS)
*
SRDOSNRM001  0.25   (25  REM DOSE TO WHOLE BODY IN 1 WEEK TRIGGERS RELOCATION)
********************************************************************************
* EARLY FATALITY MODEL PARAMETERS, LOADED BY INEFAT, STORED IN /EFATAL/
*
* NUMBER OF EARLY FATALITY EFFECTS
*
EFNUMEFA001   0
*
********************************************************************************
* EARLY INJURY MODEL PARAMETERS, LOADED BY INEINJ, STORED IN /EINJUR/
*
* NUMBER OF EARLY INJURY EFFECTS
*
EINUMEIN001   0
*
********************************************************************************
* ACUTE EXPOSURE CANCER PARAMETERS, LOADED BY INACAN STORED IN /ACANCR/.
*
* NUMBER OF LATENT EXPOSURE CANCER EFFECTS
*
LCNUMACA001   4
*
* THRESHOLD DOSE FOR APPLYING THE DOSE DEPENDENT REDUCTION FACTOR
*
LCDDTHRE001   1.0  (LOWEST DOSE FOR WHICH DDREFA WILL BE APPLIED)
*
* DOSE THRESHOLD FOR LINEAR DOSE RESPONSE (SV)
*
LCACTHRE001  1.5  (LINEAR-QUADRATIC MODEL IS NOT BEING USED)
*
*            ACNAME     ORGNAM   ACSUSC  DOSEFA  DOSEFB  CFRISK  CIRISK  DDREFA
*
LCANCERS001 'LEUKEMIA'  'L-RED MARR'   1.0   1.0   0.0   9.70E-3  9.70E-3   2.0
LCANCERS002 'BONE'      'L-BONE SUR'   1.0   1.0   0.0   9.00E-4  9.00E-4   2.0
* LCANCERS003 'BREAST'    'L-BREAST'    1.0   1.0   0.0   5.40E-3  1.59E-2   1.0
LCANCERS003 'LUNG'       'L-LUNGS'     1.0   1.0   0.0   1.55E-2  1.73E-2   2.0
LCANCERS004 'THYROID'    'L-THYROID'   1.0   1.0   0.0   7.20E-4  7.20E-3   1.0
*
********************************************************************************
* RESULT 1 OPTIONS BLOCK, LOADED BY INOUT1, STORED IN /INOUT1/
* TOTAL NUMBER OF A GIVEN EFFECT (LATENT CANCER, EARLY DEATH, EARLY INJURY)
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE1NUMBER    5
```

```
*
TYPE1OUT001     'CAN FAT/LUNG'                   1  10
TYPE1OUT002     'CAN FAT/THYROID'                1  10
TYPE1OUT003     'CAN FAT/LEUKEMIA'               1  10
TYPE1OUT004     'CAN FAT/BONE'                   1  10
TYPE1OUT005     'CAN FAT/TOTAL'                  1  10
*******************************************************************************
* 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  3
*
*           FATALITY RISK THRESHOLD
*
TYPE2OUT001  0.0
TYPE2OUT002  0.005
TYPE2OUT003  0.5                                                   *CCDF
*******************************************************************************
* RESULT 3 OPTIONS BLOCK, LOADED BY INOUT3, STORED IN /INOUT3/
* NUMBER OF PEOPLE WHOSE DOSE TO A GIVEN ORGAN EXCEEDS A GIVEN THRESHOLD.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE3NUMBER  1
*
*              ORGAN NAME   DOSE THRESHOLD (SV)   DOSE FLAG
*
TYPE3OUT001     'L-EFFECTIVE'        0.05        *CCDF
* TYPE3OUT002     'A-RED MARR'        1.5        *CCDF
* TYPE3OUT003     'A-LUNGS'           5.0            *CCDF
*******************************************************************************
* 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  0
*
*           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'
* TYPE4OUT006       6          'ERL FAT/TOTAL'
* TYPE4OUT007       7          'ERL FAT/TOTAL'
* TYPE4OUT008       8          'ERL FAT/TOTAL'
```

```
* TYPE4OUT009        9          'ERL FAT/TOTAL'
* TYPE4OUT010        10         '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     4
*
*            ORGAN      I1DIS5     I2DIS5
*
*TYPE5OUT001    'L-EFFECTIVE'      1         7            *(0 - 6 MILES)
TYPE5OUT001    'L-EFFECTIVE'     1         10      * CCDF (0 to 20 MILES)
TYPE5OUT002    'L-LUNGS'         1         10      * CCDF (0 to 20 MILES)
TYPE5OUT003    'L-RED MARR'      1         10      * CCDF (0 to 20 MILES)
TYPE5OUT004    'L-THYROID'       1         10
*****************************************************************************
* RESULT 6 OPTIONS BLOCK, LOADED BY INOUT6, STORED IN /INOUT6/
*
* CENTERLINE DOSE TO AN ORGAN VS DIST BY PATHWAY, PATHWAY NAMES ARE AS FOLLOWS:
*
*  PATHWAY NAME:
*    '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
TYPE6NUMBER     4
*
*            ORGNAM        PATHNM      I1DIS6   I2DIS6
*
TYPE6OUT001  'L-LUNGS'       'TOT LIF'      1       10    * (0 to 20 MILES)
TYPE6OUT002  'L-THYROID'     'TOT LIF'      1       10
TYPE6OUT003 'L-EFFECTIVE'    'TOT LIF'      1       10       * CCDF
TYPE6OUT004  'L-RED MARR'    'TOT LIF'      1       10     * (0 to 20 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
TYPE7NUMBER   1
*
*                  NAME             I1DIS7       I2DIS7
*
* TYPE7OUT001     'ERL FAT/TOTAL'        1            10       * (0-20 MILES)
```

```
TYPE7OUT001     'CAN FAT/TOTAL'        1           10        * (0 to 20 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   1
*
*                NAME        I1DIS8  I2DIS8
*
* TYPE8OUT001   'ERL FAT/TOTAL'   1       5      CCDF      (0-4 MI)
TYPE8OUT001   'CAN FAT/TOTAL'   1       10   *  CCDF    * (0 to 20 MILES)
******************************************************************************
* RESULT A OPTIONS BLOCK, LOADED BY INOUTA, STORED IN /INOUTA/
*
* PEAK TOTAL DOSE AT A DISTANCE
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPEANUMBER   1
*
*                           NAME        I1DISA     I2DISA
*
* TYPEAOUT001   'L-EFFECTIVE'   1       5         * (0-4 MI)
* TYPEAOUT001  'L-LUNGS'        1       10         * (0 to 20 MILES)
* TYPEAOUT001  'L-THYROID'      1       10         * (0 to 20 MILES)
TYPEAOUT001   'L-EFFECTIVE'   1       10         * (0 to 20 MILES)
*TYPEAOUT001   'L-REDMARR'      1       10         * (0 to 20 MILES)
******************************************************************************
* RESULT B OPTIONS BLOCK, LOADED BY INOUTA, STORED IN /INOUTB/
*
* PEAK TOTAL DIRECT DOSE FOUND ON A SPATIAL GRID LOCATION
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
* TYPEBNUMBER   16
TYPEBNUMBER   0
*
*                           NAME        IRAD_B     IANG_B
*
* TYPEBOUT001   'L-EFFECTIVE'   3     15        * (KUMSC, 1.5-1.7 km to NW)
* TYPEBOUT001   'L-REDMARR'     3     15        * (KUMSC, 1.5-1.7 km to NW)
*
* TYPEBOUT001   'L-EFFECTIVE'   2     1    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT002   'L-EFFECTIVE'   2     2    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT003   'L-EFFECTIVE'   2     3    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT004   'L-EFFECTIVE'   2     4    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT005   'L-EFFECTIVE'   2     5    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT006   'L-EFFECTIVE'   2     6    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT007   'L-EFFECTIVE'   2     7    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT008   'L-EFFECTIVE'   2     8    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT009   'L-EFFECTIVE'   2     9    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT010   'L-EFFECTIVE'   2    10    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT011   'L-EFFECTIVE'   2    11    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT012   'L-EFFECTIVE'   2    12    * (EDE, 0.1-0.5 km to direction shown)
```

```
* TYPEBOUT013   'L-EFFECTIVE'   2    13    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT014   'L-EFFECTIVE'   2    14    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT015   'L-EFFECTIVE'   2    15    * (EDE, 0.1-0.5 km to direction shown)
* TYPEBOUT016   'L-EFFECTIVE'   2    16    * (EDE, 0.1-0.5 km to direction shown)
*
* TYPEBOUT001   'L-EFFECTIVE'   6     1    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT002   'L-EFFECTIVE'   6     2    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT003   'L-EFFECTIVE'   6     3    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT004   'L-EFFECTIVE'   6     4    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT005   'L-EFFECTIVE'   6     5    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT006   'L-EFFECTIVE'   6     6    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT007   'L-EFFECTIVE'   6     7    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT008   'L-EFFECTIVE'   6     8    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT009   'L-EFFECTIVE'   6     9    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT010   'L-EFFECTIVE'   6    10    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT011   'L-EFFECTIVE'   6    11    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT012   'L-EFFECTIVE'   6    12    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT013   'L-EFFECTIVE'   6    13    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT014   'L-EFFECTIVE'   6    14    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT015   'L-EFFECTIVE'   6    15    * (EDE, 2.9-3.1 km to direction shown)
* TYPEBOUT016   'L-EFFECTIVE'   6    16    * (EDE, 2.9-3.1 km to direction shown)
.
```

APPENDIX C, TYPICAL 2002 DWDD ATMOS INPUT FILE

```
* Single ISOTOPES ACCIDENT SCENARIO RELEASE AT SANDIA AREA V "ATMOS" INPUT
* Executed under MACCS2 input
*
RIATNAM1001 'PGS3dA.INP, FGRDCFs, Multiple Isotopes, ATMOS'
* Pu-239, Th-230,Th-231,Th-234,U-234,U-235,U-236,U-237,U-238,U-239,Np-237,
* Np-238,Np-239,Pu-238,Pu-239,Pu-240,Pu-241,Pu-242,Am-241,Cm-242,Cm-244
*
*  SANDIA NAT.LAB., R. E. NAEGELI, DIV 06433. (11/15/02)
*    ***** GIF Stack RELEASE, No WAKE, 0.0W BOUYANT PLUME No Entrainment****
*    ***** Single RADIONUCLIDES BEING MODELED****
*    ***** RELEASE FRACTIONS ALL SET TO 1.0 ****
*    ***** Tador/Gur Power Law for Sigma Y & Z ****
*    ***** SAMPLING of all 8760 Met Hours ****
*    ***** DOE-STD-3009 App A Input + Louis Restrepo ****
*    ***** Dose in rem since multiplier on 1.0 Ci activity is 3.7E12 ****
********************************************************************************
* GEOMETRY DATA BLOCK, LOADED BY INPGEO, STORED IN /GEOM/
*
* NUMBER OF RADIAL SPATIAL ELEMENTS
*
GENUMRAD001  16
*
*  SANDIA TA-V Radial Distances
*
GESPAEND001  0.05  0.15  0.25  0.35  0.45  0.55  0.95  1.05
GESPAEND002  1.50  1.70  2.95  3.05  4.80  5.00  7.00  20.00
*
*
********************************************************************************
* NUCLIDE DATA BLOCK
*
* NUMBER OF NUCLIDES
* --------------------------------
ISNUMISO001    20         NUMBER OF ISOTOPES = CORE INVENTORY
* --------------------------------
* NUMBER OF NUCLIDE GROUPS
*
ISMAXGRP001    9
*
* WET AND DRY DEPOSITION FLAGS FOR EACH NUCLIDE GROUP
*
*              WETDEP     DRYDEP
*
ISDEPFLA001    .FALSE.   .FALSE.
ISDEPFLA002    .FALSE.   .FALSE.
ISDEPFLA003    .FALSE.   .FALSE.
ISDEPFLA004    .FALSE.   .FALSE.
ISDEPFLA005    .FALSE.   .FALSE.
```

```
ISDEPFLA006     .FALSE.    .FALSE.
ISDEPFLA007     .FALSE.    .FALSE.
ISDEPFLA008     .FALSE.    .FALSE.
ISDEPFLA009     .FALSE.    .FALSE.
*
* Number of pseudostable nuclides (used to truncate the decay chains)
*
ISNUMSTB001      9
*
* List of pseudostable nuclides
*
*               NAMSTB
*
ISNAMSTB001     Th-232  (daughter of U-236)
ISNAMSTB002     Pa-231  (daughter of Th-231)
ISNAMSTB003     Th-229
ISNAMSTB004     Pa-233
ISNAMSTB005     Pa-234
ISNAMSTB006     Pa-234m
ISNAMSTB007     Ra-226
ISNAMSTB008     Rn-222
ISNAMSTB009     U-233
*
* NUCLIDE GROUP DATA FOR 9 NUCLIDE GROUPS
*
*              NUCNAM       IGROUP
*
* ACTINIDES
*
ISOTPGRP001     Th-230        8
ISOTPGRP002     Th-231        8
ISOTPGRP003     Th-234        8
ISOTPGRP004     U-234         8
ISOTPGRP005     U-235         8
ISOTPGRP006     U-236         8
ISOTPGRP007     U-237         8
ISOTPGRP008     U-238         8
ISOTPGRP009     U-239         8
ISOTPGRP010     Np-237        8
ISOTPGRP011     Np-238        8
ISOTPGRP012     Np-239        8
ISOTPGRP013     Pu-238        8
ISOTPGRP014     Pu-239        8
ISOTPGRP015     Pu-240        8
ISOTPGRP016     Pu-241        8
ISOTPGRP017     Pu-242        8
ISOTPGRP018     Am-241        7
ISOTPGRP019     Cm-242        7
ISOTPGRP020     Cm-244        7
*
*****************************************************************************
* WET DEPOSITION DATA BLOCK, LOADED BY INPWET, STORED IN /WETCON/
*
* WASHOUT COEFFICIENT NUMBER ONE, LINEAR FACTOR
*
* WDCWASH1001  9.5E-5   (Brenk & Vogt, 1981 After Jones, 1986)
WDCWASH1001  0.0
```

```
*
* WASHOUT COEFFICIENT NUMBER TWO, EXPONENTIAL FACTOR
*
WDCWASH2001  0.8      (Brenk & Vogt, 1981 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   0.001
DDVDEPOS001   0.0
*
*********************************************************************************
* 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
*
* USE OF OPTIONAL DISPERSION TABLES INSTEAD OF THE POWER-LAW MODEL
*
NUM_DIST001  0  (dispersion tables are not being supplied, use power-law)
*
*********************************************************************************
*  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    1.0   (3 cm for flat land with Tadmor and Gur parameters)
*
********************************************************************************
* EXPANSION FACTOR DATA BLOCK, LOADED BY INPEXP, STORED IN /EXPAND/
*
* TIME BASE FOR EXPANSION FACTOR (SECONDS)
*
PMTIMBAS001     600.   (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.
PRSCLCRW001   1.0E+06
*
* 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
*
* BUILDING HEIGHT (METERS) This is now used just for plume rise entrainment.
*
WEBUILDH001   1.0    * Ground Release
* WEBUILDH001  14.3    *  9.4 ACRR + 4.9 PENTHOUSE (ACRR) (HCF too)
* WEBUILDH001   7.5    *  SPRF KIVA
* WEBUILDH001   4.0    *  SURF UTF
* WEBUILDH001  13.5    *  GIF
*
* Initial Value for Plume Sigma-y (m) due to wake effects
*
* SIGYINIT001  9.302  (initial sigma-y=W/4.3 for MACCS, for 40-m wide bldg.)
* SIGYINIT001  3.488 (initial sigma-y=W/4.3 for MACCS, for 15-m wide ACRR & HCF)
* SIGYINIT001  2.791  (initial sigma-y=W/4.3 for MACCS, for 12-m wide SPRF)
* SIGYINIT001  5.814  (initial sigma-y=W/4.3 for MACCS, for 25-m wide GIF)
```

```
SIGYINIT001  0.1   (initial sigma-y=W/4.3 for no wake or SURF)
*
* Initial Value for Plume Sigma-z (m) due to wake effects
*
* SIGZINIT001  23.26  (initial sigma-z=W/2.15 for MACCS, for 50-m high bldg.)
* SIGZINIT001  6.651  (initial sigma-z=W/2.15 for MACCS, 14.3-m high ACRR & HCF)
* SIGZINIT001  3.488  (initial sigma-z=W/2.15 for MACCS, for 7.5-m high SPRF)
* SIGZINIT001  6.279  (initial sigma-z=W/2.15 for MACCS, for 13.5-m high GIF)
SIGZINIT001  0.1   (initial sigma-z=W/2.15 for no wake or SURF)
*
*****************************************************************************
* RELEASE DATA BLOCK, LOADED BY INPREL, STORED IN /ATNAM2/, /MULREL/
*
* Specific Descriptive Text Describing This Particular Source Term
*
RDATNAM2001 'PGS3 SAR -Random Sampling Meteorological Conditions- Pu-239'
*
* Time of notification of off-site emergency response measured from accident
* initiation (s)
*
RDOALARM001      0.0
*
* NUMBER OF PLUME SEGMENTS THAT ARE RELEASED
*
RDNUMREL001       1
*
* SELECTION OF RISK DOMINANT PLUME
*
RDMAXRIS001       1
*
* REFERENCE TIME FOR DISPERSION & RADIOACTIVE DECAY (LEADING EDGE OF THE PLUME)
*
RDREFTIM001      0.0
*
* HEAT CONTENT OF THE RELEASE SEGMENTS (W)
*
RDPLHEAT001      0.0
*
* HEIGHT OF THE PLUME SEGMENTS AT RELEASE (M)
*
* RDPLHITE001    0.0      PARKING LOT
* RDPLHITE001    4.3     GIF HIGH BAY VENTS
* RDPLHITE001    10.0     SPRF & SURF
* RDPLHITE001    14.3     ACRR/SNL
* RDPLHITE001    16.4     AHCF STACK
RDPLHITE001    18.0     GIF OZONE STACK
* RDPLHITE001    38.1     HCF STACK
*
* DURATION OF THE PLUME SEGMENTS (S)
*
RDPLUDUR001     600.
*
* TIME OF RELEASE FOR EACH PLUME (S AFTER SCRAM)
*
RDPDELAY001      0.
*
* PARTICLE SIZE DISTRIBUTION OF EACH NUCLIDE GROUP
```

```
*
RDPSDIST001      1.
RDPSDIST002      1.
RDPSDIST003      1.
RDPSDIST004      1.
RDPSDIST005      1.
RDPSDIST006      1.
RDPSDIST007      1.
RDPSDIST008      1.
RDPSDIST009      1.
*
* CORE INVENTORY INFORMATION
*
*             NUCNAM    INVENTORY(Ci)
*
* ACTINIDES
*
RDCORINV001   Th-230    0.000E+00
RDCORINV002   Th-231    0.000E+00
RDCORINV003   Th-234    0.000E+00
RDCORINV004   U-234     0.000E+00
RDCORINV005   U-235     0.000E+00
RDCORINV006   U-236     0.000E+00
RDCORINV007   U-237     0.000E+00
RDCORINV008   U-238     0.000E+00
RDCORINV009   U-239     0.000E+00
RDCORINV010   Np-237    0.000E+00
RDCORINV011   Np-238    0.000E+00
RDCORINV012   Np-239    0.000E+00
RDCORINV013   Pu-238    0.000E+00
RDCORINV014   Pu-239    1.000E+00
RDCORINV015   Pu-240    0.000E+00
RDCORINV016   Pu-241    0.000E+00
RDCORINV017   Pu-242    0.000E+00
RDCORINV018   Am-241    0.000E+00
RDCORINV019   Cm-242    0.000E+00
RDCORINV020   Cm-244    0.000E+00
*
*  SCALING FACTOR TO ADJUST UNITS FROM CURIES TO BEQUERELS
*
RDCORSCA001   3.7E12    * 100 Bq/Ci -- Result is Dose in rem not Sv
*
*  RELEASE FRACTION APPLICATION TO INGROWTH DECAY PRODUCTS
*  PRODUCED AFTER ACCIDENT INITIATION
*
RDAPLFRC001    PARENT   (apply release fractions at time of accident, as prior)
*
* RELEASE FRACTIONS FOR ISOTOPE GROUPS IN RELEASE
*
* ISOTOPE GROUPS:
*
*            XE/KR    I      CS      TE      SR      RU      LA      CE      BA
*
RDRELFRC001   1.0      1.0   1.0     1.0     1.0     1.0     1.0     1.0     1.0
******************************************************************************
* OUTPUT CONTROL DATA BLOCK, LOADED BY INPOPT, STORED IN /STOPME/, /ATMOPT/
*
```

```
* FLAG TO INDICATE THAT THIS IS THE LAST PROGRAM IN THE SERIES TO BE RUN
*
OCENDAT1001  .FALSE. (SET THIS VALUE TO .TRUE. TO SKIP EARLY AND CHRONC)
*
* SPECIFIES THE QUANTITY OF DEBUG OUTPUT TO BE PRINTED.
* 0 = no debug output.
* 1 or 2 = atmospheric transport results.
* 3 or more = also hourly meteorological data used for each weather trial.
*
OCIDEBUG001  0  (REQUESTS NO DEBUG DATA BE PRINTED)
*OCIDEBUG001  1  (REQUESTS A TRACE OF ATMOSPHERIC DISPERSION)
*
* NAME OF THE NUCLIDE TO BE LISTED ON THE DISPERSION LISTINGS
* Only required if OCIDEBUG001 > zero
*
OCNUCOUT001  Pu-239
*
*****************************************************************************
* METEOROLOGICAL SAMPLING DATA BLOCK
*
* METEOROLOGICAL SAMPLING OPTION CODE:
*
* METCOD = 1, USER SPECIFIED DAY AND HOUR IN THE YEAR (FROM MET FILE),
*          2, WEATHER CATEGORY BIN SAMPLING,
*          3, 120 HOURS OF WEATHER SPECIFIED ON THE ATMOS USER INPUT FILE,
*          4, CONSTANT MET (BOUNDARY WEATHER USED FROM THE START),
*          5, STRATIFIED RANDOM SAMPLES FOR EACH DAY OF THE YEAR.
*
M1METCOD001   5   (Stratified Random SAMPLING)
*
*****************************************************************************
* LAST SPATIAL INTERVAL FOR MEASURED WEATHER
*
M2LIMSPA001  16
*
* BOUNDARY WEATHER MIXING LAYER HEIGHT
*
M2BNDMXH001 2055.  (METERS)
*
* BOUNDARY WEATHER STABILITY CLASS INDEX
*
* M2IBDSTB001  1   (A-STABILITY)
M2IBDSTB001  6   (F-STABILITY)
*
* BOUNDARY WEATHER RAIN RATE
*
M2BNDRAN001  0.     (MM/HR)
*
* BOUNDARY WEATHER WIND SPEED
*
M2BNDWND001  1.0     (M/S)
*
*****************************************************************************
*  START DAY IN THE YEAR FOR THE SINGLE WEATHER SEQUENCE
*  Not required for METCOD=2 (meteorological bin sampling)
*  and METCOD=5 (stratified random sampling).
*
```

```
*  M3ISTRDY001  157    (START TIME FOR PEAK ECONOMIC COST)
*
*  START HOUR IN THE DAY FOR THE SINGLE WEATHER SEQUENCE
*  Not required for METCOD=2 (meteorological bin sampling)
*  and METCOD=5 (stratified random sampling).
*
*  M3ISTRHR001  10     (START TIME FOR PEAK ECONOMIC COST)
*
*****************************************************************************
*  Data in this section are required for METCOD=5 (Stratified Random sampling)
*
*  NUMBER OF SAMPLES PER WEATHER BIN (or Random Samples per day)
*
* M4NSMPLS001    6    (6 samples per day or one from each 4 hours)
M4NSMPLS001   24    (24 samples per day or all met data)
*
*  INITIAL SEED FOR RANDOM NUMBER GENERATOR
*
M4IRSEED001   46
**************************************************************************
* CCDFs OF ATMOSPHERIC RESULTS
*
*             NUMO
TYPEONUMBER   16   (request 16 CCDF results)
*
*  How many & what kind of CCDF results
*
*             INDREL   INDRAD
TYPEOOUT001      1        1
TYPEOOUT002      1        2
TYPEOOUT003      1        3
TYPEOOUT004      1        4
TYPEOOUT005      1        5
TYPEOOUT006      1        6
TYPEOOUT007      1        7
TYPEOOUT008      1        8
TYPEOOUT009      1        9
TYPEOOUT010      1       10
TYPEOOUT011      1       11
TYPEOOUT012      1       12
TYPEOOUT013      1       13
TYPEOOUT014      1       14
TYPEOOUT015      1       15
TYPEOOUT016      1       16
*
.
RDATNAM2001 'PGS3 SAR -Random Sampling Meteorological Conditions- Th-230'
RDCORINV014   Pu-239    0.000E+00
RDCORINV001   Th-230    1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Th-231'
RDCORINV001   Th-230    0.000E+00
RDCORINV002   Th-231    1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Th-234'
RDCORINV002   Th-231    0.000E+00
RDCORINV003   Th-234    1.000E+00
```

```
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- U-234'
RDCORINV003   Th-234     0.000E+00
RDCORINV004   U-234      1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- U-235'
RDCORINV004   U-234      0.000E+00
RDCORINV005   U-235      1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- U-236'
RDCORINV005   U-235      0.000E+00
RDCORINV006   U-236      1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- U-237'
RDCORINV006   U-236      0.000E+00
RDCORINV007   U-237      1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- U-238'
RDCORINV007   U-237      0.000E+00
RDCORINV008   U-238      1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- U-239'
RDCORINV008   U-238      0.000E+00
RDCORINV009   U-239      1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Np-237'
RDCORINV009   U-239      0.000E+00
RDCORINV010   Np-237     1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Np-238'
RDCORINV010   Np-237     0.000E+00
RDCORINV011   Np-238     1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Np-239'
RDCORINV011   Np-238     0.000E+00
RDCORINV012   Np-239     1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Pu-238'
RDCORINV012   Np-239     0.000E+00
RDCORINV013   Pu-238     1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Pu-239'
RDCORINV013   Pu-238     0.000E+00
RDCORINV014   Pu-239     1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Pu-240'
RDCORINV014   Pu-239     0.000E+00
RDCORINV015   Pu-240     1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Pu-241'
RDCORINV015   Pu-240     0.000E+00
RDCORINV016   Pu-241     1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Pu-242'
RDCORINV016   Pu-241     0.000E+00
RDCORINV017   Pu-242     1.000E+00
.
```

```
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Am-241'
RDCORINV017   Pu-242    0.000E+00
RDCORINV018   Am-241    1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Cm-242'
RDCORINV018   Am-241    0.000E+00
RDCORINV019   Cm-242    1.000E+00
.
RDATNAM2001 'PGS2 SAR -Random Sampling Meteorological Conditions- Cm-244'
RDCORINV019   Cm-242    0.000E+00
RDCORINV020   Cm-244    1.000E+00
.
```

APPENDIX D, TYPICAL 2002 DWDD EARLY INPUT FILE

```
* SINGLE ISOTOPE ACCIDENT SCENARIO RELEASE AT SANDIA AREA V "EARLY" INPUT
* Executed under MACCS2 input format
*
* GENERAL DESCRIPTIVE INFORMATION FOR "EARLY" INPUT FILE
* ***** DOE-STD-3009 App. A Input ******
*
MIEANAM1001 'PGS1E.INP, FGRDCFs, Single Isotopes, EARLY INPUT'
*
* SANDIA NAT. LAB., R. E. NAEGELI, DIV 6433. (10/4/02)
* DCF file identification and location
*
DCF_FILE001  'D:\MACCS2\DOSDATA\Dosd825.inp'    *(DCF file of FGR 11 & 12)
*
* FLAG TO INDICATE THIS IS THE LAST PROGRAM IN THE SERIES TO BE RUN
*
MIENDAT2001  .TRUE.    (SET THIS VALUE TO .TRUE. TO SKIP CHRONC)
*
* DISPERSION MODEL OPTION CODE:  1  *  STRAIGHT LINE
*                                2  *  WIND-SHIFT WITH ROTATION
*                                3  *  WIND-SHIFT WITHOUT ROTATION
*
MIIPLUME001  1    (STRAIGHT LINE PLUME)
*
* NUMBER OF FINE GRID SUBDIVISIONS USED BY THE MODEL
*
MINUMFIN001  7    (3, 5 OR 7 ALLOWED)
*
* LEVEL OF DEBUG OUTPUT REQUIRED, NORMAL RUNS SHOULD SPECIFY ZERO
*
MIIPRINT001  0    (TURN OFF THE DEBUG PRINT)
*
* LOGICAL FLAG SIGNIFYING THAT THE BREAKDOWN OF RISK BY WEATHER CATEGORY
* BIN ARE TO BE PRESENTED TO SHOW THEIR RELATIVE CONTRIBUTION TO THE MEAN
*
*            RISBIN
*
MIRISCAT001   .FALSE.   (Do not print out risk contribution tables)
*
* FLAG INDICATING IF WIND-ROSES FROM ATMOS ARE TO BE OVERRIDDEN
*
MIOVRRID001   .FALSE.   (If no wind-roses are passed, uniform wind-roses used.)
********************************************************************************
* POPULATION DISTRIBUTION DATA BLOCK, LOADED BY INPOPU, STORED IN /POPDAT/
*
PDPOPFLG001  UNIFORM
PDIBEGIN001  1   (SPATIAL INTERVAL AT WHICH POPULATION BEGINS)
PDPOPDEN001  50. (POPULATION DENSITY (PEOPLE PER SQUARE KILOMETER))
*
```

```
*******************************************************************************
* SHIELDING AND EXPOSURE FACTORS, LOADED BY INDFAC, STORED IN /EADFAC/
*
* 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 ZONE
*      3 - SHELTERED ACTIVITY
*
* CLOUD SHIELDING FACTOR
*
*            EVACUEES  NORMAL  SHELTER
*
SECSFACT001     1.0      1.0     1.0
*
* PROTECTION FACTOR FOR INHALATION
*
SEPROTIN001     1.0      1.0      1.0
*
* BREATHING RATE (CUBIC METERS PER SECOND)
*
SEBRRATE001   3.47E-4  3.47E-4  3.47E-4
*
* SKIN PROTECTION FACTOR
*
SESKPFAC001     1.0      1.0     1.0
*
* GROUND SHIELDING FACTOR
*
SEGSHFAC001     1.0      1.0     1.0
*
* RESUSPENSION INHALATION MODEL CONCENTRATION COEFFICIENT (SECOND/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   0.0     (RESUSPENSION IS TURNED OFF)
*
* 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 SCENARIO BEING USED
*
EZEANAM2001  'WORST CASE NO EVACUATION '
*
* 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 ARE EFFECTED)
*
* LAST RING IN THE MOVEMENT ZONE
*
EZLASMOV001     0    (NO EVACUATION)
*
*************************************************************************
* SHELTER AND RELOCATION ZONE DATA BLOCK, LOADED BY INPEMR,
*                                          STORED IN /INPSRZ/, /RELOCA/
*
* DURATION OF THE EMERGENCY PHASE (SECONDS FROM PLUME ARRIVAL)
*
SRENDEMP001   86400.   (ONE DAY-Minium Time Allowed by MACCS2)
*
* CRITICAL ORGAN FOR RELOCATION DECISIONS
*
SRCRIORG001   'L-EFFECTIVE'
*
* HOT SPOT RELOCATION TIME (SECONDS FROM PLUME ARRIVAL)
*
SRTIMHOT001   7200.    (NO RELOCATION)
*
* NORMAL RELOCATION TIME (SECONDS FROM PLUME ARRIVAL)
*
SRTIMNRM001   7200.    (NO RELOCATION)
*
* HOT SPOT RELOCATION DOSE CRITERION THRESHOLD (SIEVERTS)
*
SRDOSHOT001   0.5    (50 REM DOSE TO WHOLE BODY IN 1 WEEK TRIGGERS RELOCATION)
*
* NORMAL RELOCATION DOSE CRITERION THRESHOLD (SIEVERTS)
*
SRDOSNRM001   0.25   (25  REM DOSE TO WHOLE BODY IN 1 WEEK TRIGGERS RELOCATION)
**********************************************************************************
* EARLY FATALITY MODEL PARAMETERS
*
* NUMBER OF EARLY FATALITY EFFECTS
*
EFNUMEFA001   0      (Early Fatality Turned Off)
*
**********************************************************************************
* EARLY INJURY MODEL PARAMETERS
*
* NUMBER OF EARLY INJURY EFFECTS
*
EINUMEIN001   0      (Early Injury Effects Turned Off)
*
**********************************************************************************
* ACUTE EXPOSURE CANCER PARAMETERS
*
* NUMBER OF LATENT EXPOSURE CANCER EFFECTS
*
LCNUMACA001   0      (Latent Cancer Effects Turned Off)
*
**********************************************************************************
```

```
* RESULT 1 OPTIONS BLOCK
* TOTAL NUMBER OF A GIVEN EFFECT (LATENT CANCER, EARLY DEATH, EARLY INJURY)
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE1NUMBER    0    (Given Health Effects Turned Off)
*
******************************************************************************
* RESULT 2 OPTIONS BLOCK
* FURTHEST DISTANCE AT WHICH A GIVEN RISK OF EARLY DEATH IS EXCEEDED.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE2NUMBER    0    (Early Fatalities Turned Off)
*
******************************************************************************
* RESULT 3 OPTIONS BLOCK
* NUMBER OF PEOPLE WHOSE DOSE TO A GIVEN ORGAN EXCEEDS A GIVEN THRESHOLD.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE3NUMBER    0    (Population Exceeding Threshold Dose Turned Off)
*
******************************************************************************
* RESULT 4 OPTIONS BLOCK
* 360 DEGREE AVERAGE RISK OF A GIVEN EFFECT AT A GIVEN DISTANCE.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE4NUMBER    0     (Average Risk of a Given Effect Turned Off)
*
******************************************************************************
* RESULT 5 OPTIONS BLOCK
* TOTAL POPULATION DOSE TO A GIVEN ORGAN BETWEEN TWO DISTANCES.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE5NUMBER     0     (Population Dose to a Given Organ Turned Off)
*
******************************************************************************
* RESULT 6 OPTIONS BLOCK
* CENTERLINE DOSE TO AN ORGAN VS DIST BY PATHWAY, PATHWAY NAMES ARE AS FOLLOWS:
*
*  PATHWAY NAME:
*  CLD     - CLOUDSHINE Dose
*  GRD     - GROUNDSHINE Dose
*  INH ACU - Dose from INHALATION of the passing plume (Acute)
*  INH LIF - Dose from INHALATION of the passing plume (Lifetime)
*  RES ACU - Dose from inhalation of RESUSPENSED material after plume (Acute)
*  RES LIF - Dose from inhalation of RESUSPENSED material after plume (Lifetime)
*  TOT ACU - Total dose from all direct exposure pathways (Acute)
*  TOT LIF - Total dose from all direct exposure pathways (Lifetime)
*
* Direct exposure pathways are groundshine, cloudshine, plume inhalation, and
* inhalation of resuspended material.
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
```

