NUREG/CR-1005
Vol. 2

A Radioactive Waste Disposal Classification System

The Computer Program and Groundwater Migration Models

Prepared by V. C. Rogers, R. D. Baird, B. C. Robertson, P. J. Macbeth

Ford, Bacon and Davis Utah Inc.

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A RADIOACTIVE WASTE DISPOSAL CLASSIFICATION SYSTEM

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FORWARD

This two volume report presents a proposed system for classifying radioactive waste "according to the requirements for safe disposal." This proposed system was developed under contract to the Nuclear Regulatory Commission (NRC). NRC will consider this report along with the results of other contractual efforts and other available information during the development of regulations for the disposal of commercial low-level radioactive wastes.

Volume I of this report presents in a succinct manner the proposed classification system. Volume II provides the computer program used for performing the calculations and provides a description of the equations representing the potential exposure mechanisms.

Only that information which is basic to the proposed classification system is provided in this report. An earlier progress report, NUREG-0456, "A Classification System for Radioactive Waste Disposal - What Waste Goes Where?", June 1978, provides additional information on the considerations that went into the development of the proposed system. NUREG-0456 also provides information which should be considered in implementing a classification system.

ABSTRACT

The Nuclear Regulatory Commission, as part of its development of regulations for the disposal of radioactive waste, has contracted for the development of a radioactive classification system. A five category system, based on requirements for safe disposal, has been proposed. A Computer program which calculates the "Disposal Concentration Guides" for individual isotopes for each category was prepared. The program allows parameters for the isotopes and condition of the disposal to be varied. A description of the equations representing the potential exposure mechanisms is also provided.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The Nuclear Regulatory Commission (NRC) is developing regulations for the disposal of radioactive waste. In order to regulate the disposal of radioactive wastes, there must be an adequate definition of the classes of waste. A classification system developed as part of this project[1,2] is one based upon the minimum requirements for safe disposal. This radioactive waste disposal classification system (RWDCS) is based upon estimating potential dose rates to individuals from the disposal of radioactive waste. By comparing the potential dose rates with the dose guidelines, the maximum average concentration (MAC) of radioactive materials in the waste can be modified to provide adequate protection to the public.

The potential exposures from disposed radioactive waste can occur either from individuals encountering the waste or it can occur from the waste migrating from its disposal location into man's environment.

In this classification system, a set of standard exposure events have been identified and methods for evaluating the potential exposure developed. These events are:

1. Inhalation of dust by a reclaimer or worker digging in the waste.

2. Consumption of food grown in a garden containing contaminated soil.

3. Ingestion of water from a well.

4. Direct gamma exposure to workers.

5. Groundwater migration to a resource pathway.

6. Erosion/corrosion events releasing contamination to surface waters.

The computer program CALMAC was developed to calculate the MAC's for each pathway and for each radioactive isotope. For each isotope, the most restrictive MAC from all pathways is identified.

The purpose of this volume of the project report is to present and document the computer code which has been developed to calculate the pathway and site MAC's. It is intended that, with the information presented herein, the code may be implemented at other computer installations, that correct performance of the code may be verified and that the code may be exercised with the users desired values of input parameters.

2. PROGRAM ABSTRACT

2.1 Program Identification

The program is entitled, "CALMAC", an acronym for "The Calculation of Maximum Average Concentrations".

2.2 Problem Description

The program CALMAC calculates MAC's for up to 23 nuclides and up to six pathways of exposure. CALMAC selects the most restrictive MAC for each nuclide as the MAC for the site being analyzed.

2.3 Method of Solution

The explicit equations defining the MAC's are solved algebraically.

2.4 Related Material

CALMAC requires that a double precision subroutine which calculates the complimentary error function be supplied by the user.

2.5 Computer

CALMAC was originally implemented on a Univac 1100 series, Exec 8 Computer.

2.6 Running Time

The running time for a typical CALMAC problem with 23 nuclides and six pathways is approximately 14,688 msec.

2.7 Programming Language

CALMAC is written exclusively in FORTRAN V.

2.8 Authors

The authors of CALMAC are Dr. V.C. Rogers and Messrs. R.D. Baird, B.C. Robertson and P.J. Macbeth. The mailing adress for the above individuals is:

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P. O. Box 8009
Salt Lake City, Utah 84108

The telephone number is 801/583-3773.

2.9 References

V.C. Rogers, "The Radioactive Waste Disposal Classification System", Volume I, NUREG/CR-1005, September 1979.

J.A. Adam and V.C. Rogers, "A Classification System for Radioactive Waste Disposal - What Waste Goes Where?", NUREG-0456, June 1978.

2.10 Material Available

The program CALMAC is available to the public from the NRC.

3.0 APPLICATION INFORMATION (USER'S MANUAL)

3.1 Program Description

CALMAC provides the computational framework by which the allowable of a radionuclide at a waste disposal site can be calculated. These calculations are based on the intake of radionuclides by man from six possible pathway mechanisms.

3.2 Program Considerations

The framework of the program's operation is divided into four main parts:

1 Internal data tables
2 Options for data input and output
3 Computations
4 Output

as shown in Figure 3.1.

The dimensionality of the program arrays has a total requirement of 3,700. The largest singly dimensioned array is 300 in double precision and the largest multiple dimensioned array is 25 x 7. The present CALMAC package is designed to handle 23 different radionuclides, as given in Appendix A, and produce an output table of calculated MAC's for up to 23 radionuclides.

3.2.1 Internal Data Tables

Many of the pathway calculations require nuclide specific constants. These constants are located in lookup tables internally generated from data statements in the program. A list of these constants is given in Appendix A. The nuclide specific constant tables are dimensional equivalent to a nuclide name table.

3.2.2 Options for Data Input and Output

Each of the pathway calculations require user supplied input parameters. The first program option is to specify the type user-program interaction. The program will either prompt the user with descriptive requests for all input or descriptive data requests for vital data input areas. The second program option is to determine if the waste site is to be under administrative control (time of site control 150 yr) or not, also an escape from the program is provided at this point. With these two decisions made, the program will continue as specified. The next option allows the user to specify which of the six pathways are to be used in calculating the site MAC's. The user specifies the pathway index number (1, 2, 3, 4, 5, 6) or 0 (zero) to have the pathway used or <u>not</u> used respectively. This option must be exercised for each

INTERNAL DATA TABLES:

- NUCLIDE NAMES
- INGESTION DOSE ACCUMULATION FACTORS (MAX. ORGAN)
- INHALATION DOSE ACCUMULATION FACTORS (MAX. ORGAN)
- NUCLIDE DECAY CONSTANTS
- NUCLIDE ACTIVITY DENSITY

OPTIONS:

- DESCRIPTIVE PROMPTS (YES OR NO)
- SITE UNDER ADMINISTRATIVE CONTROL OR EXIT (YES, NO, OR EXIT)
- PATHWAY INDEXES (1, 2, 3, 4, 5, 6)

COMPUTATIONS:

(1) INHALATION OF DUST BY RECLAIMER
- DESCRIPTIVE DATA PROMPT AND CALCULATION OF MAC
- CALCULATION OF MAC

(2) FOOD CONSUMPTION
- DESCRIPTIVE DATA PROMPT AND CALCULATION OF MAC
- CALCULATION OF MAC

(3) DIRECT GAMMA EXPOSURE
- DESCRIPTIVE DATA PROMPT AND CALCULATION OF MAC
- CALCULATION OF MAC

(4) SHEET EROSION
- DESCRIPTIVE DATA PROMPT AND CALCULATION OF MAC
- CALCULATION OF MAC

(5) WELL WATER (INGESTION)
- DESCRIPTIVE DATA PROMPT AND CALCULATION OF MAC
- CALCULATION OF MAC

(6) GROUNDWATER (INGESTION)
- DESCRIPTIVE DATA PROMPT AND CALCULATION OF MAC
- CALCULATION OF MAC

[(5) and (6):] CALL SUBROUTINE AUTOMI

OUTPUT:

TABLE OF MAX. AVERAGE CONCENTRATIONS (MICRO-CI/CC)
- ADMINISTRATIVE CONTROL
- NO ADMINISTRATIVE CONTROL

FIGURE 3.1 BLOCK CHART OF CALMAC

radionuclide.

3.2.3 Computations

The MAC calculations are discribed in detail in Sections 4.1 and 4.2. The well water and groundwater pathways require the use of an external subroutine to calculate the complimentary error function in double precision.

3.2.4 Output

The program output is dependent on the options (3.2.2), the descriptive data request prompts and the table of radionuclide MAC's. The descriptive request prompts for data will generate seven pages of output per nuclide or one page of output per nuclide depending on the option. The table of radionuclide MAC's is in the format shown in Appendix B. The MAC table title changes to reflect whether or not the site was calculated under administratived control.

3.3 External Data Files

Program data can be entered into CALMAC manually or from a data file added to the run stream at time of execution. The data file structure is the same as if the data was to be entered manually.

3.4 Input Data

Data entry is handled either manually or from a data file. In either case, the data is read by a FREE FORMAT statement requiring the entered data be separated by commas. The program requests data consecutively for the requested number of nuclides to be studied, see Appendix C. All computational variable names and units are listed in Appendix D.

3.5 Control Statements.

Execution of CALMAC on the University of Utah UNIVAC 1108 requires the following control statements:

```
@ASG, A FBDU*FBDU
@XQT, UO FBDU*FBDU.CALMAC
```

and to add an external data file

```
@ADD FBDU*FBDU.DATA
```

3.6 Output Information

Program outputs are divided into two types: (1) descriptive prompts, and (2) computation output. The descriptive prompts are program generated to aid the user in entering data. The computational output forms the basis for the MAC tables, a listing of radionuclides and their pathway MAC's. When a calculated pathway MAC exceeds its activity density the table value is replaced with the activity density value, (see Appendix A) followed by an asterisk.

3.7 Sample Problem

In order to allow the user to determine that the code is functioning properly at his installation, the following sample problem, together with its input and output, are presented.

The problem for which data has been prepared and which has been analyzed is similar to the reference containment facility described in Reference 1. The parameters which indicate geometry for groundwater migration calculations are presented in Table 3.1.

Samples of the output from the program have been presented in Appendix B while the input is reproduced in Appendix C. Appendix D lists the definitions of each of the input variables. Appendix E is a listing of the program.

TABLE 3.1

PARAMETERS FOR SAMPLE PROBLEM

Distance from Waste to Aquifer (m)	10
Distance from Site to Surface Water (m)	1000
Water Velocity from Waste to Aquifer (m/yr)	10
Water Velocity in Aquifer (m/yr)	100
Dilution Volume - Well Water (m^3/yr)	1.43×10^6
Dilution Volume - Groundwater (m^3/yr)	1.57×10^{10}
Site Capacity for Waste (m^3)	6.3×10^5
Site Plane Area (m^2)	2.0×10^6

4. PROBLEM DEFINITION

4.1 Description

The MAC's for each pathway is determined using the equations presented in Reference 2. These equations are reproduced here.

The MAC resulting from reclaimer-inhalation is given by the equation:

$$C_m = \frac{10^3 D_e T_d \rho}{A_d U_a T_x f_w (DF)_m} \qquad (4.1)$$

where,

C_m = MAC of isotope m in the waste at the time of burial ($\mu Ci/cm^3$)

D_e = dose rate guideline, (500 mrem/yr)

A_d = dust loading in the air, g/m^3

U_a = breathing rate of exposed individual, ℓ/yr

T_x = time period of exposure, yr

f_w = dilution factor of waste with soil or other facility material

$(DF)_m$ = dose rate conversion factor for isotope m (mrem/yr/μCi inhaled for reclaimer after administrative control, mrem/μCi inhaled for continuous exposure without administrative control)

λ_m = radioactive decay constant for isotope m, yr^{-1}

T_d = correction for decay during 150 yr control period (if applicable)

ρ = density of waste material, g/cm^3

The correction for decay is defined as $\exp(150\lambda_m)$ if administrative control of the site for 150 yr is assumed and as 1.0 if no administrative control of the site is assumed.

