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User Guide for GoldSim Model to Calculate PA/CA Doses and Limits

F. G. Smith, III

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EXECUTIVE SUMMARY

A model to calculate doses for solid waste disposal at the Savannah River Site (SRS) and corresponding disposal limits has been developed using the GoldSim commercial software. The model implements the dose calculations documented in SRNL-STI-2015-00056, Rev. 0 "Dose Calculation Methodology and Data for Solid Waste Performance Assessment (PA) and Composite Analysis (CA) at the Savannah River Site". The model was developed to support future Performance Assessment and Composite Analysis work. The GoldSim model provides the dose calculation options listed below:

1. PA groundwater dose pathways including an option to use the equations and parameters used in the 2008 E-Area Low-Level Waste Facility (ELLWF) PA (WSRC 2008) for model verification purposes.
2. CA surface water dose pathways including an option to use the dose equations and parameters used in the 2009 SRS CA (SRNL 2010) for model verification purposes.
3. Inadvertent intruder dose pathways including an option to use the dose equations and parameters used for the 2008 PA for model verification purposes.
4. Groundwater protection beta-gamma, gross alpha, uranium and radium limits. In this case the limits calculation is essentially unchanged from that used in the 2008 PA.
5. Radionuclide screening using National Council on Radiation Protection and Measurements Report Number 123 (NCRP-123) (NCRP 1996) methodology for PA groundwater and intruder dose pathways.
6. Radionuclide screening using NCRP-123 methodology for CA surface water dose pathways.

The model has been verified by reproducing previous 2008 PA and 2009 CA results using the features mentioned above.

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LIST OF ABBREVIATIONS

CA	Composite Analysis
DOE	Department of Energy
ELLWF	E-Area Low Level Waste Facility
EPA	Environmental Protection Agency
NCRP	National Council on Radiation Protection and Measurements
PA	Performance Assessment
SRNL	Savannah River National Laboratory
SRNS	Savannah River Nuclear Solutions
SRR	Savannah River Remediation
SRS	Savannah River Site
VBA	Visual Basic for Applications

1.0 Introduction

A GoldSim model has been developed to implement the dose calculations and parameters described in SRNL-STI-2015-00056, Rev. 0 “Dose Calculation Methodology and Data for Solid Waste Performance Assessment (PA) and Composite Analysis (CA) at the Savannah River Site” (Smith et al. 2015). The model calculates doses and disposal limits for a resident farmer (i.e., the groundwater only all-pathways receptor) and an inadvertent intruder for Performance Assessment (PA), resident and recreational doses for Composite Analysis (CA), and PA disposal limits based on EPA water protection standards. The model is also capable of performing radionuclide screening calculations based on the NCRP-123 methodology (NCRP, 1996).

As part of developing the dose model, the calculations were automated to a large extent through the use of Visual Basic for Applications (VBA) macros embedded in Excel files. This method of automation was chosen since Excel is both readily available and convenient for post-processing and plotting results of the dose calculations and VBA is a relatively easy to learn programming environment that provides useful Windows functions. For example, it is easy to automatically process folders and files in a Windows operating system using VBA commands. The automation method is similar to that used for the 2009 CA GoldSim modeling which used an Excel macro to run the GoldSim dose calculations and Excel files to collect and process results.

The model is structured such that all of the parameters used in the dose calculations are input to the model though links to Excel spreadsheets and an Access database. Therefore, the model requires modification only when the underlying dose calculations are changed. Any of the 1252 radionuclides in the *SRNL_Rad_Data_Package* (Smith et al., 2015) can be included in the dose calculations.

1.1 Quality Assurance

Requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.

GoldSim has a versioning feature that can be used to track changes to the model. With issue of this User Guide, Version 1.0 of the model will be created.

2.0 File Structure and Input

This section provides a description of the basic file structure required for the dose calculations. More detailed information on individual files is provided later in this report. The dose model uses the basic file structure shown in Figure 2-1. References to other files and folders used by the model are made relative to the location of these top level files. The entire dose model can be accessed by copying the *Dose_Calculations* folder shown in Figure 2-1. However, the model makes extensive use of VBA macros embedded in a number of Excel workbooks. When the *Dose_Calculations* folder is relocated, as the preferred default setting, these macros are disabled and the user must go to each file having the extension ***.xlsm*** and enable macros.

Contents of the top level folder *(..\Dose_Calculations\)* shown in Figure 2-1 includes:

- Subfolder *CA_Model_V2* which contains a revised version of the GoldSim CA model (Smith et al., 2009) without the original dose module. Analogous to PORFLOW, the revised CA model (CA_v2.gsm) performs transport calculations and writes output files with water concentrations for parent radionuclides and short chain daughters to be used as input to the dose model. This model is described further in Section 6.
- Subfolder *Dose_Data* contains basic data required to perform the dose calculations.
- Example disposal unit subfolders *E-Area*, *H_Canyon*, *Screening* and *Slit_c*. Data from transport calculations and results from dose calculations are stored in the disposal unit subfolders. The user must create subfolders for each disposal unit to be analyzed.
- The top level folder also contains the following four files:
    1. ***Dose_db.mdb***.................................. A Microsoft ACCESS database which stores a matrix used to expand short transport chains into full decay chains and a matrix listing full decay chain radionuclides that are used in the dose calculations.
    2. ***PA_CA_Limits_Doses.gsm***............. The GoldSim dose model.
    3. ***Reformat_Porflow.xlsm***.................. A Microsoft Excel workbook containing a VBA macro used to reformat data read from PORFLOW STAT.out files into a time series that the GoldSim dose model can import. This is described further in Section 5.
    4. ***Run_Limits_Doses.xlsm***.................. A Microsoft Excel workbook containing a VBA macro that automates the dose calculations.

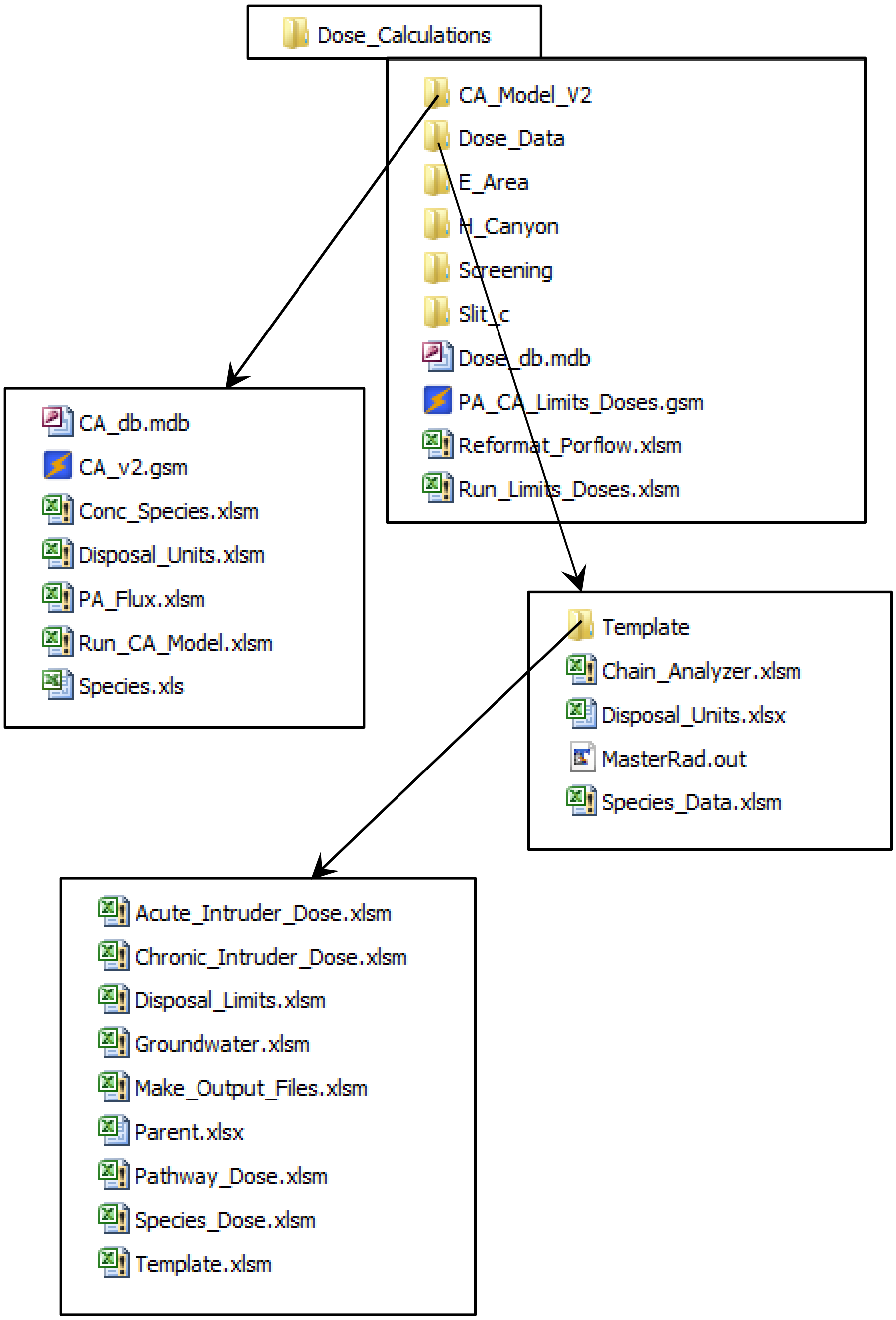


Figure 2-1. Dose Calculation File Structure.

2.1 Model Input

As shown in Figure 2-1, the *Dose_Data* subfolder contains the subfolder *Template*, three Excel files and a text file named *MasterRad.out*. Subfolder *Template* contains the Excel workbook ***Parent.xlsx*** where concentrations of radionuclides in the groundwater are temporarily stored while dose calculations for the particular disposal unit and parent radionuclide are analyzed. Output from the dose and limits calculations are initially written to the files ***Pathway_Dose.xlsm***, ***Acute_Intruder_Dose.xlsm***, ***Chronic_Intruder_Dose.xlsm***, ***Groundwater.xlsm***, ***Disposal_Limits.xlsm***, and ***Species_Dose.xlsm*** in the *Template* folder. These workbooks have separate worksheets that hold dose results for each parent radionuclide analyzed. When the dose and limits calculations for the disposal unit are finished, these files are automatically copied and stored in the disposal unit folder. The ***Make_Output_Files.xlsm*** is a Microsoft Excel file containing a VBA macro that can be used to create clean copies of the data storage files. The macro uses ***Template.xlsm*** as a clean sheet to create these files.

Note to Model Users

For purposes of code testing or debugging it is sometimes convenient to run the dose model directly without using the ***Run_Limits_Doses.xlsm*** macro. The model will then use the last result stored in the ***Parent.xlsx*** file as input. Following a test run, output will have been written into the data storage files as noted above. Running the dose model in this way bypasses file cleanup steps included in the ***Run_Limits_Doses.xlsm*** macro. The ***Run_Limits_Doses.xlsm*** macro automatically runs ***Make_Output_Files.xlsm*** at the start of a set of dose calculations so manual file cleanup is rarely required. However, if the contents of the output files are suspect, the user can run the ***Make_Output_Files.xlsm*** macro to create clean copies of the data storage files following code testing or when a set of calculations has been started and is then aborted.

The *Dose_Data* folder also contains the following three Excel workbooks holding input data for the dose calculations:

1. ***Chain_Analyzer.xlsm*** .... This workbook contains a VBA macro that reads the data in the *MasterRad.out* file and creates two matrices which are imported into the ***Dose_db.mdb*** data base and read by the dose model. One matrix is used to expand short decay chains used for transport calculations into full chains for dose calculations and the other matrix is used to identify daughters in the full decay chain for each of the 1252 radionuclides in the database. The second matrix is only used for screening calculations to include doses from all daughter radionuclides for each parent in the screening.

Important Note to Model Users

The decay chain expansion matrix depends on the half-life cutoff selected and the example furnished with the initial version of the dose model has five year chains. To use a different half-life cutoff in the limits and doses analysis, the following steps must be performed:

1) Open the file ***Dose_Data\MasterRad.out*** and change the second number in the second line to the desired half-life cutoff. The MasterRad.out file was created from the *SRNL_Rad_Data_Package* and would only need to be remade if the basic radionuclide data has changed.
2) Open the file ***Dose_Data\Chain_Analyzer.xlsm*** and run macro Chain_Analyzer. This will update the worksheets to chains based on the input cutoff.
3) Replace table tbl_Chain_Expand in Access database Dose_db.mdb by importing the data in worksheet Expand.
4) Replace table tbl_Full_Chains in Access database Dose_db.mdb with by importing the data in worksheet FullChain.
5) Open the GoldSim dose model and go to container\Data_Sets. Open the data source Chain_Expansion_Matrix and on the Database tab Download the updated chain expansion matrix. Open the data source Full_Chains and on the Database tab Download the updated full chain matrix.

Note to Model Developers

The initial version of the dose model used a full 1252 by 1252 matrix to make the transformation from short transport decay chains to full chains. Using the full matrix resulted in a compact representation of the calculation which took advantage of GoldSim vector-matrix multiplication operations. The matrix was initially read into the GoldSim model from an Excel spreadsheet. The transformation matrix is in fact very sparse with only 2718 nonzero entries and only 1466 nonzero off-diagonal entries (diagonal terms are 1). Therefore, the scheme was changed to use compressed column storage in a 1252 by 35 matrix which allows for as many as 17 daughters in the full decay chain. Using this method reduced the GoldSim model size from about 66 Mb to 20 Mb but required doing the vector-matrix multiplications in scripts. The model was also changed to input the matrix from a general ACCESS database which significantly reduced the time required to import data from about 9 seconds to 2 seconds. Unexpectedly, using the database increased model size to about 29 Mb. Adding the full chain matrix used in the screening analysis, again using a compressed column format, increased the final file size to over 36 Mb. While these changes improved model size and load time they did not appear to reduce model calculation time.

2. ***Species_Data.xlsm*** .... This workbook holds data extracted from the *SRNL_Rad_Data_Package* to be used in the dose calculations. This file could be replaced with direct links to the database when the PA working file structure is finalized. However, an intermediate step

of downloading only the required data into a format similar to these workbooks is perhaps a better approach. Workbook ***Species_Data.xlsm*** has 12 worksheets that contain the following data.

In worksheet *Species*:

1. Columns A lists the 1252 radionuclide species included in the database.
2. Columns B– N hold the basic radionuclide data from ICRP-107 (ICRP 2008) that has been imported into the GoldSim dose model. This data includes: species ID, atomic weight, half-life and decay chain for 1252 radionuclides, and 78 elements used to terminate the decay chains.

<u>Note to Model Users</u>

GoldSim includes a version of the ICRP-107 data with the radioactive transport package. However; during development of the *SRNL_Rad_Data_Package* some corrections were made to chain branching fractions and atomic weights. Therefore, data from the *SRNL_Rad_Data_Package* is used in place of the GoldSim data.

In worksheet *Nuclides*:

1. Columns B – F hold the data for groundwater protection calculations. This data includes: alpha, beta-gamma, uranium and radium fractions, and maximum concentration limits (MCL's) in drinking water for each radionuclide.
2. Columns H – M hold dose conversion factors for each radionuclide. This data includes the following dose coefficients:
    1. ingestion dose (mrem/pCi),
    2. inhalation dose (mrem/pCi),
    3. water submersion dose (mrem/yr)/(pCi/m^3),
    4. ground shine dose (mrem/yr)/(pCi/m^3),
    5. dose from external exposure to soil contaminated to a depth of 15 cm (mrem/yr)/(pCi/m^3), and
    6. dose from external exposure to soil contaminate to an infinite depth (mrem/yr)/(pCi/m^3).
3. Columns O – U hold soil shielding dose conversion factors (mrem/yr)/(pCi/m^3) for each radionuclide at seven soil thicknesses of 0, 1, 5 , 15, 30, 45 and 100 cm. Columns W and X contain coefficients that fit the soil shielding dose conversion factors to the log-linear equation:

   $$ln(DCF) = m\,x + b \quad \text{or} \quad DCF = \exp(m\,x + b)$$

   The equation slope *m* is given in Column W, the intercept *b* is in Column X and *x* is the soil shielding thickness. Through the GoldSim user interface, shown in Section 3 Figure 3-1(d), the user can choose to either use a log-linear interpolation of shielding dose coefficients between tabulated values or use the exponential fit. It should be noted that the fit is not always conservative as it may pass below some of the data points. However, it provides a close fit to the data that could be used for all practical purposes and the model and input could be simplified if the exponential fit was adopted as the method to calculate soil shielding DCF's. Soil shielding dose conversion factors are only used in the inadvertent intruder dose calculations. The shielding DCF's have been adjusted to match dose conversion factors for exposure to soil contaminated to an infinite depth when the shielding thickness is zero.

Note to Model Users

Soil shielding DCF's used in the 2008 PA intruder analysis were calculated by fitting values at 5 cm and 100 cm to the log-linear equation and using a separate interpolation between 0 cm and 5 cm. To reproduce 2008 PA intruder calculations in this model (see **Note to Model Users** below), soil shielding DCF's using the 5 cm to 100 cm fit to the original data have been provided; however, the interpolation segment from 0 cm to 5 cm has not been included.

In worksheet *Element*:

Columns B – F hold the element specific data required for the dose calculations for 98 elements. This data includes the four bio-transfer factors: soil to vegetable (-), feed to milk (d/L), feed to meat (d/kg) and water to fish (L/kg) and the sandy soil k_d (L/kg). The element data is expanded to the full set of radionuclides in Columns I – M.

In worksheet *Dose_Parameters*:

The values for 79 parameters used in the dose calculations are provided. Column A gives a description of the parameter, Column B gives the units, Column C gives the nominal value or the value for a typical person if applicable and Column D gives values for a reference person if applicable. The three soil parameters density, porosity and saturation have values for the distribution defined in Columns E-G. In this initial version of the dose model, no other parameter distributions are entered; however, possible distribution values are listed in Columns I-T.

Note to Model Users

For verification testing, three additional versions of the *Nuclides*, *Element* and *Dose_Parameters* worksheets are provided with the names prefixed by ***PA, II***, ***and CA***. These allow the user to reproduce results from All-Pathways (***PA***) and Inadvertent Intruder (***II***) analyses performed for the 2008 E-Area PA and the 2009 SRS CA (***CA***). As described in Section 3.0, the appropriate data sets and modified dose equations are automatically used when calculations based on previous analyses are selected. The first worksheet in each section contains data extracted from the current *SRNL_Rad_Data_Package* (Smith et al. 2015) which differs from the data used in any of the previous analyses. Because the radionuclide species are an integral part of the GoldSim model, the species data is not changed for the different calculations and in some cases it may not be possible to exactly reproduce previous results.

3. ***Disposal_Units.xlsx*** .... As described in the following section, this workbook contains additional data for each disposal unit primarily used for the intruder analysis (e.g. waste volume, soil depth to waste etc.).

The *Slit_c* folder provides an example of how data for each disposal unit is stored. An expanded view of the *Slit_c* folder and its subfolders is shown in Figure 2-2. At the first level within each disposal unit folder the following subfolders may be present:

1. *Dose_Limits* .... After all dose calculations are made for a particular disposal unit and parent radionuclides, the VBA macro in ***Run_Limits_Doses.xlsm*** copies the files with dose results from the *Dose_Data/Template* Folder into the *Dose_Limits* folder. This subfolder will be in every disposal unit folder.

2. *GoldSim_CA* .... A folder where results from GoldSim transport calculations for each parent radionuclide in the disposal unit are stored in subfolder *Transport*. This folder is only required when a CA calculation is requested. An example CA calculation for *Slit_c* is provided with the model.

3. *PORFLOW*................................. A folder where results from PORFLOW transport calculations for each parent radionuclide in the disposal unit are stored. It is assumed that this folder would contain complete results from vadose flow, vadose transport and aquifer transport calculations and supporting data files. For dose calculation purposes only the aquifer transport results in the STATout file are actually used. The *Aquifer_Transport* subfolder would contain PORFLOW results in separate folders for each parent radionuclide. The folder also contains an inventory.dat file giving the inventory used in the PORFLOW calculations. Running the macro in ***Reformat_Porflow.xlsm*** reads the STAT.out files in each subfolder in the *Aquifer_Transport* folder and writes an Excel file for the parent radionuclide into the *Aquifer_Transport* folder that is then used to make the dose and limit calculations. The connection between the C-14 PORFLOW output and dose input is diagramed in Figure 2-2. The *GoldSim_CA/Transport* and *PORFLOW/Aquifer_Transport* folders both have Excel files for parent radionuclides in identical formats that are read by ***PA_CA_Limits_Doses.gsm***. This folder is only required when a PA calculation is requested.

4. *Screening* .... A folder where Excel files listing the parent radionuclides that will be analyzed in the screening calculation are stored in subfolder *Screening*/*Transport*. This folder is only required when a screening calculation is requested. In the examples furnished with the model this file is only present in the *Screening* disposal unit folder.

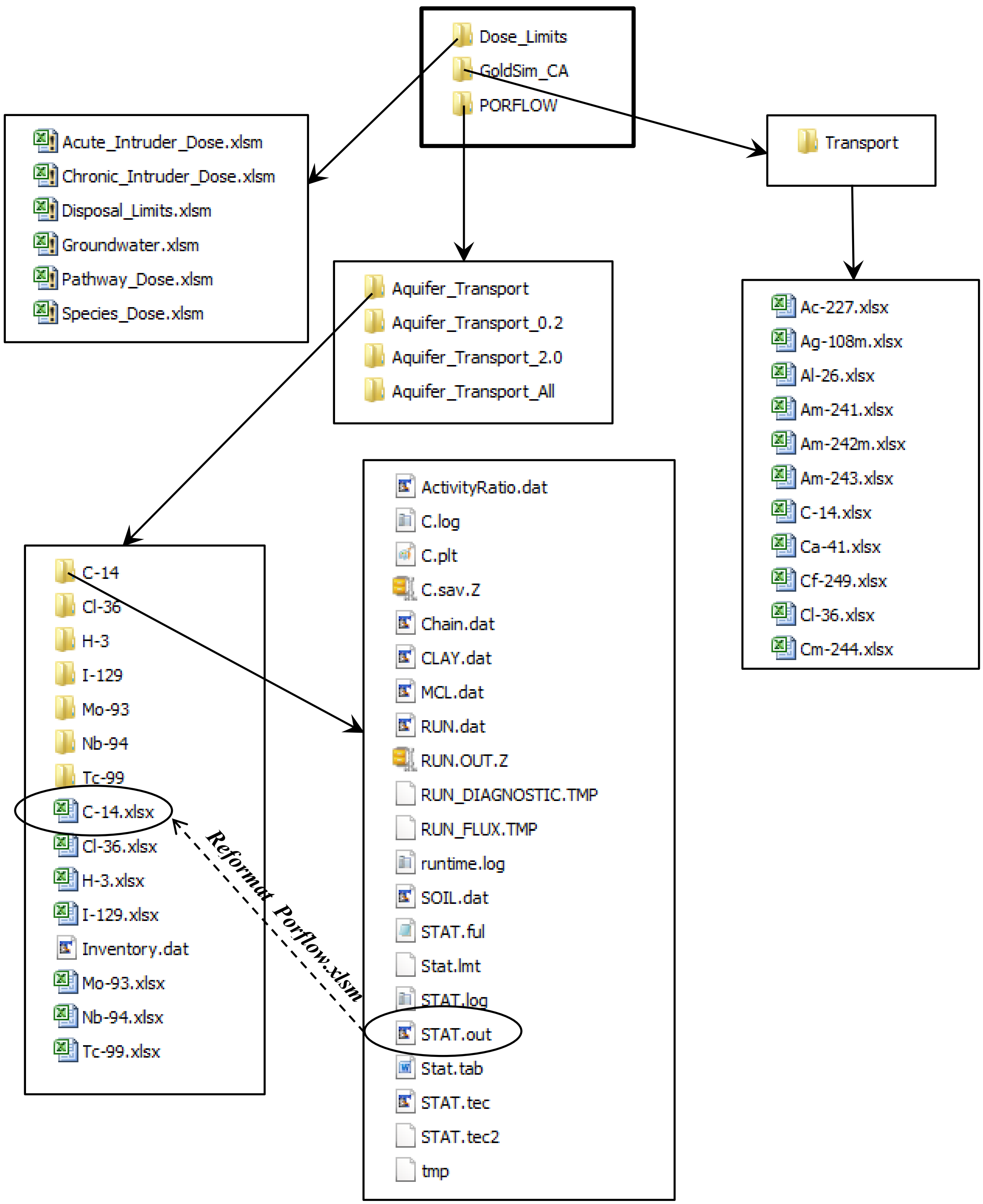


Figure 2-2. Contents of *Slit_c* Folder.

Prior to performing dose calculations, the user must enter the appropriate input data into file: *Dose_Data/**Disposal_Units.xlsx***. Figure 2-3 shows the contents of this file for the example calculations provided with the model. Parameters specific to the disposal units that are not part of the *SRNL_Rad_Data_Package*, are collected in this separate file. Data entries for each disposal unit analyzed must be provided, starting in Column C. The disposal unit name must be the same as the name used for the disposal unit folder shown in Figure 2-1 which is also the name entered in the Excel file ***Run_Limits_Doses.xlsm*** as described below. Different waste disposal dates were used in previous calculations for the different doses analyzed. Therefore, the disposal date is highlighted and the values used previously are provided in cells A30 – A32 as a reminder to change this date during model testing.

The remaining entries in ***Disposal_Units.xlsx*** fall into five categories:

1. Rows 5 and 6 specify values for E-Area disposal unit area ratios and plume interaction factors typically used in PA dose calculations.
2. Rows 8 – 16 specify various parameters used in the Inadvertent Intruder analysis for each disposal unit.
3. Row 18 has a single entry specifying the concentration factor in the stream relative to the river concentration that is used in CA dose calculations.
4. Rows 20 – 22 are used to enter an infiltration rate, aquifer dilution factor and waste release time used in screening calculations.
5. Column B rows 24 – 27 specify the simulation start time, the projected E-Area LLWF closure date, the time of institutional control, and the simulation end time. Note that the simulation end time and starting date used in the dose calculations are actually specified by the GoldSim model simulation settings shown in Figure 3-2. The simulation end date in ***Disposal_Units.xlsx*** is used to reformat the PORFLOW output.

> **Note to Model Users**
>
> The simulation start time and duration can be modified but the user must make certain that consistent values are used in the transport calculations and the GoldSim dose modeling.

The user must also create an ***Inventory.dat*** file in the *PORFLOW/Aquifer_Transport* folder giving the inventory in Curies of parent radionuclides used in PORFLOW transport calculations. The folder location is shown in Figure 2-2. An example of the file format that must be used is shown below in Figure 2-4. Either space or tab delimited data will be read correctly.

	A	B	C	D	E	F
1	4	**Disposal Unit Number**	1	2	3	4
2		**Disposal Unit Name**	Slit_c	H_Canyon	E_Area	Screening
3		**Waste Disposal Time (Year)**	2010	2025	1970	2040
4	**All-Pathways Parameters**					
5		Group Area Ratio	7.06	1.00	1.00	1.00
6		Plume Interaction Factor	1.00	1.00	1.00	1.00
7	**Intruder Parameters**					
8		Soil Depth - Surface to Erosion Barrier (m)	0.91	0.91	0.91	0
9		Soil Depth - Surface to Waste Zone (m)	4.08	4.08	4.08	1
10		WasteZone Thickness (m)	5	5	5	1
11		Waste Volume (m^3)	29450	29450	29450	15
12		Residential Geometry Factor (-)	0.637	0.637	0.637	1
13		Drilling Geometry Factor (-)	1	1	1	1
14		Barrier to Intrusion Drilling (0=No, 1=Yes)	0	0	0	0
15		Erosion Barrier Failure (yr)	1.0E+09	1.0E+09	1.0E+09	0
16		Drilling Barier Failure (yr)	0	0	0	0
17	**Composite Analysis Parameters**					
18		Dilution factor for CA residential dose (-)	38.81	38.81	38.81	38.81
19	**Screening Parameters**					
20		Infiltration Rate (m/yr)	1	1	1	0.04
21		Groundwater Dilution Volume(m^3)	1	1	1	44
22		Release Time (yr)	0	0	0	0
23	**Simulation Times (Year)**					
24	**Simulation Start**	**1960**				
25	ELLWF Closure	2040				
26	Institutional Control	100				
27	Simulation End	3140				
28	Simulation Duration (Years)	1180				
29	**Disposal Time (Year)**					
30	2008 PA All-Pathways 2010					
31	2008 PA Intruder 2040					
32	2009 CA 2025					
33						

Figure 2-3. Example contents of *Disposal_Units.xlsx* file.

Parent Nuclide	Inventory (Ci)
C-14	1.0
Cl-36	1.0
H-3	1.0
I-129	1.0
Mo-93	1.0
Nb-94	1.0
Tc-99	1.0
U-238	1.0

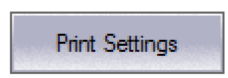
Figure 2-4. Example contents of Inventory.dat file.

3.0 Running Dose Calculations

The model structure requires the user to enter input in a number of different places and spreadsheets some of which were described in the previous section. This is perhaps less than ideal and it may be possible to simplify the input requirements. Nevertheless, the current model structure is described in this section.

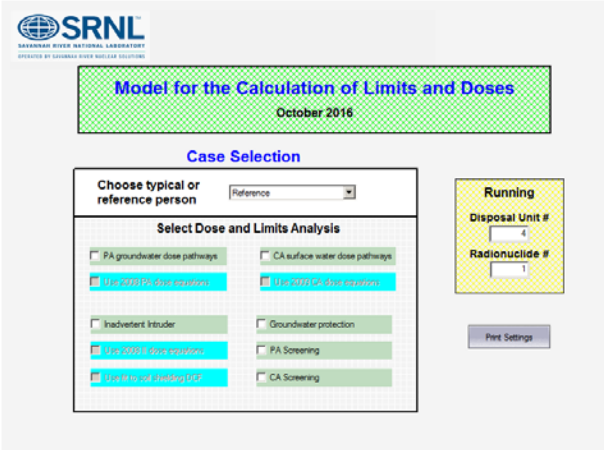
To start a dose calculation, the user first opens the model itself ***PA_CA_Limits_Doses.gsm*** and selects the calculation to be performed. Figure 3-1(a) shows the GoldSim dashboard that appears when the model is open. The combo box at the top of the Case Selection group allows the user to select whether dose parameters for a typical or reference individual are used. Figures 3-1(b) – 3-1(f) show the dashboard configuration when different types of analysis are selected. Selecting a PA groundwater analysis in Figure 3-1(b) deactivates the CA, Groundwater and Screening analysis selections and activates the option to use the 2008 PA dose equations. Similarly, selecting the CA surface water analysis in Figure 3-1(c) deactivates the PA, Groundwater and Screening analysis sections and activates the option to use the 2009 CA dose equations. Selecting the PA analysis allows the user to also include Inadvertent Intruder and Groundwater Protection dose calculations. Alternatively, either of these options can be selected alone as shown in Figure 3-1(d) and (e). When the Inadvertent Intruder analysis is selected, a check box is activated that gives the user the option of using the equations that were used in the 2008 PA and an option to use a fit to the soil shielding factors instead of interpolation. Selecting the screening option as shown in Figure 3-1(f) does not allow including any other calculation.