```
*
TYPE6NUMBER     4
*
*             ORGNAM          PATHNM      I1DIS6   I2DIS6
*
TYPE6OUT001  'L-EFFECTIVE'   'TOT LIF'      1       16      * CCDF
TYPE6OUT002  'L-LUNGS'       'TOT LIF'      1       16
TYPE6OUT003  'L-THYROID'     'TOT LIF'      1       16
TYPE6OUT004  'L-RED MARR'    'TOT LIF'      1       16
********************************************************************************
* RESULT 7 OPTIONS BLOCK
* CENTERLINE RISK OF A GIVEN EFFECT VS DISTANCE
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE7NUMBER     0      (Centerline Risk of a Given Effect Turned Off)
*
********************************************************************************
* RESULT 8 OPTIONS BLOCK
* POPULATION WEIGHTED FATALITY RISK BETWEEN 2 DISTANCES
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPE8NUMBER     0      (Population Weighted Fatality Risk Turned Off)
*
********************************************************************************
* RESULT A OPTIONS BLOCK
* PEAK TOTAL DOSE AT A DISTANCE
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPEANUMBER     0      (Peak Total Dose at a Distance Turned Off)
*
********************************************************************************
* RESULT B OPTIONS BLOCK
* PEAK TOTAL DIRECT DOSE FOUND ON A SPATIAL GRID LOCATION
*
* NUMBER OF DESIRED RESULTS OF THIS TYPE
*
TYPEBNUMBER     0      (Dose on a Spacial Grid Location Turned Off)
*
.
```

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APPENDIX E, 1998 DWDD 95TH PERCENTILE OF DOSE LISTING

Note: The printing of each individual dose in the Table E-1 dose listing indicates the dose conversion factor (DCF) preprocessor and the version of the MACCS code used to calculate that dose. Regular face type (MACCS) indicates that dose was produced with MACCS version 1.5.11.1 using DCFs from the DOSFAC DCF preprocessor. Bold regular face type (**MACCS2**) indicates that dose was produced with MACCS version 1.12 (MACCS2) using DCFs from the DOSFAC DCF preprocessor. Italic bold face type (***MACCS2***) indicates that dose was produced with MACCS version 1.12 (MACCS2) using DCFs from the FGRDCF DCF preprocessor.

Note: The half-life and decay mode are indicated for each nuclide after its name. The decay modes are the following:

- B- beta-minus (electron)
- IT internal transition producing gammas
- EC electron capture
- B+ beta-plus (positron)
- A alpha particle
- SF spontaneous fission

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998.

			Centerline Dose (rem) at Radial Range (km)									
Isotope	**Release**	**Effect**	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Br-83	Ground	THYROID	7.05E-05	3.01E-06	3.01E-07	1.08E-07	5.77E-08	3.40E-08	2.05E-08	1.11E-08	7.66E-09	2.02E-09
2.39h B-	(no wake)	EDEWBODY	3.01E-04	1.06E-05	1.05E-06	3.33E-07	1.56E-07	1.10E-07	6.03E-08	3.77E-08	2.52E-08	5.60E-09
	Ground	THYROID	1.03E-05	2.03E-06	3.16E-07	1.54E-07	7.27E-08	3.53E-08	2.40E-08	1.41E-08	1.04E-08	2.21E-09
	(wake)	EDEWBODY	5.03E-07	1.00E-06	1.29E-06	5.18E-07	2.16E-07	1.15E-07	7.78E-08	5.15E-08	3.30E-08	7.12E-09
	ACRR	THYROID	3.04E-06	1.02E-06	3.04E-07	1.12E-07	1.01E-07	5.52E-08	3.05E-08	2.01E-08	1.22E-08	2.47E-09
		EDEWBODY	1.02E-05	5.00E-06	1.18E-06	5.65E-07	3.13E-07	1.70E-07	7.89E-08	5.78E-08	3.71E-08	7.92E-09
	Stack	THYROID	4.69E-08	1.25E-07	8.06E-08	1.00E-07	7.03E-08	5.03E-08	2.58E-08	2.21E-08	1.39E-08	3.39E-09
		EDEWBODY	1.17E-07	5.17E-07	2.37E-07	3.01E-07	2.21E-07	1.73E-07	8.68E-08	6.00E-08	4.10E-08	1.05E-08
Kr-83M	Ground	THYROID	1.25E-09	3.16E-10	1.14E-10	7.08E-11	4.62E-11	3.27E-11	1.48E-11	1.18E-11	7.89E-12	2.16E-12
1.83h IT	(no wake)	EDEWBODY	2.91E-09	7.37E-10	2.65E-10	1.65E-10	1.08E-10	7.63E-11	3.85E-11	2.39E-11	1.54E-11	5.16E-12
	Ground	THYROID	5.52E-10	2.48E-10	1.04E-10	6.71E-11	3.57E-11	3.06E-11	1.48E-11	9.57E-12	7.89E-12	2.15E-12
	(wake)	EDEWBODY	1.29E-09	5.79E-10	2.41E-10	1.56E-10	1.03E-10	7.13E-11	3.85E-11	2.39E-11	1.54E-11	5.07E-12
	ACRR	THYROID	1.12E-10	1.06E-10	5.97E-11	4.53E-11	3.28E-11	2.51E-11	1.35E-11	8.51E-12	6.57E-12	2.07E-12
		EDEWBODY	3.06E-10	2.23E-10	1.39E-10	1.06E-10	7.66E-11	5.85E-11	2.56E-11	1.87E-11	1.54E-11	4.68E-12
	Stack	THYROID	4.01E-11	4.01E-11	3.75E-11	2.64E-11	1.63E-11	1.22E-11	7.57E-12	5.67E-12	4.00E-12	1.43E-12
		EDEWBODY	1.08E-10	1.01E-10	7.62E-11	6.15E-11	4.33E-11	3.12E-11	1.55E-11	1.45E-11	1.16E-11	3.55E-12
Br-84	Ground	THYROID	3.02E-03	1.06E-04	1.19E-05	5.66E-06	3.04E-06	1.22E-06	1.03E-06	6.52E-07	3.37E-07	5.24E-08
31.80m B-	(no wake)	EDEWBODY	3.05E-03	1.10E-04	1.23E-05	5.99E-06	3.11E-06	1.22E-06	1.06E-06	7.09E-07	3.41E-07	5.29E-08
	Ground	THYROID	7.03E-04	1.01E-04	1.15E-05	7.06E-08	3.41E-06	2.05E-06	1.08E-06	7.37E-07	5.01E-07	5.55E-08
	(wake)	EDEWBODY	7.05E-04	1.02E-04	2.01E-05	7.37E-06	3.59E-06	2.09E-06	1.10E-06	7.47E-07	5.13E-07	5.55E-08
	ACRR	THYROID	1.12E-04	6.03E-05	1.11E-05	7.03E-06	3.29E-06	2.14E-06	1.09E-06	7.50E-07	5.18E-07	6.33E-08
		EDEWBODY	1.19E-04	7.02E-05	1.79E-05	7.18E-06	3.42E-06	2.25E-06	1.11E-06	7.62E-07	5.31E-07	6.33E-08
	Stack	THYROID	7.89E-06	8.93E-06	5.11E-06	3.25E-06	2.14E-06	1.29E-06	1.04E-06	7.24E-07	4.73E-07	7.05E-08
		EDEWBODY	7.89E-06	1.01E-05	6.61E-06	5.01E-06	3.01E-06	1.31E-06	1.08E-06	7.43E-07	5.28E-07	7.06E-08

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

Isotope	Release	Effect	Centerline Dose (rem) at Radial Range (km)									
			0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Kr-85M	Ground	THYROID	*1.43E-05*	*3.67E-06*	*1.38E-06*	*8.92E-07*	*6.08E-07*	*4.49E-07*	*1.87E-07*	*1.45E-07*	*1.05E-07*	*3.78E-08*
4.48h ITB-	(no wake)	EDEWBODY	*1.46E-05*	*3.75E-06*	*1.14E-06*	*9.10E-07*	*6.20E-07*	*4.58E-07*	*1.87E-07*	*1.48E-07*	*1.26E-07*	*3.82E-08*
	Ground	THYROID	*6.32E-06*	*2.88E-06*	*1.26E-06*	*8.45E-07*	*5.79E-07*	*4.33E-07*	*1.87E-07*	*1.45E-07*	*9.61E-08*	*3.76E-08*
	(wake)	EDEWBODY	*6.45E-06*	*2.31E-06*	*1.28E-06*	*8.62E-07*	*5.91E-07*	*3.58E-07*	*1.87E-07*	*1.45E-07*	*1.25E-07*	*3.80E-08*
	ACRR	THYROID	*1.19E-06*	*1.23E-06*	*7.09E-07*	*5.71E-07*	*4.32E-07*	*3.45E-07*	*1.48E-07*	*1.36E-07*	*8.47E-08*	*3.62E-08*
		EDEWBODY	*1.22E-06*	*1.26E-06*	*7.15E-07*	*5.83E-07*	*4.41E-07*	*3.52E-07*	*1.48E-07*	*1.41E-07*	*9.54E-08*	*3.66E-08*
	Stack	THYROID	5.52E-07	5.10E-07	4.81E-07	3.51E-07	2.59E-07	2.08E-07	9.76E-08	7.99E-08	6.08E-08	3.28E-08
		EDEWBODY	5.14E-07	5.06E-07	4.50E-07	3.29E-07	2.42E-07	1.95E-07	9.74E-08	6.84E-08	6.01E-08	3.15E-08
Kr-85	Ground	THYROID	*2.11E-07*	*5.99E-08*	*2.31E-08*	*1.54E-08*	*1.08E-08*	*7.44E-09*	*3.86E-09*	*2.49E-09*	*1.87E-09*	*1.02E-09*
10.72y B-	(no wake)	EDEWBODY	*2.32E-07*	*6.04E-08*	*2.33E-08*	*1.55E-08*	*1.09E-08*	*8.29E-09*	*3.86E-09*	*2.49E-09*	*1.87E-09*	*1.02E-09*
	Ground	THYROID	*1.02E-07*	*3.85E-08*	*2.11E-08*	*1.46E-08*	*1.01E-08*	*7.94E-09*	*3.57E-09*	*2.49E-09*	*1.87E-09*	*9.22E-10*
	(wake)	EDEWBODY	*1.03E-07*	*4.74E-08*	*2.13E-08*	*1.47E-08*	*1.04E-08*	*8.00E-09*	*3.60E-09*	*2.49E-09*	*1.87E-09*	*1.02E-09*
	ACRR	THYROID	*2.19E-08*	*2.01E-08*	*1.22E-08*	*9.85E-09*	*7.25E-09*	*6.31E-09*	*2.84E-09*	*1.93E-09*	*1.55E-09*	*9.22E-10*
		EDEWBODY	*2.19E-08*	*2.03E-08*	*1.23E-08*	*9.93E-09*	*7.74E-09*	*6.36E-09*	*2.85E-09*	*2.40E-09*	*1.58E-09*	*9.22E-10*
	Stack	THYROID	7.53E-09	7.35E-09	7.46E-09	5.96E-09	4.66E-09	3.89E-09	1.92E-09	1.49E-09	1.36E-09	7.24E-10
		EDEWBODY	1.54E-08	1.27E-08	1.31E-08	1.10E-08	9.95E-09	8.29E-09	3.86E-09	2.92E-09	2.50E-09	1.45E-09
Rb-86	Ground	THYROID	*1.09E-02*	*7.01E-04*	*7.00E-05*	*2.15E-05*	*1.09E-05*	*7.24E-06*	*3.83E-06*	*2.51E-06*	*1.86E-06*	*4.72E-07*
18.66d B-	(no wake)	EDEWBODY	*2.01E-02*	*7.35E-04*	*7.95E-05*	*3.06E-05*	*1.20E-05*	*8.59E-06*	*5.46E-06*	*3.45E-06*	*2.33E-06*	*6.13E-07*
	Ground	THYROID	*3.01E-03*	*5.02E-04*	*7.36E-05*	*3.09E-05*	*1.42E-05*	*7.87E-06*	*5.18E-06*	*3.38E-06*	*2.31E-06*	*6.09E-07*
	(wake)	EDEWBODY	*3.07E-03*	*7.11E-04*	*1.02E-04*	*3.80E-05*	*2.05E-05*	*1.07E-05*	*7.04E-06*	*3.95E-06*	*3.13E-06*	*7.83E-07*
	ACRR	THYROID	*5.30E-04*	*3.00E-04*	*7.27E-05*	*3.20E-05*	*2.04E-05*	*1.16E-05*	*6.12E-06*	*3.96E-06*	*2.82E-06*	*7.48E-07*
		EDEWBODY	*7.25E-04*	*3.02E-04*	*1.02E-04*	*5.08E-05*	*3.00E-05*	*1.38E-05*	*8.34E-06*	*5.48E-06*	*3.56E-06*	*1.02E-06*
	Stack	THYROID	5.86E-06	3.15E-05	1.37E-05	2.00E-05	1.24E-05	1.07E-05	6.08E-06	4.13E-06	3.73E-06	1.05E-06
		EDEWBODY	8.55E-06	3.35E-05	2.24E-05	2.04E-05	2.06E-05	1.40E-05	8.61E-06	6.08E-06	4.66E-06	1.26E-06

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	**Release**	**Effect**	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Kr-87	Ground	THYROID	*7.36E-05*	*2.00E-05*	*6.96E-06*	*4.22E-06*	*2.67E-06*	*1.83E-06*	*8.45E-07*	*6.00E-07*	*4.07E-07*	*1.04E-07*
76.3m B-	(no wake)	EDEWBODY	*7.98E-05*	*2.00E-05*	*6.95E-06*	*4.21E-06*	*2.66E-06*	*1.82E-06*	*8.45E-07*	*6.00E-07*	*4.07E-07*	*1.04E-07*
	Ground	THYROID	*3.54E-05*	*1.57E-05*	*6.35E-06*	*4.00E-06*	*2.54E-06*	*1.76E-06*	*8.45E-07*	*5.80E-07*	*4.07E-07*	*1.03E-07*
	(wake)	EDEWBODY	*3.53E-05*	*1.57E-05*	*6.33E-06*	*3.99E-06*	*2.54E-06*	*1.76E-06*	*8.33E-07*	*5.80E-07*	*4.00E-07*	*1.03E-07*
	ACRR	THYROID	*7.64E-06*	*5.82E-06*	*3.66E-06*	*2.24E-06*	*1.90E-06*	*1.40E-06*	*6.13E-07*	*4.76E-07*	*3.76E-07*	*8.69E-08*
		EDEWBODY	*7.63E-06*	*6.71E-06*	*3.65E-06*	*2.70E-06*	*1.89E-06*	*1.40E-06*	*6.13E-07*	*4.76E-07*	*3.76E-07*	*8.69E-08*
	Stack	THYROID	2.90E-06	2.18E-06	2.28E-06	1.28E-06	1.06E-06	7.94E-07	4.02E-07	3.43E-07	2.45E-07	7.43E-08
		EDEWBODY	2.48E-06	2.14E-06	2.21E-06	1.51E-06	1.03E-06	7.26E-07	4.02E-07	2.87E-07	2.45E-07	7.34E-08
Kr-88	Ground	THYROID	*2.01E-04*	*5.03E-05*	*2.01E-05*	*1.02E-05*	*1.00E-05*	*7.03E-06*	*3.85E-06*	*2.53E-06*	*1.82E-06*	*6.55E-07*
2.84h B-	(no wake)	EDEWBODY	*2.01E-04*	*5.04E-05*	*2.01E-05*	*1.02E-05*	*1.00E-05*	*7.04E-06*	*3.85E-06*	*2.53E-06*	*1.82E-06*	*7.09E-07*
	Ground	THYROID	*7.10E-05*	*3.08E-05*	*2.01E-05*	*1.02E-05*	*1.00E-05*	*7.03E-06*	*3.85E-06*	*2.49E-06*	*1.82E-06*	*6.55E-07*
	(wake)	EDEWBODY	*7.10E-05*	*5.00E-05*	*2.01E-05*	*1.02E-05*	*1.00E-05*	*7.03E-06*	*3.85E-06*	*2.53E-06*	*1.82E-06*	*7.03E-07*
	ACRR	THYROID	*2.09E-05*	*2.00E-05*	*1.02E-05*	*1.00E-05*	*7.03E-06*	*5.04E-06*	*2.85E-06*	*2.33E-06*	*1.53E-06*	*5.83E-07*
		EDEWBODY	*2.09E-05*	*2.01E-05*	*1.02E-05*	*1.00E-05*	*7.04E-06*	*5.04E-06*	*3.57E-06*	*2.44E-06*	*1.54E-06*	*5.90E-07*
	Stack	THYROID	9.70E-06	1.00E-05	8.28E-06	5.96E-06	4.31E-06	3.41E-06	1.51E-06	1.46E-06	1.21E-06	4.03E-07
		EDEWBODY	7.08E-06	7.05E-06	5.98E-06	4.30E-06	3.10E-06	2.46E-06	1.39E-06	8.79E-07	7.95E-07	3.26E-07
Rb-88	Ground	THYROID	*1.01E-03*	*3.16E-05*	*3.40E-06*	*1.13E-06*	*7.35E-07*	*3.41E-07*	*2.12E-07*	*1.09E-07*	*7.56E-08*	*6.89E-09*
17.8m B-	(no wake)	EDEWBODY	*1.02E-03*	*5.01E-05*	*3.60E-06*	*1.21E-06*	*7.60E-07*	*5.05E-07*	*2.48E-07*	*1.17E-07*	*8.80E-08*	*6.92E-09*
	Ground	THYROID	*2.01E-04*	*3.03E-05*	*3.59E-06*	*1.48E-06*	*7.53E-07*	*5.07E-07*	*2.22E-07*	*1.17E-07*	*1.00E-07*	*6.91E-09*
	(wake)	EDEWBODY	*3.00E-04*	*3.11E-05*	*5.18E-06*	*2.06E-06*	*1.01E-06*	*5.27E-07*	*3.07E-07*	*1.52E-07*	*1.02E-07*	*7.12E-09*
	ACRR	THYROID	*3.47E-05*	*1.74E-05*	*3.20E-06*	*1.24E-06*	*7.42E-07*	*4.73E-07*	*2.22E-07*	*1.19E-07*	*1.01E-07*	*7.12E-09*
		EDEWBODY	*5.15E-05*	*2.01E-05*	*5.01E-06*	*1.60E-06*	*1.01E-06*	*5.28E-07*	*3.11E-07*	*1.77E-07*	*1.04E-07*	*7.12E-09*
	Stack	THYROID	*2.62E-06*	*2.83E-06*	*1.12E-06*	*9.59E-07*	*5.28E-07*	*3.24E-07*	*2.15E-07*	*1.15E-07*	*8.46E-08*	*7.22E-09*
		EDEWBODY	*2.88E-06*	*3.14E-06*	*1.15E-06*	*1.01E-06*	*5.61E-07*	*3.34E-07*	*2.22E-07*	*1.19E-07*	*1.02E-07*	*8.07E-09*

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Rb-89	Ground	THYROID	3.02E-03	1.02E-04	1.07E-05	3.39E-06	2.10E-06	1.08E-06	7.01E-07	3.17E-07	2.12E-07	1.22E-08
15.2m B-	(no wake)	EDEWBODY	3.03E-03	1.05E-04	1.10E-05	3.42E-06	2.13E-06	1.09E-06	7.01E-07	3.18E-07	2.13E-07	1.22E-08
	Ground	THYROID	7.02E-04	1.01E-04	1.14E-05	5.17E-06	2.16E-06	1.12E-06	7.22E-07	3.29E-07	2.27E-07	1.23E-08
	(wake)	EDEWBODY	7.03E-04	1.01E-04	1.16E-05	5.30E-06	2.19E-06	1.13E-06	7.26E-07	3.87E-07	2.11E-07	1.23E-08
	ACRR	THYROID	1.10E-04	5.03E-05	1.03E-05	3.61E-06	2.13E-06	1.12E-06	7.31E-07	3.93E-07	2.12E-07	1.23E-08
		EDEWBODY	1.12E-04	5.04E-05	1.04E-05	5.03E-06	2.16E-06	1.13E-06	7.36E-07	3.93E-07	2.40E-07	1.23E-08
	Stack	THYROID	8.08E-06	7.79E-06	3.30E-06	2.26E-06	1.18E-06	1.02E-06	5.44E-07	3.33E-07	2.11E-07	1.23E-08
		EDEWBODY	8.08E-06	7.80E-06	3.32E-06	2.32E-06	1.19E-06	1.04E-06	5.44E-07	3.36E-07	2.15E-07	1.96E-08
Sr-89	Ground	THYROID	5.03E-03	1.42E-04	1.48E-05	5.48E-06	3.11E-06	1.56E-06	1.11E-06	7.40E-07	5.14E-07	1.28E-07
50.5d B-	(no wake)	EDEWBODY	2.02E-02	7.12E-04	7.14E-05	2.25E-05	1.13E-05	7.70E-06	4.07E-06	3.11E-06	2.12E-06	5.64E-07
	Ground	THYROID	7.05E-04	1.09E-04	2.06E-05	8.06E-06	3.86E-06	2.16E-06	1.15E-06	8.51E-07	5.96E-07	1.45E-07
	(wake)	EDEWBODY	3.02E-03	5.21E-04	1.00E-04	3.28E-05	1.52E-05	1.01E-05	5.34E-06	3.59E-06	2.45E-06	6.11E-07
	ACRR	THYROID	1.15E-04	7.13E-05	2.06E-05	1.02E-05	5.19E-06	3.10E-06	1.54E-06	1.12E-06	7.58E-07	2.04E-07
		EDEWBODY	5.35E-04	3.04E-04	1.00E-04	3.51E-05	2.09E-05	1.24E-05	7.56E-06	4.15E-06	3.21E-06	7.96E-07
	Stack	THYROID	1.41E-06	7.79E-06	3.77E-06	5.20E-06	5.01E-06	3.12E-06	1.59E-06	1.45E-06	9.35E-07	3.08E-07
		EDEWBODY	7.78E-06	3.16E-05	2.13E-05	2.11E-05	2.02E-05	1.20E-05	7.90E-06	5.63E-06	3.94E-06	1.18E-06
Sr-90	Ground	THYROID	3.03E-02	1.02E-03	1.03E-04	3.37E-05	2.01E-05	1.15E-05	7.20E-06	4.03E-06	3.18E-06	8.28E-09
29.12y B-	(no wake)	EDEWBODY	7.13E-01	2.14E-02	2.44E-03	7.97E-04	5.02E-04	3.01E-04	1.45E-04	1.11E-04	7.64E-05	2.06E-05
	Ground	THYROID	5.02E-03	1.00E-03	1.15E-04	5.14E-05	2.47E-05	1.19E-05	7.75E-06	5.60E-06	3.67E-06	1.05E-06
	(wake)	EDEWBODY	1.01E-01	2.06E-02	3.12E-03	1.19E-03	7.02E-04	3.26E-04	2.08E-04	1.27E-04	1.01E-04	2.45E-05
	ACRR	THYROID	1.01E-03	3.41E-04	1.08E-04	7.02E-05	3.14E-05	2.03E-05	1.10E-05	7.30E-06	4.62E-06	1.19E-06
		EDEWBODY	2.10E-02	1.03E-02	3.09E-03	1.31E-03	7.39E-04	5.07E-04	2.51E-04	1.49E-04	1.13E-04	3.14E-05
	Stack	THYROID	7.55E-06	4.13E-05	2.34E-05	2.34E-05	2.08E-05	2.01E-05	8.61E-06	6.08E-06	4.66E-06	1.34E-06
		EDEWBODY	2.17E-04	1.06E-03	5.69E-04	7.12E-04	5.21E-04	5.04E-04	2.44E-04	1.59E-04	1.42E-04	3.59E-05

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Y-90	Ground	THYROID	1.02E-04	5.02E-06	5.07E-07	2.05E-07	1.02E-07	5.90E-08	3.23E-08	2.17E-08	1.21E-08	3.98E-09
64.0h B-	(no wake)	EDEWBODY	2.10E-02	1.00E-03	1.00E-04	3.16E-05	1.25E-05	1.03E-05	5.75E-06	3.63E-06	2.46E-06	6.72E-07
	Ground	THYROID	3.00E-05	5.00E-06	7.02E-07	3.00E-07	1.08E-07	7.44E-08	3.59E-08	3.08E-08	2.09E-08	5.31E-09
	(wake)	EDEWBODY	5.00E-03	7.21E-04	1.05E-04	5.00E-05	2.23E-05	1.11E-05	7.27E-06	5.04E-06	3.31E-06	8.45E-07
	ACRR	THYROID	5.08E-06	2.01E-06	7.02E-07	3.02E-07	1.13E-07	1.01E-07	5.17E-08	3.55E-08	2.38E-08	5.99E-09
		EDEWBODY	7.44E-04	3.25E-04	1.04E-04	5.14E-05	3.04E-05	1.49E-05	8.67E-06	5.77E-06	3.77E-06	1.06E-06
	Stack	THYROID	1.53E-09	1.01E-08	5.27E-09	5.35E-09	5.10E-09	3.23E-09	2.15E-09	1.47E-09	1.18E-09	3.23E-10
		EDEWBODY	8.09E-06	5.06E-05	2.34E-05	2.34E-05	2.09E-05	2.09E-05	9.57E-06	6.69E-06	5.60E-06	1.39E-06
Sr-91	Ground	THYROID	2.01E-02	7.03E-04	7.09E-05	2.32E-05	1.18E-05	8.30E-06	5.13E-06	3.21E-06	2.17E-06	5.88E-07
9.5h B-	(no wake)	EDEWBODY	2.01E-02	7.06E-04	7.30E-05	3.10E-05	1.23E-05	1.01E-05	5.29E-06	3.29E-06	2.22E-06	6.72E-07
Including:	Ground	THYROID	3.03E-03	7.00E-04	1.00E-04	3.14E-05	2.00E-05	1.06E-05	5.60E-06	3.85E-06	3.02E-06	7.48E-07
Y-91m	(wake)	EDEWBODY	3.07E-03	7.02E-04	1.01E-04	3.24E-05	2.02E-05	1.10E-05	7.23E-06	5.01E-06	3.24E-06	7.94E-07
	ACRR	THYROID	7.10E-04	3.01E-04	1.00E-04	5.01E-05	2.05E-05	1.08E-05	7.22E-06	5.11E-06	3.41E-06	8.44E-07
		EDEWBODY	7.25E-04	3.02E-04	1.01E-04	5.02E-05	3.00E-05	1.11E-05	8.36E-06	5.32E-06	3.70E-06	1.02E-06
	Stack	THYROID	9.33E-06	3.01E-05	1.28E-05	2.01E-05	1.03E-05	1.01E-05	5.98E-06	4.04E-06	3.40E-06	8.20E-07
		EDEWBODY	6.56E-06	2.10E-05	1.23E-05	1.03E-05	1.01E-05	1.00E-05	4.13E-06	3.76E-06	2.49E-06	7.35E-07
Y-91	Ground	THYROID	2.03E-04	1.00E-05	1.00E-06	3.28E-07	1.29E-07	1.08E-07	7.02E-08	3.39E-08	3.05E-08	7.95E-09
58.51d B-	(no wake)	EDEWBODY	1.09E-01	5.12E-03	5.14E-04	2.01E-04	1.00E-04	5.73E-05	3.40E-05	2.24E-05	1.36E-05	3.93E-06
	Ground	THYROID	5.01E-05	7.05E-06	1.01E-06	5.01E-07	2.39E-07	1.17E-07	7.60E-08	5.41E-08	3.57E-08	8.68E-09
	(wake)	EDEWBODY	3.00E-02	5.01E-03	7.09E-04	2.44E-04	1.23E-04	7.27E-05	3.50E-05	2.54E-05	2.04E-05	5.27E-06
	ACRR	THYROID	7.53E-06	3.07E-06	1.01E-06	5.05E-07	3.02E-07	2.02E-07	9.66E-08	6.16E-08	4.02E-08	1.13E-08
		EDEWBODY	5.07E-03	2.06E-03	7.08E-04	3.07E-04	1.44E-04	1.02E-04	5.49E-05	3.43E-05	2.28E-05	5.97E-06
	Stack	THYROID	8.98E-08	3.16E-07	2.13E-07	2.02E-07	2.00E-07	1.02E-07	7.47E-08	4.76E-08	3.94E-08	1.14E-08
		EDEWBODY	5.36E-05	2.26E-04	1.23E-04	1.19E-04	1.08E-04	1.02E-04	5.60E-05	3.94E-05	2.80E-05	8.19E-06

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Y-91m	Ground	THYROID	1.04E-03	5.05E-05	5.47E-06	2.19E-06	1.17E-06	7.27E-07	3.42E-07	2.22E-07	1.56E-07	2.74E-08
49.71m IT	(no wake)	EDEWBODY	1.09E-03	7.00E-05	5.58E-06	2.24E-06	1.21E-06	7.35E-07	3.42E-07	3.06E-07	2.03E-07	3.14E-08
	Ground	THYROID	3.01E-04	5.02E-05	7.05E-06	3.04E-06	1.19E-06	8.27E-07	5.17E-07	3.18E-07	2.12E-07	3.26E-08
	(wake)	EDEWBODY	3.02E-04	5.03E-05	7.14E-06	3.10E-06	1.22E-06	8.67E-07	5.23E-07	3.21E-07	2.15E-07	3.50E-08
	ACRR	THYROID	5.22E-05	2.04E-05	7.03E-06	3.02E-06	1.24E-06	8.86E-07	5.59E-07	3.24E-07	2.17E-07	3.56E-08
		EDEWBODY	5.30E-05	3.01E-05	7.05E-06	3.06E-06	1.26E-06	1.01E-06	5.78E-07	3.27E-07	2.19E-07	3.88E-08
	Stack	THYROID	2.40E-06	3.23E-06	2.11E-06	2.01E-06	1.03E-06	7.32E-07	5.15E-07	3.23E-07	2.16E-07	3.97E-08
		EDEWBODY	2.40E-06	3.27E-06	3.27E-06	2.01E-06	1.06E-06	9.34E-07	5.32E-07	3.36E-07	2.19E-07	4.01E-08
Sr-92	Ground	THYROID	1.00E-02	3.03E-04	3.14E-05	1.17E-05	7.17E-06	3.96E-06	2.20E-06	1.22E-06	1.09E-06	2.51E-07
2.71h B-	(no wake)	EDEWBODY	1.01E-02	3.19E-04	3.29E-05	1.25E-05	7.76E-06	5.21E-06	3.09E-06	2.07E-06	1.13E-06	3.21E-07
	Ground	THYROID	2.00E-03	3.01E-04	5.01E-05	2.00E-05	7.86E-06	5.28E-06	3.10E-06	2.05E-06	1.13E-06	3.20E-07
	(wake)	EDEWBODY	2.01E-03	3.03E-04	5.04E-05	2.03E-05	1.05E-05	5.65E-06	3.35E-06	2.37E-06	1.18E-06	3.65E-07
	ACRR	THYROID	3.11E-04	1.03E-04	5.01E-05	2.01E-05	1.01E-05	7.02E-06	3.32E-06	2.22E-06	1.44E-06	3.59E-07
		EDEWBODY	3.23E-04	2.00E-04	5.03E-05	2.06E-05	1.07E-05	7.23E-06	3.61E-06	3.02E-06	2.08E-06	4.12E-07
	Stack	THYROID	6.72E-06	1.80E-05	1.80E-05	1.01E-05	7.08E-06	7.02E-06	3.20E-06	2.49E-06	1.54E-06	4.72E-07
		EDEWBODY	6.72E-06	2.09E-05	1.17E-05	1.02E-05	1.00E-05	7.04E-06	4.00E-06	2.85E-06	2.85E-06	5.53E-07
Y-92	Ground	THYROID	2.01E-03	7.03E-05	7.19E-06	3.02E-06	1.21E-06	8.72E-07	5.29E-07	3.28E-07	2.21E-07	5.63E-08
3.54h B-	(no wake)	EDEWBODY	3.05E-03	1.09E-04	1.59E-05	5.40E-06	3.03E-06	1.50E-06	1.07E-06	7.06E-07	3.42E-07	1.04E-07
	Ground	THYROID	3.03E-04	7.01E-05	1.00E-05	3.20E-06	2.03E-06	1.08E-06	7.08E-07	3.42E-07	3.08E-07	7.17E-08
	(wake)	EDEWBODY	7.04E-04	1.01E-04	2.01E-05	8.00E-06	3.92E-06	2.11E-06	1.22E-06	8.04E-07	5.56E-07	1.21E-07
	ACRR	THYROID	7.13E-05	3.02E-05	1.00E-05	5.01E-06	2.09E-06	1.09E-06	7.52E-07	5.21E-07	3.52E-07	8.03E-08
		EDEWBODY	1.14E-04	7.01E-05	2.01E-05	1.00E-05	5.15E-06	3.03E-06	1.22E-06	1.01E-06	7.06E-07	1.34E-07
	Stack	THYROID	1.55E-06	3.19E-06	2.13E-06	2.03E-06	2.01E-06	1.04E-06	7.47E-07	5.63E-07	3.86E-07	1.04E-07
		EDEWBODY	2.65E-06	8.43E-06	5.28E-06	5.06E-06	3.08E-06	3.02E-06	1.59E-06	1.31E-06	8.46E-07	2.23E-07

Table E-1. Centerline dose (95^{th} Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

Isotope	Release	Effect	Centerline Dose (rem) at Radial Range (km)									
			0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Y-93	Ground	THYROID	*1.02E-03*	*5.02E-05*	*5.06E-06*	*2.05E-06*	*1.03E-06*	*5.94E-07*	*3.25E-07*	*2.18E-07*	*1.21E-07*	*3.90E-08*
10.1h B-	(no wake)	EDEWBODY	*7.04E-03*	*3.04E-04*	*3.02E-05*	*1.02E-05*	*5.12E-06*	*3.12E-06*	*1.53E-06*	*1.15E-06*	*7.92E-07*	*2.04E-07*
	Ground	THYROID	*2.04E-04*	*5.00E-05*	*7.02E-06*	*3.00E-06*	*1.07E-06*	*7.46E-07*	*3.59E-07*	*3.11E-07*	*2.04E-07*	*5.24E-08*
	(wake)	EDEWBODY	*1.02E-03*	*2.01E-04*	*3.42E-05*	*1.42E-05*	*7.23E-06*	*3.38E-06*	*2.12E-06*	*1.31E-06*	*1.03E-06*	*2.42E-07*
	ACRR	THYROID	*5.07E-05*	*2.01E-05*	*7.02E-06*	*3.02E-06*	*1.13E-06*	*1.00E-06*	*5.15E-07*	*3.27E-07*	*2.40E-07*	*5.92E-08*
		EDEWBODY	*2.17E-04*	*1.01E-04*	*3.34E-05*	*1.65E-05*	*8.80E-06*	*5.31E-06*	*2.59E-06*	*1.27E-06*	*1.17E-06*	*3.12E-07*
	Stack	THYROID	7.76E-07	2.10E-06	1.23E-06	1.04E-06	1.01E-06	1.00E-06	5.31E-07	3.87E-07	2.51E-07	7.59E-08
		EDEWBODY	3.99E-06	1.29E-05	8.03E-06	1.00E-05	7.05E-06	7.07E-06	3.56E-06	2.39E-06	1.54E-06	5.04E-07
Y-94	Ground	THYROID	*2.01E-03*	*7.04E-05*	*7.20E-06*	*2.22E-06*	*1.13E-06*	*7.49E-07*	*3.98E-07*	*2.40E-07*	*1.17E-07*	*1.11E-08*
19.1m B-	(no wake)	EDEWBODY	*2.01E-03*	*7.15E-05*	*7.48E-06*	*3.04E-06*	*1.14E-06*	*7.63E-07*	*5.01E-07*	*3.00E-07*	*1.24E-07*	*1.16E-08*
	Ground	THYROID	*3.07E-04*	*7.02E-05*	*7.63E-06*	*3.23E-06*	*1.15E-06*	*7.67E-07*	*5.13E-07*	*3.05E-07*	*1.56E-07*	*1.15E-08*
	(wake)	EDEWBODY	*5.01E-04*	*7.03E-05*	*7.85E-06*	*3.39E-06*	*1.19E-06*	*1.00E-06*	*5.21E-07*	*3.10E-07*	*2.00E-07*	*1.19E-08*
	ACRR	THYROID	*7.29E-05*	*3.02E-05*	*7.05E-06*	*3.11E-06*	*1.39E-06*	*7.67E-07*	*5.19E-07*	*3.10E-07*	*2.00E-07*	*1.18E-08*
		EDEWBODY	*7.53E-05*	*3.05E-05*	*7.26E-06*	*3.21E-06*	*1.45E-06*	*1.01E-06*	*5.32E-07*	*3.16E-07*	*2.03E-07*	*1.19E-08*
	Stack	THYROID	*4.40E-06*	*5.20E-06*	*3.02E-06*	*1.17E-06*	*1.03E-06*	*7.09E-07*	*3.42E-07*	*2.22E-07*	*1.23E-07*	*1.52E-08*
		EDEWBODY	*4.76E-06*	*5.20E-06*	*3.02E-06*	*2.01E-06*	*1.07E-06*	*7.18E-07*	*3.42E-07*	*2.76E-07*	*1.56E-07*	*1.54E-08*
Y-95	Ground	THYROID	*1.01E-03*	*3.24E-05*	*3.67E-06*	*1.14E-06*	*7.15E-07*	*3.21E-07*	*2.01E-07*	*1.01E-07*	*5.07E-08*	*3.24E-09*
10.7m B-	(no wake)	EDEWBODY	*1.02E-03*	*5.01E-05*	*3.96E-06*	*1.17E-06*	*7.29E-07*	*3.25E-07*	*2.08E-07*	*1.06E-07*	*5.36E-08*	*3.31E-09*
	Ground	THYROID	*2.04E-04*	*3.04E-05*	*3.53E-06*	*1.16E-06*	*7.41E-07*	*3.36E-07*	*2.04E-07*	*1.07E-07*	*5.43E-08*	*3.24E-09*
	(wake)	EDEWBODY	*3.01E-04*	*3.20E-05*	*4.21E-06*	*1.19E-06*	*7.58E-07*	*3.98E-07*	*2.05E-07*	*1.09E-07*	*5.46E-08*	*3.31E-09*
	ACRR	THYROID	*5.08E-05*	*2.01E-05*	*3.25E-06*	*1.14E-06*	*7.29E-07*	*3.38E-07*	*2.04E-07*	*1.08E-07*	*5.46E-08*	*3.28E-09*
		EDEWBODY	*5.20E-05*	*2.01E-05*	*3.40E-06*	*1.17E-06*	*7.46E-07*	*3.41E-07*	*2.08E-07*	*1.05E-07*	*7.04E-08*	*3.31E-09*
	Stack	THYROID	*4.08E-06*	*3.07E-06*	*1.10E-06*	*7.34E-07*	*3.52E-07*	*2.51E-07*	*1.25E-07*	*1.00E-07*	*5.13E-08*	*3.31E-09*
		EDEWBODY	*4.11E-06*	*3.11E-06*	*1.11E-06*	*7.60E-07*	*4.81E-07*	*3.13E-07*	*1.25E-07*	*1.02E-07*	*5.15E-08*	*3.33E-09*

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Zr-95	Ground	THYROID	*3.01E-02*	*1.01E-03*	*1.03E-04*	*3.55E-05*	*2.13E-05*	*1.24E-05*	*7.83E-06*	*5.16E-06*	*3.23E-06*	*8.68E-07*
63.98d B-	(no wake)	EDEWBODY	*7.02E-02*	*2.02E-03*	*2.43E-04*	*7.97E-05*	*5.02E-05*	*3.01E-05*	*1.46E-05*	*1.11E-05*	*7.69E-06*	*2.10E-06*
	Ground	THYROID	*5.04E-03*	*1.00E-03*	*1.08E-04*	*5.11E-05*	*3.05E-05*	*1.25E-05*	*1.01E-05*	*6.10E-06*	*3.98E-06*	*1.14E-06*
	(wake)	EDEWBODY	*1.01E-02*	*2.01E-03*	*3.12E-04*	*1.21E-04*	*7.02E-05*	*3.29E-05*	*2.08E-05*	*1.28E-05*	*1.01E-05*	*2.47E-06*
	ACRR	THYROID	*1.03E-03*	*5.02E-04*	*1.04E-04*	*7.03E-05*	*3.08E-05*	*2.09E-05*	*1.22E-05*	*7.97E-06*	*5.43E-06*	*1.33E-06*
		EDEWBODY	*2.10E-03*	*1.01E-03*	*3.02E-04*	*1.31E-04*	*7.39E-05*	*5.07E-05*	*2.51E-05*	*1.50E-05*	*1.14E-05*	*3.15E-06*
	Stack	THYROID	1.41E-05	5.18E-05	3.26E-05	3.05E-05	3.01E-05	2.02E-05	1.09E-05	8.50E-06	5.99E-06	2.03E-06
		EDEWBODY	2.64E-05	1.07E-04	7.41E-05	7.06E-05	7.00E-05	5.09E-05	2.48E-05	1.59E-05	1.45E-05	3.70E-06
Nb-95	Ground	THYROID	*3.00E-02*	*1.00E-03*	*1.00E-04*	*3.36E-05*	*2.01E-05*	*1.14E-05*	*7.07E-06*	*3.46E-06*	*3.14E-06*	*8.25E-07*
35.15d B-	(no wake)	EDEWBODY	*3.04E-02*	*1.07E-03*	*1.10E-04*	*5.30E-05*	*2.62E-05*	*1.45E-05*	*1.04E-05*	*7.03E-06*	*3.41E-06*	*1.20E-06*
	Ground	THYROID	*5.02E-03*	*7.08E-04*	*1.03E-04*	*5.03E-05*	*2.12E-05*	*1.19E-05*	*7.76E-06*	*5.61E-06*	*3.68E-06*	*1.05E-06*
	(wake)	EDEWBODY	*7.04E-03*	*1.01E-03*	*2.00E-04*	*7.24E-05*	*3.62E-05*	*2.09E-05*	*1.12E-05*	*8.07E-06*	*5.64E-06*	*1.37E-06*
	ACRR	THYROID	*7.53E-04*	*3.08E-04*	*1.01E-04*	*5.31E-05*	*3.02E-05*	*2.01E-05*	*1.10E-05*	*7.32E-06*	*4.62E-06*	*1.19E-06*
		EDEWBODY	*1.12E-05*	*7.01E-04*	*2.00E-04*	*1.00E-04*	*5.07E-05*	*3.04E-05*	*1.49E-05*	*1.05E-05*	*7.18E-06*	*1.55E-06*
	Stack	THYROID	1.41E-05	5.12E-05	2.35E-05	3.03E-05	2.03E-05	2.01E-05	1.02E-05	7.94E-06	5.64E-06	1.44E-06
		EDEWBODY	1.78E-05	7.26E-05	3.49E-05	3.09E-05	3.03E-05	3.01E-05	1.48E-05	1.21E-05	8.19E-06	2.30E-06
Zr-97	Ground	THYROID	*3.05E-02*	*1.09E-03*	*1.13E-04*	*5.46E-05*	*3.06E-05*	*1.54E-05*	*1.05E-05*	*7.29E-06*	*5.19E-06*	*1.25E-06*
16.90h B-	(no wake)	EDEWBODY	*5.02E-02*	*2.01E-03*	*2.01E-04*	*7.31E-05*	*3.38E-05*	*2.24E-05*	*1.26E-05*	*7.66E-06*	*5.45E-06*	*1.42E-06*
Including: Nb-97m	Ground	THYROID	*7.04E-03*	*1.01E-03*	*2.01E-04*	*7.14E-05*	*3.23E-05*	*2.16E-05*	*1.15E-05*	*8.51E-06*	*5.97E-06*	*1.42E-06*
Including: Nb-97	(wake)	EDEWBODY	*1.00E-02*	*1.09E-03*	*2.06E-04*	*1.00E-04*	*5.02E-05*	*3.03E-05*	*1.26E-05*	*1.10E-05*	*7.69E-06*	*2.04E-06*
	ACRR	THYROID	*1.13E-03*	*7.02E-04*	*2.01E-04*	*1.00E-04*	*5.03E-05*	*3.02E-05*	*1.54E-05*	*1.11E-05*	*7.58E-06*	*1.86E-06*
		EDEWBODY	*1.32E-03*	*7.10E-04*	*2.03E-04*	*1.01E-04*	*7.01E-05*	*3.15E-05*	*2.17E-05*	*1.28E-05*	*8.64E-06*	*2.30E-06*
	Stack	THYROID	1.87E-05	5.21E-05	3.26E-05	3.05E-05	3.01E-05	2.02E-05	1.09E-05	8.37E-06	5.99E-06	1.52E-06
		EDEWBODY	6.29E-06	2.46E-05	1.24E-05	1.07E-05	1.02E-05	1.09E-05	5.89E-06	3.94E-06	2.83E-06	8.22E-07

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	**Release**	**Effect**	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Nb-97	Ground	THYROID	*2.02E-03*	*1.00E-04*	*1.00E-05*	*3.35E-06*	*2.01E-06*	*1.06E-06*	*7.16E-07*	*3.42E-07*	*3.10E-07*	*5.38E-08*
72.1m B-	(no wake)	EDEWBODY	*3.00E-03*	*1.00E-04*	*1.02E-05*	*3.43E-06*	*2.08E-06*	*1.07E-06*	*7.31E-07*	*4.11E-07*	*3.17E-07*	*5.71E-08*
	Ground	THYROID	*5.01E-04*	*7.05E-05*	*1.02E-05*	*5.00E-06*	*2.18E-06*	*1.16E-06*	*7.45E-07*	*5.24E-07*	*3.25E-07*	*5.91E-08*
	(wake)	EDEWBODY	*5.02E-04*	*7.08E-05*	*1.05E-05*	*5.02E-06*	*2.25E-06*	*1.18E-06*	*8.31E-07*	*5.30E-07*	*3.29E-07*	*6.42E-08*
	ACRR	THYROID	*7.53E-05*	*3.07E-05*	*1.01E-05*	*5.03E-06*	*2.14E-06*	*1.23E-06*	*7.89E-07*	*5.33E-07*	*3.32E-07*	*7.11E-08*
		EDEWBODY	*7.75E-05*	*3.08E-05*	*1.01E-05*	*5.04E-06*	*3.01E-06*	*1.25E-06*	*1.01E-06*	*5.98E-07*	*3.36E-07*	*7.64E-08*
	Stack	THYROID	*2.89E-06*	*5.20E-06*	*3.16E-06*	*3.02E-06*	*2.02E-06*	*1.10E-06*	*8.60E-07*	*5.45E-07*	*3.88E-07*	*8.12E-08*
		EDEWBODY	*2.89E-06*	*5.20E-06*	*3.21E-06*	*3.02E-06*	*2.02E-06*	*1.11E-06*	*8.74E-07*	*5.57E-07*	*4.05E-07*	*8.34E-08*
Nb-97m	Ground	THYROID	*5.12E-04*	*7.43E-06*	*2.04E-07*	*5.37E-08*	*2.52E-08*	*1.19E-08*	*1.01E-08*	*5.45E-09*	*3.41E-09*	*7.54E-10*
60s IT	(no wake)	EDEWBODY	*5.12E-04*	*7.44E-06*	*2.04E-07*	*5.44E-08*	*3.01E-08*	*1.22E-08*	*1.04E-08*	*6.13E-09*	*3.41E-09*	*8.01E-10*
	Ground	THYROID	*1.01E-04*	*5.35E-06*	*2.04E-07*	*7.03E-08*	*3.19E-08*	*2.01E-08*	*1.06E-08*	*7.34E-09*	*5.18E-09*	*8.36E-10*
	(wake)	EDEWBODY	*1.01E-04*	*5.36E-06*	*2.09E-07*	*7.04E-08*	*3.27E-08*	*2.05E-08*	*1.18E-08*	*7.43E-09*	*5.25E-09*	*9.12E-10*
	ACRR	THYROID	*2.12E-05*	*2.29E-06*	*1.28E-07*	*7.05E-08*	*3.18E-08*	*2.13E-08*	*1.13E-08*	*7.47E-09*	*5.31E-09*	*1.01E-09*
		EDEWBODY	*2.12E-05*	*2.29E-06*	*1.29E-07*	*7.06E-08*	*3.21E-08*	*2.17E-08*	*1.15E-08*	*8.40E-09*	*5.37E-09*	*1.09E-09*
	Stack	THYROID	*1.75E-06*	*5.37E-07*	*7.75E-08*	*3.12E-08*	*3.01E-08*	*2.02E-08*	*1.06E-08*	*7.65E-09*	*5.79E-09*	*1.15E-09*
		EDEWBODY	*1.75E-06*	*5.37E-07*	*7.80E-08*	*5.04E-08*	*3.02E-08*	*2.02E-08*	*1.08E-08*	*7.85E-09*	*6.06E-09*	*1.18E-09*
Mo-99	Ground	THYROID	*5.04E-03*	*2.01E-04*	*2.06E-05*	*7.59E-06*	*3.52E-06*	*2.42E-06*	*1.15E-06*	*1.03E-06*	*7.20E-07*	*1.54E-07*
66.0h B-	(no wake)	EDEWBODY	*1.09E-02*	*7.00E-04*	*7.02E-05*	*2.16E-05*	*1.10E-05*	*7.30E-06*	*3.87E-06*	*2.56E-06*	*2.02E-06*	*5.15E-07*
	Ground	THYROID	*1.01E-03*	*2.00E-04*	*3.01E-05*	*1.02E-05*	*5.16E-06*	*3.15E-06*	*1.89E-06*	*1.19E-06*	*8.30E-07*	*2.23E-07*
	(wake)	EDEWBODY	*3.02E-03*	*5.03E-04*	*7.38E-05*	*3.10E-05*	*1.44E-05*	*7.92E-06*	*5.21E-06*	*3.43E-06*	*2.34E-06*	*6.09E-07*
	ACRR	THYROID	*2.04E-04*	*1.00E-04*	*3.01E-05*	*1.03E-05*	*7.03E-06*	*3.26E-06*	*2.40E-06*	*1.41E-06*	*1.06E-06*	*2.57E-07*
		EDEWBODY	*5.30E-04*	*3.00E-04*	*7.05E-05*	*3.21E-05*	*2.05E-05*	*1.17E-05*	*6.12E-06*	*4.01E-06*	*3.06E-06*	*7.52E-07*
	Stack	THYROID	3.18E-06	1.02E-05	7.41E-06	7.09E-06	7.02E-06	5.02E-06	2.48E-06	1.59E-06	1.45E-06	3.71E-07
		EDEWBODY	6.32E-06	3.16E-05	1.41E-05	2.01E-05	1.06E-05	1.08E-05	6.72E-06	4.75E-06	3.94E-06	1.08E-06

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Tc-99m	Ground	THYROID	1.04E-03	5.05E-05	5.21E-06	2.13E-06	1.08E-06	7.12E-07	3.35E-07	2.22E-07	1.23E-07	4.02E-08
6.02h IT	(no wake)	EDEWBODY	1.02E-03	5.04E-05	5.16E-06	2.11E-06	1.06E-06	7.02E-07	3.32E-07	2.22E-07	1.22E-07	3.95E-08
	Ground	THYROID	3.01E-04	5.02E-05	7.05E-06	3.01E-06	1.11E-06	7.74E-07	5.13E-07	3.31E-07	2.11E-07	5.47E-08
	(wake)	EDEWBODY	3.01E-04	5.01E-05	7.03E-06	3.01E-06	1.10E-06	7.67E-07	5.07E-07	3.23E-07	2.10E-07	5.34E-08
	ACRR	THYROID	5.18E-05	2.03E-05	7.04E-06	3.03E-06	2.00E-06	1.02E-06	5.23E-07	3.43E-07	2.53E-07	6.04E-08
		EDEWBODY	5.16E-05	2.03E-05	7.03E-06	3.03E-06	2.00E-06	1.01E-06	5.21E-07	3.39E-07	2.49E-07	6.03E-08
	Stack	THYROID	9.90E-07	3.19E-06	2.13E-06	2.03E-06	2.00E-06	1.02E-06	7.47E-07	5.63E-07	3.93E-07	1.05E-07
		EDEWBODY	9.58E-07	3.15E-06	1.40E-06	2.01E-06	1.05E-06	1.01E-06	6.06E-07	4.09E-07	3.39E-07	8.34E-08
Mo-101	Ground	THYROID	2.02E-03	7.33E-05	7.80E-06	3.14E-06	1.18E-06	1.00E-06	5.16E-07	3.05E-07	1.78E-07	1.18E-08
14.62m B-	(no wake)	EDEWBODY	3.00E-03	1.00E-04	7.96E-06	3.18E-06	1.20E-06	1.02E-06	5.18E-07	3.06E-07	2.00E-07	1.19E-08
	Ground	THYROID	5.01E-04	7.04E-05	1.01E-05	3.66E-06	1.24E-06	1.05E-06	5.41E-07	3.18E-07	2.04E-07	1.20E-08
	(wake)	EDEWBODY	5.02E-04	7.07E-05	1.04E-05	3.76E-06	2.02E-06	1.07E-06	5.41E-07	3.21E-07	2.04E-07	1.21E-08
	ACRR	THYROID	7.75E-05	3.06E-05	7.38E-06	3.35E-06	1.55E-06	1.05E-06	5.44E-07	3.22E-07	2.08E-07	1.20E-08
		EDEWBODY	1.02E-04	3.07E-05	1.00E-05	3.42E-06	2.03E-06	1.06E-06	5.44E-07	3.31E-07	2.09E-07	1.22E-08
	Stack	THYROID	5.60E-06	5.53E-06	3.06E-06	2.03E-06	1.12E-06	7.48E-07	4.73E-07	3.15E-07	2.04E-07	1.56E-08
		EDEWBODY	5.60E-06	6.29E-06	3.06E-06	2.05E-06	1.13E-06	7.57E-07	5.26E-07	3.21E-07	2.08E-07	1.57E-08
Tc-101	Ground	THYROID	5.04E-04	2.01E-05	2.01E-06	7.22E-07	3.20E-07	2.00E-07	1.01E-07	5.12E-08	3.17E-08	2.10E-09
14.2m B-	(no wake)	EDEWBODY	7.01E-04	2.01E-05	2.04E-06	7.28E-07	3.25E-07	2.02E-07	1.02E-07	5.14E-08	3.19E-08	2.10E-09
	Ground	THYROID	1.01E-04	2.00E-05	2.09E-06	7.89E-07	3.30E-07	2.08E-07	1.05E-07	6.34E-08	3.09E-08	2.13E-09
	(wake)	EDEWBODY	1.01E-04	2.00E-05	2.12E-06	8.05E-07	3.33E-07	2.09E-07	1.06E-07	7.01E-08	3.10E-08	2.16E-09
	ACRR	THYROID	2.09E-05	1.00E-05	1.16E-06	7.22E-07	3.26E-07	2.10E-07	1.06E-07	7.01E-08	3.18E-08	2.15E-09
		EDEWBODY	2.10E-05	1.00E-05	2.00E-06	7.32E-07	3.28E-07	2.12E-07	1.07E-07	7.02E-08	3.19E-08	2.17E-09
	Stack	THYROID	1.53E-06	1.09E-06	7.04E-07	3.50E-07	2.15E-07	1.17E-07	7.66E-08	5.31E-08	3.16E-08	2.15E-09
		EDEWBODY	1.53E-06	1.38E-06	7.06E-07	3.54E-07	2.17E-07	1.18E-07	8.53E-08	5.31E-08	3.18E-08	2.17E-09

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	**Release**	**Effect**	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Ru-103	Ground	THYROID	*1.09E-02*	*7.00E-04*	*7.00E-05*	*2.18E-05*	*1.11E-05*	*7.36E-06*	*3.93E-06*	*3.03E-06*	*2.05E-06*	*5.33E-07*
39.28d B-	(no wake)	EDEWBODY	*3.04E-02*	*1.07E-03*	*1.37E-04*	*5.29E-05*	*2.62E-05*	*1.45E-05*	*1.04E-05*	*7.01E-06*	*3.98E-06*	*1.19E-06*
Including: Rh-103m	Ground	THYROID	*3.02E-03*	*5.03E-04*	*7.07E-05*	*3.02E-05*	*1.13E-05*	*1.00E-05*	*5.25E-06*	*3.49E-06*	*2.38E-06*	*6.11E-07*
	(wake)	EDEWBODY	*7.04E-03*	*1.01E-03*	*2.03E-04*	*7.24E-05*	*3.62E-05*	*2.09E-05*	*1.11E-05*	*8.04E-06*	*5.62E-06*	*1.36E-06*
	ACRR	THYROID	*5.30E-04*	*3.00E-04*	*7.05E-05*	*3.04E-05*	*2.01E-05*	*1.05E-05*	*6.12E-06*	*4.06E-06*	*3.09E-06*	*7.57E-07*
		EDEWBODY	*1.12E-03*	*7.01E-04*	*2.00E-04*	*1.00E-04*	*5.07E-05*	*3.03E-05*	*1.49E-05*	*1.05E-05*	*7.17E-06*	*1.55E-06*
	Stack	THYROID	9.33E-06	3.16E-05	1.42E-05	2.01E-05	1.06E-05	1.01E-05	6.08E-06	4.19E-06	3.76E-06	1.06E-06
		EDEWBODY	1.76E-05	7.25E-05	3.49E-05	5.01E-05	3.04E-05	3.05E-05	1.48E-05	1.22E-05	8.19E-06	2.33E-06
Rh-103m	Ground	THYROID	*2.02E-06*	*7.19E-08*	*7.60E-09*	*3.08E-09*	*1.16E-09*	*7.67E-10*	*5.29E-10*	*3.23E-10*	*2.12E-10*	*3.41E-11*
56.12m IT	(no wake)	EDEWBODY	*1.05E-05*	*5.66E-07*	*5.17E-08*	*2.01E-08*	*8.76E-09*	*5.36E-09*	*3.12E-09*	*2.00E-09*	*1.17E-09*	*1.78E-10*
	Ground	THYROID	*5.01E-07*	*7.04E-08*	*1.01E-08*	*3.33E-09*	*1.29E-09*	*1.02E-09*	*5.45E-10*	*3.36E-10*	*2.22E-10*	*3.61E-11*
	(wake)	EDEWBODY	*3.01E-06*	*5.01E-07*	*7.17E-08*	*2.43E-08*	*1.06E-08*	*6.02E-09*	*3.44E-09*	*2.20E-09*	*1.11E-09*	*2.14E-10*
	ACRR	THYROID	*7.53E-08*	*3.06E-08*	*1.00E-08*	*3.26E-09*	*2.09E-09*	*1.10E-09*	*7.07E-10*	*3.42E-10*	*2.22E-10*	*3.97E-11*
		EDEWBODY	*5.22E-07*	*2.03E-07*	*7.15E-08*	*3.03E-08*	*1.36E-08*	*7.25E-09*	*3.76E-09*	*2.38E-09*	*1.37E-09*	*2.30E-10*
	Stack	THYROID	*1.55E-09*	*4.21E-09*	*2.26E-09*	*2.03E-09*	*1.12E-09*	*1.01E-09*	*5.54E-10*	*3.56E-10*	*3.09E-10*	*5.10E-11*
		EDEWBODY	*6.04E-09*	*3.04E-08*	*1.24E-08*	*1.03E-08*	*1.04E-08*	*7.25E-09*	*3.73E-09*	*2.27E-09*	*1.49E-09*	*3.03E-10*
Tc-104	Ground	THYROID	*3.02E-03*	*1.05E-04*	*1.12E-05*	*5.03E-06*	*2.16E-06*	*1.12E-06*	*7.24E-07*	*3.93E-07*	*2.33E-07*	*1.96E-08*
18.2m B-	(no wake)	EDEWBODY	*3.04E-03*	*1.07E-04*	*1.14E-05*	*5.08E-06*	*2.18E-06*	*1.13E-06*	*7.36E-07*	*4.50E-07*	*2.40E-07*	*2.04E-08*
	Ground	THYROID	*7.03E-04*	*1.01E-04*	*1.18E-05*	*5.52E-06*	*2.21E-06*	*1.16E-06*	*7.61E-07*	*5.08E-07*	*3.04E-07*	*2.04E-08*
	(wake)	EDEWBODY	*7.04E-04*	*1.01E-04*	*1.20E-05*	*5.63E-06*	*2.22E-06*	*1.17E-06*	*7.61E-07*	*5.09E-07*	*3.05E-07*	*2.04E-08*
	ACRR	THYROID	*1.12E-04*	*5.04E-05*	*1.06E-05*	*5.23E-06*	*2.46E-06*	*1.16E-06*	*7.66E-07*	*5.17E-07*	*3.06E-07*	*2.07E-08*
		EDEWBODY	*1.13E-04*	*5.08E-05*	*1.07E-05*	*5.32E-06*	*2.51E-06*	*1.17E-06*	*7.66E-07*	*5.25E-07*	*3.12E-07*	*2.28E-08*
	Stack	THYROID	*7.89E-06*	*7.79E-06*	*5.03E-06*	*3.01E-06*	*1.30E-06*	*1.07E-06*	*7.33E-07*	*3.42E-07*	*3.01E-07*	*2.35E-08*
		EDEWBODY	*7.89E-06*	*9.16E-06*	*5.04E-06*	*3.02E-06*	*1.32E-06*	*1.08E-06*	*7.39E-07*	*3.99E-07*	*3.06E-07*	*2.43E-08*

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Ru-105	Ground	THYROID	7.04E-03	3.00E-04	3.01E-05	1.06E-05	5.36E-06	3.35E-06	2.05E-06	1.12E-06	7.67E-07	2.15E-07
4.44h B-	(no wake)	EDEWBODY	1.00E-02	3.02E-04	3.08E-05	1.12E-05	5.65E-06	3.68E-06	2.13E-06	1.16E-06	1.05E-06	2.34E-07
	Ground	THYROID	1.02E-03	2.02E-04	3.08E-05	1.09E-05	7.13E-06	3.54E-06	2.23E-06	1.17E-06	1.06E-06	2.47E-07
	(wake)	EDEWBODY	1.06E-03	3.01E-04	3.20E-05	1.14E-05	7.33E-06	5.08E-06	3.01E-06	2.00E-06	1.09E-06	3.10E-07
	ACRR	THYROID	2.17E-04	1.01E-04	3.03E-05	1.12E-05	1.00E-05	5.07E-06	3.07E-06	2.02E-06	1.25E-06	3.18E-07
		EDEWBODY	3.06E-04	1.02E-04	3.05E-05	2.01E-05	1.01E-05	5.25E-06	3.21E-06	2.12E-06	1.36E-06	3.50E-07
	Stack	THYROID	4.76E-06	1.26E-05	7.79E-06	1.00E-05	7.04E-06	5.03E-06	2.56E-06	2.06E-06	1.53E-06	3.82E-07
		EDEWBODY	4.76E-06	1.29E-05	1.06E-05	1.00E-05	7.05E-06	5.06E-06	3.11E-06	2.39E-06	1.54E-06	4.04E-07
Rh-105	Ground	THYROID	2.00E-03	7.02E-05	7.03E-06	2.30E-06	1.16E-06	8.02E-07	5.06E-07	3.16E-07	2.14E-07	5.72E-08
35.36h B-	(no wake)	EDEWBODY	5.01E-03	1.11E-04	1.50E-05	5.61E-06	3.15E-06	2.01E-06	1.14E-06	7.61E-07	5.30E-07	1.29E-07
	Ground	THYROID	3.02E-04	5.04E-05	1.00E-05	3.12E-06	1.54E-06	1.03E-06	5.52E-07	3.72E-07	2.53E-07	7.17E-08
	(wake)	EDEWBODY	7.06E-04	1.02E-04	2.02E-05	8.19E-06	3.99E-06	2.20E-06	1.17E-06	8.65E-07	6.10E-07	1.46E-07
	ACRR	THYROID	5.36E-05	3.01E-05	1.00E-05	3.20E-06	2.02E-06	1.08E-06	7.14E-07	4.73E-07	3.29E-07	8.23E-08
		EDEWBODY	1.20E-04	7.03E-05	2.01E-05	1.02E-05	5.22E-06	3.11E-06	1.54E-06	1.13E-06	7.72E-07	2.09E-07
	Stack	THYROID	1.08E-06	3.19E-06	2.13E-06	2.03E-06	2.01E-06	1.02E-06	7.90E-07	5.63E-07	3.95E-07	1.15E-07
		EDEWBODY	1.85E-06	7.26E-06	3.72E-06	5.04E-06	3.08E-06	3.02E-06	1.58E-06	1.43E-06	8.47E-07	2.46E-07
Ru-106	Ground	THYROID	2.02E-02	1.00E-03	1.00E-04	3.21E-05	1.27E-05	1.05E-05	5.94E-06	3.74E-06	2.53E-06	7.62E-07
4.44h B-	(no wake)	EDEWBODY	1.09E+00	5.10E-02	5.12E-03	1.29E-03	1.00E-03	5.61E-04	3.36E-04	2.21E-04	1.33E-04	3.89E-05
Including: Rh-106	Ground	THYROID	5.01E-03	7.04E-04	1.06E-04	5.03E-05	2.30E-05	1.14E-05	7.36E-06	5.20E-06	3.43E-06	8.66E-07
	(wake)	EDEWBODY	2.03E-01	3.28E-02	7.07E-03	2.39E-03	1.22E-03	7.21E-04	3.48E-04	2.54E-04	2.01E-04	5.23E-05
	ACRR	THYROID	7.44E-04	3.06E-04	1.04E-04	5.17E-05	3.06E-05	2.00E-05	8.83E-06	5.97E-06	3.88E-06	1.08E-06
		EDEWBODY	3.57E-02	2.06E-02	7.06E-03	3.07E-03	1.43E-03	1.01E-03	5.45E-04	3.40E-04	2.26E-04	5.85E-05
	Stack	THYROID	1.32E-05	5.17E-05	3.26E-05	3.04E-05	3.01E-05	2.01E-05	1.38E-05	8.50E-06	5.99E-06	2.05E-06
		EDEWBODY	3.96E-04	2.08E-03	1.23E-03	1.18E-03	1.07E-03	1.02E-03	5.31E-04	3.94E-04	2.51E-04	8.12E-05

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Rh-106	Ground	THYROID	*1.03E-04*	*7.47E-07*	*8.85E-09*	*8.56E-10*	*6.04E-11*	*5.55E-12*	*2.27E-13*	*7.81E-15*	*2.27E-16*	*6.16E-21*
29.9s B-	(no wake)	EDEWBODY	*1.03E-04*	*7.48E-07*	*8.85E-09*	*8.56E-10*	*6.04E-11*	*5.55E-12*	*2.27E-13*	*7.81E-15*	*2.27E-16*	*6.20E-21*
	Ground	THYROID	*2.02E-05*	*5.33E-07*	*8.85E-09*	*8.56E-10*	*6.04E-11*	*5.55E-12*	*2.27E-13*	*7.81E-15*	*2.27E-16*	*6.24E-21*
	(wake)	EDEWBODY	*2.02E-05*	*5.34E-07*	*8.85E-09*	*8.56E-10*	*6.04E-11*	*5.55E-12*	*2.27E-13*	*7.81E-15*	*2.27E-16*	*6.28E-21*
	ACRR	THYROID	*3.32E-06*	*2.29E-07*	*7.31E-09*	*7.11E-10*	*5.55E-11*	*5.55E-12*	*2.27E-13*	*7.81E-15*	*2.27E-16*	*6.29E-21*
		EDEWBODY	*3.33E-06*	*2.29E-07*	*7.44E-09*	*7.11E-10*	*5.55E-11*	*5.55E-12*	*2.27E-13*	*7.81E-15*	*2.27E-16*	*6.32E-21*
	Stack	THYROID	*2.78E-07*	*5.72E-08*	*4.20E-09*	*5.08E-10*	*4.20E-11*	*4.01E-12*	*1.48E-13*	*7.81E-15*	*2.27E-16*	*6.32E-21*
		EDEWBODY	*2.79E-07*	*6.53E-08*	*4.20E-09*	*5.08E-10*	*4.20E-11*	*4.01E-12*	*1.48E-13*	*7.81E-15*	*2.27E-16*	*6.36E-21*
Xe-125	Ground	THYROID	*3.13E-05*	*1.02E-05*	*3.20E-06*	*3.05E-06*	*2.06E-06*	*2.00E-06*	*7.57E-07*	*5.52E-07*	*4.10E-07*	*3.11E-07*
17.0h	(no wake)	EDEWBODY	*2.38E-05*	*5.15E-06*	*2.05E-06*	*1.09E-06*	*1.01E-06*	*7.18E-07*	*3.86E-07*	*2.49E-07*	*1.87E-07*	*9.22E-08*
ECB+	Ground	THYROID	*1.01E-05*	*7.17E-06*	*3.16E-06*	*3.02E-06*	*2.05E-06*	*1.13E-06*	*7.57E-07*	*5.44E-07*	*4.04E-07*	*3.11E-07*
	(wake)	EDEWBODY	*1.00E-05*	*3.38E-06*	*2.02E-06*	*1.06E-06*	*1.01E-06*	*7.14E-07*	*3.60E-07*	*2.49E-07*	*1.87E-07*	*9.22E-08*
	ACRR	THYROID	*3.03E-06*	*3.08E-06*	*3.01E-06*	*2.07E-06*	*2.01E-06*	*1.08E-06*	*7.57E-07*	*5.44E-07*	*4.04E-07*	*3.10E-07*
		EDEWBODY	*2.16E-06*	*2.00E-06*	*1.03E-06*	*1.00E-06*	*7.13E-07*	*5.19E-07*	*2.85E-07*	*2.40E-07*	*1.58E-07*	*8.30E-08*
	Stack	THYROID	*8.25E-07*	*7.67E-07*	*1.00E-06*	*1.02E-06*	*1.02E-06*	*1.02E-06*	*5.38E-07*	*4.06E-07*	*3.69E-07*	*2.74E-07*
		EDEWBODY	*8.13E-07*	*7.18E-07*	*7.02E-07*	*5.02E-07*	*3.28E-07*	*3.10E-07*	*1.92E-07*	*1.49E-07*	*1.36E-07*	*7.23E-08*
I-125	Ground	THYROID	*2.08E+00*	*7.42E-02*	*8.25E-03*	*3.11E-03*	*1.23E-03*	*1.00E-03*	*5.60E-04*	*3.54E-04*	*2.39E-04*	*6.72E-05*
60.14d EC	(no wake)	EDEWBODY	*7.15E-02*	*2.29E-03*	*2.48E-04*	*1.01E-04*	*5.03E-05*	*3.05E-05*	*1.48E-05*	*1.12E-05*	*7.76E-06*	*2.12E-06*
	Ground	THYROID	*3.07E-01*	*7.16E-02*	*1.04E-02*	*3.89E-03*	*2.12E-03*	*1.09E-03*	*7.16E-04*	*4.05E-04*	*3.21E-04*	*8.22E-05*
	(wake)	EDEWBODY	*1.02E-02*	*2.07E-03*	*3.14E-04*	*1.23E-04*	*7.05E-05*	*3.30E-05*	*2.09E-05*	*1.29E-05*	*1.02E-05*	*2.50E-06*
	ACRR	THYROID	*7.29E-02*	*3.21E-02*	*1.03E-02*	*5.11E-03*	*3.02E-03*	*1.42E-03*	*8.46E-04*	*5.67E-04*	*3.67E-04*	*1.05E-04*
		EDEWBODY	*2.10E-03*	*1.03E-03*	*3.10E-04*	*1.33E-04*	*7.43E-05*	*5.09E-05*	*2.55E-05*	*1.52E-05*	*1.15E-05*	*3.17E-06*
	Stack	THYROID	*7.54E-04*	*3.35E-03*	*2.24E-03*	*2.17E-03*	*2.06E-03*	*1.39E-03*	*8.49E-04*	*6.08E-04*	*4.10E-04*	*1.25E-04*
		EDEWBODY	*2.19E-05*	*1.07E-04*	*7.41E-05*	*7.37E-05*	*7.07E-05*	*5.12E-05*	*2.53E-05*	*1.59E-05*	*1.47E-05*	*3.86E-06*

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

Isotope	Release	Effect	Centerline Dose (rem) at Radial Range (km)									
			0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Te-125m	Ground	THYROID	1.02E-03	5.02E-05	5.02E-06	1.29E-06	1.00E-06	5.67E-07	3.36E-07	2.10E-07	1.15E-07	3.84E-08
58d IT	(no wake)	EDEWBODY	2.07E-02	7.36E-04	7.98E-05	3.06E-05	1.21E-05	8.61E-06	5.47E-06	3.45E-06	2.34E-06	6.13E-07
	Ground	THYROID	2.03E-04	3.05E-05	7.01E-06	2.10E-06	1.22E-06	7.23E-07	3.49E-07	2.54E-07	2.01E-07	4.70E-08
	(wake)	EDEWBODY	3.07E-03	7.12E-04	1.03E-04	3.81E-05	2.05E-05	1.07E-05	7.07E-06	3.95E-06	3.13E-06	7.84E-07
	ACRR	THYROID	3.58E-05	2.01E-05	7.01E-06	3.01E-06	1.11E-06	1.01E-06	5.46E-07	3.42E-07	2.27E-07	5.79E-08
		EDEWBODY	7.25E-04	3.02E-04	1.03E-04	5.08E-05	3.00E-05	1.39E-05	8.34E-06	5.56E-06	3.57E-06	1.02E-06
	Stack	THYROID	6.45E-07	2.10E-06	1.23E-06	1.04E-06	1.01E-06	1.00E-06	5.31E-07	3.94E-07	2.51E-07	7.97E-08
		EDEWBODY	7.75E-06	3.35E-05	2.13E-05	2.15E-05	2.04E-05	1.23E-05	8.33E-06	5.91E-06	4.04E-06	1.23E-06
I-126	Ground	THYROID	3.27E+00	1.35E-01	1.42E-02	5.34E-03	3.01E-03	1.48E-03	1.05E-03	7.10E-04	4.04E-04	1.22E-04
13.02d	(no wake)	EDEWBODY	1.09E-01	5.12E-03	5.28E-04	2.01E-04	1.01E-04	5.75E-05	3.41E-05	2.25E-05	1.38E-05	3.94E-06
ECB+B-	Ground	THYROID	7.04E-01	1.08E-01	2.04E-02	7.29E-03	3.69E-03	2.11E-03	1.12E-03	8.16E-04	5.70E-04	1.39E-04
	(wake)	EDEWBODY	3.00E-02	5.01E-03	7.09E-04	2.45E-04	1.24E-04	7.29E-05	3.51E-05	3.01E-05	2.04E-05	5.28E-06
	ACRR	THYROID	1.13E-01	7.06E-02	2.04E-02	1.01E-02	5.10E-03	3.05E-03	1.51E-03	1.06E-03	7.23E-04	1.55E-04
		EDEWBODY	5.07E-03	2.01E-03	7.09E-04	3.08E-04	1.45E-04	1.02E-04	5.50E-05	3.44E-05	2.30E-05	5.98E-06
	Stack	THYROID	1.41E-03	7.25E-03	3.69E-03	5.03E-03	3.22E-03	3.07E-03	1.50E-03	1.23E-03	8.47E-04	2.39E-04
		EDEWBODY	5.53E-05	2.26E-04	1.24E-04	1.04E-04	1.08E-04	1.02E-04	5.60E-05	3.94E-05	2.80E-05	8.18E-06
Sb-127	Ground	THYROID	2.01E-02	7.05E-04	7.21E-05	3.03E-05	1.20E-05	8.52E-06	5.21E-06	3.23E-06	2.18E-06	6.13E-07
3.85d B-	(no wake)	EDEWBODY	3.00E-02	1.00E-03	1.00E-04	3.30E-05	1.61E-05	1.11E-05	7.08E-06	3.42E-06	3.09E-06	8.02E-07
	Ground	THYROID	3.06E-03	7.01E-04	1.00E-04	3.19E-05	2.01E-05	1.07E-05	7.03E-06	3.94E-06	3.12E-06	7.75E-07
	(wake)	EDEWBODY	5.02E-03	7.05E-04	1.03E-04	5.02E-05	2.11E-05	1.18E-05	7.65E-06	5.47E-06	3.61E-06	9.58E-07
	ACRR	THYROID	7.14E-04	3.02E-04	1.00E-04	5.01E-05	2.06E-05	1.10E-05	8.35E-06	5.47E-06	3.55E-06	8.66E-07
		EDEWBODY	7.53E-04	3.07E-04	1.01E-04	5.05E-05	3.02E-05	2.02E-05	1.08E-05	6.75E-07	4.06E-06	1.15E-06
	Stack	THYROID	1.08E-05	3.19E-05	2.13E-05	2.03E-05	2.01E-05	1.02E-05	7.47E-06	5.63E-06	3.95E-06	1.14E-06
		EDEWBODY	1.69E-05	5.55E-05	3.47E-05	3.07E-05	3.02E-05	2.03E-05	1.45E-05	8.62E-06	6.60E-06	2.13E-06

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	**Release**	**Effect**	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Te-127	Ground	THYROID	1.00E-04	3.03E-06	3.14E-07	1.16E-07	7.10E-08	3.85E-08	2.16E-08	1.20E-08	1.07E-08	2.55E-09
9.35h B-	(no wake)	EDEWBODY	1.04E-03	3.43E-05	3.74E-06	1.13E-06	6.25E-07	3.68E-07	2.27E-07	1.34E-07	1.05E-07	2.47E-08
	Ground	THYROID	2.00E-05	3.01E-06	5.01E-07	2.00E-07	1.00E-07	5.22E-08	3.11E-08	2.08E-08	1.27E-08	3.37E-09
	(wake)	EDEWBODY	2.00E-04	3.16E-05	5.06E-06	1.78E-06	9.08E-07	5.05E-07	3.01E-07	1.52E-07	1.21E-07	3.17E-08
	ACRR	THYROID	3.12E-06	1.03E-06	5.01E-07	2.02E-07	1.01E-07	7.03E-08	3.18E-08	2.19E-08	1.45E-08	3.84E-09
		EDEWBODY	3.12E-05	1.03E-05	5.05E-06	2.14E-06	1.11E-06	7.11E-07	3.52E-07	2.12E-07	1.36E-07	3.63E-08
	Stack	THYROID	4.76E-08	1.62E-07	1.07E-07	1.01E-07	7.08E-08	7.02E-08	3.85E-08	2.53E-08	1.82E-08	5.30E-09
		EDEWBODY	3.11E-07	1.25E-06	8.02E-07	1.01E-06	7.25E-07	5.31E-07	3.28E-07	2.31E-07	1.54E-07	4.66E-08
Te-127m	Ground	THYROID	1.02E-03	5.11E-05	5.14E-06	2.01E-06	1.01E-06	5.75E-07	3.41E-07	2.25E-07	1.38E-07	3.94E-08
109d ITB-	(no wake)	EDEWBODY	7.03E-02	2.10E-03	2.27E-04	7.65E-05	3.53E-05	2.44E-05	1.35E-05	1.04E-05	7.17E-06	1.54E-06
	Ground	THYROID	3.00E-04	5.00E-05	7.09E-06	2.45E-06	1.24E-06	7.29E-07	3.54E-07	3.01E-07	2.04E-07	5.28E-08
	(wake)	EDEWBODY	1.01E-02	2.03E-03	3.05E-04	1.09E-04	5.66E-05	3.15E-05	2.01E-05	1.19E-05	8.30E-06	2.23E-06
	ACRR	THYROID	5.07E-05	2.01E-05	7.08E-06	3.08E-06	1.45E-06	1.02E-06	5.51E-07	3.46E-07	2.30E-07	5.98E-08
		EDEWBODY	2.07E-03	1.01E-03	3.05E-04	1.17E-04	7.26E-05	3.98E-05	2.40E-05	1.39E-05	1.06E-05	2.57E-06
	Stack	THYROID	6.04E-07	2.26E-06	1.24E-06	1.04E-06	1.01E-06	1.02E-06	5.60E-07	3.94E-07	2.80E-07	8.18E-08
		EDEWBODY	2.18E-05	1.06E-04	5.69E-05	7.10E-05	5.20E-05	5.03E-05	2.44E-05	1.59E-05	1.41E-05	3.57E-06
Xe-127	Ground	THYROID	2.14E-05	6.24E-06	2.41E-06	1.60E-06	1.13E-06	8.57E-07	3.86E-07	2.49E-07	1.87E-07	1.03E-07
36.41d EC	(no wake)	EDEWBODY	2.44E-05	6.34E-06	2.45E-06	1.63E-06	1.14E-06	8.71E-07	3.86E-07	2.56E-07	1.87E-07	1.03E-07
	Ground	THYROID	1.06E-05	4.90E-06	2.20E-06	1.52E-06	1.07E-06	8.27E-07	3.86E-07	2.49E-07	1.87E-07	1.02E-07
	(wake)	EDEWBODY	1.08E-05	4.98E-06	2.24E-06	1.54E-06	1.09E-06	8.40E-07	3.86E-07	2.49E-07	1.87E-07	1.03E-07
	ACRR	THYROID	2.22E-06	2.10E-06	1.27E-06	1.01E-06	8.00E-07	6.57E-07	3.29E-07	2.40E-07	1.58E-07	9.22E-08
		EDEWBODY	2.23E-06	2.13E-06	1.29E-06	1.04E-06	8.13E-07	6.68E-07	3.29E-07	2.40E-07	1.58E-07	9.22E-08
	Stack	THYROID	8.27E-07	7.26E-07	7.97E-07	5.97E-07	3.77E-07	3.75E-07	1.93E-07	1.49E-07	1.36E-07	7.28E-08
		EDEWBODY	8.34E-07	7.27E-07	8.10E-07	6.06E-07	4.60E-07	3.81E-07	1.93E-07	1.49E-07	1.36E-07	7.72E-08

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	**Release**	**Effect**	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Sn-128	Ground	THYROID	*5.04E-03*	*2.02E-04*	*3.01E-05*	*1.09E-05*	*5.65E-06*	*3.67E-06*	*2.15E-06*	*1.19E-06*	*1.07E-06*	*1.78E-07*
59.1m B-	(no wake)	EDEWBODY	*7.01E-03*	*3.00E-04*	*3.02E-05*	*1.11E-05*	*7.03E-06*	*3.76E-06*	*2.17E-06*	*1.20E-06*	*1.08E-06*	*1.78E-07*
	Ground	THYROID	*1.01E-03*	*2.01E-04*	*3.04E-05*	*1.11E-05*	*7.61E-06*	*5.04E-06*	*3.09E-06*	*2.02E-06*	*1.11E-06*	*2.19E-07*
	(wake)	EDEWBODY	*1.01E-03*	*2.01E-04*	*3.10E-05*	*1.12E-05*	*7.71E-06*	*5.10E-06*	*3.15E-06*	*2.03E-06*	*1.11E-06*	*2.30E-07*
	ACRR	THYROID	*2.07E-04*	*1.01E-04*	*3.04E-05*	*2.00E-05*	*1.00E-05*	*5.35E-06*	*3.16E-06*	*2.18E-06*	*1.13E-06*	*2.39E-07*
		EDEWBODY	*2.09E-04*	*1.01E-04*	*3.04E-05*	*2.01E-05*	*1.00E-05*	*5.45E-06*	*3.22E-06*	*2.24E-06*	*1.14E-06*	*2.50E-07*
	Stack	THYROID	*4.62E-06*	*1.09E-05*	*1.05E-05*	*1.01E-05*	*7.07E-06*	*5.05E-06*	*3.06E-06*	*2.14E-06*	*1.39E-06*	*3.04E-07*
		EDEWBODY	*4.62E-06*	*1.20E-05*	*1.06E-05*	*1.01E-05*	*7.08E-06*	*5.05E-06*	*3.07E-06*	*2.16E-06*	*1.42E-06*	*3.15E-07*
Sb-128m	Ground	THYROID	*3.02E-03*	*1.01E-04*	*8.56E-06*	*3.20E-06*	*1.17E-06*	*7.33E-07*	*3.21E-07*	*2.12E-07*	*1.00E-07*	*7.11E-09*
10.4m B-	(no wake)	EDEWBODY	*3.02E-03*	*1.01E-04*	*8.62E-06*	*3.21E-06*	*1.17E-06*	*7.44E-07*	*3.21E-07*	*2.12E-07*	*1.00E-07*	*7.12E-09*
(Sb-128a)	Ground	THYROID	*7.01E-04*	*1.00E-04*	*1.01E-05*	*3.26E-06*	*1.19E-06*	*9.21E-07*	*4.31E-07*	*2.18E-07*	*1.17E-07*	*7.12E-09*
	(wake)	EDEWBODY	*7.01E-04*	*1.00E-04*	*1.02E-05*	*3.27E-06*	*1.19E-06*	*1.00E-06*	*5.01E-07*	*2.18E-07*	*1.17E-07*	*7.12E-09*
	ACRR	THYROID	*1.06E-04*	*5.01E-05*	*7.59E-06*	*3.16E-06*	*1.18E-06*	*7.61E-07*	*5.01E-07*	*2.11E-07*	*1.19E-07*	*7.12E-09*