For consumption of food, the MAC's are determined from the equation:

$$C_m = \frac{10^{-3} D_e f_w f_2 T_d}{(DF)_m B_{mv} (U_{ap}^{meat} F_f Q_a + U_{ap}^{milk} F_m Q_a + U_{ap}^{veg}) f_3} \qquad (4.2)$$

where,

f_2 = mixing factor for buried materials transferred to surface and intermingled with clean soil at surface

$(DF)_m$ = dose conversion factor from Reference 4 for m^{th} nuclide, mrem/μCi

B_{mv} = vegetative bioaccumulation and uptake factor for m^{th} nuclide by v^{th} plant from Reference 4 (concentration in vegetable/concentration in soil)

U^i_{ap} = usage factors from Reference 4 (U^{milk}_{ap} = 310 ℓ/yr; U^{meat}_{ap} = 110 kg/yr; U^{veg}_{ap} = 520 kg/yr)

F_f = stable element transfer coefficient relating animal consumption rate to concentration in edible meat from Reference 4 , day/kg

Q_a = animal consumption rate from Reference 4, 50 kg/day

F_m = stable element transfer coefficient relating animal consumption rate to concentration in milk from Reference 4, day/ℓ

f_3 = fraction of annual food consumption produced on site

and the remaining variables are those previously defined.

The MAC resulting from direct gamma exposure is determined by the equation:

$$C_m = \frac{2\mu D_e T_d}{(0.0575) G (\mu/\rho)_t E_m T'_x f_w} \qquad (4.3)$$

where,

μ = effective gamma ray attenuation coefficient for soil, cm^{-1}

G = gamma emission rate per μCi of radionuclide, γ/sec/μCi

$(\mu/\rho)_t$ = mass absorption coefficient for tissue, cm^2/g

E_m = average energy of the emitted gamma rays (MeV) times the multiplicity of average energy gamma rays

T'_x = hours of exposure per year, hr/yr and other variables are those previously defined.

The MAC resulting from sheet erosion is determined by the equation:

$$C_m = \frac{D_e \dot{m}_t \; d \; T_d}{F_e U_a (DF)_m V_w} \exp\,(120\lambda_m) \qquad (4.4)$$

where,

d = dilution with clean dirt

F_e = fraction of waste eroded from the site per year, 1.0×10^{-3}

V_w = volume of waste, m^3

and other variables are as previously defined.

The MAC's resulting from the well water and groundwater pathways are determined from the equation:

$$C_m = \frac{10^{-3} \; D_e m_v}{\lambda_L f_o U_b (DF)_m} \qquad (4.5)$$

where,

m_v = aquifer flow rate per unit volume of waste, m^3/yr per m^3 of waste

λ_L = nuclide leach constant, yr^{-1}

U_b = water consumption factor for maximum or average individual from Reference 3, ℓ/yr

f_o = peak ratio of quantity of nuclide arriving in groundwater at well to that leaving waste in first year

and other variables are those previously defined.

The quantity f_o is determined from the solution of a second-order partical differential mass balance equation for groundwater migration using a spatially dependent source and element dependent leach constants, λ_L, and retardation factors, K. For a two-region aquifer flow system, the following equation is used to obtain f_o:

$$
\begin{aligned}
f_o'(X_2,t_2) = \tfrac{1}{2}\sum_{i=1}^{N} \Bigg\{ & A \exp\left[\frac{V_2 X_{2i}}{2D} - a_1(t_2-\tau) - G_2 X_{2i}\right] \operatorname{erfc}\left[\frac{\sqrt{\frac{K}{D}}\, X_{2i} - 2\sqrt{\frac{D}{K}}\, G_2 t_2}{2\, t^{\frac{1}{2}}}\right] \\
& - B \exp\left[\frac{V_2 X_{2i}}{2D} - a_1(t_2-\tau) + G_2 X_{2i}\right] \operatorname{erfc}\left[\frac{\sqrt{\frac{K}{D}}\, X_{2i} - 2\sqrt{\frac{D}{K}}\, G_3 t_2}{2\, t^{\frac{1}{2}}}\right] \\
& + A \exp\left[\frac{V_2 X_{2i}}{2D} - a_1(t_2-\tau) + G_2 X_{2i}\right] \operatorname{erfc}\left[\frac{\sqrt{\frac{K}{D}}\, X_{2i} - 2\sqrt{\frac{D}{K}}\, G_2 t_2}{2\, t^{\frac{1}{2}}}\right] \\
& - B \exp\left[\frac{V_2 X_{2i}}{2D} - b_1(t_2-\tau) + G_3 X_{2i}\right] \operatorname{erfc}\left[\frac{\sqrt{\frac{K}{D}}\, X_{2i} - 2\sqrt{\frac{D}{K}}\, G_3 t_2}{2\, t^{\frac{1}{2}}}\right] \Bigg\} \qquad (4.6)
\end{aligned}
$$

where

N = number of source nodes

V_2 = water velocity in Region Two, m/yr

X_{2i} = horizontal distance from source mode i to the outlet from Region Two, m

D = longitudinal dispersion coefficient, m^2/yr

K = retardation factor

t = time

$a_1 = \sqrt{\frac{K}{D}}\; X_1$

$b_1 = \sqrt{\frac{V_1^2}{4KD} - \lambda_\ell}$

$G_2 = \sqrt{\frac{V_2^2}{4D^2} - \frac{K\;(\lambda_\ell - a_1)}{D}}$

$G_3 = \sqrt{\frac{V_2^2}{4D^2} - \frac{K(\lambda_\ell - b_1)}{D}}$

τ = time of peak release rate from Region One, yr.

The constants A and B are determined from the release rate as a function of time from Region One.

Finally, f_o is obtained by multiplying f'_o by a correction factor to account for the fact that waste is being delivered to the site over a 40 year period, i.e.,

$$f_o = f'_o \left[\frac{1-e^{-40\lambda_E}}{40\lambda_E} \right] \qquad (4.7)$$

A list of the nuclide inventories that are influenced by the rate of delivery is given in Table 4.1.

In the code CALMAC, the value of the dispersion coefficient is forced to satisfy the condition

$$D \leq \frac{V^2}{4KD\lambda_L}$$

If the condition is violated, the imaginary solutions result. Therefore, in practice, if the condition is violated, the value of D is halved until the condition is satisfied. This technique assures conservatively small estimates of the MAC's.

4.2 Numerical Techniques

In all but one of the equations presented in the preceeding section, the solutions are straightforward evaluations of the equations using input data. In the case of nuclide migration in groundwater systems, however, the evaluation is somewhat more involved.

For groundwater systems, the predicted water concentrations are estimated using Eq. (4.7) at many points in time. The maximum concentration is selected and used to determine the value of f_o shown in Eq. (4.5). Thus, the minimum value of the MAC for this pathway is determined.

It is necessary to calculate water concentrations in double precision, due to the complex interactions between the exponential and the error functions shown in Eq. (4.7).

The complimentary error function is evaluated using a subroutine entitled, MERFCD (4). At the facility where CALMAC was developed, this subroutine is available as a library subroutine. The user must provide this subroutine, either as a user-provided subroutine or as a library subroutine.

4.3 Data Libraries

All data libraries required for the execution of the CALMAC are contained within the code. These libraries are inhalation and ingestion dose conversion factors for critical organs, decay constants and specific activities. Dose conversion factors are taken from Reference 3.

Table 4.1

NUCLIDES WHICH ARE STRONGLY INFLUENCED BY THEIR RATES OF DELIVERY

Nuclide	Effective Decay Constant (yr^{-1})	Final Inventory (pCi per delivered pCi)
^{3}H	1.56×10^{-1}	0.160*
^{14}C	2.21×10^{-4}	0.996
^{55}Fe	3.57×10^{-1}	0.070+
^{59}Ni	1.00×10^{-1}	0.245+
^{60}Co	2.31×10^{-1}	0.108+
^{90}Sr	3.43×10^{-2}	0.544*
^{99}Tc	1.03×10^{-4}	0.998
^{129}I	1.0×10^{-1}	0.245*
^{135}Cs	1.0×10^{-3}	0.980
^{137}Cs	1.0×10^{-3}	0.980
^{235}U	1.0×10^{-5}	1.000
^{238}U	1.0×10^{-5}	1.000
^{237}Np	3.25×10^{-5}	1.000
^{238}Pu	7.90×10^{-3}	0.857*
^{239}Pu	3.84×10^{-5}	1.000
^{240}Pu	1.16×10^{-4}	0.998
^{241}Pu	4.62×10^{-2}	0.456+
^{242}Pu	1.18×10^{-5}	1.000
^{241}Am	1.16×10^{-3}	0.968
^{243}Am	1.04×10^{-4}	0.998
^{242}Cm	2.55×10^{-5}	1.000
^{244}Cm	3.87×10^{-2}	0.509+

* - Depends strongly on delivery rate

+ - Depends strongly on delivery rate but completely decays before release from typical groundwater systems.

The user must provide substantial quantities of information, much of which is generally held constant. Yet, these data were not included in CALMAC as data libraries since it was felt that certain users might wish to conduct parametric studies on these variables. They are supplied as an input file with the program.

5. PROGRAMMING INFORMATION

5.1 Source Program

The program CALMAC was written in Fortran V and implemented at the University of Utah Computer Center on a UNIVAC 1108, and is directly compatible with computers of similar configuration (36 bit words). A block chart of the program CALMAC is shown in Figure 3.1 and a flowchart for the internal subroutine AUTOMI is presented in Figure 5.1.

The present version of CALMAC includes one subroutine which is computer facility dependent. This is an external subroutine that calculates the complimentary error function in double precision (MERFCD), and is common to most computer facility mathematical libraries. An error in calculating the complimentary error function would lead an error trace routine to the subroutine AUTOMI which in turn would lead to the main program CALMAC. AUTOMI has two internal subroutines: (1) for fitting the boundary conditions between migration Region One and Region Two, and (2) for locating the maximum normalize release rate, f_o. All arguments passed between CALMAC and AUTOMI go through the subroutine call statement. AUTOMI uses a common block to communicate with its internal subroutines.

REFERENCES

1. J.A. Adam and V.C. Rogers, "A Classification System for Radioactive Waste Disposal - What Waste Goes Where?," NUREG-0456, June 1978.

2. V.C. Rogers, "A Radioactive Waste Disposal Classification System, NUREG/CR-1005, September 1979.

3. "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR Part 50, Appendix I, "U.S. Nuclear Regulatory Commission, Regulatory Guide 1.109, Revision 1, October 1977.