The user should only choose to use the 2008 PA or 2009 CA dose equations for testing purposes. In this case, the simulation settings listed in Appendix A must also be used to reproduce the earlier PA, CA or Inadvertent Intruder results. Simulation time and time steps are set using the GoldSim simulation setting control panel show in Figure 3-2. Settings used to emulate the previous calculations are given in Appendix A. As noted in the previous section, it is the user responsibility to ensure that the simulation settings are consistent with the input data.

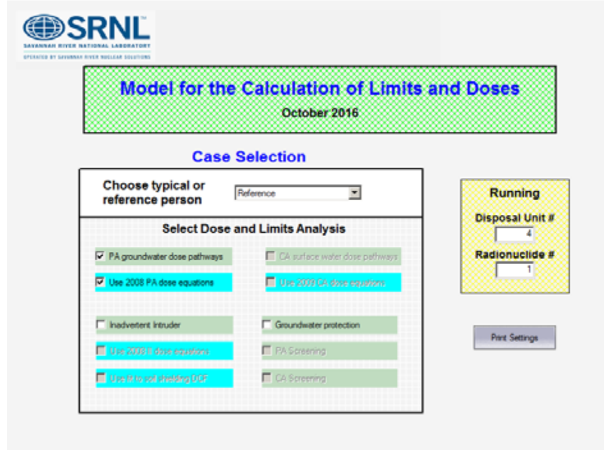
The model user controls the output frequency by clicking on the button: 

This action opens the dashboard shown in 3-3 where the user can divide the simulation into four time windows and specify a printout frequency for each time window as explained on the input screen. This function controls output to the Excel files described in Section 3.1.

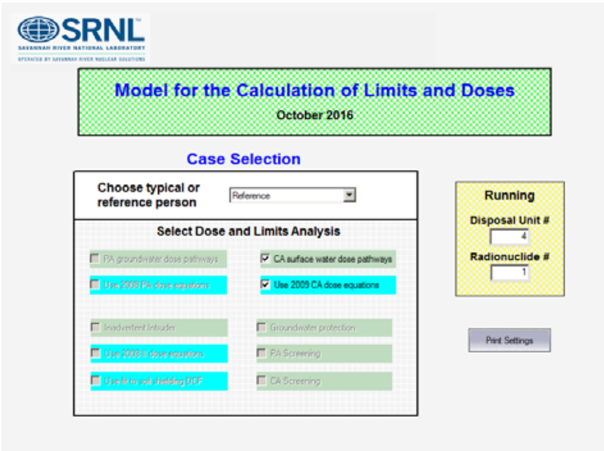
Note that the top-level dashboard displays the number of the disposal unit and radionuclide currently being analyzed. This information will give the user an idea of how far the calculation has progressed.



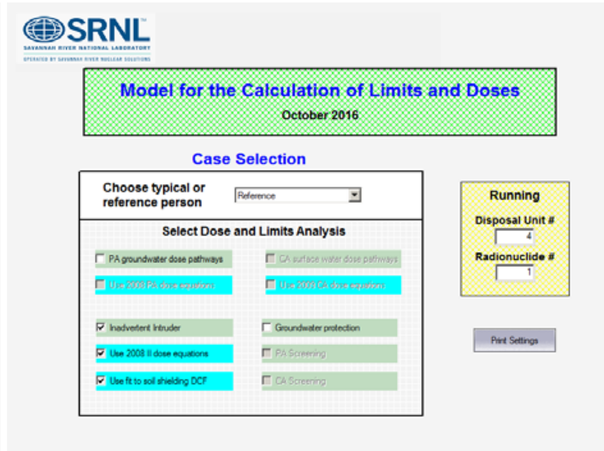
(a)



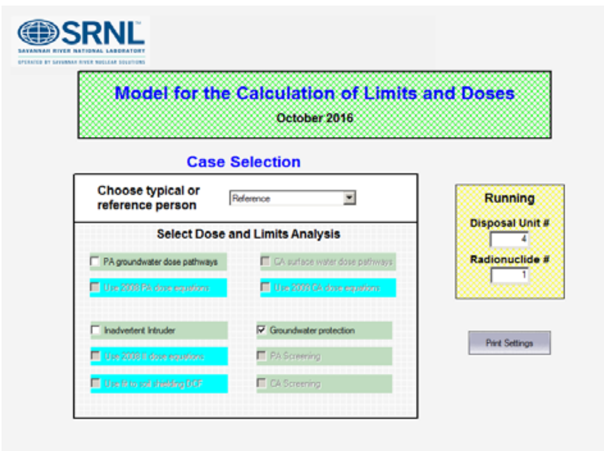
(b)



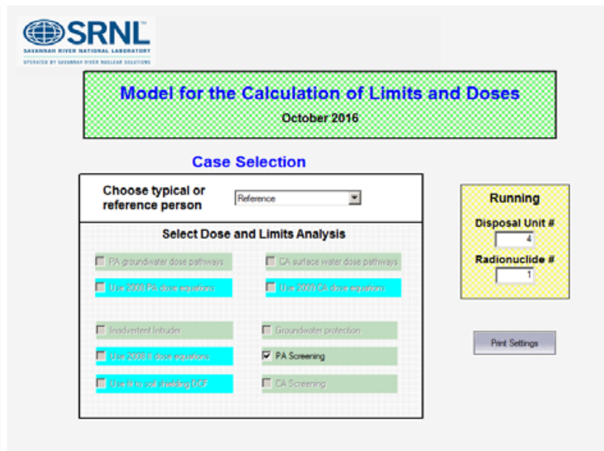
(c)



(d)



(e)



(f)

Figure 3-1. User interface dashboard in GoldSim Doses and Limits Model.

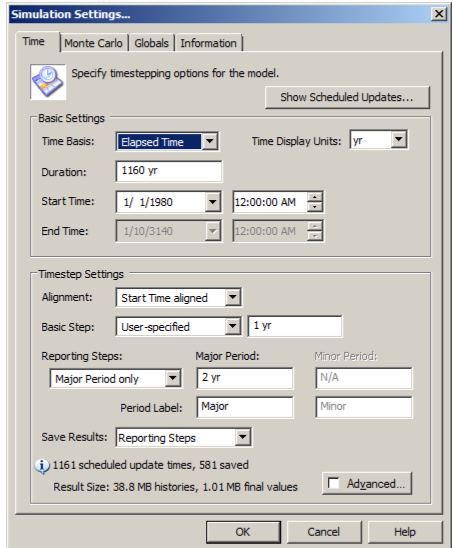


Figure 3-2. Simulation settings control panel.

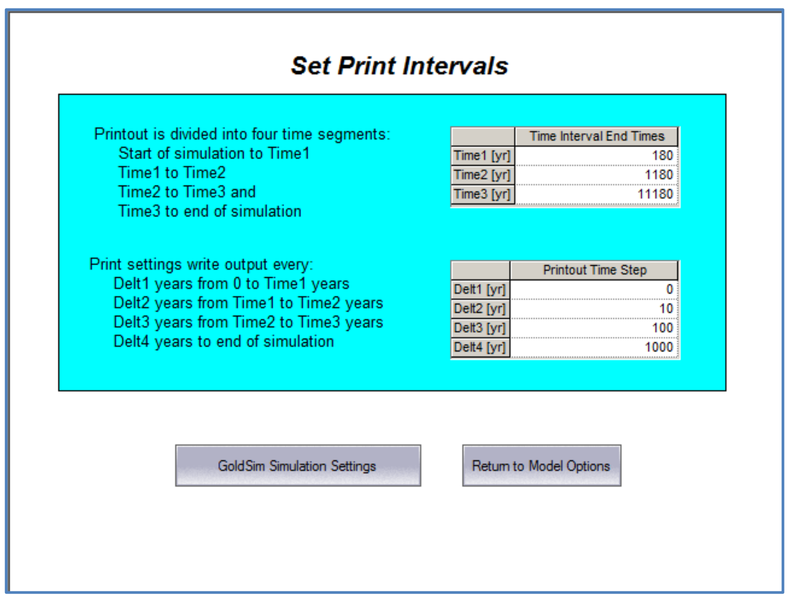


Figure 3-3. Print control panel.

Once the user has entered all of the data required to perform the intended analysis, the following steps are executed to run the calculation:

1) Open ***Run_Limits_Doses.xlsm*** and enter the list of disposal units to be analyzed in Column A starting in Row 2. Example screen displays for running a PA analysis and a CA analysis are shown in Figure 3-3(a) and 3-3(b), respectively. Each example has only one disposal unit entry but up to 100 entries can be made and this can easily be expanded to a larger list if desired. The macro must know where to read the data so either 1, 2 or 3 must be entered in Column B row 1 to

specify a PA, CA or Screening analysis, respectively. Specifying a PA analysis directs the macro to read data from the *PORFLOW* folder, specifying a CA analysis directs the macro to read data from the *GoldSim_CA* folder and specifying Screening directs the macro to read data from the *Screening* folder. Folders with these names must exist in the disposal unit folder for the respective calculations to be made.

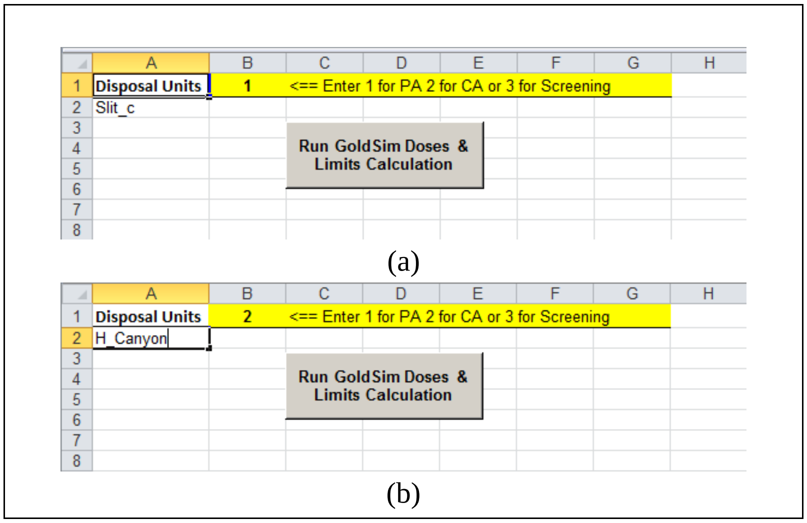
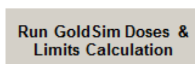


Figure 3-4. Screen display on opening *Run_Limits_Doses.xls*m.

2) The user then clicks on the button  to launch the VBA macro.

The macro reads and processes entries from the list of disposal units to be analyzed in Column A until a blank is encountered. A blank entry will terminate the calculations.

When starting a new PA analysis that uses output from PORFLOW transport calculations, the output must first be reformatted as described in Section 5. This writes the data into Excel workbooks for each parent radionuclide in folder *PORFLOW/Aquifer_Transport* as shown in Figure 2-2. When a PA analysis is requested, for each disposal unit and parent radionuclide, the macro automatically copies the Excel file for the parent radionuclide into the *Dose_Data/Template/**Parent.xlsx*** file for GoldSim to read.

For an intruder analysis, the macro reads the same type of Excel workbooks as are used for the PA analysis but only uses the parent radionuclide name and the specified inventory. GoldSim performs radionuclide decay and daughter ingrowth calculations for the intruder analysis internally.

Similarly, for a screening analysis, the macro reads parent radionuclide names from the same type of Excel workbook. Whereas for PA analyses the workbook contains concentrations of radionuclides in the short decay chain obtained from PORFLOW transport calculations; for screening the user can enter up to 10 parent radionuclide names in the file. These parents will be run as a group in the screening. To obtain correct results, no parents in a group can have common daughter radionuclides. A set of groups that satisfy this restriction has been created in the *Screening* example folder shown in Figure 2-1. The screening calculation automatically uses an inventory of one Curie for each parent.

When a CA analysis is requested, for each disposal unit the macro processes the parent radionuclide Excel workbooks in the *GoldSim_CA/Transport* folder shown in Figure 2-2. Output from the CA transport model is already formatted as input for the GoldSim Doses and Limits Model. The macro again copies each CA Excel file to the *Dose_Data/Template/**Parent.xlsx*** file for GoldSim to read.

Following data retrieval, the macro runs ***PA_CA_Limits_Doses.gsm*** to make requested dose calculations for the parent radionuclide. GoldSim reads water concentrations calculated by the transport models from the *Dose_Data/Template/**Parent.xlsx*** file and dose parameter input from the files shown in Figure 2-1. Results of the doses and limits calculations are written to the Excel workbooks in the *Dose_Data/Template* folder as shown in Figure 2-1. A worksheet for each parent radionuclide is created in these workbooks. When all radionuclides have been analyzed for a disposal unit, the macro copies the Excel workbooks from the *Dose_Data/Template* folder into the *Dose_Limits* folder for the disposal unit shown in Figure 2-2. The macro uses the same folder to store either PA or CA results replacing any existing results as each parent radionuclide is analyzed. When all of the disposal units have been analyzed, the macro closes Excel.

3.1 Model Output Files

In this section some examples of model output are provided. Figure 3-5 shows the GoldSim user interface settings and the GoldSim Simulation Settings used to run the example simulations. PA All-Pathways, Inadvertent Intruder, and Groundwater Protection limits and doses have been calculated to show how the output Excel files are populated. As shown in Figure 2-3, the calculations assume that the E-Area Low Level Waste Facility is closed in 2040 followed by a 100 year period of institutional control. This causes the All-Pathways and Inadvertent Intruder limits to start in 2140. Therefore, as shown below in Figure 3-6, no output was specified for the first 180 years of simulation and output will start in 1960 + 180 = 2140. Actually, groundwater protection limits should be applied as soon as the waste is buried in 2010 but this difference is ignored for purposes of the example calculations shown here.

Example output files are shown in Figures 3-6 through 3-11and are briefly discussed below. As shown in Figure 2-2, these six files are collected in the *Dose_Limits* folder for each disposal unit analyzed.

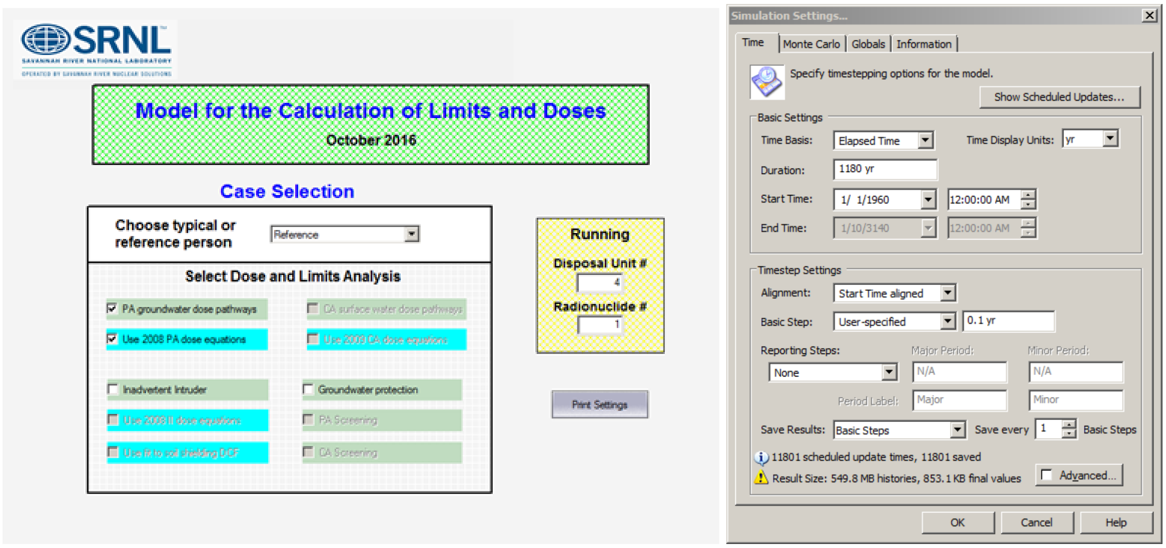


Figure 3-5. Example model settings for Slit_c PA doses and limits calculation.

Figure 3-6 shows an example output from the all-pathways dose calculation written to file ***Pathway_Dose.xlsm***. The dose pathways are grouped into ingestion, inhalation and external exposure pathways. Dose pathways where the name is shaded are recreational pathways used in the CA but not applied in PA calculations. As can be seen, all recreational doses are zero for this PA based example. The dose from each group of pathways is totaled and total residential, recreational and overall dose are provided as well as the disposal limit based on the total dose. Note that a separate worksheet has been created in the output file for each of the eight parent radionuclides analyzed in the example calculation.

Figure 3-7 shows an example output from the groundwater limits calculation written to file ***Groundwater.xlsm***. Both doses or concentrations and disposal limits for the four groundwater pathways (alpha concentration, beta-gamma dose, uranium concentration and radium concentration) are listed.

Figure 3-8 shows an example of output from the acute intruder dose calculation written to file ***Acute_Intruder.xlsm***. The acute intruder exposure comes from basement construction, drilling and discovery activity at the waste disposal site. The construction and drilling dose is further broken down into exposure from ingestion, inhalation and external exposure. The total acute intruder dose and corresponding disposal limit are also calculated and output from the model.

Figure 3-9 shows an example of output from the chronic intruder dose calculation written to file ***Chronic_Intruder.xlsm***. The chronic intruder exposure comes from agricultural, post drilling and residential activity at the waste disposal site. The agriculture and post drilling dose is further broken down into exposure pathways. The total chronic intruder dose and corresponding disposal limit are also calculated and output from the model. As shown in Figure 3-10, the model outputs a summary table in file ***Disposal_Limits.xlsm*** showing all seven of the disposal limits calculated.

The final model output shown in Figure 3-11 is a breakdown of the total dose from each parent radionuclide into the dose from each of the short chain daughter radionuclides. This output is in file ***Species_Dose.xlsm***. Notice that for U-238, the dose is primarily from the daughter radionuclides Ra-226 and Pb-210. The breakdown of reported doses and concentrations into contributions from daughter radionuclides could be done for all of the dose pathways but this would create an extremely large amount of output and has not been implemented.

The screening calculation also outputs results to the ***Species_Dose.xlsm*** workbook. In this case, each column represents the total dose from the parent radionuclide in the column heading and two sets of output are created. The first set labeled as “Resident Farmer” gives the groundwater ingestion dose and the second set labeled “Intruder Agriculture” gives the inadvertent intruder dose. An example screening output is shown in Figure 3-12.

Two final points to consider about the model output are:

1) All of the output files are Excel files of type ***xlsm*** because a VBA plotting program has been embedded into each file. A version of this program was used to quickly create plots of output from the 2009 CA. The CA program was modified to plot output from the dose model. The plotting program is described in the following section where some examples are shown.

2) Time in the output is in years. Originally, the time output was a date (e.g. 1/1/2140) but Excel cannot process dates beyond year 9999 so the model output was revised to print the year using a number format.

	Ingestion Pathways								Inhalation Pathways				External Pathways					Residential	Recreational	Overall	Disposal
	Water	Vegetable	Meat	Milk	Soil	Fish	H3 Dermal	Total	Soil	Shower	Swim	Total	Soil	Swim	Boat	Shore	Total	Total	Total	Total	Limit
Year	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	Ci
2140	4.36E-18	6.00E-18	2.08E-19	3.10E-19	8.06E-24	0.00E+00	0.00E+00	1.09E-17	1.14E-24	1.27E-23	0.00E+00	1.38E-23	1.56E-21	0.00E+00	0.00E+00	0.00E+00	1.56E-21	1.09E-17	0.00E+00	1.09E-17	2.30E+18
2150	4.74E-18	6.52E-18	2.26E-19	3.36E-19	8.76E-24	0.00E+00	0.00E+00	1.18E-17	1.24E-24	1.38E-23	0.00E+00	1.50E-23	1.70E-21	0.00E+00	0.00E+00	0.00E+00	1.70E-21	1.18E-17	0.00E+00	1.18E-17	2.11E+18
2160	5.11E-18	7.04E-18	2.44E-19	3.63E-19	9.45E-24	0.00E+00	0.00E+00	1.28E-17	1.34E-24	1.49E-23	0.00E+00	1.62E-23	1.83E-21	0.00E+00	0.00E+00	0.00E+00	1.83E-21	1.28E-17	0.00E+00	1.28E-17	1.96E+18
2170	5.36E-18	7.37E-18	2.55E-19	3.80E-19	9.90E-24	0.00E+00	0.00E+00	1.34E-17	1.40E-24	1.56E-23	0.00E+00	1.70E-23	1.91E-21	0.00E+00	0.00E+00	0.00E+00	1.91E-21	1.34E-17	0.00E+00	1.34E-17	1.87E+18
2180	5.44E-18	7.49E-18	2.59E-19	3.86E-19	1.01E-23	0.00E+00	0.00E+00	1.36E-17	1.43E-24	1.58E-23	0.00E+00	1.72E-23	1.94E-21	0.00E+00	0.00E+00	0.00E+00	1.94E-21	1.36E-17	0.00E+00	1.36E-17	1.84E+18
2190	5.40E-18	7.43E-18	2.57E-19	3.83E-19	9.98E-24	0.00E+00	0.00E+00	1.35E-17	1.41E-24	1.57E-23	0.00E+00	1.71E-23	1.93E-21	0.00E+00	0.00E+00	0.00E+00	1.93E-21	1.35E-17	0.00E+00	1.35E-17	1.86E+18
2200	5.33E-18	7.34E-18	2.54E-19	3.78E-19	9.85E-24	0.00E+00	0.00E+00	1.33E-17	1.40E-24	1.55E-23	0.00E+00	1.69E-23	1.90E-21	0.00E+00	0.00E+00	0.00E+00	1.90E-21	1.33E-17	0.00E+00	1.33E-17	1.88E+18
2210	5.21E-18	7.16E-18	2.48E-19	3.69E-19	9.62E-24	0.00E+00	0.00E+00	1.30E-17	1.36E-24	1.51E-23	0.00E+00	1.65E-23	1.86E-21	0.00E+00	0.00E+00	0.00E+00	1.86E-21	1.30E-17	0.00E+00	1.30E-17	1.92E+18
2220	5.07E-18	6.97E-18	2.41E-19	3.59E-19	9.36E-24	0.00E+00	0.00E+00	1.26E-17	1.33E-24	1.47E-23	0.00E+00	1.60E-23	1.81E-21	0.00E+00	0.00E+00	0.00E+00	1.81E-21	1.26E-17	0.00E+00	1.26E-17	1.98E+18
2230	4.94E-18	6.80E-18	2.35E-19	3.50E-19	9.13E-24	0.00E+00	0.00E+00	1.23E-17	1.29E-24	1.43E-23	0.00E+00	1.56E-23	1.76E-21	0.00E+00	0.00E+00	0.00E+00	1.76E-21	1.23E-17	0.00E+00	1.23E-17	2.03E+18
2240	4.86E-18	6.68E-18	2.31E-19	3.44E-19	8.97E-24	0.00E+00	0.00E+00	1.21E-17	1.27E-24	1.41E-23	0.00E+00	1.54E-23	1.73E-21	0.00E+00	0.00E+00	0.00E+00	1.73E-21	1.21E-17	0.00E+00	1.21E-17	2.06E+18
2250	4.81E-18	6.62E-18	2.29E-19	3.41E-19	8.90E-24	0.00E+00	0.00E+00	1.20E-17	1.26E-24	1.40E-23	0.00E+00	1.52E-23	1.72E-21	0.00E+00	0.00E+00	0.00E+00	1.72E-21	1.20E-17	0.00E+00	1.20E-17	2.08E+18
2260	4.92E-18	6.76E-18	2.34E-19	3.48E-19	9.08E-24	0.00E+00	0.00E+00	1.23E-17	1.29E-24	1.43E-23	0.00E+00	1.56E-23	1.75E-21	0.00E+00	0.00E+00	0.00E+00	1.75E-21	1.23E-17	0.00E+00	1.23E-17	2.04E+18
2270	5.32E-18	7.32E-18	2.53E-19	3.77E-19	9.83E-24	0.00E+00	0.00E+00	1.33E-17	1.39E-24	1.55E-23	0.00E+00	1.68E-23	1.90E-21	0.00E+00	0.00E+00	0.00E+00	1.90E-21	1.33E-17	0.00E+00	1.33E-17	1.88E+18
2280	6.07E-18	8.35E-18	2.89E-19	4.30E-19	1.12E-23	0.00E+00	0.00E+00	1.51E-17	1.59E-24	1.76E-23	0.00E+00	1.92E-23	2.17E-21	0.00E+00	0.00E+00	0.00E+00	2.17E-21	1.51E-17	0.00E+00	1.51E-17	1.65E+18
2290	7.10E-18	9.77E-18	3.38E-19	5.04E-19	1.31E-23	0.00E+00	0.00E+00	1.77E-17	1.86E-24	2.06E-23	0.00E+00	2.25E-23	2.54E-21	0.00E+00	0.00E+00	0.00E+00	2.54E-21	1.77E-17	0.00E+00	1.77E-17	1.41E+18
2300	8.34E-18	1.15E-17	3.97E-19	5.92E-19	1.54E-23	0.00E+00	0.00E+00	2.08E-17	2.19E-24	2.42E-23	0.00E+00	2.64E-23	2.98E-21	0.00E+00	0.00E+00	0.00E+00	2.98E-21	2.08E-17	0.00E+00	2.08E-17	1.20E+18
2310	9.90E-18	1.36E-17	4.72E-19	7.03E-19	1.83E-23	0.00E+00	0.00E+00	2.47E-17	2.60E-24	2.88E-23	0.00E+00	3.14E-23	3.54E-21	0.00E+00	0.00E+00	0.00E+00	3.54E-21	2.47E-17	0.00E+00	2.47E-17	1.01E+18
2320	1.22E-17	1.68E-17	5.83E-19	8.69E-19	2.26E-23	0.00E+00	0.00E+00	3.05E-17	3.21E-24	3.56E-23	0.00E+00	3.88E-23	4.38E-21	0.00E+00	0.00E+00	0.00E+00	4.38E-21	3.05E-17	0.00E+00	3.05E-17	8.19E+17
2330	1.55E-17	2.14E-17	7.40E-19	1.10E-18	2.87E-23	0.00E+00	0.00E+00	3.87E-17	4.07E-24	4.52E-23	0.00E+00	4.93E-23	5.56E-21	0.00E+00	0.00E+00	0.00E+00	5.56E-21	3.87E-17	0.00E+00	3.87E-17	6.45E+17
2340	1.96E-17	2.69E-17	9.33E-19	1.39E-18	3.62E-23	0.00E+00	0.00E+00	4.88E-17	5.14E-24	5.70E-23	0.00E+00	6.21E-23	7.02E-21	0.00E+00	0.00E+00	0.00E+00	7.02E-21	4.89E-17	0.00E+00	4.89E-17	5.12E+17
2350	2.42E-17	3.33E-17	1.15E-18	1.72E-18	4.47E-23	0.00E+00	0.00E+00	6.04E-17	6.35E-24	7.05E-23	0.00E+00	7.68E-23	8.68E-21	0.00E+00	0.00E+00	0.00E+00	8.68E-21	6.04E-17	0.00E+00	6.04E-17	4.14E+17
2360	2.96E-17	4.07E-17	1.41E-18	2.10E-18	5.46E-23	0.00E+00	0.00E+00	7.37E-17	7.76E-24	8.60E-23	0.00E+00	9.38E-23	1.06E-20	0.00E+00	0.00E+00	0.00E+00	1.06E-20	7.38E-17	0.00E+00	7.38E-17	3.39E+17
2370	3.63E-17	4.99E-17	1.73E-18	2.58E-18	6.71E-23	0.00E+00	0.00E+00	9.05E-17	9.52E-24	1.06E-22	0.00E+00	1.15E-22	1.30E-20	0.00E+00	0.00E+00	0.00E+00	1.30E-20	9.05E-17	0.00E+00	9.05E-17	2.76E+17
2380	4.47E-17	6.15E-17	2.13E-18	3.18E-18	8.27E-23	0.00E+00	0.00E+00	1.12E-16	1.17E-23	1.30E-22	0.00E+00	1.42E-22	1.60E-20	0.00E+00	0.00E+00	0.00E+00	1.60E-20	1.12E-16	0.00E+00	1.12E-16	2.24E+17
2390	5.48E-17	7.53E-17	2.61E-18	3.89E-18	1.01E-22	0.00E+00	0.00E+00	1.37E-16	1.44E-23	1.59E-22	0.00E+00	1.74E-22	1.96E-20	0.00E+00	0.00E+00	0.00E+00	1.96E-20	1.37E-16	0.00E+00	1.37E-16	1.83E+17
2400	6.61E-17	9.10E-17	3.15E-18	4.70E-18	1.22E-22	0.00E+00	0.00E+00	1.65E-16	1.73E-23	1.92E-22	0.00E+00	2.10E-22	2.37E-20	0.00E+00	0.00E+00	0.00E+00	2.37E-20	1.65E-16	0.00E+00	1.65E-16	1.52E+17
2410	7.93E-17	1.09E-16	3.78E-18	5.64E-18	1.47E-22	0.00E+00	0.00E+00	1.98E-16	2.08E-23	2.31E-22	0.00E+00	2.52E-22	2.84E-20	0.00E+00	0.00E+00	0.00E+00	2.84E-20	1.98E-16	0.00E+00	1.98E-16	1.26E+17
2420	9.57E-17	1.32E-16	4.56E-18	6.80E-18	1.77E-22	0.00E+00	0.00E+00	2.39E-16	2.51E-23	2.79E-22	0.00E+00	3.04E-22	3.43E-20	0.00E+00	0.00E+00	0.00E+00	3.43E-20	2.39E-16	0.00E+00	2.39E-16	1.05E+17
2430	1.16E-16	1.60E-16	5.54E-18	8.27E-18	2.15E-22	0.00E+00	0.00E+00	2.90E-16	3.05E-23	3.38E-22	0.00E+00	3.69E-22	4.17E-20	0.00E+00	0.00E+00	0.00E+00	4.17E-20	2.90E-16	0.00E+00	2.90E-16	8.62E+16
2440	1.41E-16	1.94E-16	6.73E-18	1.00E-17	2.61E-22	0.00E+00	0.00E+00	3.53E-16	3.71E-23	4.11E-22	0.00E+00	4.48E-22	5.06E-20	0.00E+00	0.00E+00	0.00E+00	5.06E-20	3.53E-16	0.00E+00	3.53E-16	7.09E+16
2450	1.71E-16	2.35E-16	8.15E-18	1.22E-17	3.16E-22	0.00E+00	0.00E+00	4.27E-16	4.48E-23	4.98E-22	0.00E+00	5.42E-22	6.13E-20	0.00E+00	0.00E+00	0.00E+00	6.13E-20	4.27E-16	0.00E+00	4.27E-16	5.86E+16
2460	2.07E-16	2.85E-16	9.87E-18	1.47E-17	3.83E-22	0.00E+00	0.00E+00	5.17E-16	5.44E-23	6.03E-22	0.00E+00	6.57E-22	7.42E-20	0.00E+00	0.00E+00	0.00E+00	7.42E-20	5.17E-16	0.00E+00	5.17E-16	4.84E+16
2470	2.55E-16	3.51E-16	1.21E-17	1.81E-17	4.71E-22	0.00E+00	0.00E+00	6.36E-16	6.69E-23	7.42E-22	0.00E+00	8.09E-22	9.13E-20	0.00E+00	0.00E+00	0.00E+00	9.13E-20	6.36E-16	0.00E+00	6.36E-16	3.93E+16
2480	3.19E-16	4.38E-16	1.52E-17	2.26E-17	5.89E-22	0.00E+00	0.00E+00	7.95E-16	8.36E-23	9.27E-22	0.00E+00	1.01E-21	1.14E-19	0.00E+00	0.00E+00	0.00E+00	1.14E-19	7.95E-16	0.00E+00	7.95E-16	3.15E+16
2490	4.02E-16	5.53E-16	1.91E-17	2.86E-17	7.42E-22	0.00E+00	0.00E+00	1.00E-15	1.05E-22	1.17E-21	0.00E+00	1.27E-21	1.44E-19	0.00E+00	0.00E+00	0.00E+00	1.44E-19	1.00E-15	0.00E+00	1.00E-15	2.49E+16
2500	5.09E-16	7.00E-16	2.43E-17	3.62E-17	9.41E-22	0.00E+00	0.00E+00	1.27E-15	1.34E-22	1.48E-21	0.00E+00	1.62E-21	1.83E-19	0.00E+00	0.00E+00	0.00E+00	1.83E-19	1.27E-15	0.00E+00	1.27E-15	1.97E+16
2510	6.53E-16	8.98E-16	3.11E-17	4.64E-17	1.21E-21	0.00E+00	0.00E+00	1.63E-15	1.71E-22	1.90E-21	0.00E+00	2.07E-21	2.34E-19	0.00E+00	0.00E+00	0.00E+00	2.34E-19	1.63E-15	0.00E+00	1.63E-15	1.54E+16
2520	8.58E-16	1.18E-15	4.09E-17	6.11E-17	1.59E-21	0.00E+00	0.00E+00	2.14E-15	2.25E-22	2.50E-21	0.00E+00	2.72E-21	3.08E-19	0.00E+00	0.00E+00	0.00E+00	3.08E-19	2.14E-15	0.00E+00	2.14E-15	1.17E+16
2530	1.16E-15	1.59E-15	5.52E-17	8.24E-17	2.14E-21	0.00E+00	0.00E+00	2.89E-15	3.04E-22	3.37E-21	0.00E+00	3.68E-21	4.15E-19	0.00E+00	0.00E+00	0.00E+00	4.15E-19	2.89E-15	0.00E+00	2.89E-15	8.65E+15
2540	1.59E-15	2.19E-15	7.59E-17	1.13E-16	2.94E-21	0.00E+00	0.00E+00	3.97E-15	4.18E-22	4.64E-21	0.00E+00	5.05E-21	5.71E-19	0.00E+00	0.00E+00	0.00E+00	5.71E-19	3.97E-15	0.00E+00	3.97E-15	6.30E+15
2550	2.23E-15	3.07E-15	1.06E-16	1.59E-16	4.12E-21	0.00E+00	0.00E+00	5.56E-15	5.85E-22	6.49E-21	0.00E+00	7.08E-21	8.00E-19	0.00E+00	0.00E+00	0.00E+00	8.00E-19	5.56E-15	0.00E+00	5.56E-15	4.50E+15
2560	3.24E-15	4.46E-15	1.55E-16	2.31E-16	5.99E-21	0.00E+00	0.00E+00	8.09E-15	8.51E-22	9.45E-21	0.00E+00	1.03E-20	1.16E-18	0.00E+00	0.00E+00	0.00E+00	1.16E-18	8.09E-15	0.00E+00	8.09E-15	3.09E+15
2570	5.08E-15	6.99E-15	2.42E-16	3.62E-16	9.38E-21	0.00E+00	0.00E+00	1.27E-14	1.33E-21	1.48E-20	0.00E+00	1.61E-20	1.82E-18	0.00E+00	0.00E+00	0.00E+00	1.82E-18	1.27E-14	0.00E+00	1.27E-14	1.97E+15
2580	8.64E-15	1.19E-14	4.12E-16	6.16E-16	1.60E-20	0.00E+00	0.00E+00	2.16E-14	2.27E-21	2.52E-20	0.00E+00	2.75E-20	3.11E-18	0.00E+00	0.00E+00	0.00E+00	3.11E-18	2.16E-14	0.00E+00	2.16E-14	1.16E+15
2590	1.58E-14	2.18E-14	7.55E-16	1.13E-15	2.92E-20	0.00E+00	0.00E+00	3.95E-14	4.16E-21	4.61E-20	0.00E+00	5.03E-20	5.69E-18	0.00E+00	0.00E+00	0.00E+00	5.69E-18	3.95E-14	0.00E+00	3.95E-14	6.33E+14
2600	3.06E-14	4.21E-14	1.46E-15	2.18E-15	5.65E-20	0.00E+00	0.00E+00	7.63E-14	8.04E-21	8.91E-20	0.00E+00	9.72E-20	1.10E-17	0.00E+00	0.00E+00	0.00E+00	1.10E-17	7.63E-14	0.00E+00	7.63E-14	3.28E+14
2610	6.26E-14	8.62E-14	2.99E-15	4.46E-15	1.16E-19	0.00E+00	0.00E+00	1.56E-13	1.65E-20	1.83E-19	0.00E+00	1.99E-19	2.25E-17	0.00E+00	0.00E+00	0.00E+00	2.25E-17	1.56E-13	0.00E+00	1.56E-13	1.60E+14
2620	1.36E-13	1.87E-13	6.49E-15	9.70E-15	2.52E-19	0.00E+00	0.00E+00	3.40E-13	3.58E-20	3.97E-19	0.00E+00	4.33E-19	4.90E-17	0.00E+00	0.00E+00	0.00E+00	4.90E-17	3.40E-13	0.00E+00	3.40E-13	7.36E+13
2630	3.01E-13	4.14E-13	1.44E-14	2.15E-14	5.56E-19	0.00E+00	0.00E+00	7.51E-13	7.91E-20	8.78E-19	0.00E+00	9.57E-19	1.08E-16	0.00E+00	0.00E+00	0.00E+00	1.08E-16	7.51E-13	0.00E+00	7.51E-13	3.33E+13
2640	6.54E-13	9.00E-13	3.12E-14	4.66E-14	1.21E-18	0.00E+00	0.00E+00	1.63E-12	1.72E-19	1.91E-18	0.00E+00	2.08E-18	2.35E-16	0.00E+00	0.00E+00	0.00E+00	2.35E-16	1.63E-12	0.00E+00	1.63E-12	1.53E+13
2650	1.38E-12	1.90E-12	6.59E-14	9.85E-14	2.55E-18	0.00E+00	0.00E+00	3.45E-12	3.63E-19	4.03E-18	0.00E+00	4.39E-18	4.97E-16	0.00E+00	0.00E+00	0.00E+00	4.97E-16	3.45E-12	0.00E+00	3.45E-12	7.25E+12
2660	2.88E-12	3.96E-12	1.37E-13	2.05E-13	5.32E-18	0.00E+00	0.00E+00	7.19E-12	7.58E-19	8.40E-18	0.00E+00	9.16E-18	1.04E-15	0.00E+00	0.00E+00	0.00E+00	1.04E-15	7.19E-12	0.00E+00	7.19E-12	3.48E+12
2670	6.02E-12	8.29E-12	2.87E-13	4.29E-13	1.11E-17	0.00E+00	0.00E+00	1.50E-11	1.58E-18	1.76E-17	0.00E+00	1.92E-17	2.17E-15	0.00E+00	0.00E+00	0.00E+00	2.17E-15	1.50E-11	0.00E+00	1.50E-11	1.66E+12
2680	1.24E-11	1.70E-11	5.91E-13	8.83E-13	2.29E-17	0.00E+00	0.00E+00	3.09E-11	3.26E-18	3.61E-17	0.00E+00	3.94E-17	4.46E-15	0.00E+00	0.00E+00	0.00E+00	4.46E-15	3.09E-11	0.00E+00	3.09E-11	8.09E+11
2690	2.47E-11	3.39E-11	1.18E-12	1.76E-12	4.55E-17	0.00E+00	0.00E+00	6.15E-11	6.48E-18	7.19E-17	0.00E+00	7.84E-17	8.87E-15	0.00E+00	0.00E+00	0.00E+00	8.87E-15	6.15E-11	0.00E+00	6.15E-11	4.06E+11
2700	4.74E-11	6.52E-11	2.26E-12	3.38E-12	8.75E-17	0.00E+00	0.00E+00	1.18E-10	1.25E-17	1.38E-16	0.00E+00	1.51E-16	1.70E-14	0.00E+00	0.00E+00	0.00E+00	1.70E-14	1.18E-10	0.00E+00	1.18E-10	2.11E+11
2710	8.94E-11	1.23E-10	4.26E-12	6.37E-12	1.65E-16	0.00E+00	0.00E+00	2.23E-10	2.35E-17	2.61E-16	0.00E+00	2.84E-16	3.22E-14	0.00E+00	0.00E+00	0.00E+00	3.22E-14	2.23E-10	0.00E+00	2.23E-10	1.12E+11
2720	1.68E-10	2.32E-10	8.03E-12	1.20E-11	3.11E-16	0.00E+00	0.00E+00	4.20E-10	4.42E-17	4.91E-16	0.00E+00	5.35E-16	6.05E-14	0.00E+00	0.00E+00	0.00E+00	6.05E-14	4.20E-10	0.00E+00	4.20E-10	5.95E+10
2730	3.12E-10	4.29E-10	1.49E-11	2.22E-11	5.76E-16	0.00E+00	0.00E+00	7.78E-10	8.20E-17	9.10E-16	0.00E+00	9.92E-16	1.12E-13	0.00E+00	0.00E+00	0.00E+00	1.12E-13	7.78E-10	0.00E+00	7.78E-10	3.21E+10