		EDEWBODY	*1.07E-04*	*5.01E-05*	*7.62E-06*	*3.17E-06*	*1.18E-06*	*8.46E-07*	*5.01E-07*	*2.12E-07*	*1.20E-07*	*7.12E-09*
	Stack	THYROID	*7.88E-06*	*7.43E-06*	*3.02E-06*	*1.28E-06*	*1.05E-06*	*5.45E-07*	*3.24E-07*	*2.05E-07*	*1.03E-07*	*7.12E-09*
		EDEWBODY	*7.88E-06*	*7.43E-06*	*3.02E-06*	*1.29E-06*	*1.05E-06*	*5.45E-07*	*3.24E-07*	*2.05E-07*	*1.03E-07*	*7.12E-09*
Sb-129	Ground	THYROID	*1.01E-02*	*5.01E-04*	*5.02E-05*	*1.59E-05*	*1.01E-05*	*5.76E-06*	*3.23E-06*	*2.17E-06*	*1.20E-06*	*3.62E-07*
4.32h B-	(no wake)	EDEWBODY	*1.02E-02*	*5.04E-04*	*5.16E-05*	*2.11E-05*	*1.07E-05*	*7.07E-06*	*3.32E-06*	*2.22E-06*	*1.22E-06*	*3.84E-07*
	Ground	THYROID	*2.02E-03*	*3.05E-04*	*7.01E-05*	*2.11E-05*	*1.06E-05*	*7.39E-06*	*3.54E-06*	*3.05E-06*	*2.03E-06*	*4.70E-07*
	(wake)	EDEWBODY	*3.01E-03*	*5.01E-04*	*7.04E-05*	*3.01E-05*	*1.10E-05*	*7.68E-06*	*5.08E-06*	*3.26E-06*	*2.10E-06*	*5.28E-07*
	ACRR	THYROID	*3.47E-04*	*2.01E-04*	*7.01E-05*	*3.01E-05*	*1.11E-05*	*1.00E-05*	*5.21E-06*	*3.22E-06*	*2.33E-06*	*5.50E-07*
		EDEWBODY	*5.16E-04*	*2.03E-04*	*7.03E-05*	*3.03E-05*	*2.00E-05*	*1.01E-05*	*5.41E-06*	*3.39E-06*	*2.49E-06*	*5.94E-07*
	Stack	THYROID	9.58E-06	2.31E-05	1.24E-05	1.07E-05	1.01E-05	1.01E-05	5.31E-06	3.87E-06	2.51E-06	7.35E-07
		EDEWBODY	9.47E-06	2.49E-05	1.24E-05	1.07E-05	1.02E-05	1.00E-05	5.79E-06	3.94E-06	2.82E-06	7.61E-07

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Te-129m	Ground	THYROID	*5.02E-03*	*2.00E-04*	*2.00E-05*	*7.15E-06*	*3.29E-06*	*2.13E-06*	*1.21E-06*	*7.47E-07*	*5.31E-07*	*1.39E-07*
33.6d ITB-	(no wake)	EDEWBODY	*7.18E-02*	*3.01E-03*	*3.00E-04*	*1.02E-04*	*5.07E-05*	*3.09E-05*	*1.50E-05*	*1.14E-05*	*7.88E-06*	*2.20E-06*
Including: Te-129	Ground	THYROID	*1.00E-03*	*1.04E-04*	*2.02E-05*	*1.00E-05*	*5.06E-06*	*2.31E-06*	*1.23E-06*	*1.05E-06*	*7.34E-07*	*1.57E-07*
	(wake)	EDEWBODY	*1.02E-02*	*2.07E-03*	*3.15E-04*	*1.24E-04*	*7.09E-05*	*3.33E-05*	*2.11E-05*	*1.31E-05*	*1.04E-05*	*2.54E-06*
	ACRR	THYROID	*1.30E-04*	*7.05E-05*	*2.02E-05*	*1.01E-05*	*7.00E-06*	*3.51E-06*	*1.87E-06*	*1.25E-06*	*8.37E-07*	*2.19E-07*
		EDEWBODY	*2.17E-03*	*1.01E-03*	*3.11E-04*	*1.38E-04*	*7.88E-05*	*5.14E-05*	*2.60E-05*	*1.53E-05*	*1.18E-05*	*3.20E-06*
	Stack	THYROID	1.69E-06	7.08E-06	3.47E-06	3.07E-06	3.02E-06	3.00E-06	1.48E-06	9.57E-07	7.89E-07	2.23E-07
		EDEWBODY	2.25E-05	1.07E-04	7.41E-05	7.40E-05	7.09E-05	5.14E-05	2.56E-05	1.87E-05	1.50E-05	3.94E-06
Te-129	Ground	THYROID	*2.01E-04*	*7.07E-06*	*7.64E-07*	*3.18E-07*	*1.49E-07*	*1.02E-07*	*5.45E-08*	*3.36E-08*	*2.22E-08*	*4.56E-09*
69.6m B-	(no wake)	EDEWBODY	*3.05E-04*	*1.10E-05*	*1.20E-06*	*5.36E-07*	*3.04E-07*	*1.47E-07*	*1.02E-07*	*5.45E-08*	*3.38E-08*	*7.46E-09*
	Ground	THYROID	*3.07E-05*	*7.03E-06*	*1.01E-06*	*3.26E-07*	*2.09E-07*	*1.11E-07*	*7.18E-08*	*3.42E-08*	*3.15E-08*	*5.38E-09*
	(wake)	EDEWBODY	*7.05E-05*	*1.01E-05*	*2.00E-06*	*7.57E-07*	*3.27E-07*	*2.09E-07*	*1.16E-07*	*7.26E-08*	*5.11E-08*	*7.99E-09*
	ACRR	THYROID	*7.30E-06*	*3.04E-06*	*1.00E-06*	*5.01E-07*	*2.09E-07*	*1.18E-07*	*7.62E-08*	*5.13E-08*	*3.22E-08*	*5.80E-09*
		EDEWBODY	*1.14E-05*	*7.02E-06*	*2.00E-06*	*8.48E-07*	*4.30E-07*	*2.17E-07*	*1.14E-07*	*8.24E-08*	*5.24E-08*	*1.01E-08*
	Stack	THYROID	2.40E-07	4.52E-07	3.06E-07	2.04E-07	1.13E-07	1.03E-07	6.76E-08	5.05E-08	3.29E-08	6.56E-09
		EDEWBODY	3.69E-07	1.05E-06	5.28E-07	5.03E-07	3.10E-07	3.01E-07	1.14E-07	1.06E-07	7.53E-08	1.27E-08
Xe-129m	Ground	THYROID	*2.09E-06*	*5.43E-07*	*2.10E-07*	*1.39E-07*	*9.77E-08*	*7.44E-08*	*3.57E-08*	*2.40E-08*	*1.53E-08*	*8.14E-09*
8.0d IT	(no wake)	EDEWBODY	*2.07E-06*	*5.38E-07*	*2.08E-07*	*1.38E-07*	*9.68E-08*	*7.37E-08*	*3.29E-08*	*2.40E-08*	*1.53E-08*	*8.14E-09*
	Ground	THYROID	*9.24E-07*	*4.26E-07*	*1.91E-07*	*1.32E-07*	*9.31E-08*	*7.18E-08*	*3.29E-08*	*2.40E-08*	*1.53E-08*	*8.14E-09*
	(wake)	EDEWBODY	*9.15E-07*	*4.22E-07*	*1.89E-07*	*1.31E-07*	*9.22E-08*	*7.11E-08*	*3.29E-08*	*2.40E-08*	*1.53E-08*	*8.14E-09*
	ACRR	THYROID	*2.08E-07*	*1.82E-07*	*1.10E-07*	*8.91E-08*	*6.94E-08*	*5.71E-08*	*2.49E-08*	*1.64E-08*	*1.48E-08*	*8.06E-09*
		EDEWBODY	*2.06E-07*	*1.50E-07*	*1.03E-07*	*8.83E-08*	*6.88E-08*	*5.65E-08*	*2.49E-08*	*1.64E-08*	*1.48E-08*	*8.03E-09*
	Stack	THYROID	*7.68E-08*	*7.14E-08*	*6.93E-08*	*5.07E-08*	*3.93E-08*	*3.26E-08*	*1.49E-08*	*1.38E-08*	*9.59E-09*	*6.49E-09*
		EDEWBODY	*7.64E-08*	*7.13E-08*	*6.86E-08*	*5.14E-08*	*3.89E-08*	*3.23E-08*	*1.49E-08*	*1.36E-08*	*9.59E-09*	*6.49E-09*

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

Isotope	Release	Effect	Centerline Dose (rem) at Radial Range (km)									
			0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Sb-131	Ground	THYROID	1.00E-02	5.00E-04	5.47E-05	2.06E-05	1.05E-05	6.16E-06	3.67E-06	2.40E-06	1.46E-06	3.17E-07
23m B-	(no wake)	EDEWBODY	5.00E-03	1.11E-04	1.27E-05	7.04E-06	3.16E-06	2.06E-06	1.08E-06	7.26E-07	5.01E-07	5.55E-08
	Ground	THYROID	2.01E-03	3.04E-04	7.38E-05	3.08E-05	1.44E-05	7.54E-06	5.04E-06	3.14E-06	2.10E-06	3.50E-07
	(wake)	EDEWBODY	1.00E-03	1.04E-04	2.01E-05	7.55E-06	3.75E-06	2.12E-06	1.11E-06	7.61E-07	5.21E-07	6.21E-08
	ACRR	THYROID	3.15E-04	2.00E-04	7.32E-05	3.36E-05	2.01E-05	1.05E-05	5.30E-06	3.50E-06	2.31E-06	3.85E-07
		EDEWBODY	1.30E-04	7.04E-05	2.01E-05	7.31E-06	3.53E-06	2.38E-06	1.12E-06	7.67E-07	5.40E-07	6.33E-08
	Stack	THYROID	9.38E-06	2.08E-05	1.22E-05	1.64E-05	1.27E-05	1.06E-05	5.79E-06	3.72E-06	2.53E-06	5.35E-07
		EDEWBODY	8.20E-06	1.05E-05	7.10E-06	5.02E-06	3.02E-06	2.05E-06	1.11E-06	7.54E-07	5.35E-07	7.64E-08
Te-131m	Ground	THYROID	3.28E-01	1.36E-02	1.44E-03	5.39E-04	3.04E-04	1.51E-04	1.08E-04	7.23E-05	5.05E-05	1.26E-05
30h ITB-	(no wake)	EDEWBODY	5.03E-02	2.01E-03	2.02E-04	7.45E-05	3.44E-05	2.34E-05	1.30E-05	1.00E-05	5.45E-06	1.49E-06
Including: Te-131	Ground	THYROID	7.05E-02	1.08E-02	2.04E-03	7.62E-04	3.75E-04	2.13E-04	1.14E-04	8.34E-05	5.85E-05	1.42E-05
	(wake)	EDEWBODY	1.00E-02	2.00E-03	3.00E-04	1.01E-04	5.30E-05	3.08E-05	1.29E-05	1.15E-05	7.96E-06	2.12E-06
	ACRR	THYROID	1.14E-02	7.01E-03	2.04E-03	1.01E-03	5.12E-04	3.08E-04	1.54E-04	1.09E-04	7.41E-05	2.03E-05
		EDEWBODY	2.03E-03	1.00E-03	3.00E-04	1.01E-04	7.02E-05	3.76E-05	2.27E-05	1.33E-05	1.02E-05	2.41E-06
	Stack	THYROID	1.50E-04	7.08E-04	3.47E-04	3.38E-04	3.13E-04	3.03E-04	1.48E-04	9.60E-05	7.89E-05	2.29E-05
		EDEWBODY	1.89E-05	7.83E-05	5.28E-05	5.06E-05	5.01E-05	3.02E-05	1.59E-05	1.45E-05	9.40E-06	3.04E-06
Te-131	Ground	THYROID	3.06E-02	1.02E-03	7.49E-05	3.01E-05	1.25E-05	7.65E-06	3.78E-06	2.43E-06	1.39E-06	2.48E-07
25.0m B-	(no wake)	EDEWBODY	2.01E-03	7.04E-05	6.25E-06	2.38E-06	1.17E-06	7.11E-07	3.30E-07	2.14E-07	1.33E-07	1.53E-08
	Ground	THYROID	5.31E-03	7.71E-04	1.04E-04	3.19E-05	1.40E-05	8.39E-06	5.16E-06	3.12E-06	2.02E-06	3.11E-07
	(wake)	EDEWBODY	3.07E-04	7.01E-05	8.59E-06	3.02E-06	1.31E-06	7.86E-07	3.41E-07	2.22E-07	1.18E-07	1.78E-08
	ACRR	THYROID	7.52E-04	3.75E-04	1.03E-04	4.05E-05	1.28E-05	1.03E-05	5.54E-06	3.35E-06	2.15E-06	3.41E-07
		EDEWBODY	7.26E-05	3.02E-05	7.05E-06	3.27E-06	1.20E-06	8.21E-07	5.02E-07	3.05E-07	2.00E-07	2.17E-08
	Stack	THYROID	1.06E-05	5.06E-05	2.24E-05	2.05E-05	1.38E-05	1.01E-05	5.47E-06	3.47E-06	2.30E-06	4.09E-07
		EDEWBODY	1.89E-06	3.54E-06	2.13E-06	1.13E-06	1.01E-06	7.08E-07	3.82E-07	2.23E-07	1.21E-07	2.49E-08

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	**Release**	**Effect**	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
I-131 8.04d B-	Ground	THYROID	3.03E+00	1.05E-01	1.15E-02	3.54E-03	2.11E-03	1.23E-03	7.78E-04	5.22E-04	3.41E-04	8.68E-05
	(no wake)	EDEWBODY	1.00E-01	3.45E-03	3.77E-04	1.19E-04	7.33E-05	4.01E-05	2.47E-05	1.48E-05	1.15E-05	3.23E-06
	Ground	THYROID	5.04E-01	1.02E-01	1.29E-02	5.46E-03	3.04E-03	1.23E-03	1.00E-03	5.96E-04	3.89E-04	1.11E-04
	(wake)	EDEWBODY	2.01E-02	3.10E-03	5.10E-04	2.03E-04	1.02E-04	5.29E-05	3.13E-05	2.12E-05	1.31E-05	3.71E-06
	ACRR	THYROID	1.03E-01	5.07E-02	1.19E-02	7.12E-03	3.38E-03	2.08E-03	1.20E-03	7.79E-04	5.29E-04	1.30E-04
		EDEWBODY	3.15E-03	1.05E-03	5.09E-04	2.11E-04	1.13E-04	7.24E-05	3.93E-05	2.50E-05	1.50E-05	4.14E-06
	Stack	THYROID	1.09E-03	5.17E-03	3.25E-03	3.18E-03	3.04E-03	2.08E-03	1.35E-03	8.36E-04	5.99E-04	2.02E-04
		EDEWBODY	3.68E-05	2.03E-04	1.08E-04	1.01E-04	1.02E-04	7.23E-05	3.94E-05	2.53E-05	2.29E-05	5.96E-06
Xe-131m 11.9d IT	Ground	THYROID	*7.63E-07*	*1.98E-07*	*7.66E-08*	*5.09E-08*	*3.57E-08*	*2.72E-08*	*1.26E-08*	*8.34E-09*	*6.01E-09*	*3.10E-09*
	(no wake)	EDEWBODY	*7.22E-07*	*1.97E-07*	*7.62E-08*	*5.06E-08*	*3.56E-08*	*2.71E-08*	*1.26E-08*	*8.34E-09*	*6.01E-09*	*3.10E-09*
	Ground	THYROID	*3.38E-07*	*1.56E-07*	*6.99E-08*	*4.82E-08*	*3.40E-08*	*2.62E-08*	*1.26E-08*	*8.34E-09*	*6.01E-09*	*3.10E-09*
	(wake)	EDEWBODY	*3.36E-07*	*1.55E-07*	*6.95E-08*	*3.71E-08*	*3.39E-08*	*2.61E-08*	*1.26E-08*	*8.34E-09*	*6.01E-09*	*3.09E-09*
	ACRR	THYROID	*7.34E-08*	*6.66E-08*	*4.03E-08*	*3.26E-08*	*2.54E-08*	*2.09E-08*	*9.53E-09*	*6.84E-09*	*5.81E-09*	*3.07E-09*
		EDEWBODY	*7.42E-08*	*6.63E-08*	*4.01E-08*	*3.09E-08*	*2.53E-08*	*2.08E-08*	*9.53E-09*	*6.84E-09*	*5.81E-09*	*3.07E-09*
	Stack	THYROID	*2.48E-08*	*2.17E-08*	*2.53E-08*	*1.43E-08*	*1.44E-08*	*1.19E-08*	*5.73E-09*	*4.21E-09*	*3.97E-09*	*2.35E-09*
		EDEWBODY	*2.48E-08*	*2.17E-08*	*2.52E-08*	*1.89E-08*	*1.43E-08*	*1.19E-08*	*5.73E-09*	*4.21E-09*	*3.97E-09*	*2.35E-09*
Te-132 *78.2h B-*	Ground	THYROID	*7.17E-01*	*3.00E-02*	*2.50E-03*	*1.01E-03*	*5.07E-04*	*3.09E-04*	*1.50E-04*	*1.14E-04*	*7.86E-05*	*2.19E-05*
	(no wake)	EDEWBODY	*7.05E-02*	*3.01E-03*	*3.02E-04*	*1.08E-04*	*5.47E-05*	*3.47E-05*	*2.15E-05*	*1.12E-05*	*1.01E-05*	*2.53E-06*
	Ground	THYROID	*1.02E-01*	*2.07E-02*	*3.15E-03*	*2.40E-03*	*7.09E-04*	*3.33E-04*	*2.10E-04*	*1.30E-04*	*1.04E-04*	*2.53E-05*
	(wake)	EDEWBODY	*1.03E-02*	*2.03E-03*	*3.10E-04*	*1.11E-04*	*7.88E-05*	*4.12E-05*	*2.28E-05*	*1.46E-05*	*1.17E-05*	*3.22E-06*
	ACRR	THYROID	*2.13E-02*	*1.01E-02*	*3.11E-03*	*1.38E-03*	*7.87E-04*	*5.13E-04*	*2.60E-04*	*1.53E-04*	*1.18E-04*	*3.20E-05*
		EDEWBODY	*2.25E-03*	*1.02E-03*	*3.04E-04*	*2.00E-04*	*1.00E-04*	*5.89E-05*	*3.35E-05*	*2.21E-05*	*1.33E-05*	*3.68E-06*
	Stack	THYROID	2.26E-04	1.06E-03	5.69E-04	7.10E-04	5.19E-04	5.03E-04	2.44E-04	1.59E-04	1.41E-04	3.55E-05
		EDEWBODY	2.94E-05	1.17E-04	7.41E-05	7.11E-05	7.04E-05	5.04E-05	2.86E-05	2.31E-05	1.53E-05	5.12E-06

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

Isotope	Release	Effect	Centerline Dose (rem) at Radial Range (km)									
			0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
I-132	Ground	THYROID	3.01E-02	1.01E-03	1.23E-04	3.54E-05	2.17E-05	1.23E-05	7.67E-06	5.07E-06	3.15E-06	7.24E-07
2.30h B-	(no wake)	EDEWBODY	1.01E-02	5.02E-04	5.05E-05	2.02E-05	1.02E-05	5.84E-06	3.25E-06	2.17E-06	1.20E-06	3.42E-07
	Ground	THYROID	5.04E-03	1.00E-03	1.08E-04	5.72E-05	2.31E-05	1.21E-05	8.60E-06	5.73E-06	3.64E-06	7.79E-07
	(wake)	EDEWBODY	2.02E-03	3.05E-04	7.01E-05	2.12E-05	1.11E-05	7.34E-06	3.94E-06	3.01E-06	2.03E-06	3.76E-07
	ACRR	THYROID	1.04E-03	5.01E-04	1.04E-04	7.14E-05	3.51E-05	2.06E-05	1.05E-05	7.08E-06	4.06E-06	9.52E-07
		EDEWBODY	3.47E-04	2.01E-04	7.01E-05	3.01E-05	1.10E-05	7.41E-06	5.16E-06	3.13E-06	2.24E-06	5.02E-07
	Stack	THYROID	1.82E-05	5.17E-05	3.26E-05	3.04E-05	2.40E-05	2.01E-05	1.14E-05	7.84E-06	5.50E-06	1.18E-06
		EDEWBODY	9.61E-06	2.53E-05	1.27E-05	1.07E-05	1.01E-05	1.00E-05	4.76E-06	3.16E-06	2.42E-06	5.84E-07
Te-133	Ground	THYROID	*7.04E-03*	*3.03E-04*	*2.21E-05*	*8.62E-06*	*4.07E-06*	*2.42E-06*	*1.33E-06*	*1.01E-06*	*5.88E-07*	*1.36E-07*
12.45m B-	(no wake)	EDEWBODY	*2.00E-03*	*7.01E-05*	*5.78E-06*	*2.10E-06*	*1.05E-06*	*5.37E-07*	*3.05E-07*	*1.56E-07*	*1.04E-07*	*9.39E-09*
	Ground	THYROID	*1.03E-03*	*2.23E-04*	*3.24E-05*	*1.20E-05*	*5.28E-06*	*3.19E-06*	*1.51E-06*	*1.12E-06*	*7.56E-07*	*1.56E-07*
	(wake)	EDEWBODY	*3.04E-04*	*5.05E-05*	*5.65E-06*	*2.36E-06*	*1.07E-06*	*6.03E-07*	*3.17E-07*	*2.03E-07*	*1.04E-07*	*1.17E-08*
	ACRR	THYROID	*2.24E-04*	*1.01E-04*	*3.18E-05*	*1.38E-05*	*7.23E-06*	*4.03E-06*	*2.18E-06*	*1.13E-06*	*8.55E-07*	*2.15E-07*
		EDEWBODY	*7.14E-05*	*3.01E-05*	*5.18E-06*	*2.19E-06*	*1.06E-06*	*5.45E-07*	*3.28E-07*	*2.06E-07*	*1.07E-07*	*1.27E-08*
	Stack	THYROID	*4.37E-06*	*1.25E-05*	*7.41E-06*	*7.24E-06*	*5.34E-06*	*3.60E-06*	*2.15E-06*	*1.53E-06*	*1.15E-06*	*3.11E-07*
		EDEWBODY	*3.68E-06*	*3.77E-06*	*2.04E-06*	*1.05E-06*	*7.17E-07*	*3.49E-07*	*3.02E-07*	*1.57E-07*	*1.10E-07*	*1.52E-08*
Te-133m	Ground	THYROID	*3.02E-02*	*1.28E-03*	*1.34E-04*	*4.22E-05*	*2.36E-05*	*1.31E-05*	*8.18E-06*	*5.50E-06*	*3.54E-06*	*8.14E-07*
55.4m ITB-	(no wake)	EDEWBODY	*1.00E-02*	*3.02E-04*	*3.23E-05*	*1.15E-05*	*7.22E-06*	*3.33E-06*	*2.18E-06*	*1.18E-06*	*1.06E-06*	*1.78E-07*
	Ground	THYROID	*7.01E-03*	*1.01E-03*	*1.68E-04*	*6.56E-05*	*3.29E-05*	*1.28E-05*	*1.06E-05*	*7.06E-06*	*3.97E-06*	*1.04E-06*
	(wake)	EDEWBODY	*1.06E-03*	*3.01E-04*	*3.26E-05*	*1.14E-05*	*7.79E-06*	*5.17E-06*	*3.08E-06*	*1.88E-06*	*1.10E-06*	*2.15E-07*
	ACRR	THYROID	*1.05E-03*	*5.03E-04*	*1.61E-04*	*7.52E-05*	*4.06E-05*	*2.38E-05*	*1.10E-05*	*7.44E-06*	*5.40E-06*	*1.18E-06*
		EDEWBODY	*3.10E-04*	*1.03E-04*	*3.11E-05*	*2.00E-05*	*1.00E-05*	*5.37E-06*	*3.15E-06*	*2.15E-06*	*1.12E-06*	*2.36E-07*
	Stack	THYROID	*1.69E-05*	*6.42E-05*	*3.47E-05*	*3.06E-05*	*3.17E-05*	*2.26E-05*	*1.35E-05*	*8.49E-06*	*5.90E-06*	*1.40E-06*
		EDEWBODY	*9.67E-06*	*2.08E-05*	*1.07E-05*	*1.01E-05*	*7.06E-06*	*5.04E-06*	*3.06E-06*	*2.12E-06*	*1.36E-06*	*3.02E-07*

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

Isotope	Release	Effect	Centerline Dose (rem) at Radial Range (km)									
			0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
I-133	Ground	THYROID	5.07E-01	2.04E-02	2.05E-03	7.26E-04	3.34E-04	2.17E-04	1.23E-04	8.19E-05	5.69E-05	1.38E-05
20.8h B-	(no wake)	EDEWBODY	3.00E-02	1.01E-03	1.12E-04	3.50E-05	2.09E-05	1.21E-05	7.62E-06	5.13E-06	3.34E-06	8.55E-07
	Ground	THYROID	1.00E-01	1.37E-02	2.26E-03	1.01E-03	5.07E-04	2.31E-04	1.22E-04	1.05E-04	7.31E-05	1.56E-05
	(wake)	EDEWBODY	5.03E-03	1.00E-03	1.06E-04	5.20E-05	3.01E-05	1.22E-05	7.89E-06	5.83E-06	3.80E-06	1.06E-06
	ACRR	THYROID	1.34E-02	7.47E-03	2.13E-03	1.05E-03	7.02E-04	3.50E-04	1.87E-04	1.22E-04	8.38E-05	2.16E-05
		EDEWBODY	1.02E-03	5.01E-04	1.02E-04	7.07E-05	3.17E-05	2.06E-05	1.14E-05	7.50E-06	5.16E-06	1.21E-06
	Stack	THYROID	1.56E-04	1.01E-03	5.27E-04	5.31E-04	5.07E-04	3.21E-04	1.87E-04	1.45E-04	1.15E-04	3.13E-05
		EDEWBODY	1.34E-05	5.17E-05	3.26E-05	3.03E-05	3.01E-05	2.01E-05	1.32E-05	7.94E-06	5.91E-06	1.48E-06
Xe-133	Ground	THYROID	2.95E-06	7.66E-07	2.32E-07	1.96E-07	1.38E-07	1.05E-07	4.70E-08	3.63E-08	2.45E-08	1.17E-08
5.245d B-	(no wake)	EDEWBODY	3.04E-06	7.91E-07	3.05E-07	2.03E-07	1.42E-07	1.03E-07	4.70E-08	3.77E-08	2.45E-08	1.22E-08
	Ground	THYROID	1.30E-06	6.02E-07	2.24E-07	1.32E-07	1.11E-07	1.01E-07	4.09E-08	2.92E-08	2.45E-08	1.17E-08
	(wake)	EDEWBODY	1.17E-06	6.22E-08	2.79E-07	1.92E-07	1.36E-07	1.04E-07	4.70E-08	3.77E-08	2.45E-08	1.18E-08
	ACRR	THYROID	3.07E-07	2.57E-07	1.28E-07	1.26E-07	9.79E-08	8.04E-08	3.86E-08	2.56E-08	2.39E-08	1.14E-08
		EDEWBODY	3.08E-07	2.66E-07	1.61E-07	1.30E-07	1.01E-07	8.30E-08	3.86E-08	2.61E-08	2.40E-08	1.16E-08
	Stack	THYROID	1.18E-07	1.03E-07	1.13E-07	8.50E-08	6.47E-09	5.37E-08	2.54E-08	1.93E-08	1.55E-08	1.04E-08
		EDEWBODY	1.12E-07	1.03E-07	1.02E-07	7.74E-08	5.90E-08	4.90E-08	2.31E-08	1.65E-08	1.53E-08	1.02E-08
Xe-133m	Ground	THYROID	2.65E-06	6.90E-07	2.66E-07	1.77E-07	1.24E-07	9.42E-08	3.94E-08	2.56E-08	2.39E-08	1.09E-08
2.188d IT	(no wake)	EDEWBODY	2.23E-06	6.95E-07	2.68E-07	1.78E-07	1.25E-07	9.49E-08	3.94E-08	2.85E-08	2.39E-08	1.09E-08
	Ground	THYROID	1.17E-06	5.42E-07	2.43E-07	1.67E-07	1.06E-07	9.09E-08	3.86E-08	2.56E-08	2.39E-08	1.09E-08
	(wake)	EDEWBODY	1.18E-06	5.46E-07	2.45E-07	1.69E-07	1.19E-07	9.16E-08	3.86E-08	2.56E-08	2.39E-08	1.09E-08
	ACRR	THYROID	3.01E-07	2.32E-07	1.19E-07	1.13E-07	8.80E-08	7.23E-08	3.60E-08	2.44E-08	1.87E-08	1.03E-08
		EDEWBODY	3.01E-07	2.33E-07	1.41E-07	1.14E-07	8.87E-08	7.28E-08	3.60E-08	2.49E-08	1.87E-08	1.03E-08
	Stack	THYROID	9.70E-08	1.01E-07	7.63E-08	6.58E-08	4.98E-08	4.13E-08	1.93E-08	1.53E-08	1.41E-08	1.41E-08
		EDEWBODY	9.70E-08	1.01E-07	8.86E-08	6.63E-08	5.02E-08	4.16E-08	1.93E-08	1.58E-08	1.41E-08	8.14E-09

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

Isotope	Release	Effect	Centerline Dose (rem) at Radial Range (km) 0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Te-134	Ground	THYROID	*1.01E-02*	*3.18E-04*	*3.24E-05*	*1.23E-05*	*8.06E-06*	*5.09E-06*	*3.05E-06*	*1.88E-06*	*1.10E-06*	*2.47E-07*
41.8m B-	(no wake)	EDEWBODY	*7.00E-03*	*2.02E-04*	*2.12E-05*	*1.03E-05*	*5.17E-06*	*3.22E-06*	*2.02E-06*	*1.11E-06*	*7.66E-07*	*2.03E-07*
	Ground	THYROID	*2.01E-03*	*3.02E-04*	*5.03E-05*	*2.14E-05*	*1.03E-05*	*5.51E-06*	*3.46E-06*	*2.26E-06*	*1.13E-06*	*3.04E-07*
	(wake)	EDEWBODY	*1.01E-03*	*2.01E-04*	*3.02E-05*	*1.07E-05*	*7.04E-06*	*3.49E-06*	*2.21E-06*	*1.41E-06*	*1.05E-06*	*2.27E-07*
	ACRR	THYROID	*3.23E-04*	*2.00E-04*	*5.02E-05*	*2.02E-05*	*1.32E-05*	*7.58E-06*	*3.48E-06*	*2.49E-06*	*1.48E-06*	*3.37E-07*
		EDEWBODY	*2.07E-04*	*1.00E-04*	*3.02E-05*	*1.09E-05*	*7.17E-06*	*5.02E-06*	*2.60E-06*	*1.89E-06*	*1.22E-06*	*2.46E-07*
	Stack	THYROID	*6.60E-06*	*2.08E-05*	*1.22E-05*	*1.02E-05*	*1.00E-05*	*7.03E-06*	*3.99E-06*	*2.86E-06*	*2.03E-06*	*3.80E-07*
		EDEWBODY	*4.71E-06*	*1.09E-05*	*7.46E-06*	*7.12E-06*	*7.03E-06*	*5.02E-06*	*2.56E-06*	*1.87E-06*	*1.32E-06*	*3.23E-07*
I-134	Ground	THYROID	1.00E-02	3.14E-04	3.44E-05	1.21E-05	7.81E-06	3.42E-06	2.22E-06	1.22E-06	1.07E-06	1.78E-07
52.6m B-	(no wake)	EDEWBODY	7.02E-03	3.01E-04	3.04E-05	1.09E-05	5.79E-06	3.21E-06	2.10E-06	1.13E-06	7.66E-07	1.38E-07
	Ground	THYROID	2.01E-03	3.02E-04	5.01E-05	1.87E-05	7.97E-06	5.45E-06	3.11E-06	2.06E-06	1.11E-06	2.02E-07
	(wake)	EDEWBODY	1.03E-03	2.02E-04	3.13E-05	1.18E-05	7.13E-06	3.87E-06	2.17E-06	1.16E-06	1.05E-06	1.52E-07
	ACRR	THYROID	3.21E-04	1.07E-04	5.01E-05	2.01E-05	1.03E-05	5.54E-06	3.45E-06	2.10E-06	1.14E-06	2.19E-07
		EDEWBODY	2.25E-04	1.02E-04	3.03E-05	1.10E-05	7.44E-06	3.61E-06	2.52E-06	1.20E-06	1.07E-06	1.77E-07
	Stack	THYROID	1.26E-05	2.09E-05	1.16E-05	1.02E-05	7.07E-06	5.09E-06	3.18E-06	2.11E-06	1.35E-06	2.46E-07
		EDEWBODY	1.26E-05	1.45E-05	1.04E-05	1.00E-05	6.24E-06	3.25E-06	2.22E-06	1.26E-06	1.07E-06	2.12E-07
Cs-134	Ground	THYROID	*1.05E-01*	*5.05E-03*	*5.98E-04*	*2.14E-04*	*1.09E-04*	*7.15E-05*	*3.79E-05*	*2.49E-05*	*1.55E-05*	*4.70E-06*
2.062y ECB-	(no wake)	EDEWBODY	*2.00E-01*	*7.08E-03*	*7.09E-04*	*2.20E-04*	*1.12E-04*	*7.51E-05*	*4.00E-05*	*3.07E-05*	*2.09E-05*	*5.55E-06*
	Ground	THYROID	*3.01E-02*	*5.02E-03*	*7.33E-04*	*3.08E-04*	*1.41E-04*	*7.76E-05*	*5.17E-05*	*3.35E-05*	*2.28E-05*	*5.96E-06*
	(wake)	EDEWBODY	*3.02E-02*	*5.03E-03*	*7.45E-04*	*3.25E-04*	*1.49E-04*	*1.00E-04*	*5.31E-05*	*3.54E-05*	*2.41E-05*	*6.11E-06*
	ACRR	THYROID	*5.22E-03*	*2.04E-03*	*7.04E-04*	*3.19E-04*	*2.04E-04*	*1.10E-04*	*6.07E-05*	*3.93E-05*	*2.82E-05*	*7.44E-06*
		EDEWBODY	*5.35E-03*	*3.01E-03*	*7.44E-04*	*3.47E-04*	*2.08E-04*	*1.20E-04*	*6.76E-05*	*4.15E-05*	*3.15E-05*	*7.67E-06*
	Stack	THYROID	3.81E-05	1.65E-04	1.08E-04	1.01E-04	1.01E-04	7.20E-05	3.94E-05	2.53E-05	2.29E-05	5.88E-06
		EDEWBODY	3.81E-05	2.03E-04	1.09E-04	1.01E-04	1.02E-04	7.26E-05	4.00E-05	2.85E-05	2.29E-05	7.08E-06

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
I-135	Ground	THYROID	1.00E-01	4.04E-03	4.33E-04	1.20E-04	7.41E-05	4.06E-05	2.51E-05	1.49E-05	1.15E-05	2.86E-06
6.61h B-	(no wake)	EDEWBODY	2.01E-02	7.07E-04	7.38E-05	3.16E-05	1.25E-05	1.03E-05	5.33E-06	3.30E-06	2.22E-06	6.13E-07
Including: Xe-135m	Ground	THYROID	2.01E-02	3.02E-03	5.32E-04	2.10E-04	1.04E-04	5.32E-05	3.15E-05	2.13E-05	1.30E-05	3.39E-06
	(wake)	EDEWBODY	3.07E-03	7.03E-04	1.01E-04	3.24E-05	2.04E-05	1.10E-05	7.19E-06	5.01E-06	3.25E-06	7.73E-07
	ACRR	THYROID	3.21E-03	1.07E-03	5.30E-04	2.29E-04	1.33E-04	7.53E-05	3.89E-05	2.25E-05	1.48E-05	3.86E-06
		EDEWBODY	7.27E-04	3.04E-04	1.01E-04	5.02E-05	3.00E-05	1.12E-05	8.45E-06	5.30E-06	3.67E-06	8.56E-07
	Stack	THYROID	4.32E-05	2.08E-04	1.09E-04	1.01E-04	1.04E-04	7.58E-05	4.00E-05	2.56E-05	2.26E-05	5.50E-06
		EDEWBODY	1.41E-05	3.37E-05	2.26E-05	2.04E-05	2.01E-05	1.09E-05	8.59E-06	6.00E-06	4.13E-06	1.17E-06
Xe-135	Ground	THYROID	2.11E-05	5.95E-06	2.27E-06	1.49E-06	1.03E-06	7.26E-07	3.57E-07	2.44E-07	1.54E-07	7.87E-08
9.09h B-	(no wake)	EDEWBODY	2.32E-05	6.00E-06	2.29E-06	1.50E-06	1.04E-06	7.78E-07	3.57E-07	2.44E-07	1.54E-07	7.90E-08
	Ground	THYROID	1.02E-05	4.67E-06	2.07E-06	1.41E-06	7.95E-07	7.45E-07	3.57E-07	2.40E-07	1.54E-07	7.84E-08
	(wake)	EDEWBODY	1.03E-05	4.71E-06	2.03E-06	1.42E-06	9.88E-07	7.51E-07	3.57E-07	2.44E-07	1.54E-07	7.86E-08
	ACRR	THYROID	2.19E-06	2.00E-06	1.19E-06	9.52E-07	7.31E-07	5.92E-07	2.84E-07	1.93E-07	1.50E-07	7.67E-08
		EDEWBODY	2.15E-06	2.02E-06	1.07E-06	9.60E-07	7.37E-07	5.35E-07	2.84E-07	1.93E-07	1.50E-07	7.70E-08
	Stack	THYROID	8.06E-07	7.21E-07	7.43E-07	5.51E-07	3.38E-07	3.37E-07	1.49E-07	1.43E-07	9.59E-08	5.76E-08
		EDEWBODY	7.83E-07	7.17E-07	7.01E-07	5.22E-07	3.91E-07	3.19E-07	1.49E-07	1.36E-07	9.59E-08	5.67E-08
Xe-135m	Ground	THYROID	3.84E-05	7.46E-06	1.91E-06	8.23E-07	3.34E-07	2.32E-07	1.19E-07	7.89E-08	5.12E-08	3.73E-09
15.29m	(no wake)	EDEWBODY	3.84E-05	8.28E-06	1.91E-06	8.23E-07	3.34E-07	2.32E-07	1.19E-07	7.89E-08	5.12E-08	3.73E-09
ITB-	Ground	THYROID	1.34E-05	6.51E-06	1.74E-06	7.80E-07	3.29E-07	2.25E-07	1.18E-07	7.74E-08	5.09E-08	3.73E-09
	(wake)	EDEWBODY	1.70E-05	6.51E-06	1.75E-06	7.52E-07	3.29E-07	2.25E-07	1.18E-07	7.74E-08	5.09E-08	3.73E-09
	ACRR	THYROID	3.31E-06	2.78E-06	1.01E-06	5.27E-07	2.28E-07	1.47E-07	1.07E-07	7.13E-08	3.86E-08	3.58E-09
		EDEWBODY	3.39E-06	2.78E-06	1.01E-06	5.12E-07	2.28E-07	1.71E-07	1.07E-07	7.13E-08	3.86E-08	3.58E-09
	Stack	THYROID	1.25E-06	1.03E-06	6.32E-07	3.07E-07	1.21E-07	1.03E-07	5.85E-08	3.78E-08	3.04E-08	3.03E-09
		EDEWBODY	1.25E-06	1.03E-06	6.33E-07	3.07E-07	1.21E-07	1.03E-07	5.85E-08	3.78E-08	3.04E-08	3.03E-09

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Cs-137	Ground	THYROID	1.00E-01	3.20E-03	3.63E-04	1.16E-04	7.11E-05	3.89E-05	2.40E-05	1.44E-05	1.12E-05	2.86E-06
30.0y B-	(no wake)	EDEWBODY	1.01E-01	3.46E-03	3.78E-04	1.20E-04	7.37E-05	4.07E-05	2.50E-05	1.50E-05	1.17E-05	3.34E-06
Including: Ba-137m	Ground	THYROID	2.00E-02	3.01E-03	5.07E-04	2.02E-04	1.01E-04	5.23E-05	3.11E-05	2.10E-05	1.29E-05	3.66E-06
	(wake)	EDEWBODY	2.01E-02	3.11E-03	5.12E-04	2.05E-04	1.02E-04	5.36E-05	3.19E-05	2.19E-05	1.35E-05	3.83E-06
	ACRR	THYROID	3.14E-03	1.03E-03	5.07E-04	2.10E-04	1.12E-04	7.20E-05	3.87E-05	2.42E-05	1.47E-05	4.14E-06
		EDEWBODY	3.20E-03	1.07E-03	5.12E-04	2.12E-04	1.22E-04	7.29E-05	4.09E-05	2.59E-05	1.53E-05	5.08E-06
	Stack	THYROID	3.81E-05	1.65E-04	1.08E-04	1.01E-04	1.01E-04	7.20E-05	3.94E-05	2.53E-05	2.29E-05	5.88E-06
		EDEWBODY	3.81E-05	2.03E-04	1.09E-04	1.01E-04	1.02E-04	7.26E-05	4.00E-05	2.85E-05	2.29E-05	7.08E-06
Ba-137m	Ground	THYROID	7.02E-04	1.27E-05	7.28E-07	1.60E-07	4.21E-08	2.10E-08	7.44E-09	3.18E-09	1.12E-09	4.01E-12
2.552m IT	(no wake)	EDEWBODY	7.02E-04	1.27E-05	7.28E-07	1.60E-07	4.21E-08	2.10E-08	7.44E-09	3.18E-09	1.12E-09	4.01E-12
	Ground	THYROID	1.02E-04	1.04E-05	7.28E-07	2.01E-07	5.03E-08	2.10E-08	7.44E-09	3.20E-09	1.12E-09	5.55E-12
	(wake)	EDEWBODY	1.02E-04	1.04E-05	7.28E-07	2.01E-07	5.03E-08	2.10E-08	7.44E-09	3.20E-09	1.12E-09	5.55E-12
	ACRR	THYROID	2.25E-05	5.11E-06	5.31E-07	1.20E-07	4.21E-08	2.04E-08	7.44E-09	3.20E-09	1.12E-09	5.55E-12
		EDEWBODY	2.25E-05	5.05E-06	5.31E-07	1.20E-07	4.21E-08	2.04E-08	7.44E-09	3.20E-09	1.12E-09	5.55E-12
	Stack	THYROID	1.73E-06	9.10E-07	2.21E-07	8.09E-08	3.41E-08	1.21E-08	7.12E-09	3.07E-09	1.12E-09	5.55E-12
		EDEWBODY	1.73E-06	9.06E-07	2.21E-07	8.09E-08	3.39E-08	1.21E-08	7.12E-09	3.07E-09	1.12E-09	5.55E-12
Xe-138	Ground	THYROID	2.00E-04	5.01E-05	1.02E-05	7.03E-06	3.15E-06	2.13E-06	1.15E-06	8.40E-07	5.29E-07	7.70E-08
14.17m B-	(no wake)	EDEWBODY	2.01E-04	5.01E-05	1.02E-05	7.04E-06	3.17E-06	2.18E-06	1.17E-06	8.62E-07	5.35E-07	8.72E-08
	Ground	THYROID	5.07E-05	3.02E-05	1.01E-05	7.03E-06	3.15E-06	2.12E-06	1.14E-06	8.34E-07	5.27E-07	7.70E-08
	(wake)	EDEWBODY	7.00E-05	3.02E-05	1.02E-05	7.04E-06	3.17E-06	2.17E-06	1.17E-06	8.57E-07	5.33E-07	8.72E-08
	ACRR	THYROID	1.14E-05	1.03E-05	1.00E-05	5.05E-06	3.03E-06	2.02E-06	1.09E-06	7.84E-07	5.44E-07	7.70E-08
		EDEWBODY	1.15E-05	1.03E-05	1.00E-05	5.82E-06	3.03E-06	2.06E-06	1.12E-06	8.16E-07	5.62E-07	7.70E-08
	Stack	THYROID	3.80E-06	3.51E-06	3.05E-06	3.01E-06	2.01E-06	1.08E-06	7.67E-07	5.44E-07	3.89E-07	7.57E-08
		EDEWBODY	3.81E-06	3.51E-06	3.06E-06	3.02E-06	2.02E-06	1.10E-06	7.75E-07	6.15E-07	4.01E-07	7.67E-08

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Cs-138	Ground	THYROID	5.02E-03	2.00E-04	2.04E-05	7.76E-06	3.30E-06	2.15E-06	1.13E-06	7.61E-07	5.26E-07	7.28E-08
32.2m B-	(no wake)	EDEWBODY	5.03E-03	2.01E-04	2.09E-05	8.08E-06	3.35E-06	2.19E-06	1.15E-06	8.53E-07	5.31E-07	7.35E-08
	Ground	THYROID	1.00E-03	1.09E-04	2.08E-05	7.97E-06	4.69E-06	2.22E-06	1.17E-06	1.03E-06	6.03E-07	7.80E-08
	(wake)	EDEWBODY	1.01E-03	2.00E-04	2.13E-05	1.01E-05	5.15E-06	3.03E-06	1.18E-06	1.05E-06	7.08E-07	7.82E-08
	ACRR	THYROID	2.02E-04	7.12E-05	2.02E-05	1.00E-05	5.03E-06	3.02E-06	1.18E-06	1.06E-06	7.16E-07	8.08E-08
		EDEWBODY	2.06E-04	1.00E-04	2.02E-05	1.01E-05	5.19E-06	3.12E-06	1.21E-06	1.07E-06	7.27E-07	8.99E-08
	Stack	THYROID	9.67E-06	1.03E-05	7.15E-06	5.06E-06	3.13E-06	2.18E-06	1.17E-06	1.02E-06	5.44E-07	8.99E-08
		EDEWBODY	9.67E-06	1.07E-05	7.16E-06	6.28E-06	3.20E-06	2.22E-06	1.19E-06	1.04E-06	7.24E-07	9.00E-08
Ba-139	Ground	THYROID	2.01E-04	7.05E-06	7.17E-07	3.02E-07	1.37E-07	7.64E-08	5.29E-08	3.26E-08	2.19E-08	4.04E-09
82.7m B-	(no wake)	EDEWBODY	7.01E-04	2.28E-05	2.37E-06	7.66E-07	3.86E-07	2.34E-07	1.29E-07	8.51E-08	5.35E-08	1.10E-08
	Ground	THYROID	3.04E-05	7.01E-06	1.00E-06	3.17E-07	1.29E-07	1.06E-07	7.02E-08	3.37E-08	2.55E-08	5.43E-09
	(wake)	EDEWBODY	1.01E-04	2.01E-05	3.10E-06	1.11E-06	5.18E-07	3.07E-07	1.45E-07	1.09E-07	7.36E-08	1.19E-08
	ACRR	THYROID	7.14E-06	3.02E-06	1.00E-06	3.23E-07	2.06E-07	1.12E-07	7.28E-08	5.08E-08	3.13E-08	5.77E-09
		EDEWBODY	2.08E-05	1.00E-05	3.08E-06	1.25E-06	6.56E-07	3.23E-07	2.03E-07	1.19E-07	7.98E-08	1.32E-08
	Stack	THYROID	1.89E-07	3.19E-07	3.19E-07	2.01E-07	1.09E-07	1.01E-07	6.07E-08	3.56E-08	3.12E-08	3.12E-08
		EDEWBODY	4.68E-07	1.62E-06	8.06E-07	1.00E-06	7.02E-07	5.01E-07	2.57E-07	1.59E-07	1.23E-07	2.38E-08
Ba-140	Ground	THYROID	2.01E-02	7.03E-04	7.04E-05	2.31E-05	1.17E-05	8.12E-06	5.15E-06	3.15E-06	2.13E-06	6.13E-07
12.74d B-	(no wake)	EDEWBODY	3.01E-02	1.00E-03	1.01E-04	3.42E-05	2.04E-05	1.17E-05	7.36E-06	5.02E-06	3.12E-06	8.68E-07
	Ground	THYROID	3.03E-03	7.00E-04	1.00E-04	3.14E-05	2.02E-05	1.09E-05	5.56E-06	3.76E-06	2.54E-06	7.55E-07
	(wake)	EDEWBODY	5.03E-03	1.00E-03	1.06E-04	5.18E-05	3.01E-05	1.40E-05	7.87E-06	5.77E-06	3.77E-06	1.08E-06
	ACRR	THYROID	7.10E-04	3.01E-04	1.00E-04	5.00E-05	2.02E-05	1.33E-05	7.87E-06	5.35E-06	3.43E-06	8.56E-07
		EDEWBODY	1.02E-03	5.00E-04	1.02E-04	7.01E-05	3.17E-05	2.07E-05	1.16E-05	7.55E-06	5.20E-06	1.28E-06
	Stack	THYROID	9.83E-06	3.19E-05	2.13E-05	2.03E-05	2.01E-05	1.02E-05	7.90E-06	5.67E-06	3.95E-06	1.19E-06
		EDEWBODY	1.38E-05	5.06E-05	2.35E-05	3.03E-05	2.15E-05	2.01E-05	1.21E-05	7.94E-06	5.64E-06	1.51E-06

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
La-140	Ground	THYROID	*5.02E-02*	*2.00E-03*	*2.01E-04*	*7.32E-05*	*3.39E-05*	*2.25E-05*	*1.12E-05*	*7.68E-06*	*5.45E-06*	*1.45E-06*
40.272h B-	(no wake)	EDEWBODY	*7.02E-02*	*2.02E-03*	*2.12E-04*	*1.01E-04*	*5.07E-05*	*3.06E-05*	*1.51E-05*	*1.07E-05*	*7.49E-06*	*2.13E-06*
	Ground	THYROID	*1.00E-02*	*1.09E-03*	*2.06E-04*	*1.00E-04*	*5.02E-05*	*3.03E-05*	*1.27E-05*	*1.12E-05*	*7.75E-06*	*2.05E-06*
	(wake)	EDEWBODY	*1.01E-02*	*2.01E-03*	*3.02E-04*	*1.06E-04*	*7.01E-05*	*3.33E-05*	*2.11E-05*	*1.30E-05*	*1.04E-05*	*2.49E-06*
	ACRR	THYROID	*1.32E-03*	*7.10E-04*	*2.03E-04*	*1.01E-04*	*7.01E-05*	*3.15E-05*	*2.04E-05*	*1.30E-05*	*8.64E-06*	*2.35E-06*
		EDEWBODY	*2.10E-03*	*1.01E-03*	*3.02E-04*	*1.08E-04*	*7.08E-05*	*5.02E-05*	*2.59E-05*	*1.52E-05*	*1.17E-05*	*3.16E-06*
	Stack	THYROID	2.94E-05	1.00E-04	5.28E-05	5.07E-05	5.03E-05	3.05E-05	1.87E-05	1.48E-05	1.18E-05	3.20E-06
		EDEWBODY	2.94E-05	1.07E-04	7.41E-05	7.04E-05	5.04E-05	5.01E-05	2.45E-05	1.59E-05	1.43E-05	3.57E-06
Ba-141	Ground	THYROID	*1.04E-03*	*5.04E-05*	*5.19E-06*	*2.06E-06*	*1.04E-06*	*5.39E-07*	*3.15E-07*	*2.00E-07*	*1.03E-07*	*9.85E-09*
18.27m B-	(no wake)	EDEWBODY	*2.00E-03*	*7.01E-05*	*5.58E-06*	*2.29E-06*	*1.07E-06*	*7.01E-07*	*3.27E-07*	*2.07E-07*	*1.08E-07*	*1.04E-08*
	Ground	THYROID	*3.01E-04*	*5.02E-05*	*5.53E-06*	*2.34E-06*	*1.07E-06*	*7.02E-07*	*3.28E-07*	*2.08E-07*	*1.08E-07*	*1.02E-08*
	(wake)	EDEWBODY	*3.02E-04*	*5.05E-05*	*7.12E-06*	*2.30E-06*	*1.10E-06*	*7.36E-07*	*3.40E-07*	*2.19E-07*	*1.14E-07*	*1.07E-08*
	ACRR	THYROID	*5.30E-05*	*2.04E-05*	*5.09E-06*	*2.16E-06*	*1.13E-06*	*6.75E-07*	*3.33E-07*	*2.12E-07*	*1.13E-07*	*1.04E-08*
		EDEWBODY	*7.11E-05*	*3.01E-05*	*7.01E-06*	*2.31E-06*	*1.25E-06*	*7.37E-07*	*3.42E-07*	*2.22E-07*	*1.18E-07*	*1.36E-08*
	Stack	THYROID	*3.55E-06*	*3.36E-06*	*2.02E-06*	*1.07E-06*	*7.45E-07*	*5.12E-07*	*3.18E-07*	*2.06E-07*	*1.12E-07*	*1.05E-08*
		EDEWBODY	*3.56E-06*	*3.77E-06*	*2.04E-06*	*1.11E-06*	*7.89E-07*	*5.31E-07*	*3.27E-07*	*2.18E-07*	*1.17E-07*	*1.49E-08*
La-141	Ground	THYROID	*3.04E-04*	*1.08E-05*	*1.12E-06*	*5.48E-07*	*3.08E-07*	*1.56E-07*	*1.06E-07*	*7.35E-08*	*5.23E-08*	*1.15E-08*
3.93h B-	(no wake)	EDEWBODY	*2.01E-03*	*7.41E-05*	*7.39E-06*	*2.27E-06*	*1.25E-06*	*7.76E-07*	*4.11E-07*	*3.12E-07*	*2.10E-07*	*4.61E-08*
	Ground	THYROID	*7.04E-05*	*1.01E-05*	*2.01E-06*	*7.23E-07*	*3.21E-07*	*2.17E-07*	*1.15E-07*	*8.49E-08*	*5.41E-08*	*1.30E-08*
	(wake)	EDEWBODY	*3.02E-04*	*5.06E-05*	*1.01E-05*	*3.68E-06*	*1.73E-06*	*1.02E-06*	*5.66E-07*	*3.53E-07*	*2.36E-07*	*5.66E-08*
	ACRR	THYROID	*1.13E-05*	*7.02E-06*	*2.01E-06*	*1.00E-06*	*5.02E-07*	*3.01E-07*	*1.26E-07*	*1.05E-07*	*7.42E-08*	*1.49E-08*
		EDEWBODY	*7.10E-05*	*3.01E-05*	*1.01E-05*	*4.27E-06*	*2.20E-06*	*1.32E-06*	*7.28E-07*	*3.53E-07*	*3.09E-07*	*7.11E-08*
	Stack	THYROID	2.82E-07	7.27E-07	3.49E-07	3.08E-07	3.02E-07	2.03E-07	1.48E-07	9.57E-08	7.69E-08	2.02E-08
		EDEWBODY	1.27E-06	5.06E-06	2.34E-06	3.01E-06	2.01E-06	1.11E-06	8.68E-07	6.00E-07	4.66E-07	1.14E-07

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Ce-141	Ground	THYROID	2.02E-03	1.00E-04	1.00E-05	3.21E-06	1.27E-06	1.05E-06	5.43E-07	3.35E-07	2.56E-07	7.63E-08
32.501d	(no wake)	EDEWBODY	3.03E-02	1.02E-03	1.03E-04	3.37E-05	2.01E-05	1.15E-05	7.20E-06	4.03E-06	3.18E-06	8.27E-07
B-	Ground	THYROID	5.01E-04	7.04E-05	1.01E-05	5.01E-06	2.08E-06	1.14E-06	7.38E-07	5.22E-07	3.46E-07	8.66E-08
	(wake)	EDEWBODY	5.02E-03	1.00E-03	1.15E-04	5.14E-05	2.46E-05	1.19E-05	7.75E-06	5.59E-06	3.67E-06	1.05E-06
	ACRR	THYROID	7.45E-05	3.06E-05	1.01E-05	5.04E-06	3.01E-06	2.00E-06	8.83E-07	5.97E-07	3.90E-07	1.08E-07
		EDEWBODY	1.01E-03	3.08E-04	1.08E-04	7.02E-05	3.14E-05	2.03E-05	1.10E-05	7.30E-06	4.62E-06	1.19E-06
	Stack	THYROID	1.41E-06	5.18E-06	3.26E-06	3.04E-06	3.01E-06	2.01E-06	1.08E-06	7.99E-07	5.81E-07	1.51E-07
		EDEWBODY	1.13E-05	5.17E-05	2.37E-05	3.11E-05	3.00E-05	2.05E-05	1.20E-05	7.94E-06	5.80E-06	1.49E-06
Ba-142	Ground	THYROID	2.02E-03	7.18E-05	7.68E-06	3.22E-06	1.18E-06	7.67E-07	5.27E-07	3.20E-07	2.09E-07	3.59E-08
10.6m B-	(no wake)	EDEWBODY	3.00E-03	1.00E-04	7.91E-06	3.35E-06	1.21E-06	1.02E-06	5.37E-07	3.27E-07	2.15E-07	3.80E-08
	Ground	THYROID	5.01E-04	7.04E-05	1.00E-05	3.36E-06	1.54E-06	1.04E-06	5.45E-07	3.33E-07	2.20E-07	4.05E-08
	(wake)	EDEWBODY	5.02E-04	7.07E-05	1.01E-05	3.45E-06	2.04E-06	1.06E-06	5.45E-07	3.38E-07	2.22E-07	4.05E-08
	ACRR	THYROID	7.53E-05	3.06E-05	1.00E-05	3.19E-06	2.01E-06	1.07E-06	5.48E-07	3.38E-07	2.22E-07	5.04E-08
		EDEWBODY	1.02E-04	3.07E-05	1.00E-05	3.27E-06	2.08E-06	1.10E-06	7.14E-07	3.45E-07	3.02E-07	5.25E-08
	Stack	THYROID	4.40E-06	5.20E-06	3.07E-06	2.02E-06	1.10E-06	1.01E-06	5.26E-07	3.45E-07	2.56E-07	5.68E-08
		EDEWBODY	4.40E-06	5.41E-06	3.11E-06	2.04E-06	1.13E-06	1.02E-06	6.22E-07	3.55E-07	3.06E-07	5.92E-08
La-142	Ground	THYROID	1.00E-02	3.08E-04	3.25E-05	1.24E-05	8.20E-06	5.09E-06	3.12E-06	2.08E-06	1.13E-06	2.49E-07
92.5m B-	(no wake)	EDEWBODY	1.01E-02	3.20E-04	3.33E-05	1.28E-05	8.69E-06	5.23E-06	3.18E-06	2.13E-06	1.15E-06	3.04E-07
	Ground	THYROID	2.01E-03	3.02E-04	5.03E-05	2.02E-05	1.05E-05	5.60E-06	3.58E-06	2.16E-06	1.17E-06	3.26E-07
	(wake)	EDEWBODY	2.01E-03	3.04E-04	5.05E-05	2.06E-05	1.08E-05	7.03E-06	3.78E-06	2.20E-06	1.21E-06	3.41E-07
	ACRR	THYROID	3.16E-04	1.07E-04	5.02E-05	2.02E-05	1.05E-05	7.23E-06	3.50E-06	2.53E-06	1.21E-06	3.51E-07
		EDEWBODY	3.36E-04	2.00E-04	5.03E-05	2.11E-05	1.07E-05	7.44E-06	3.59E-06	3.10E-06	2.03E-06	3.68E-07
	Stack	THYROID	1.55E-05	2.10E-05	1.23E-05	1.03E-05	1.00E-05	7.03E-06	3.99E-06	2.59E-06	2.03E-06	3.94E-07
		EDEWBODY	1.51E-05	2.10E-05	1.23E-05	1.03E-05	1.00E-05	7.03E-06	3.99E-06	2.87E-06	2.07E-06	3.94E-07

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
La-143	Ground	THYROID	*2.01E-04*	*7.05E-06*	*7.15E-07*	*2.20E-07*	*1.11E-07*	*7.28E-08*	*3.40E-08*	*2.14E-08*	*1.14E-08*	*1.56E-09*
14.23m B-	(no wake)	EDEWBODY	*3.04E-04*	*1.05E-05*	*1.09E-06*	*3.93E-07*	*2.07E-07*	*1.07E-07*	*7.01E-08*	*3.32E-08*	*2.12E-08*	*3.58E-09*
	Ground	THYROID	*3.07E-05*	*7.02E-06*	*7.55E-07*	*3.13E-07*	*1.15E-07*	*7.61E-08*	*4.49E-08*	*2.75E-08*	*1.21E-08*	*2.09E-09*
	(wake)	EDEWBODY	*7.03E-05*	*1.01E-05*	*1.08E-06*	*5.06E-07*	*2.30E-07*	*1.10E-07*	*7.29E-08*	*3.42E-08*	*3.00E-08*	*4.06E-09*
	ACRR	THYROID	*7.31E-06*	*3.02E-06*	*7.04E-07*	*3.08E-07*	*1.34E-07*	*7.62E-08*	*5.10E-08*	*3.04E-08*	*1.50E-08*	*2.30E-09*
		EDEWBODY	*1.12E-05*	*5.03E-06*	*1.05E-06*	*5.47E-07*	*2.23E-07*	*1.30E-07*	*7.41E-08*	*5.06E-08*	*3.07E-08*	*5.45E-09*
	Stack	THYROID	*4.40E-07*	*5.18E-07*	*2.27E-07*	*1.16E-07*	*1.01E-07*	*5.71E-08*	*3.41E-08*	*2.23E-08*	*1.21E-08*	*3.14E-09*
		EDEWBODY	*4.76E-07*	*7.26E-07*	*3.48E-07*	*3.00E-07*	*1.16E-07*	*1.05E-07*	*7.48E-08*	*4.06E-08*	*3.39E-08*	*7.34E-09*
Ce-143	Ground	THYROID	*7.02E-03*	*2.02E-04*	*2.12E-05*	*7.97E-06*	*5.03E-06*	*3.02E-06*	*1.21E-06*	*1.07E-06*	*7.52E-07*	*2.04E-07*
33.0h B-	(no wake)	EDEWBODY	*1.05E-02*	*5.05E-04*	*5.89E-05*	*2.14E-05*	*1.08E-05*	*7.14E-06*	*3.81E-06*	*2.49E-06*	*1.55E-06*	*4.70E-07*
	Ground	THYROID	*1.01E-03*	*2.01E-04*	*3.02E-05*	*1.06E-05*	*7.01E-06*	*3.31E-06*	*2.10E-06*	*1.29E-06*	*1.01E-06*	*2.45E-07*
	(wake)	EDEWBODY	*3.01E-03*	*5.02E-04*	*7.06E-05*	*3.08E-05*	*1.40E-05*	*7.75E-06*	*5.16E-06*	*3.34E-06*	*2.27E-06*	*5.85E-07*
	ACRR	THYROID	*2.09E-04*	*1.01E-04*	*3.02E-05*	*1.08E-05*	*7.07E-06*	*5.01E-06*	*2.55E-06*	*1.50E-06*	*1.14E-06*	*3.13E-07*
		EDEWBODY	*5.21E-04*	*2.04E-04*	*7.04E-05*	*3.19E-05*	*2.03E-05*	*1.10E-05*	*6.07E-06*	*3.88E-06*	*2.54E-06*	*7.37E-07*
	Stack	THYROID	3.18E-06	1.02E-05	7.41E-06	7.09E-06	7.02E-06	5.02E-06	2.53E-06	1.59E-06	1.47E-06	3.65E-07
		EDEWBODY	6.32E-06	3.14E-05	1.37E-05	2.00E-05	1.03E-05	1.01E-05	6.08E-06	4.13E-06	3.55E-06	1.03E-06
Pr-143	Ground	THYROID	2.00E-05	*7.02E-07*	*7.03E-08*	*2.30E-08*	*1.16E-08*	*8.02E-09*	*5.06E-09*	*3.16E-09*	*2.14E-09*	*5.74E-10*
13.56d B-	(no wake)	EDEWBODY	*2.08E-02*	*7.43E-04*	*8.30E-05*	*3.12E-05*	*1.23E-05*	*1.01E-05*	*5.64E-06*	*3.56E-06*	*2.41E-06*	*6.72E-07*
	Ground	THYROID	*3.02E-06*	*5.05E-07*	*1.00E-07*	*3.13E-08*	*2.00E-08*	*1.03E-08*	*5.52E-09*	*3.71E-09*	*2.53E-09*	*7.18E-10*
	(wake)	EDEWBODY	*3.08E-03*	*7.17E-04*	*1.04E-04*	*3.92E-05*	*2.19E-05*	*1.10E-05*	*7.18E-06*	*4.06E-06*	*3.22E-06*	*8.27E-07*
	ACRR	THYROID	*5.36E-07*	*3.01E-07*	*1.00E-07*	*3.20E-08*	*2.02E-08*	*1.08E-08*	*7.15E-09*	*4.74E-09*	*3.29E-09*	*8.27E-10*
		EDEWBODY	*7.31E-04*	*3.22E-04*	*1.03E-04*	*5.12E-05*	*3.03E-05*	*1.43E-05*	*8.46E-06*	*5.70E-06*	*3.70E-06*	*1.05E-06*
	Stack	THYROID	3.33E-10	1.65E-09	1.07E-09	1.05E-09	1.01E-09	7.18E-10	3.94E-10	2.53E-10	1.82E-10	5.81E-11
		EDEWBODY	7.64E-06	4.13E-05	2.24E-05	2.21E-05	2.07E-05	2.00E-05	8.61E-06	6.08E-06	4.66E-06	1.29E-06

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Ce-144	Ground	THYROID	*5.01E-03*	*2.00E-04*	*1.54E-05*	*5.65E-06*	*3.20E-06*	*2.07E-06*	*1.16E-06*	*7.81E-07*	*5.44E-07*	*1.34E-07*
284.3d B-	(no wake)	EDEWBODY	*1.03E+00*	*3.44E-02*	*3.75E-03*	*1.19E-03*	*7.32E-04*	*4.01E-04*	*2.47E-04*	*1.48E-04*	*1.15E-04*	*3.26E-05*
Including: Pr-144m	Ground	THYROID	*1.00E-03*	*1.04E-04*	*2.10E-05*	*1.00E-05*	*5.00E-06*	*2.25E-06*	*1.19E-06*	*1.02E-06*	*7.06E-07*	*1.56E-07*
	(wake)	EDEWBODY	*2.01E-01*	*3.11E-02*	*5.11E-03*	*2.03E-03*	*1.02E-03*	*5.32E-04*	*3.15E-04*	*2.17E-04*	*1.33E-04*	*3.78E-05*
Including: Pr-144	ACRR	THYROID	*1.21E-04*	*7.04E-05*	*2.01E-05*	*1.03E-05*	*5.26E-06*	*3.28E-06*	*1.59E-06*	*1.18E-06*	*7.99E-07*	*2.14E-07*
		EDEWBODY	*3.16E-02*	*1.27E-02*	*5.11E-03*	*2.12E-03*	*1.14E-03*	*7.27E-04*	*4.02E-04*	*2.54E-04*	*1.52E-04*	*4.68E-05*
	Stack	THYROID	1.82E-06	7.26E-06	3.78E-06	5.04E-06	3.08E-06	3.11E-06	1.58E-06	1.45E-06	9.35E-07	3.03E-07
		EDEWBODY	3.33E-04	2.03E-03	1.08E-03	1.07E-03	1.02E-03	7.25E-04	4.00E-04	2.85E-04	2.29E-04	7.03E-05
Pr-144	Ground	THYROID	*2.00E-04*	*7.01E-06*	*7.02E-07*	*2.28E-07*	*1.15E-07*	*7.87E-08*	*5.06E-08*	*3.16E-08*	*2.14E-08*	*5.31E-09*
17.28m B-	(no wake)	EDEWBODY	*2.13E-03*	*7.53E-05*	*7.80E-06*	*2.30E-06*	*1.28E-06*	*7.93E-07*	*5.08E-07*	*3.19E-07*	*2.15E-07*	*5.19E-08*
	Ground	THYROID	*3.02E-05*	*5.03E-06*	*8.85E-07*	*3.11E-07*	*1.15E-07*	*1.03E-07*	*5.48E-08*	*3.66E-08*	*2.21E-08*	*6.09E-09*
	(wake)	EDEWBODY	*3.03E-04*	*7.10E-05*	*1.03E-05*	*3.81E-06*	*1.80E-06*	*1.03E-06*	*5.81E-07*	*3.63E-07*	*2.43E-07*	*6.02E-08*
	ACRR	THYROID	*5.36E-06*	*3.01E-06*	*7.08E-07*	*3.10E-07*	*2.02E-07*	*1.07E-07*	*7.09E-08*	*4.15E-08*	*3.21E-08*	*7.59E-09*
		EDEWBODY	*7.12E-05*	*3.01E-05*	*1.03E-05*	*4.44E-06*	*2.26E-06*	*1.39E-06*	*7.47E-07*	*3.57E-07*	*3.21E-07*	*7.45E-08*
	Stack	THYROID	*1.57E-07*	*1.53E-07*	*7.33E-08*	*5.15E-08*	*3.12E-08*	*2.09E-08*	*1.13E-08*	*7.61E-09*	*5.21E-09*	*4.06E-10*
		EDEWBODY	*1.77E-07*	*3.16E-07*	*1.37E-07*	*1.01E-07*	*5.58E-08*	*3.30E-08*	*2.17E-08*	*1.16E-08*	*1.01E-08*	*7.36E-10*
Pr-145	Ground	THYROID	*2.00E-04*	*7.01E-06*	*7.02E-07*	*2.28E-07*	*1.15E-07*	*7.87E-08*	*5.06E-08*	*3.16E-08*	*2.14E-08*	*5.31E-09*
5.98h B-	(no wake)	EDEWBODY	*2.13E-03*	*7.53E-05*	*7.80E-06*	*2.30E-06*	*1.28E-06*	*7.93E-07*	*5.08E-07*	*3.19E-07*	*2.15E-07*	*5.19E-08*
	Ground	THYROID	*3.02E-05*	*5.03E-06*	*8.85E-07*	*3.11E-07*	*1.15E-07*	*1.03E-07*	*5.48E-08*	*3.66E-08*	*2.21E-08*	*6.09E-09*
	(wake)	EDEWBODY	*3.03E-04*	*7.10E-05*	*1.03E-05*	*3.81E-06*	*1.80E-06*	*1.03E-06*	*5.81E-07*	*3.63E-07*	*2.43E-07*	*6.02E-08*
	ACRR	THYROID	*5.36E-06*	*3.01E-06*	*7.08E-07*	*3.10E-07*	*2.02E-07*	*1.07E-07*	*7.09E-08*	*4.15E-08*	*3.21E-08*	*7.59E-09*
		EDEWBODY	*7.12E-05*	*3.01E-05*	*1.03E-05*	*4.44E-06*	*2.26E-06*	*1.39E-06*	*7.47E-07*	*3.57E-07*	*3.21E-07*	*7.45E-08*
	Stack	THYROID	*1.08E-07*	*3.19E-07*	*2.13E-07*	*2.03E-07*	*1.10E-07*	*1.02E-07*	*7.47E-08*	*4.76E-08*	*3.93E-08*	*1.04E-08*
		EDEWBODY	*7.74E-07*	*3.16E-06*	*2.13E-06*	*2.22E-06*	*2.01E-06*	*1.23E-06*	*7.47E-07*	*4.76E-07*	*3.86E-07*	*1.03E-07*

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

Isotope	Release	Effect	Centerline Dose (rem) at Radial Range (km) 0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Pr-147	Ground	THYROID	1.02E-03	5.02E-05	4.09E-06	1.19E-06	7.61E-07	4.49E-07	2.11E-07	1.07E-07	7.43E-08	4.47E-09
13.6m B-	(no wake)	EDEWBODY	1.04E-03	5.03E-05	5.11E-06	1.22E-06	7.66E-07	5.06E-07	2.15E-07	1.12E-07	7.53E-08	5.21E-09
	Ground	THYROID	3.01E-04	5.00E-05	5.19E-06	2.04E-06	7.67E-07	5.14E-07	2.48E-07	1.11E-07	7.67E-08	4.50E-09
	(wake)	EDEWBODY	3.01E-04	5.01E-05	5.30E-06	2.11E-06	1.02E-06	5.22E-07	3.01E-07	1.18E-07	8.01E-08	5.26E-09
	ACRR	THYROID	5.20E-05	2.01E-05	3.30E-06	1.28E-06	7.67E-07	5.17E-07	2.75E-07	1.17E-07	8.01E-08	4.93E-09
		EDEWBODY	5.30E-05	2.03E-05	4.75E-06	2.01E-06	7.67E-07	5.28E-07	3.04E-07	1.21E-07	1.00E-07	5.30E-09
	Stack	THYROID	3.55E-06	3.08E-06	1.16E-06	8.93E-07	5.36E-07	3.79E-07	2.12E-07	1.14E-07	7.36E-08	4.93E-09
		EDEWBODY	3.55E-06	3.27E-06	1.17E-06	1.03E-06	5.42E-07	3.36E-07	2.18E-07	1.16E-07	7.36E-08	5.30E-09
Nd-147	Ground	THYROID	3.05E-03	1.09E-04	1.13E-05	5.48E-06	3.09E-06	1.55E-06	1.05E-06	7.30E-07	5.19E-07	1.26E-07
10.98d B-	(no wake)	EDEWBODY	2.02E-02	7.46E-04	8.49E-05	3.16E-05	1.25E-05	1.02E-05	5.74E-06	3.63E-06	2.46E-06	6.72E-07
	Ground	THYROID	7.05E-04	1.01E-04	2.01E-05	7.15E-06	3.24E-06	2.16E-06	1.15E-06	8.53E-07	5.97E-07	1.43E-07
	(wake)	EDEWBODY	5.00E-03	7.03E-04	1.05E-04	3.98E-05	2.22E-05	1.11E-05	7.27E-06	5.04E-06	3.31E-06	8.54E-07
	ACRR	THYROID	1.14E-04	7.02E-05	2.01E-05	1.00E-05	5.03E-06	3.02E-06	1.54E-06	1.13E-06	7.59E-07	1.84E-07
		EDEWBODY	7.33E-04	3.04E-04	1.04E-04	5.14E-05	3.04E-05	1.48E-05	8.67E-06	5.79E-06	3.77E-06	1.06E-06
	Stack	THYROID	2.09E-06	7.31E-06	3.73E-06	5.05E-06	3.08E-06	3.02E-06	1.58E-06	1.45E-06	8.48E-07	2.47E-07
		EDEWBODY	8.55E-06	4.13E-05	2.24E-05	3.00E-05	2.07E-05	2.00E-05	8.61E-06	6.08E-06	4.66E-06	1.30E-06
Pm-147	Ground	THYROID	1.01E-06	3.09E-08	3.21E-09	1.20E-09	7.39E-10	4.07E-10	2.50E-10	1.22E-10	1.09E-10	3.28E-11
2.6234y B-	(no wake)	EDEWBODY	1.04E-01	3.75E-03	3.88E-04	1.21E-04	7.45E-05	4.13E-05	2.54E-05	1.53E-05	1.18E-05	3.38E-06
	Ground	THYROID	2.01E-07	3.02E-08	5.02E-09	2.01E-09	1.00E-09	5.38E-10	3.19E-10	2.20E-10	1.35E-10	3.79E-11
	(wake)	EDEWBODY	2.01E-02	3.13E-03	5.15E-04	2.06E-04	1.05E-04	5.40E-05	3.21E-05	2.24E-05	1.37E-05	3.89E-06
	ACRR	THYROID	3.20E-08	1.06E-08	5.02E-09	2.02E-09	1.05E-09	7.05E-10	4.10E-10	2.59E-10	1.53E-10	4.15E-11
		EDEWBODY	3.22E-03	2.00E-03	5.14E-04	2.13E-04	1.24E-04	7.62E-05	4.12E-05	2.59E-05	1.81E-05	5.10E-06
	Stack	THYROID	4.88E-10	2.03E-09	1.09E-09	1.02E-09	1.01E-09	7.05E-10	4.00E-10	2.86E-10	2.29E-10	5.96E-11
		EDEWBODY	3.34E-05	2.08E-04	1.22E-04	1.08E-04	1.03E-04	7.30E-05	4.00E-05	2.86E-05	2.38E-05	7.23E-06

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	**Release**	**Effect**	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Pm-148	Ground	THYROID	*1.04E-02*	*5.05E-04*	*5.22E-05*	*2.13E-05*	*1.08E-05*	*7.12E-06*	*3.35E-06*	*2.22E-06*	*1.23E-06*	*4.72E-07*
5.37d B-	(no wake)	EDEWBODY	*5.01E-02*	*1.12E-03*	*1.53E-04*	*5.65E-05*	*3.19E-05*	*2.05E-05*	*1.15E-05*	*7.73E-06*	*5.39E-06*	*1.32E-06*
	Ground	THYROID	*3.01E-03*	*5.02E-04*	*7.05E-05*	*3.01E-05*	*1.12E-05*	*7.75E-06*	*5.14E-06*	*3.35E-06*	*2.28E-06*	*5.91E-07*
	(wake)	EDEWBODY	*1.00E-02*	*1.04E-03*	*2.09E-04*	*8.31E-05*	*4.07E-05*	*2.22E-05*	*1.19E-05*	*1.01E-05*	*7.04E-06*	*1.52E-06*
	ACRR	THYROID	*5.18E-04*	*2.03E-04*	*7.04E-05*	*3.03E-05*	*2.01E-05*	*1.02E-05*	*6.07E-06*	*3.91E-06*	*2.82E-06*	*7.39E-07*
		EDEWBODY	*1.21E-03*	*7.03E-04*	*2.01E-04*	*1.03E-04*	*5.25E-05*	*3.13E-05*	*1.59E-05*	*1.16E-05*	*7.90E-06*	*2.12E-06*
	Stack	THYROID	*7.92E-06*	*3.04E-05*	*1.33E-05*	*2.01E-05*	*1.03E-05*	*1.01E-05*	*6.00E-06*	*4.13E-06*	*3.59E-06*	*1.03E-06*
		EDEWBODY	*1.85E-05*	*7.81E-05*	*5.28E-05*	*5.05E-05*	*5.00E-05*	*3.12E-05*	*1.59E-05*	*1.45E-05*	*9.35E-06*	*3.05E-06*
Nd-149	Ground	THYROID	*2.00E-03*	*7.01E-05*	*7.02E-06*	*2.30E-06*	*1.28E-06*	*7.45E-07*	*5.14E-07*	*3.19E-07*	*2.15E-07*	*4.06E-08*
1.73h B-	(no wake)	EDEWBODY	*2.02E-03*	*1.00E-04*	*9.44E-06*	*3.26E-06*	*1.53E-06*	*1.09E-06*	*5.45E-07*	*3.38E-07*	*2.55E-07*	*5.76E-08*
	Ground	THYROID	*3.02E-04*	*5.03E-05*	*7.19E-06*	*3.10E-06*	*1.27E-06*	*1.02E-06*	*5.85E-07*	*3.30E-07*	*2.22E-07*	*5.28E-08*
	(wake)	EDEWBODY	*5.01E-04*	*7.04E-05*	*1.01E-05*	*5.00E-06*	*2.14E-06*	*1.15E-06*	*7.81E-07*	*5.19E-07*	*3.18E-07*	*7.22E-08*
	ACRR	THYROID	*5.36E-05*	*3.01E-05*	*7.08E-06*	*3.17E-06*	*2.01E-06*	*1.09E-06*	*7.07E-07*	*3.53E-07*	*3.05E-07*	*5.82E-08*
		EDEWBODY	*7.45E-05*	*3.06E-05*	*1.01E-05*	*5.03E-06*	*3.00E-06*	*1.61E-06*	*7.89E-07*	*5.42E-07*	*3.67E-07*	*7.86E-08*
	Stack	THYROID	*1.89E-06*	*3.19E-06*	*2.15E-06*	*2.02E-06*	*1.10E-06*	*1.01E-06*	*6.13E-07*	*4.74E-07*	*3.31E-07*	*7.46E-08*
		EDEWBODY	*1.90E-06*	*5.17E-06*	*3.15E-06*	*3.01E-06*	*2.01E-06*	*1.10E-06*	*8.68E-07*	*6.00E-07*	*4.04E-07*	*1.03E-07*
Pm-149	Ground	THYROID	*3.01E-04*	*1.01E-05*	*1.03E-06*	*3.51E-07*	*2.10E-07*	*1.22E-07*	*7.35E-08*	*5.16E-08*	*3.25E-08*	*8.68E-09*
53.08h B-	(no wake)	EDEWBODY	*1.00E-02*	*3.08E-04*	*3.19E-05*	*1.08E-05*	*5.50E-06*	*3.49E-06*	*2.15E-06*	*1.26E-06*	*1.01E-06*	*2.47E-07*
	Ground	THYROID	*5.03E-05*	*1.00E-05*	*1.07E-06*	*5.10E-07*	*3.01E-07*	*1.24E-07*	*1.01E-07*	*6.00E-08*	*3.91E-08*	*1.10E-08*
	(wake)	EDEWBODY	*1.05E-03*	*3.01E-04*	*3.74E-05*	*1.40E-05*	*7.88E-06*	*3.59E-06*	*2.27E-06*	*1.45E-06*	*1.16E-06*	*3.17E-07*
	ACRR	THYROID	*1.02E-05*	*5.01E-06*	*1.02E-06*	*7.02E-07*	*3.08E-07*	*2.01E-07*	*1.05E-07*	*7.80E-08*	*5.35E-08*	*1.27E-08*
		EDEWBODY	*3.05E-04*	*1.11E-04*	*3.25E-05*	*2.03E-05*	*1.02E-05*	*5.83E-06*	*3.39E-06*	*2.16E-06*	*1.31E-06*	*3.59E-07*
	Stack	THYROID	*1.44E-07*	*5.21E-07*	*3.26E-07*	*3.05E-07*	*3.01E-07*	*2.02E-07*	*1.09E-07*	*8.37E-08*	*5.99E-08*	*1.54E-08*
		EDEWBODY	*3.20E-06*	*1.25E-05*	*8.02E-06*	*1.01E-05*	*7.26E-06*	*7.03E-06*	*3.56E-06*	*2.39E-06*	*1.54E-06*	*5.27E-07*

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	**Release**	**Effect**	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Pm-151	Ground	THYROID	*7.03E-03*	*3.00E-04*	*3.00E-05*	*1.03E-05*	*5.24E-06*	*3.19E-06*	*2.01E-06*	*1.10E-06*	*7.67E-07*	*2.25E-07*
28.40h B-	(no wake)	EDEWBODY	*1.01E-02*	*5.00E-04*	*5.00E-05*	*1.27E-05*	*7.85E-06*	*5.27E-06*	*3.21E-06*	*2.05E-06*	*1.12E-06*	*3.60E-07*
	Ground	THYROID	*1.02E-03*	*2.01E-04*	*3.03E-05*	*1.08E-05*	*7.03E-06*	*3.46E-06*	*2.18E-06*	*1.36E-06*	*1.03E-06*	*2.55E-07*
	(wake)	EDEWBODY	*2.01E-03*	*3.04E-04*	*5.05E-05*	*2.04E-05*	*1.15E-05*	*7.02E-06*	*3.39E-06*	*2.42E-06*	*1.47E-06*	*4.08E-07*
	ACRR	THYROID	*2.17E-04*	*1.01E-04*	*3.03E-05*	*1.10E-05*	*1.00E-05*	*5.03E-06*	*2.88E-06*	*1.86E-06*	*1.23E-06*	*3.23E-07*
		EDEWBODY	*3.47E-04*	*2.01E-04*	*2.01E-04*	*3.00E-05*	*1.08E-05*	*8.33E-06*	*4.21E-06*	*3.21E-06*	*2.15E-06*	*5.36E-07*
	Stack	THYROID	*3.92E-06*	*1.17E-05*	*7.44E-06*	*7.12E-06*	*7.04E-06*	*5.04E-06*	*2.56E-06*	*1.87E-06*	*1.53E-06*	*3.99E-07*
		EDEWBODY	*6.32E-06*	*2.08E-05*	*1.22E-05*	*1.03E-05*	*1.01E-05*	*1.00E-05*	*4.13E-06*	*3.60E-06*	*2.49E-06*	*7.44E-07*
Sm-151	Ground	THYROID	*2.02E-07*	*1.00E-08*	*1.00E-09*	*3.18E-10*	*1.26E-10*	*1.04E-10*	*5.81E-11*	*3.67E-11*	*2.48E-11*	*6.72E-12*
90y B-	(no wake)	EDEWBODY	*7.46E-02*	*3.08E-03*	*3.19E-04*	*1.08E-04*	*5.50E-05*	*3.48E-05*	*2.15E-05*	*1.26E-05*	*1.01E-05*	*2.49E-06*
	Ground	THYROID	*5.01E-08*	*7.04E-09*	*1.01E-09*	*5.01E-10*	*2.24E-10*	*1.13E-10*	*7.31E-11*	*5.11E-11*	*3.37E-11*	*8.62E-12*
	(wake)	EDEWBODY	*1.03E-02*	*3.01E-03*	*3.73E-04*	*1.40E-04*	*7.88E-05*	*3.59E-05*	*2.27E-05*	*1.45E-05*	*1.16E-05*	*3.19E-06*
	ACRR	THYROID	*7.44E-09*	*3.06E-09*	*1.01E-09*	*5.15E-10*	*3.05E-10*	*1.51E-10*	*8.68E-11*	*5.93E-11*	*3.81E-11*	*1.07E-11*
		EDEWBODY	*3.05E-03*	*1.11E-03*	*3.25E-04*	*2.03E-04*	*1.02E-04*	*5.84E-05*	*3.32E-05*	*2.17E-05*	*1.31E-05*	*3.62E-06*
	Stack	THYROID	*8.98E-11*	*4.13E-10*	*2.34E-10*	*3.00E-10*	*2.01E-10*	*2.00E-10*	*8.61E-11*	*6.08E-11*	*4.66E-11*	*1.31E-11*
		EDEWBODY	*3.15E-05*	*1.25E-04*	*8.02E-05*	*1.01E-04*	*7.27E-05*	*7.03E-05*	*3.56E-05*	*2.39E-05*	*1.54E-05*	*5.31E-06*
Sm-153	Ground	THYROID	*1.02E-03*	*5.04E-05*	*5.15E-06*	*2.09E-06*	*1.05E-06*	*6.12E-07*	*3.31E-07*	*2.21E-07*	*1.23E-07*	*4.08E-08*
46.7h B-	(no wake)	EDEWBODY	*7.03E-03*	*3.00E-04*	*2.50E-05*	*1.01E-05*	*5.07E-06*	*3.09E-06*	*1.50E-06*	*1.14E-06*	*7.86E-07*	*2.12E-07*
	Ground	THYROID	*3.01E-04*	*5.01E-05*	*7.03E-06*	*3.01E-06*	*1.10E-06*	*7.58E-07*	*5.03E-07*	*3.18E-07*	*2.08E-07*	*5.52E-08*
	(wake)	EDEWBODY	*1.02E-03*	*2.01E-04*	*3.15E-05*	*1.24E-05*	*7.08E-06*	*3.33E-06*	*2.10E-06*	*1.30E-06*	*1.03E-06*	*2.50E-07*
	ACRR	THYROID	*5.15E-05*	*2.03E-05*	*7.03E-06*	*3.03E-06*	*2.00E-06*	*1.01E-06*	*5.91E-07*	*3.72E-07*	*2.48E-07*	*6.07E-08*