4. International Mathematical and Statistical Library Inc., Houston, Texas, November 1977.

APPENDIX A

NUCLIDE SPECIFIC CONSTANTS

APPENDIX A
NUCLIDE SPECIFIC CONSTANTS

Nuclide	Dose Factor Ingestion* (mrem/pCi)	Dose Factor Inhalation* (mrem/pCi)	Decay Constant (yr^{-1})	Activity Density (μCi/cc)
^{3}H	1.05E-7	1.58E-7	5.62E-2	2.90E+9
^{14}C	2.84E-6	2.27E-6	1.21E-4	7.10E+6
^{55}Fe	2.75E-6	9.01E-6	2.57E-1	1.90E+10
^{60}Co	4.02E-5	7.64E-4	1.32E-1	9.70E+9
^{90}Sr	7.58E-3	1.24E-2	2.43E-2	3.60E+8
^{99}Tc	4.13E-7	5.20E-7	3.26E-6	1.00E+4
^{129}I	9.22E-6	5.55E-3	4.36E-8	8.50E+2
^{135}Cs	1.95E-5	1.46E-5	3.01E-7	2.40E+3
^{137}Cs	1.09E-4	7.77E-5	2.30E-2	1.70E+8
^{226}Ra	3.45E-3	1.25E-1	4.33E-4	4.94E+6
^{232}Th	4.92E-5	2.23E-1	6.93E-3	1.28E+0
^{235}U	8.02E-4	4.90E-2	9.85E-10	4.10E+1
^{237}Np	1.38E-3	1.69E-0	3.24E-7	6.40E+0
^{238}U	7.67E-4	4.58E-2	1.55E-10	1.30E+4
^{238}Pu	6.73E-4	2.69E-0	7.89E-3	3.40E+8
^{239}Pu	7.60E-4	3.05E-0	2.84E-5	1.20E+6
^{240}Pu	7.58E-4	3.04E-0	1.06E-4	4.70E+6
^{241}Pu	1.56E-5	6.05E-2	4.62E-2	2.20E+9
^{242}Pu	7.22E-4	2.89E-0	1.79E-6	7.60E+4
^{241}Am	8.10E-4	9.93E-1	1.60E-3	6.40E+7
^{243}Am	8.12E-4	9.94E-1	9.40E-5	3.60E+6
^{242}Cm	7.92E-5	3.74E-2	1.55E+0	6.30E+4
^{244}Cm	6.43E-4	5.90E-1	3.87E-2	1.60E+9

* Reference 3

APPENDIX B

SAMPLE OF PROGRAM OUTPUT FORMAT

```
THIS PROGRAM HAS 2 DATA INPUT MODES,
   (1) INTERACTIVE,
   (2) NONINTERACTIVE.
IN THE INTERACTIVE DATA INPUT MODE THE PROGRAM
PROMPTS THE USER FOR INPUT DATA WITH DESCRIPTIVE
DATA REQUESTS, AND WILL USE ** 7 ** PAGES FOR
EACH NUCLIDE.  THE NONINTERACTIVE DATA INPUT MODE
DESCRIPTIVELY REQUESTS THE NUMBER OF NUCLIDES TO BE
STUDIED, THE NUCLIDE NAME, AND THE PATHWAYS TO BE USED,
AND WILL USE ** 1 ** PAGE PER NUCLIDE.  ALSO A COPY OF
PATHWAY VARIBLES WILL BE PRINTED ONCE AT THE BEING OF
THE PROGRAM

DO YOU WISH THE ### INTERACTIVE MODE ### (YES OR NO)?


 INHALATION PATHWAY VARIABLES

D(MREM/YR), DOSE GUIDELINE
AD(KG/M3), DUST LOADING IN AIR
UA(M3/YR), BREATHING RATE OF EXPOSED
TX(YR), TIME PERIOD OF EXPOSURE
FW, DILUTION FACTOR OF WASTE WITH SOIL OR OTHER MATERIALS
RHO(KG/M3), DENSITY OF WASTE MATERIAL


 FOOD CONSUMPTION PATHWAY VARIABLES

D(MREM/YR), DOSE GUIDELINE
FW, DILUTION FACTOR OF WASTE WITH SOIL
F2, MIXING FACTOR FOR BURIED MATERIALS
RHO(KG/M3), DENSITY OF WASTE MATERIAL
BMV, VEGETATIVE BIOACCUMULATION AND UPTAKE FACTOR
UMEAT(KG/YR), MEAT CONSUMPTION RATE
UMILK(M3/YR), MILK CONSUMPTION RATE
UVEG(KG/YR), VEGETABLE CONSUMPTION RATE
FF(DAY/KG), STABLE ELEMENT TRANSFER COEF. ANIMAL TO MEAT
QA(KG/DAY), ANIMAL CONSUMPTION RATE
FM(DAY/M3), STABLE ELEMENT TRANSFER COEF. ANIMAL TO MILK
F3, FRACTION ON ANNUAL FOOD CONSUMPTION PRODUCED ON SITE


 DIRECT GAMMA EXPOSURE PATHWAY VARIABLES

MU(M-1),EFFECTIVE GAMMA RAY ATTENUATION
D(MRAD/YR), ABSORBED DOSE RATE
G(( /SEC)/MICRO-CI), GAMMA EMISSION RATE
MURHO(M2/KG), MASS ABSORPTION COEFFICIENT FOR TISSUE
```

EM(MEV), AVERAGE ENERGY OF THE EMITTED GAMMA RAYS TIMES THE MULTIPLICITY OF AVERAGE ENERGY GAMMA RAYS. SET EM = 0.0 FOR NUCLIDES WITH NO EMITTED GAMMA RADIATION.
TX(HR/YR), TIME OF EXPOSURE
FW, DILUTION FACTOR OF WASTE WITH SOIL

SHEET EROSION PATHWAY VARIABLES

D(MREM/YR), DOSE GUIDELINE
MT(M3/YR), WATER DILUTION RATE
DD, DILUTION WITH CLEAN DIRT
FE(1/YR), FRACTION OF THE SOIL ERODED AWAY PER YEAR
VW(M3), WASTE VOLUME
UA(M3/YR), WATER UTILIZATION RATE

WELL WATER INGESTION PATHWAY VARIABLES

VA(M/YR), VERTICAL WATER VELOCITY
XA(M), VERTICAL DISTANCE
DWA(M3/YR), DILUTION WATER RATE
VB(M/YR), VELOCITY OF LATERIALLY MOVING WATER(AQUIFER)
DWB(M3/YR), DILUTION WATER RATE
NXB, NUMBER NODE POINTS FOR DISTRIBUTED SOURCE (NXB = 1 FOR POINT SOURCE)
XB(I)(M), DISTANCE TO THE WELL FROM EACH NODE POINT
XK, NUCLIDE SPECIFIC SORPTION COEFF.
D(M2/YR), AQUIFER DISPERSION COEFF.
CLCH(YR-1), NUCLIDE SPECIFIC LEACH CONSTANT
VW(M3), WASTE VOLUME
DG(MREM/YR), DOSE GUIDELINE
USEFAC(M3/YR), WATER UTILIZATION RATE

GROUNDWATER INGESTION PATHWAY VARIABLES

VA(M/YR), VERTICAL WATER VELOCITY
XA(M), VERTICAL DISTANCE
DWA(M3/YR), DILUTION WATER RATE
VB(M/YR), VELOCITY OF LATERIALLY MOVING WATER(AQUIFER)

DWB(M3/YR), DILUTION WATER RATE
NXB, NUMBER NODE POINTS FOR DISTRIBUTED SOURCE (NXB = 1 FOR POINT SOURCE)

XB(I)(M), DISTANCE TO OUTLET FROM EACH NODE POINT
XK, NUCLIDE SPECIFIC SORPTION COEFF.
D(M2/YR), AQUIFER DISPERSION COEFF.

CLCH(YR-1), NUCLIDE SPECIFIC LEACH CONSTANT
VW(M3), WASTE VOLUME
DG(MREM/YR), DOSE GUIDELINE

USEFAC(M3/YR), WATER UTILIZATION RATE

INDEX NUMBERS FOR PATHWAY MAC¤S TO BE CALCULATED

(1) INHALATION OF DUST
(2) CONSUMPTION OF FOOD
(3) DIRECT GAMMA EXPOSURE
(4) SHEET EROSION
(5) WELL WATER(INGESTION)
(6) GROUNDWATER(INGESTION)

DO YOU WISH TO CALCULATE THESE PATHWAYS WITH THE SITE UNDER ADMINISTRATIVE CONTROL? (YES OR NO, IF YOU WISH TO EXIT AT THIS POINT TYPE EXIT)

SELECT THE LENGTH OF TIME (0, 150, OR 10000 YEARS) FOR WHICH THE PROPER DECAY DAUGHTER INGROWTH ADJUSTMENT FACTOR IS TO BE USED

ENTER THE NUMBER OF NUCLIDES TO BE STUDIED, 1-23

```
ENTER THE  1 NUCLIDE NAME, E.G., RA-226

ENTER INDEX NUMBER (TO CALCULATE) OR ZERO (NOT TO CALCULATE)
FOR EACH OF THE 6 PATHWAYS

ENTER THE  2 NUCLIDE NAME, E.G., RA-226

ENTER INDEX NUMBER (TO CALCULATE) OR ZERO (NOT TO CALCULATE)
FOR EACH OF THE 6 PATHWAYS
```

O M I T T E D

F O R

B R E V I T Y

```
ENTER THE 22 NUCLIDE NAME, E.G., RA-226

ENTER INDEX NUMBER (TO CALCULATE) OR ZERO (NOT TO CALCULATE)
FOR EACH OF THE 6 PATHWAYS

ENTER THE 23 NUCLIDE NAME, E.G., RA-226

ENTER INDEX NUMBER (TO CALCULATE) OR ZERO (NOT TO CALCULATE)
FOR EACH OF THE 6 PATHWAYS
```

DO YOU WISH TO CALCULATE THESE PATHWAYS WITH THE SITE UNDER ADMINISTRATIVE CONTROL? (YES OR NO, IF YOU WISH TO EXIT AT THIS POINT TYPE EXIT)

SELECT THE LENGTH OF TIME (0, 150, OR 10000 YEARS) FOR WHICH THE PROPER DECAY DAUGHTER INGROWTH ADJUSTMENT FACTOR IS TO BE USED

MAXIMUM AVERAGE CONCENTRATIONS FOR NUCLIDES (MICRO-CI/CC)
DECAY DAUGHTER INGROWTH TIME (YR) 150
UNDER ADMINISTRATIVE CONTROL

NUCLIDE	MAC FROM RECLAIMER INHALATION	MAC FROM FOOD PATHWAY	MAC FROM WELL WATER	MAC FROM DIRECT EXPOSURE	(MAC) FROM GROUND WATER	(MAC) FROM SHEET EROSION	MAXIMUM AVERAGE CONCENTRATION
H-3	0.00	3.93+02	1.20+00	0.00	3.88+04	0.00	1.20+00
C-14	1.57+05	2.38-03	5.43+00	0.00	6.24+04	6.21+03	2.38-03
FE-55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO-60	9.70+09*	5.54+07	0.00	0.00	0.00	0.00	5.54+07
SR-90	1.08+03	1.72-02	3.82-03	0.00	0.00	0.00	3.82-03
TC-99	1.00+04*	9.98-02	3.69+01	0.00	1.00+04*	1.00+04*	9.98-02
I-129	6.30+01	2.76-01	7.73-03	4.60+00	9.33+01	8.50+02*	7.73-03
CS-135	2.40+03*	1.88-01	1.60-01	0.00	2.40+03*	8.75+02	1.60-01
CS-137	1.42+05	1.06+00	0.00	8.87-01	0.00	0.00	8.87-01
RA-226	2.98+00	9.16-05	1.10-03	0.00	4.53+02	5.56+00	9.16-05
TH-232	1.28+00*	8.40-01	1.28+00*	0.00	0.00	1.28+00*	8.40-01
U-235	7.13+00	3.01-02	2.27-01	2.16-01	4.10+01*	2.13+01	3.01-02
NP-237	2.07-01	1.78-02	1.11-01	1.93+00	6.40+00*	6.40+00*	1.78-02
U-238	7.63+00	3.15-02	2.38-01	1.10+00	3.62+03	2.23+01	3.15-02
PU-238	4.24-01	1.19+00	0.00	6.09+00	0.00	2.13+02	4.24-01
PU-239	1.15-01	3.50-01	6.45-01	0.00	1.20+06*	2.44+01	1.15-01
PU-240	1.17-01	3.30-01	4.43+00	1.97+00	0.00	2.32+01	1.17-01
PU-241	5.91+03	1.61+04	0.00	0.00	0.00	0.00	5.91+03
PU-242	1.21-01	3.41-01	2.69-01	0.00	6.58+03	2.37+01	1.21-01
AM-241	4.47-01	3.85-01	0.00	4.73-01	0.00	3.25+01	3.85-01
AM-243	3.57-01	3.07-01	3.17+00	1.72-01	0.00	2.16+01	1.72-01
CM-242	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CM-244	1.97+02	1.27+01	0.00	7.29+02	0.00	0.00	1.27+01