Figure 3-6. Example output from file Slit_c\Dose_Limits\Pathway_Dose.xlsm

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		Alpha			Beta-Gamma			Uranium			Radium		
2		Conc	Limit		Dose	Limit		Conc	Limit		Conc	Limit	
3	Year	pCi/L	Ci		mrem/yr	Ci		ug/L	Ci		pCi/L	Ci	
4	2140	1.92E-17	7.81E+17		5.31E-20	7.53E+19		2.75E-41	1.00E+20		6.40E-18	7.82E+17	
5	2150	2.09E-17	7.19E+17		5.88E-20	6.80E+19		4.98E-41	1.00E+20		6.95E-18	7.20E+17	
6	2160	2.25E-17	6.67E+17		6.46E-20	6.19E+19		8.57E-41	1.00E+20		7.49E-18	6.67E+17	
7	2170	2.36E-17	6.37E+17		7.00E-20	5.71E+19		1.41E-40	1.00E+20		7.85E-18	6.37E+17	
8	2180	2.39E-17	6.27E+17		7.45E-20	5.37E+19		2.23E-40	1.00E+20		7.97E-18	6.28E+17	
9	2190	2.37E-17	6.33E+17		7.75E-20	5.16E+19		3.41E-40	1.00E+20		7.90E-18	6.33E+17	
10	2200	2.34E-17	6.41E+17		7.93E-20	5.04E+19		5.08E-40	1.00E+20		7.80E-18	6.41E+17	
11	2210	2.28E-17	6.57E+17		8.02E-20	4.99E+19		7.37E-40	1.00E+20		7.61E-18	6.57E+17	
12	2220	2.22E-17	6.75E+17		8.01E-20	4.99E+19		1.05E-39	1.00E+20		7.40E-18	6.76E+17	
13	2230	2.17E-17	6.92E+17		7.98E-20	5.01E+19		1.46E-39	1.00E+20		7.22E-18	6.93E+17	
14	2240	2.13E-17	7.05E+17		7.92E-20	5.05E+19		1.99E-39	1.00E+20		7.09E-18	7.05E+17	
15	2250	2.11E-17	7.11E+17		7.86E-20	5.09E+19		2.68E-39	1.00E+20		7.03E-18	7.11E+17	
16	2260	2.16E-17	6.96E+17		7.83E-20	5.11E+19		3.55E-39	1.00E+20		7.18E-18	6.96E+17	
17	2270	2.34E-17	6.42E+17		7.93E-20	5.04E+19		4.65E-39	1.00E+20		7.78E-18	6.43E+17	
18	2280	2.67E-17	5.62E+17		8.31E-20	4.81E+19		6.01E-39	1.00E+20		8.89E-18	5.63E+17	
19	2290	3.12E-17	4.80E+17		9.01E-20	4.44E+19		7.67E-39	1.00E+20		1.04E-17	4.80E+17	
20	2300	3.67E-17	4.09E+17		1.00E-19	3.98E+19		9.70E-39	1.00E+20		1.22E-17	4.09E+17	
21	2310	4.36E-17	3.44E+17		1.14E-19	3.50E+19		1.21E-38	1.00E+20		1.45E-17	3.44E+17	
22	2320	5.39E-17	2.78E+17		1.33E-19	3.00E+19		1.51E-38	1.00E+20		1.80E-17	2.78E+17	
23	2330	6.84E-17	2.19E+17		1.61E-19	2.49E+19		1.85E-38	1.00E+20		2.28E-17	2.19E+17	
24	2340	8.63E-17	1.74E+17		1.97E-19	2.03E+19		2.26E-38	1.00E+20		2.88E-17	1.74E+17	
25	2350	1.07E-16	1.40E+17		2.43E-19	1.64E+19		2.75E-38	1.00E+20		3.56E-17	1.41E+17	
26	2360	1.30E-16	1.15E+17		2.99E-19	1.34E+19		3.31E-38	1.00E+20		4.34E-17	1.15E+17	
27	2370	1.60E-16	9.38E+16		3.67E-19	1.09E+19		3.97E-38	1.00E+20		5.33E-17	9.38E+16	
28	2380	1.97E-16	7.61E+16		4.51E-19	8.86E+18		4.74E-38	1.00E+20		6.57E-17	7.61E+16	
29	2390	2.41E-16	6.21E+16		5.55E-19	7.21E+18		5.64E-38	1.00E+20		8.04E-17	6.22E+16	
30	2400	2.92E-16	5.15E+16		6.77E-19	5.90E+18		6.69E-38	1.00E+20		9.71E-17	5.15E+16	
31	2410	3.49E-16	4.29E+16		8.22E-19	4.87E+18		7.91E-38	1.00E+20		1.16E-16	4.29E+16	
32	2420	4.22E-16	3.56E+16		9.94E-19	4.02E+18		9.35E-38	1.00E+20		1.41E-16	3.56E+16	
33	2430	5.13E-16	2.93E+16		1.20E-18	3.32E+18		1.10E-37	1.00E+20		1.71E-16	2.93E+16	
34	2440	6.23E-16	2.41E+16		1.46E-18	2.74E+18		1.30E-37	1.00E+20		2.08E-16	2.41E+16	
35	2450	7.54E-16	1.99E+16		1.77E-18	2.26E+18		1.54E-37	1.00E+20		2.51E-16	1.99E+16	
36	2460	9.13E-16	1.64E+16		2.14E-18	1.87E+18		1.82E-37	1.00E+20		3.04E-16	1.64E+16	
37	2470	1.12E-15	1.34E+16		2.61E-18	1.53E+18		2.15E-37	1.00E+20		3.74E-16	1.34E+16	
38	2480	1.40E-15	1.07E+16		3.21E-18	1.25E+18		2.55E-37	1.00E+20		4.68E-16	1.07E+16	
39	2490	1.77E-15	8.47E+15		3.98E-18	1.01E+18		3.04E-37	1.00E+20		5.90E-16	8.47E+15	
40	2500	2.24E-15	6.68E+15		4.98E-18	8.04E+17		3.63E-37	1.00E+20		7.48E-16	6.69E+15	
41	2510	2.88E-15	5.21E+15		6.28E-18	6.37E+17		4.34E-37	1.00E+20		9.59E-16	5.21E+15	
42	2520	3.79E-15	3.96E+15		8.04E-18	4.97E+17		5.21E-37	1.00E+20		1.26E-15	3.96E+15	
43	2530	5.11E-15	2.94E+15		1.05E-17	3.80E+17		6.28E-37	1.00E+20		1.70E-15	2.94E+15	
44	2540	7.02E-15	2.14E+15		1.40E-17	2.85E+17		7.58E-37	1.00E+20		2.34E-15	2.14E+15	
45	2550	9.84E-15	1.52E+15		1.91E-17	2.09E+17		9.19E-37	1.00E+20		3.28E-15	1.53E+15	
46	2560	1.43E-14	1.05E+15		2.67E-17	1.50E+17		1.12E-36	1.00E+20		4.77E-15	1.05E+15	
47	2570	2.24E-14	6.69E+14		3.91E-17	1.02E+17		1.36E-36	1.00E+20		7.47E-15	6.69E+14	
48	2580	3.82E-14	3.93E+14		6.13E-17	6.52E+16		1.67E-36	1.00E+20		1.27E-14	3.93E+14	
49	2590	7.00E-14	2.14E+14		1.04E-16	3.85E+16		2.04E-36	1.00E+20		2.33E-14	2.14E+14	
50	2600	1.35E-13	1.11E+14		1.89E-16	2.12E+16		2.52E-36	1.00E+20		4.51E-14	1.11E+14	
51	2610	2.77E-13	5.41E+13		3.67E-16	1.09E+16		3.11E-36	1.00E+20		9.24E-14	5.41E+13	
52	2620	6.02E-13	2.49E+13		7.59E-16	5.27E+15		3.85E-36	1.00E+20		2.01E-13	2.49E+13	

Form / C-14 / Cl-36 / H-3 / I-129 / Mo-93 / Nb-94 / Tc-99 / U-238

Figure 3-7. Example output from file Slit_c\Dose_Limits\Groundwater.xlsm

	A	B	C	D	E	G	H	I	J	L	N	O
1		Construction				Drilling				Discovery	Acute	Disposal
2		External	Ingest	Inhale	Total	External	Ingest	Inhale	Total	Total	Total	Limit
3	Year	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	Ci
4	2140	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
5	2150	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
6	2160	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
7	2170	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
8	2180	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
9	2190	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
10	2200	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
11	2210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
12	2220	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
13	2230	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
14	2240	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
15	2250	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
16	2260	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
17	2270	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
18	2280	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
19	2290	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
20	2300	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
21	2310	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
22	2320	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
23	2330	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
24	2340	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
25	2350	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.07E-15	1.74E-03	2.87E+05
26	2360	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
27	2370	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
28	2380	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.08E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
29	2390	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
30	2400	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
31	2410	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
32	2420	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
33	2430	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
34	2440	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
35	2450	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
36	2460	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
37	2470	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.16E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
38	2480	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.08E-15	1.74E-03	2.87E+05
39	2490	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.09E-15	1.74E-03	2.87E+05
40	2500	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.09E-15	1.74E-03	2.87E+05
41	2510	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.09E-15	1.74E-03	2.87E+05
42	2520	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.09E-15	1.74E-03	2.87E+05
43	2530	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.09E-15	1.74E-03	2.87E+05
44	2540	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.09E-15	1.74E-03	2.87E+05
45	2550	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.09E-15	1.74E-03	2.87E+05
46	2560	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.09E-15	1.74E-03	2.87E+05
47	2570	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.10E-15	1.74E-03	2.87E+05
48	2580	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.10E-15	1.74E-03	2.87E+05
49	2590	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.10E-15	1.74E-03	2.87E+05
50	2600	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.10E-15	1.74E-03	2.87E+05
51	2610	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.10E-15	1.74E-03	2.87E+05
52	2620	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.55E-04	7.09E-05	7.17E-04	1.74E-03	5.10E-15	1.74E-03	2.87E+05

Form / C-14 / Cl-36 / H-3 / I-129 / Mo-93 / Nb-94 / Tc-99 / **U-238**

Figure 3-8. Example output from file Slit_c\Dose_Limits\Acute_Intruder.xlsm

	Agriculture							Post Drilling					Residential	Chronic	Disposal
	Garden Ext	Home Ext	Vege Ingest	Soil Ingest	Home Inhale	Soil Inhale	Total	Garden Ext	Vege Ingest	Soil Ingest	Soil Inhale	Total	Total	Total	Limit
Year	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	Ci
2140	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.16E-03	4.01E-04	2.82E-02	2.72E-05	2.82E-02	3.55E+03
2150	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.16E-03	4.01E-04	2.82E-02	3.09E-05	2.82E-02	3.55E+03
2160	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.16E-03	4.01E-04	2.82E-02	3.51E-05	2.82E-02	3.55E+03
2170	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.16E-03	4.01E-04	2.82E-02	3.98E-05	2.82E-02	3.55E+03
2180	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	4.51E-05	2.82E-02	3.55E+03
2190	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	5.12E-05	2.82E-02	3.54E+03
2200	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	5.81E-05	2.82E-02	3.54E+03
2210	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	6.59E-05	2.82E-02	3.54E+03
2220	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	7.48E-05	2.82E-02	3.54E+03
2230	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	8.49E-05	2.83E-02	3.54E+03
2240	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	9.63E-05	2.83E-02	3.54E+03
2250	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	1.09E-04	2.83E-02	3.54E+03
2260	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	1.24E-04	2.83E-02	3.53E+03
2270	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	1.41E-04	2.83E-02	3.53E+03
2280	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	1.60E-04	2.83E-02	3.53E+03
2290	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	1.81E-04	2.84E-02	3.53E+03
2300	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	2.05E-04	2.84E-02	3.52E+03
2310	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	2.33E-04	2.84E-02	3.52E+03
2320	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	2.64E-04	2.84E-02	3.52E+03
2330	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	3.00E-04	2.85E-02	3.51E+03
2340	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	3.41E-04	2.85E-02	3.51E+03
2350	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	3.86E-04	2.86E-02	3.50E+03
2360	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	4.38E-04	2.86E-02	3.49E+03
2370	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	4.97E-04	2.87E-02	3.49E+03
2380	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	5.64E-04	2.87E-02	3.48E+03
2390	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	6.40E-04	2.88E-02	3.47E+03
2400	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	7.27E-04	2.89E-02	3.46E+03
2410	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	8.25E-04	2.90E-02	3.45E+03
2420	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	9.36E-04	2.91E-02	3.43E+03
2430	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	1.06E-03	2.92E-02	3.42E+03
2440	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	1.20E-03	2.94E-02	3.40E+03
2450	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	1.37E-03	2.96E-02	3.38E+03
2460	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	1.55E-03	2.97E-02	3.36E+03
2470	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	1.76E-03	2.99E-02	3.34E+03
2480	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	2.00E-03	3.02E-02	3.31E+03
2490	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	2.27E-03	3.05E-02	3.28E+03
2500	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	2.57E-03	3.08E-02	3.25E+03
2510	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	2.92E-03	3.11E-02	3.21E+03
2520	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	3.31E-03	3.15E-02	3.17E+03
2530	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	3.76E-03	3.20E-02	3.13E+03
2540	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	4.27E-03	3.25E-02	3.08E+03
2550	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.01E-04	2.82E-02	4.84E-03	3.30E-02	3.03E+03
2560	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.02E-04	2.82E-02	5.49E-03	3.37E-02	2.97E+03
2570	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.02E-04	2.82E-02	6.23E-03	3.44E-02	2.90E+03
2580	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.02E-04	2.82E-02	7.07E-03	3.53E-02	2.84E+03
2590	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.02E-04	2.82E-02	8.03E-03	3.62E-02	2.76E+03
2600	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.02E-04	2.82E-02	9.11E-03	3.73E-02	2.68E+03
2610	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.02E-04	2.82E-02	1.03E-02	3.85E-02	2.59E+03
2620	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.04E-04	2.31E-02	4.17E-03	4.02E-04	2.82E-02	1.17E-02	3.99E-02	2.50E+03

Form C-14 Cl-36 H-3 I-129 Mo-93 Nb-94 Tc-99 U-238

Figure 3-9. Example output from file Slit_c\Dose_Limits\Chronic_Intruder.xlsm

Year	All-Pathways Disposal Limit Ci	Alpha Disposal Limit Ci	Beta-Gamma Disposal Limit Ci	Uranium Disposal Limit Ci	Radium Disposal Limit Ci	Chronic Intruder Disposal Limit Ci	Acute Intruder Disposal Limit Ci
2140	2.30E+18	7.81E+17	7.53E+19	1.00E+20	7.82E+17	2.87E+05	3.55E+03
2150	2.11E+18	7.19E+17	6.80E+19	1.00E+20	7.20E+17	2.87E+05	3.55E+03
2160	1.96E+18	6.67E+17	6.19E+19	1.00E+20	6.67E+17	2.87E+05	3.55E+03
2170	1.87E+18	6.37E+17	5.71E+19	1.00E+20	6.37E+17	2.87E+05	3.55E+03
2180	1.84E+18	6.27E+17	5.37E+19	1.00E+20	6.28E+17	2.87E+05	3.55E+03
2190	1.86E+18	6.33E+17	5.16E+19	1.00E+20	6.33E+17	2.87E+05	3.54E+03
2200	1.88E+18	6.41E+17	5.04E+19	1.00E+20	6.41E+17	2.87E+05	3.54E+03
2210	1.92E+18	6.57E+17	4.99E+19	1.00E+20	6.57E+17	2.87E+05	3.54E+03
2220	1.98E+18	6.75E+17	4.99E+19	1.00E+20	6.76E+17	2.87E+05	3.54E+03
2230	2.03E+18	6.92E+17	5.01E+19	1.00E+20	6.93E+17	2.87E+05	3.54E+03
2240	2.06E+18	7.05E+17	5.05E+19	1.00E+20	7.05E+17	2.87E+05	3.54E+03
2250	2.08E+18	7.11E+17	5.09E+19	1.00E+20	7.11E+17	2.87E+05	3.54E+03
2260	2.04E+18	6.96E+17	5.11E+19	1.00E+20	6.96E+17	2.87E+05	3.53E+03
2270	1.88E+18	6.42E+17	5.04E+19	1.00E+20	6.43E+17	2.87E+05	3.53E+03
2280	1.65E+18	5.62E+17	4.81E+19	1.00E+20	5.63E+17	2.87E+05	3.53E+03
2290	1.41E+18	4.80E+17	4.44E+19	1.00E+20	4.80E+17	2.87E+05	3.53E+03
2300	1.20E+18	4.09E+17	3.98E+19	1.00E+20	4.09E+17	2.87E+05	3.52E+03
2310	1.01E+18	3.44E+17	3.50E+19	1.00E+20	3.44E+17	2.87E+05	3.52E+03
2320	8.19E+17	2.78E+17	3.00E+19	1.00E+20	2.78E+17	2.87E+05	3.52E+03
2330	6.45E+17	2.19E+17	2.49E+19	1.00E+20	2.19E+17	2.87E+05	3.51E+03
2340	5.12E+17	1.74E+17	2.03E+19	1.00E+20	1.74E+17	2.87E+05	3.51E+03
2350	4.14E+17	1.40E+17	1.64E+19	1.00E+20	1.41E+17	2.87E+05	3.50E+03
2360	3.39E+17	1.15E+17	1.34E+19	1.00E+20	1.15E+17	2.87E+05	3.49E+03
2370	2.76E+17	9.38E+16	1.09E+19	1.00E+20	9.38E+16	2.87E+05	3.49E+03
2380	2.24E+17	7.61E+16	8.86E+18	1.00E+20	7.61E+16	2.87E+05	3.48E+03
2390	1.83E+17	6.21E+16	7.21E+18	1.00E+20	6.22E+16	2.87E+05	3.47E+03
2400	1.52E+17	5.15E+16	5.90E+18	1.00E+20	5.15E+16	2.87E+05	3.46E+03
2410	1.26E+17	4.29E+16	4.87E+18	1.00E+20	4.29E+16	2.87E+05	3.45E+03
2420	1.05E+17	3.56E+16	4.02E+18	1.00E+20	3.56E+16	2.87E+05	3.43E+03
2430	8.62E+16	2.93E+16	3.32E+18	1.00E+20	2.93E+16	2.87E+05	3.42E+03
2440	7.09E+16	2.41E+16	2.74E+18	1.00E+20	2.41E+16	2.87E+05	3.40E+03
2450	5.86E+16	1.99E+16	2.26E+18	1.00E+20	1.99E+16	2.87E+05	3.38E+03
2460	4.84E+16	1.64E+16	1.87E+18	1.00E+20	1.64E+16	2.87E+05	3.36E+03
2470	3.93E+16	1.34E+16	1.53E+18	1.00E+20	1.34E+16	2.87E+05	3.34E+03
2480	3.15E+16	1.07E+16	1.25E+18	1.00E+20	1.07E+16	2.87E+05	3.31E+03
2490	2.49E+16	8.47E+15	1.01E+18	1.00E+20	8.47E+15	2.87E+05	3.28E+03
2500	1.97E+16	6.68E+15	8.04E+17	1.00E+20	6.69E+15	2.87E+05	3.25E+03
2510	1.54E+16	5.21E+15	6.37E+17	1.00E+20	5.21E+15	2.87E+05	3.21E+03
2520	1.17E+16	3.96E+15	4.97E+17	1.00E+20	3.96E+15	2.87E+05	3.17E+03
2530	8.65E+15	2.94E+15	3.80E+17	1.00E+20	2.94E+15	2.87E+05	3.13E+03
2540	6.30E+15	2.14E+15	2.85E+17	1.00E+20	2.14E+15	2.87E+05	3.08E+03
2550	4.50E+15	1.52E+15	2.09E+17	1.00E+20	1.53E+15	2.87E+05	3.03E+03
2560	3.09E+15	1.05E+15	1.50E+17	1.00E+20	1.05E+15	2.87E+05	2.97E+03
2570	1.97E+15	6.69E+14	1.02E+17	1.00E+20	6.69E+14	2.87E+05	2.90E+03
2580	1.16E+15	3.93E+14	6.52E+16	1.00E+20	3.93E+14	2.87E+05	2.84E+03
2590	6.33E+14	2.14E+14	3.85E+16	1.00E+20	2.14E+14	2.87E+05	2.76E+03
2600	3.28E+14	1.11E+14	2.12E+16	1.00E+20	1.11E+14	2.87E+05	2.68E+03
2610	1.60E+14	5.41E+13	1.09E+16	1.00E+20	5.41E+13	2.87E+05	2.59E+03
2620	7.36E+13	2.49E+13	5.27E+15	1.00E+20	2.49E+13	2.87E+05	2.50E+03