		EDEWBODY	*2.13E-04*	*1.01E-04*	*3.11E-05*	*1.38E-05*	*7.86E-06*	*5.13E-06*	*2.61E-06*	*1.53E-06*	*1.18E-06*	*3.17E-07*
	Stack	THYROID	*7.32E-07*	*2.49E-06*	*1.28E-06*	*1.07E-06*	*1.03E-06*	*1.01E-06*	*5.89E-07*	*4.04E-07*	*3.49E-07*	*8.43E-08*
		EDEWBODY	*2.63E-06*	*1.16E-05*	*7.41E-06*	*7.08E-06*	*7.09E-06*	*5.13E-06*	*2.56E-06*	*1.87E-06*	*1.48E-06*	*3.88E-07*

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Cr-51	Ground	THYROID	1.00E-03	3.08E-05	3.19E-06	1.19E-06	7.35E-07	4.03E-07	2.21E-07	1.22E-07	1.09E-07	3.28E-08
27.704d	(no wake)	EDEWBODY	2.00E-03	7.02E-05	7.03E-06	2.29E-06	1.15E-06	7.97E-07	5.08E-07	3.22E-07	2.18E-07	5.76E-08
EC	Ground	THYROID	2.01E-04	3.02E-05	5.02E-06	2.01E-06	1.00E-06	5.36E-07	3.18E-07	2.19E-07	1.34E-07	3.79E-08
	(wake)	EDEWBODY	3.02E-04	5.04E-05	1.00E-05	3.47E-06	2.00E-06	1.03E-06	5.47E-07	3.69E-07	2.51E-07	7.34E-08
	ACRR	THYROID	3.15E-05	1.06E-05	5.02E-06	2.02E-06	1.03E-06	7.05E-07	4.10E-07	2.55E-07	1.53E-07	4.15E-08
		EDEWBODY	5.36E-05	3.01E-05	1.00E-05	3.20E-06	2.11E-06	1.28E-06	7.67E-07	4.73E-07	3.28E-07	8.30E-08
	Stack	THYROID	5.19E-07	2.03E-06	1.08E-06	1.02E-06	1.00E-06	7.05E-07	4.00E-07	2.85E-07	2.29E-07	5.96E-08
		EDEWBODY	8.98E-09	3.16E-06	2.13E-06	2.02E-06	2.00E-06	1.02E-06	7.47E-07	5.63E-07	3.94E-07	1.14E-07
Mn-56	Ground	THYROID	1.00E-02	3.03E-04	3.17E-05	1.20E-05	7.30E-06	4.14E-06	2.22E-06	1.23E-06	1.11E-06	2.53E-07
2.5785h B-	(no wake)	EDEWBODY	1.01E-02	3.18E-04	3.28E-05	1.25E-05	7.73E-06	5.21E-06	3.10E-06	2.08E-06	1.13E-06	3.12E-07
	Ground	THYROID	2.00E-03	3.01E-04	5.01E-05	2.01E-05	1.01E-05	5.40E-06	3.38E-06	2.10E-06	1.14E-06	3.25E-07
	(wake)	EDEWBODY	2.01E-03	3.02E-04	5.04E-05	2.03E-05	1.05E-05	5.65E-06	3.60E-06	2.15E-06	1.19E-06	3.43E-07
	ACRR	THYROID	3.13E-04	1.03E-04	5.01E-05	2.02E-05	1.02E-05	7.02E-06	3.44E-06	2.26E-06	1.48E-06	3.62E-07
		EDEWBODY	3.22E-04	2.00E-04	5.03E-05	2.05E-05	1.06E-05	7.19E-06	3.59E-06	3.01E-06	2.04E-06	3.84E-07
	Stack	THYROID	9.41E-06	2.09E-05	1.09E-05	1.02E-05	1.00E-05	7.03E-06	3.99E-06	2.55E-06	2.10E-06	5.08E-07
		EDEWBODY	9.44E-06	2.10E-05	1.23E-05	1.03E-05	1.01E-05	7.07E-06	4.09E-06	3.07E-06	2.23E-06	5.38E-07
Fe-55	Ground	THYROID	2.04E-03	7.16E-05	7.20E-06	2.29E-06	1.16E-06	8.02E-07	5.10E-07	3.22E-07	2.18E-07	5.81E-08
2.7y EC	(no wake)	EDEWBODY	3.22E-03	1.26E-04	1.31E-05	5.18E-06	2.29E-06	1.40E-06	1.01E-06	5.90E-07	3.82E-07	1.15E-07
	Ground	THYROID	3.03E-04	7.01E-05	1.01E-05	3.49E-06	2.01E-06	1.03E-06	5.48E-07	3.69E-07	2.52E-07	7.38E-08
	(wake)	EDEWBODY	7.03E-04	1.05E-04	2.01E-05	7.17E-06	3.48E-06	2.05E-06	1.09E-06	7.66E-07	5.35E-07	1.31E-07
	ACRR	THYROID	7.10E-05	3.06E-05	1.01E-05	5.00E-06	2.11E-06	1.29E-06	7.69E-07	4.73E-07	3.29E-07	8.36E-08
		EDEWBODY	1.08E-04	5.35E-05	2.01E-05	7.43E-06	5.04E-06	3.01E-06	1.43E-06	9.62E-07	6.10E-07	1.50E-07
	Stack	THYROID	7.42E-07	3.16E-06	2.13E-06	2.09E-06	2.01E-06	1.09E-06	7.47E-07	5.63E-07	3.94E-07	1.16E-07
		EDEWBODY	1.15E-06	7.08E-06	3.47E-06	3.38E-06	3.13E-06	3.03E-06	1.48E-06	9.60E-07	7.89E-07	2.26E-07

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	**Release**	**Effect**	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Fe-59	Ground	THYROID	*5.01E-02*	*1.11E-03*	*1.14E-04*	*5.63E-05*	*3.17E-05*	*2.04E-05*	*1.14E-05*	*7.35E-06*	*5.22E-06*	*1.32E-06*
44.529d	(no wake)	EDEWBODY	*7.02E-02*	*2.06E-03*	*2.13E-04*	*1.01E-04*	*5.03E-05*	*3.06E-05*	*1.49E-05*	*1.13E-05*	*7.84E-06*	*2.14E-06*
B-	Ground	THYROID	*7.06E-03*	*1.02E-03*	*2.02E-04*	*7.32E-05*	*4.04E-05*	*2.22E-05*	*1.19E-05*	*1.01E-05*	*7.04E-06*	*1.52E-06*
	(wake)	EDEWBODY	*1.02E-02*	*2.01E-03*	*3.02E-04*	*1.23E-04*	*7.05E-05*	*3.32E-05*	*2.10E-05*	*1.30E-05*	*1.03E-05*	*2.51E-06*
	ACRR	THYROID	*1.20E-03*	*7.03E-04*	*2.01E-04*	*1.00E-04*	*5.04E-05*	*3.13E-05*	*1.59E-05*	*1.16E-05*	*7.90E-06*	*2.12E-06*
		EDEWBODY	*2.10E-03*	*1.01E-03*	*3.02E-04*	*1.08E-04*	*7.43E-05*	*5.09E-05*	*2.55E-05*	*1.53E-05*	*1.16E-05*	*3.18E-06*
	Stack	THYROID	*1.97E-05*	*7.90E-05*	*5.28E-05*	*5.05E-05*	*5.01E-05*	*3.02E-05*	*1.59E-05*	*1.45E-05*	*9.36E-06*	*3.04E-06*
		EDEWBODY	*2.72E-05*	*1.07E-04*	*7.41E-05*	*7.09E-05*	*7.02E-05*	*5.02E-05*	*2.56E-05*	*1.59E-05*	*1.48E-05*	*3.89E-06*
Co-58	Ground	THYROID	*3.04E-02*	*1.06E-03*	*1.09E-04*	*5.25E-05*	*2.32E-05*	*1.43E-05*	*1.03E-05*	*5.46E-06*	*3.42E-06*	*1.18E-06*
70.80d	(no wake)	EDEWBODY	*5.04E-02*	*2.02E-03*	*2.24E-04*	*7.65E-05*	*3.53E-05*	*2.44E-05*	*1.35E-05*	*1.04E-05*	*7.18E-06*	*1.54E-06*
ECB+	Ground	THYROID	*7.03E-03*	*1.01E-03*	*2.00E-04*	*7.04E-05*	*3.16E-05*	*2.07E-05*	*1.11E-05*	*7.95E-06*	*5.55E-06*	*1.35E-06*
	(wake)	EDEWBODY	*1.01E-02*	*2.00E-03*	*3.01E-04*	*1.09E-04*	*5.64E-05*	*3.15E-05*	*2.01E-05*	*1.20E-05*	*8.31E-06*	*2.22E-06*
	ACRR	THYROID	*1.08E-03*	*5.07E-04*	*2.00E-04*	*1.00E-04*	*5.01E-05*	*3.03E-05*	*1.47E-05*	*1.05E-05*	*7.13E-06*	*1.54E-06*
		EDEWBODY	*2.06E-03*	*1.00E-03*	*3.01E-04*	*1.03E-04*	*7.19E-05*	*3.97E-05*	*2.40E-05*	*1.40E-05*	*1.06E-05*	*2.57E-06*
	Stack	THYROID	1.87E-05	7.26E-06	3.50E-05	3.51E-05	3.03E-05	3.01E-05	1.48E-05	1.21E-05	8.19E-06	2.30E-06
		EDEWBODY	2.65E-05	1.06E-04	5.69E-04	7.02E-05	5.03E-05	5.00E-05	2.44E-05	1.54E-05	1.39E-05	3.50E-06
Co-60	Ground	THYROID	*2.02E-01*	*1.00E-02*	*1.00E-03*	*3.18E-04*	*1.26E-04*	*1.04E-04*	*5.84E-05*	*3.69E-05*	*2.50E-05*	*7.40E-06*
5.271y B-	(no wake)	EDEWBODY	*7.14E-01*	*2.28E-02*	*2.47E-03*	*1.01E-03*	*5.03E-04*	*3.04E-04*	*1.48E-04*	*1.12E-04*	*7.76E-05*	*2.12E-05*
	Ground	THYROID	*5.01E-02*	*7.04E-03*	*1.05E-03*	*5.02E-04*	*2.25E-04*	*1.13E-04*	*7.32E-05*	*5.12E-05*	*3.39E-05*	*8.66E-06*
	(wake)	EDEWBODY	*1.02E-01*	*2.06E-02*	*3.14E-03*	*1.22E-03*	*7.04E-04*	*3.30E-04*	*2.09E-04*	*1.29E-04*	*1.02E-04*	*2.50E-05*
	ACRR	THYROID	*7.44E-03*	*3.05E-03*	*1.01E-03*	*5.15E-04*	*3.05E-04*	*1.52E-04*	*8.68E-05*	*5.94E-05*	*3.84E-05*	*1.07E-05*
		EDEWBODY	*2.10E-02*	*1.01E-02*	*3.10E-03*	*1.33E-03*	*7.42E-04*	*5.08E-04*	*2.51E-04*	*1.52E-04*	*1.15E-04*	*3.17E-05*
	Stack	THYROID	*8.93E-05*	*4.13E-04*	*2.34E-04*	*3.00E-04*	*2.01E-04*	*2.01E-04*	*8.61E-05*	*6.08E-05*	*4.66E-05*	*1.33E-05*
		EDEWBODY	*2.36E-04*	*1.07E-03*	*7.41E-04*	*7.07E-04*	*7.07E-04*	*5.12E-04*	*2.53E-04*	*1.59E-04*	*1.47E-04*	*3.85E-05*

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Co-60m	Ground	THYROID	7.04E-06	2.11E-07	2.25E-08	7.57E-09	3.34E-09	2.06E-09	1.02E-09	5.65E-10	3.21E-10	3.02E-11
10.47m	(no wake)	EDEWBODY	1.01E-05	3.24E-07	3.50E-08	1.09E-08	5.40E-09	3.11E-09	1.43E-09	1.01E-09	5.51E-10	8.04E-11
ITB-	Ground	THYROID	1.03E-06	2.02E-07	2.25E-08	7.67E-09	3.42E-09	2.16E-09	1.07E-09	7.01E-10	3.46E-10	3.18E-11
	(wake)	EDEWBODY	2.04E-06	3.04E-07	3.44E-08	1.32E-08	7.01E-09	3.25E-09	2.01E-09	1.08E-09	7.02E-10	9.58E-11
	ACRR	THYROID	3.05E-07	1.01E-07	2.08E-08	8.35E-09	3.38E-09	2.17E-09	1.10E-09	7.11E-10	3.64E-10	3.93E-11
		EDEWBODY	5.07E-07	2.00E-07	3.13E-08	1.16E-08	7.01E-09	3.26E-09	2.03E-09	1.07E-09	7.20E-10	1.16E-10
	Stack	THYROID	1.62E-08	1.54E-08	7.13E-09	3.64E-09	2.26E-09	1.28E-09	1.03E-09	5.41E-10	3.31E-10	5.59E-11
		EDEWBODY	1.89E-08	2.29E-08	1.07E-08	7.02E-09	3.46E-09	2.25E-09	1.20E-09	1.05E-09	7.43E-10	1.42E-10
Ni-63	Ground	THYROID	3.01E-03	1.01E-04	1.02E-05	3.26E-06	1.29E-06	1.08E-06	6.09E-07	3.86E-07	3.04E-07	7.89E-08
96y B-	(no wake)	EDEWBODY	7.09E-03	2.12E-04	2.37E-05	7.88E-06	3.61E-06	2.54E-06	1.40E-06	1.08E-06	7.46E-07	1.85E-07
	Ground	THYROID	5.01E-04	7.29E-05	1.07E-05	5.06E-06	2.38E-06	1.16E-06	7.48E-07	5.29E-07	3.52E-07	8.66E-08
	(wake)	EDEWBODY	1.01E-03	2.05E-04	3.08E-05	1.17E-05	5.96E-06	3.22E-06	2.05E-06	1.24E-06	8.60E-07	2.36E-07
	ACRR	THYROID	7.52E-05	3.35E-05	1.07E-05	5.27E-06	3.08E-06	2.01E-06	9.65E-07	6.15E-07	3.98E-07	1.10E-07
		EDEWBODY	2.09E-04	1.02E-04	3.08E-05	1.29E-05	7.34E-06	5.04E-06	2.48E-06	1.46E-06	1.10E-06	3.05E-07
	Stack	THYROID	7.55E-07	5.06E-06	2.34E-06	3.04E-06	2.09E-06	2.03E-06	9.57E-07	6.69E-07	5.60E-07	1.41E-07
		EDEWBODY	2.17E-06	1.07E-05	5.69E-06	7.26E-06	7.00E-06	5.07E-06	2.48E-06	1.59E-06	1.45E-06	3.68E-07
Ni-65	Ground	THYROID	3.01E-03	1.01E-04	1.05E-05	3.62E-06	2.22E-06	1.34E-06	7.67E-07	5.41E-07	3.37E-07	8.35E-08
2.520h B-	(no wake)	EDEWBODY	3.04E-03	1.06E-04	1.10E-05	5.35E-06	3.03E-06	1.51E-06	1.04E-06	7.20E-07	4.13E-07	1.04E-07
	Ground	THYROID	5.04E-04	1.00E-04	1.10E-05	5.25E-06	3.10E-06	1.29E-06	1.09E-06	7.12E-07	5.07E-07	1.06E-07
	(wake)	EDEWBODY	7.03E-04	1.01E-04	2.00E-05	7.09E-06	3.30E-06	2.11E-06	1.22E-06	8.12E-07	5.30E-07	1.16E-07
	ACRR	THYROID	1.04E-04	5.02E-05	1.04E-05	7.03E-06	3.15E-06	2.05E-06	1.13E-06	7.62E-07	5.62E-07	1.17E-07
		EDEWBODY	1.11E-04	7.01E-05	2.00E-05	7.08E-06	5.00E-06	2.13E-06	1.22E-06	1.01E-06	7.04E-07	1.29E-07
	Stack	THYROID	2.82E-06	5.94E-06	3.49E-06	3.07E-06	3.01E-06	2.02E-06	1.09E-06	8.50E-07	5.97E-07	1.39E-07
		EDEWBODY	2.83E-06	7.27E-06	5.28E-06	5.02E-06	3.04E-06	3.00E-06	1.50E-06	1.11E-06	7.71E-07	1.56E-07

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Th-231	Ground	THYROID	*3.02E-04*	*1.01E-05*	*1.05E-06*	*3.62E-07*	*2.18E-07*	*1.28E-07*	*7.51E-08*	*5.30E-08*	*3.32E-08*	*9.58E-09*
25.52h B-	(no wake)	EDEWBODY	*3.01E-03*	*1.03E-04*	*1.06E-05*	*3.42E-06*	*2.03E-06*	*1.16E-06*	*7.32E-07*	*4.09E-07*	*3.22E-07*	*8.21E-08*
	Ground	THYROID	*5.04E-05*	*1.00E-05*	*1.10E-06*	*5.22E-07*	*3.03E-07*	*1.28E-07*	*1.04E-07*	*7.07E-08*	*4.10E-08*	*1.16E-08*
	(wake)	EDEWBODY	*5.03E-04*	*1.01E-04*	*1.25E-05*	*5.17E-06*	*2.49E-06*	*1.20E-06*	*7.81E-07*	*5.68E-07*	*3.70E-07*	*1.05E-07*
	ACRR	THYROID	*1.04E-05*	*5.02E-06*	*1.04E-06*	*7.04E-07*	*3.17E-07*	*2.04E-07*	*1.07E-07*	*8.04E-08*	*5.55E-08*	*1.34E-08*
		EDEWBODY	*1.02E-04*	*5.00E-05*	*1.08E-05*	*7.04E-06*	*3.15E-06*	*2.05E-06*	*1.13E-06*	*7.30E-07*	*5.08E-07*	*1.19E-07*
	Stack	THYROID	*1.75E-07*	*5.64E-07*	*3.27E-07*	*3.07E-07*	*3.02E-07*	*2.03E-07*	*1.11E-07*	*8.62E-08*	*6.57E-08*	*2.04E-08*
		EDEWBODY	*1.17E-06*	*5.17E-06*	*2.37E-06*	*3.02E-06*	*3.01E-06*	*2.05E-06*	*1.20E-06*	*7.94E-07*	*5.78E-07*	*1.45E-07*
U-234	Ground	THYROID	*3.01E-02*	*1.02E-03*	*1.06E-04*	*3.37E-05*	*2.01E-05*	*1.15E-05*	*7.21E-06*	*4.04E-06*	*3.19E-06*	*8.29E-07*
2.445E5y	(no wake)	EDEWBODY	*3.14E+02*	*1.26E+01*	*1.30E+00*	*5.15E-01*	*2.28E-01*	*1.39E-01*	*1.00E-01*	*5.87E-02*	*3.81E-02*	*1.14E-02*
A	Ground	THYROID	*5.09E-03*	*1.00E-03*	*1.16E-04*	*5.15E-05*	*2.47E-05*	*1.19E-05*	*7.76E-06*	*5.61E-06*	*3.67E-06*	*1.06E-06*
	(wake)	EDEWBODY	*7.09E+01*	*1.04E+01*	*2.01E+00*	*7.16E-01*	*3.47E-01*	*2.04E-01*	*1.07E-01*	*7.63E-02*	*5.33E-02*	*1.31E-02*
	ACRR	THYROID	*1.01E-03*	*5.00E-04*	*1.08E-04*	*7.02E-05*	*3.14E-05*	*2.03E-05*	*1.10E-05*	*7.31E-06*	*4.62E-06*	*1.20E-06*
		EDEWBODY	*1.07E+01*	*5.34E+00*	*2.01E+00*	*7.42E-01*	*5.03E-01*	*3.01E-01*	*1.42E-01*	*8.79E-02*	*6.10E-02*	*1.50E-02*
	Stack	THYROID	*1.07E-05*	*5.17E-05*	*2.36E-05*	*3.11E-05*	*2.15E-05*	*2.05E-05*	*1.19E-05*	*7.94E-06*	*5.78E-06*	*1.48E-06*
		EDEWBODY	*1.15E-01*	*7.08E-01*	*3.47E-01*	*3.37E-01*	*3.13E-01*	*3.03E-01*	*1.48E-01*	*9.57E-02*	*7.89E-02*	*2.25E-02*
U-235	Ground	THYROID	*3.26E-02*	*2.00E-03*	*2.00E-04*	*5.65E-05*	*3.19E-05*	*2.06E-05*	*1.15E-05*	*7.76E-06*	*5.41E-06*	*1.34E-06*
703.8E6y	(no wake)	EDEWBODY	*3.10E+02*	*1.14E+01*	*1.24E+00*	*5.03E-01*	*2.22E-01*	*1.32E-01*	*8.33E-02*	*5.62E-02*	*3.64E-02*	*1.06E-02*
A	Ground	THYROID	*7.23E-03*	*1.20E-03*	*2.10E-04*	*1.00E-04*	*5.00E-05*	*2.22E-05*	*1.19E-05*	*1.01E-05*	*7.05E-06*	*1.55E-06*
	(wake)	EDEWBODY	*7.01E+01*	*1.03E+01*	*1.44E+00*	*7.05E-01*	*3.31E-01*	*2.00E-01*	*1.05E-01*	*7.28E-02*	*5.10E-02*	*1.25E-02*
	ACRR	THYROID	*1.21E-03*	*7.04E-04*	*2.08E-04*	*1.03E-04*	*5.26E-05*	*3.27E-05*	*1.59E-05*	*1.16E-05*	*7.93E-06*	*2.13E-06*
		EDEWBODY	*1.05E+01*	*5.16E+00*	*1.37E+00*	*7.25E-01*	*3.79E-01*	*2.37E-01*	*1.31E-01*	*8.40E-02*	*5.74E-02*	*1.42E-02*
	Stack	THYROID	*1.63E-05*	*7.79E-05*	*5.27E-05*	*5.22E-05*	*5.02E-05*	*3.13E-05*	*1.59E-05*	*1.45E-05*	*9.40E-06*	*3.10E-06*
		EDEWBODY	*1.09E-01*	*5.53E-01*	*3.47E-01*	*3.27E-01*	*3.09E-01*	*2.15E-01*	*1.45E-01*	*8.61E-02*	*6.60E-02*	*2.15E-02*

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
U-236	Ground	THYROID	2.14E-02	1.02E-03	1.02E-04	3.28E-05	1.29E-05	1.10E-05	7.02E-06	3.91E-06	3.07E-06	7.99E-07
2.3415E7y	(no wake)	EDEWBODY	3.11E+02	1.15E+01	1.25E+00	5.05E-01	2.23E-01	1.34E-01	8.43E-02	5.69E-02	3.69E-02	1.09E-02
A	Ground	THYROID	5.05E-03	7.31E-04	1.14E-04	5.07E-05	2.40E-05	1.17E-05	7.51E-06	5.33E-06	3.56E-06	8.66E-07
	(wake)	EDEWBODY	7.03E+01	1.04E+01	1.46E+00	7.07E-01	3.34E-01	2.00E-01	1.05E-01	7.35E-02	5.17E-02	1.26E-02
	ACRR	THYROID	7.52E-04	3.36E-04	1.07E-04	5.28E-05	3.11E-05	2.02E-05	1.04E-05	6.16E-06	4.02E-06	1.13E-06
		EDEWBODY	1.07E+01	5.17E+00	1.39E+00	7.35E-01	3.91E-01	2.39E-01	1.37E-01	8.44E-02	5.88E-02	1.44E-02
	Stack	THYROID	7.56E-06	5.06E-05	2.34E-05	3.05E-05	2.10E-05	2.03E-05	9.57E-06	6.71E-06	5.60E-06	1.42E-06
		EDEWBODY	1.09E-01	5.53E-01	3.47E-01	3.32E-01	3.10E-01	3.00E-01	1.48E-01	9.53E-02	7.89E-02	2.19E-02
U-237	Ground	THYROID	3.04E-03	1.06E-04	1.08E-05	5.21E-06	2.31E-06	1.41E-06	1.01E-06	5.46E-07	3.42E-07	1.15E-07
6.75d B-	(no wake)	EDEWBODY	1.02E-02	5.02E-04	5.27E-05	2.02E-05	1.01E-05	5.76E-06	3.42E-06	2.26E-06	1.39E-06	3.94E-07
	Ground	THYROID	7.03E-04	1.01E-04	2.00E-05	7.04E-06	3.13E-06	2.06E-06	1.10E-06	7.84E-07	5.48E-07	1.32E-07
	(wake)	EDEWBODY	3.00E-03	5.00E-04	7.09E-05	2.45E-05	1.24E-05	7.30E-06	3.54E-06	3.02E-06	2.04E-06	5.27E-07
	ACRR	THYROID	1.07E-04	5.07E-05	2.00E-05	7.08E-06	5.01E-06	3.00E-06	1.44E-06	9.62E-07	6.64E-07	1.51E-07
		EDEWBODY	5.07E-04	2.01E-04	7.08E-05	3.08E-05	1.45E-05	1.02E-05	5.51E-06	3.45E-06	2.30E-06	5.98E-07
	Stack	THYROID	2.09E-06	7.27E-06	3.50E-06	3.08E-06	3.03E-06	3.01E-06	1.48E-06	1.20E-06	7.95E-06	2.26E-07
		EDEWBODY	6.28E-06	2.26E-05	1.24E-05	1.04E-05	1.01E-05	1.02E-05	5.60E-06	3.94E-06	2.80E-06	8.16E-07
U-239	Ground	THYROID	1.01E-04	5.01E-06	3.60E-07	1.47E-07	7.56E-08	5.15E-08	3.03E-08	1.20E-08	1.06E-08	1.43E-09
23.54m B-	(no wake)	EDEWBODY	2.02E-04	7.08E-06	7.49E-07	3.07E-07	1.32E-07	7.51E-08	5.06E-08	3.06E-08	2.02E-08	3.16E-09
	Ground	THYROID	2.02E-05	3.04E-06	5.07E-07	2.05E-07	1.03E-07	5.33E-08	3.20E-08	2.07E-08	1.12E-08	1.56E-09
	(wake)	EDEWBODY	5.01E-05	7.03E-06	1.00E-06	3.25E-07	1.25E-07	1.02E-07	5.27E-08	3.20E-08	2.12E-08	3.49E-09
	ACRR	THYROID	3.58E-06	2.01E-06	5.02E-07	2.03E-07	1.05E-07	5.93E-08	3.24E-08	2.14E-08	1.15E-08	1.79E-09
		EDEWBODY	7.44E-06	3.05E-06	1.00E-06	3.20E-07	2.01E-07	1.05E-07	5.93E-08	3.27E-08	2.17E-08	3.73E-09
	Stack	THYROID	1.90E-07	2.77E-07	1.32E-07	1.02E-07	7.14E-08	5.06E-08	3.11E-08	2.07E-08	1.15E-08	2.32E-09
		EDEWBODY	1.90E-07	5.17E-07	2.25E-07	2.01E-07	1.09E-07	1.00E-07	5.79E-08	3.71E-08	2.46E-08	5.43E-09

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	Release	Effect	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Np-238	Ground	THYROID	1.02E-02	5.02E-04	5.06E-05	2.04E-05	1.02E-05	5.89E-06	3.23E-06	2.17E-06	1.21E-06	3.99E-07
2.117d B-	(no wake)	EDEWBODY	1.01E-01	5.00E-03	4.08E-04	1.24E-04	7.69E-05	5.14E-05	3.08E-05	2.03E-05	1.23E-05	3.50E-06
	Ground	THYROID	2.04E-03	5.00E-04	7.02E-05	3.00E-05	1.08E-05	7.43E-06	3.59E-06	3.08E-06	2.10E-06	5.32E-07
	(wake)	EDEWBODY	2.01E-02	3.20E-03	5.25E-04	2.08E-04	1.11E-04	5.54E-05	3.32E-05	2.34E-05	1.42E-05	4.04E-06
	ACRR	THYROID	5.07E-04	2.01E-04	7.02E-05	3.02E-05	1.13E-05	1.01E-05	5.17E-06	3.55E-06	2.38E-06	6.04E-07
		EDEWBODY	3.35E-03	2.00E-03	5.19E-04	3.01E-04	1.30E-04	8.16E-05	4.21E-05	3.12E-05	2.07E-05	5.31E-06
	Stack	THYROID	7.29E-06	2.31E-05	1.25E-05	1.07E-05	1.02E-05	1.01E-05	5.60E-06	3.95E-06	2.81E-06	8.19E-07
		EDEWBODY	4.15E-05	2.08E-04	1.22E-04	1.02E-04	1.03E-04	1.00E-04	4.09E-05	3.59E-05	2.49E-05	7.39E-06
Np-239	Ground	THYROID	3.05E-03	1.09E-04	1.12E-05	5.45E-06	3.05E-06	1.53E-06	1.05E-06	7.26E-07	5.14E-07	1.25E-07
2.355d B-	(no wake)	EDEWBODY	1.01E-02	3.19E-04	3.93E-05	1.22E-05	7.59E-06	5.04E-06	3.05E-06	2.00E-06	1.21E-06	3.43E-07
	Ground	THYROID	7.05E-04	1.01E-04	2.01E-05	7.14E-06	3.23E-06	2.15E-06	1.15E-06	8.45E-07	5.92E-07	1.41E-07
	(wake)	EDEWBODY	2.01E-03	3.03E-04	5.21E-05	2.07E-05	1.09E-05	5.50E-06	3.28E-06	2.30E-06	1.40E-06	3.95E-07
	ACRR	THYROID	1.13E-04	7.02E-05	2.01E-05	1.00E-05	5.02E-06	3.02E-06	1.54E-06	1.11E-06	7.53E-07	1.57E-07
		EDEWBODY	3.23E-04	2.00E-04	5.03E-05	2.15E-05	1.25E-05	7.70E-06	4.13E-06	2.87E-06	2.05E-06	5.24E-07
	Stack	THYROID	2.77E-06	7.95E-06	5.28E-06	5.07E-06	5.02E-06	3.04E-06	1.59E-06	1.45E-06	9.44E-07	3.11E-07
		EDEWBODY	4.55E-06	2.08E-05	1.22E-05	1.02E-05	1.01E-05	7.08E-06	4.09E-06	3.59E-06	2.39E-06	7.27E-07
Pu-238	Ground	THYROID	3.22E-03	1.29E-04	1.39E-05	5.31E-06	3.01E-06	1.46E-06	1.04E-06	7.03E-07	3.99E-07	1.20E-07
87.74y SFA	(no wake)	EDEWBODY	7.25E+02	3.04E+00	3.08E+00	1.06E+00	5.37E-01	3.40E-01	2.10E-01	1.23E-01	8.52E-02	2.43E-02
	Ground	THYROID	7.16E-04	1.06E-04	2.03E-05	7.26E-06	3.65E-06	2.09E-06	1.12E-06	8.07E-07	5.64E-07	1.37E-07
	(wake)	EDEWBODY	1.14E+02	2.12E+01	3.44E+00	1.37E+00	7.73E-01	3.54E-01	2.24E-01	1.42E-01	1.13E-01	3.14E-02
	ACRR	THYROID	1.11E-04	7.04E-05	2.03E-05	1.01E-05	5.09E-06	3.04E-06	1.50E-06	1.05E-06	7.19E-07	1.55E-07
		EDEWBODY	2.24E+01	1.10E+01	3.23E+00	2.01E+00	1.02E+00	5.50E-01	3.27E-01	2.11E-01	1.28E-01	3.51E-02
	Stack	THYROID	1.41E-06	7.25E-06	3.65E-06	5.02E-06	3.21E-06	3.06E-06	1.48E-06	1.22E-06	8.19E-07	2.37E-07
		EDEWBODY	2.45E-01	1.23E+00	8.02E-01	1.01E+00	7.23E-01	5.24E-01	3.29E-01	2.31E-01	1.54E-01	5.23E-02

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

			Centerline Dose (rem) at Radial Range (km)									
Isotope	**Release**	**Effect**	0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Pu-239	Ground	THYROID	3.21E-03	1.25E-04	1.36E-05	5.26E-06	2.32E-06	1.43E-06	1.03E-06	6.04E-07	3.92E-07	1.17E-07
24065y A	(no wake)	EDEWBODY	7.32E+02	3.06E+01	3.22E+00	1.09E+00	5.55E-01	3.54E-01	2.19E-01	1.30E-01	1.02E-01	2.53E-02
	Ground	THYROID	7.13E-04	1.05E-04	2.02E-05	7.22E-06	3.59E-06	2.07E-06	1.11E-06	7.90E-07	5.52E-07	1.35E-07
	(wake)	EDEWBODY	1.16E+02	2.15E+01	3.78E+00	1.45E+00	8.08E-01	5.00E-01	2.29E-01	1.48E-01	1.18E-01	3.22E-02
	ACRR	THYROID	1.10E-04	7.01E-05	2.02E-05	1.00E-05	5.06E-06	3.03E-06	1.47E-06	1.04E-06	6.64E-07	1.54E-07
		EDEWBODY	2.24E+01	1.12E+01	3.27E+00	2.03E+00	1.03E+00	7.01E-01	3.44E-01	2.23E-01	1.34E-01	3.72E-02
	Stack	THYROID	1.41E-06	7.25E-06	3.47E-06	3.50E-06	3.15E-06	3.05E-06	1.48E-06	1.21E-06	8.19E-07	2.33E-07
		EDEWBODY	3.15E-01	1.25E+00	8.02E-01	1.01E+00	7.29E-01	7.06E-01	3.85E-01	2.40E-01	1.54E-01	5.38E-02
Pu-240	Ground	THYROID	3.21E-03	1.25E-04	1.36E-05	5.27E-06	2.32E-06	1.44E-06	1.03E-06	6.06E-07	3.92E-07	1.18E-07
6537y	(no wake)	EDEWBODY	7.32E+02	3.06E+01	3.22E+00	1.09E+00	5.55E-01	3.54E-01	2.19E-01	1.30E-01	1.02E-01	2.53E-02
SFA	Ground	THYROID	7.14E-04	1.05E-04	2.02E-05	7.23E-06	3.60E-06	2.07E-06	1.11E-06	7.92E-07	5.53E-07	1.35E-07
	(wake)	EDEWBODY	1.16E+02	2.15E+01	3.78E+00	1.45E+00	8.08E-01	5.00E-01	2.29E-01	1.48E-01	1.18E-01	3.22E-02
	ACRR	THYROID	1.10E-04	7.02E-05	2.02E-05	1.00E-05	5.07E-06	3.03E-06	1.47E-06	1.04E-06	7.12E-07	1.55E-07
		EDEWBODY	2.24E+01	1.12E+01	3.27E+00	2.03E+00	1.03E+00	7.01E-01	3.44E-01	2.23E-01	1.34E-01	3.72E-02
	Stack	THYROID	1.41E-06	7.25E-06	3.47E-06	5.00E-06	3.15E-06	3.05E-06	1.48E-06	1.21E-06	8.19E-07	2.34E-07
		EDEWBODY	3.15E-01	1.25E+00	8.02E-01	1.01E+00	7.29E-01	7.06E-01	3.85E-01	2.40E-01	1.54E-01	5.38E-02
Pu-241	Ground	THYROID	1.02E-04	3.17E-06	3.51E-07	1.14E-07	7.03E-08	3.76E-08	2.32E-08	1.38E-08	1.09E-08	2.55E-09
14.4y A B-	(no wake)	EDEWBODY	1.09E+01	5.13E-01	5.30E-02	2.02E-02	1.01E-02	5.78E-03	3.43E-03	2.26E-03	1.39E-03	3.97E-04
	Ground	THYROID	2.00E-05	3.06E-06	5.04E-07	2.00E-07	1.00E-07	5.13E-08	3.06E-08	2.04E-08	1.25E-08	3.46E-09
	(wake)	EDEWBODY	3.00E+00	5.02E-01	7.10E-02	2.46E-02	1.24E-02	7.30E-03	3.55E-03	3.02E-03	2.05E-03	5.30E-04
	ACRR	THYROID	3.12E-06	1.15E-06	5.04E-07	2.06E-07	1.05E-07	7.10E-08	3.73E-08	2.36E-08	1.43E-08	4.03E-09
		EDEWBODY	5.08E-01	2.07E-01	7.10E-02	3.08E-02	1.45E-02	1.02E-02	5.52E-03	3.46E-03	2.31E-03	5.99E-04
	Stack	THYROID	3.33E-08	1.65E-07	1.07E-07	1.04E-07	1.00E-07	7.15E-08	3.86E-08	2.53E-08	1.82E-08	5.75E-09
		EDEWBODY	5.29E-03	2.26E-02	1.23E-02	1.19E-02	1.08E-02	1.03E-02	5.60E-03	3.94E-03	2.80E-03	8.24E-04

Table E-1. Centerline dose (95th Quantile) for 1 curie of a single isotope at ten ranges, released January 1998 (continued).

Isotope	Release	Effect	Centerline Dose (rem) at Radial Range (km)									
			0.0 - 0.1	0.1 - 0.5	0.5 - 1.5	1.5 - 1.7	1.7-2.9	2.9-3.1	3.1-4.8	4.8-5.0	5.0-7.0	7.0 - 20.0
Am-241	Ground	THYROID	*1.23E-02*	*5.27E-04*	*7.05E-05*	*2.18E-05*	*1.11E-05*	*7.37E-06*	*3.93E-06*	*3.02E-06*	*2.05E-06*	*5.30E-07*
432.2y A	(no wake)	EDEWBODY	*1.05E+03*	*5.00E+01*	*5.04E+00*	*1.27E+00*	*7.85E-01*	*5.28E-01*	*3.18E-01*	*2.11E-01*	*1.27E-01*	*3.71E-02*
	Ground	THYROID	*3.06E-03*	*5.10E-04*	*7.42E-05*	*3.11E-05*	*1.46E-05*	*1.00E-05*	*5.24E-06*	*3.47E-06*	*2.37E-06*	*6.11E-07*
	(wake)	EDEWBODY	*2.07E+02*	*3.20E+01*	*5.31E+00*	*2.30E+00*	*1.16E+00*	*7.02E-01*	*3.39E-01*	*2.42E-01*	*1.47E-01*	*4.08E-02*
	ACRR	THYROID	*5.19E-04*	*3.00E-04*	*7.41E-05*	*3.23E-05*	*2.06E-05*	*1.18E-05*	*6.12E-06*	*4.05E-06*	*3.09E-06*	*7.60E-07*
		EDEWBODY	*3.35E+01*	*2.04E-01*	*5.30E+00*	*3.03E+00*	*1.37E+00*	*1.00E+00*	*4.76E-01*	*3.24E-01*	*2.16E-01*	*5.44E-02*
	Stack	THYROID	*5.51E-06*	*3.16E-05*	*1.37E-05*	*2.03E-05*	*1.27E-05*	*1.07E-05*	*6.13E-06*	*4.19E-06*	*3.76E-06*	*1.08E-06*
		EDEWBODY	*3.88E-01*	*2.08E+00*	*1.22E+00*	*1.12E+00*	*1.04E+00*	*1.01E+00*	*4.72E-01*	*3.60E-01*	*2.49E-01*	*7.71E-02*
Cm-242	Ground	THYROID	*1.01E-02*	*3.19E-04*	*3.60E-05*	*1.15E-05*	*7.09E-06*	*3.83E-06*	*2.36E-06*	*1.42E-06*	*1.10E-06*	*2.86E-07*
162.8d	(no wake)	EDEWBODY	*5.05E+01*	*2.01E+00*	*2.01E-01*	*7.05E-02*	*3.22E-02*	*2.09E-02*	*1.17E-02*	*7.88E-03*	*5.49E-03*	*1.36E-03*
SFA	Ground	THYROID	*2.00E-03*	*3.08E-04*	*5.06E-05*	*2.01E-05*	*1.01E-05*	*5.17E-06*	*3.09E-06*	*2.07E-06*	*1.27E-06*	*3.57E-07*
	(wake)	EDEWBODY	*1.00E+01*	*1.21E+00*	*2.11E-01*	*1.00E-01*	*5.02E-02*	*2.26E-02*	*1.20E-02*	*1.03E-02*	*7.15E-03*	*1.56E-03*
	ACRR	THYROID	*3.13E-04*	*1.16E-04*	*5.06E-05*	*2.07E-05*	*1.06E-05*	*7.13E-06*	*3.78E-06*	*2.39E-06*	*1.45E-06*	*4.12E-07*
		EDEWBODY	*1.30E+00*	*7.23E-01*	*2.08E-01*	*1.03E-01*	*5.29E-02*	*3.30E-02*	*1.59E-02*	*1.19E-02*	*8.05E-03*	*2.16E-03*
	Stack	THYROID	*3.33E-06*	*1.65E-05*	*1.07E-05*	*1.05E-05*	*1.01E-05*	*7.18E-06*	*3.94E-06*	*2.53E-06*	*1.82E-06*	*5.84E-07*
		EDEWBODY	*1.53E-02*	*7.79E-02*	*5.27E-02*	*5.24E-02*	*5.04E-02*	*3.14E-02*	*1.59E-02*	*1.45E-02*	*9.40E-03*	*3.14E-03*
Cm-244	Ground	THYROID	*1.02E-02*	*3.37E-04*	*3.75E-05*	*1.19E-05*	*7.32E-06*	*4.01E-06*	*2.47E-06*	*1.48E-06*	*1.15E-06*	*3.26E-07*
18.11y	(no wake)	EDEWBODY	*7.10E+02*	*2.24E+01*	*2.49E+00*	*1.01E+00*	*5.06E-01*	*3.06E-01*	*1.48E-01*	*1.13E-01*	*7.80E-02*	*2.17E-02*
SFA	Ground	THYROID	*2.02E-03*	*3.08E-04*	*5.11E-05*	*2.03E-05*	*1.02E-05*	*5.32E-06*	*3.15E-06*	*2.17E-06*	*1.33E-06*	*3.78E-07*
	(wake)	EDEWBODY	*1.05E+02*	*2.05E+01*	*3.14E+00*	*1.23E+00*	*7.05E-01*	*3.31E-01*	*2.10E-01*	*1.29E-01*	*1.02E-01*	*2.51E-02*
	ACRR	THYROID	*3.14E-04*	*1.27E-04*	*5.11E-05*	*2.12E-05*	*1.14E-05*	*7.26E-06*	*4.02E-06*	*2.54E-06*	*1.52E-06*	*4.68E-07*
		EDEWBODY	*2.09E+01*	*1.03E+01*	*3.11E+00*	*1.37E+00*	*7.84E-01*	*5.09E-01*	*2.55E-01*	*1.52E-01*	*1.15E-01*	*3.18E-02*
	Stack	THYROID	*3.33E-06*	*2.03E-05*	*1.08E-05*	*1.07E-05*	*1.02E-05*	*7.25E-06*	*4.00E-06*	*2.85E-06*	*2.29E-06*	*7.03E-07*
		EDEWBODY	*2.18E-01*	*1.07E+00*	*7.41E-01*	*7.38E-01*	*7.08E-01*	*5.13E-01*	*2.56E-01*	*1.59E-01*	*1.47E-01*	*3.87E-02*

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APPENDIX F, 2000 DWDD 95TH PERCENTILE OF DOSE LISTING

Table F-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2000 DWDD Calculated with MACCS2 at the 2.9-3.1 km Range for the 3000m Exclusion Area Boundary

Nuclide Information for the 1 Curie Released Activity				Release Condition for 95th Quantile of TEDE (rem/Ci)			
No.	Nuclide	Half-Life & Decay Type	Other Nuclides Included in Dose	Ground Release (no wake)	Ground Release (wake)	ACRR Release (wake)	HCF Stack Release (wake)
1	H-3	12.34y B-		*7.54E-08*	*1.01E-07*	*1.23E-07*	*1.08E-07*
2	Ge-77	11.30h B-		*8.55E-06*	*1.07E-05*	*1.09E-05*	*1.05E-05*
3	As-77	38.8h B-		*1.24E-06*	*1.25E-06*	*2.17E-06*	*2.08E-06*
4	Se-81	18.5m B-		*2.02E-08*	*2.10E-08*	*2.26E-08*	*1.48E-08*
5	Se-81m	57.25m ITB-		*1.12E-07*	*1.15E-07*	*1.23E-07*	*1.65E-07*
6	Br-82	35.30h B-		*3.02E-05*	*3.31E-05*	*5.01E-05*	*5.02E-05*
7	Br-83	2.39h B-		*1.10E-07*	*1.15E-07*	*1.70E-07*	*1.73E-07*
8	Se-83	22.4m B-		*2.05E-06*	*2.13E-06*	*2.13E-06*	*1.29E-06*
9	Kr-83M	1.83h IT		*7.63E-11*	*7.13E-11*	*5.85E-11*	*3.12E-11*
10	Br-84	31.80m B-		*1.22E-06*	*2.09E-06*	*2.25E-06*	*1.31E-06*
11	Kr-85	10.72y B-		*8.29E-09*	*8.00E-09*	*6.36E-09*	*3.63E-09*
12	Kr-85M	4.48h ITB-		*4.58E-07*	*3.58E-07*	*3.52E-07*	*2.01E-07*
13	Rb-86	18.66d B-		*8.59E-06*	*1.07E-05*	*1.38E-05*	*1.23E-05*
14	Kr-87	76.3m B-		*1.82E-06*	*1.76E-06*	*1.40E-06*	*7.99E-07*
15	Kr-88	2.84h B-		*7.04E-06*	*7.03E-06*	*5.04E-06*	*3.03E-06*
16	Rb-88	17.8m B-		*5.05E-07*	*5.27E-07*	*5.28E-07*	*3.34E-07*
17	Rb-89	15.2m B-		*1.09E-06*	*1.13E-06*	*1.13E-06*	*1.04E-06*
18	Sr-89	50.5d B-		*7.70E-06*	*1.01E-05*	*1.24E-05*	*1.09E-05*
19	Sr-90	29.12y B-		*3.01E-04*	*3.26E-04*	*5.07E-04*	*5.10E-04*
20	Y-90	64.0h B-		*1.03E-05*	*1.11E-05*	*1.49E-05*	*2.00E-05*
21	Sr-91	9.5h B-	Y-91m	*1.01E-05*	*1.10E-05*	*1.11E-05*	*1.10E-05*
22	Y-91	58.51d B-		*5.73E-05*	*7.27E-05*	*1.02E-04*	*1.02E-04*
23	Y-91m*	49.71m IT		*7.35E-07*	*8.67E-07*	*1.01E-06*	*9.34E-07*
24	Sr-92	2.71h B-		*5.21E-06*	*5.65E-06*	*7.23E-06*	*7.08E-06*
25	Y-92	3.54h B-		*1.50E-06*	*2.11E-06*	*3.03E-06*	*3.01E-06*
26	Y-93	10.1h B-		*3.12E-06*	*3.38E-06*	*5.31E-06*	*5.36E-06*
27	Y-94	19.1m B-		*7.63E-07*	*1.00E-06*	*1.01E-06*	*7.18E-07*
28	Y-95	10.7m B-		*3.25E-07*	*3.98E-07*	*3.41E-07*	*3.13E-07*
29	Zr-95	63.98d B-		*3.01E-05*	*3.29E-05*	*5.07E-05*	*5.11E-05*
30	Nb-95	35.15d B-		*1.45E-05*	*2.09E-05*	*3.04E-05*	*3.01E-05*
31	Nb-95m	86.6h IT		*3.59E-06*	*5.01E-06*	*7.03E-06*	*7.08E-06*
32	Nb-96	23.35h B-		*2.45E-05*	*3.18E-05*	*3.26E-05*	*5.01E-05*
33	Zr-97	16.90h B-	Nb-97 & m	*2.24E-05*	*3.03E-05*	*3.15E-05*	*3.05E-05*
34	Nb-97*	72.1m B-		*1.07E-06*	*1.18E-06*	*1.25E-06*	*1.11E-06*
35	Nb-97m*	60s IT		*1.22E-08*	*2.05E-08*	*2.17E-08*	*2.02E-08*

Table F-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2000 DWDD Calculated with MACCS2 at the 2.9-3.1 km Range for the 3000m Exclusion Area Boundary (Continued)

Nuclide Information for the 1 Curie Released Activity				Release Condition for 95th Quantile of TEDE (rem/Ci)			
No.	Nuclide	Half-Life & Decay Type	Other Nuclides Included in Dose	Ground Release (no wake)	Ground Release (wake)	ACRR Release (wake)	HCF Stack Release (wake)
36	**Mo-99**	66.0h B-		*7.30E-06*	*7.92E-06*	*1.17E-05*	*1.07E-05*
37	**Tc-99m**	6.02h IT		*7.02E-07*	*7.67E-07*	*1.01E-06*	*1.01E-06*
38	**Mo-101**	14.62m B-		*1.02E-06*	*1.07E-06*	*1.06E-06*	*7.57E-07*
39	**Tc-101**	14.2m B-		*2.02E-07*	*2.09E-07*	*2.12E-07*	*1.18E-07*
40	**Ru-103**	39.28d B-	**Rh-103m**	*1.45E-05*	*2.09E-05*	*3.03E-05*	*3.06E-05*
41	**Rh-103m***	56.12m IT		*5.36E-09*	*6.02E-09*	*7.25E-09*	*7.25E-09*
42	**Tc-104**	18.2m B-		*1.13E-06*	*1.17E-06*	*1.17E-06*	*1.08E-06*
43	**Ru-105**	4.44h B-		*3.68E-06*	*5.08E-06*	*5.25E-06*	*7.01E-06*
44	**Rh-105**	35.36h B-		*2.01E-06*	*2.20E-06*	*3.11E-06*	*3.02E-06*
45	**Ru-106**	4.44h B-	**Rh-106**	*5.61E-04*	*7.21E-04*	*1.01E-03*	*1.02E-03*
46	**Rh-106***	29.9s B-		*5.55E-12*	*5.55E-12*	*5.55E-12*	*4.01E-12*
47	**Pd-109**	13.427h B-		*1.24E-06*	*1.25E-06*	*2.32E-06*	*2.22E-06*
48	**Ag-109m**	39.6s IT		*1.09E-12*	*1.09E-12*	*1.09E-12*	*1.03E-12*
49	**Ag-111**	7.45d B-		*7.54E-06*	*1.01E-05*	*1.22E-05*	*1.08E-05*
50	**Ag-112**	3.12h B-		*3.01E-06*	*3.27E-06*	*4.53E-06*	*5.01E-06*
51	**Cd-115**	53.46h B-		*8.46E-06*	*1.07E-05*	*1.35E-05*	*1.04E-05*
52	**Cd-115m**	44.6d B-		*5.21E-05*	*7.01E-05*	*8.29E-05*	*1.01E-04*
53	**In-115m**	4.486h ITB-		*7.94E-07*	*1.03E-06*	*1.06E-06*	*1.02E-06*
54	**Sn-119m**	293.0d IT		*7.52E-06*	*1.01E-05*	*1.20E-05*	*1.08E-05*
55	**Sn-121**	27.06h B-		*5.80E-07*	*7.31E-07*	*1.02E-06*	*1.02E-06*
56	**Sn-123**	129.2d B-		*3.67E-05*	*5.05E-05*	*7.07E-05*	*7.12E-05*
57	**Sn-125**	9.64d B-		*2.20E-05*	*3.01E-05*	*3.57E-05*	*3.23E-05*
58	**Sb-125**	2.77y B-		*5.14E-06*	*1.04E-05*	*1.30E-05*	*1.02E-05*
59	**Xe-125**	17.0h ECB+		*7.18E-07*	*7.14E-07*	*5.19E-07*	*3.10E-07*
60	**I-125**	60.14d EC		*3.05E-05*	*3.30E-05*	*5.09E-05*	*5.12E-05*
61	**Te-125m**	58d IT		*8.61E-06*	*1.07E-05*	*1.39E-05*	*1.23E-05*
62	**Sb-126**	12.4d B-		*3.86E-05*	*5.23E-05*	*7.04E-05*	*7.04E-05*
63	**I-126**	13.02d ECB+B-		*5.75E-05*	*7.29E-05*	*1.02E-04*	*1.02E-04*
64	**Sb-127**	3.85d B-		*1.11E-05*	*1.18E-05*	*2.02E-05*	*2.01E-05*
65	**Te-127**	9.35h B-		*3.68E-07*	*5.05E-07*	*7.11E-07*	*7.25E-07*
66	**Te-127m**	109d ITB-		*2.44E-05*	*3.15E-05*	*3.98E-05*	*5.03E-05*
67	**Xe-127**	36.41d EC		*8.71E-07*	*8.40E-07*	*6.68E-07*	*3.81E-07*
68	**Sn-128**	59.1m B-		*3.76E-06*	*5.10E-06*	*5.45E-06*	*5.05E-06*
69	**Sb-128m**	10.4m B-		*7.44E-07*	*1.00E-06*	*8.46E-07*	*5.45E-07*
70	**Sb-129**	4.32h B-		*7.07E-06*	*7.68E-06*	*1.01E-05*	*1.01E-05*

Table F-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2000 DWDD Calculated with MACCS2 at the 2.9-3.1 km Range for the 3000m Exclusion Area Boundary (Continued)

Nuclide Information for the 1 Curie Released Activity				Release Condition for 95th Quantile of TEDE (rem/Ci)			
No.	Nuclide	Half-Life & Decay Type	Other Nuclides Included in Dose	Ground Release (no wake)	Ground Release (wake)	ACRR Release (wake)	HCF Stack Release (wake)
71	Te-129*	69.6m B-		1.47E-07	2.09E-07	2.17E-07	2.02E-07
72	Te-129m	33.6d ITB-	Te-129	3.09E-05	3.33E-05	5.14E-05	5.14E-05
73	Xe-129m	8.0d IT		7.37E-08	7.11E-08	5.65E-08	3.23E-08
74	Sb-130	40m B-		3.32E-06	4.15E-06	5.08E-06	3.26E-06
75	Sb-131	23m B-		2.06E-06	2.12E-06	2.38E-06	2.05E-06
76	Te-131*	25.0m B-		7.11E-07	7.86E-07	8.21E-07	7.08E-07
77	Te-131m	30h ITB-	Te-131	2.34E-05	3.08E-05	3.76E-05	3.05E-05
78	I-131	8.04d B-		3.97E-05	5.30E-05	7.24E-05	7.24E-05
79	Xe-131m	11.9d IT		2.71E-08	2.61E-08	2.08E-08	1.19E-08
80	Te-132	78.2h B-		3.47E-05	4.12E-05	5.89E-05	7.01E-05
81	I-132	2.30h B-		6.05E-06	7.54E-06	1.00E-05	1.00E-05
82	Te-133	12.45m B-		5.37E-07	6.03E-07	5.45E-07	3.49E-07
83	Te-133m	55.4m ITB-		3.33E-06	5.17E-06	5.37E-06	5.04E-06
84	I-133	20.8h B-		1.19E-05	1.22E-05	2.15E-05	2.01E-05
85	Xe-133	5.245d B-		1.03E-07	1.04E-07	8.30E-08	4.74E-08
86	Xe-133m	2.188d IT		9.49E-08	9.16E-08	7.28E-08	4.16E-08
87	Te-134	41.8m B-		3.22E-06	3.49E-06	5.02E-06	5.02E-06
88	I-134	52.6m B-		3.28E-06	4.09E-06	5.05E-06	4.58E-06
89	Cs-134	2.062y ECB-		7.51E-05	1.00E-04	1.20E-04	1.08E-04
90	I-135	6.61h B-	Xe-135m	1.09E-05	1.17E-05	1.82E-05	2.00E-05
91	Xe-135	9.09h B-		7.78E-07	7.51E-07	5.35E-07	3.41E-07
92	Xe-135m*	15.29m ITB-		2.32E-07	2.25E-07	1.71E-07	1.03E-07
93	Cs-136	13.1d B-		3.51E-05	3.62E-05	5.88E-05	7.01E-05
94	Cs-137	30.0y B-	Ba-137m	4.07E-05	5.36E-05	7.29E-05	7.27E-05
95	Ba-137m*	2.552m IT		2.10E-08	2.10E-08	2.04E-08	1.21E-08
96	Xe-138	14.17m B-		2.18E-06	2.17E-06	2.06E-06	1.10E-06
97	Cs-138	32.2m B-		2.19E-06	3.03E-06	3.12E-06	2.22E-06
98	Ba-139	82.7m B-		2.34E-07	3.07E-07	3.23E-07	3.39E-07
99	Ba-140	12.74d B-		1.17E-05	1.40E-05	2.07E-05	2.01E-05
100	La-140	40.272h B-		3.06E-05	3.33E-05	5.02E-05	5.03E-05
101	Ba-141	18.27m B-		7.01E-07	7.36E-07	7.37E-07	5.31E-07
102	La-141	3.93h B-		7.76E-07	1.02E-06	1.32E-06	1.19E-06
103	Ce-141	32.501d B-		1.15E-05	1.19E-05	2.03E-05	2.05E-05
104	Ba-142	10.6m B-		1.02E-06	1.06E-06	1.10E-06	1.02E-06
105	La-142	92.5m B-		5.23E-06	7.03E-06	7.44E-06	7.06E-06

Table F-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2000 DWDD Calculated with MACCS2 at the 2.9-3.1 km Range for the 3000m Exclusion Area Boundary (Continued)

Nuclide Information for the 1 Curie Released Activity				Release Condition for 95th Quantile of TEDE (rem/Ci)			
No.	**Nuclide**	**Half-Life & Decay Type**	**Other Nuclides Included in Dose**	**Ground Release (no wake)**	**Ground Release (wake)**	**ACRR Release (wake)**	**HCF Stack Release (wake)**
106	**La-143**	14.23m B-		*1.07E-07*	*1.10E-07*	*1.30E-07*	*1.05E-07*
107	**Ce-143**	33.0h B-		*7.14E-06*	*7.75E-06*	*1.10E-05*	*1.01E-05*
108	**Pr-143**	13.56d B-		*1.01E-05*	*1.10E-05*	*1.43E-05*	*1.40E-05*
109	**Ce-144**	284.3d B-	**Pr-144 & m**	*4.01E-04*	*5.32E-04*	*7.27E-04*	*7.25E-04*
110	**Pr-144***	17.28m B-		*7.93E-07*	*1.03E-06*	*1.39E-06*	*3.30E-08*
111	**Pr-144m***	7.2m ITB-		*2.14E-08*	*2.53E-08*	*3.10E-08*	*2.10E-08*
112	**Pr-145**	5.98h B-		*7.93E-07*	*1.03E-06*	*1.39E-06*	*1.23E-06*
113	**Pr-147**	13.6m B-		*5.06E-07*	*5.22E-07*	*5.28E-07*	*3.36E-07*
114	**Nd-147**	10.98d B-		*1.02E-05*	*1.11E-05*	*1.48E-05*	*2.00E-05*
115	**Pm-147**	2.6234y B-		*4.13E-05*	*5.40E-05*	*7.62E-05*	*7.30E-05*
116	**Pm-148**	5.37d B-		*2.05E-05*	*2.22E-05*	*3.13E-05*	*3.12E-05*
117	**Pm-148m**	41.3d B-IT		*5.32E-05*	*7.06E-05*	*1.00E-04*	*1.00E-04*
118	**Nd-149**	1.73h B-		*1.09E-06*	*1.15E-06*	*1.61E-06*	*1.10E-06*
119	**Pm-149**	53.08h B-		*3.49E-06*	*3.59E-06*	*5.83E-06*	*7.03E-06*
120	**Nd-151**	12.44m B-		*5.07E-07*	*5.24E-07*	*5.31E-07*	*3.38E-07*
121	**Pm-151**	28.40h B-		*5.27E-06*	*7.02E-06*	*8.33E-06*	*1.00E-05*
122	**Sm-151**	90y B-		*3.48E-05*	*3.59E-05*	*5.84E-05*	*7.03E-05*
123	**Sm-153**	46.7h B-		*3.09E-06*	*3.33E-06*	*5.13E-06*	*5.13E-06*
124	**Eu-155**	4.96y B-		*5.16E-05*	*5.55E-05*	*8.19E-05*	*1.00E-04*
125	**Eu-156**	15.19d B-		*3.25E-05*	*3.50E-05*	*5.23E-05*	*5.04E-05*
126	**P-32**	14.29d B-		*7.32E-06*	*7.93E-06*	*1.18E-05*	*1.07E-05*
127	**S-35**	87.44d B-		*3.50E-07*	*3.61E-07*	*5.86E-07*	*7.04E-07*
128	**Cr-51**	27.704d EC		*7.97E-07*	*1.03E-06*	*1.28E-06*	*1.02E-06*
129	**Mn-56**	2.5785h B-		*5.21E-06*	*5.65E-06*	*7.19E-06*	*7.07E-06*
130	**Fe-55**	2.7y EC		*1.40E-06*	*2.05E-06*	*3.01E-06*	*3.03E-06*
131	**Fe-59**	44.529d B-		*3.06E-05*	*3.32E-05*	*5.09E-05*	*5.02E-05*
132	**Co-58**	70.80d ECB+		*2.44E-05*	*3.15E-05*	*3.97E-05*	*5.01E-05*
133	**Co-60**	5.271y B-		*3.04E-04*	*3.30E-04*	*5.08E-04*	*5.12E-04*
134	**Co-60m**	10.47m ITB-		*3.11E-09*	*3.25E-09*	*3.26E-09*	*2.25E-09*
135	**Ni-59**	7.5E4y EC		*1.08E-06*	*1.16E-06*	*2.01E-06*	*2.03E-06*
136	**Ni-63**	96y B-		*2.54E-06*	*3.22E-06*	*5.04E-06*	*5.07E-06*
137	**Ni-65**	2.520h B-		*1.51E-06*	*2.11E-06*	*2.13E-06*	*3.00E-06*
138	**Th-230**	7.7E4y A		*3.14E-01*	*3.40E-01*	*5.17E-01*	*5.17E-01*
139	**Th-231**	25.52h B-		*1.16E-06*	*1.20E-06*	*2.05E-06*	*2.05E-06*
140	**U-234**	2.445E5y A		*1.39E-01*	*2.04E-01*	*3.01E-01*	*3.03E-01*

Table F-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2000 DWDD Calculated with MACCS2 at the 2.9-3.1 km Range for the 3000m Exclusion Area Boundary (Continued)

Nuclide Information for the 1 Curie Released Activity				Release Condition for 95th Quantile of TEDE (rem/Ci)			
No.	Nuclide	Half-Life & Decay Type	Other Nuclides Included in Dose	Ground Release (no wake)	Ground Release (wake)	ACRR Release (wake)	HCF Stack Release (wake)
141	U-235	703.8E6y A		*1.32E-01*	*2.00E-01*	*2.37E-01*	*2.15E-01*
142	U-236	2.3415E7y A		*1.34E-01*	*2.00E-01*	*2.39E-01*	*3.00E-01*
143	U-237	6.75d B-		*5.76E-06*	*7.30E-06*	*1.02E-05*	*1.02E-05*
144	U-238	4.468E9y SFA		*1.29E-01*	*1.28E-01*	*2.32E-01*	*2.13E-01*
145	U-239	23.54m B-		*7.51E-08*	*1.02E-07*	*1.05E-07*	*1.00E-07*
146	Np-237	2.14E6y A		*6.09E-01*	*7.52E-01*	*1.04E+00*	*1.04E+00*
147	Np-238	2.117d B-		*5.14E-05*	*5.54E-05*	*8.16E-05*	*1.00E-04*
148	Np-239	2.355d B-		*5.04E-06*	*5.50E-06*	*7.70E-06*	*7.08E-06*
149	Pu-238	87.74y SFA		*3.40E-01*	*3.54E-01*	*5.50E-01*	*5.24E-01*
150	Pu-239	24065y A		*3.54E-01*	*5.00E-01*	*7.01E-01*	*7.06E-01*
151	Pu-240	6537y SFA		*3.54E-01*	*5.00E-01*	*7.01E-01*	*7.06E-01*
152	Pu-241	14.4y A B-		*5.78E-03*	*7.30E-03*	*1.02E-02*	*1.03E-02*
153	Am-241	432.2y A		*5.28E-01*	*7.02E-01*	*1.00E+00*	*1.01E+00*
154	Cm-242	162.8d SFA		*2.09E-02*	*2.26E-02*	*3.30E-02*	*3.14E-02*
155	Cm-244	18.11y SFA		*3.06E-01*	*3.31E-01*	*5.09E-01*	*5.13E-01*

Note:

* The dose for these isotopes is included with the dose for their parent for the activity corresponding to secular equilibrium. Thus, their activity should be shown as zero when in secular equilibrium with the parent.

Note: The half-life and decay mode are shown for each nuclide after its name. The decay modes are the following:

- B- beta-minus (electron)
- IT internal transition producing gammas
- EC electron capture
- B+ beta-plus (positron)
- A alpha particle
- SF spontaneous fission

APPENDIX G, 2002 DWDD 95TH PERCENTILE OF DOSE LISTING

Table G-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2002 DWDD Calculated with MACCS2 at the 2.95-3.05 km Range for the 3000m Exclusion Area Boundary

Nuclide Information for 1 Ci Release Activity				95th Quantile of TEDE (rem/Ci) for Release Facility & Height						
No.	Nuclide	Half-Life & Decay Type	Other Nuclides Included in Dose	Ground 0.0 m **	GIF Vents 4.3 m **	SPRF 10.0 m **	ACRRF 14.3 m **	AHCF Stack 16.4 m **	GIF Stack 18.0 m **	HCF Stack 38.1 m **
	<u>Fission Products</u>									
1	**H-3**	12.34y B-		1.87E-06	1.87E-06	1.65E-06	1.49E-06	1.34E-06	1.26E-06	6.03E-07
2	**Ge-77**	11.30h B-		3.40E-05	3.34E-05	3.16E-05	2.88E-05	2.85E-05	2.61E-05	1.11E-05
3	**As-77**	38.8h B-		3.08E-05	3.08E-05	2.85E-05	2.57E-05	2.38E-05	2.23E-05	1.01E-05
4	**Se-81**	18.5m B-		**2.02E-07**	2.01E-07	**1.19E-07**	1.16E-07	**1.15E-07**	1.13E-07	**5.60E-08**
5	**Se-81m**	57.25m ITB-		2.01E-06	1.81E-06	1.62E-06	1.36E-06	1.29E-06	1.19E-06	6.07E-07
6	**Br-82**	35.30h B-		5.13E-05	4.76E-05	4.28E-05	3.87E-05	3.58E-05	3.41E-05	1.63E-05
7	**Br-83**	2.39h B-		2.12E-06	2.11E-06	2.03E-06	1.66E-06	1.65E-06	1.49E-06	7.03E-07
8	**Se-83**	22.4m B-		5.15E-06	5.08E-06	**3.35E-06**	**3.23E-06**	3.16E-06	3.13E-06	2.03E-06
9	**Kr-83m**	1.83h IT		1.10E-10	1.09E-10	1.03E-10	8.92E-11	8.29E-11	7.84E-11	5.29E-11
10	**Br-84**	31.80m B-		5.23E-06	5.21E-06	5.09E-06	3.23E-06	3.22E-06	3.18E-06	2.08E-06
11	**Kr-85**	10.72y B-		1.15E-08	1.13E-08	1.05E-08	8.93E-09	8.31E-09	7.84E-09	5.29E-09
12	**Kr-85m**	4.48h ITB-		7.50E-07	7.20E-07	6.11E-07	5.18E-07	4.82E-07	4.43E-07	2.98E-07
13	**Rb-86**	18.66d B-		1.88E-04	1.87E-04	1.66E-04	1.50E-04	1.36E-04	1.34E-04	6.49E-05
14	**Kr-87**	76.3m B-		3.11E-06	3.07E-06	2.61E-06	2.19E-06	2.05E-06	2.02E-06	1.11E-06
15	**Rb-87**	4.7E10y B-		9.51E-05	9.51E-05	8.72E-05	7.99E-05	7.53E-05	7.29E-05	3.04E-05
16	**Kr-88**	2.84h B-		1.24E-05	1.15E-05	1.07E-05	9.68E-06	8.90E-06	8.76E-06	5.45E-06
17	**Rb-88**	17.8m B-		**1.16E-06**	**1.15E-06**	1.11E-06	1.07E-06	1.05E-06	**1.04E-06**	**5.28E-07**
18	**Rb-89**	15.2m B-		2.99E-06	2.28E-06	2.10E-06	2.02E-06	1.89E-06	**1.31E-06**	1.03E-06
19	**Sr-89**	50.5d B-		1.87E-04	1.87E-04	1.66E-04	1.49E-04	1.36E-04	1.34E-04	6.04E-05
20	**Sr-90**	29.12y B-		7.20E-03	7.20E-03	6.65E-03	5.77E-03	5.67E-03	5.36E-03	2.23E-03
21	Y-90	64.0h B-		2.37E-04	2.37E-04	2.22E-04	2.07E-04	2.06E-04	1.89E-04	7.88E-05
22	**Sr-91**	9.5h B-	**Y-91m**	3.16E-05	3.16E-05	3.05E-05	2.61E-05	2.42E-05	2.38E-05	1.08E-05
23	Y-91	58.51d B-		1.25E-03	1.25E-03	1.24E-03	1.13E-03	1.06E-03	1.05E-03	**4.69E-04**
24	Y-91m*	49.71m IT		2.62E-06	2.46E-06	2.19E-06	2.02E-06	1.86E-06	1.68E-06	1.01E-06
25	**Sr-92**	2.71h B-		2.41E-05	2.36E-05	2.17E-05	2.04E-05	1.88E-05	1.68E-05	8.41E-06

Table G-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2002 DWDD Calculated with MACCS2 at the 2.95-3.05 km Range for the 3000m Exclusion Area Boundary (Continued)

Nuclide Information for 1 Ci Release Activity				95th Quantile of TEDE (rem/Ci) for Release Facility & Height						
No.	Nuclide	Half-Life & Decay Type	Other Nuclides Included in Dose	Ground 0.0 m **	GIF Vents 4.3 m **	SPRF 10.0 m **	ACRRF 14.3 m **	AHCF Stack 16.4 m **	GIF Stack 18.0 m **	HCF Stack 38.1 m **
26	**Y-92**	3.54h B-		2.12E-05	2.12E-05	2.04E-05	1.67E-05	1.51E-05	1.50E-05	7.04E-06
27	**Y-93**	10.1h B-		6.05E-05	6.05E-05	5.64E-05	5.18E-05	4.77E-05	4.74E-05	2.02E-05
28	**Y-94**	19.1m B-		2.12E-06	2.09E-06	2.01E-06	1.23E-06	1.15E-06	1.14E-06	7.54E-07
29	**Y-95**	10.7m B-		8.02E-07	7.69E-07	7.04E-07	5.86E-07	5.35E-07	5.15E-07	**3.12E-07**
30	**Zr-95**	63.98d B-		4.72E-04	4.72E-04	4.22E-04	3.87E-04	3.58E-04	3.41E-04	1.38E-04
31	**Nb-95**	35.15d B-		1.65E-04	1.65E-04	1.49E-04	1.34E-04	1.26E-04	1.24E-04	5.59E-05
32	**Nb-95m**	86.6h IT		7.20E-05	7.20E-05	6.70E-05	6.08E-05	5.67E-05	5.36E-05	2.31E-05
33	**Nb-96**	23.35h B-		7.69E-05	7.52E-05	7.20E-05	6.64E-05	6.09E-05	5.68E-05	2.58E-05
34	**Zr-97**	16.90h B-	**Nb-97 & m**	1.13E-04	1.12E-04	1.06E-04	1.02E-04	9.60E-05	9.51E-05	3.84E-05
35	**Nb-97***	72.1m B-		3.94E-06	3.69E-06	3.31E-06	3.11E-06	3.02E-06	2.83E-06	1.26E-06
36	**Nb-97m***	60s IT		5.75E-08	5.48E-08	5.14E-08	4.28E-08	3.74E-08	3.55E-08	2.08E-08
37	**Mo-99**	66.0h B-		1.06E-04	1.06E-04	1.04E-04	9.61E-05	9.56E-05	8.75E-05	3.64E-05
38	**Tc-99m**	6.02h IT		1.16E-06	1.16E-06	1.06E-06	1.02E-06	9.60E-07	9.55E-07	4.97E-07
39	**Mo-101**	14.62m B-		**2.13E-06**	2.10E-06	2.02E-06	**1.28E-06**	**1.23E-06**	**1.19E-06**	**7.83E-07**
40	**Tc-101**	14.2m B-		3.38E-07	3.31E-07	3.20E-07	3.08E-07	3.02E-07	2.79E-07	1.34E-07
41	**Ru-103**	39.28d B-	**Rh-103m**	2.60E-04	2.56E-04	2.37E-04	2.22E-04	2.13E-04	2.07E-04	8.53E-05
42	**Rh-103m***	56.12m IT		8.81E-08	8.35E-08	7.90E-08	7.22E-08	7.11E-08	7.03E-08	2.74E-08
43	**Tc-104**	18.2m B-		**3.17E-06**	**3.14E-06**	3.01E-06	2.16E-06	2.11E-06	2.08E-06	**1.15E-06**
44	**Ru-105**	4.44h B-		1.49E-05	1.36E-05	1.27E-05	1.16E-05	1.14E-05	1.08E-05	5.49E-06
45	**Rh-105**	35.36h B-		2.85E-05	2.84E-05	2.56E-05	2.37E-05	2.22E-05	2.13E-05	9.23E-06
46	**Ru-106**	4.44h B-	**Rh-106**	1.25E-02	1.25E-02	1.14E-02	1.13E-02	1.06E-02	1.05E-02	4.59E-03
47	**Rh-106***	29.9s B-		**2.54E-11**	**2.32E-11**	**2.32E-11**	**2.13E-11**	**2.13E-11**	**2.11E-11**	**1.54E-11**
48	**Pd-109**	13.427h B-		3.08E-05	3.08E-05	2.86E-05	2.60E-05	2.41E-05	2.37E-05	1.01E-05
49	**Ag-109m**	39.6s IT		**3.11E-12**	**3.11E-12**	**2.96E-12**	**2.80E-12**	**2.80E-12**	**2.76E-12**	**1.97E-12**
50	**Ag-111**	7.45d B-		1.66E-04	1.66E-04	1.50E-04	1.35E-04	1.27E-04	1.26E-04	5.92E-05
51	**Ag-112**	3.12h B-		2.04E-05	2.03E-05	1.66E-05	1.49E-05	1.37E-05	1.36E-05	7.03E-06

Table G-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2002 DWDD Calculated with MACCS2 at the 2.95-3.05 km Range for the 3000m Exclusion Area Boundary (Continued)

Nuclide Information for 1 Ci Release Activity				95th Quantile of TEDE (rem/Ci) for Release Facility & Height						
No.	Nuclide	Half-Life & Decay Type	Other Nuclides Included in Dose	Ground 0.0 m **	GIF Vents 4.3 m **	SPRF 10.0 m **	ACRRF 14.3 m **	AHCF Stack 16.4 m **	GIF Stack 18.0 m **	HCF Stack 38.1 m **
52	**Cd-115**	53.46h B-		1.13E-04	1.13E-04	1.06E-04	1.04E-04	1.02E-04	9.57E-05	3.84E-05
53	**Cd-115m**	44.6d B-		1.14E-03	1.13E-03	1.06E-03	1.05E-03	1.02E-03	9.63E-04	3.84E-04
54	**In-115m**	4.486h ITB-		3.88E-06	3.83E-06	3.45E-06	3.22E-06	3.15E-06	3.05E-06	1.23E-06
55	**Sn-119m**	293.0d IT		1.66E-04	1.66E-04	1.50E-04	1.36E-04	1.34E-04	1.26E-04	6.02E-05
56	**Sn-121**	27.06h B-		1.33E-05	1.33E-05	1.24E-05	1.14E-05	1.08E-05	1.06E-05	4.72E-06
57	**Sn-123**	129.2d B-		9.53E-04	9.51E-04	8.72E-04	7.99E-04	7.53E-04	7.29E-04	3.04E-04
58	**Sn-125**	9.64d B-		4.29E-04	4.27E-04	3.92E-04	3.58E-04	3.51E-04	3.34E-04	1.35E-04
59	**Sb-125**	2.77y B-		6.64E-05	6.15E-05	5.77E-05	5.36E-05	5.20E-05	5.15E-05	2.14E-05
60	**Te-125m**	58d IT		2.13E-04	2.13E-04	2.07E-04	1.67E-04	1.66E-04	1.50E-04	7.06E-05
61	**Sb-126**	12.4d B-		1.35E-04	1.33E-04	1.26E-04	1.14E-04	1.13E-04	1.06E-04	5.10E-05
62	**I-126**	13.02d ECB+B-		1.14E-03	1.14E-03	1.13E-03	1.05E-03	1.02E-03	1.02E-03	4.20E-04
63	**Sb-127**	3.85d B-		7.50E-05	7.27E-05	6.72E-05	6.16E-05	5.78E-05	5.67E-05	2.35E-05
64	**Te-127**	9.35h B-		8.69E-06	8.69E-06	8.13E-06	7.51E-06	7.20E-06	7.20E-06	2.84E-06
65	**Te-127m**	109d ITB-		6.15E-04	6.08E-04	5.66E-04	5.36E-04	5.19E-04	4.79E-04	2.03E-04
66	**Xe-127**	36.41d EC		1.25E-06	1.15E-06	1.05E-06	9.68E-07	8.83E-07	8.20E-07	5.47E-07
67	**Sn-128**	59.1m B-		1.09E-05	1.07E-05	1.04E-05	9.46E-06	8.74E-06	8.19E-06	4.81E-06
68	**Sb-128m**	10.4m B-		1.04E-06	**1.04E-06**	1.01E-06	9.67E-07	9.15E-07	8.85E-07	**5.57E-07**
69	**Sb-129**	4.32h B-		2.27E-05	2.22E-05	2.13E-05	1.88E-05	1.68E-05	1.67E-05	7.99E-06
70	**Te-129***	69.6m B-		1.62E-06	1.62E-06	1.36E-06	1.20E-06	1.12E-06	1.11E-06	5.70E-07
71	**Te-129m**	33.6d ITB-	**Te-129**	7.20E-04	7.20E-04	6.65E-04	5.77E-04	5.67E-04	5.36E-04	2.23E-04
72	**I-129**	1.57E7y B-		5.18E-03	5.13E-03	4.73E-03	4.23E-03	3.88E-03	3.59E-03	1.49E-03
73	**Xe-129m**	8.0d IT		1.06E-07	1.05E-07	9.65E-08	8.12E-08	7.64E-08	7.33E-08	4.52E-08
74	**Sb-130**	40m B-		1.05E-05	1.04E-05	8.84E-06	7.29E-06	7.17E-06	7.08E-06	3.51E-06
75	**I-130**	12.36h B-		8.58E-05	8.13E-05	7.69E-05	7.20E-05	6.71E-05	6.18E-05	**2.84E-05**
76	**Sb-131**	23m B-		1.03E-05	1.02E-05	9.36E-06	7.90E-06	7.37E-06	7.17E-06	3.24E-06
77	**Te-131***	25.0m B-		7.17E-06	7.13E-06	6.60E-06	5.42E-06	5.22E-06	5.18E-06	2.13E-06

Table G-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2002 DWDD Calculated with MACCS2 at the 2.95-3.05 km Range for the 3000m Exclusion Area Boundary (Continued)

Nuclide Information for 1 Ci Release Activity				95th Quantile of TEDE (rem/Ci) for Release Facility & Height						
No.	Nuclide	Half-Life & Decay Type	Other Nuclides Included in Dose	Ground 0.0 m **	GIF Vents 4.3 m **	SPRF 10.0 m **	ACRRF 14.3 m **	AHCF Stack 16.4 m **	GIF Stack 18.0 m **	HCF Stack 38.1 m **
78	**Te-131m**	30h ITB-	**Te-131**	2.07E-04	1.88E-04	1.67E-04	1.50E-04	1.50E-04	1.36E-04	**6.61E-05**
79	**I-131**	8.04d B-		9.56E-04	9.53E-04	8.72E-04	7.99E-04	7.53E-04	7.53E-04	3.18E-04
80	**Xe-131m**	11.9d IT		3.96E-08	3.91E-08	3.37E-08	2.95E-08	2.67E-08	2.49E-08	1.58E-08
81	**Te-132**	78.2h B-		2.85E-04	2.84E-04	2.57E-04	2.37E-04	2.22E-04	2.13E-04	9.23E-05
82	**I-132**	2.30h B-		2.02E-05	1.85E-05	1.51E-05	1.30E-05	1.19E-05	1.17E-05	7.18E-06
83	**Te-133**	12.45m B-		2.40E-06	2.33E-06	2.20E-06	2.06E-06	2.02E-06	1.65E-06	8.17E-07
84	**Te-133m**	55.4m ITB-		1.84E-05	1.65E-05	1.50E-05	1.29E-05	1.19E-05	1.11E-05	6.82E-06
85	**I-133**	20.8h B-		1.64E-04	1.49E-04	1.36E-04	1.27E-04	1.26E-04	1.16E-04	5.58E-05
86	**Xe-133**	5.245d B-		1.52E-07	1.51E-07	1.26E-07	1.08E-07	1.06E-07	1.03E-07	7.00E-08
87	**Xe-133m**	2.188d IT		1.35E-07	1.27E-07	1.14E-07	1.03E-07	9.83E-08	9.06E-08	5.82E-08
88	**Te-134**	41.8m B-		9.47E-06	8.70E-06	7.95E-06	7.19E-06	6.70E-06	6.20E-06	3.42E-06
89	**I-134**	52.6m B-		1.06E-05	1.04E-05	9.42E-06	7.72E-06	7.22E-06	7.16E-06	3.85E-06
90	**Cs-134**	2.062y ECB-		1.24E-03	1.24E-03	1.14E-03	1.06E-03	1.05E-03	1.02E-03	4.25E-04
91	**I-135**	6.61h B-	**Xe-135**	3.95E-05	3.91E-05	3.57E-05	3.34E-05	3.16E-05	3.16E-05	1.34E-05
92	**Xe-135**	9.09h B-		1.15E-06	1.08E-06	1.02E-06	8.76E-07	8.14E-07	7.63E-07	4.99E-07
93	**Xe-135m***	15.29m ITB-		5.09E-07	5.02E-07	3.32E-07	3.18E-07	3.10E-07	3.06E-07	2.03E-07
94	**Cs-135**	2.3E6y B-		1.24E-04	1.24E-04	1.13E-04	1.06E-04	1.05E-04	1.02E-04	4.22E-05
95	**Cs-135m**	53m IT		5.59E-06	5.24E-06	4.64E-06	3.60E-06	3.24E-06	3.19E-06	2.09E-06
96	**Cs-136**	13.1d B-		2.22E-04	2.17E-04	2.07E-04	1.89E-04	1.68E-04	1.67E-04	7.44E-05
97	**Cs-137**	30.0y B-	**Ba-137m**	9.51E-04	9.51E-04	8.61E-04	7.98E-04	7.53E-04	7.29E-04	3.04E-04
98	**Ba-137m***	2.552m IT		**3.25E-08**	**3.23E-08**	**3.19E-08**	**3.15E-08**	**3.13E-08**	**3.12E-08**	**2.12E-08**
99	**Xe-138**	14.17m B-		5.01E-06	4.22E-06	3.23E-06	3.14E-06	3.07E-06	3.04E-06	1.71E-06
100	**Cs-138**	32.2m B-		7.21E-06	7.16E-06	5.26E-06	5.14E-06	5.09E-06	5.01E-06	3.01E-06
101	**Ba-139**	82.7m B-		3.55E-06	3.51E-06	3.28E-06	3.11E-06	3.08E-06	3.03E-06	1.12E-06
102	**Ba-140**	12.74d B-		1.06E-04	1.05E-04	1.02E-04	9.56E-05	8.76E-05	8.63E-05	3.52E-05