APPENDIX C

SAMPLE OF INPUT DATA FORMAT

```
NO
YES
150
23
H-3
0,2,0,0,5,6
500.,0.5,10.,1.6E+3,4.8E+0,110.,0.31,520.,1.2E-2,50.,10.,0.5
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
1.0,10.,0.1,6.3E+5,500.,7.30E-1
10.,10.,2.2E+6,100.,1.577E+10,1
1700
1.0,10.,0.1,6.3E+5,500.,7.30E-1
C-14
1,2,0,4,5,6
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,5.50E+0,110.,3.10E-1,520.,3.10E-2,50.,1.20E+1,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
10.,10.,1.0E-4,6.30E+5,500.,7.30E-1
10.,10.,2.2E+6,100.,1.577E+10,1
1700
10.,10.,1.0E-4,6.30E+5,500.,7.30E-1
FE-55
0,0,0,0,0,0
CO-60
1,2,0,0,0,0
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,9.4E-3,110.,0.31,520.,1.3E-2,50.,1.0,0.5
SR-90
1,2,0,0,5,0
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,1.72E-2,110.,3.10E-1,520.,6.00E-4,50.,8.00E-1,0.5
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
100.,10.,1.0E-2,6.30E+5,500.,7.30E-1
TC-99
1,2,0,4,5,6
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.50E-1,110.,3.10E-1,520.,4.0E-1,50.,2.50E+1,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
1.0,10.,1.0E-4,6.30E+5,500.,7.30E-1
10.,10.,2.2E+6,100.,1.577E+10,1
1700
1.0,10.,1.0E-4,6.30E+5,500.,7.30E-1
I-129
1,2,3,4,5,6
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.0E-2,110.,3.10E-1,520.,2.90E-3,50.,6.00E+0,0.5
2.20E+1,500.,3.7E+4,5.0E-3,3.6E-3,500.,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
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1.0,10.,0.1,6.3E+5,500.,7.30E-1
10.,10.,2.2E+6,100.,1.577E+10,1
1700
1.0,10.,0.1,6.3E+5,500.,7.30E-1
CS-135
1,2,0,4,5,6
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,1.20E-2,110.,3.10E-1,520.,4.0E-3,50.,1.2E+1,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
1.0E+3,10.,1.0E-3,6.30E+5,500.,7.30E-1
10.,10.,2.2E+6,100.,1.577E+10,1
1700
1.0E+3,10.,1.0E-3,6.30E+5,500.,7.30E-1
CS-137
1,2,3,0,0,0
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,1.20E-2,110.,3.10E-1,520.,4.0E-3,50.,1.20E+1,0.5
1.30E+1,500.,3.7E+4,3.10E-3,5.60E-1,500.,0.5
RA-226
1,2,0,4,5,6
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,1.30E-1,110.,3.10E-1,520.,3.40E-2,50.,8.0E+0,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
5.0E+2,10.,1.0E-3,6.30E+5,500.,7.30E-1
10.,10.,2.2E+6,100.,1.577E+10,1
1700
5.0E+2,10.,1.0E-3,6.30E+5,500.,7.30E-1
TH-232
1,2,0,4,5,0
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,4.20E-3,110.,3.10E-1,520.,2.0E-4,50.,5.00E-3,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
5.0E+2,10.,1.0E-5,6.30E+5,500.,7.30E-1
U-235
1,2,3,4,5,6
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.50E-3,110.,3.10E-1,520.,3.40E-4,50.,5.0E-1,0.5
2.10E+1,500.,3.7E+4,2.90E-3,1.26E-1,500.,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
1.4E+4,10.,1.0E-5,6.30E+5,500.,7.30E-1
10.,10.,2.2E+6,100.,1.577E+10,1
1700
1.4E+4,10.,1.0E-5,6.30E+5,500.,7.30E-1
NP-237
1,2,3,4,5,6
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.5E-3,110.,3.10E-1,520.,2.00E-4,50.,5.00E-3,0.5
2.50E+1,500.,3.7E+4,2.71E-3,1.8E-2,500.,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
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10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
1.0E+2,10.,1.0E-5,6.30E+5,500.,7.30E-1
10.,10.,2.2E+6,100.,1.577E+10,1
1700
1.0E+2,10.,1.0E-5,6.30E+5,500.,7.30E-1
U-238
1,2,3,4,5,6
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.50E-3,110.,3.10E-1,520.,3.40E-4,50.,5.0E-1,0.5
1.80E+1,500.,3.7E+4,2.80E-3,2.2E-2,500.,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
1.4E+4,10.,1.0E-5,6.30E+5,500.,7.30E-1
10.,10.,2.2E+6,100.,1.577E+10,1
1700
1.4E+4,10.,1.0E-5,6.30E+5,500.,7.30E-1
PU-238
1,2,3,4,0,0
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.50E-4,110.,3.10E-1,520.,1.40E-5,50.,2.0E-3,0.5
2.50E+1,500.,3.7E+4,4.50E-3,1.12E-2,500.,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
PU-239
1,2,0,4,5,6
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.50E-4,110.,3.10E-1,520.,1.40E-5,50.,2.0E-3,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
1.4E+4,10.,1.0E-5,6.30E+5,500.,7.30E-1
10.,10.,2.2E+6,100.,1.577E+10,1
1700
1.4E+4,10.,1.0E-5,6.30E+5,500.,7.30E-1
PU-240
1,2,3,4,5,0
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.50E-4,110.,3.10E-1,520.,1.40E-5,50.,2.0E-3,0.5
2.50E+1,500.,3.7E+4,4.50E-3,1.08E-2,500.,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
1.4E+4,10.,1.0E-5,6.30E+5,500.,7.30E-1
PU-241
1,2,0,0,0,0
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.50E-4,110.,3.10E-1,520.,1.40E-5,50.,2.0E-3,0.5
PU-242
1,2,0,4,5,6
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.50E-4,110.,3.10E-1,520.,1.40E-5,50.,2.0E-3,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
1.4E+4,10.,1.0E-5,6.30E+5,500.,7.30E-1
10.,10.,2.2E+6,100.,1.577E+10,1
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1700
1.4E+4,10.,1.0E-5,6.30E+5,500.,7.30E-1
AM-241
1,2,3,4,0,0
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.50E-4,110.,3.10E-1,520.,2.0E-4,50.,5.00E-3,0.5
1.80E+1,500.,3.7E+4,2.80E-3,6.50E-2,500.,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
AM-243
1,2,3,4,5,0
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.50E-4,110.,3.10E-1,520.,2.0E-4,50.,5.00E-3,0.5
2.70E+1,500.,3.7E+4,2.70E-3,2.22E-1,500.,0.5
500.,1.57E+10,1.0,0.001,6.3E+5,7.30E-1
10.,10.,2.2E+6,100.,1.4E+6,10
71.,213.,355.,497.,639.,781.,923.,1065.,1207.,1349.
1.4E+4,10.,1.0E-5,6.30E+5,500.,7.30E-1
CM-242
0,0,0,0,0,0
CM-244
1,2,3,0,0,0
500.,5.0E-7,8000.,5.723E-2,0.5,1.6E+3
500.,0.5,10.,1.6E+3,2.50E-3,110.,3.10E-1,520.,2.0E-4,50.,5.00E-3,0.5
2.60E+1,500.,3.7E+4,4.50E-3,9.89E-3,500.,0.5
EXIT
```

APPENDIX D

VARIABLE NAMES AND UNITS

INHALATION PATHWAY VARIABLES

D(MREM/YR), DOSE GUIDELINE
AD(KG/M3), DUST LOADING IN AIR
UA(M3/YR), BREATHING RATE OF EXPOSED
TX(YR), TIME PERIOD OF EXPOSURE
FW, DILUTION FACTOR OF WASTE WITH SOIL OR OTHER MATERIALS
RHO(KG/M3), DENSITY OF WASTE MATERIAL

FOOD CONSUMPTION PATHWAY VARIABLES

D(MREM/YR), DOSE GUIDELINE
FW, DILUTION FACTOR OF WASTE WITH SOIL
F2, MIXING FACTOR FOR BURIED MATERIALS
RHO(KG/M3), DENSITY OF WASTE MATERIAL
BMV, VEGETATIVE BIOACCUMULATION AND UPTAKE FACTOR
UMEAT(KG/YR), MEAT CONSUMPTION RATE
UMILK(M3/YR), MILK CONSUMPTION RATE
UVEG(KG/YR), VEGETABLE CONSUMPTION RATE
FF(DAY/KG), STABLE ELEMENT TRANSFER COEF. ANIMAL TO MEAT
QA(KG/DAY), ANIMAL CONSUMPTION RATE
FM(DAY/M3), STABLE ELEMENT TRANSFER COEF. ANIMAL TO MILK
F3, FRACTION ON ANNUAL FOOD CONSUMPTION PRODUCED ON SITE

DIRECT GAMMA EXPOSURE PATHWAY VARIABLES

MU(M-1),EFFECTIVE GAMMA RAY ATTENUATION
D(MRAD/YR), ABSORBED DOSE RATE
G((/SEC)/MICRO-CI), GAMMA EMISSION RATE
MURHO(M2/KG), MASS ABSORPTION COEFFICIENT FOR TISSUE
EM(MEV), AVERAGE ENERGY OF THE EMITTED GAMMA RAYS TIMES
THE MULTIPLICITY OF AVERAGE ENERGY GAMMA RAYS. SET
EM = 0.0 FOR NUCLIDES WITH NO EMITTED GAMMA RADIATION.
TX(HR/YR), TIME OF EXPOSURE
FW, DILUTION FACTOR OF WASTE WITH SOIL

SHEET EROSION PATHWAY VARIABLES

D(MREM/YR), DOSE GUIDELINE
MT(M3/YR), WATER DILUTION RATE
DD, DILUTION WITH CLEAN DIRT
FE(1/YR), FRACTION OF THE SOIL ERODED AWAY PER YEAR
VW(M3), WASTE VOLUME
UA(M3/YR), WATER UTILIZATION RATE

WELL WATER INGESTION PATHWAY VARIABLES

VA(M/YR), VERTICAL WATER VELOCITY
XA(M), VERTICAL DISTANCE
DWA(M3/YR), DILUTION WATER RATE
VB(M/YR), VELOCITY OF LATERIALLY MOVING WATER(AQUIFER)
DWB(M3/YR), DILUTION WATER RATE
NXB, NUMBER NODE POINTS FOR DISTRIBUTED SOURCE (NXB = 1 FOR POINT SOURCE)
XB(I)(M), DISTANCE TO THE WELL FROM EACH NODE POINT
XK, NUCLIDE SPECIFIC SORPTION COEFF.
D(M2/YR), AQUIFER DISPERSION COEFF.
CLCH(YR-1), NUCLIDE SPECIFIC LEACH CONSTANT
VW(M3), WASTE VOLUME
DG(MREM/YR), DOSE GUIDELINE
USEFAC(M3/YR), WATER UTILIZATION RATE

GROUNDWATER INGESTION PATHWAY VARIABLES

VA(M/YR), VERTICAL WATER VELOCITY
XA(M), VERTICAL DISTANCE
DWA(M3/YR), DILUTION WATER RATE
VB(M/YR), VELOCITY OF LATERIALLY MOVING WATER(AQUIFER)
DWB(M3/YR), DILUTION WATER RATE
NXB, NUMBER NODE POINTS FOR DISTRIBUTED SOURCE (NXB = 1 FOR POINT SOURCE)
XB(I)(M), DISTANCE TO OUTLET FROM EACH NODE POINT
XK, NUCLIDE SPECIFIC SORPTION COEFF.
D(M2/YR), AQUIFER DISPERSION COEFF.
CLCH(YR-1), NUCLIDE SPECIFIC LEACH CONSTANT
VW(M3), WASTE VOLUME
DG(MREM/YR), DOSE GUIDELINE
USEFAC(M3/YR), WATER UTILIZATION RATE