Form | C-14 | Cl-36 | H-3 | I-129 | Mo-93 | Nb-94 | Tc-99 | U-238

Figure 3-10. Example output from file Slit_c\Dose_Limits\Disposal_Limits.xlsm

	A	B	C	D	E	F	G	H	I	J	K	L
1												
2		U-238	U-234	Th-230	Ra-226	Pb-210						
3	Year	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	
4	2140	3.06E-42	1.40E-45	9.02E-50	1.08E-17	1.12E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
5	2150	5.55E-42	2.71E-45	1.91E-49	1.17E-17	1.24E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
6	2160	9.53E-42	4.95E-45	3.78E-49	1.26E-17	1.37E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
7	2170	1.57E-41	8.60E-45	7.09E-49	1.32E-17	1.49E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
8	2180	2.48E-41	1.43E-44	1.27E-48	1.34E-17	1.59E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
9	2190	3.80E-41	2.31E-44	2.19E-48	1.33E-17	1.66E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
10	2200	5.65E-41	3.60E-44	3.63E-48	1.31E-17	1.70E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
11	2210	8.20E-41	5.47E-44	5.85E-48	1.28E-17	1.72E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
12	2220	1.16E-40	8.12E-44	9.17E-48	1.25E-17	1.73E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
13	2230	1.62E-40	1.18E-43	1.40E-47	1.22E-17	1.72E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
14	2240	2.22E-40	1.68E-43	2.10E-47	1.19E-17	1.71E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
15	2250	2.98E-40	2.34E-43	3.08E-47	1.18E-17	1.70E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
16	2260	3.96E-40	3.23E-43	4.44E-47	1.21E-17	1.69E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
17	2270	5.18E-40	4.37E-43	6.30E-47	1.31E-17	1.70E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
18	2280	6.69E-40	5.85E-43	8.79E-47	1.50E-17	1.77E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
19	2290	8.54E-40	7.72E-43	1.21E-46	1.75E-17	1.91E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
20	2300	1.08E-39	1.01E-42	1.64E-46	2.06E-17	2.12E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
21	2310	1.35E-39	1.30E-42	2.21E-46	2.45E-17	2.40E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
22	2320	1.68E-39	1.66E-42	2.93E-46	3.03E-17	2.79E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
23	2330	2.06E-39	2.11E-42	3.85E-46	3.84E-17	3.34E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
24	2340	2.52E-39	2.65E-42	5.00E-46	4.84E-17	4.08E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
25	2350	3.06E-39	3.31E-42	6.45E-46	5.99E-17	5.04E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
26	2360	3.68E-39	4.10E-42	8.25E-46	7.31E-17	6.20E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
27	2370	4.42E-39	5.05E-42	1.05E-45	8.98E-17	7.61E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
28	2380	5.28E-39	6.18E-42	1.32E-45	1.11E-16	9.35E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
29	2390	6.28E-39	7.54E-42	1.65E-45	1.35E-16	1.15E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
30	2400	7.45E-39	9.16E-42	2.06E-45	1.64E-16	1.41E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
31	2410	8.81E-39	1.11E-41	2.55E-45	1.96E-16	1.71E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
32	2420	1.04E-38	1.34E-41	3.14E-45	2.37E-16	2.07E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
33	2430	1.23E-38	1.62E-41	3.86E-45	2.88E-16	2.50E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
34	2440	1.45E-38	1.95E-41	4.73E-45	3.50E-16	3.03E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
35	2450	1.71E-38	2.36E-41	5.78E-45	4.23E-16	3.68E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
36	2460	2.02E-38	2.85E-41	7.04E-45	5.13E-16	4.46E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
37	2470	2.40E-38	3.44E-41	8.57E-45	6.31E-16	5.42E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
38	2480	2.84E-38	4.17E-41	1.04E-44	7.88E-16	6.64E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
39	2490	3.38E-38	5.06E-41	1.27E-44	9.94E-16	8.23E-18	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
40	2500	4.04E-38	6.16E-41	1.54E-44	1.26E-15	1.03E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
41	2510	4.83E-38	7.52E-41	1.87E-44	1.62E-15	1.29E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
42	2520	5.80E-38	9.20E-41	2.28E-44	2.13E-15	1.65E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
43	2530	6.99E-38	1.13E-40	2.78E-44	2.87E-15	2.15E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
44	2540	8.44E-38	1.39E-40	3.40E-44	3.94E-15	2.86E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
45	2550	1.02E-37	1.71E-40	4.16E-44	5.52E-15	3.88E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
46	2560	1.24E-37	2.12E-40	5.09E-44	8.04E-15	5.40E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
47	2570	1.52E-37	2.63E-40	6.26E-44	1.26E-14	7.83E-17	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
48	2580	1.85E-37	3.27E-40	7.71E-44	2.14E-14	1.21E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
49	2590	2.27E-37	4.08E-40	9.51E-44	3.93E-14	2.03E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
50	2600	2.80E-37	5.11E-40	1.18E-43	7.59E-14	3.65E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
51	2610	3.46E-37	6.41E-40	1.46E-43	1.56E-13	7.00E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
52	2620	4.29E-37	8.08E-40	1.82E-43	3.38E-13	1.44E-15	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	

Form / C-14 / Cl-36 / H-3 / I-129 / Mo-93 / Nb-94 / Tc-99 / U-238

Figure 3-11. Example output from file Slit_c\Dose_Limits\Species_Dose.xlsm

	Resident Farmer									
	Zn-63	Y-90m	Ag-108m	Te-129m	Pr-144m	Dy-152	W-179	Tl-206	Th-233	
Year	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr
2040	9.61E-08	1.64E-03	2.78E+00	1.92E-01	6.13E-09	2.13E-02	2.02E-03	0.00E+00	4.05E-02	0.00E+00
2041	4.95E-188	1.34E-29	3.46E+01	7.18E-03	1.51E-220	7.16E-07	1.56E-02	0.00E+00	8.98E-05	0.00E+00
2042	0.00E+00	2.37E-58	4.63E+01	6.23E-03	0.00E+00	5.02E-07	1.25E-02	0.00E+00	6.84E-07	0.00E+00
2043	0.00E+00	3.20E-87	5.05E+01	5.91E-03	0.00E+00	4.22E-07	7.95E-03	0.00E+00	3.30E-07	0.00E+00
2044	0.00E+00	3.92E-116	5.20E+01	5.15E-03	0.00E+00	3.90E-07	4.71E-03	0.00E+00	2.05E-07	0.00E+00
2045	0.00E+00	4.59E-145	5.25E+01	4.35E-03	0.00E+00	3.76E-07	2.71E-03	0.00E+00	1.58E-07	0.00E+00
2046	0.00E+00	5.24E-174	5.26E+01	3.61E-03	0.00E+00	3.69E-07	1.54E-03	0.00E+00	1.41E-07	0.00E+00
2047	0.00E+00	5.89E-203	5.26E+01	2.99E-03	0.00E+00	3.64E-07	8.72E-04	0.00E+00	1.35E-07	0.00E+00
2048	0.00E+00	6.58E-232	5.26E+01	2.46E-03	0.00E+00	3.60E-07	4.92E-04	0.00E+00	1.33E-07	0.00E+00
2049	0.00E+00	7.32E-261	5.25E+01	2.03E-03	0.00E+00	3.57E-07	2.77E-04	0.00E+00	1.32E-07	0.00E+00
2050	0.00E+00	8.11E-290	5.24E+01	1.67E-03	0.00E+00	3.53E-07	1.56E-04	0.00E+00	1.32E-07	0.00E+00
2051	0.00E+00	0.00E+00	5.23E+01	1.38E-03	0.00E+00	3.50E-07	8.80E-05	0.00E+00	1.32E-07	0.00E+00
2052	0.00E+00	0.00E+00	5.22E+01	1.13E-03	0.00E+00	3.47E-07	4.95E-05	0.00E+00	1.32E-07	0.00E+00
2053	0.00E+00	0.00E+00	5.21E+01	9.31E-04	0.00E+00	3.43E-07	2.79E-05	0.00E+00	1.32E-07	0.00E+00
2054	0.00E+00	0.00E+00	5.20E+01	7.66E-04	0.00E+00	3.40E-07	1.57E-05	0.00E+00	1.32E-07	0.00E+00
2055	0.00E+00	0.00E+00	5.19E+01	6.30E-04	0.00E+00	3.37E-07	8.84E-06	0.00E+00	1.33E-07	0.00E+00
2056	0.00E+00	0.00E+00	5.18E+01	5.19E-04	0.00E+00	3.34E-07	4.98E-06	0.00E+00	1.33E-07	0.00E+00
2057	0.00E+00	0.00E+00	5.17E+01	4.27E-04	0.00E+00	3.31E-07	2.80E-06	0.00E+00	1.33E-07	0.00E+00
2058	0.00E+00	0.00E+00	5.16E+01	3.51E-04	0.00E+00	3.28E-07	1.58E-06	0.00E+00	1.33E-07	0.00E+00
2059	0.00E+00	0.00E+00	5.15E+01	2.89E-04	0.00E+00	3.25E-07	8.89E-07	0.00E+00	1.33E-07	0.00E+00
2060	0.00E+00	0.00E+00	5.14E+01	2.38E-04	0.00E+00	3.22E-07	5.00E-07	0.00E+00	1.33E-07	0.00E+00
2061	0.00E+00	0.00E+00	5.13E+01	1.96E-04	0.00E+00	3.19E-07	2.82E-07	0.00E+00	1.33E-07	0.00E+00
2062	0.00E+00	0.00E+00	5.12E+01	1.61E-04	0.00E+00	3.16E-07	1.59E-07	0.00E+00	1.34E-07	0.00E+00
2063	0.00E+00	0.00E+00	5.11E+01	1.32E-04	0.00E+00	3.13E-07	8.93E-08	0.00E+00	1.34E-07	0.00E+00
2064	0.00E+00	0.00E+00	5.10E+01	1.09E-04	0.00E+00	3.10E-07	5.03E-08	0.00E+00	1.34E-07	0.00E+00
2065	0.00E+00	0.00E+00	5.09E+01	8.97E-05	0.00E+00	3.07E-07	2.83E-08	0.00E+00	1.34E-07	0.00E+00
2066	0.00E+00	0.00E+00	5.08E+01	7.38E-05	0.00E+00	3.04E-07	1.59E-08	0.00E+00	1.34E-07	0.00E+00
2067	0.00E+00	0.00E+00	5.07E+01	6.07E-05	0.00E+00	3.02E-07	8.97E-09	0.00E+00	1.34E-07	0.00E+00
2068	0.00E+00	0.00E+00	5.06E+01	5.00E-05	0.00E+00	2.99E-07	5.05E-09	0.00E+00	1.35E-07	0.00E+00
2069	0.00E+00	0.00E+00	5.05E+01	4.11E-05	0.00E+00	2.96E-07	2.84E-09	0.00E+00	1.35E-07	0.00E+00
2070	0.00E+00	0.00E+00	5.04E+01	3.38E-05	0.00E+00	2.93E-07	1.60E-09	0.00E+00	1.35E-07	0.00E+00
2071	0.00E+00	0.00E+00	5.03E+01	2.78E-05	0.00E+00	2.90E-07	9.02E-10	0.00E+00	1.35E-07	0.00E+00
2072	0.00E+00	0.00E+00	5.02E+01	2.29E-05	0.00E+00	2.88E-07	5.08E-10	0.00E+00	1.35E-07	0.00E+00
2073	0.00E+00	0.00E+00	5.01E+01	1.88E-05	0.00E+00	2.85E-07	2.86E-10	0.00E+00	1.35E-07	0.00E+00
2074	0.00E+00	0.00E+00	5.00E+01	1.55E-05	0.00E+00	2.82E-07	1.61E-10	0.00E+00	1.35E-07	0.00E+00
2075	0.00E+00	0.00E+00	4.99E+01	1.28E-05	0.00E+00	2.80E-07	9.06E-11	0.00E+00	1.36E-07	0.00E+00
2076	0.00E+00	0.00E+00	4.98E+01	1.05E-05	0.00E+00	2.77E-07	5.10E-11	0.00E+00	1.36E-07	0.00E+00
2077	0.00E+00	0.00E+00	4.97E+01	8.64E-06	0.00E+00	2.75E-07	2.87E-11	0.00E+00	1.36E-07	0.00E+00
2078	0.00E+00	0.00E+00	4.96E+01	7.11E-06	0.00E+00	2.72E-07	1.62E-11	0.00E+00	1.36E-07	0.00E+00
2079	0.00E+00	0.00E+00	4.95E+01	5.85E-06	0.00E+00	2.70E-07	9.11E-12	0.00E+00	1.36E-07	0.00E+00
2080	0.00E+00	0.00E+00	4.94E+01	4.81E-06	0.00E+00	2.67E-07	5.13E-12	0.00E+00	1.36E-07	0.00E+00
2081	0.00E+00	0.00E+00	4.93E+01	3.96E-06	0.00E+00	2.65E-07	2.89E-12	0.00E+00	1.37E-07	0.00E+00
2082	0.00E+00	0.00E+00	4.92E+01	3.26E-06	0.00E+00	2.62E-07	1.63E-12	0.00E+00	1.37E-07	0.00E+00
2083	0.00E+00	0.00E+00	4.91E+01	2.68E-06	0.00E+00	2.60E-07	9.15E-13	0.00E+00	1.37E-07	0.00E+00
2084	0.00E+00	0.00E+00	4.91E+01	2.20E-06	0.00E+00	2.57E-07	5.15E-13	0.00E+00	1.37E-07	0.00E+00
2085	0.00E+00	0.00E+00	4.90E+01	1.81E-06	0.00E+00	2.55E-07	2.90E-13	0.00E+00	1.37E-07	0.00E+00
2086	0.00E+00	0.00E+00	4.89E+01	1.49E-06	0.00E+00	2.53E-07	1.63E-13	0.00E+00	1.37E-07	0.00E+00
2087	0.00E+00	0.00E+00	4.88E+01	1.23E-06	0.00E+00	2.50E-07	9.20E-14	0.00E+00	1.37E-07	0.00E+00
2088	0.00E+00	0.00E+00	4.87E+01	1.01E-06	0.00E+00	2.48E-07	5.18E-14	0.00E+00	1.38E-07	0.00E+00
2089	0.00E+00	0.00E+00	4.86E+01	8.32E-07	0.00E+00	2.46E-07	2.92E-14	0.00E+00	1.38E-07	0.00E+00
2090	0.00E+00	0.00E+00	4.85E+01	6.84E-07	0.00E+00	2.43E-07	1.64E-14	0.00E+00	1.38E-07	0.00E+00
2091	0.00E+00	0.00E+00	4.84E+01	5.63E-07	0.00E+00	2.41E-07	9.24E-15	0.00E+00	1.38E-07	0.00E+00
2092	0.00E+00	0.00E+00	4.83E+01	4.63E-07	0.00E+00	2.39E-07	5.20E-15	0.00E+00	1.38E-07	0.00E+00
2093	0.00E+00	0.00E+00	4.82E+01	3.81E-07	0.00E+00	2.37E-07	2.93E-15	0.00E+00	1.38E-07	0.00E+00
2094	0.00E+00	0.00E+00	4.81E+01	3.14E-07	0.00E+00	2.34E-07	1.65E-15	0.00E+00	1.38E-07	0.00E+00

	Intruder Agriculture									
	Zn-63	Y-90m	Ag-108m	Te-129m	Pr-144m	Dy-152	W-179	Tl-206	Th-233	
Year	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr
2040	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2041	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2042	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2043	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2044	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2045	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2046	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2047	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2048	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2049	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2050	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2051	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2052	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2053	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2054	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2055	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2056	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2057	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2058	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2059	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2060	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2061	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2062	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2063	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2064	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2065	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2066	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2067	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2068	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2069	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2070	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2071	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2072	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2073	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2074	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2075	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2076	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2077	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2078	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2079	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2080	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2081	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2082	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2083	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2084	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2085	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2086	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2087	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2088	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2089	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2090	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2091	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2092	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2093	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2094	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Group115 Group116 Group117 Group118 Group119 Group120 Group121 Group122 Group123 **Group124** Group125 Group126 Summary

Figure 3-12. Example output from file Screening\Dose_Limits\Species_Dose.xlsm

3.2 Graphical Display of Model Output

All of the Excel workbooks capturing model output have identical VBA macros that can be used to plot results. As shown in Figures 3-6 through 3-11, the first worksheet in each output file is named "Form" and holds a form with column headings that was used to create the worksheets where output from each individual parent radionuclide is stored. Following a doses and limits model run, the Form worksheet is no longer used and it served as a convenient location to place plots of the results.

If the user opens any of the Excel output files, selects the View button on the top ribbon, and clicks on "Macros", as illustrated below in the top part of Figure 3-13, a list of the macros contained in the workbook appears as shown in the lower part of Figure 3-13.

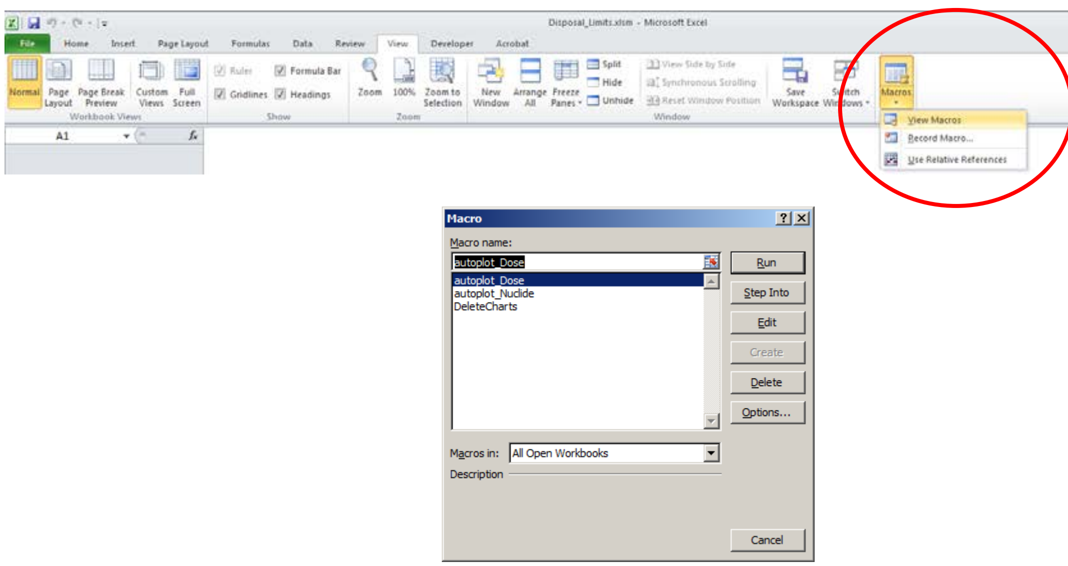


Figure 3-13. Opening macro menu.

Each workbook contains two primary plotting programs named autoplot_Dose and autoplot_Nuclide. The programs can be run by selecting one of the macros and clicking the Run button on the menu. Clicking the Edit button allows the user to view and modify the macros.

The two plotting programs are very similar. In general, the function of each can be summarized as follows:

1. autoplot_Dose – loops over all worksheets in the workbook and plots the total dose or disposal limit for each parent radionuclide as a function of time on a single graph.
2. autoplot_Nuclide – loops over all worksheets in the workbook and plots the dose for each pathway on individual graphs for each parent radionuclide.

Table 3-1 shows which programs produce plots for each output file. The plotting program is aware of which output file it is located in and if a program not checked in Table 3-1 is run for a particular output file nothing happens. At the bottom of the plotting macro, subroutines Define_Dose and Define_Nuclide contain fixed parameter used for each type of output. The user can edit these setting to produce better graphs. Of course, once the plots are created, they can also be edited using the Excel ChartTools.

Table 3-1. Plotting functions active for each output file.

Output File	autoplot_Dose	autoplot_Nuclide
Acute_Intruder_Dose	✓	✓
Chronic_Intruder_Dose	✓	✓
Disposal_Limits		✓
Groundwater	✓ **(4 pathways)**	
Pathway_Dose	✓	✓
Species_Dose		✓

Examples of each of the 12 different plot types indicated in Table 3-1 that can be generated using the autoplot macros are shown below in Figures 3-14 through 3-25. Note that Nuclide plotting will create a plot for each parent radionuclide on separate graphs and that Dose plotting will create a plot for each parent radionuclide on a single graph. If 10 parents are analyzed, a total of 57 plots can be created.

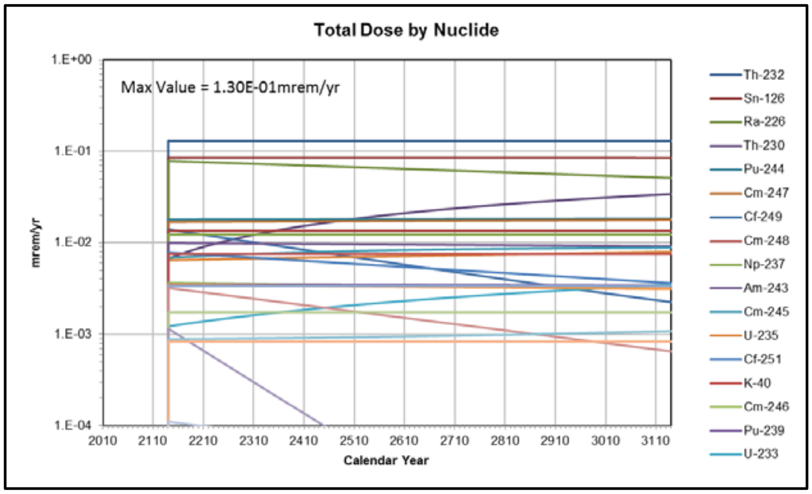


Figure 3-14. Dose plot from Acute_Intruder_Dose workbook.

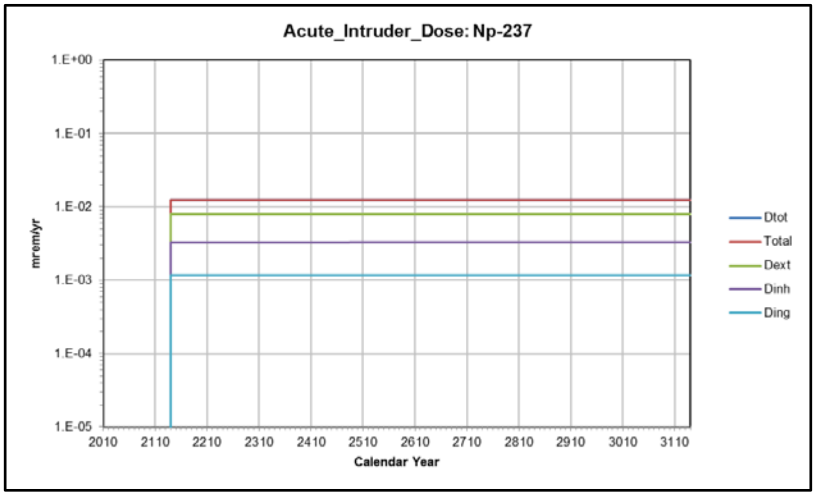


Figure 3-15. Single nuclide plot from Acute_Intruder_Dose workbook.

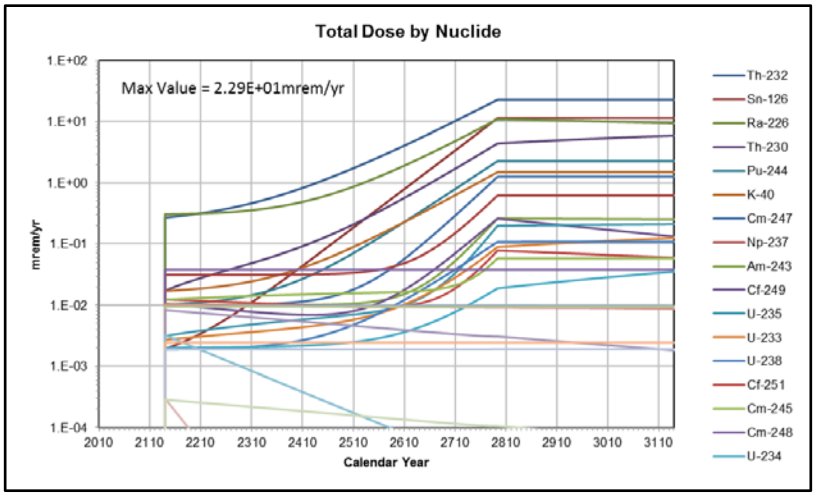


Figure3-16. Dose plot from Chronic_Intruder_Dose workbook.

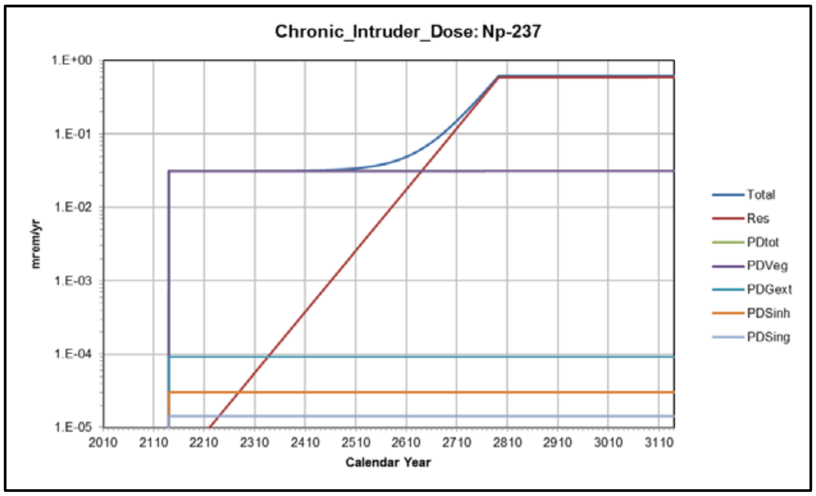


Figure 3-17. Single nuclide plot from Chronic_Intruder_Dose workbook.

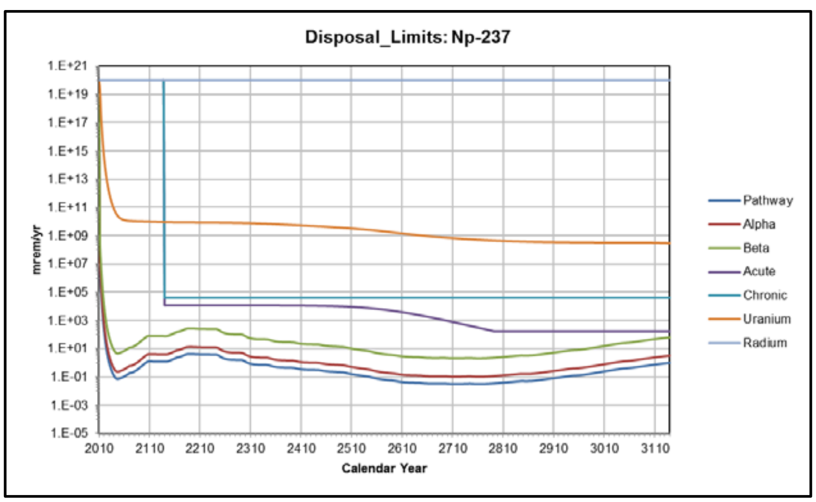


Figure 3-18. Single nuclide plot from Disposal_Limits workbook.

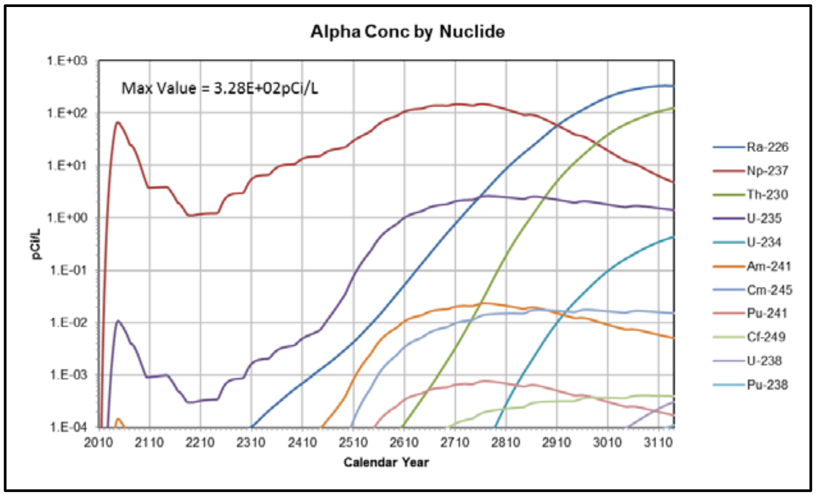


Figure 3-19. Dose plot of alpha concentration from Groundwater workbook.

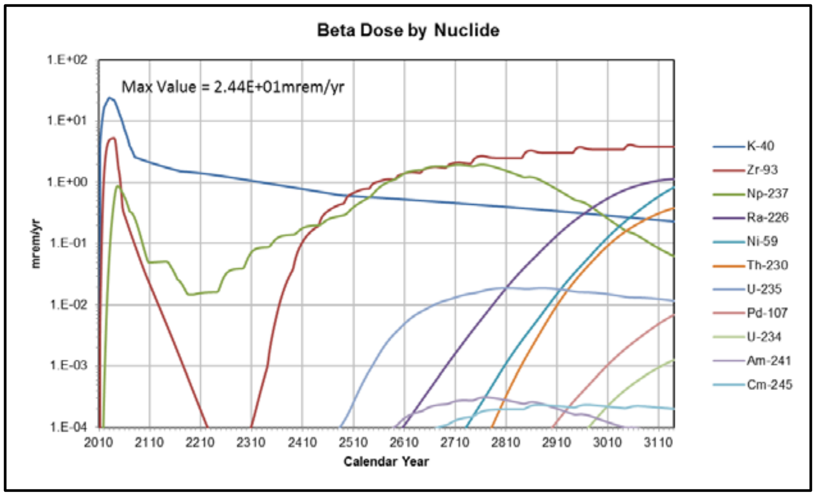


Figure 3-20. Dose plot of beta-gamma dose from Groundwater workbook.

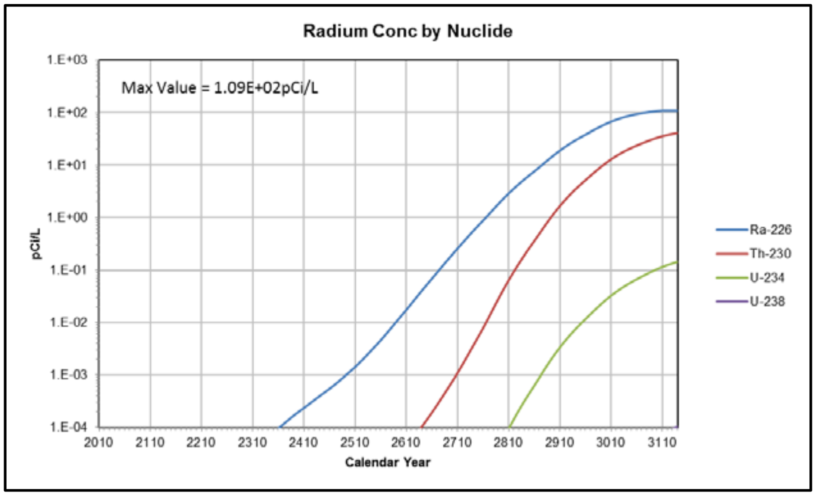


Figure 3-21. Dose plot of radium concentration from Groundwater workbook.

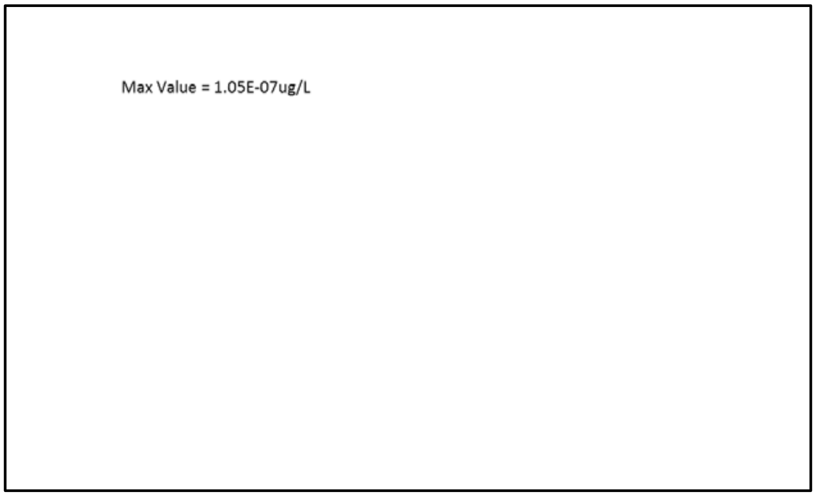


Figure 3-22. Dose plot of uranium concentration from Groundwater workbook.

In this case, the maximum uranium concentration was below the minimum value specified for plotting (1.0E-05) so no graph was generated. However, the maximum value is still shown for information.