103	**La-140**	40.272h B-		1.35E-04	1.35E-04	1.26E-04	1.14E-04	1.13E-04	1.06E-04	5.10E-05

Table G-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2002 DWDD Calculated with MACCS2 at the 2.95-3.05 km Range for the 3000m Exclusion Area Boundary (Continued)

Nuclide Information for 1 Ci Release Activity				95[th] Quantile of TEDE (rem/Ci) for Release Facility & Height						
No.	Nuclide	Half-Life & Decay Type	Other Nuclides Included in Dose	Ground 0.0 m **	GIF Vents 4.3 m **	SPRF 10.0 m **	ACRRF 14.3 m **	AHCF Stack 16.4 m **	GIF Stack 18.0 m **	HCF Stack 38.1 m **
104	**Ba-141**	18.27m B-		2.49E-06	2.32E-06	2.13E-06	2.09E-06	2.04E-06	1.82E-06	9.54E-07
105	**La-141**	3.93h B-		1.36E-05	1.34E-05	1.26E-05	1.16E-05	1.09E-05	1.08E-05	5.02E-06
106	**Ce-141**	32.501d B-		2.60E-04	2.56E-04	2.37E-04	2.17E-04	2.13E-04	2.07E-04	8.53E-05
107	**Ba-142**	10.6m B-		2.39E-06	2.30E-06	2.08E-06	1.85E-06	1.53E-06	1.35E-06	9.60E-07
108	**La-142**	92.5m B-		1.49E-05	1.37E-05	1.19E-05	1.09E-05	1.06E-05	1.05E-05	6.25E-06
109	**La-143**	14.23m B-		1.03E-06	1.01E-06	8.96E-07	8.07E-07	7.76E-07	7.40E-07	3.20E-07
110	**Ce-143**	33.0h B-		1.02E-04	9.58E-05	8.83E-05	8.15E-05	7.99E-05	7.53E-05	3.21E-05
111	**Pr-143**	13.56d B-		2.37E-04	2.23E-04	2.17E-04	2.07E-04	1.89E-04	1.68E-04	7.69E-05
112	**Ce-144**	284.3d B-	**Pr-144 & m**	1.04E-02	1.04E-02	1.02E-02	9.54E-03	8.74E-03	8.16E-03	3.51E-03
113	**Pr-144***	17.28m B-		3.25E-07	3.22E-07	3.16E-07	3.07E-07	**3.04E-07**	**2.82E-07**	1.11E-07
114	**Pr-144m***	7.2m ITB-		**2.10E-07**	**2.08E-07**	**2.02E-07**	**1.24E-07**	**1.22E-07**	**1.20E-07**	**7.11E-08**
115	**Pr-145**	5.98h B-		1.85E-05	1.66E-05	1.50E-05	1.36E-05	1.34E-05	1.27E-05	6.00E-06
116	**Pr-147**	13.6m B-		1.04E-06	1.03E-06	9.97E-07	7.39E-07	7.26E-07	7.13E-07	3.58E-07
117	**Nd-147**	10.98d B-		2.07E-04	2.07E-04	1.87E-04	1.50E-04	1.50E-04	1.36E-04	**6.62E-05**
118	**Pm-147**	2.6234y B-		1.06E-03	1.06E-03	1.04E-03	9.61E-04	9.55E-04	8.75E-04	3.53E-04
119	**Pm-148**	5.37d B-		3.16E-04	3.16E-04	3.08E-04	2.61E-04	2.57E-04	2.38E-04	1.05E-04
120	**Pm-148m**	41.3d B-IT		6.68E-04	6.68E-04	6.08E-04	5.66E-04	5.36E-04	5.20E-04	2.17E-04
121	**Nd-149**	1.73h B-		7.36E-06	7.17E-06	6.66E-06	5.75E-06	5.45E-06	5.33E-06	2.35E-06
122	**Pm-149**	53.08h B-		8.58E-05	8.14E-05	7.69E-05	7.21E-05	6.72E-05	6.71E-05	**2.83E-05**
123	**Nd-151**	12.44m B-		1.06E-06	1.05E-06	1.03E-06	7.36E-07	7.34E-07	7.34E-07	**3.61E-07**
124	**Pm-151**	28.40h B-		5.18E-05	5.18E-05	4.75E-05	4.27E-05	3.92E-05	3.87E-05	1.65E-05
125	**Sm-151**	90y B-		8.71E-04	8.59E-04	7.98E-04	7.53E-04	7.22E-04	6.73E-04	2.84E-04
126	**Sm-153**	46.7h B-		5.65E-05	5.65E-05	5.34E-05	4.76E-05	4.72E-05	4.29E-05	**1.87E-05**
127	**Eu-155**	4.96y B-		1.13E-03	1.13E-03	1.06E-03	1.02E-03	9.62E-04	9.56E-04	3.78E-04
128	**Eu-156**	15.19d B-		3.91E-04	3.91E-04	3.58E-04	3.41E-04	3.34E-04	3.17E-04	1.22E-04

Table G-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2002 DWDD Calculated with MACCS2 at the 2.95-3.05 km Range for the 3000m Exclusion Area Boundary (Continued)

Nuclide Information for 1 Ci Release Activity				95th Quantile of TEDE (rem/Ci) for Release Facility & Height						
No.	**Nuclide**	**Half-Life & Decay Type**	**Other Nuclides Included in Dose**	**Ground 0.0 m ****	**GIF Vents 4.3 m ****	**SPRF 10.0 m ****	**ACRRF 14.3 m ****	**AHCF Stack 16.4 m ****	**GIF Stack 18.0 m ****	**HCF Stack 38.1 m ****
	Actinides & Daughters									
129	**Th-230**	7.7E4y A		7.51E+00	7.51E+00	7.20E+00	6.66E+00	6.09E+00	5.68E+00	2.40E+00
130	**Th-231**	25.52h B-		2.41E-05	2.41E-05	2.23E-05	2.13E-05	2.07E-05	1.89E-05	7.96E-06
131	**Th-234**	24.10d B-		1.02E-03	1.02E-03	9.55E-04	8.62E-04	8.00E-04	7.99E-04	3.27E-04
132	**U-234**	2.445E5y A		3.58E+00	3.57E+00	3.40E+00	3.25E+00	3.09E+00	3.09E+00	1.20E+00
133	**U-235**	703.8E6y A		3.40E+00	3.40E+00	3.25E+00	3.08E+00	2.88E+00	2.86E+00	1.10E+00
134	**U-236**	2.3415E7y A		3.51E+00	3.51E+00	3.34E+00	3.08E+00	3.08E+00	2.87E+00	1.11E+00
135	**U-237**	6.75d B-		1.02E-04	1.02E-04	9.55E-05	8.73E-05	8.15E-05	8.00E-05	3.28E-05
136	**U-238**	4.468E9y SFA		3.33E+00	3.33E+00	3.16E+00	2.88E+00	2.86E+00	2.61E+00	1.08E+00
137	**U-239**	23.54m B-		7.83E-07	7.66E-07	7.21E-07	6.67E-07	6.23E-07	5.85E-07	2.55E-07
138	**Np-237**	2.14E6y A		1.48E+01	1.35E+01	1.33E+01	1.24E+01	1.14E+01	1.13E+01	5.10E+00
139	**Np-238**	2.117d B-		1.04E-03	1.04E-03	1.02E-03	8.75E-04	8.62E-04	8.16E-04	3.46E-04
140	**Np-239**	2.355d B-		7.50E-05	7.27E-05	6.70E-05	6.16E-05	5.77E-05	5.67E-05	2.35E-05
141	**Pu-238**	87.74y SFA		8.14E+00	8.13E+00	7.53E+00	7.21E+00	6.73E+00	6.67E+00	**2.82E+00**
142	**Pu-239**	24065y A		8.72E+00	8.72E+00	8.14E+00	7.53E+00	7.29E+00	7.22E+00	3.02E+00
143	**Pu-240**	6537y SFA		8.72E+00	8.72E+00	8.14E+00	7.53E+00	7.29E+00	7.22E+00	3.02E+00
144	**Pu-241**	14.4y A B-		1.33E-01	1.25E-01	1.24E-01	1.13E-01	1.06E-01	1.06E-01	4.70E-02
145	**Pu-242**	3.763E5y A		8.59E+00	8.14E+00	7.98E+00	7.28E+00	7.21E+00	6.72E+00	**2.83E+00**
146	**Am-241**	432.2y A		1.14E+01	1.14E+01	1.13E+01	1.05E+01	1.02E+01	1.02E+01	4.20E+00
147	**Cm-242**	162.8d SFA		5.18E-01	5.13E-01	4.73E-01	4.23E-01	3.88E-01	3.59E-01	1.49E-01
148	**Cm-244**	18.11y SFA		7.27E+00	7.20E+00	6.70E+00	6.08E+00	5.67E+00	5.67E+00	2.31E+00

Table G-1. The 95th Quantile TEDE Dose (rem) for 1 Ci of the Nuclide from the 2002 DWDD Calculated with MACCS2 at the 2.95-3.05 km Range for the 3000m Exclusion Area Boundary (Continued)

Nuclide Information for 1 Ci Release Activity				95th Quantile of TEDE (rem/Ci) for Release Facility & Height						
No.	Nuclide	Half-Life & Decay Type	Other Nuclides Included in Dose	Ground 0.0 m **	GIF Vents 4.3 m **	SPRF 10.0 m **	ACRRF 14.3 m **	AHCF Stack 16.4 m **	GIF Stack 18.0 m **	HCF Stack 38.1 m **
	Activation Products									
149	**P-32**	14.29d B-		1.66E-04	1.65E-04	1.49E-04	1.34E-04	1.26E-04	1.24E-04	5.59E-05
150	**S-35**	87.44d B-		8.71E-06	8.59E-06	7.98E-06	7.53E-06	7.22E-06	6.73E-06	2.84E-06
151	**Cr-51**	27.704d EC		1.02E-05	9.58E-06	8.74E-06	8.15E-06	7.99E-06	7.53E-06	3.18E-06
152	**Mn-56**	2.5785h B-		1.48E-05	1.36E-05	1.26E-05	1.10E-05	1.07E-05	1.06E-05	5.78E-06
153	**Fe-55**	2.7y EC		3.58E-05	3.57E-05	3.50E-05	3.25E-05	3.09E-05	3.09E-05	1.20E-05
154	**Fe-59**	44.529d B-		3.51E-04	3.40E-04	3.34E-04	3.08E-04	2.88E-04	2.87E-04	1.11E-04
155	**Co-58**	70.80d ECB+		3.16E-04	3.16E-04	3.08E-04	2.61E-04	2.57E-04	2.38E-04	1.05E-04
156	**Co-60**	5.271y B-		6.16E-03	6.15E-03	5.76E-03	5.36E-03	5.20E-03	5.15E-03	2.14E-03
157	**Co-60m**	10.47m ITB-		3.08E-08	3.03E-08	2.67E-08	2.39E-08	2.37E-08	2.27E-08	9.92E-09
158	**Ni-59**	7.5E4y EC		2.60E-05	2.60E-05	2.38E-05	2.22E-05	2.13E-05	2.07E-05	8.64E-06
159	**Ni-63**	96y B-		6.69E-05	6.68E-05	6.08E-05	5.66E-05	5.36E-05	5.20E-05	2.17E-05
160	**Ni-65**	2.520h B-		8.07E-06	7.65E-06	7.17E-06	6.63E-06	6.11E-06	5.74E-06	2.77E-06
161	**Xe-125**	17.0h ECB+		1.34E-06	1.26E-06	1.12E-06	1.04E-06	9.87E-07	9.07E-07	5.78E-07
162	**I-125**	60.14d EC		7.20E-04	7.20E-04	6.65E-04	6.08E-04	5.67E-04	5.36E-04	2.29E-04

Note:

* The dose for these isotopes is included with the dose for their parent for the activity corresponding to secular equilibrium. Thus, their activity should be shown as zero when in secular equilibrium with the parent.

** Doses shown in **BOLD** type were more than the dose for that nuclide in the 1994 weather year set of doses. These higher doses were adopted for conservatism for the affected nuclide dose. Weather files for the years 1994-2000 were used for dose calculation and comparison. The 1994 weather year produced the highest dose for almost all of the nuclides in this table.

Note: The half-life and decay mode are shown for each nuclide after its name. The decay modes are the following:

B-	beta-minus (electron)	B+	beta-plus (positron)
IT	internal transition producing gammas	EC	electron capture
A	alpha particle	SF	spontaneous fission

APPENDIX H, QUALITY ASSURANCE DOCUMENTATION FOR THE MACCS2 CODE

Computer Software Control

APPENDIX A

EXISTING SOFTWARE QUALIFICATION FORM
(Please Use Blue or Black Ink)

A. Software Name and/or Type MELCOR Accident Consequence Code System (MACCS)

B. Original Version Number (from supplier) Version 1.12 (MACCS2) QA Level II

C. List User Application Requirements: Used to calculate downwind dose from airborne releases of 1 Ci of many radionuclides to prepare a database (DWDD) of these dose calculations for use in safety analyses for TA-V facilities.

D. Identify User Documentation(Check if available; if not available, please generate and list below-if applicable):

Ref 1 User Instructions
Ref 2 Technical Description
Ref 1 I/O Specifications
Ref 1 I/O Formats
Ref 1 Description of anticipated errors and how the user can respond
Ref 1 Information for obtaining user and maintenance support

List all items of user documentation that were generated: (if applic.)
– Standard input files were used to run MACCS2 for each radionuclide dose calculation. See Ref 3 for 1998/2000 DWDD and Ref 4 for 2002 DWDD

E. [X] SOFTWARE MAY BE USED AS IS (Check if applicable)
(Attach SVVR providing explanation for acceptance)
(contact QA Coordinator for SVVR template)

F. Were test cases or acceptance/performance tests used (besides benchmarking) to validate the software for acceptability?
YES X NO ______ (Attach SVVR, STP (or ATP) which documents test results, reviews, and an explanation why the software is acceptable with the additional testing.)

G. Was a benchmark test used to validate the software for acceptability?
YES ____ NO X
(Attach SVVR containing results, reviews, and explanation)

PL/E Signature [signature] **Date** 1/13/03
****
Reviewed By: Thomas E Vandenbeek 1/14/03
6400 QA Coordinator

References for MACCS2 Existing Software Qualification Form (Appendix A)

Reference 1: (Chanin and Young 1997) D.I. Chanin, and M.L. Young, *Code Manual for MACCS2: Volume 1, User's Guide*, SAND97-0594, Sandia National Laboratories, Albuquerque, NM, March 1997.

Reference 2: (Jow et al. 1990) H-N Jow, J. L. Sprung, J. A. Rollstin, L. T. Ritchie, and D. I. Chanin, *MELCOR Accident Consequence Code System (MACCS), Model Description*, NUREG/CR-4691, SAND86-1562, Vol. 2, Sandia National Laboratories, Albuquerque, NM, February 1990.

Reference 3: (Naegeli 1998) R. E. Naegeli, *Transmittal of MACCS2 Single Isotope Airborne Dose Versus Distance Database*, Memorandum to Distribution, Sandia National Laboratories, Albuquerque, NM, January 9, 1998.

Reference 4: (Naegeli 2002) R. E. Naegeli, *A MACCS2 Single Isotope Downwind Dose Database for Sandia National Laboratories*, Technical Area V, draft report, Sandia National Laboratories, Albuquerque, NM, December 2002.

Computer Software Control

QA REVIEW	YES	NO	COMMENTS (if applic.)
A. User Application Requirements Listed?	X		
B. All User Documentation Submitted...			
• User Instructions?	X		
• Technical Description?	X		
• I/O Specifications?	X		
• I/O Format?	X		
• Description of errors anticipated?	X		
• Info. on User & Maintenance support?	User only		MAINT IS RESP OF CODE AUTHOR
C. SVVR/STP attached showing explanations for acceptance and reviewer(s) signature(s)?	X		

QA Acceptance Signature Thomas E. Vanderbeek **Date** 1/14/2003

ASSIGNED QA VERSION NUMBER SAME AS ORIGINAL

Software Verification and Validation Report
MACCS2 Software on the Dell Optiplex GX1 Computer
Property Number S824741

SECTION I

1.0 Introduction

1.1 Purpose

The purpose of this SVVR is to serve as documentation of software reviews, testing reviews, and as documentation of existing software qualification as applicable.

1.2 Scope

This document details the STP review and conclusions. The SRS review and conclusions and the SDD review and conclusions are not included since this SVVR covers existing software. This SVVR documents the justification for the use of the existing software as is, documents that further testing of the existing software beyond the comparison of outputs from standard problems for new installations is not required, and documents that benchmark testing is not required to justify the acceptance of the existing software. Testing other than benchmarking shall be documented in the STP.

1.3 Definitions, Acronyms, and Abbreviations

The definitions of technical terms and phrases used in this report are given in the Glossary in SVVR Appendix 1. Acronyms and abbreviations also appear in the Glossary.

1.4 References

(Chanin and Young 1997) D.I. Chanin, and M.L. Young, Code Manual for MACCS2: Volume 1, User's Guide, SAND97-0594, Sandia National Laboratories, Albuquerque, NM, March 1997.

(DOE 1994) U.S. Department of Energy (DOE), DOE-STD-3009-94, (Change Notice 2, April 2002), Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses, U.S. Department of Energy, Washington, DC, July 1994.

(Jow et al. 1990) H-N Jow, J. L. Sprung, J. A. Rollstin, L. T. Ritchie, and D. I. Chanin, MELCOR Accident Consequence Code System (MACCS), Model Description, NUREG/CR-4691, SAND86-1562, Vol. 2, Sandia National Laboratories, Albuquerque, NM, February 1990.

(Liscum-Powell 1997) J. Liscum-Powell, "Review of MACCS2 Input Files," Sandia National Laboratories internal memorandum to R. Naegeli, June 18, 1997.

(Naegeli 1998) R. E. Naegeli, Transmittal of MACCS2 Single Isotope Airborne Dose Versus Distance Database, Memorandum to Distribution, Sandia National Laboratories, Albuquerque, NM, January 9, 1998.

(Naegeli 2002) R. E. Naegeli, A MACCS2 Single Isotope Downwind Dose Database for Sandia National Laboratories, Technical Area V, draft report, Sandia National Laboratories, Albuquerque, NM, December 2002.

(NRC 1982) U.S. Nuclear Regulatory Commission (NRC), Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants, Regulatory Guide 1.145, Revision 1 (Reissued February 1983), U.S. Nuclear Regulatory Commission, Washington DC, November 1982.

(Restrepo 2002) L. Restrepo, Letter Report on TA-V MACCS2 Input Files to William T. Mullen, DOE/OKSO, Omicron Safety and Risk Technologies, Albuquerque, NM, October 18, 2002.

1.5 Overview

This SVVR justifies the use of existing software, Melcor Accident Consequence Code System (MACCS) version 1.12 (MACCS2) as is. The test activities described in Section IV were conducted to verify proper operation of the software on this computer. Independent experts reviewed the MACCS2 inputs as described in Section V instead of benchmark testing.

SECTION II

2.0 SRS Review

Not applicable since this SVVR justifies the use of existing software.

SECTION III

3.0 SDD Review

Not applicable since this SVVR justifies the use of existing software.

SECTION IV

4.0 STP Review

A separate STP was not written since this SVVR justifies the use of existing software. Instead, the sample problems provided with the code distribution package were run after code installation using the procedure detailed in the users manual and the outputs were compared to outputs provided in the distribution package. The results of the comparison are discussed below. The quality assurance of this existing externally developed code was not examined in conjunction with the sample problem comparison. Specific inputs for the Downwind Dose Database (DWDD) calculations performed with the MACCS2 code on this computer were not examined as part of this sample problem comparison.

4.1 Participant Names and Responsibilities

Robert E. Naegeli of 06433 will ensure the MACCS2 code is correctly installed on the intended computer, run the 14 sample problems as directed in Appendix B of the users manual (Chanin and Young 1997), and compare the calculated output to the output files provided with the code distribution package.

4.2 STP Review Criteria

The output of the sample problems calculated on the computer used must match the output of the sample problems distributed with the code package. Minor mismatches such as changed dates that the calculation was run are allowable for successful code performance validation.

4.3 Description and Resolution of Issues

The sample problem calculations were performed on December 5, 2002 on the Dell Optiplex GX1 computer with Pentium® III processor running at 550 MHx with property number S824741. The MACCS2 calculations were run in a DOS window of the Microsoft® Windows® 2000 Professional operating system. The comparison of the calculated and distribution output files was done on January 4, 2003 using Microsoft® Word 97 on another computer. The Word Compare Documents function of Track Changes was used to identify changes in the calculated output files from the distribution output files. The outputs for all 14 sample problems were compared. The only differences found by examining the Word output files were different dates for execution. This was an expected difference. The calculated doses were exactly the same for all of the output files. Thus, there were no discrepancies and no issues for resolution in the sample output testing. It is concluded that the MACCS2 code was installed correctly and calculated radionuclide concentrations and doses correctly for the inputs used.

SECTION V

5.0 Existing Software Acceptance

5.1.1 Purpose

The purpose of this SVVR is to document the justification of accepting the existing software as is with additional benchmark testing, or as is with no further testing required.

5.1.2 Scope

The existing software is MELCOR Accident Consequence Code System (MACCS) version 1.12 (MACCS2). The software originated from the Sandia National Laboratories (SNL), Accident Analysis/Consequence Assessment Department that developed version 1.12 and provided this copy as part of the initial release in April 1997. The original distribution was on 3.5-inch floppy disks using compressed archive files (zip files). The software has been installed and used on a series of computers since that time. The software was also obtained on a compact disk with documentation from the SNL department.

The software is currently available for distribution on a compact disk as RSICC CODE PACKAGE CCC-652 from the Radiation Safety Information Computational Center (RSICC), Building 6025, MS 6362, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6362, phone 865-574-6176, URL http://www-rsicc.ornl.gov/rsicc.html.

The scope of the review was comparison of the output of the MACCS2 sample problems run on the current computer with the outputs of the sample problems provided with the code distribution package. The computer used was a Dell Optiplex GX1 computer with Pentium® III processor running at 550 MHz and property number S824741. The MACCS2 calculations were run in a DOS window of the Microsoft® Windows® 2000 Professional operating system. The same comparisons must be run on each new computer where the code is used.

A benchmark is a standard by which something can be measured or judged such as a standard problem or test that serves as a basis for evaluation or comparison (as of computer or software performance). Sometimes appropriate experimental measurements are used as a benchmark and computer software calculations of the measured values under the same set of conditions are compared to it in benchmark testing. The ability of the analyst to model the conditions present is tested along with the calculation algorithms of the software in benchmark testing. The result is often a bias or correction to be applied to further calculations using the same software for similar calculations under similar conditions. Thus, benchmark testing can provide a calibration of the combined modeling and software for calculations of interest.

In cases where no appropriate experimental measurements of the software calculated values are available for direct comparison, confirmation of the correct operation of the software and independent expert reviews of the inputs and other modeling for the calculations of interest may be more valuable to quality assurance than benchmark testing. Independent expert reviews of the standard inputs for the 1998/2000 Downwind Dose Database (DWDD) and the 2002 DWDD MACCS2 calculations were obtained.

5.1.3 Existing Software Review

Robert E. Naegeli of 06433 reviewed the comparison of calculated outputs and distributed outputs for the 14 sample problems provided with the MACCS2 code. The output of the sample problems as calculated on the computer used must match the output of the sample problems distributed with the code package. Minor mismatches such as changed dates that the calculation was run are allowable for successful code performance validation. The only differences found by examining the calculated and distributed output files were different dates for execution. This was an expected difference. The calculated doses were exactly the same for all of the output files. Thus, there were no discrepancies and no issues for resolution in the sample output testing. It is concluded that the MACCS2 code was installed correctly and calculated the radionuclide concentrations and doses correctly.

Robert E. Naegeli of 06433 reviewed the independent expert reviews of the standard inputs for the 1998/2000 DWDD (Liscum-Powell 1997) and the 2002 DWDD MACCS2 calculations (Restrepo 2002) as the calculations of interest for this SVVR. The inputs used for the 1998/2000 DWDD and the 2002 DWDD must be assessed to be sufficient for the intended MACCS2 calculations. The issues raised and suggestions made in the independent expert reviews were either incorporated into the standard inputs or denied as not consistent with the intent of the MACCS2 calculations. Thus, no issues with the independent expert reviews or their implementation were raised in the SVVR existing software review.

5.1.4 Software Acceptance As Is

The MACCS2 software is acceptable for use in 2002 DWDD dose calculation as is and no further software development or input development is needed. The MACCS2 sample problems must be run on each new computer installation of the software and the calculated output files compared to the output files that were distributed with the software to ensure the code is operating correctly. No further benchmark or other testing is required to accept the calculated dose results since correct operation of the code is verified by comparison of sample problem results and since no appropriate experimental measurements of the software calculated values are available for direct comparison. Thus, the appropriateness of the code inputs for the 2002 DWDD was confirmed by independent expert reviews of the inputs.

5.1.5 Software Acceptance After Benchmark Testing

Additional benchmark testing is not appropriate for the MACCS2 software. Appropriate experimental measurements of the airborne dose calculated by MACCS2 are not available. Measurements of airborne transport and the resulting dose from radionuclides in the exhaust plume from a nuclear facility for accidents or normal operations and the associated atmospheric and release conditions are non-existent or highly uncertain. Measurements of the concentration of pollutants downwind from a release point have been made for limited downwind ranges and a wide variety of atmospheric transport conditions. Fits to these empirical measurements exist and are used in the MACCS2 code. The dose resulting from exposure to airborne radionuclides has been calculated and measured with some uncertainty. Those fits and many other inputs are selectable by the user. The results of the calculations vary widely depending on the inputs specified. In this case, confirmation of the correct operation of the software and independent expert reviews of the inputs and other modeling for the calculations of interest are more valuable to quality assurance than benchmark testing.

Confirmation of correct operation of the MACCS2 code is discussed in previous sections. Independent expert reviews of the standard inputs for the 1998/2000 DWDD (Liscum-Powell 1997) and the 2002 DWDD MACCS2 (Restrepo 2002) calculations were obtained to assess whether the MACCS2 inputs were appropriate for safety analysis to establish the safety basis for TA-V nuclear facilities. Both independent expert reviews found that the inputs were appropriate to perform the desired calculations and both reviews suggested changes to improve the calculations.

The changes suggested by the independent reviews were compared against the available documentation of the 1998/2000 DWDD (Naegeli 1998) and the 2002 DWDD (Naegeli 2002) MACCS2 dose calculations to see if the suggested changes had been incorporated into the standard input files for those sets of calculations. Almost all of the suggested changes had been incorporated in the inputs. A few changes that were not incorporated would not impact the calculation of dose or were not consistent with the intent of the MACCS2 calculations. An example of the later type of suggestion that was not incorporated was the (Liscum-Powell 1997) suggestion that the 1998/2000 DWDD MACCS2 calculation inputs be changed from centerline dose to use Type B results of the peak dose on a spatial grid location. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145 (NRC 1982) and later DOE-STD-3009 (DOE 1994) required the 95th percentile of dose at or beyond the site boundary as the dose of interest for safety basis dose estimation and not the peak dose. Thus, no issues from the independent expert reviews or their implementation were raised that would make the inputs for the 1998/2000 DWDD or the 2002 DWDD questionable.

SECTION VII

6.0 Review and Approval of SVVR

PL/E Approval____________________________ **Date** 1/14/03

QA Approval____________________________ **Date** 1/14/2003

SVVR Appendix 1: Glossary

DOE	Department of Energy
DWDD	Downwind Dose Database
MACCS2	MELCOR Accident Consequence Code System, version 1.12
NRC	Nuclear Regulatory Commission
SDD	Software Design Description
SRS	Software Requirements Specification
STP	Software Test Plan
SVVR	Software Verification and Validation Report

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APPENDIX I, INDEPENDENT REVIEW DOCUMENTS FOR THE DWDD STANDARD INPUTS

Sandia National Laboratories
Operated for the U.S. Department of Energy by
Sandia Corporation
LOCKHEED MARTIN
Albuquerque, New Mexico 87185-1175

date: June 18, 1997

to: Robert Naegeli (9361), MS-1141

Jennifer Liscum-Powell

from: Jennifer Liscum-Powell (9364), MS-1175

subject: Review of MACCS2 Input Files

This memo documents the review of MACCS2 ATMOS and EARLY module input files. The objective of the input files is to instruct MACCS2 to calculate the 95th percentile whole body lifetime dose at 3000 m following the release of 1 Ci of a given isotope for standard release heights and building wake effects that are typical of Tech Area V release scenarios.

The ATMOS input file reviewed is entitled singl2_a.inp. All variables are set appropriately to perform the desired calculations.

The EARLY input file reviewed is singl2_e.inp. There is a problem with the evacuation zone data. The desired emergency response scenario is "NO EVACUATION" and the weight fraction applicable to this scenario should be set equal to 1.0 (EZWTFRAC001) which says this scenario applies to 100% of the people. Currently, the variable EZWTFRAC001 is set equal to 0 which means that the emergency scenario is applied to no one and everyone essentially evacuates. While the results obtained will give you the centerline dose at 3000 m, you might also want to try setting MIIPLUME001 equal to 2 (wind-shift with rotation) and obtain TYPE B results which are the peak dose found on a spatial grid. By setting the organ name to L-EDEWBODY you will obtain the peak lifetime dose to the whole body on a given spatial grid (as specified on your TYPEBOUT cards) from all exposure pathways used in EARLY. This may give you a more conservative dose than the centerline dose (TYPE 6 results).

Once the error in the EARLY input file as described above is fixed your MACCS2 calculations should be accurate as long as you continue to use site specific weather data and your release heights, building wake effects and shielding protection factors are representative of the site of interest. The resulting peak dose at 3000 m from a 1 Ci release can be used as a dose conversion factor (DCF) in Sv/Ci at 3000 m. As long as the scenario for a larger activity release is identical to the modeled scenario in the 1 Ci release, the dose at 3000 m would be obtained by multiplying this DCF by the activity of the isotope released (in Ci).

If you have any questions or concerns, please feel free to contact me.

AL F 1325 8(1) (2/91)
United States Government

Department of Energy
National Nuclear Security Administration

Memorandum

Albuquerque Operations Office
Office of Kirtland Site Operations

DATE: OCT 31 2002

REPLY TO ATTN OF: OKSO:NF:emr

SUBJECT: TA-V Nuclear Facilities Dispersion and Consequence Analysis Actions

TO: Tom Blejwas, Director, Nuclear and Risk Technologies, SNL/NM, MS-0736

Earlier this year, concerns were raised questioning the degree of conservatism of atmospheric dispersion assumptions/parameters used in the MACCS2 code (reference: memorandum from M. J. Zamorski to you, dated May 22, 2002). A plan of action was submitted providing completion dates and planned actions to be performed (reference: letter from you to M. J. Zamorski, dated July 15, 2002). Subsequently, discussions were held regarding the performance of a "third party" review to help develop agreed upon levels of conservatism to be used in conducting MACCS2 code airborne dose calculations. This action would extend the completion date for submittal of a SAND report to December, 1, 2002 (reference: letter from yourself to M. J. Zamorski, dated Sept. 5, 2002) that documented the TA-V Nuclear Facilities dispersion and consequence analysis.

A "third party" review has been completed and is attached. The review was conducted by Omicron. The report recommends a few changes to the SNL MACCS2 input files. The changes provide for a conservative and defensible basis for evaluation against the DOE-STD-3009 Appendix A guidance. The results of the review also indicated that the SNL analysis using the more conservative input parameters and Omicron's analysis did not identify any significant differences. OKSO requests that these changes suggested by Omicron be incorporated into the SNL analysis.

Omicron also recommended that for review of documented safety analysis (DSAs), SNL focus on the comprehensiveness of the hazard and accident analysis with emphasis on:

1. Comprehensiveness of scenarios and controls, including selection of bounding accident scenarios
2. Evaluations of source terms for the accident scenarios, and
3. Identification of safety class and safety significant systems, structures, or components and the bases for their selection.

OKSO further requests that these recommendations be addressed as each TA-V DSA is developed and/or revised. These recommendations should also be incorporated into the action for item number 2 of the plan of action referenced above. Additionally, actions for items number 1 and 3 of the plan of action should be completed as agreed. It is requested that as planned actions are completed supporting documentation be provided to OKSO.

If you have any questions, please call Bill Mullen at (505) 845-5025.

Patricia O'Guin
Michael J. Zamorski for
Director

Attachment

Cc w/attachment:
J. Loye, Org. 6430, MS-1145
S. Walker, Org. 6432, MS-1143
D. Coats, Org. 6432, MS-1141
W. Mullen, OKSO
L. Roybal, OKSO
M. Hamilton, OKSO
R. Clement, OKSO
K. Gray, OKSO

October 18, 2002

Mr. William T. Mullen
U.S. Department of Energy
Office of Kirtland Site Operations
Albuquerque, New Mexico 87185

Dear Mr. Mullen:

Recently, I reviewed the dispersion and consequence documentation for the Area 5 DSAs, including Sandia TA-V MACCS2 input files (ATMOS and EARLY) and the output of a SNL MACCS2 run for a 1 Ci release of Pu-239. The input for the cases presented by SNL was reviewed against acceptable values for the site and potential releases. The most bounding case presented by SNL provides a very reasonable conservative evaluation that meets the DOE-STD-3009 Appendix A guidance with respect to dispersion and consequence calculation assumptions.

OMICRON performed a confirmatory MACCS2 calculation for comparison to SNL results. A few changes were made to the SNL MACCS2 input files to provide a conservative and defensible basis for evaluation against the STD guidance. Those changes fit into the following general categories:

- Revised ATMOS input file to preclude entrainment of the plume in a building wake
- Altered meteorological data sampling frequency from 6 hr/day to 24 hr/day to take advantage of every hour of meteorology data in the input file. This results in a more robust, defendable calculation.
- Revised Last Radial Ring fixed meteorological conditions from A-stability, 1 m/s winds to F-stability, 1 m/s winds. This change had no effect on the dose to the MOI but precludes a potential reviewer's comment.
- Performed other minor cleanups of input data to reduce the potential for questions from reviewers. As an example, the dry deposition rate was changed from 1 cm/s to 0 cm/s to conform to the deposition flags already specified as FALSE.

A table containing a description of key MACCS2 input parameters and why specific values were selected is included as an attachment.

2500 louisiana ne, suite 410
albuquerque, nm 87110
tel 505.883.0553
fax 505.883.0588
www.omicronsafetyrisk.com

When comparing the dose-to-source term ratios for a 1 Curie release of Pu-239 provided by SNL and those calculated by OMICRON based on the changes listed above, the following results are presented

Sandia Dose:	7.01 rem/PE-Ci at 3000 m from release point
OMICRON Dose	7.33 rem/PE-Ci at 3000 m from release point

The differences in the results are small enough to be of no concern.

Since the site boundary is defined as a 3000 m radius circle, use of MACCS2 to determine doses to the MOI is acceptable. SNL is fortunate in this case, because MACCS2 is incapable of performing a dose calculation according to the methodology in DOE-STD-3009 Appendix A when the site boundary geometry is not circular.

My recommendation is to focus the review of the DSA on the comprehensiveness of the hazard and accident analysis with emphasis on:

1. Comprehensiveness of scenarios and controls, including selection of bounding accident scenarios,

2. Evaluations of source terms for the accident scenarios, and

3. Identification of SC and SS-SSCs and the bases for their selection.

In conclusion, the dispersion and consequence evaluations performed by SNL are reasonably conservative and meet the DOE-STD-3009 guidance.

Sincerely,

Louis Restrepo, PhD
President

Attachments: Explanation of Review Process for SNL TA-V MACCS2 Calculation
Basis for Parameter Selection,
MACCS2 Output File for OMICRON Confirmatory Calculation

Explanation of Review Process for SNL TA-V MACCS2 Calculation

The following steps were taken in reviewing the SNL TA-V MACCS2 calculation:

- Reviewed draft SNL document, *White Paper on Choosing Conservative MACCS2 Inputs for TA-V Safety Analysis*, dated September 3, 2002. This document describes MACCS2 inputs that impact doses and the requirements that affect the conservative selection of inputs in light of the recommendations specified in Appendix A of DOE-STD-3009.

- Determined that due to the circular geometry of the site boundary, MACCS2 is suitable for use, by itself, in calculating doses to the MOI.

- Reviewed TA-V MACCS2 calculation output file provided by SNL, paying particular attention to input parameters.

- Selected MACCS2 input parameters to be changed in order to provide a more robust and defendable dose calculation.

- Performed additional MACCS2 calculation with revised input parameters and compared results between SNL and OMICRON runs.

Basis for Parameter Selection

The draft SNL document, *White Paper on Choosing Conservative MACCS2 Inputs for TA-V Safety Analysis*, dated September 3, 2002, provided a table showing MACCS2 input parameters specified conservatively to satisfy DOE-STD-3009 recommendations. OMICRON recommended a single change to the input parameters specified in this table that affected the dose results significantly. It was:

- Specify input parameters to preclude entrainment of the plume in a building wake. Plume entrainment causes the doses to the MOI to be lower than without entrainment.

Additional input parameter changes were incorporated into the OMICRON MACCS2 calculation as *good practice* measures. These included:

- Specify selection of 24 hours of meteorological data per day for evaluation. This causes every hour of meteorological data to be evaluated as a separate weather trial for an entire year, 8760 trials in all. The result is a more robust and defendable calculation, even though the dose result will change little.

- Revision of Last Radial Ring fixed meteorological conditions from A-stability, 1 m/s winds to F-stability, 1 m/s winds. This change had no effect on the dose to the MOI but was made for correctness. F-stability is the common stability class associated with 1 m/s winds when specifying fixed weather conditions.

- Set the dry deposition rate to 0 m/s, even though the deposition flags were already specified as FALSE, which automatically stops all deposition irregardless of the value selected for the deposition rate.

The following table contains a description of individual modeling and input parameters for the ATMOS and EARLY modules, along with justification for the values selected. Specification of input such as descriptive headers or comments is not included in the table since it has no effect on the dose results.

Modeling and Input Parameters	**Value used by Sandia**	**Value used by OMICRON**	**Justification of OMICRON Parameter Value**
ATMOS Module			
Radial grid specification	16 radial rings, ranging from 50 m to 20 km. Range of interest for dose to the MOI is annular ring bounded by 2950 m and 3050 m radial distances	16 radial rings, ranging from 50 m to 20 km. Range of interest for dose to the MOI is annular ring bounded by 2950 m and 3050 m radial distances	Minimum distance between radial rings is 100 m. Specification of 2950 m and 3050 m radial distances provides the finest resolution for estimating doses to the MOI at the 3000 m site boundary.
Number of nuclides	140	140	The large number of nuclides defined is left over from a previous analysis. For comparison purposes, only Pu-239 was released. The other 139 nuclides were not released.
Number of pseudostable nuclides	17	17	This specification was left over from a previous analysis. Definition of the pseudostable nuclides did

Modeling and Input Parameters	Value used by Sandia	Value used by OMICRON	Justification of OMICRON Parameter Value
			not affect the dose results for the confirmatory calculation which modeled release of Pu-239, a very long-lived isotope that will not decay appreciably into daughter products during the duration of the release modeled.
Wet depostion Flags	Set to FALSE	Set to FALSE	Conservative assumption. Specification of FALSE flag precludes removal of Pu-239 from the atmosphere due to precipitation defined in the meteorological data input file.
Dry depostion Flags	Set to FALSE	Set to FALSE	Conservative assumption. Specification of FALSE flag precludes removal of Pu-239 from the atmosphere due settling or other mechanisms.
Wet deposition coefficients	Washout coefficient linear factor set to 9.5E-05 and exponential factor set to 0.8	Washout coefficient linear factor set to 0.0 and exponential factor set to 1.0	Conservative assumption, does not allow wet deposition, even if deposition flag is set to TRUE.
Dry deposition velocity	Set to 0.001 m/s	Set to 0.0 m/s	Conservative assumption, does not allow dry deposition, even if deposition flag is set to TRUE.
Plume dispersion parameters	Lookup table using Tadmor and Gur dispersion parameters for 0.5 – 5 km distances.	Lookup table using Tadmor and Gur dispersion parameters for 0.5 – 5 km distances.	Conservative assumption, based on measurements over flat terrain covered with shore grasses.
Sigma-Y linear scaling factor	1.0	1.0	Use original Tadmor and Gur dispersion parameters without scaling as a conservative assumption
Sigma-Z linear scaling factor	1.0 (implies 3 cm average surface roughness length)	1.0 (implies 3 cm average surface roughness length)	Use original Tadmor and Gur dispersion parameters, with conservative implication that the TA-V average surface roughness length is 3 cm (smooth, flat surface)
Plume meander expansion factor time base	600 s	600 s	Conservative assumption when set equal to plume duration in order to suppress plume meander for low speed, stable .wind conditions

Modeling and Input Parameters	Value used by Sandia	Value used by OMICRON	Justification of OMICRON Parameter Value
Plume meander formula break point time	3600 s	3600 s	Specification of this parameter is irrelevant when plume meander expansion factor time base is equal to the plume release duration, 600 s for this analysis.
Plume meander expansion factors	0.2 and 0.25	1.0 and 1.0	Conservatively set to 1.0 in order to suppress plume meander
Critical wind speed scaling factor	1.0	1.0E+06	Set to maximum allowable value to suppress entrainment of a buoyant plume in a building wake
Scaling factors for A-D and E-F stability plume rise formula	1.0 and 1.0	1.0 and 1.0	No scaling of plume rise desired in this calculation.
Building wake effects	Building height = 14.3 m Initial plume σ_y = 9.302 Initial plume σ_z = 6.651	Building height = 1.0 m Initial plume σ_y = 0.1 m Initial plume σ_z = 0.1 m	Conservative assumption, parameters set to minimum allowable values to model point release. This will disperse the plume less initially and will result in higher doses to the MOI.
Plume heat content	0 W	0 W	Conservative assumption, no sensible energy added to plume that would loft the plume above its initial release elevation, resulting in lower doses to the MOI.
Plume release height	14.3 m	14.3 m	Scenario specific parameter used to allow a valid comparison between the two runs
Plume release duration	600 s	600 s	When the plume meander expansion factor time base value matches the plume release duration, plume meander is suppressed. Otherwise, the actual value of the release duration is irrelevant because the dose to the MOI is a time-integrated quantity and does not depend on the duration of the plume release.
Radionuclide released	1 Ci, Pu-239 for comparison purposes	1 Ci, Pu-239 for comparison purposes	Scenario specific parameter used to allow a valid comparison between the two runs
Meteorological sampling option	Stratified random sampling, 6 hrs / day	Stratified random sampling, 24 hrs / day	24 hrs / day sampling results in every hour of an entire year being used. The result is a

Modeling and Input Parameters	Value used by Sandia	Value used by OMICRON	Justification of OMICRON Parameter Value
			more robust, defendable calculation.
Meteorological data	Tower A-36 meteorological data	Tower A-36 meteorological data	Input specific file used to allow a valid comparison between the two runs
Last spatial interval meteorology data	Mixing layer height=2055 m Rain rate = 0.0 mm/hr Wind speed = 1.0 m/s Stability class = A	Mixing layer height=2055 m Rain rate = 0.0 mm/hr Wind speed = 1.0 m/s Stability class = F	All inputs are identical between the two runs except the stability class. Stability class A, unstable conditions, is not normally associated with 1 m/s winds. Stability class F is usually associated with this low wind speed for boundary weather specification. Since the MOI is located well inside the last radial ring where these weather conditions prevail, the different stability class specification doesn't affect the dose to the MOI anyway.
EARLY Module			
Dose conversion factors	FGR 11	FGR 11	Identical DCFs used to allow a valid comparison between the two runs
Population data file	Not used	Not used	Not applicable for dose to MOI, which is independent of actual population disbribution
Dispersion model	Straight line plume	Straight line plume	Same model used to allow a valid comparison between the two runs
Cloud shielding factor	1.0 for all three classes of people	1.0 for all three classes of people	Results in conservative estimate of dose because effect of cloud shielding is zero.
Inhalation protection factor	1.0 for all three classes of people	1.0 for all three classes of people	Results in conservative estimate of dose because effect of inhalation protection factor is zero.
Skin protection factor	1.0 for all three classes of people	1.0 for all three classes of people	Results in conservative estimate of dose because effect of skin protection factor is zero.
Ground shielding factor	1.0 for all three classes of people	1.0 for all three classes of people	Results in conservative estimate of dose because effect of ground shielding factor is zero.
Breathing rate	3.47E-04 m^3/s	3.47E-04 m^3/s	Same value used to allow a valid comparison between the two runs

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APPENDIX J, WINDAT2 CODE DOCUMENTATION

Requirements, Description, Use and Testing for the WINDAT2 Code
By: Robert E. Naegeli, 06433, January 16, 2003

This document provides the requirements, description, use and testing information for the WINDAT2 Fortran computer program. WINDAT2 was written to translate hourly meteorological data for tower A36 from the format provided by the Sandia National Laboratories (SNL) meteorologist to the format read by the MELCOR Accident Consequence Code System, version 1.12 code (MACCS2). One year of hourly weather data is needed by MACCS2 for airborne radioactive material dose calculations. Those doses will be used to analyze hypothetical releases of radionuclides from SNL Technical Area V (TA-V) nuclear facilities as part of the safety analysis effort for each facility's safety basis. Changing safety basis requirements mandated the change from weather data of the Typical Meteorological Year at the Albuquerque, NM airport that was considered typical of all years to yearly weather data measured at a local TA-V weather tower (tower A36). Ed Parma of SNL department 06422 wrote WINDAT2 for Rob Naegeli of department 06433 in July 2002. Regina Deola of 03121 is the meteorologist.

Requirements

There are three basic requirements for the WINDAT2 computer program:

1. Read the weather data from the SNL meteorologist and pick the desired year of data.
2. Convert the meteorological data from SNL meteorologist format to the MACCS2 format.
3. Write a one-year long file of hourly weather data with the converted data to use for the MACCS2 calculations. Some data that are not provided in the meteorologist data file (seasonal morning and evening mixing height) are added manually to make the final file.

<u>The SNL meteorologist weather data</u> came in a comma delimited text file (.csv files) with multiple years of weather data and a header. The format was as follows:

Year(YYYY),month(MM),day(DD),hour(HH),FV(degrees),WSs(m/s),T(K),Stability(1-6), Precip(inches),EPA Guidance Stability(l-6)

The file was converted manually using Microsoft® Excel to a text file to make it easier to use in verifying the output. WINDAT2 can read either format. Examples of the two file formats follow.

<u>.csv</u>