APPENDIX E

PROGRAM LISTING

```
C=136**********************************************************************
C*********************************** CALMAC *******************************
C*************************************************************************
C
C      THIS PROGRAM CALCULATES THE MAXIMUM AVERAGE CONCENTRATIONS FOR
C      6 PATHWAYS
C
       REAL MAC(25,7),D,MINMAC,MU,MT,MURHO
       REAL*8 ATOMAC
       INTEGER TIME
       DIMENSION TABLE1(23,2),TABLE2(23),TABLE5(23),
      $TABLE3(23),TABLE4(23),TABLE6(23),
      $TABL10(23),TABL11(23),TABL12(23),TABL13(23),
      $XNAME(25,2),NPATH(25,7),NROW(25),X(50),B(10),IFLAG1(25,7)
C
C*****DATA TABLES
C
C*****TABLE 1 NUCLIDE NAMES
C
       DATA ((TABLE1(IR,IC),IC=1,2),IR=1,23)/
      $'H-3 ','    ','C-14','    ','FE-5','5   ',
      $'CO-6','0   ','SR-9','0   ','TC-9','9   ',
      $'I-12','9   ','CS-1','35  ','CS-1','37  ',
      $'RA-2','26  ','TH-2','32  ','U-23','5   ',
      $'NP-2','37  ','U-23','8   ','PU-2','38  ',
      $'PU-2','39  ','PU-2','40  ','PU-2','41  ',
      $'PU-2','42  ','AM-2','41  ','AM-2','43  ',
      $'CM-2','42  ','CM-2','44  ' /
C
C*****TABLE 2 NUCLIDE INGESTION DOSE FACTORS (MREM/PICO-CI)
C
       DATA (TABLE2(IR),IR=1,23) /
      $1.05E-7,2.84E-6,2.75E-6,
      $4.02E-5,7.75E-3,4.13E-7,
      $9.22E-6,1.95E-5,1.09E-4,
      $3.45E-3,4.92E-5,8.02E-4,
      $1.38E-3,7.67E-4,6.73E-4,
      $7.06E-4,7.58E-4,1.56E-5,
      $7.22E-4,8.10E-4,8.12E-4,
      $7.92E-5,6.43E-4 /
C
C*****TABLE 3 NUCLIDE DOSE NORMALIZATION FACTORS (YR)
C
       DATA (TABLE3(IR),IR=1,23) /
      $50.,50.,50.,
      $50.,50.,50.,
      $50.,50.,50.,
      $50.,50.,50.,
      $50.,50.,50.,
      $50.,50.,50.,
      $50.,50.,50.,
      $50.,50. /
C
C****TABLE 4 NUCLIDE INHALATION DOSE FACTORS (MREM/PICO-CI)
C
       DATA (TABLE4(IR),IR=1,23) /
```

```
      $1.58E-7,2.27E-6,9.01E-6,
      $7.46E-4,1.24E-2,5.20E-7,
      $5.55E-3,1.46E-5,7.77E-5,
      $1.25E-1,2.23E-1,4.90E-2,
      $1.69E-0,4.58E-2,2.69E-0,
      $3.05E-0,3.04E-0,6.05E-2,
      $2.89E-0,9.93E-1,9.94E-1,
      $3.74E-2,5.90E-1 /
C
C*****TABLE 5 NUCLIDE DECAY CONSTANTS (YR-1)
C
       DATA (TABLE5(IR),IR=1,23) /
      $5.62E-02,1.21E-04,2.57E-01,
      $1.32E-01,2.43E-02,3.26E-06,
      $4.36E-08,3.01E-07,2.30E-02,
      $4.33E-04,6.93E-03,9.85E-10,
      $3.24E-07,1.55E-10,7.89E-03,
      $2.84E-05,1.06E-04,4.62E-02,
      $1.79E-06,1.60E-03,9.40E-05,
      $1.55E-00,3.87E-02 /
C
C*****TABLE 6 ACTIVITY DENSITY (MICRO-CI/CC)
C
       DATA (TABLE6(IR),IR=1,23) /
      $2.90E+9,7.10E+6,1.90E10,
      $9.70E+9,3.60E 8,1.00E+4,
      $8.50E+2,2.40E+3,1.70E+8,
      $4.94E+6,1.28E+0,4.10E+1,
      $6.40E+0,1.30E+4,3.40E+8,
      $1.20E+6,4.70E+6,2.20E+9,
      $7.60E+4,6.40E+7,3.60E+6,
      $6.30E+4,1.60E+9 /
C
C*****TABLE 10 IHALATION DECAY DAUGHTER INGROWTH (150YR)
C
       DATA (TABL10(IR),IR=1,23) /
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,5.00E-3,1.00E+0,
      $1.00E+0,1.00E+0,7.70E-2,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,3.60E-2,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.25E-1,6.20E-1 /
C
C*****TABLE 11 INGESTION DECAY DAUGHTER INGROWTH (150 YR)
C
       DATA (TABL11(IR),IR=1,23) /
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.80E-1,
      $7.70E-1,6.20E-2,1.00E+0,
      $1.00E+0,1.00E+0,1.00E-2,
      $1.00E+0,1.00E+0,7.70E-1,
      $1.00E+0,9.10E-1 /
C
```

```
C*****TABLE 12 INHALATION DECAY DAUGHTER INGROWTH (10000 YR)
C
       DATA (TABL12(IR),IR=1,23) /
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0 /
C
C*****TABLE 13 INGESTION DECAY DAUGHTER INGROWTH (10000 YR)
C
       DATA (TABL13(IR),IR=1,23) /
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0,1.00E+0,
      $1.00E+0,1.00E+0 /
C
C*****END DATA TABLES
C
C*****EXTRA DATA
C
       DATA IBLANK /' '/
       DATA BLANK2 /'      '/
       DATA IASTRC /'*'/
C
C*****PROGRAM OPTIONS
C
C      DATA INPUT MODE
C
       WRITE(6,605)
605    FORMAT(1H1,6X,
      $' THIS PROGRAM HAS 2 DATA INPUT MODES,',/,6X,
      $'     (1) INTERACTIVE,',/,6X,
      $'     (2) NONINTERACTIVE.',/,6X,
      $' IN THE INTERACTIVE DATA INPUT MODE THE PROGRAM',/,6X,
      $' PROMPTS THE USER FOR INPUT DATA WITH DESCRIPTIVE',/,6X,
      $' DATA REQUESTS, AND WILL USE ** 7 ** PAGES FOR',/,6X,
      $' EACH NUCLIDE.  THE NONINTERACTIVE DATA INPUT MODE',/,6X,
      $' DESCRIPTIVELY REQUESTS THE NUMBER OF NUCLIDES TO BE',/,6X,
      $' STUDIED, THE NUCLIDE NAME, AND THE PATHWAYS TO BE USED,',/,6X,
      $' AND WILL USE ** 1 ** PAGE PER NUCLIDE.  ALSO A COPY OF',/,6X,
      $' PATHWAY VARIBLES WILL BE PRINTED ONCE AT THE BEING OF',/,6X,
      $' THE PROGRAM',//,6X,
      $' DO YOU WISH THE ### INTERACTIVE MODE ### (YES OR NO)?',//)
       READ(5,520)INACT
C
       IF(INACT.EQ.'Y') GO TO 110
       CALL PATH1
       CALL PATH2
       CALL PATH3
```

```
             CALL PATH4
             CALL PATH5
             CALL PATH6
      110    CONTINUE
      C
      C        PATHWAYS
      C
             WRITE(6,610)
      610    FORMAT(1H1,6X,
           $' INDEX NUMBERS FOR PATHWAY MAC¤S TO BE CALCULATED',//,6X
           $' (1) INHALATION OF DUST',/,6X,
           $' (2) CONSUMPTION OF FOOD',/,6X,
           $' (3) DIRECT GAMMA EXPOSURE',/,6X,
           $' (4) SHEET EROSION',/,6X,
           $' (5) WELL WATER(INGESTION)',/,6X
           $' (6) GROUNDWATER(INGESTION)'//,)
      C
      C*****TYPE OF SITE CONTROL
      C
      115    WRITE(6,620)
      620    FORMAT(6(/),6X,
           $' DO YOU WISH TO CALCULATE THESE PATHWAYS WITH THE SITE',/,6X,
           $' UNDER ADMINISTRATIVE CONTROL? (YES OR NO, IF YOU',/,6X,
           $' WISH TO EXIT AT THIS POINT TYPE EXIT)',//)
             READ(5,520)IADM
             IF(IADM.EQ.'E') CALL EXIT
             WRITE(6,622)
      622    FORMAT(6X,
           $' SELECT THE LENGTH OF TIME ( 0, 150, OR 10000 YEARS)',/,6X,
           $' FOR WHICH THE PROPER DECAY DAUGHTER INGROWTH ',/,6X,
           $' ADJUSTMENT FACTOR IS TO BE USED',/)
             READ(5,520) TIME
      C
      C*****BLANK-OUT OR ZERO-OUT ARRAYS
      C
             DO 117 IRI = 1,25
             DO 118 ICI = 1,7
             NPATH(IRI,ICI) = 0
      118    IFLAG1(IRI,ICI) = IBLANK
             DO 119 ICI = 1,2
      119    XNAME(IRI,ICI) = BLANK2
      117    CONTINUE
      C
      C*****NUMBER OF NUCLIDES TO BE STUDIED
      C
      122    WRITE(6,630)
      630     FORMAT(1H1,6X,
           $' ENTER THE NUMBER OF NUCLIDES TO BE STUDIED, 1-23',//)
             READ(5,525)NSTUDY
      C
      C*****ENTER NAME OF NUCLIDE TO BE STUDIED, TO BE DONE NSTUDY TIMES
      C
             INUC = 0
      1000   INUC = INUC + 1
             ITRYS = 0
      123    WRITE(6,635)INUC
      635    FORMAT(/,6X,
```

```
         $' ENTER THE ',I2,' NUCLIDE NAME, E.G., RA-226',/)
          READ(5,515)(XNAME(INUC,IL),IL=1,2)
    515   FORMAT(2A4)
    C
    C*****SEARCH LOOKUP TABLES FOR NUCLIDE NAME
    C
          DO 125 IR = 1,23
              IF(TABLE1(IR,1).EQ.XNAME(INUC,1).AND.
         $        TABLE1(IR,2).EQ.XNAME(INUC,2)) GO TO 130
    125   CONTINUE
    C
    C*****NUCLIDE NAME NOT FOUND
    C
          WRITE(6,640)
    640   FORMAT(1H1,6X,
         $' NUCLIDE NOT FOUND IN TABLES',/)
          WRITE(6,641)
    641   FORMAT(1H1,6X,
         $' NUCLIDE TABLE')
          DO 127 II =1,23