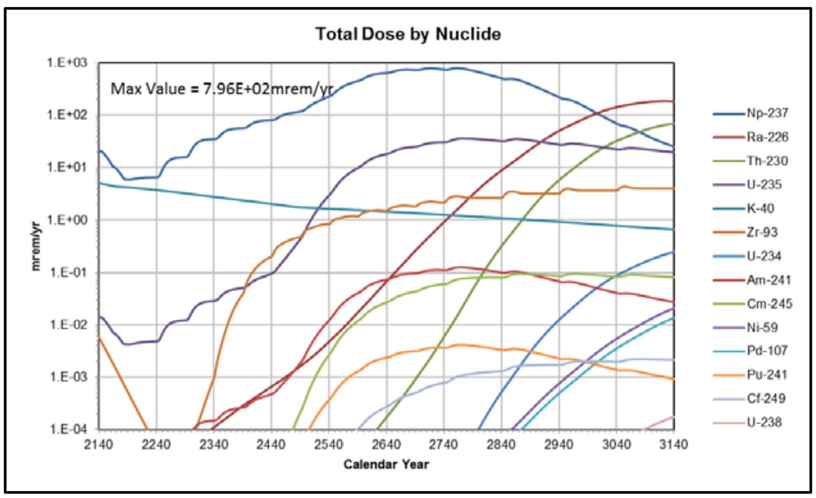


Figure 3-23. Dose plot from Pathway_Dose workbook.

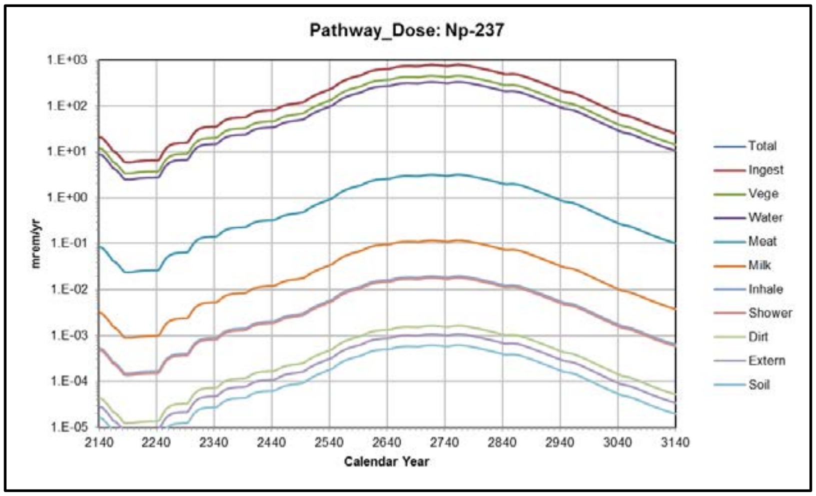


Figure 3-24. Single nuclide plot from Pathway_Dose workbook.

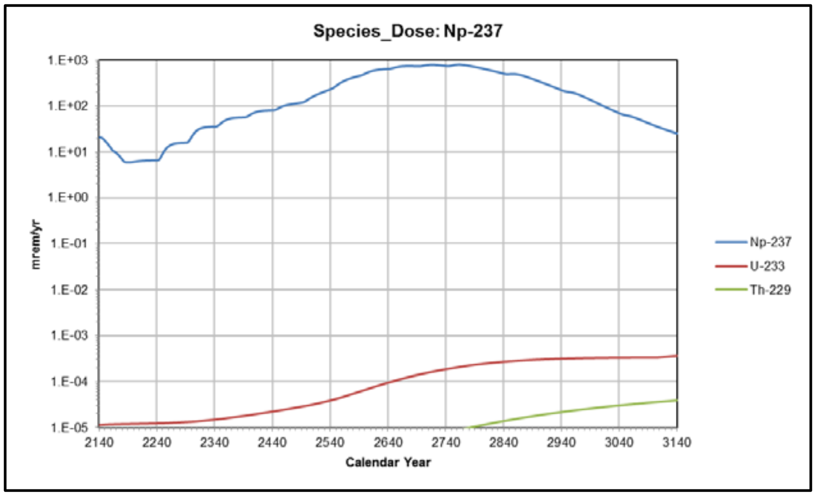
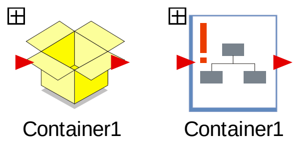


Figure 3-25. Single nuclide plot from Species_Dose workbook.

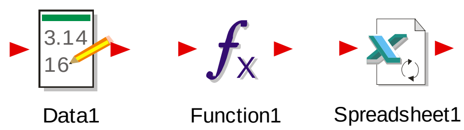
4.0 Model Description

A complete description of the GoldSim Doses and Limits Model and all of the calculations performed is beyond the scope of this document. The dose calculations follow the equations described in SRNL-STI-2015-00056 (Smith et al., 2015). A brief overview of the model is provided in this section to help the user understand the model and as a guide for future development work. Typically the user would interface with the model through the GoldSim dashboard shown in Figure 3-1. If it is necessary to modify the model, the code developer will need to access the underlying GoldSim structure. Note that the model can be distributed to users as a GoldSim Player version that allows users to view and run but not edit the model. A user does not need to license the GoldSim software to run the player version but must install the GoldSim Player, available on www.goldsim.com/Web/downloads/**,** on their computer.

The basic model structure is described in this section. The graphical nature of GoldSim models allows the modeler to collect common functions and data into "Containers" indicated by either the open box symbol or flowchart symbol shown below:



The flowchart symbol indicates that the container function is controlled by conditions imposed on its operation. Data tables, functions that perform calculations, and links to Excel spreadsheets frequently appear in the model diagrams and are indicated by the following symbols:



This construction allows a modular approach to developing a complex model such as the Limits and Doses Model. Many containers and levels of structure were created in the model to follow the natural flow of the calculations and group like functions together without putting too much detail in any one place. The top level of the GoldSim Limits and Doses Model is shown in Figure 4-1. The Model_Options dashboard provides a link to the user interface shown in Figure 3-1. The shaded block labeled "Data and Parameters" in Figure 4-1 has three containers where the input data is processed and materials are specified. The shaded block labeled "Dose and Limits Calculation" has three conditional containers where specific dose calculations are made. Arrows in GoldSim model diagrams indicate the direction of information flow between containers and functions.

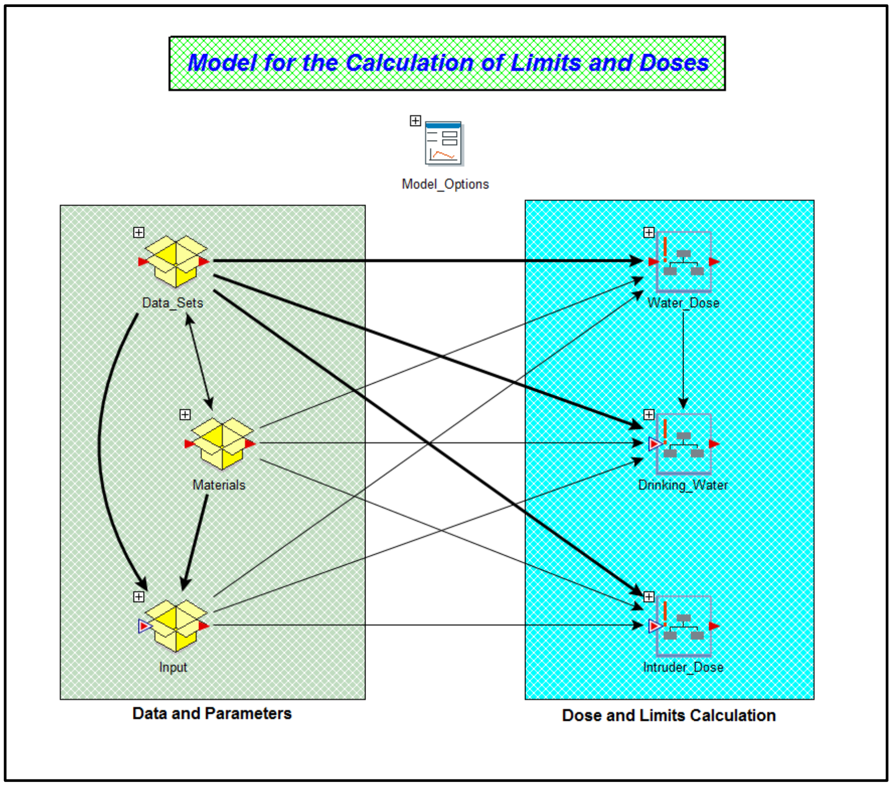
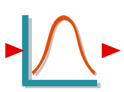


Figure 4-1. Top level of GoldSim Doses and Limits Model.

4.1 Data and Parameters

The contents of container **\Data_Sets** are shown in Figure 4-2. The block of data elements labeled "Dashboard Selections and Activation Logic" stores the dashboard entries, verifies that an analysis has been requested before stating the calculations, and supplies the logic to activate selection boxes on the dashboard. The chain expansion matrix and full chains matrix, described in the section on File Structure, are stored in data elements with the names. Figure 4-3 shows the contents of the **\Data_Sets\Dose_Parameters** container. These spreadsheet functions link to Excel workbook **.\Dose_Data*Species_Data.xlsm*** and all of the links to this Excel workbook are in this container. As an example, the spreadsheet links in function Dose_Coeff are shown.

Limited material property data for agricultural soil is required for dose calculations. The contents of the **\Materials** container are shown in Figure 4-4. Soil properties are read from Excel workbook **".\Dose_Data*Species_Data.xlsm*".** As noted in the section on File Structure, the only parameter distributions currently in the model are ones for soil properties. These are indicated by the symbol:



Stochastic1

The GoldSim species list is also in the **\Materials** container as element **Species**.

Figure 4-5 shows the contents of the **\Input** container. The yellow ovals highlight areas where the model imports data from external sources. Starting with the box labeled "Input to Ground/Surface Water Analysis", a time series of radionuclide concentrations at the point of analysis are read from spreadsheet **.\Dose_Data\Template*Parent.xlsx*** in the time series function Water_Conc_Short_Chain. The script Water_Conc_Species converts PORFLOW results into pCi/L. As explained in the text box, PORFLOW reactions used to mimic radionuclide decay do not distinguish between Curies, moles or mass. Therefore, the short chain radionuclide daughter concentrations must be corrected by multiplying by the ratio of the specific activity of the daughter to that of the parent. The parent inventory and the radionuclides used in the short chain transport calculations are read from Excel workbook **" .\Dose_Data\Template*Parent.xlsx*"** in spreadsheet function Short_Chain.

In the upper box labeled "Input to Intruder Analysis" in Figure 4-5 the container Unit_Model includes a GoldSim cell representing the waste disposal unit where inventories of parent radionuclides are deposited at the specified disposal time for the Inadvertent Intruder analysis. The GoldSim cell calculates the decayed inventory including daughter ingrowth over time. The Unit_Model container is also designed to track inventory for screening analyses as described in Section 4.2.4. The spreadsheet function Disposal_Unit reads the input data from **.\Dose_Data*Disposal_Units.xlsx*** which is, in part, used to define the disposal cell geometry. Container Print_Control uses the print frequency entered in the print control dashboard shown in Figure 3-3 to set the timing when output is written to the Excel workbooks that collect the results of the dose and limit calculations.

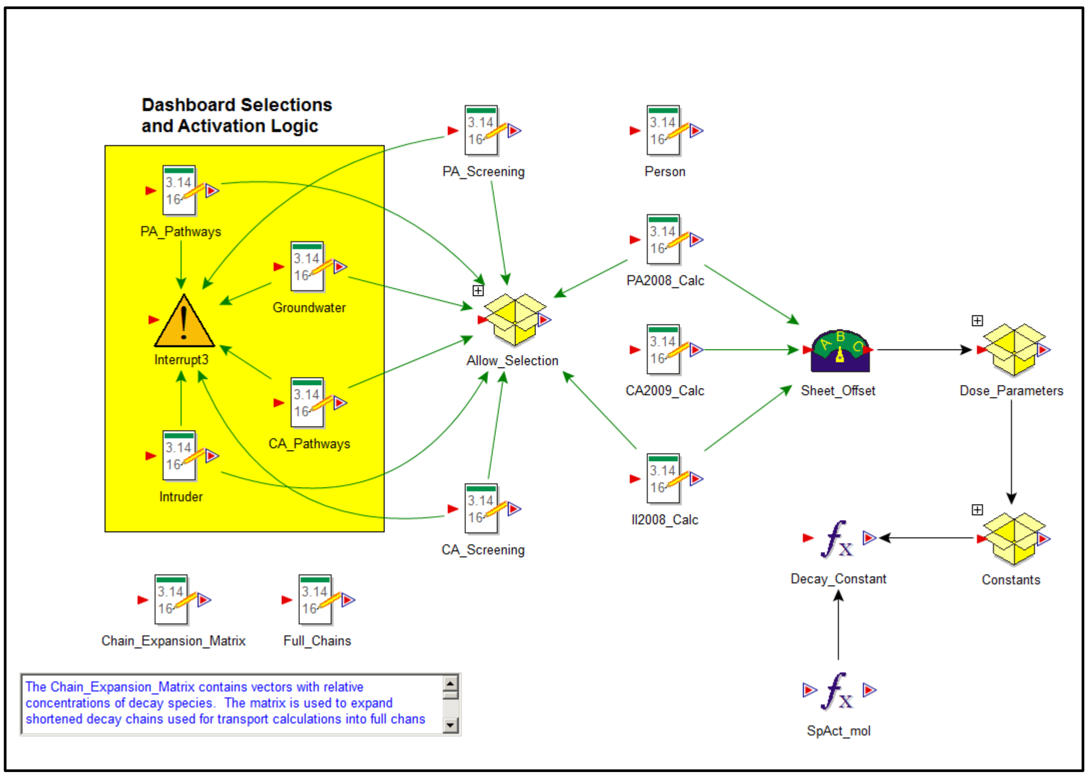


Figure 4-2. Contents of \Data_Sets container.

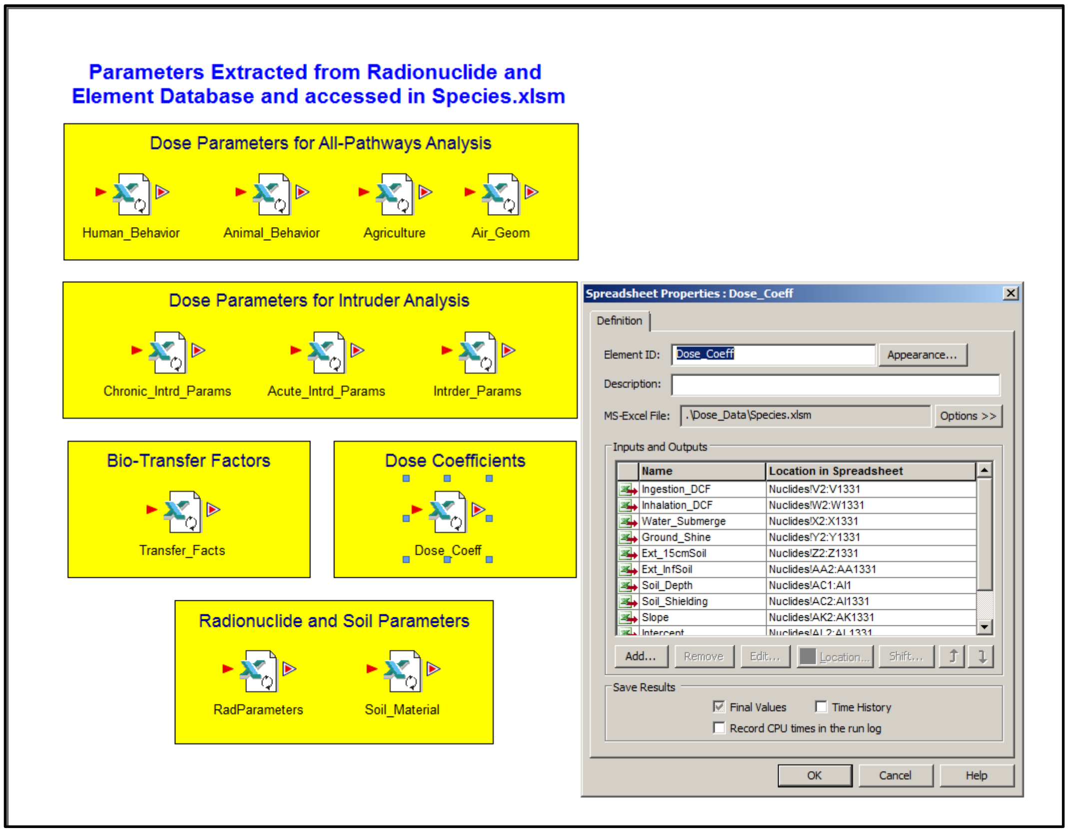


Figure 4-3. Contents of \Data_Sets\Dose_Parameters container with a view of the Dose_Coeff link to Excel file .\Dose_Data*Species.xlsm*.

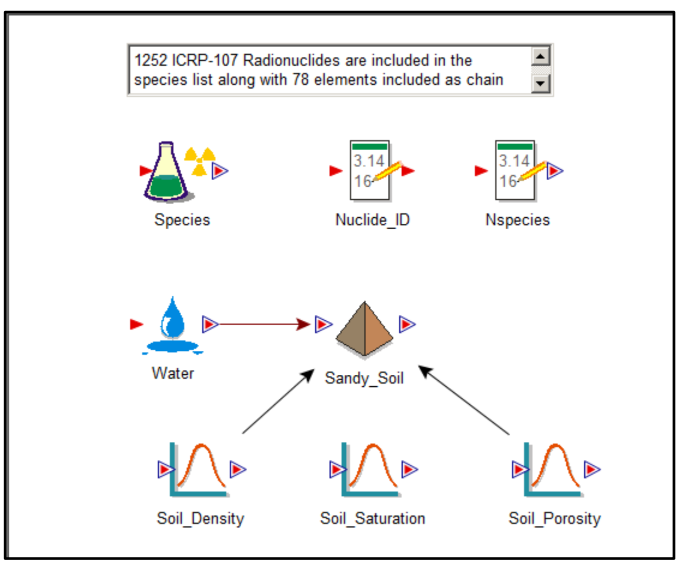


Figure 4-4. Contents of \Materials container.

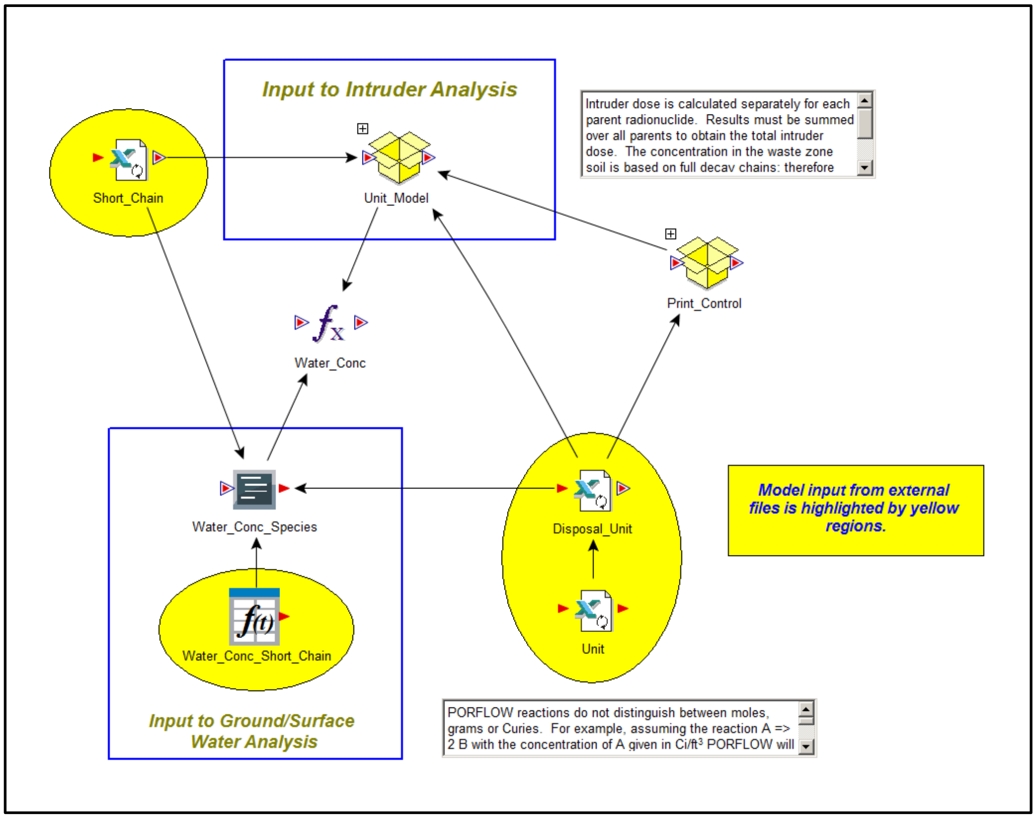


Figure 4-5. Contents of \Input container.

4.2 Dose and Limits Calculation

Returning to Figure 4-1, we will now describe the three conditional containers in the "Dose and Limits Calculation" block.

Dose and disposal limit calculations for PA groundwater analyses, dose calculations for CA surface water analyses, and radionuclide screening calculations are made in container Water_Dose. Dose and disposal limit calculations based on drinking water protection standards are made in container Drinking_Water. Dose and disposal limit calculations for Inadvertent Intruder analyses and radionuclide screening calculations are made in container Intruder_Dose. To increase computational efficiency, the containers are activated based on the analysis selections made by the user on the interface dashboard as shown in Figure 3-1. For example, if only the Inadvertent Intruder analysis is selected as shown in Figure 3-1(d), container Intruder_Dose is activated while the Water_Dose and Drinking_Water containers remain inactive and perform no calculations.

4.2.1 Water_Dose

Figure 4-6 shows the contents of the Water_Dose container. The All_Pathways container, which appears at the top of Figure 4-6, is a conditional container that calculates effective dose coefficients for the 1252 radionuclides in the GoldSim species list. This container is conditional because the dose coefficients do not vary over time and can be calculated once at the start of the simulation.

Contents of the All_Pathways container are shown in Figure 4-7. The Uptake container holds functions that calculate the basic all-pathways dose equations described by Smith et al. (2015). Figure 4-8 shows the contents of the Uptake container along with an expanded view of the vegetable uptake function Vege_Uptake which is typical of most GoldSim functions. The Vege_Uptake calculation is for a vector of dimension Species so the calculation is performed for all radionuclides using a single function. This function also contains logic to modify the calculation if the results are intended to reproduce those in the 2009 CA. Several of the functions in the Uptake container contain logic to alter the calculations to reproduce either 2008 PA or 2009 CA results.

As shown in Figure 4-7, output from the Uptake container goes to three containers where effective dose conversion factors are calculated for ingestion, inhalation and direct exposure doses. As an example, Figure 4-9 shows the contents of container Ingest_EDCF and the function Vege_Ingest. Figure 4-7 also shows the two scripts Uptake_DCF and Expanded_DCF where parent radionuclide dose coefficients are expanded to incorporate dose conversion factors for full chain radionuclides into the dose conversion factor. The expanded dose coefficients account for radionuclides assumed to be in secular equilibrium in the shortened decay chains use for transport calculations.

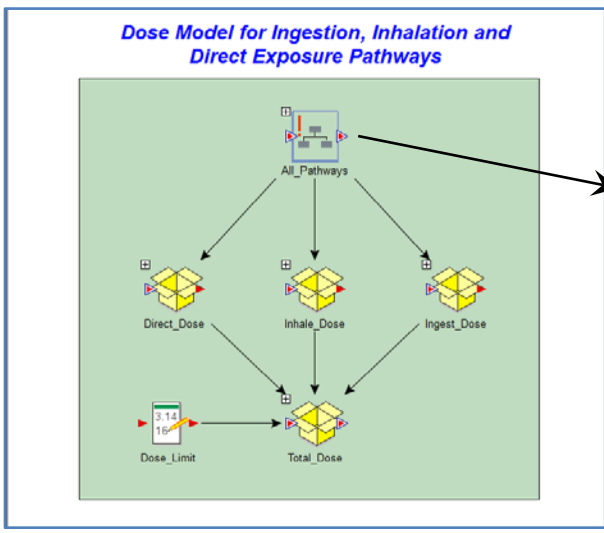


Figure 4-6. Contents of \Water_Dose container

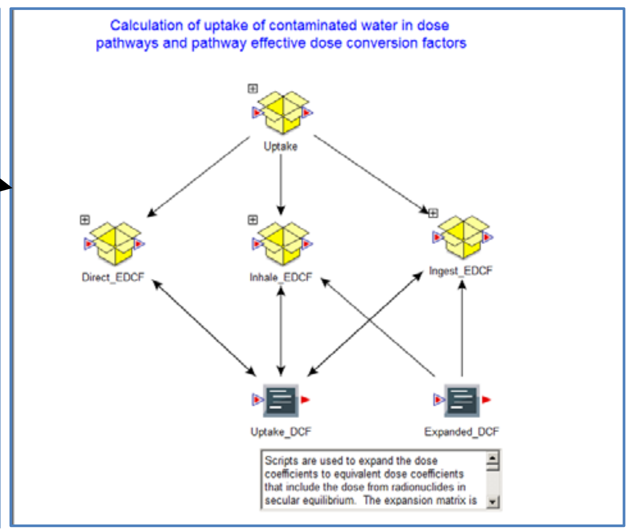


Figure 4-7. Contents of \Water_Dose\All_Pathways container.

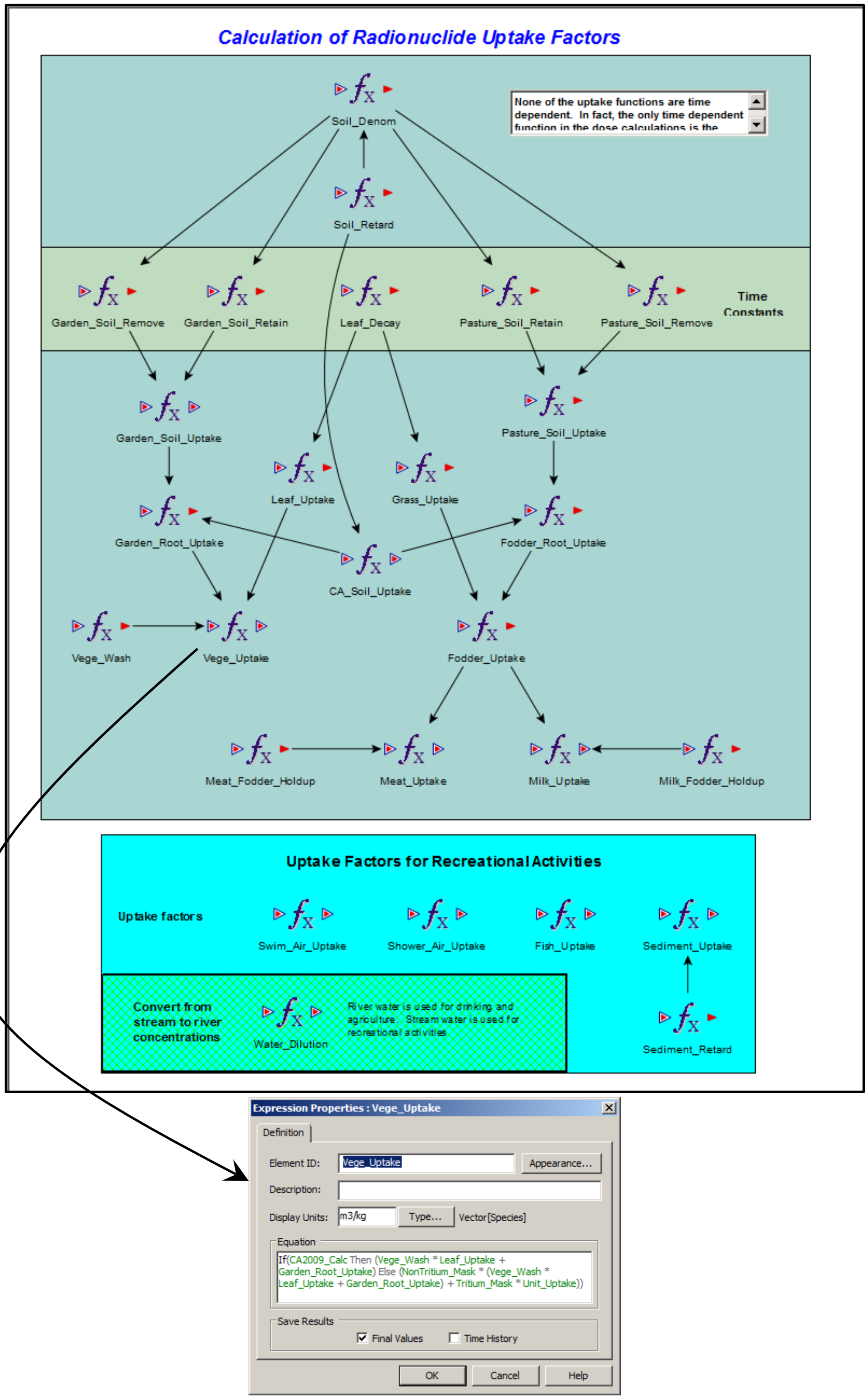


Figure 4-8. Contents of \Water_Dose\All_Pathways\Uptake container and the Vege_Uptake function.

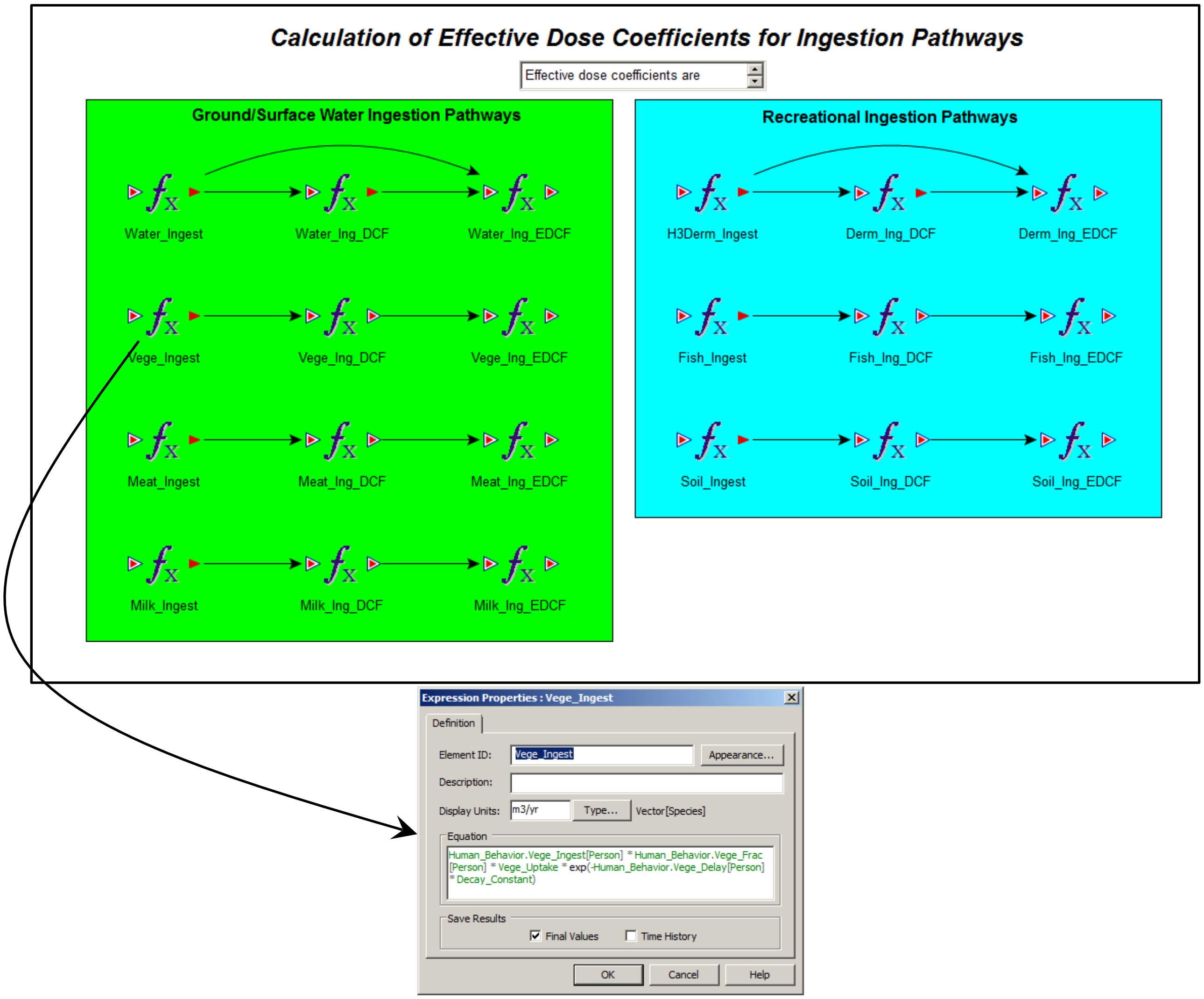


Figure 4-9. Contents of \Water_Dose\All_Pathways\Ingest_ECDF container and the Vege_Ingest function.