```
Year,Month,Day,Hour,FV,WS,T,Stability,Precip,EPA Stab
1996,1,1,1,67.2,1.18,272.9,6,0,6
1996,1,1,2,174.5,1.73,272.9,4,0,5
1996,1,1,3,345.2,1.24,272.7,5,0,4
1996,1,1,4,215.2,0.97,272.5,5,0,5
```

<u>.txt</u>

Year	Month	Day	Hour	FV	WS	T	Stability	Precip	EPA Stab
1996	1	1	1	67.2	1.18	272.9	6	0	6
1996	1	1	2	174.5	1.73	272.9	4	0	5
1996	1	1	3	345.2	1.24	272.7	5	0	4
1996	1	1	4	215.2	0.97	272.5	5	0	5

Some of the weather data was integer and some was real. The FV direction was the flow direction in degrees (direction the wind was blowing toward) from North. The stability used in the MACCS2 code was the actual measured stability (first stability) not the smoothed or limited variation EPA stability. The stability was calculated using the Pasquill-Gifford Sigma Theta criteria where 1=A...6=F stability class as in the MACCS2 code file.

The MACCS weather file format contains only one year of hourly weather data (8760 hours) in a different format with less of the data than the SNL meteorologist file. That MACCS2 hourly weather format is as follows as taken from Appendix A of the MACCS2 users manual (Chanin and Young 1997):

"There are a total of 8763 records (lines) in the meteorological data file. The first two records contain identification information. Up to 80 characters may be used on each line. This header information is printed on the output listing. If an additional identification record is added at the beginning of the file, CRAC2 meteorological data files may be used with MACCS2. Records 3 through 8762 contain hourly meteorological observations, one hour per line. The hourly meteorological data is input as integers. The format of the information is as follows:

Columns	Format	Variable	Information	Range
2-4	I3	ISTRDY	Julian day of the year	1 to 365
6-7	I2	ISTRHR	Hour of the day	1 to 24
9-10	I2	WINDIR	Direction the wind is blowing toward (N to NNW)	1 to 16
11-13	I3	WINDSPD	Wind speed (10ths of meters per second)	1 to 300*
14	I1	ISTAB	Stability Category (Pasquill A through G)	1 to 7**
15-17	I3	RNMM	Accumulated precipitation (100ths of inches)	-1 to 999***

*Values between 1 and 4 are automatically changed to 5 (0.5 m/s).
**A value of 7 is automatically changed to 6 by the code.
***Some meteorological data files use –1 to indicate a trace of precipitation during the hour. MACCS2 assumes these values to be 0.

The 8763rd record contains a table of eight values of mixing layer height. Two values of mixing heights are supplied for each of the four seasons of the year. The first of these two values corresponds to the morning mixing height and the second to the afternoon height."

The MACCS2 code does extensive error checking on its inputs such as the meteorological file. MACCS2 will terminate its run and write an error message for diagnosis if the input data are in the wrong range or inconsistent with other input data (Chanin and Young 1997). Error checking on the meteorological file will uncover missing data and data out of the allowed range defined by the format above. Error checking requirements are greatly eased for WINDAT2 due to the extensive error checking of MACCS2. Those error-checking requirements consist of setting negative input weather data to zero to identify an error in the source meteorological data easily by inspecting the WINDAT2 output weather file. In addition, MACCS2 rejects zero data in some fields and changes negative precipitation to zero.

Description

WINDAT2 was coded in Fortran 77 and runs in a DOS window on a personal computer. Input data files need to be in the same directory as the executable file and the output goes to the same directory. The executable file name is "WINDAT2.exe" and the Fortran source code file name is "WINDAT2.FOR". Both files are dated 7/31/02. The Fortran source code is listed below in Figure 1 as the basis for this description.

The first 30 lines of the code initialize variables, receive the names of files and the year of weather data to extract from the input weather data file, and read the header of the input weather data file. The name of the input weather data file (SNL meteorologist file) is requested first and then a name for the MACCS2 format output weather data file. WINDAT2 also requests the year of weather data to pull out of the input file. WINDAT2 reads the header line of the input weather data file to move the pointer in the file to the first line of weather data. Nothing is done with the header line information.

The next 43 lines of the code (starting with "10 continue") select the desired year of weather data, write a two line lead in to the new MACCS2 format output file, read the input weather data, convert the weather data from the SNL meteorologist file format to the MACCS2 file format, and write the weather data in a new format to the MACCS2 output file. The code reads through the whole input file but only converts and writes data from the desired year to the output file. A few lines of code that were used in program development are commented out so they are not implemented in the executable file. In addition, weather data with a value less than zero are set to zero to aid in error checking of the output file. Finally, when the code gets to the end of the input weather file, the code branches to the end (11 continue).

The last ten lines of this simple code (starting at "11 continue") write an end of data message to the DOS window, close the input and output files, and stop execution to end the program. The user generally does not see the end of data message since the DOS window closes as soon as the program stops execution.

Figure 1. WINDAT2 Fortran Source Code Listing