    127   WRITE(6,642)(TABLE1(II,IC),IC=1,2)
    642   FORMAT(7X,2A4)
          ITRYS = ITRYS + 1
          IF(ITRYS.GE.4) STOP XNAME
          WRITE(6,643)
    643   FORMAT(1H1,6X,
         $' PLEASE USE ONLY THE ABOVE SPECIFIED NUCLIDE NAMES',/,6X,
         $' DO YOU NEED TO CHANGE THE NUMBER OF CASE TO BE STUDIED?(Y OR N)'
         $)
          READ(5,520)CHANGE
    520   FORMAT(1A1)
          IF(CHANGE.EQ.'Y') WRITE(6,631)
    631   FORMAT(/,6X,
         $' REENTER THE NUMBER OF NUCLIDES TO BE STUDIED,1-23',/,)
          IF(CHANGE.EQ.'Y') READ(5,525)NSTUDY
          GO TO 123
    130   CONTINUE
          NROW(INUC) = IR
    C
    C*****PATHWAYS TO BE CALCULATED FOR THIS NUCLIDE
    C
    132   WRITE(6,645)
    645   FORMAT(/,6X,
         $' ENTER INDEX NUMBER (TO CALCULATE) OR ZERO (NOT TO CALCULATE)',/,
         $6X,' FOR EACH OF THE 6 PATHWAYS' )
          READ(5,525)(NPATH(INUC,IPATH),IPATH =1,6)
    525   FORMAT( )
    C
          DO 135 ITEST = 1,6
          NP = NPATH(INUC,ITEST)
          IF(NP.EQ.0.OR.NP.EQ.ITEST) GO TO 135
          WRITE(6,647)
    647   FORMAT(/,6X,' PATHWAY INDEX NUMBERS INCORRECT')
          GO TO 132
    135   CONTINUE
    C
    C*****GO TO APPROPRIATE PATHWAY ROUTINE
```

```
C
      IROW = NROW(INUC)
      XLAMD = TABLE5(IROW)
      DOSFAC = TABLE2(IROW)
      DOSINH = TABLE4(IROW)
      DAF = TABLE3(IROW)
      DUGAFW = 1.0
      DUGAFA = 1.0
      IF(TIME.NE.150) GO TO 141
      DUGAFA = TABL10(IROW)
      DUGAFW = TABL11(IROW)
141   IF(TIME.NE.10000) GO TO 143
      DUGAFA = TABL12(IROW)
      DUGAFW = TABL13(IROW)
143   CONTINUE
      TD = 1.0
      VALUE1 = 150*XLAMD
      IF(VALUE1.GT.80.) VALUE1=80.
      IF(IADM.EQ.'Y') TD=EXP(VALUE1)
      VALUE2 = 120*XLAMD
      IF(VALUE2.GT.80.) VALUE2=80.
      MAC(INUC,1) = IROW
C
      DO 999 IJ =1,6
      IERROR = 0
      JI = IJ + 1
      J=NPATH(INUC,IJ) + 1
      GO TO(999,10,20,30,40,50,60),J
C
10    CONTINUE
C
C*****INHALATION PATHWAY
C
      IF(INACT.EQ.'N') GO TO 1611
      WRITE(6,1610)XNAME(INUC,1),XNAME(INUC,2)
1610  FORMAT(1H1,6X
     $' INHALATION PATHWAY VARIABLES FOR NUCLIDE ',2A4,//,6X,
     $' D(MREM/YR), DOSE GUIDELINE',/,6X,
     $' AD(KG/M3), DUST LOADING IN AIR',/,6X,
     $' UA(M3/YR), BREATHING RATE OF EXPOSED',/,6X,
     $' TX(YR), TIME PERIOD OF EXPOSURE',/,6X,
     $' FW, DILUTION FACTOR OF WASTE WITH SOIL OR OTHER MATERIALS',/,6X,
     $' RHO(KG/M3), DENSITY OF WASTE MATERIAL',//)
1611  CONTINUE
      READ(5,525) D,AD,UA,TX,FW,RHO
      IF(IADM.EQ.'Y') DOSINH=DOSINH/DAF
      TOP = D*TD*RHO*DUGAFA
      BOTTOM  = AD*UA*TX*FW*DOSINH
      MAC(INUC,JI) = 1.00E-12*TOP/BOTTOM
C*****MAC(MICRO-CI/CM3), MAX. AVERAGE CONCENTRATION
      GO TO 999
C
20    CONTINUE
C
C*****FOOD CONSUMPTION PATHWAY
C
      IF(INACT.EQ.'N') GO TO 2611
```

```
      WRITE(6,2610)XNAME(INUC,1),XNAME(INUC,2)
2610  FORMAT(1H1,6X,
     $' FOOD CONSUMPTION PATHWAY VARIABLES FOR NUCLIDE ',2A4,//,6X,
     $' D(MREM/YR), DOSE GUIDELINE',/,6X,
     $' FW, DILUTION FRACTION OF WASTE WITH SOIL',/,6X,
     $' F2, MIXING FACTOR FOR BURIED MATERIALS',/,6X,
     $' RHO(KG/M3), DENSITY OF WASTE MATERIAL',/,6X,
     $' BMV, VEGETATIVE BIOACCUMULATION AND UPTAKE FACTOR',/,6X,
     $' UMEAT(KG/YR), MEAT CONSUMPTION RATE',/,6X,
     $' UMILK(M3/YR), MILK CONSUMPTION RATE',/,6X,
     $' UVEG(KG/YR), VEGETABLE CONSUMPTION RATE',/,6X,
     $' FF(DAY/KG), STABLE ELEMENT TRANSFER COEF. ANIMAL TO MEAT',/,6X,
     $' QA(KG/DAY), ANIMAL CONSUMPTION RATE',/,6X,
     $' FM(DAY/M3), STABLE ELEMENT TRANSFER COEF. ANIMAL TO MILK',/,6X,
     $' F3, FRACTION ON ANNUAL FOOD CONSUMPTION PRODUCED ON SITE',//)
2611  CONTINUE
      READ(5,525)D,FW,F2,RHO,BMV,UMEAT,UMILK,UVEG,FF,QA,FM,F3
      TOP = D*F2*TD*RHO*DUGAFW
      BOTTOM = DOSFAC*BMV*F3*FW*(UMEAT*FF*QA+UMILK*FM*QA+UVEG)
      MAC(INUC,JI) = 1.00E-12*TOP/BOTTOM
C*****MAC(MICRO-CI/CM3), MAX. AVERAGE CONCENTRATION
      GO TO 999
C
30    CONTINUE
C
C*****DIRECT GAMMA EXPOSURE PATHWAY
C
      IF(INACT.EQ.'N') GO TO 3611
      WRITE(6,3610)XNAME(INUC,1),XNAME(INUC,2)
3610  FORMAT(1H1,6X,
     $' DIRECT GAMMA EXPOSURE PATHWAY VARIABLES FOR NUCLIDE ',2A4,//,6X,
     $' MU(M-1),EFFECTIVE GAMMA RAY ATTENUATION',/,6X,
     $' D(MRAD/YR), ABSORBED DOSE RATE',/,6X,
     $' G(( /SEC)/MICRO-CI), GAMMA EMISSION RATE ',/,6X,
     $' MURHO(M2/KG), MASS ABSORPTION COEFFICIENT FOR TISSUE',/,6X,
     $' EM(MEV), AVERAGE ENERGY OF THE EMITTED GAMMA RAYS TIMES',/,6X,
     $'  THE MULTIPLICITY OF AVERAGE ENERGY GAMMA RAYS.  SET ',/,6X,
     $'  EM = 0.0 FOR NUCLIDES WITH NO EMITTED GAMMA RADIATION.',/,6X,
     $' TX(HR/YR), TIME OF EXPOSURE',/,6X,
     $' FW, DILUTION FACTOR OF WASTE WITH SOIL',//)
3611  CONTINUE
      READ(5,525)MU,D,G,MURHO,EM,TX,FW
      IF(EM.EQ.0.0)GO TO 999
      TOP = 2.*MU*D*TD
      BOTTOM = 0.0575*G*MURHO*EM*TX*FW*0.5
      MAC(INUC,JI) = 1.00E-3*TOP/BOTTOM
C*****MAC(MICRO-CI/CM3) MAX. AVERAGE CONCENTRATION
      GO TO 999
C
40    CONTINUE
C
C*****SHEET EROSION PATHWAY
C
      IF(INACT.EQ.'N') GO TO 4611
      WRITE(6,4610)XNAME(INUC,1),XNAME(INUC,2)
4610  FORMAT(1H1,6X,
     $' SHEET EROSION PATHWAY VARIABLES FOR NUCLIDE ',2A4,//,6X,
```

```
               $' D(MREM/YR), DOSE GUIDELINE',/,6X,
               $' MT(M3/YR), WATER DILUTION RATE',/,6X,
               $' DD, DILUTION WITH CLEAN DIRT',/,6X,
               $' FE(1/YR), FRACTION OF THE SOIL ERODED AWAY PER YEAR',/,6X,
               $' VW,(M3), WASTE VOLUME',/,6X,
               $' UA(M3/YR), WATER UTILIZATION RATE',//)
      4611     CONTINUE
               READ(5,525)D,MT,DD,FE,VW,UA
               TOP = D*MT*DD*EXP(VALUE2)*TD*DUGAFW
               BOTTOM = FE*UA*DOSFAC*VW
               MAC(INUC,JI) = 1.00E-12*TOP/BOTTOM
      C*****MAC(MICRO-CI/CM3) MAX. AVERAGE CONCENTRATION
               GO TO 999
      C
      50       CONTINUE
      C
      C*****INGESTION (WELL WATER) PATHWAY
      C
               IF(INACT.EQ.'N') GO TO 5611
               WRITE(6,5610)XNAME(INUC,1),XNAME(INUC,2)
      5610     FORMAT(1H1,6X,
               $' WELL WATER INGESTION PATHWAY VARIABLES FOR NUCLIDE ',2A4,//,6X,
               $' VA(M/YR), VERTICAL WATER VELOCITY',/,6X,
               $' XA(M),VERTICAL DISTANCE',/,6X,
               $' DWA(M3/YR), DILUTION WATER RATE',/,6X,
               $' VB(M/YR), VELOCITY OF LATERIALLY MOVING WATER(AQUIFER)',/,6X,
               $' DWB(M3/YR), DILUTION WATER RATE',/,6X,
               $' NXB, NUMBER NODE POINTS FOR DISTRIBUTED SOURCE (NXB = 1 FOR',/,
               $6X,' POINT SOURCE)',/,6X,
               $' XB(I)(M), DISTANCE TO THE WELL FROM EACH NODE POINT',/,6X,
               $' XK, NUCLIDE SPECIFIC SORPTION COEFF.',/,6X,
               $' D(M2/YR), AQUIFER DISPERSION COEFF.',/,6X,
               $' CLCH(YR-1), NUCLIDE SPECIFIC LEACH CONSTANT',/,6X,
               $' VW(M3), WASTE VOLUME')
               WRITE(6,5609)
      5609     FORMAT(6X,
               $' DG(MREM/YR), DOSE GUIDELINE',/,6X,
               $' USEFAC(M3/YR), WATER UTILIZATION RATE',//)
      5611     CONTINUE
               READ(5,525)X(1),X(2),X(3),X(4),X(5),IX1
               INUM = IX1 + 5
               READ(5,525)(X(IN),IN=6,INUM)
               READ(5,525)B(1),B(2),CLCH,VW,DG,USEFAC
               DWA = X(3)
               DWB = X(5)
               GAG = CLCH + XLAMD
               B(3) = GAG