With effective dose conversion factors calculated for all radionuclides, the calculation proceeds to calculate doses. As shown in Figure 4-6 the dose calculations are separated into doses from ingestion, inhalation and direct (external) exposure. Figure 4-10 shows the contents of the Ingest_Dose container and the function Vege_Ing_Dose. The function is simply multiplying effective dose conversion factors by the radionuclide concentrations in the water to calculate the dose. The dilution factor is applied for CA and screening dose calculations. The Total_Dose container shown in Figure 4-6 collects the doses calculated from all exposure sources and writes the results to Excel workbook **\Dose_Data\Template*Pathway_Dose.xlsm*** at times determined by the calculation time steps and Print Frequency. Figure 4-11 shows the contents of the Total_Dose container and a view of the link to Excel in spreadsheet function Parent_Dose_Output.

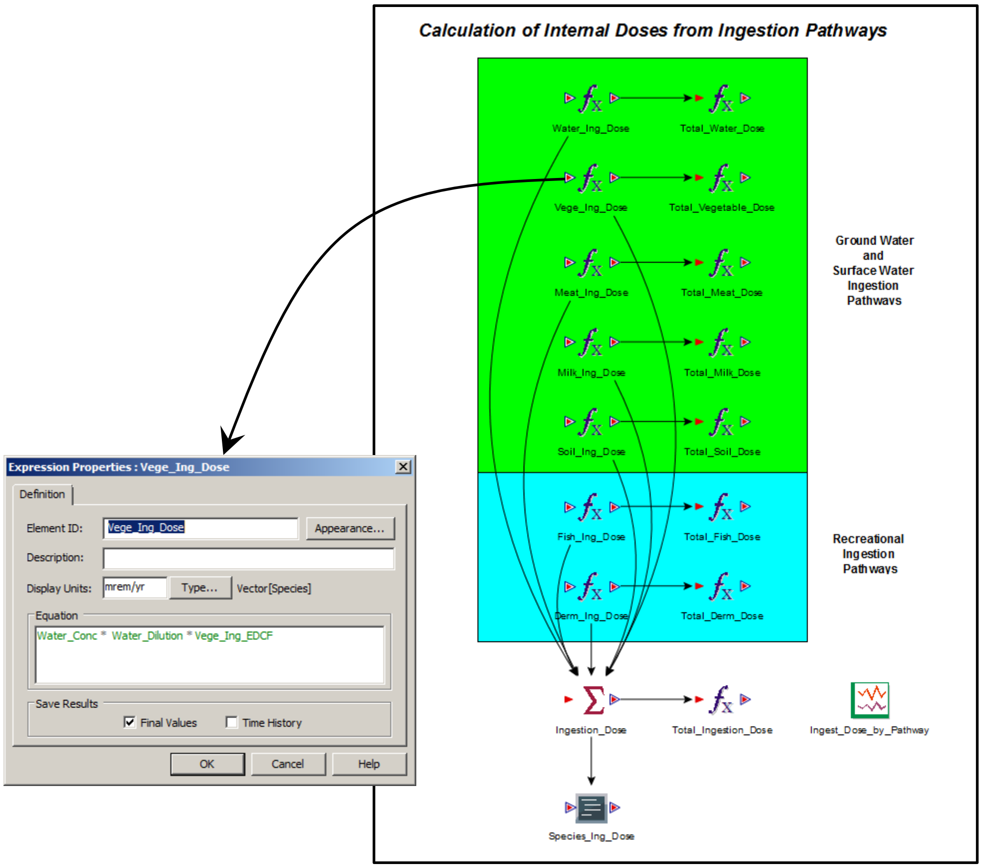


Figure 4-10. Contents of \Water_Dose\ Ingest_Dose container and the Vege_Ing_Dose function.

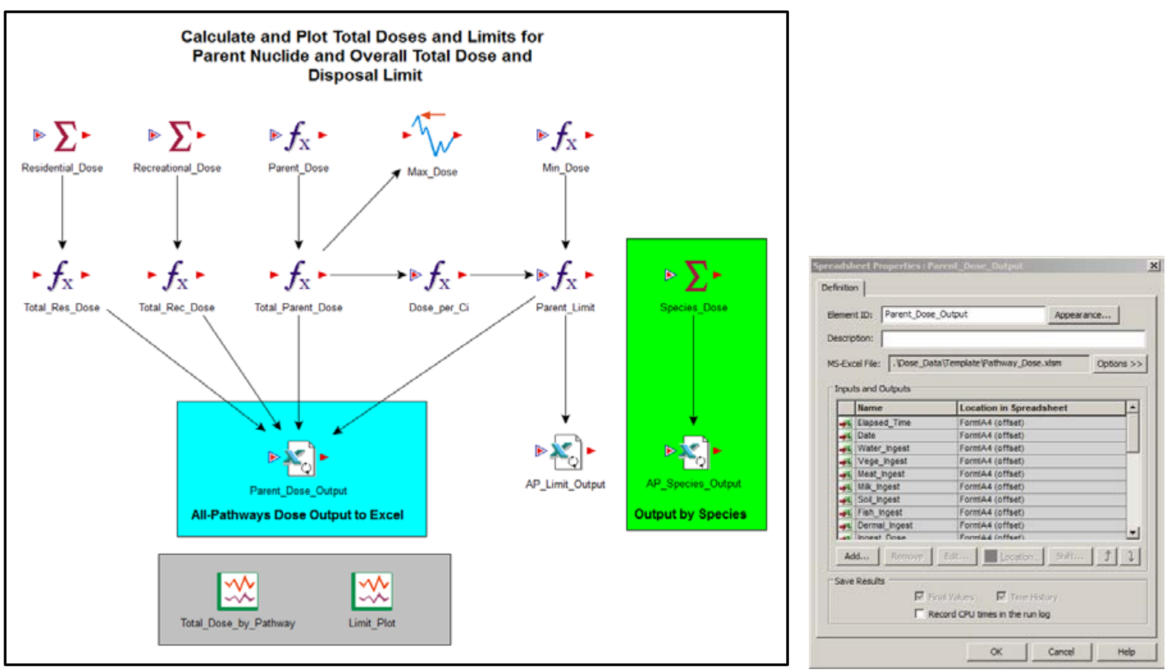


Figure 4-11. Contents of \Water_Dose\Total_Dose container and Parent_Dose_Output Excel link.

4.2.2 Drinking_Water

Figure 4-12 shows a view of the contents of container Drinking_Water. The functions in this container apply the EPA drinking water protection standards for contamination from:

1. alpha emitting radionuclides (limit = 15 pCi/L),
2. beta-gamma emitting radionuclides (limit = 4 mrem/yr),
3. uranium (limit = 30 μg/L) and
4. radium (limit = 5 pCi/L).

Conditional container Alpha_Beta_Fractions uses scripts to apply the chain expansion matrix to all parent radionuclides. That is, similar to the calculation of effective dose coefficients described in the previous section, effective alpha and beta-gamma decay fractions are calculated for all radionuclides in the shortened decay chains used for transport calculations to include the contribution from daughters assumed to be in secular equilibrium. Since this calculation only needs to be done one time, a conditional container is used that is only active for a short time at the beginning of the simulation. Results from the calculations are collected and output to Excel workbook **.\Dose_Data\Template*Groundwater.xlsm*** in spreadsheet function GW_Limits_Output.

The four containers in Figure 4-12 where the groundwater protection concentration and disposal limit calculations are performed all use the same logic. As an example, Figure 4-13 provides a view of the contents of the Alpha_Limit container. Moving from left to right, the functions perform the following calculations:

1. Alpha_Conc.........................Calculates the concentration of alpha emitting radionuclides in the water for all of the radionuclides present,
2. Total_Alpha_Conc ....Sums concentration of the individual alpha emitting radionuclides to obtain a total concentration,
3. Alpha_Conc_per_Ci ....Divides the total alpha concentration by the Curies of parent radionuclide specified in the input to obtain the concentration per Curie, and
4. Total_Alpha_Limit ....Divides the limit concentration by the concentration per Curie to calculate the maximum curies of parent that can be disposed.

<u>Note to Model Users</u>

Each parent radionuclide is processed through the doses and limits calculation separately. The concentrations of parent and short chain daughters are calculated by the transport modeling and serve as input to the limits and doses model. The above calculations have been made very general so that any parent radionuclide and short chain can be handled.

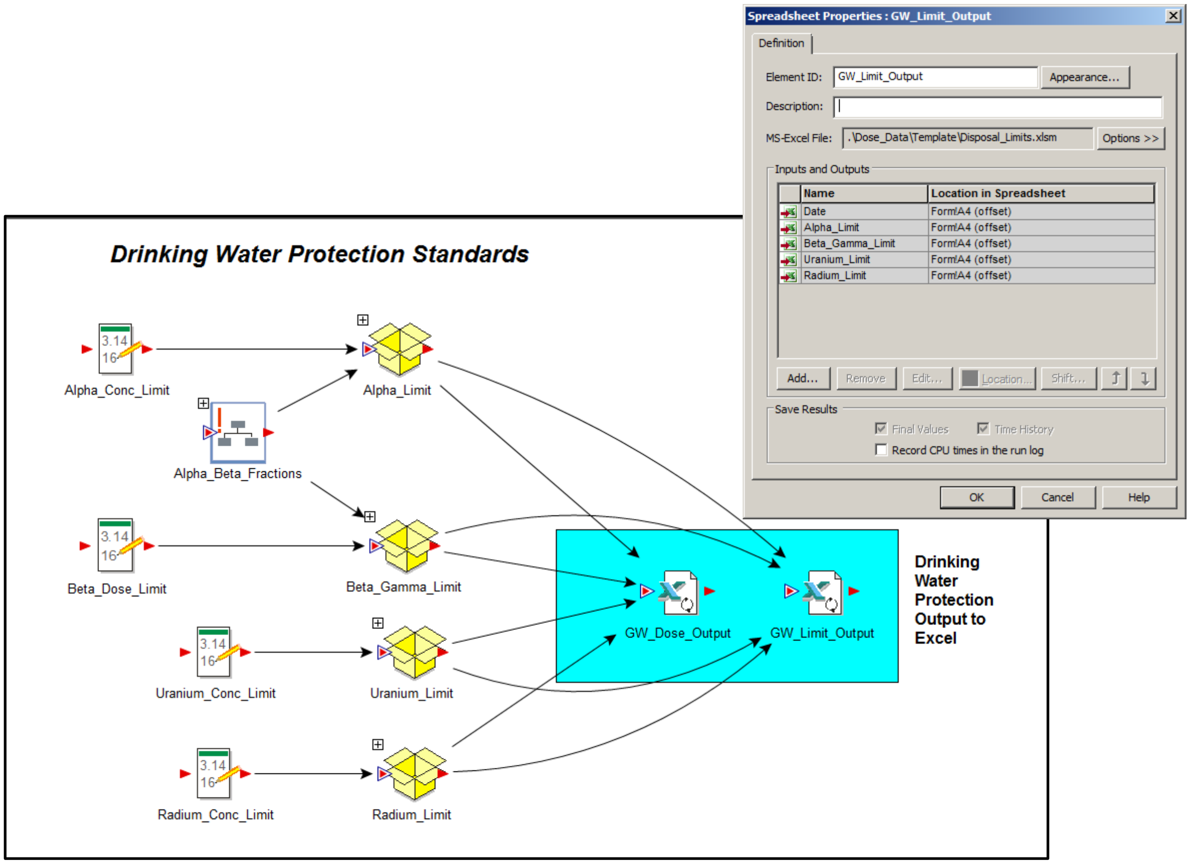


Figure 4-12. Contents of \Drinking_Water container and view of spreadsheet function GW_Limit_Output.

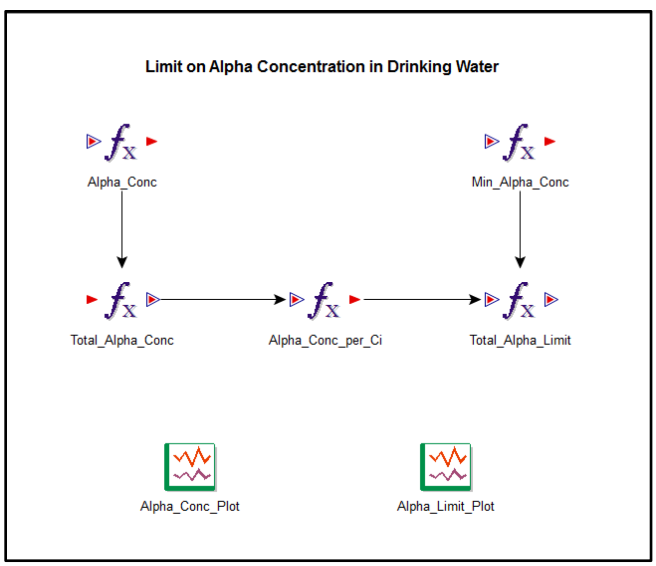


Figure 4-13. Contents of \Drinking_Water\Alpha_Limit container.

4.2.3 Intruder_Dose

Figure 4-14 shows a view of the contents of container \Intruder_Dose. As shown in the figure, calculations for chronic and acute intruder scenarios are performed in this section of the dose model. The equations used are described in the report by Smith et al. (2015).

The container Soil_Shielding, appearing at the top of the container "pyramid", calculates soil shielding dose conversion factors for an individual residing in a home constructed above the waste disposal site in the chronic intruder scenario and for basement construction during the acute intruder scenario. Results from the Soil_Shielding calculation are used in containers Acute_Intruder_Dose and Chronic_Intruder_Dose where doses from each pathway in the acute intruder and chronic intruder scenarios are calculated. Containers Acute_Intruder_Dose_Plots and Chronic_Intruder_Dose_Plots determine maximum doses, the time maximum doses are reached for each pathway and provide some plots of the results that may be useful for diagnostic purposes. It should be noted that these and any other graphs of results provided in the model would be of limited value during PA and CA work where calculations are performed for many radionuclides and disposal units. The display of results embedded in the model may be useful for debugging, understanding results, and special one-time calculations.

Containers Total_Acute_Doses and Total_Chronic_Doses sum the doses from each pathway and send them to the respective output files which appear at the bottom of the container. Because the two sets of intruder dose calculations are similar, the following discussion follows the chronic intruder calculation to give the user an introduction to the model structure.

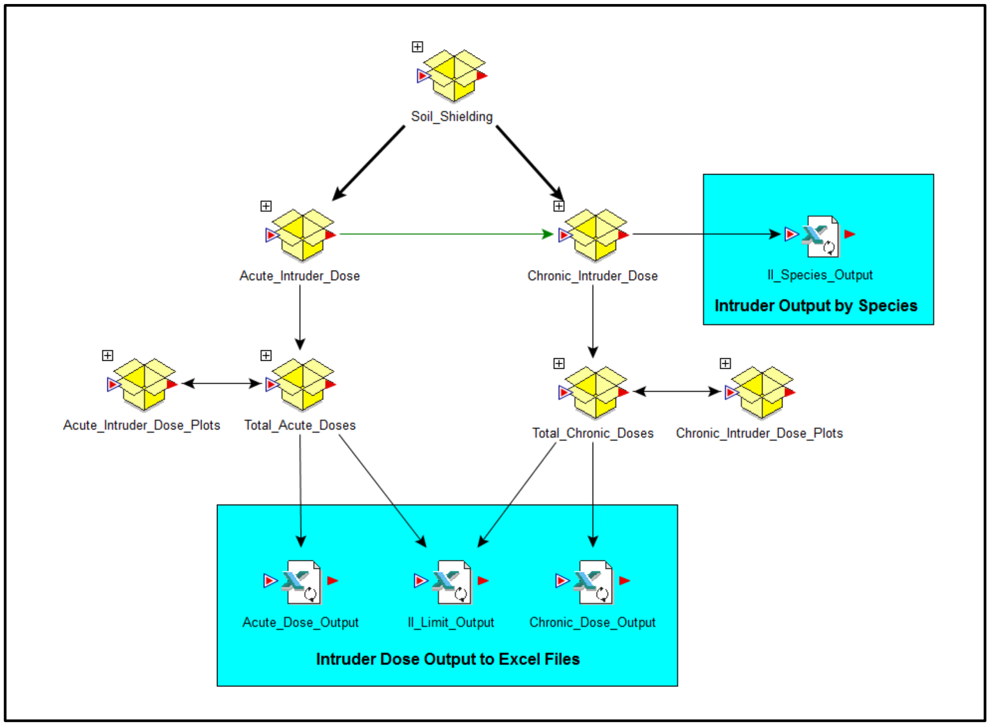


Figure 4-14. Contents of \Intruder_Dose container.

Figure 4-15 shows the contents of the Chronic_Intruder_Dose container with a view of the function PD_Ingest_Vege. The chronic intruder dose determines doses from resident agricultural (Ag) activity, a post drilling (PD) scenario, and a residential scenario. The functions calculate doses for a particular pathway in each scenario. The agriculture scenario has six dose pathways, the post drilling scenario four dose pathways, and the residential scenario one pathway. As the function PD_Ingest_Vege shows, the dose is calculated as the product of the radionuclide concentration in the soil (Soil_Conc), an uptake factor (PD_Vege_Ingest) and the ingestion dose coefficient (Dose_Coeff.Ingestion_DCF). The summation functions Agriculture_Dose and Post_Drilling_Dose sum the doses over all pathways for each radionuclide.

Uptake factors for the dose pathways are calculated in container Chronic_Dose_Factors shown in Figure 4-16. The uptake factors are grouped by dose scenario and there is one factor for each dose pathway. Figure 4-16 shows the uptake function PD_Vege_Ingest which computes the product of human vegetable ingestion (Human_Behavior.Vege_Ingest[Person], the fraction of vegetables consumed grown in contaminated soil (Human_Behavior.Vege_Frac[Person]), the soil to plant transfer factor (Transfer_Facts.Soil_Ratio) and a geometry factor (PD_Geometry). Note that the prefixes Human_Behavior and Transfer_Facts in the uptake function parameter definitions point to the Excel functions shown in Figure 4-3 where dose parameters are input.

In container Total_Chronic_Dose shown in Figure 4-14, total doses for each scenario and pathway are calculated by summing doses over all radionuclides. These are further combined into a total chronic intruder dose for the parent radionuclide and the disposal limit is calculated. A view of the contents of container Total_Chronic_Dose is show in Figure 4-17. Container Chronic_Intruder_Dose_Plots determines the maximum dose for each scenario and the time when the maximum dose occurs. This container also provides summary plots of dose by scenario and pathway. As discussed above, these plots would likely only be useful if a single parent radionuclide is run outside of the calculation automation features. A view of the contents of container Chronic_Intruder_Dose_Plots is show in Figure 4-18.

Note to Model Developers

It might appear that containers Chronic_Dose_Factors and Acute_Dose_Factors could be made conditional to save computational effort as was done for All_Pathways container in Water_Dose. However, they cannot be because the intruder dose pathways and dose conversion factors vary over time as soil erosion reduces the cover over the waste. At some point in time the waste may become exposed through basement excavation.

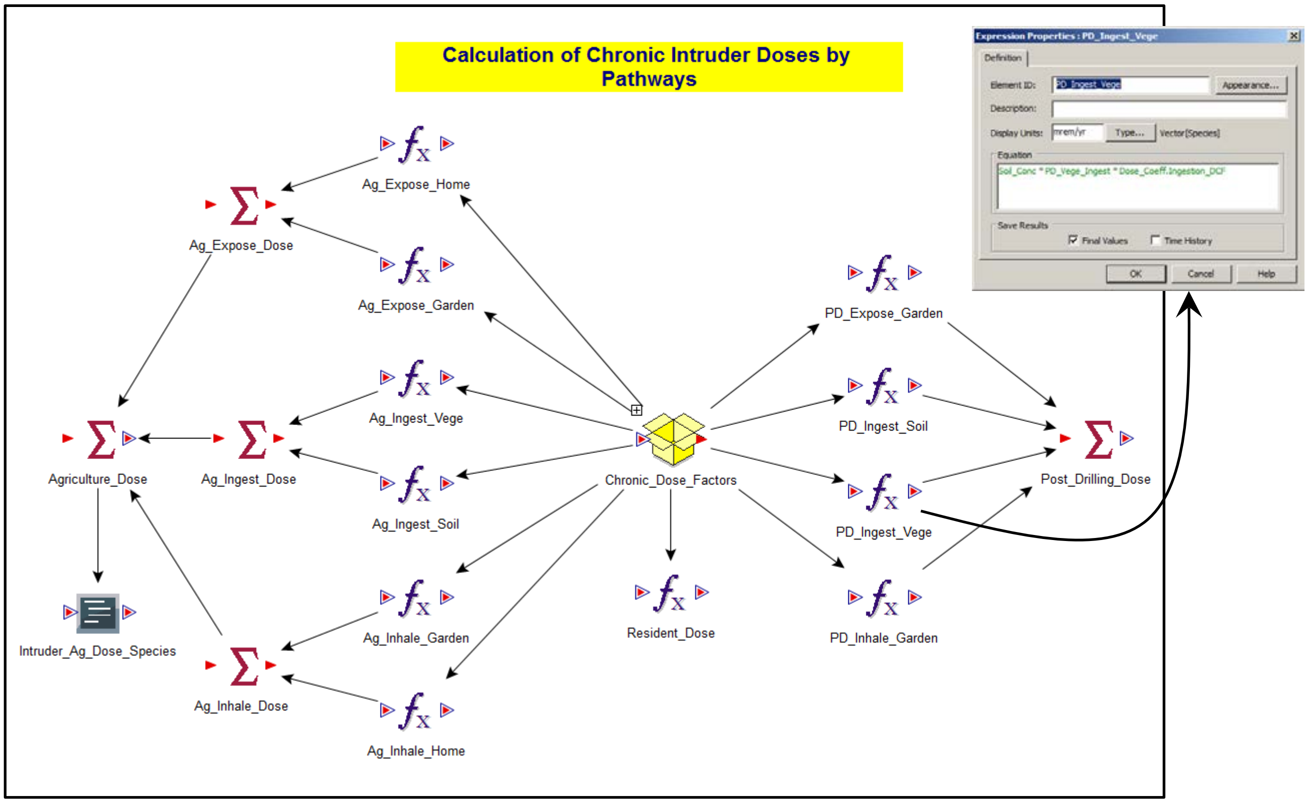


Figure 4-15. Contents of \Intruder_Dose\Chronic_Intruder_Dose container showing function PD_Ingest_Vege.

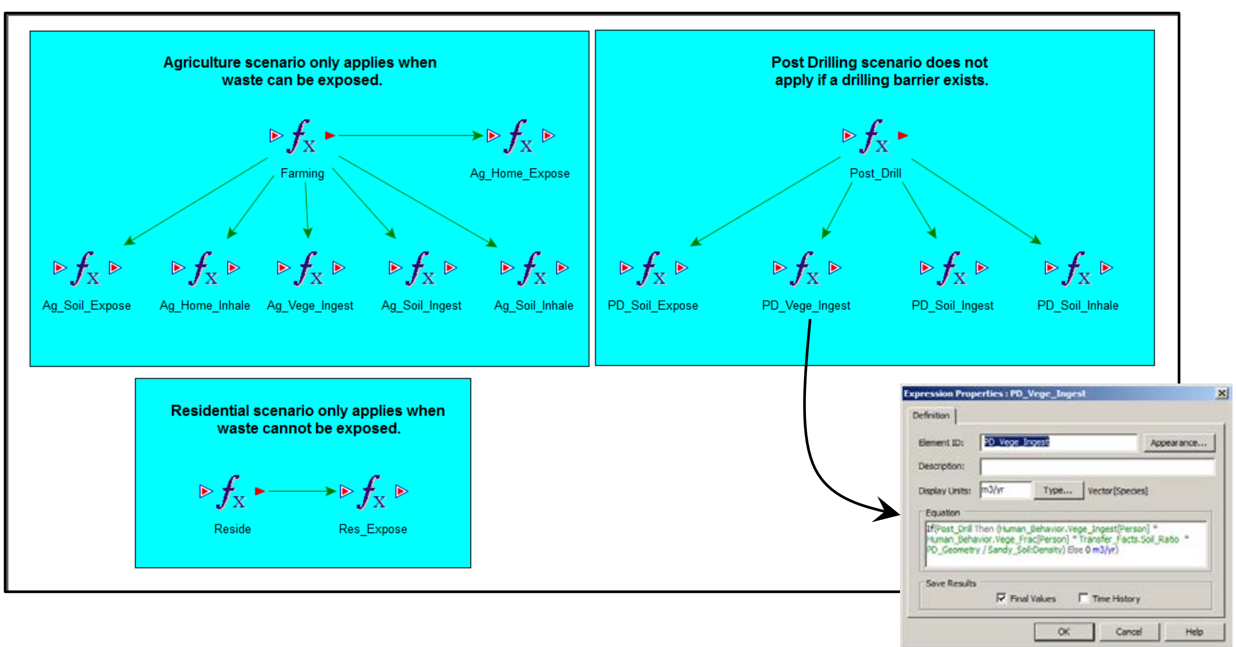


Figure 4-16. Contents of \Intruder_Dose\Chronic_Intruder_Dose\Chronic_Dose_Factors container showing function PD_Vege_Ingest.

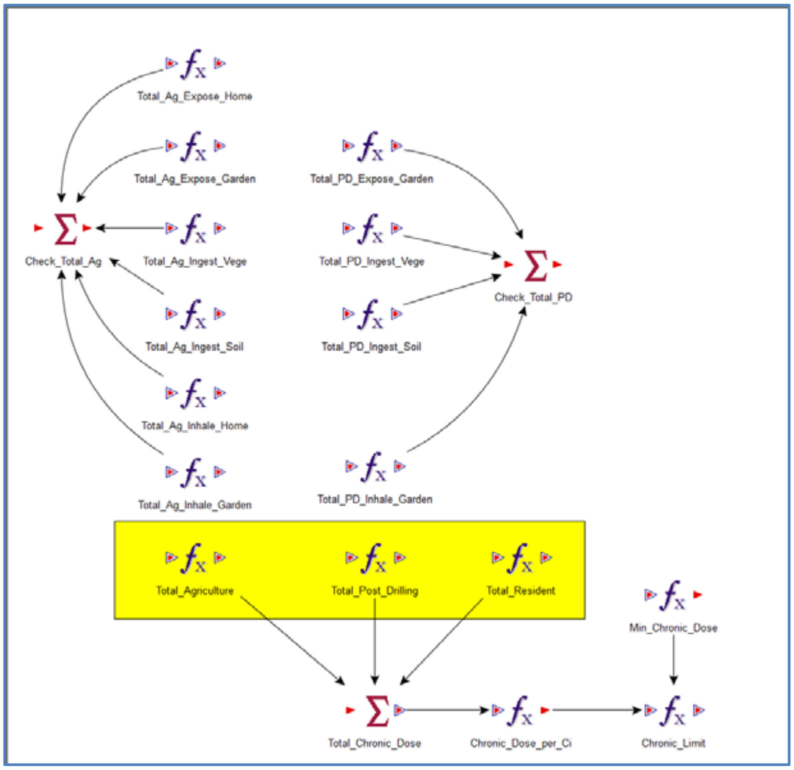


Figure 4-17. Contents of \Intruder_Dose\Total_Chronic_Doses container.

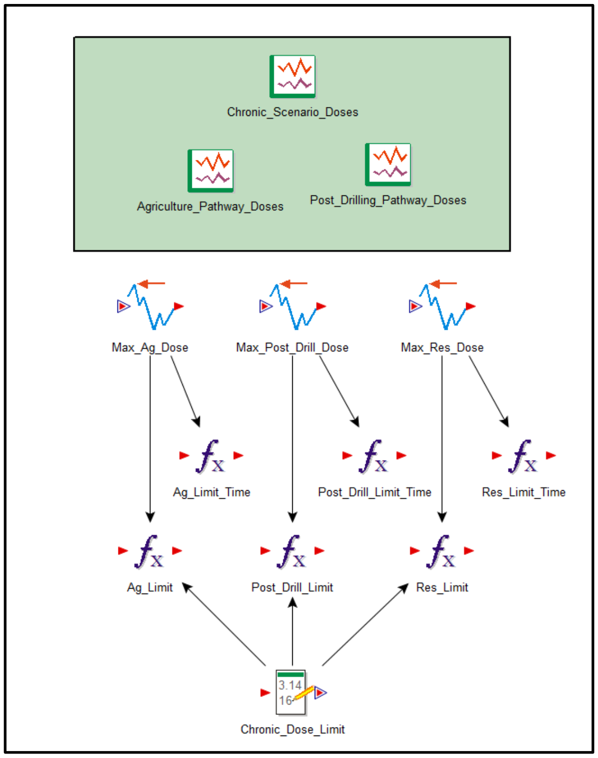


Figure 4-18. Contents of \Intruder_Dose\Chronic_Intruder_Dose_Plots container.

4.2.4 NCRP-123 Screening

The radionuclide screening calculation combines a groundwater dose calculation using a conservative estimate of the concentration of radionuclides in the water with a chronic Inadvertent Intruder dose calculation. In general, the screening calculations are based on a modified version of the methodology described in NCRP-123 (1996) using parameters specific to SRS.

Radionuclide concentrations in the soil and groundwater are calculated in container Unit_Model shown in Figure 4-5. An expanded view of the container is shown in Figure 4-19. Inadvertent Intruder calculations are performed by depositing one Curie of the parent radionuclides in GoldSim cell Waste_Zone where radioactive decay and daughter ingrowth take place. To perform the screening calculations, this model was extended to include infiltration flow through the waste zone eluting into the Water_Source cell where the concentration is diluted. Infiltration flow and aquifer dilution are set on lines 20 and 21 of the ***Disposal_Units.xlsx*** Excel workbook as shown in Figure 2-3. The release time which determines when leaching starts is set on line 22.

The water concentration in the Water_Source cell is used for groundwater screening dose calculations. Radioactive materials eluted from the waste zone and remaining in the soil are combined in function Soil_Conc to determine an un-eluted soil concentration used for the chronic intruder screening dose calculations. The Soil_Conc is also used for normal intruder dose calculations although, in this case, infiltration is turned off. The screening calculation uses all of the groundwater pathways to determine the dose.