```
C
C
C
C  TAKES DATA FROM A36.DAT FILES - A36_5yrFV.TXT
C  TRANFORMS TO A MACCS READABLE FILE (MACCS.DAT)
C
C
      PROGRAM WINDAT2
      IMPLICIT REAL*4(A-H,O-Z)
      DIMENSION armht(2,2,4),aumht(2,2,4)
      CHARACTER*20 a$
      CHARACTER*15 FILEA$,FILEB$
      WRITE(*,*)' '
      WRITE(*,*)'DATA FILE TO TRANSFORM? '
      READ(*,*)FILEA$
      WRITE(*,*)' '
      WRITE(*,*)'NEW MACCS WIND DATA FILE NAME? '
      READ(*,*)FILEB$
```

```
      OPEN(2,FILE=FILEA$,STATUS='OLD')
      OPEN(3,FILE=FILEB$,STATUS='UNKNOWN')
C
      WRITE(*,*)' '
      WRITE(*,*)'YEAR TO PULL OUT? '
      READ(*,*)yenter
C
      j=0
      kday=0
      iprecip=0
      read(2,*)a$
c
   10 continue
c
      READ(2,*,end=11)iyr,imo,ida,ihr,deg,vel,temp,istab,precip,iepastb
c      if(j.eq.20)stop
      if(iyr.ne.yenter)go to 10
c      write(*,*)iyr,imo,ida,ihr,deg,vel,temp,istab,precip,iepastb
      j=j+1
c
      if(j.eq.1)then
       write(3,*)' A36-data - year=',iyr
       write(3,*)'   MACCS2 FORMAT'
      endif
c
      if(deg.lt.0.0)deg=0.0
      if(vel.lt.0.0)vel=0.0
      if(temp.lt.0.0)temp=0.0
      if(istab.lt.0)istab=0
      if(precip.lt.0.0)precip=0.0
      if(iepastb.lt.0)iepastb=0
c
      if(ihr.eq.1)kday=kday+1
      isector=1 + (deg+11.25)/22.5
      if(isector.eq.17)isector=16
      ivel=ifix(10.0*vel)
      dif=vel-ivel/10.0
      if(dif.ge.0.05)ivel=ivel+1
      iprecip=100.0*precip
      dif=precip-iprecip/100.0
      if(dif.ge.0.005)iprecip=iprecip+1
      write(3,112)kday,ihr,isector,ivel,istab,iprecip
  112 format(' ',i3,1x,i2,1x,i2,i3,i1,i3)
c      write(*,*)kday,ihr,isector,ivel,istab,iprecip
c
c
      go to 10
 11   continue
c
c
      write(*,*)'***end of data*** last day=',kday
c
      close(2)
      close(3)
      stop
      end
c
```

Use

To use WINDAT2 to convert multi-year SNL meteorologist format weather files from the A36 tower to the desired single year MACCS2 format weather files, the WINDAT2 code must be executed by the user. The steps in the execution process are listed below:

1. Change the .csv format SNL meteorologist weather files to .txt files by double clicking on the .csv file to open it in Microsoft® Excel. Then save the file as an additional .txt file for easier output checking. WINDAT2 will read and convert either file format.
2. Place the WINDAT2.exe executable file and the multi-year SNL meteorologist format weather file in the same directory.
3. Double click the WINDAT2.exe executable file in Windows Explorer to open it and start program execution in a DOS window. The user may also do a Run command from the Start menu and browse to select the file to start program execution in a DOS window.
4. Enter the information when prompted by WINDAT2 for the three requested items listed in Figure 2 below. The WINDAT2 data request is shown in ordinary font in Figure 2. The user typed response is shown in **bold** font in Figure 2. Enter the name of the SNL meteorologist weather input file and press return for the first prompt. (If the file is not in the same directory as the executable, the program stops execution after entering an output file name.) Enter a name for the MACCS2 format weather output file and press return for the second prompt. (If you enter an existing file name in that directory, WINDAT2 will over write it.) Finally, enter the desired year of weather data to pull out of the SNL meteorologist file and press return for the third prompt. (If the SNL meteorologist input file does not contain that year of weather data, WINDAT2 looks through the whole file for it and ends normal program execution with an empty output file.)
5. After the desired year is entered at the third prompt, the WINDAT2 program quickly writes an output file, completes execution, and closes the DOS window. The user may then add the mixing height information on an additional line at the end of the output weather file to make the final weather file in the MACCS2 format. The mixing height data for the specific year should be provided by the SNL meteorologist or in its absence climatologically typical mixing height values may be used. The user is cautioned to inspect the output file to ensure only 365 days of weather data are present in the file (check the number of the last day). MACCS2 only accepts files with exactly 365, 24-hour days of weather data so the 366th day can be deleted for leap years.

Figure 2. WINDAT2 Program Execution Example