               CALL AUTOMI(X,IX1,B,XLAMD,ATOMAC,IERROR)
               IF(IERROR-0) 999,5615,999
      5615     TOP = DWB*DG*DUGAFW
               FZERO = ((1.-EXP(-40.*GAG))/(40.*GAG))*ATOMAC
               BOTTOM = CLCH*FZERO*USEFAC*VW*DOSFAC
               MAC(INUC,JI) = 1.00E-12*TOP/BOTTOM
      C*****MAC(MICRO-CI/CM3) MAX. AVERAGE CONCENTRATION
               GO TO 999
      C
      60       CONTINUE
```

```
C
C*****INGESTION (GROUNDWATER) PATHWAY
C
      IF(INACT.EQ.'N') GO TO 6611
      WRITE(6,6610)XNAME(INUC,1),XNAME(INUC,2)
 6610 FORMAT(1H1,6X,
     $' GROUNDWATER INGESTION PATHWAY VARIABLES FOR NUCLIDE ',2A4,//,6X,
     $' VA(M/YR), VERTICAL WATER VELOCITY',/,6X,
     $' XA(M),VERTICAL DISTANCE',/,6X,
     $' DWA(M3/YR), DILUTION WATER RATE',/,6X,
     $' VB(M/YR), VELOCITY OF LATERIALLY MOVING WATER(AQUIFER)',/,6X,
     $' DWB(M3/YR), DILUTION WATER RATE',/,6X,
     $' NXB, NUMBER NODE POINTS FOR DISTRIBUTED SOURCE (NXB = 1 FOR',/,
     $6X,' POINT SOURCE)',/,6X,
     $' XB(I)(M), DISTANCE TO OUTLET FROM EACH NODE POINT',/,6X,
     $' XK, NUCLIDE SPECIFIC SORPTION COEFF.',/,6X,
     $' D(M2/YR), AQUIFER DISPERSION COEFF.',/,6X,
     $' CLCH(YR-1), NUCLIDE SPECIFIC LEACH CONSTANT',/,6X,
     $' VW(M3), WASTE VOLUME')
      WRITE(6,6609)
 6609 FORMAT(6X,
     $' DG(MREM/YR), DOSE GUIDELINE',/,6X,
     $' USEFAC(M3/YR), WATER UTILIZATION RATE',//)
 6611 CONTINUE
      READ(5,525)X(1),X(2),X(3),X(4),X(5),IX1
      INUM = IX1 + 5
      READ(5,525)(X(IN),IN=6,INUM)
      READ(5,525)B(1),B(2),CLCH,VW,DG,USEFAC
      DWA = X(3)
      DWB = X(5)
      GAG = CLCH + XLAMD
      B(3) = GAG
      CALL AUTOMI(X,IX1,B,XLAMD,ATOMAC,IERROR)
      IF(IERROR-0) 999,6615,999
 6615 TOP = DWB*DG*DUGAFW
      FZERO = ((1.-EXP(-40.*GAG))/(40.*GAG))*ATOMAC
      BOTTOM = CLCH*FZERO*USEFAC*VW*DOSFAC
      MAC(INUC,JI) = 1.00E-12*TOP/BOTTOM
C*****MAC(MICRO-CI/CM3) MAX. AVERAGE CONCENTRATION
      GO TO 999
C
  999 CONTINUE
      IF(INUC.LT.NSTUDY) GO TO 1000
C
C*****OUTPUT OF MAC'S FOR NUCLIDES AND PATHWAYS
C
C*****PRINT TITLES AND HEADINGS
C
      WRITE(6,650)
  650 FORMAT(1H1,6(/),T18,19X,
     $'MAXIMUM AVERAGE CONCENTRATIONS FOR NUCLIDES  (MICRO-CI/CC)')
      IF(TIME.NE.0)WRITE(6,653)TIME
  653 FORMAT(T47,'DECAY DAUGHTER INGROWTH TIME (YR) ',A5)
      IF(IADM.EQ.'N') WRITE(6,659)
  659 FORMAT(T50,' NO ADMINISTRATIVE CONTROL')
      IF(IADM.EQ.'Y') WRITE(6,651)
  651 FORMAT(T49,' UNDER ADMINISTRATIVE CONTROL')
```

```
      WRITE(6,654)
  654 FORMAT(//,T18,11X,
     $'MAC FROM    MAC FROM',16X,'MAC FROM    (MAC) FROM',3X,
     $'(MAC) FROM      MAXIMUM',/,T18,11X,
     $'RECLAIMER    FOOD      MAC FROM    DIRECT      GROUND',8X,
     $'SHEET        AVERAGE',/,T18,
     $'NUCLIDE   INHALATION   PATHWAY   WELL WATER   EXPOSURE',6X,
     $'WATER      EROSION   CONCENTRATION',/,T18,
     $'=======  ==========  ========  =========  ========',3X,
     $'==========  ==========  ==============',/)
C
      IP3 = 0
      DO 1100 IPTROW =1,23
      DO 1110 IP = 1,NSTUDY
      IF(IPTROW.NE.MAC(IP,1)) GO TO 1110
      IP3 = IP3 + 1
      DO 1118 ITEST = 2,7
      IIROW = MAC(IP,1)
      IF(MAC(IP,ITEST).LE.TABLE6(IIROW)) GO TO 1118
      MAC(IP,ITEST) = TABLE6(IIROW)
      IFLAG1(IP,ITEST) = IASTRC
 1118 CONTINUE
      DO 1119 IZERO = 2,7
      IF(MAC(IP,IZERO).EQ.0.0) GO TO 1119
      MINMAC = MAC(IP,IZERO)
      GO TO 1117
 1119 CONTINUE
 1117 CONTINUE
      DO 1120 IMIN = 2,7
      IF(MAC(IP,IMIN).EQ.0.0) GO TO 1120
      IF(MINMAC.GT.MAC(IP,IMIN))MINMAC = MAC(IP,IMIN)
 1120 CONTINUE
      WRITE(6,655)(XNAME(IP,IX),IX=1,2),
     $MAC(IP,2),IFLAG1(IP,2),MAC(IP,3),IFLAG1(IP,3),
     $MAC(IP,6),IFLAG1(IP,6),MAC(IP,4),IFLAG1(IP,4),
     $MAC(IP,7),IFLAG1(IP,7),MAC(IP,5),IFLAG1(IP,5),
     $MINMAC
  655 FORMAT(T18,2A4,
     $5(3X,1PE8.2,1A1),4X,1PE8.2,1A1,5X,1PE8.2)
      MINMAC = 0.0
      IF(IP3.GE.3)WRITE(6,660)
  660 FORMAT(T10)
      IF(IP3.GE.3) IP3 = 0
 1110 CONTINUE
 1100 CONTINUE
      WRITE(6,670)
  670 FORMAT(1X,50(/))
      DO 1114 IIR = 1,25
      DO 1113 IIC = 1,7
 1113 MAC(IIR,IIC) = 0.0
 1114 CONTINUE
      ITIMES = ITIMES + 1
      IF(ITIMES.GE.2) GO TO 99999
      GO TO 115
99999 STOP
C
C
```

```
C*****SUBROUTINE PATH1
C
      SUBROUTINE PATH1
      WRITE(6,1610)
 1610 FORMAT(1H1,6X
     $' INHALATION PATHWAY VARIABLES ',//,6X,
     $' D(MREM/YR), DOSE GUIDELINE',/,6X,
     $' AD(KG/M3), DUST LOADING IN AIR',/,6X,
     $' UA(M3/YR), BREATHING RATE OF EXPOSED',/,6X,
     $' TX(YR), TIME PERIOD OF EXPOSURE',/,6X,
     $' FW, DILUTION FACTOR OF WASTE WITH SOIL OR OTHER MATERIALS',/,6X,
     $' RHO(KG/M3), DENSITY OF WASTE MATERIAL',//)
      RETURN
C
C*****SUBROUTINE PATH2
C
      SUBROUTINE PATH2
      WRITE(6,2610)
 2610 FORMAT(1H1,6X,
     $' FOOD CONSUMPTION PATHWAY VARIABLES ',//,6X,
     $' D(MREM/YR), DOSE GUIDELINE',/,6X,
     $' FW, DILUTION FACTOR OF WASTE WITH SOIL',/,6X,
     $' F2, MIXING FACTOR FOR BURIED MATERIALS',/,6X,
     $' RHO(KG/M3), DENSITY OF WASTE MATERIAL',/,6X,
     $' BMV, VEGETATIVE BIOACCUMULATION AND UPTAKE FACTOR',/,6X,
     $' UMEAT(KG/YR), MEAT CONSUMPTION RATE',/,6X,
     $' UMILK(M3/YR), MILK CONSUMPTION RATE',/,6X,
     $' UVEG(KG/YR), VEGETABLE CONSUMPTION RATE',/,6X,
     $' FF(DAY/KG), STABLE ELEMENT TRANSFER COEF. ANIMAL TO MEAT',/,6X,
     $' QA(KG/DAY), ANIMAL CONSUMPTION RATE',/,6X,
     $' FM(DAY/M3), STABLE ELEMENT TRANSFER COEF. ANIMAL TO MILK',/,6X,
     $' F3, FRACTION ON ANNUAL FOOD CONSUMPTION PRODUCED ON SITE',//)
      RETURN
C
C*****SUBROUTINE PATH3
C
      SUBROUTINE PATH3
      WRITE(6,3610)
 3610 FORMAT(1H1,6X,
     $' DIRECT GAMMA EXPOSURE PATHWAY VARIABLES ',//,6X,
     $' MU(M-1),EFFECTIVE GAMMA RAY ATTENUATION',/,6X,
     $' D(MRAD/YR), ABSORBED DOSE RATE',/,6X,
     $' G(( /SEC)/MICRO-CI), GAMMA EMISSION RATE ',/,6X,
     $' MURHO(M2/KG), MASS ABSORPTION COEFFICIENT FOR TISSUE',/,6X,
     $' EM(MEV), AVERAGE ENERGY OF THE EMITTED GAMMA RAYS TIMES',/,6X,
     $'  THE MULTIPLICITY OF AVERAGE ENERGY GAMMA RAYS.  SET ',/,6X,
     $'  EM = 0.0 FOR NUCLIDES WITH NO EMITTED GAMMA RADIATION.',/,6X,
     $' TX(HR/YR), TIME OF EXPOSURE',/,6X,
     $' FW, DILUTION FACTOR OF WASTE WITH SOIL',//)
      RETURN
C
C*****SUBROUTINE PATH4
C
      SUBROUTINE PATH4
      WRITE(6,4610)
 4610 FORMAT(1H1,6X,
     $' SHEET EROSION PATHWAY VARIABLES ',//,6X,
```

```
     $' D(MREM/YR), DOSE GUIDELINE',/,6X,
     $' MT(M3/YR), WATER DILUTION RATE',/,6X,
     $' DD, DILUTION WITH CLEAN DIRT',/,6X,
     $' FE(1/YR), FRACTION OF THE SOIL ERODED AWAY PER YEAR',/,6X,
     $' VW(M3), WASTE VOLUME',/,6X,
     $' UA(M3/YR), WATER UTILIZATION RATE',//)
      RETURN
C
C*****SUBROUTINE PATH5
C
      SUBROUTINE PATH5
      WRITE(6,5610)
5610  FORMAT(1H1,6X,
     $' WELL WATER INGESTION PATHWAY VARIABLES ',//,6X,
     $' VA(M/YR), VERTICAL WATER VELOCITY',/,6X,
     $' XA(M),VERTICAL DISTANCE',/,6X,
     $' DWA(M3/YR), DILUTION WATER RATE',/,6X,
     $' VB(M/YR), VELOCITY OF LATERIALLY MOVING WATER(AQUIFER)',/,6X,
     $' DWB(M3/YR), DILUTION WATER RATE',/,6X,
     $' NXB, NUMBER NODE POINTS FOR DISTRIBUTED SOURCE (NXB = 1 FOR',/,
     $6X,' POINT SOURCE)',/,6X,
     $' XB(I)(M), DISTANCE TO THE WELL FROM EACH NODE POINT',/,6X,
     $' XK, NUCLIDE SPECIFIC SORPTION COEFF.',/,6X,
     $' D(M2/YR), AQUIFER DISPERSION COEFF.',/,6X,