As shown in Figure 3-1, an option is also provided to perform a CA screening calculation. For the CA screening, recreational pathways are included in the dose calculation and the water concentration used for residential pathways is diluted by the factor on line 18 in the ***Disposal_Units.xlsx*** Excel workbook. This represents the dilution obtained when the surface water discharges into a river. For CA screening, the dilution volume on line 21 should be a conservative estimate of the dilution obtained when groundwater discharges into surface water.

When running screening calculations the model assumes that radionuclides specified in the input file are parent radionuclides not chains. Daughter ingrowth from parent decay is calculated by GoldSim as the parent resides in the waste zone and is eluted into the Water_Source and Sink cells. As many as 10 different parent radionuclides can be included in a single screening calculation with the restriction that there are no daughter radionuclides common to any of the parents. In the *Screening* folder shown in Figure 2-1 subfolder *Screening* has a file ***Chain_Dependence.xlsm***. Tab “Numbered” in this Excel workbook contains a list of radionuclides in groups of 9 or 10 that satisfy this restriction. The radionuclide names are on even numbered rows and the corresponding radionuclide number in the GoldSim species list are in the row above each list.

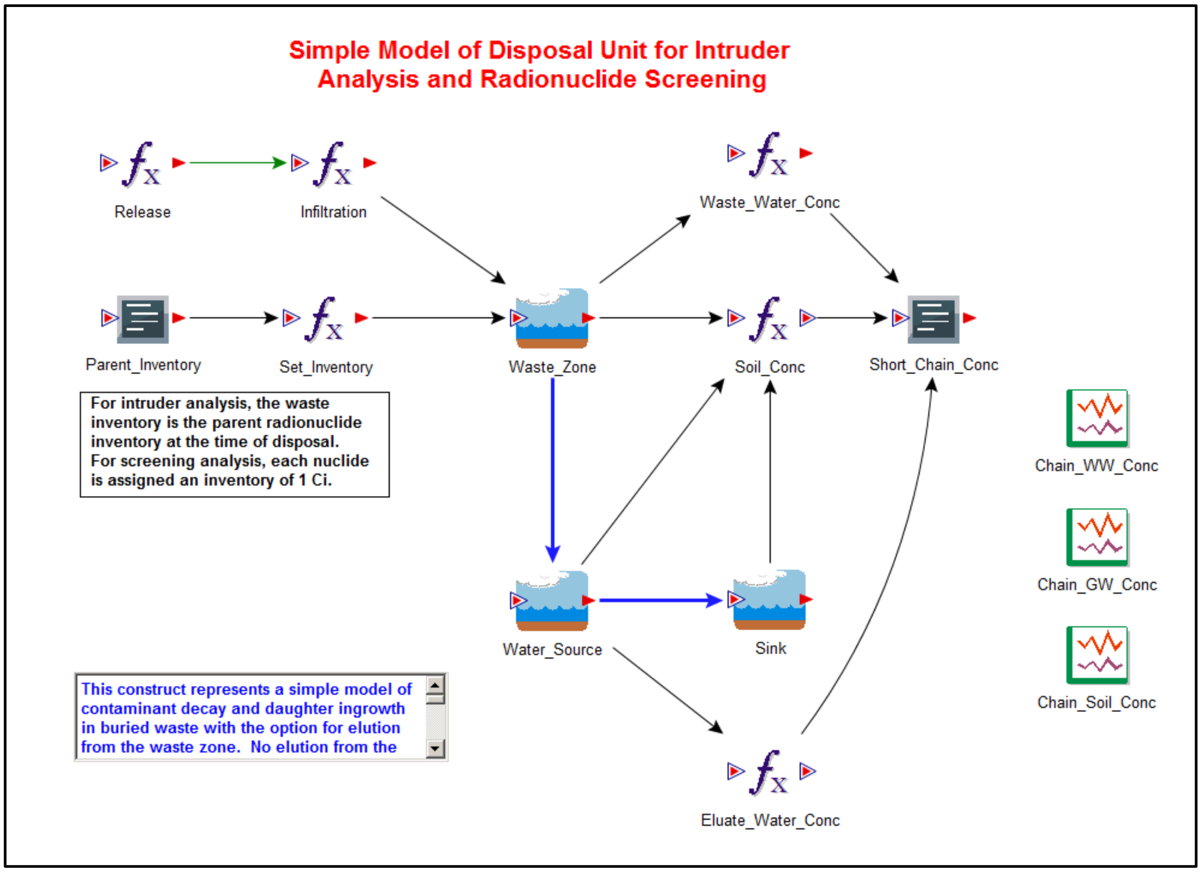


Figure 4-19. Contents of \Intruder_Dose\Chronic_Intruder_Dose_Plots container.

5.0 PORFLOW Output Formatting

As shown in Figure 2-1, the overall structure of the dose calculation assumes that each disposal unit has a folder where files holding input to the calculation are located and where results from the calculation are stored. Using the Slit_c disposal unit as an example, Figure 2-2 further shows that the structure assumes a subfolder named *PORFLOW* exists in the disposal unit folder and that the *PORFLOW* folder has a subfolder named *Aquifer_Transport* which in turn has subfolders for each radionuclide for which PORFLOW transport calculations were made. Within each radionuclide subfolder there would then be a STAT.out file containing the PORFLOW output. The PORFLOW output has a particular format that is not suited for input to GoldSim. Therefore, an Excel VBA macro embedded in file ***Reformat_PORFLOW.xlsm*** was written to read the data in STAT.out files and write Excel files in a format convenient for input to GoldSim.

To reformat the STAT.out data, the user opens the ***Reformat_PORFLOW.xlsm*** file. This displays the Excel worksheet shown in Figure 5-1. The user enters the names of disposal units that need reformatting in Column A starting in Row 2. Clicking on the "Reformat PORFLOW" button the macro will automatically reformat the output for all radionuclides present in all of the listed disposal units. The result will be similar to that shown in Figure 2-2 with Excel files created for each radionuclide. During the reformatting process, the name of the radionuclide being processed appears in cell (C,2). When all of the requested reformatting is complete the file will automatically close. Figure 5-1(a) searches for files to reformat using the file structure shown in Figure 2-2. As an alternative, the user can specify a remote file location as illustrated in Figure 5-1(b) in which case the macro will search the specified directory. Reformatting remote files will typically be slower than using local file. Note that a backslash is needed at the end of the remote file path.

The upper 30 lines of the output obtained from reformatting PORFLOW transport results for U-238 with a five year decay chain are shown in Figure 5-2. The radionuclides in the five year decay chain are U-238, U-234, Th-230, Ra-226 and Pb-210. The output contains the following data:

Line 1: Column A .... Number of the radionuclide in the list of radionuclides processed (U-238 was the 8th radionuclide processed in the test series)
Line 1: Column B................ Parent inventory read from the file Inventory.dat (1 Ci of U-238)
Line 2: Column A .... Number of radionuclides in the short chain used for transport calculations
Line 2: Columns B-K.......... Short chain radionuclide number in list of 1252 (GoldSim cannot read alpha numeric input therefore the radionuclide is identified by a unique number)
Line 3: Columns A.............. Time from start of simulation (1960). The waste material is disposed in 2010 and the model assumes that the PORFLOW output starts at this time.
Line 3: Columns B-K.......... Short chain radionuclide name (up to 10 radionuclides can be specified)
Line 4: Column A .... Time when GoldSim simulation begins
Line 4: Columns B-K.......... Zero concentration in groundwater at starting time
Line 5: Column A .... PORFLOW recorded transport time
Line 5: Columns B-K.......... Concentrations in groundwater (Ci/m^3)

Lines following Line 5 contain times and concentrations for the remaining PORFLOW output.

Note to Model Users

PORFLOW output formatting may change as new versions are released which may in turn require modifying the VBA reformatting macro. The macro searches for the key word "ID#" to find the output column headings. It assumes that the input begins two lines following the header and that time is in the column labeled "Time:Step#" and the concentration is the column labeled "Maximum_Value". The macro also assumes that PORFLOW output concentrations are in units of Ci/ft^3 and converts to Ci/m^3. The user needs to be aware that if any of these assumptions change subroutine Read_Stat_Out in the macro must be modified.

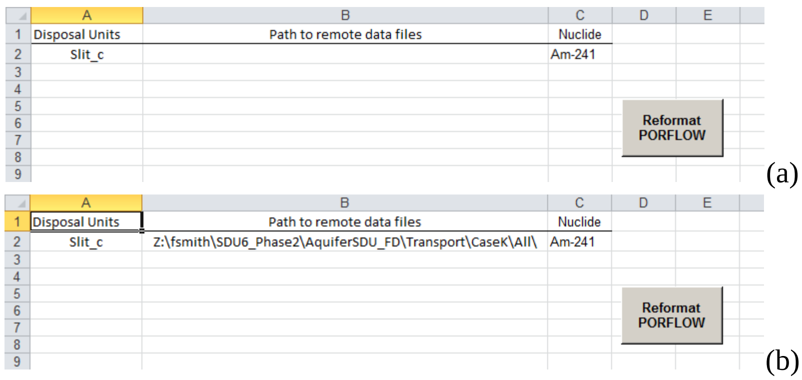
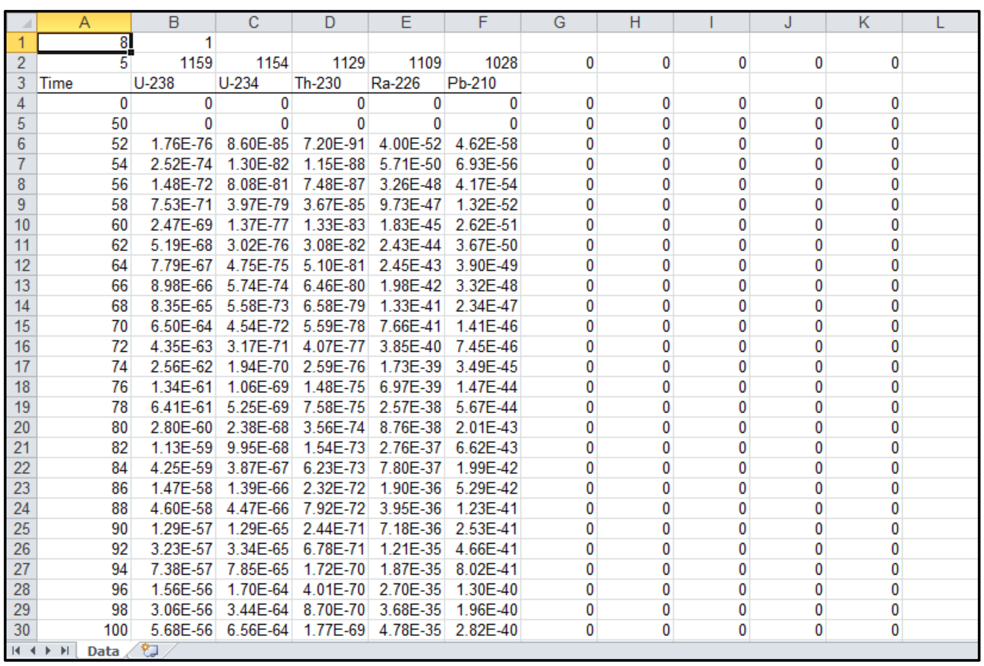


Figure 5-1. Screen display on opening *Reformat_PORFLOW.xls*m.



	A	B	C	D	E	F	G	H	I	J	K	L
1	8	1										
2	5	1159	1154	1129	1109	1028	0	0	0	0	0	
3	Time	U-238	U-234	Th-230	Ra-226	Pb-210						
4	0	0	0	0	0	0	0	0	0	0	0	
5	50	0	0	0	0	0	0	0	0	0	0	
6	52	1.76E-76	8.60E-85	7.20E-91	4.00E-52	4.62E-58	0	0	0	0	0	
7	54	2.52E-74	1.30E-82	1.15E-88	5.71E-50	6.93E-56	0	0	0	0	0	
8	56	1.48E-72	8.08E-81	7.48E-87	3.26E-48	4.17E-54	0	0	0	0	0	
9	58	7.53E-71	3.97E-79	3.67E-85	9.73E-47	1.32E-52	0	0	0	0	0	
10	60	2.47E-69	1.37E-77	1.33E-83	1.83E-45	2.62E-51	0	0	0	0	0	
11	62	5.19E-68	3.02E-76	3.08E-82	2.43E-44	3.67E-50	0	0	0	0	0	
12	64	7.79E-67	4.75E-75	5.10E-81	2.45E-43	3.90E-49	0	0	0	0	0	
13	66	8.98E-66	5.74E-74	6.46E-80	1.98E-42	3.32E-48	0	0	0	0	0	
14	68	8.35E-65	5.58E-73	6.58E-79	1.33E-41	2.34E-47	0	0	0	0	0	
15	70	6.50E-64	4.54E-72	5.59E-78	7.66E-41	1.41E-46	0	0	0	0	0	
16	72	4.35E-63	3.17E-71	4.07E-77	3.85E-40	7.45E-46	0	0	0	0	0	
17	74	2.56E-62	1.94E-70	2.59E-76	1.73E-39	3.49E-45	0	0	0	0	0	
18	76	1.34E-61	1.06E-69	1.48E-75	6.97E-39	1.47E-44	0	0	0	0	0	
19	78	6.41E-61	5.25E-69	7.58E-75	2.57E-38	5.67E-44	0	0	0	0	0	
20	80	2.80E-60	2.38E-68	3.56E-74	8.76E-38	2.01E-43	0	0	0	0	0	
21	82	1.13E-59	9.95E-68	1.54E-73	2.76E-37	6.62E-43	0	0	0	0	0	
22	84	4.25E-59	3.87E-67	6.23E-73	7.80E-37	1.99E-42	0	0	0	0	0	
23	86	1.47E-58	1.39E-66	2.32E-72	1.90E-36	5.29E-42	0	0	0	0	0	
24	88	4.60E-58	4.47E-66	7.92E-72	3.95E-36	1.23E-41	0	0	0	0	0	
25	90	1.29E-57	1.29E-65	2.44E-71	7.18E-36	2.53E-41	0	0	0	0	0	
26	92	3.23E-57	3.34E-65	6.78E-71	1.21E-35	4.66E-41	0	0	0	0	0	
27	94	7.38E-57	7.85E-65	1.72E-70	1.87E-35	8.02E-41	0	0	0	0	0	
28	96	1.56E-56	1.70E-64	4.01E-70	2.70E-35	1.30E-40	0	0	0	0	0	
29	98	3.06E-56	3.44E-64	8.70E-70	3.68E-35	1.96E-40	0	0	0	0	0	
30	100	5.68E-56	6.56E-64	1.77E-69	4.78E-35	2.82E-40	0	0	0	0	0	

Figure 5-2. First 30 lines of *Slit_c\PORFLOW\Aquifer_Transport\U-238.xlsx* file created from reformatting *Slit_c\PORFLOW\Aquifer_Transport\U-238\STAT.out* file.

```
BEGIN FILE IDENTIFICATION INFORMATION
DATA_TYPE_ID:::::::       30
PROBLEM_TITLE:::::: SLIT TRENCH AQUIFER TRANSPORT MODEL, Case01_off_SLITc, U-238
ACRi_SOFTWARE_TOOL: PORFLOW-3D  VERSION 5.97.0 /ACRi:  DATE: 15 APR 2004
LICENSED USER:::::: Len Collard                              License ID:LENCOLLA00000101
USER NAME:::::::::: ACRi - GEN
DATE::::::::::::::: 05/12/2007
TIME::::::::::::::: 21:33:28
END FILE IDENTIFICATION INFORMATION
BEGIN HEADER FOR TABLE COLUMNS
 ID# VAR#  ZoneID    Time:Step#     Average_Value    Variance      Minimum_Value Element   Maximum_Value Element
END HEADER FOR TABLE COLUMNS
   1   8  EAREABC   0.0000000E+00   0.0000000E+00  0.0000000E+00   0.0000000E+00       1   0.0000000E+00       1
   2   9  EAREABC   0.0000000E+00   0.0000000E+00  0.0000000E+00   0.0000000E+00       1   0.0000000E+00       1
   3  10  EAREABC   0.0000000E+00   0.0000000E+00  0.0000000E+00   0.0000000E+00       1   0.0000000E+00       1
   4  11  EAREABC   0.0000000E+00   0.0000000E+00  0.0000000E+00   0.0000000E+00       1   0.0000000E+00       1
   5  12  EAREABC   0.0000000E+00   0.0000000E+00  0.0000000E+00   0.0000000E+00       1   0.0000000E+00       1
   1   8  EAREABC   2.0000000E+00   2.0340426E-82  2.7326027E-80   0.0000000E+00       1   4.9871290E-78   47199
   2   9  EAREABC   2.0000000E+00   9.9611096E-91  1.3339912E-88   0.0000000E+00       1   2.4345463E-86   47199
   3  10  EAREABC   2.0000000E+00   8.3015864E-97  1.1170818E-94   0.0000000E+00       1   2.0393204E-92   47199
   4  11  EAREABC   2.0000000E+00   6.2807248E-57  1.4825498E-55   0.0000000E+00       1   1.1334758E-53   50172
   5  12  EAREABC   2.0000000E+00   7.2417060E-63  1.7100547E-61   0.0000000E+00    4103   1.3068577E-59   50172
   1   8  EAREABC   4.0000000E+00   4.4107081E-80  4.2159943E-78   0.0000000E+00       1   7.1240275E-76   47199
   2   9  EAREABC   4.0000000E+00   2.2343882E-88  2.1633627E-86   0.0000000E+00       1   3.6893119E-84   47199
   3  10  EAREABC   4.0000000E+00   1.9326535E-94  1.8930567E-92   0.0000000E+00       1   3.2459580E-90   47199
   4  11  EAREABC   4.0000000E+00   9.1385698E-55  2.1211330E-53   0.0000000E+00       1   1.6176216E-51   50172
   5  12  EAREABC   4.0000000E+00   1.1077093E-60  2.5729218E-59   0.0000000E+00    1441   1.9625125E-57   50172
   1   8  EAREABC   6.0000000E+00   4.0391861E-78  3.1511532E-76   0.0000000E+00       1   4.1778678E-74   47199
   2   9  EAREABC   6.0000000E+00   2.1184518E-86  1.6641781E-84   0.0000000E+00       1   2.2882606E-82   47199
   3  10  EAREABC   6.0000000E+00   1.9035796E-92  1.5090846E-90   0.0000000E+00       1   2.1179269E-88   47199
   4  11  EAREABC   6.0000000E+00   5.3503316E-53  1.2196138E-51   0.0000000E+00       1   9.2240109E-50   50172
   5  12  EAREABC   6.0000000E+00   6.8278012E-59  1.5585962E-57   0.0000000E+00      36   1.1797298E-55   50172
```

Figure 5-3. Initial portion of U-238\STAT.out file.

The macro reads the calculation end date from file ***Disposal_Units.xlsx*** shown in Figure 2-3. If the final PORFLOW transport end time is less than the specified calculation end date, the macro will create a final line of output repeating the last recorded PORFLOW concentrations at the simulation end time.

6.0 Composite Analysis Transport Calculations

As described in Section 3, the model is intended to calculate doses for both CA and PA applications. For the 2009 CA, one-dimensional radionuclide transport and subsequent dose calculations were combined into a single GoldSim model as described by Smith et al. (2009). One fundamental difference between the 2009 CA and 2008 PA dose calculations is that the PA results were obtained for individual parent radionuclides whereas the 2009 CA doses were obtained for entire disposal units. (Note: For the purpose of CA dose calculations the term "disposal units" is used here to generically refer to decommissioned SRS facilities, low-level waste disposal units, high-level waste tanks and waste sites projected to contain residual radionuclides at the SRS end state). Because the PA dose results are intended to set disposal limits for parent radionuclides, doses from each parent must be calculated separately. CA results are intended to calculate the dose resulting from a disposal unit for a given inventory; therefore, the total dose from all parent radionuclides was calculated. CA doses were presented in terms of the dose from the radionuclides actually present in the contaminated water including daughter products of radionuclide decay. This approach simplified the CA dose calculations and decreased the analysis time because all parent radionuclides in a single source of residual radionuclides could be analyzed simultaneously. However; using this approach, the CA dose could not be uniquely assigned to parent radionuclides having common daughters in their decay chains.

A different approach to the CA dose calculations is taken in the new GoldSim model. The dose calculation module was removed from the 2009 CA GoldSim model leaving only the transport calculation as a stand-alone model. The model driver (an Excel VBA macro) was modified to loop over each parent radionuclide present in the initial inventory for each disposal unit and the output was modified to save results for each parent individually. That is, the existing CA model was modified to produce results identical to those obtained from PA modeling. While this approach allows tracing CA dose results back to parent radionuclides, it significantly increases the analysis time. There were 51 unique parent radionuclides and 152 disposal units used for the 2009 CA modeling. Counting radionuclides with non-zero inventories, the required CA analyses would increase from 152 to 3104 (approximately 20 times) using the more detailed method of determining the dose from individual parents.

Separating the dose calculation from the transport means that the analyst must now run CA transport calculations prior to making the dose calculations. The transport calculations are performed by running the revised CA model (***CA_v2.gsm***) in the *CA_Model_V2* folder shown in Figure 2-1. This model is basically the same as the 2009 CA GoldSim model without the internal dose calculation. As was done for the 2009 CA, a VBA macro is provided in Excel workbook ***Run_CA_Model.xlsm*** to automate the calculations. The worksheet displayed on opening the Excel workbook is shown in Figure 6-1. Similar to the other macros described previously, the user enters a list of disposal units to be analyzed in Column A starting in row 2. The user must also enter the unit number corresponding to the disposal unit in Column B. The unit number is found in Excel workbook ***Disposal_Units.xlsm*** which has worksheets "Units" and "Inventory" that list CA input and inventory for the disposal units analyzed during the 2009 CA. The disposal unit name must be the same as the top level folder name for the disposal unit shown in Figure 2-1. This is the name "H_Canyon" for the example shown in Figure 6-1. Clicking on the "Run GoldSim CA" button shown in Figure 6-1 will automatically run transport calculations for the list of disposal units identified in Columns A and B. Results of the transport calculations are written into the *GoldSim_CA\Transport* folder for each disposal unit as Excel workbooks for each parent radionuclide. The Excel file will automatically close when the calculations are finished.

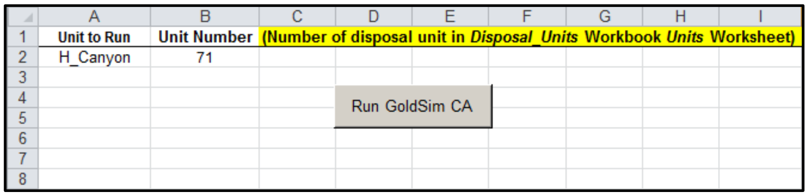


Figure 6-1. Screen display on opening *CA_Model_V2\Run_CA_Model.xlsm*.

6.1 Revisions to Original CA Model

During development of the CA dose calculation for the new GoldSim Limits and Doses Model, the original CA dose model was thoroughly evaluated. Differences between the original CA dose calculation and the most recent methodology described by Smith et al. (2015) were noted and, in two cases, the original calculation was modified. These differences and modifications are listed below:

1. In the original CA model, equilibrium partitioning of dose species from agricultural water to bulk soil was calculated based on the soil retardation factor according to the equation:

$$C_{si} = \frac{C_{wi}}{\rho_w}\left[1 + \frac{k_{di}\,\rho_s}{\theta_w}\right] \qquad (6\text{-}1)$$

Where:

C_{si} ....concentration of radionuclide *i* in agricultural soil (pCi/kg),
C_{wi} ....concentration of radionuclide *i* in agricultural water (pCi/L),
k_{di}.....................soil/water partition coefficient for radionuclide *i* (L/kg),
ρ_s ....soil bulk density (kg/L), and
ρ_w.....................water bulk density (kg/L), and
θ_w.....................volumetric water content of soil (–).

Note that Eq. (6-1) is reported incorrectly in both Perona and Tauxe (2009) and Phifer et al. (2009) where the retardation factor [the term enclosed in the square brackets in Eq. (6-1)] is missing the "1 +" term. The new dose model uses a more elaborate calculation of radionuclide concentration in the soil as described by Smith, et al. (2015). Initially it was thought that simply using the calculation of soil concentration shown in Eq. (6-1) would bring the new dose model calculations into agreement with the CA model. However, this was not the case and the additional factors described below were also significant.

2. The original CA model was limited to considering 52 parent and daughter radionuclides with half-lives greater than 3 years and an additional 50 daughters with half-lives less than 3 years. The new dose model is intended to be more flexible such that any of the 1252 radionuclides in the radionuclide

database could be used as parents. Because the CA model only included 102 radionuclides, the "rollup" from parent species to full chains (including radionuclides in secular equilibrium with the parents) for dose calculations was done explicitly. The new dose model is able to automatically determine full decay chains for all radionuclides.

The original CA model contains the following comment in numerous places:

"When doing the dose rollup back to Species, we recalculate the contributions to dose from Th228 and its progeny to the two parents: Ra228 and U232. This contribution is apportioned by the initial concentration of each parent in water that was read in from the transport model."

This leads to some peculiar dose equations such as the following equation used to calculate the dose from Ra-228 and its daughters. Note the concentration ratio in bold type multiplying daughter species except for Ac-228.

```
Dose_Ing_water[Ra228] + Dose_Ing_water[Ac228] + ( ( InputConc_DrinkWater[Ra228] /
( InputConc_DrinkWater[Ra228] + InputConc_DrinkWater[U232] + Epsilon Bq/L ) ) *
( Dose_Ing_water[Th228] + Dose_Ing_water[Ra224] + Dose_Ing_water[Rn220] +
Dose_Ing_water[Po216] + Dose_Ing_water[Pb212] + Dose_Ing_water[Bi212] +
Dose_Ing_water[Po212] + Dose_Ing_water[Tl208] ) )
```

This construct, which affects decay chains having Ra-228 as a member, is believed to be incorrect and possibly originates from an error in the decay chains used by Neptune. If such a correction is needed to determine the dose from daughter radionuclides, it would have to appear in many decay chains because different parent radionuclides often decay to the same daughter. Being reluctant to include this "correction" in the new dose model even for test purposes, it was instead deleted from the version of the CA model used to calculate the comparison doses reported in Chapter 7.

3. The following term was used to calculate the uptake of radionuclides in leaves in the original CA model:

$$leaf\ uptake = \frac{r\ F_W\ (1 - e^{-\lambda_g t_{irr}})}{Y\ \lambda_g} \tag{6-2}$$

Where:

r .... retention of radionuclides on plant leaf surface (–),
F_w .... washing factor; differs for leafy and non-leafy plants (–),
t_{irr} .... irrigation time (yr),
Y .... vegetable production yield (kg/L), and
λ_g .... weathering and radiological decay constant (1/yr).

In the original CA model the weathering and radiological decay constant only included the constant leaf weathering term while in the new dose model it includes leaf weathering and radioactive decay and consequently varies with radionuclide. While this difference appears to be small, it changed the vegetable ingestion dose from Sr-90 by 1.5% and for several other radionuclides by about 1%.

4. The external radiation dose from sediment exposure for radionuclide i (D_{sedi}) is calculated in the original CA model as:

$$D_{sedi} = C_{sedi}\,\rho_s\,t_{shore}\,F_{shape}\,DCF\_ext_i \quad (6\text{-}3)$$

Where:

C_{sedi} ....concentration of radionuclide *i* in sediment (pCi/kg),
ρ_s ....sediment soil density (kg/L),
t_{shore} ....fraction of time spent on the shoreline (–),
F_{shape} ....shape factor for external dose from shoreline deposits (–), and
DCF_ext_i ....dose conversion factor for external irradiation from soil contaminated to a depth of 15 cm (mrem/yr)/(pCi/L).

Equation (6-1) is used to calculate the concentration of radionuclide *i* in shoreline sediment where the only difference between sediment and soil is that the sediment is assumed to be saturated. A different calculation was proposed in the methodology developed by Smith et al. (2015). However; using Eq. (6-3) is attractive because it introduces no new parameters into the dose calculation. Consequently, the shore-shine dose calculation in the new dose model was changed to use Eq. (6-3). Shore-shine is a relatively minor contribution to total dose.

5. In the original CA dose calculations involving food sources (vegetables, milk and meat) the dose is based on the maximum of either the concentration of the dose species or parent radionuclide. This approach is justified by the following comment which appears in the Neptune model:

“Calculations for concentrations in vegetables [*also meat and milk*] are performed separately for parent nuclides and all dose species nuclides because of the need to factor decay during food storage (the "holdup time"). All nuclide concentrations are defined as being in secular equilibrium in irrigation water. In plant tissue, their concentration is a factor of water concentration and plant-soil ratio. Following harvest and the holdup time decay period, the concentration of any progeny will be either equal to the parent or possibly higher than that of the parent if its plant-soil ratio was much larger and/or the holdup period was very brief. The max of either progeny or parent activity in plant tissue is used in the dose calculations.”

While this approach may have some merit, it was decided not to modify the new dose calculations to incorporate this change. The new dose model bases dose strictly on dose species concentration and the CA model used for test purposes was modified to not use the maximum of parent or daughter concentration. Items 2 and 5 are the only changes made to the original CA dose model for purposes of model to model comparisons.

6. Neptune applied a concept similar to that outlined in Item 5 for radionuclide transport through soil. That is, the assumption is made that secular equilibrium occurs in the contaminated water followed by transport of parent and daughter radionuclides through the soil.

Items 5 and 6 are both related to the treatment of the radionuclides assumed to be in secular equilibrium with their parents. The two methods that can be used are summarized below using the example of plant uptake of radionuclides:

1) Method of accounting for secular equilibrium used in 2008 PA:
   1. Transport in the groundwater of short-chain radionuclides having half-lives greater than some cut-off value is explicitly calculated.
   2. Short-chain radionuclides are absorbed by the plant based on their plant-soil transfer ratios.
   3. In the plant the short-chain radionuclides establish secular equilibrium with shorter lived radionuclides in their decay chains.
   4. The ingestion dose from consumption of all radionuclides in the plant is calculated.

2) Method of accounting for secular equilibrium used in original CA dose model:
   1. Transport in the groundwater of short-chain radionuclides having half-lives greater than some cut-off value is explicitly calculated.
   2. In the groundwater, the short-chain radionuclides establish secular equilibrium with shorter lived radionuclides in their decay chains.
   3. Short-chain radionuclides and daughters are absorbed by the plant based on their plant-soil transfer ratios.
   4. The ingestion dose from consumption of all radionuclides in the plant is calculated.

Item 5 described above is equivalent to using whichever assumption (i.e. secular equilibrium before or after transport) gives the highest concentration. Typically time steps of a year are taken in the transport calculations. Shorter time steps are used for radionuclides with low k_d values that transport faster while larger time steps are used to extend the calculations beyond 1,000 years. To continue with the plant uptake example, plants are grown and consumed in less than a year. The approach to secular equilibrium occurs quickly for radionuclides with very short half -lives and more slowly as the half-live approaches the cutoff value. Therefore; while either method could reasonably be applied, the new dose model uses the first method.