```
 DATA FILE TO TRANSFORM?
A36_5yrFV.txt

 NEW MACCS WIND DATA FILE NAME?
A36-1997.dat

 YEAR TO PULL OUT?
1997
```

Testing

The operation of WINDAT2 was checked during and after the final version was compiled on 7/31/02. The error conditions noted under the Use section above were found through varying the inputs and seeing what it would do. WINDAT2 is a simple program. If it doesn't work right check the information in the Use section to figure out the problem and try it again.

The accuracy of weather data conversion was also verified after 7/31/02 by checking multiple hours of weather data in some of the output files to ensure the conversion was done correctly. The hours checked included samples throughout the range of data for each of the input data types. The .txt version of the SNL meteorologist weather file made comparison easier. Of course the MACCS2 code does complete data range and consistency checks on every hour of every weather input file in every MACCS2 run. MACCS2 confirmed the 110 hours of missing weather data in December of the 1997 weather file by stopping its execution. The SNL meteorologist said that the data were missing when that A36 tower input file was supplied. The MACCS2 format weather file with the data missing was run in MACCS2 to confirm the error checking capability of the MACCS2 code. Subsequently, data from the days just before and just after the missing section were copied to the corresponding hour locations to make the present 1997 weather file that runs correctly in MACCS2. The same corrections were made on both formats of the SNL meteorologist source weather file so subsequent WINDAT2 conversions of the 1997 year provide weather files with no missing weather hours.

The WINDAT2 conversion accuracy may be verified for new weather years through comparison with the SNL meteorologist files by using the following checks.

1. Scroll down through the new MACCS2 weather file to ensure that data for 1 through 24 hours are available for each day by stopping to check columns 2-4 (day) and 6-7 (hour) in several places during the scroll. Also check for missing data, which is easily visible against the moving pattern of numbers in columns during the scroll. The same moving data check can be used to locate missing data in the SNL meteorologist weather file.
2. Check the wind direction in columns 9-10 of the MACCS2 format file to ensure it is within the allowed range for the direction sectors (1-16) and that the correct sector has been assigned from the input wind direction angle for that weather hour from the fifth column of the .txt file. Table 1 below provides the corresponding angle range to MACCS2 direction sector conversion. Each sector is 22.5° wide and North (N) is the center of sector 1 so the range is from 337.5° to 22.5° for sector 1. Check several hours through out the weather file with sectors throughout the range of MACCS2 direction sectors. Care is needed to find the corresponding MACCS2 and SNL meteorologist file weather hours since MACCS2 lists days from 1-365 with the associated hours and the SNL meteorologist convention is year, month, day of the month and hour.
3. Check the wind speed in columns 11-13 of the MACCS2 format file to ensure it is consistent with the wind speed in the sixth column of the .txt file for that weather hour. Note that the MACCS2 wind speed is an integer number of tenths of meters per second (m/s) and the .txt wind speed is a real number in m/s. To do the conversion in your head just multiply the .txt number by ten and round the result to the integer MACCS2 number. The wind direction and wind speed do not have a blank column between so be careful.

4. Check the stability class in column 14 of the MACCS2 format file to ensure it is the same number as the .txt file for that weather hour and within the range of 1-6 as explained in the MACCS2 format information in the Requirements section above. The wind speed and stability class do not have a blank column between them so be careful.
5. Check the precipitation amount in column 15-17 of the MACCS2 format file to ensure it is the same number of hundredths of an inch as in the .txt file. To do the conversion in your head just multiply the real number of the .txt file by 100 to get the integer number for the MACCS2 file.

Table 1. MACCS2 Direction Sector to Flow Vector Angle Correspondence

Compass Direction	MACCS2 Direction Sector	Flow Vector Angle (degrees)
N	1	$348.75 \leq FV \leq 360.0$ $0.0 \leq FV < 11.25$
NNE	2	$11.25 \leq FV < 33.75$
NE	3	$33.75 \leq FV < 56.25$
ENE	4	$56.25 \leq FV < 78.75$
E	5	$78.75 \leq FV < 101.25$
ESE	6	$101.25 \leq FV < 123.75$
SE	7	$123.75 \leq FV < 146.25$
SSE	8	$146.25 \leq FV < 168.75$
S	9	$168.75 \leq FV < 191.25$
SSW	10	$191.25 \leq FV < 213.75$
SW	11	$213.75 \leq FV < 236.25$
WSW	12	$236.25 \leq FV < 258.75$
W	13	$258.75 \leq FV < 281.25$
WNW	14	$281.25 \leq FV < 303.75$
NW	15	$303.75 \leq FV < 326.25$
NNW	16	$326.25 \leq FV < 348.75$

APPENDIX K, SPREADSHEET EXTRACTION AND COMPARISON OF THE 2002 DWDD DOSES

The Microsoft® Excel 2000 commercial spreadsheet program was used for 2002 DWDD dose extraction from MACCS2 output files and for comparing doses to find the highest dose for each nuclide for each release height. This Appendix describes the two types of spreadsheets used for extraction of dose results from MACCS2 output files (input-year files) and for the compilation and comparison of nuclide downwind dose for a release height (DWDD-height files).

Input-Year Files for Dose Extraction

The first spreadsheet file type (input-year files) was essentially a spreadsheet version of the text MACCS2 output file. Five text output files modeled different released nuclides in the MACCS2 calculations for each of seven years of local A36 tower weather data for each release height (35 output files per release height). Each of these text format output files was opened as a spreadsheet in Excel as delimited data type with both tab and space data delimiters. Successive delimiters were treated as one. The result was a spreadsheet (input-year file) that contained all of the output file's information, notably the input echo and calculation following section and the calculated results section. In the calculated results section, the atmospheric modeling parameters and the calculated dose outputs for each nuclide were organized in spreadsheet columns that greatly eased the extraction of downwind dose for each of the 16 distance ranges for each nuclide. Each output file and its associated input-year file could contain doses for up to a maximum of 60 individual nuclides. The 95th percentile of dose column for each nuclide could then be extracted by coping to a compilation spreadsheet file for that release height (DWDD-height file) for later comparison to find the highest dose for each nuclide at that release height.

Each input-year file was saved as a spreadsheet file (.xls extension) in addition to its text output file that was retained. The input-year files were given names to identify the release height, the ATMOS released nuclide input file, and the year of weather data. For example "PSP3a-A36-94.xls" was the name for the SPRF release height (10 m), the "a" ATMOS input file for the first 60 fission product nuclides, and the 1994 weather year. For comparison, the corresponding MACCS2 text output file was named simply "TEMP1.OUT". All of the files for each release height were kept in a separate subdirectory on the processing computer's hard drive for positive organization and identification of the input and output files.

No data scaling or alteration of the dose data columns was done in the process of dose extraction from the input-year files to the associated DWDD-height file for the 2002 DWDD except for transposition of the dose data from a column to a row format. The dose versus distance column of the input-year file became a row in the DWDD-height file. Copying and transposition were accomplished manually using the Paste Special function of Excel for some of the initial weather years in the first two release heights analyzed. The process was later automated through the use of formulas in a separate sheet of the input-year spreadsheet workbook file for the last years and the other release heights.

The later input-year spreadsheet workbook files that automated dose value extraction were composed of three sheets. The first sheet contained the image of the MACCS2 output file that had been opened in Excel as described previously and copied to a special input-year file template. The template was developed to make the first input-year file with automated dose extraction. Copying over the previous file and saving as another name made subsequent input-year files. The first sheet in the workbook was named Temp# to indicate that it was the spreadsheet image of the MACCS2 output file. The second sheet (named Sheet1) contained only the dose output section of the first sheet. The atmospheric parameter section of the output and each of the up to 60 nuclide dose output sections start with the text "DATE" in the second column of the first row. Thus, "DATE" could be searched and found easily by Excel. The second instance of "DATE" was the start of the copied dose output data for the second sheet that included the rest of the Temp# sheet.

The third sheet in the input-year automated dose extraction workbook (named Sheet2) contains formulas that copy the dose data from Sheet1 based on the relative row and column location of the data in the output data section for each nuclide. Each nuclide dose output section has 141 rows to contain the dose output from the EARLY and CHRONC modules of MACCS2. CHRONC was not used in the 1998/2000 DWDD and 2002 DWDD calculations so that space in the output was all Xs. The first column in the row for each nuclide in Sheet2 is the nuclide name from column H of row 6 in each nuclide output section in Sheet1. The subsequent columns in the row for each nuclide in Sheet2 are column K of rows 15 through 30 of each nuclide output section in Sheet1. Succeeding nuclide rows in Sheet2 were made by copying the preceding row and increasing the row number of the formula in each cell of the new row by 141 from the previous row of Sheet2. Sheet2 contains 60 rows for nuclide name and doses with the 16 distance ranges so it can accommodate the largest number of nuclides in a MACCS2 output. Three of the five outputs for each weather year contained less than 60 nuclides so some of the rows in Sheet2 were zeros for many of the input-year files. Once the Sheet2 nuclide name and dose rows were populated, the data were copied to the appropriate DWDD-height file by manually copying with the Paste Special function of Excel (specifying Values).

The process for making the new input-year automated dose extraction workbook for each MACCS2 output TEMP#.OUT file was as follows.

1. Open the appropriate TEMP#.OUT file as a spreadsheet of delimited data type with both tab and space data delimiters. Check that the source strength (3.70×10^{12}), X/Q material concentration, and Pu-239 dose at 3.0 km was consistent with the values for that release height and weather year that had been calculated previously. This check verified that the calculation was the one expected so that the doses could be extracted to the correct DWDD-height file later.
2. Copy the entire TEMP#.OUT spreadsheet over the entire Temp# sheet of the old input-year automated dose extraction workbook and save the workbook as a new file name to match the data in the TEMP#.OUT file. File names are described above. The entire old Temp# sheet information may be deleted before copying the new information to the Temp# sheet if desired. The TEMP#.OUT file can then be closed as it is no longer needed.

3. Search on "DATE" and stop on the second instance. Verify that the search stopped at dose output section for Pu-239 (the first nuclide in every MACCS2 dose calculation of the 2002 DWDD). If the search did not stop in the Pu-239 output section, return the cursor to the start of the file and search again until the Pu-239 section is found. Then highlight the dose output sections starting with the first column of the row with "DATE" in it through the end of all data in the Temp# sheet. Copy the highlighted dose output sections to fill the entire Sheet1. All of the old information in Sheet1 may be deleted before copying the new if desired to ensure no old data is retained in Sheet1.
4. Verify that Sheet2 now displays the nuclide name and doses for the 16 downwind distances in each row for the expected group of released nuclides. Save the new input-year automated dose extraction workbook in its completed form. If the nuclide name and the associated doses are not displayed in the rows of Sheet2, examine Sheet1 and verify that the entire first dose output section has been copied as described above. If more or fewer rows or fewer columns of the output data have been copied to Sheet1, the formula values in Sheet2 will not copy the correct information. If the correct information has not been copied to Sheet1, return to the Temp# sheet and copy the correct information as described above to Sheet1. Then verify that the Sheet2 nuclide name and doses are as expected. Save the new input-year automated dose extraction workbook.

Correct operation of the Sheet2 formulas in the design of the input-year automated dose extraction workbook file was verified with a special test output file in the Temp# sheet. An ATMOS "a" nuclide inventory file was copied to the Temp# sheet as described above as a starting point for the test output file. Then, the nuclide name in the dose output sections was changed to TN-1 through TN-60 for the 60 nuclides in the output file. The new nuclide name verifies that only the correct row and column of Sheet1 are copied by the formulas of Sheet2 for each nuclide output row. Next, columns J, K and L of rows 15 through 31 of each nuclide output section in the Temp# sheet were modified so the K rows contained the numbers 1 through 16 for rows 15 through 30 and zero for row 31. The column J and L rows 15 through 31 of each nuclide output were modified so that rows 15 through 30 contained zero and row 31 contained 17. Thus, if the dose output sections of Temp# were not copied correctly to Sheet1, the data would fail to line up and the data would change in a predictable manner. If the dose outputs sections were copied correctly, then TN-# followed by the numbers 1 through 16 would appear on the nuclide rows of Sheet2.

The test input-year automated dose extraction workbook file was used to verify that the correct data were displayed in Sheet2 when the test dose output sections were copied correctly to Sheet1 and to verify that the correct data were not displayed in Sheet2 if the test dose output sections were not copied correctly to Sheet1. The only way to display the correct nuclide name and the numbers 1 through 16 in the nuclide rows of Sheet2 was to copy the test output sections correctly to Sheet1. Otherwise, the nuclide names (TN-1 through 60) were never displayed in Sheet2. The test dose numbers 1 through 16 were also not displayed in the correct column unless the test output sections were copied correctly to Sheet1. Thus, the input-year automated dose extraction workbook file provides a built in error detection feature to preclude extracting erroneous dose data from the MACCS2 output files.

DWDD-Height Files for Compilation and Comparison of Nuclide Dose

A spreadsheet workbook file (DWDD-height files) was used for compilation and comparison of nuclide downwind dose for each release height. Thus, there are seven DWDD-height files for the seven release heights in the 2002 DWDD. Each DWDD-height file had a sheet corresponding to a particular weather year file for compilation of the downwind dose (all 16 distance range doses) for all 162 nuclides in the 2002 DWDD that were calculated using that weather year file. Thus, each DWDD-height workbook file had seven sheets of nuclide dose data for the seven years (1994-2000) of weather data files. Each DWDD-height workbook file also had an eighth sheet for comparison of nuclide dose at the 3000 m exclusion area boundary distance from all of the weather year sheets so that the maximum dose for a given nuclide could be selected from the seven candidates that were provided from the seven weather year sheets of downwind doses.

This laborious process of calculating the downwind doses for all 162 nuclides seven times for the different weather years and then comparing the seven doses at 3000 m for each nuclide was undertaken solely to ensure that the most conservative 95th percentile dose (highest dose) was selected for each nuclide at that release height. The 1994 weather file produced the highest doses at 3000 m for the vast majority of nuclides at all of the release heights but the MACCS2 calculations were repeated for the other six weather year files to find the few cases when the calculated dose was slightly higher than the 1994 weather dose.

Each weather year sheet of compiled nuclide dose had 162 rows, one for each of the 162 nuclides in the 2002 DWDD calculations. The nuclides were organized into three groups for fission products, actinides and daughters, and activation products. Each nuclide row had a column for the nuclide name and 16 columns for the downwind dose at each of the 16 distance ranges in the MACCS2 calculation. Each weather year sheet also had a header that identified the weather year and release height as well as a heading that identified the distance ranges for the dose data.

Compilation of the downwind dose data in the DWDD-height file weather year sheets was done from the five input-year files for that weather year. As noted previously the dose data was copied manually using the Copy and Paste Special functions of Excel. Error checking for the copying process was done differently for the input-year files that used manual and automated dose date extraction. In the manual dose data extraction input-year files, the column of 95th percentile doses copied to the input year file was highlighted in bold font and the entire file was checked after all nuclide doses had been extracted to ensure that the correct column of dose data had been copied for all nuclides. The bold highlighting made it obvious if the copy process had not started or stopped at the correct row in the input-year file. The rows of dose data in the input-year files were also inspected during the copying process to ensure that no more or less data were copied to the sheet.

For the input-year files with automated dose extraction, the entire section of multiple rows of nuclide name and dose data were copied and pasted (as values not formulas) at the same time. The rows were pasted so that the existing nuclide names in the DWDD-height file sheet could be compared to the nuclide names in the copied material to ensure the doses were positioned on the correct line. After comparison the dose data was moved one column to the left so that only one column of nuclide names remained. The nuclide name comparison was useful for more than error checking as two nuclides that were six rows from the end of the ATMOS file "b" dose outputs were missing so that the doses for the last six nuclides were out of order and had to be moved down the list of nuclides. The missing doses for the two nuclides were provided at the start of the ATMOS file "c" dose outputs and they were copied into the correct lines of the DWDD-height file weather year sheet.

Comparison of the 3000 m doses from the weather year sheets for each nuclide was done in the eighth sheet of the DWDD-height workbook file. The comparison sheet had rows labeled for the nuclides in the same way as the weather year sheets. The 3000 m range nuclide doses were copied from the weather year sheets to the comparison sheet to a column that was labeled to identify them. Since the 1994 weather year file had the highest X/Q airborne concentration at 3000 m in previous calculations it produced the highest doses for the majority of nuclides. Thus, all weather year 3000 m nuclide doses were compared to the 1994 doses by calculating the ratio of the candidate dose to the 1994 dose. Most comparisons showed a ratio less than one confirming that the 1994 dose was the higher and a few comparisons showed a ratio greater than 1.0 indicating a higher dose than the 1994 dose. After all of the comparisons were made and the higher than 1994 doses highlighted in bold, the highest doses for each nuclide were copied into a separate column that became the 2002 DWDD 3000 m dose for that release height. Those release height 3000 m 95th percentile TEDE doses were collected into a combined table that tabulated the entire 2002 DWDD (See Appendix G of this report.)

No data scaling or alteration of the dose data was done in the process of dose compilation and comparison within DWDD-height workbook file for any release height of the 2002 DWDD. The comparison process required calculation of ratios of dose data to facilitate comparison by inspecting the dose ratios. The comparison process did not scale or alter the dose data of the 2002 DWDD. Thus, the application of commercial spreadsheet software for extraction, compilation and comparison of the downwind dose data of the 2002 DWDD are outside of the scope of RREP 3-2 as a commercial software product that has no potential for altering design data and the requirements of RREP 3-2 for software quality assurance do not apply.

APPENDIX L, INDEPENDENT VERIFICATION OF THE 2002 DWDD CALCULATIONS

JOB # QA-1

TA-V RREP

ANALYSIS PACKAGE COVER SHEET

Analysis Subject Calculation of radiation doses from a hypothetical release of airborne radioactive material at downwind locations for use in safety analysis for TA-V nuclear facilities. The complete 2002 Downwind Dose Database (DWDD) of dose calculations will facilitate future safety analysis by others.

By Robert E. Naegeli **Date** 1/29/03

Checked By Ed Parma **Date** 1/29/03

What software was used for the analysis?

Code Name(s)	Version	Modified Before Use? YES	NO
MELCOR Accident Consequence Code System (MACCS2)	1.12		X
WINDAT2 (converts data format and was written for 2002 DWDD analysis)	1		X

If YES, see note below

NOTE: Please attach a "Modification Summary" to the analysis package if code was modified.

Review and Approval

PL/E Signature Robert E. Naegeli **Date** 1/29/03

Manager (Department #) Sharon L. Walker **Date** 2/10/03

1

DOCUMENTATION RECORD
Analysis and/or Calculations

Preparer Robert E. Naegeli **Date** 1/29/03

Subject Calculation of the 2002 DWDD radiation doses at downwind distances from hypothetical airborne releases in TA-V.

Control # QA-1 **Rev.** 0 **Quality Level** II

1. Define the objective (of analysis or calculation):

Calculate the downwind dose at a variety of distances due to a hypothetical 1 curie airborne release of a single radionuclide from TA-V nuclear facilities using conservative, defensible inputs consistent with DOE-STD-3009 requirements. A database of doses for 162 radionuclides for seven release heights that are typical of TA-V nuclear facilities is the intended result of the calculations. The calculations will use local weather measurements from the A36 tower to assess the variability of dose with local weather conditions.

2. Define inputs and their sources:

- Conservative, defensible MACCS2 standard input sources include:
  - MACCS2 users manual (Reference 1)
  - 1998/2000 DWDD standard inputs (Reference 2)
  - Extensive literature search
  - Independent expert review of draft standard inputs (Reference 3)
- TA-V release heights- safety basis documents and building drawings
- Radionuclides for dose calculation- the 1998/2000 DWDD and past requests
- Local A36 tower weather data- SNL meteorologist Regina Deola

3. Record results of literature searches (or other background data):

See the draft report of 2002 DWDD standard input development (Reference 4).

4. Identify assumptions - indicate those that must be verified:

- No plume broadening- conservative and consistent with TA-V ventilation systems
- No wet or dry deposition- conservative with minor impact
- Surface roughness of 3 cm for no vertical dispersion enhancement- conservative with small impact
- Suppress entrainment of a buoyant plume- no heat in the DWDD releases so no impact for this conservative assumption
- No building wake effect broadening of plume dispersion- conservative with small impact

5. Was a computer used? Yes X **no** ____

- **Computer program evaluated for applicability to this activity:**

yes X **no** ____ **IF yes, attach results of evaluation.**

Evaluation shall address the appropriateness of application, the adequacy of verification and validation of models used, and whether additional testing or verification is required.

- **Type of Computer:** Dell OptiPlex GX1, Pentium III, running at 550 MHz

- **Name of Computer Program:** MACCS2

- **Computer Program Revision:** Version 1.12

- **Inputs:** Conservative, defensible MACCS2 standard inputs, TA-V release heights, Radionuclides for dose calculation, and Local A36 tower weather data

- **Outputs:** Doses at various distances downwind for 1 curie of a single nuclide at the TA-V nuclear facility release heights for all seven of the local A36 weather tower data years. The highest dose from the seven local weather years for the 3.0 km exclusion area boundary will be tabulated in the 2002 DWDD for all 162 radionuclides.

6. **Name and Org. of person performing calculation/analysis:**
Robert E. Naegeli, 6433

7. **Date of calculation/analysis:** December 2002 completion

8. **Identify reviewer(s) and date of review approval:**
Ed Parma, 6424 **Date** 1/29/03
____ **Date** ____
____ **Date** ____

9. **Documents generated as a result of analyses or calculations shall be attached to this form.**

The final results of the calculations will be contained in a SAND report to be published so not attached.

NOTE: If additional space is needed, attach sheets and reference to the appropriate section number.

Added Sheet for the Documentation Record

Results of Computer Program Evaluation for Applicability to this Activity

This information supports Section 5 above.

Evaluation shall address the appropriateness of application.

The MACCS2 code is appropriate for radiological dose calculation and assessment for safety analyses according to a Health Physics Society expert (Reference 5, attached). The MACCS2 users manual (Reference 1) also indicates that MACCS2 is appropriate for this application.

Evaluation shall address the adequacy of verification and validation of models used, and whether additional testing or verification is required.

The verification and validation of models used and whether additional testing or verification is required are addressed in the Software Verification and Validation Report (SVVR) for the MACCS2 code on this computer (Reference 6, attached) and in the Requirements, Description, Use and Testing for the WINDAT2 Code (Reference 7, attached). The overall conclusion is that MACCS2 can be used as is without additional testing or verification. Part of that conclusion is based on independent expert review of the conservative and defensible standard inputs for the Downwind Dose Database (DWDD) calculations of 1998/2000 and 2002. The WINDAT2 code is an input format conversion program that was written to support the MACCS2 calculations for the 2002 DWDD development. Reference 7 details the testing done to verify correct operation of the WINDAT2 code and correct format conversion of the MACCS2 weather data files produced by WINDAT2.

Conclusions

The MACCS2 code is appropriate for this application. The MACCS2 code and the supporting WINDAT2 input format conversion code are adequately verified and validated so that additional testing or verification is not required.

Evaluator Signature Matthew Naegeli **Date** 1/29/03

4

REVIEW RECORD
Analyses and/or Calculations

Reviewer Ed Parma **Date** 1/29/03

Subject Calculation of the 2002 DWDD radiation doses at downwind distances from hypothetical airborne releases in TA-V.

Control # QA-1 **Rev.** 0

Criteria

1. **Were inputs correctly identified and selected? yes** ✓ **no**___ **N/A**___

   Comments See attached memo by E.J. Parma

2. **Were assumptions adequately described and reasonable for the application? yes** ✓ **no**___ **N/A**___

   Comments___

3. **Was the computer program and encoded mathematical model appropriately evaluated? yes**___ **no**___ **N/A** ✓

   Comments___

4. **Do literature searches appear to be complete and conclusions based on them reasonable? yes** ✓ **no**___ **N/A**___

   Comments___

5. **Are the results of the analyses reasonable in relation to inputs and the defined objective? yes** ✓ **no**___ **N/A**___

   Comments___

6. **Were acceptable methods used to assess correctness of work and reasonableness of recommendations? yes** ✓ **no**___ **N/A**___

   Comments___

7. **Are the generated documents sufficient in detail (and legibility) so that a qualified person could produce the same results using the same inputs and methods? yes** ✓ **no**___ **N/A**___

   Comments___

NOTE: If additional space is needed, attach sheets and reference to the appropriate section number.

References

Reference 1 (Chanin and Young 1997) D.I. Chanin, and M.L. Young, *Code Manual for MACCS2: Volume 1, User's Guide,* SAND97-0594, Sandia National Laboratories, Albuquerque, NM, March 1997.

Reference 2 (Naegeli 1998) R. E. Naegeli, *Transmittal of MACCS2 Single Isotope Airborne Dose Versus Distance Database*, Memorandum to Distribution, Sandia National Laboratories, Albuquerque, NM, January 9, 1998.

Reference 3 (Restrepo 2002) L. Restrepo, Letter Report on TA-V MACCS2 Input Files to William T. Mullen, DOE/OKSO, Omicron Safety and Risk Technologies, Albuquerque, NM, October 18, 2002.

Reference 4 (Naegeli 2002) R. E. Naegeli, *A MACCS2 Single Isotope Downwind Dose Database for Sandia National Laboratories, Technical Area V*, draft report, Sandia National Laboratories, Albuquerque, NM, December 2002.

Reference 5 (HPS 2000) Health Physics Society (HPS), *Answer to Question #364 Submitted by Linda Vickers*, (URL: http://www.hps.org/publicinformation/ate/q364.html), Category: Software, Health Physics Society, McLean, VA, July 28, 2000.

Reference 6 (Naegeli 2003a) R. E. Naegeli, *Software Verification and Validation Report MACCS2 Software on the Dell Optiplex GX1 Computer Property Number S824741*, SVVR for existing software qualification, Sandia National Laboratories, Albuquerque, NM, January 13, 2003.

Reference 7 (Naegeli 2003b) R. E. Naegeli, *Requirements, Description, Use and Testing for the WINDAT2 Code*, description of a code developed for use in a particular calculation or analysis, Sandia National Laboratories, Albuquerque, NM, January 16, 2003.

Sandia National Laboratories
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date : January 28, 2003

to: R. E. Naegeli, 6433

E. J. Parma

from: E. J. Parma, 6424

subject: Review of MACCS2 Calculations for 2002 DWDD

I have performed a review of your calculations for the 2002 Downwind Dose Database (DWDD) using the MACCS2 code. The following outline describes the steps I used to install the code on my computer, perform sample calculation checks of specified nuclides, and check and compare your inputs for the production runs to the values described in your draft SAND report entitled "A MACCS2 Single Isotope Downwind Dose Database for Sandia National Laboratories, Technical Area V."

Code Installation

- The CD entitled "MACC2 QA CD – Rob Naegeli: 1/14/03 – Copy 1" was used to install MACCS2 on my computer. The complete image of the CD was copied.
- The 14 sample problem outputs were run in the MACCS2 directory using the RUNEM.BAT script. The output files were compared to those on the CD using MS-WORD. No differences, other than date, time, and CPU time were noted.

Comparison of Sample Tests

- A subset of the production cases were run using the RUNCMI39.BAT script, CMI39A.inp (ATMOS input), CMI39E.inp (EARLY input), and A36-94N.inp (weather file input). This run analyzed one curie releases of Ce-144, K-88, Xe-138, I-131, I-133, and Pu-239 for the ACRR facility with no wake effects.

- The results were found to be exactly the same as those presented in the draft SAND report, Table G-1. It was noted that the output results from MACCS2 are in Sv. However, the variable CORSCA with the value of 3.7e12, converts Sv/Bq to Rem/Ci.

- The input variables for CMI39A.inp and CMI39E.inp were compared to the draft SAND report to determine if they were consistent with the information presented. The variables were found to be consistent.

- The production run PAC3aA.inp (ATMOS input) and PAC1E.inp (EARLY input) were examined and compared to CMI39A.inp and CMI39E.inp, respectively. The variables were found to be consistent, and therefore consistent with those reported in the draft SAND report.

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