     $' CLCH(YR-1), NUCLIDE SPECIFIC LEACH CONSTANT',/,6X,
     $' VW(M3), WASTE VOLUME')
      WRITE(6,5609)
5609  FORMAT(6X,
     $' DG(MREM/YR), DOSE GUIDELINE',/,6X,
     $' USEFAC(M3/YR), WATER UTILIZATION RATE',//)
      RETURN
C
C*****SUBROUTINE PATH6
C
      SUBROUTINE PATH6
      WRITE(6,6610)
6610  FORMAT(1H1,6X,
     $' GROUNDWATER INGESTION PATHWAY VARIABLES ',//,6X,
     $' VA(M/YR), VERTICAL WATER VELOCITY',/,6X,
     $' XA(M),VERTICAL DISTANCE',/,6X,
     $' DWA(M3/YR), DILUTION WATER RATE',/,6X,
     $' VB(M/YR), VELOCITY OF LATERIALLY MOVING WATER(AQUIFER)',/,6X,
     $' DWB(M3/YR), DILUTION WATER RATE',/,6X,
     $' NXB, NUMBER NODE POINTS FOR DISTRIBUTED SOURCE (NXB = 1 FOR',/,
     $6X,' POINT SOURCE)',/,6X,
     $' XB(I)(M), DISTANCE TO OUTLET FROM EACH NODE POINT',/,6X,
     $' XK, NUCLIDE SPECIFIC SORPTION COEFF.',/,6X,
     $' D(M2/YR), AQUIFER DISPERSION COEFF.',/,6X,
     $' CLCH(YR-1), NUCLIDE SPECIFIC LEACH CONSTANT',/,6X,
     $' VW(M3), WASTE VOLUME')
      WRITE(6,6609)
6609  FORMAT(6X,
     $' DG(MREM/YR), DOSE GUIDELINE',/,6X,
     $' USEFAC(M3/YR), WATER UTILIZATION RATE',//)
      RETURN
      END
```

```
      SUBROUTINE AUTOMI(XREAL,IX1,BREAL,XLAMD,ATOMAC,IERROR)
      REAL XREAL(50),BREAL(10),XLAMD
      IMPLICIT DOUBLE PRECISION(A-H,O-Z)
      COMMON CA(300),CB(300),TA(300),TB(300),XLAM,GA,XB(20),SUM2(300)
      N=0
    5 SUM1=0.
      DO 54 J=1,300
      TA(J)=0.
      TB(J)=0.
      CA(J)=0.
      CB(J)=0.
      AXCA = 0.0
      AXCB = 0.0
   54 SUM2(J)=0.
      VA = XREAL(1)
      XA = XREAL(2)
      DWA = XREAL(3)
      VB = XREAL(4)
      DWB = XREAL(5)
      NXB = IX1
      JEND = IX1 + 5
      DO 5000 ITRANS =6,JEND
 5000 XB(ITRANS-5) = XREAL(ITRANS)
      XK = BREAL(1)
      D = BREAL(2)
      GA = BREAL(3)
      XLAM = XLAMD
      TSA = 0.2*XK*XA/VA
      TFA = 1.0E+8
      TFB = 1.0E+8
      THALF = 0.69314/GA
      TEND = 60.*THALF
      CHECK = VA**2./(4.*XK*(GA-XLAM))
      IF(D.GT.CHECK)D=0.5*CHECK
      C1 = 1.0
      I=0
      T=TSA
      AA=DSQRT(XK/D)*XA
      BRADA=((VA**2)/(4.*D*XK)+XLAM-GA)
      IF(BRADA.LT.0.)GO TO 30
      D1=DSQRT(BRADA)
   20 ARGA1=XA*VA/(2.*D)-GA*T-AA*D1
      ARGA2=(AA-2.*D1*T)/(2.*DSQRT(T))
      ARGA4 = (AA+2.*T*D1)/(2.*DSQRT(T))
      ARGA3 = XA*VA/(2.*D)-GA*T +AA*D1
      CALL MERFCD(ARGA2,ERFC1)
      IF(ARGA4.GT.25.)GO TO 22
      IF(ARGA3.GT.691.)GO TO 33
      E1=DEXP(ARGA3)
      CALL MERFCD(ARGA4,ERFC4)
      GO TO 26
   22 E1=0.
      ERFC4=0.
   26 I=I+1
      DT=.05
      IF(T.GE..15)DT=.05
```

```
      IF(T.GE.1.5)DT=.5
      IF(T.GE.15.)DT=5.
      IF(T.GE.150.)DT=50.
      IF(T.GE.1500.)DT=500.
      IF(T.GE.15000.)DT=5000.
      IF(T.GE.150000.)DT=50000.
      IF(T.GE.1500000.)DT=500000.
      IF(T.GE.15000000.)DT=5000000.
      TA(I)=T
      CA(I)=0.5*C1*(DEXP(ARGA1)*ERFC1+E1*ERFC4)
      IF(I.EQ.1) GO TO 1599
      IF(CA(I).GT.CA(I-1))AXCA=CA(I)
 1599 CONTINUE
      IF(I.EQ.1)GO TO 21
      IF(I.GT.1)SUM1=SUM1+0.5*(CA(I-1)+CA(I))*DT
   21 CONTINUE
      T=T+DT
      IF(CA(I).LT.(AXCA/1.0E+10)) GO TO 1600
      IF(TA(I).GT.TEND) GO TO 1600
      IF(T.LE.TFA)GO TO 20
 1600 CONTINUE
      IF(XB(1).LT..1)GO TO 55
      IEND=I
   40 CALL FIT(GB,GC,C3,JTAU,IEND,IFLAG)
      IF(IFLAG.EQ.1)GO TO 55
      TAU=TA(JTAU)
      BRADB1=((VB**2)/(4.*D*XK)+XLAM-GB)
      IF(BRADB1.LT.0.)GO TO 31
      BRADB2=((VB**2)/(4.*D*XK)+XLAM-GC)
      IF(BRADB2.LT.0)GO TO 32
      D2=DSQRT(BRADB1)
      D3=DSQRT(BRADB2)
      IENDB = 0
      DO 53 J=1,NXB
      AB=DSQRT(XK/D)*XB(J)
      I=0
      T=TAU
   50 ARG3=VB*XB(J)/(2.*D)-GB*(T-TAU)-AB*D2
      ARG4=VB*XB(J)/(2.*D)-GC*(T-TAU)-AB*D3
      ARG5=(AB-2.*D2*T)/(2.*DSQRT(T))
      ARG6=(AB-2.*D3*T)/(2.*DSQRT(T))
      ARG7=VB*XB(J)/(2.*D)-GB*(T-TAU)+AB*D2
      ARG8=VB*XB(J)/(2.*D)-GC*(T-TAU)+AB*D3
      ARG9=(AB+2.*D2*T)/(2.*DSQRT(T))
      ARG10=(AB+2.*D3*T)/(2.*DSQRT(T))
      CALL MERFCD(ARG5,ERFC2)
      CALL MERFCD(ARG6,ERFC3)
      IF(ARG9.GT.25.)GO TO 23
      IF(ARG7.GT.691.)GO TO 34
      E1=DEXP(ARG7)
      CALL MERFCD(ARG9,ERFC9)
      GO TO 27
   23 E1=0.
      ERFC9=0.
   27 IF(ARG10.GT.25.)GO TO 24
      IF(ARG8.GT.691.)GO TO 35
      E2=DEXP(ARG8)
```

```
      CALL MERFCD(ARG10,ERFC10)
      GO TO 28
24    E2=0.
      ERFC10=0.
28    I=I+1
      DT=.05
      IF(T.GE..15)DT=.05
      IF(T.GE.1.5)DT=.5
      IF(T.GE.15.)DT=5.
      IF(T.GE.150.)DT=50.
      IF(T.GE.1500.)DT=500.
      IF(T.GE.15000.)DT=5000.
      IF(T.GE.150000.)DT=50000.
      IF(T.GE.1500000.)DT=500000.
      IF(T.GE.15000000.)DT=5000000.
      TB(I)=T
      FAC=DEXP(ARGC)*ERFC2-DEXP(ARG4)*ERFC3+E1*ERFC9-E2*ERFC10
      IF(FAC.LT.0.)CB(I)=CB(I)+0.
      IF(FAC.LT.0.)GO TO 52
      CB(I)=0.5*C3*FAC+CB(I)
      IENDB=MAX(IENDB,I)
      IF(I.EQ.1) GO TO 1699
      IF(CB(I).GT.CB(I-1)) AXCB =CB(I)
1699  CONTINUE
52    IF(I.EQ.1)GO TO 51
      SUM2(I)=SUM2(I-1)+0.5*(CB(I-1)+CB(I))*DT
51    T=T+DT
      IF(CB(I).LT.(AXCB/1.0E+10)) GO TO 1700
      IF(TB(I).GT.TEND) GO TO 1700
      IF(T.LE.TEB) GO TO 50
1700  CONTINUE
53    CONTINUE
      CBMAX=CB(1)
      IF(IENDB.EQ.1) GO TO 57
      DO 56 IMAX=2,IENDB
      IF(CBMAX.LT.CB(IMAX))CBMAX=CB(IMAX)
56    CONTINUE
57    CONTINUE
55    IERROR = IFLAG
      ATOMAC = CBMAX
      IERROR = IFLAG
      RETURN
30    IFLAG = 2
      GO TO 55
31    IFLAG = 3
      GO TO 55
32    IFLAG = 4
      GO TO 55
33    IFLAG = 5
      GO TO 55
34    FLAG = 6
      GO TO 55
35    IFLAG = 7
      GO TO 55
      SUBROUTINE FIT (GB,GC,A,JTAU,IEND,IFLAG)
      IMPLICIT DOUBLE PRECISION(A-H,O-Z)
      COMMON CA(300),CB(300),TA(300),TB(300),XLAM,GA
```

```
      CALL LOCATE(CMAX,JMAX,JSL,JTAU,IEND,IFLAG)
      IF(IFLAG.EQ.1)RETURN
      GB=GA
      T11=TA(JTAU)
      T12=TA(JSL)
      A=CA(JSL)*DEXP(GA*(TA(JSL)-TA(JTAU)))
      Q=A
      S1=Q*DEXP(-GA*(TA(JMAX)-TA(JTAU)))
      GC=(DLOG(Q)-DLOG(S1-CMAX))/(TA(JMAX)-TA(JTAU))
      T1=TA(JTAU)
      T2=TA(JMAX)
      T3=TA(JSL)
      C1=CA(JTAU)
      C2=CMAX
      C4=CA(JSL)
      RETURN
      SUBROUTINE LOCATE(CMAX,JMAX,JSL,JTAU,IEND,IFLAG)
      IMPLICIT DOUBLE PRECISION(A-H,O-Z)
      COMMON CA(300),CB(300),TA(300),TB(300),XLAM,GA
      IFLAG=0
      DO 10 J=1,IEND
      IF(CA(J+1).GT.CA(J))CMAX=CA(J+1)
      IF(CA(J+1).GT.CA(J))JMAX=J+1
   10 CONTINUE
      CTAU=0.1*CMAX
      DO 20 J=1,JMAX
      IF(CA(J+1).GT.CTAU)JTAU=J
      IF(CA(J+1).GT.CTAU)GO TO 30
   20 CONTINUE
      IFLAG=1
      RETURN
   30 CSL=(1.E-10)*CMAX
      DO 40 J=JMAX,IEND
      IF(CA(J+1).LT.CSL)JSL=J+1
      IF(CA(J+1).LT.CSL)RETURN
   40 CONTINUE
      IFLAG=1
      RETURN
      END

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16. ABSTRACT (200 words or less)

The Nuclear Regulatory Commission, as part of its development of regulations for the disposal of radioactive waste, has contracted for the development of a radioactive classification system. A five category system, based on requirements for safe disposal, has been proposed. A Computer program which calculates the "Disposal Concentration Guides" for individual isotopes for each category was prepared. The program allows parameters for the isotopes and condition of the disposal to be varied. A description of the equations representing the potential exposure mechanisms is also provided.

17. KEY WORDS AND DOCUMENT ANALYSIS

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