7.0 Verification Testing

Limited verification testing has been conducted on the GoldSim limits and doses model. The testing showed that results from the 2008 E-Area PA and the 2009 SRS CA could be reproduced using the GoldSim model. To reproduce the earlier results, the most recent dose equations and parameters established in the *SRNL_Rad_Data_Package* and the accompanying report by Smith, et al. (2015) could not be used directly. As shown in Figure 3-1, the model user has the option to use the 2008 PA and the 2009 CA dose equations and parameters for testing purposes. To accomplish this, logic was added to the dose equations to revert to the previous formulation when these options were chosen. An example appears in Figure 4-8 where the function Vege_Uptake is shown. When the CA dose calculation is selected, a different version of the equation is used. The user must also use the GoldSim simulation settings given in Appendix A to reproduce previous results.

Specification of the model species (radionuclides) is a fundamental property of the GoldSim model. For example, functions can be copied from one GoldSim model to another only if both models have the same species list. Because it is very inconvenient to modify the species list, the most recent radionuclide data from the *SRNL_Rad_Data_Package* was used to define the dose model species. This creates some difference between the new model and previous dose calculations even when the same dose equations and parameters are used. Appendix B gives an example of reconciling these differences in the calculation of doses and limits for the E-Area Center Slit Trench. In this case, all of the differences were resolved such that the calculations agreed within one percent.

Verification testing was performed using the new GoldSim Doses and Limits Model to reproduce the:

1. 2008 PA calculation of preliminary disposal limits (not including plume interaction) for an E-Area LLWF Center Slit Trench,
2. 2009 CA doses from an E-Area LLWF Center Slit Trench, and
3. 2009 CA doses form H-Canyon.

The PA comparison calculations tested All-Pathways, Groundwater Protection, and Inadvertent Intruder doses. Values for the PA comparison were obtained from archive files in folder:

\\hpcfs1\hpc_archive\Analyses\pa\ArchiveHolding\Analyses\SlitTrench\PA\2008\AllPathways\Center Slit Trenches\Case01 CDPoff

Data for PA all-pathways and groundwater protection limits were extracted from the following files:

Cental Slit No Non-crush CDPoff Alpha-Radium 0-1000 yrs 6-6-2007.xls
Cental Slit No Non-crush CDPoff Alpha-Radium 1000-1120 yrs 6-6-2007.xls
Cental Slit No Non-crush CDPoff Alpha-Radium 1120-1130 yrs 6-6-2007.xls
Cental Slit No Non-crush CDPoff Beta-Gamma 0-12 yrs 6-6-2007.xls
Cental Slit No Non-crush CDPoff Beta-Gamma 12-100 yrs 6-6-2007.xls
Cental Slit No Non-crush CDPoff Beta-Gamma 100-1130 yrs 6-6-2007.xls
Cental Slit No Non-crush CDPoff LADTAP 100-1130 yrs 6-6-2007.xls

Cental Slit No Non-crush CDPoff LADTAP 130-200 yrs 6-6-2007.xls
Cental Slit No Non-crush CDPoff LADTAP 200-1000 yrs 6-6-2007.xls
Cental Slit No Non-crush CDPoff LADTAP 1000-1130 yrs 6-6-2007.xls
Cental Slit No Non-crush CDPoff Uranium 0-1130 yrs 6-6-2007.xls

Data for the PA intruder limits could only be obtained to three significant figures from the archived results of the 2008 PA (WSRC, 2008). Therefore, the Intruder Application used to generate the 2008 PA limits (Koffman, 2006 and Lee, 2004) was run and results to full precision used for the comparison. The CA results were obtained by first rerunning transport calculations using the revised CA model described in the previous section. CA doses calculated using the new GoldSim model were compared to results in files from the original CA so that full calculation precision was used.

Table 7-1 lists the 2008 PA disposal limits obtained from the archived files and Table 7-2 shows disposal limits for the same dose scenarios calculated using the new GoldSim model. Table 7-3 gives ratios of the 2008 PA disposal limits to the values calculated using the GoldSim model. All of the differences in Table 7-3 are less than 1% except for the five highlighted intruder results. As summarized in Appendix B, the differences greater than 1% were traced to changes in the basic radionuclide data. Calculations made in and Excel spreadsheet reproduced both the 2008 PA limits and the new limits for these five cases confirming that the differences were caused by the radionuclide data.

Table 7-4 shows doses calculated using the new GoldSim dose model for 32 radionuclides in the Center Slit Trench disposal unit having non-zero inventories and eight radionuclides in the H-Canyon inventory that contribute to dose over the first 1,000 years. Cm-246, Ra-228 and Th-232 which had overall doses less than 10^{-20} mrem/yr were eliminated from the comparison. Table 7-5 compares the 11 pathway doses for each radionuclide to those calculated using the original CA dose module modified to output results in a format comparable to that used for PA doses. Differences between the two calculations are all less than 0.33% and most of the differences occur in calculations involving soil dose pathways. This appears to indicate that some small difference in soil radionuclide concentration exists between the two models. The maximum Center Slit Trench dose reported by Smith et al. (2009) is 1.33e-02 (mrem/yr) primarily from I-129 and the maximum dose for H Canyon is 1.04 (mrem/yr) almost entirely from Np-237. The new dose calculations are in agreement with these results.

Table 7-1. Center Slit Trench Disposal Limits produced in 2008 ELLWF PA

	Beta-Gamma			Gross Alpha			Radium			Uranium	All-Pathways			Residential Intruder	Post Drilling Intruder
Radionuclide	0-12 Years	12-100 Years	100-1130 Years	0-1000 Years	1000-1120 Years	1120-1130 Years	0-1000 Years	1000-1120 Years	1120-1130 Years	0-1130 Years	130-200 Years	200-1000 Years	1000-1130 Years	130-1130 Years	130-1130 Years
Am-241	4.59E+09	2.07E+06	1.28E+04	6.41E+02	1.64E+03	2.84E+03	---	---	---	1.93E+12	3.46E+05	1.99E+02	5.10E+02	6.35E+05	1.39E+03
Am-243	---	1.71E+17	3.04E+10	1.07E+09	8.61E+08	8.57E+08	---	---	---	---	1.46E+15	1.27E+08	1.02E+08	3.97E+02	1.14E+03
C-14	2.89E-01	2.89E-01	1.02E+01	---	---	---	---	---	---	---	1.33E+01	1.33E+01	1.33E+01	---	1.98E+03
Cf-249	1.42E+17	3.68E+12	7.31E+05	4.02E+04	3.66E+04	3.76E+04	---	---	---	1.13E+14	3.09E+11	1.25E+04	1.13E+04	3.72E+02	1.26E+03
Cf-251	---	---	1.12E+17	5.20E+15	3.02E+15	2.94E+15	---	---	---	---	---	6.17E+14	3.49E+14	1.39E+03	1.16E+03
Cl-36	1.01E-01	1.01E-01	3.51E+00	---	---	---	---	---	---	---	2.33E+00	2.33E+00	2.33E+00	---	2.51E+01
Cm-244	---	---	---	---	---	---	---	---	---	---	---	---	---	4.56E+11	9.97E+04
Cm-245	1.97E+13	1.25E+09	1.70E+04	8.51E+02	8.93E+02	9.78E+02	---	---	---	2.12E+12	1.27E+08	2.64E+02	2.77E+02	2.40E+03	7.65E+02
Cm-246	---	---	6.09E+17	5.88E+16	6.67E+15	5.85E+15	5.88E+16	6.68E+15	5.86E+15	---	---	1.73E+17	1.72E+16	1.10E+11	1.47E+03
Cm-247	---	---	1.03E+12	4.21E+10	2.83E+10	2.78E+10	---	---	---	---	3.13E+18	5.00E+09	3.30E+09	7.97E+01	1.26E+03
Cm-248	---	---	---	---	---	---	---	---	---	---	---	---	---	5.55E+06	3.93E+02
H-3	5.50E+00	5.64E+00	2.72E+04	---	---	---	---	---	---	---	4.77E+06	4.77E+06	4.77E+06	---	2.07E+06
I-129	2.21E+04	1.89E-04	8.89E-03	---	---	---	---	---	---	---	6.30E-01	6.30E-01	6.30E-01	7.96E+09	3.79E+02
K-40	2.20E-01	1.64E-01	1.87E+00	---	---	---	---	---	---	---	4.90E+00	6.17E+00	3.04E+01	6.73E+01	5.11E+02
Mo-93	2.24E-01	2.22E-01	4.13E+00	---	---	---	---	---	---	---	2.47E+01	2.47E+01	2.47E+01	---	4.74E+05
Nb-94	1.11E-01	1.11E-01	3.86E+00	---	---	---	---	---	---	---	2.74E+00	2.74E+00	2.74E+00	9.70E+00	2.73E+03
Ni-59	6.79E+19	4.01E+09	4.78E+00	---	---	---	---	---	---	---	4.93E+11	7.89E+03	1.20E+03	---	4.17E+05
Np-237	2.82E+03	4.56E+00	2.03E+00	1.01E-01	7.78E-01	2.90E+00	---	---	---	2.84E+08	1.20E+00	3.14E-02	2.41E-01	1.69E+02	1.09E+02
Pd-107	---	4.90E+11	5.78E+02	---	---	---	---	---	---	---	7.59E+11	1.21E+04	1.83E+03	---	8.73E+05
Pu-238	---	---	1.25E+07	6.75E+05	1.45E+05	1.35E+05	6.75E+06	1.46E+05	1.35E+05	---	1.98E+18	1.98E+06	3.95E+05	1.36E+07	3.57E+03
Pu-239	1.13E+18	2.28E+13	3.89E+08	1.15E+07	1.09E+07	1.15E+07	---	---	---	---	2.46E+11	1.36E+06	1.30E+06	3.87E+06	1.47E+03
Pu-240	---	---	---	---	---	---	---	---	---	---	---	---	---	1.26E+09	1.48E+03
Pu-241	1.68E+12	2.88E+08	3.92E+05	1.96E+04	4.88E+04	8.34E+04	---	---	---	5.90E+13	3.76E+07	6.07E+03	1.51E+04	1.91E+07	4.09E+04
Pu-242	---	---	1.65E+14	1.29E+13	1.84E+12	1.64E+12	1.29E+13	1.84E+12	1.64E+12	---	---	3.79E+13	4.81E+12	7.21E+08	1.54E+03
Pu-244	---	---	---	---	---	---	---	---	---	---	---	---	---	4.43E+01	1.27E+03
Ra-226	2.72E+17	2.98E+07	3.49E+00	7.47E-02	4.57E-02	4.58E-02	7.48E-02	4.57E-02	4.58E-02	---	5.91E+05	2.19E-01	1.34E-01	9.19E+00	7.13E+01
Se-79	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2.36E+04
Sn-126	---	---	---	---	---	---	---	---	---	---	---	---	---	8.76E+00	2.07E+03
Sr-90	1.16E+15	4.00E+06	5.39E+06	---	---	---	---	---	---	---	1.77E+08	8.39E+08	2.79E+10	---	1.64E+03
Tc-99	4.11E-01	1.83E-01	6.02E+00	---	---	---	---	---	---	---	1.02E+01	1.02E+01	1.02E+01	1.07E+09	2.43E+03
Th-230	---	2.37E+10	1.04E+01	3.88E-01	1.27E-01	1.22E-01	3.88E-01	1.27E-01	1.22E-01	---	4.38E+08	1.14E+00	3.57E-01	1.89E+01	1.91E+02
Th-232	7.05E+16	4.50E+09	1.89E+09	4.57E+09	2.24E+09	1.92E+09	6.09E+09	2.99E+09	2.56E+09	---	1.26E+13	7.97E+10	5.10E+09	4.41E+00	1.48E+02
U-233	---	---	---	---	---	---	---	---	---	---	---	---	---	9.40E+02	2.20E+03
U-234	---	8.86E+14	3.16E+03	1.54E+02	3.71E+01	3.47E+01	1.54E+02	3.71E+01	3.47E+01	---	1.54E+13	4.53E+02	1.02E+02	3.83E+03	3.41E+03
U-235	1.96E+09	1.22E+05	2.11E+02	5.77E+00	8.36E+00	1.04E+01	---	---	---	---	1.79E+03	6.85E-01	9.93E-01	5.13E+02	2.21E+03
U-236	---	2.67E+19	2.03E+16	3.97E+17	2.44E+16	2.06E+16	5.30E+17	3.25E+16	2.75E+16	---	---	1.06E+18	5.47E+16	2.85E+07	3.92E+03
U-238	---	---	4.65E+06	2.89E+05	5.31E+04	4.85E+04	2.90E+05	5.32E+04	4.85E+04	---	1.84E+18	3.09E+08	1.42E+05	9.80E+02	4.00E+03
Zr-93	1.73E+00	7.50E-01	9.58E-01	---	---	---	---	---	---	---	4.36E+03	6.24E+00	5.71E+00	---	9.48E+05

Table 7-2. Center Slit Trench PA Disposal Limits calculated by new GoldSim Dose Model

GoldSim Radionuclide	Beta-Gamma 0-1130 Years	Gross Alpha 0-1130 Years	Radium 0-1130 Years	Uranium 0-1130 Years	All-Pathways 130-1130 Years	Residential Intruder 130-1130 Years	Post Drilling Intruder 130-1130 Years
Am-241	1.28E+04	6.39E+02	---	1.93E+12	1.98E+02	6.35E+05	1.39E+03
Am-243	3.04E+10	8.58E+08	---	---	1.02E+08	3.97E+02	1.14E+03
C-14	2.89E-01	---	---	---	1.33E+01	---	1.98E+03
Cf-249	7.31E+05	3.66E+04	---	1.13E+14	1.13E+04	3.72E+02	1.26E+03
Cf-251	1.12E+17	2.93E+15	---	---	3.48E+14	1.39E+03	1.16E+03
Cl-36	1.01E-01	---	---	---	2.33E+00	---	2.51E+01
Cm-244	---	---	---	---	---	4.56E+11	1.00E+05
Cm-245	1.70E+04	8.49E+02	---	2.12E+12	2.63E+02	2.40E+03	7.65E+02
Cm-246	6.09E+17	5.85E+15	5.86E+15	---	1.72E+16	1.10E+11	1.47E+03
Cm-247	1.03E+12	2.79E+10	---	---	3.31E+09	7.97E+01	1.26E+03
Cm-248	---	---	---	---	---	5.54E+06	3.93E+02
H-3	5.50E+00	---	---	---	4.77E+06	---	2.09E+06
I-129	1.89E-04	---	---	---	6.30E-01	7.96E+09	3.79E+02
K-40	1.64E-01	---	---	---	4.90E+00	6.73E+01	5.10E+02
Mo-93	2.22E-01	---	---	---	2.47E+01	---	4.90E+05
Nb-94	1.11E-01	---	---	---	2.73E+00	9.70E+00	2.73E+03
Ni-59	4.78E+00	---	---	---	1.20E+03	---	4.16E+05
Np-237	2.03E+00	1.01E-01	---	2.85E+08	3.14E-02	1.69E+02	1.09E+02
Pd-107	5.78E+02	---	---	---	1.84E+03	---	8.73E+05
Pu-238	1.25E+07	1.35E+05	1.35E+05	---	3.97E+05	1.35E+07	3.58E+03
Pu-239	3.89E+08	1.10E+07	---	---	1.30E+06	3.87E+06	1.47E+03
Pu-240	---	---	---	---	---	1.26E+09	1.48E+03
Pu-241	3.90E+05	1.95E+04	---	5.88E+13	6.03E+03	1.90E+07	4.07E+04
Pu-242	1.64E+14	1.64E+12	1.64E+12	---	4.82E+12	7.18E+08	1.54E+03
Pu-244	---	---	---	---	---	4.41E+01	1.27E+03
Ra-226	3.49E+00	4.57E-02	4.57E-02	---	1.34E-01	9.19E+00	7.13E+01
Se-79	---	---	---	---	---	---	2.35E+04
Sn-126	---	---	---	---	---	8.76E+00	2.07E+03
Sr-90	4.00E+06	---	---	---	1.77E+08	---	1.66E+03
Tc-99	1.83E-01	---	---	---	1.02E+01	1.07E+09	2.43E+03
Th-230	1.04E+01	1.22E-01	1.22E-01	---	3.58E-01	1.89E+01	1.91E+02
Th-232	1.89E+09	1.92E+09	2.56E+09	---	5.10E+09	4.41E+00	1.48E+02
U-233	---	---	---	---	---	9.51E+02	2.20E+03
U-234	3.16E+03	3.47E+01	3.47E+01	---	1.02E+02	3.82E+03	3.41E+03
U-235	2.11E+02	5.78E+00	---	---	6.85E-01	5.13E+02	2.21E+03
U-236	2.03E+16	2.06E+16	2.75E+16	---	5.47E+16	2.85E+07	3.92E+03
U-238	4.65E+06	4.85E+04	4.85E+04	---	1.43E+05	9.41E+02	3.99E+03
Zr-93	7.52E-01	---	---	---	5.72E+00	---	9.61E+05

Table 7-3. Percent difference between PA Disposal Limits and GoldSim Model Values

Radionuclide	Beta-Gamma	Gross Alpha	Radium	Uranium	All-Pathways	Residential Intruder	Post Drilling Intruder
Am-241	-0.28%	-0.28%	---	-0.02%	-0.28%	0.01%	-0.05%
Am-243	0.12%	0.14%	---	---	-0.23%	0.00%	-0.09%
C-14	-0.14%	---	---	---	-0.26%	---	0.00%
Cf-249	0.01%	0.01%	---	0.25%	0.01%	0.05%	0.05%
Cf-251	-0.33%	-0.16%	---	---	-0.33%	-0.11%	0.00%
Cl-36	0.01%	---	---	---	-0.07%	---	0.00%
Cm-244	---	---	---	---	---	0.05%	0.56%
Cm-245	-0.18%	-0.29%	---	-0.04%	-0.44%	-0.01%	-0.05%
Cm-246	0.00%	0.00%	0.00%	---	0.34%	-0.07%	0.00%
Cm-247	0.00%	0.19%	---	---	0.02%	0.00%	-0.01%
Cm-248	---	---	---	---	---	-0.25%	0.00%
H-3	-0.08%	---	---	---	0.09%	---	0.75%
I-129	-0.19%	---	---	---	0.05%	0.00%	0.00%
K-40	0.01%	---	---	---	-0.08%	0.00%	-0.21%
Mo-93	0.12%	---	---	---	-0.03%	---	3.26%
Nb-94	0.00%	---	---	---	-0.34%	0.00%	0.00%
Ni-59	0.00%	---	---	---	-0.10%	---	-0.02%
Np-237	-0.16%	0.34%	---	0.40%	-0.03%	0.00%	0.00%
Pd-107	0.01%	---	---	---	0.33%	---	0.00%
Pu-238	0.38%	-0.02%	0.05%	---	0.47%	-0.10%	0.17%
Pu-239	-0.09%	0.17%	---	---	0.00%	0.00%	-0.03%
Pu-240	---	---	---	---	---	0.00%	-0.03%
Pu-241	-0.63%	-0.63%	---	-0.36%	-0.64%	-0.41%	-0.47%
Pu-242	-0.26%	-0.27%	-0.28%	---	0.07%	-0.48%	-0.03%
Pu-244	---	---	---	---	---	-0.36%	-0.07%
Ra-226	0.09%	0.02%	0.10%	---	0.09%	-0.02%	-0.01%
Se-79	---	---	---	---	---	---	-0.45%
Sn-126	---	---	---	---	---	0.00%	0.00%
Sr-90	-0.09%	---	---	---	0.09%	---	0.97%
Tc-99	-0.01%	---	---	---	0.30%	0.00%	0.00%
Th-230	0.34%	-0.01%	0.06%	---	0.37%	-0.06%	-0.04%
Th-232	0.17%	0.18%	0.17%	---	-0.05%	-0.02%	0.00%
U-233	---	---	---	---	---	1.08%	-0.01%
U-234	-0.01%	0.02%	0.02%	---	0.36%	-0.09%	-0.01%
U-235	-0.17%	0.15%	---	---	0.03%	-0.01%	-0.04%
U-236	0.18%	0.18%	0.18%	---	-0.05%	-0.01%	0.00%
U-238	0.00%	0.00%	0.00%	---	0.34%	-4.14%	-0.05%
Zr-93	0.18%	---	---	---	0.17%	---	1.40%

Table 7-4. CA Doses for Center Slit Trench and H Canyon calculated using new GoldSim Dose Model.

Center Slit	Ingestion						Inhalation	External				
Parent	Water	Vegetable	Meat	Milk	Soil	Fish	Soil	Soil	Swim	Boat	Shore	Total
Nuclide	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr
Am241	1.39E-08	3.11E-08	3.08E-10	3.25E-12	7.28E-14	3.01E-07	4.99E-13	5.22E-12	1.06E-11	1.25E-11	1.19E-11	3.47E-07
Am242m	3.56E-11	8.11E-11	7.80E-13	2.16E-12	9.21E-15	1.90E-09	1.85E-15	7.57E-11	8.90E-14	1.05E-13	1.58E-10	2.26E-09
Am243	4.87E-15	1.09E-14	4.85E-17	1.17E-18	6.59E-20	5.06E-14	3.86E-19	3.69E-19	9.62E-20	1.14E-19	7.79E-19	6.64E-14
C14	2.09E-13	6.44E-13	2.05E-13	1.65E-13	1.47E-17	6.51E-13	2.23E-18	2.60E-18	5.84E-19	6.89E-19	5.46E-18	1.87E-12
Ca41	9.87E-10	2.42E-09	4.87E-11	1.53E-10	3.52E-14	4.09E-08	5.06E-16	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.45E-08
Cf249	4.39E-11	9.84E-11	9.75E-13	1.03E-14	2.30E-16	9.52E-10	1.58E-15	1.65E-14	3.34E-14	3.94E-14	3.77E-14	1.10E-09
Cl36	1.56E-09	5.50E-09	1.14E-09	2.02E-09	1.69E-15	8.06E-08	2.02E-16	3.16E-14	2.76E-13	3.26E-13	9.66E-14	9.08E-08
Cm245	2.64E-11	5.91E-11	5.86E-13	6.18E-15	1.38E-16	5.72E-10	9.47E-16	9.91E-15	2.01E-14	2.37E-14	2.27E-14	6.59E-10
Cm247	2.83E-18	6.35E-18	2.82E-20	6.79E-22	3.75E-23	2.94E-17	2.18E-22	2.08E-22	5.60E-23	6.61E-23	4.39E-22	3.86E-17
H3	5.13E-06	1.38E-05	1.68E-06	4.39E-06	5.57E-12	5.31E-06	2.12E-13	0.00E+00	1.84E-07	0.00E+00	0.00E+00	3.05E-05
I129	2.65E-04	5.94E-04	2.36E-04	1.12E-04	2.88E-10	1.10E-02	3.82E-12	2.59E-10	7.92E-09	9.34E-09	7.90E-10	1.22E-02
K40	4.03E-10	1.17E-09	2.39E-10	1.79E-10	2.83E-14	4.18E-07	1.46E-16	2.98E-11	4.18E-12	4.93E-12	6.25E-11	4.20E-07
Mo93	4.14E-09	9.90E-09	5.06E-11	1.14E-10	4.88E-14	1.05E-06	5.91E-16	3.08E-09	2.77E-08	3.27E-08	9.40E-09	1.14E-06
Nb93m	1.27E-06	2.84E-06	8.19E-09	1.90E-09	1.38E-12	3.95E-04	3.24E-14	1.16E-06	1.04E-05	1.23E-05	3.54E-06	4.26E-04
Nb94	1.34E-07	3.00E-07	8.66E-10	2.01E-10	1.46E-13	4.17E-05	6.38E-14	5.54E-09	4.86E-08	5.73E-08	1.69E-08	4.22E-05
Ni59	7.68E-09	1.76E-08	8.76E-10	5.89E-09	3.79E-13	7.96E-07	7.60E-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.28E-07
Ni63	1.00E-08	2.30E-08	1.14E-09	7.69E-09	4.95E-13	1.04E-06	1.00E-13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.08E-06
Np237	3.49E-06	7.81E-06	7.74E-08	8.17E-10	1.83E-11	7.56E-05	1.25E-10	1.31E-09	2.65E-09	3.13E-09	2.99E-09	8.70E-05
Pa231	2.76E-06	6.20E-06	2.75E-08	6.63E-10	3.80E-11	2.87E-05	2.26E-10	2.16E-10	5.47E-11	6.45E-11	4.57E-10	3.77E-05
Pd107	1.37E-14	3.11E-14	1.24E-15	6.50E-15	6.76E-19	1.42E-13	1.64E-19	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.94E-13
Pu238	3.23E-09	7.35E-09	7.08E-11	1.96E-10	8.57E-13	1.73E-07	1.69E-13	6.85E-09	8.06E-12	9.50E-12	1.43E-08	2.05E-07
Pu239	1.81E-11	4.05E-11	1.80E-13	4.34E-15	2.51E-16	1.88E-10	1.48E-15	1.42E-15	3.57E-16	4.22E-16	2.99E-15	2.46E-10
Pu241	7.21E-09	1.61E-08	1.60E-10	1.69E-12	3.77E-14	1.56E-07	2.59E-13	2.70E-12	5.47E-12	6.46E-12	6.19E-12	1.80E-07
Pu242	1.55E-19	3.52E-19	3.38E-21	9.40E-21	3.83E-23	8.26E-18	7.90E-24	3.29E-19	3.87E-22	4.57E-22	6.87E-19	9.79E-18
Ra226	4.90E-05	1.12E-04	1.07E-06	2.98E-06	1.31E-08	2.62E-03	2.55E-09	1.04E-04	1.22E-07	1.44E-07	2.17E-04	3.10E-03
Sr90	8.73E-09	2.06E-08	1.64E-09	1.20E-09	1.29E-12	5.19E-07	3.31E-14	6.40E-11	3.96E-13	4.67E-13	1.34E-10	5.51E-07
Tc99	1.22E-06	2.77E-06	1.74E-07	1.08E-07	6.40E-12	2.54E-05	1.98E-12	9.55E-12	2.21E-11	2.61E-11	2.19E-11	2.96E-05
Th230	4.04E-06	9.21E-06	8.92E-08	2.45E-07	1.15E-09	2.16E-04	2.18E-10	8.56E-06	1.01E-08	1.19E-08	1.79E-05	2.56E-04
U234	2.24E-06	5.09E-06	4.91E-08	1.36E-07	6.03E-10	1.20E-04	1.18E-10	4.74E-06	5.58E-09	6.58E-09	9.90E-06	1.42E-04
U235	9.81E-06	2.20E-05	9.77E-08	2.36E-09	1.40E-10	1.02E-04	8.33E-10	8.00E-10	1.94E-10	2.29E-10	1.69E-09	1.34E-04
U238	5.03E-09	1.14E-08	1.10E-10	3.05E-10	1.29E-12	2.69E-07	2.61E-13	1.07E-08	1.26E-11	1.48E-11	2.23E-08	3.18E-07
Zr93	6.08E-11	1.36E-10	3.92E-13	9.10E-14	6.60E-17	1.89E-08	1.55E-18	5.55E-11	4.99E-10	5.89E-10	1.69E-10	2.04E-08
H-Canyon	**Ingestion**						**Inhalation**	**External**				
Parent	Water	Vegetable	Meat	Milk	Soil	Fish	Soil	Soil	Swim	Boat	Shore	Total
Nuclide	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr
Am241	2.05E-05	4.60E-05	4.56E-07	4.81E-09	1.08E-10	4.45E-04	7.37E-10	7.71E-09	1.56E-08	1.84E-08	1.76E-08	5.13E-04
H3	6.29E-15	1.69E-14	2.06E-15	5.39E-15	6.84E-21	6.52E-15	2.60E-22	0.00E+00	2.26E-16	0.00E+00	0.00E+00	3.74E-14
I129	2.15E-06	4.81E-06	1.91E-06	9.05E-07	2.33E-12	8.90E-05	3.09E-14	2.10E-12	6.42E-11	7.57E-11	6.40E-12	9.88E-05
Np237	4.17E-02	9.33E-02	9.24E-04	9.75E-06	2.18E-07	9.03E-01	1.49E-06	1.56E-05	3.16E-05	3.73E-05	3.58E-05	1.04E+00
Pu239	3.11E-10	6.97E-10	3.10E-12	7.47E-14	4.34E-15	3.23E-09	2.57E-14	2.46E-14	6.15E-15	7.25E-15	5.20E-14	4.24E-09
Pu241	1.60E-05	3.58E-05	3.54E-07	3.74E-09	8.35E-11	3.46E-04	5.72E-10	5.99E-09	1.21E-08	1.43E-08	1.37E-08	3.98E-04
Tc99	4.47E-06	1.01E-05	6.36E-07	3.95E-07	2.34E-11	9.27E-05	7.22E-12	3.49E-11	8.09E-11	9.55E-11	7.99E-11	1.08E-04
U235	1.16E-07	2.61E-07	1.16E-09	2.79E-11	1.62E-12	1.21E-06	9.65E-12	9.26E-12	2.30E-12	2.71E-12	1.96E-11	1.59E-06

Table 7-5. Percent difference between CA doses for Center Slit Trench and H Canyon calculated using new GoldSim Dose Model and original CA Dose Module.

Center Slit	Ingestion						Inhalation	External			
Parent	Water	Vegetable	Meat	Milk	Soil	Fish	Soil	Soil	Swim	Boat	Shore
Nuclide	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr
Am241	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.21%	0.00%	0.00%	0.30%
Am242m	0.00%	0.00%	0.01%	0.00%	0.19%	0.00%	0.19%	0.19%	0.00%	0.00%	0.30%
Am243	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.19%	0.21%	0.00%	0.00%	0.31%
C14	0.00%	0.05%	0.06%	0.06%	0.19%	0.00%	0.19%	0.19%	0.00%	0.00%	0.30%
Ca41	0.00%	0.02%	0.02%	0.02%	0.19%	0.00%	0.19%	0.00%	0.00%	0.00%	0.00%
Cf249	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.21%	0.00%	0.00%	0.30%
Cl36	0.00%	0.11%	0.12%	0.11%	0.30%	0.00%	0.30%	0.30%	0.00%	0.00%	0.30%
Cm245	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.21%	0.00%	0.00%	0.30%
Cm247	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.19%	0.21%	0.00%	0.00%	0.31%
H3	0.00%	0.05%	0.06%	0.05%	0.30%	0.00%	0.30%	0.00%	0.00%	0.00%	0.00%
I129	0.00%	0.00%	0.00%	0.00%	0.30%	0.00%	0.30%	0.30%	0.00%	0.00%	0.30%
K40	0.00%	0.04%	0.05%	0.05%	0.19%	0.00%	0.19%	0.19%	0.00%	0.00%	0.30%
Mo93	0.00%	0.01%	0.03%	0.04%	0.20%	0.00%	0.21%	0.30%	0.00%	0.00%	0.30%
Nb93m	0.00%	0.00%	0.00%	0.00%	0.30%	0.00%	0.30%	0.30%	0.00%	0.00%	0.30%
Nb94	0.00%	0.00%	0.00%	0.00%	0.30%	0.00%	0.30%	0.30%	0.00%	0.00%	0.30%
Ni59	0.00%	0.00%	0.01%	0.00%	0.19%	0.00%	0.19%	0.00%	0.00%	0.00%	0.00%
Ni63	0.00%	0.00%	0.01%	0.00%	0.19%	0.00%	0.19%	0.00%	0.00%	0.00%	0.00%
Np237	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.21%	0.00%	0.00%	0.30%
Pa231	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.19%	0.21%	0.00%	0.00%	0.31%
Pd107	0.00%	0.00%	0.00%	0.00%	0.19%	0.00%	0.19%	0.00%	0.00%	0.00%	0.00%
Pu238	0.00%	0.00%	0.01%	0.00%	0.19%	0.00%	0.19%	0.19%	0.00%	0.00%	0.30%
Pu239	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.19%	0.21%	0.00%	0.00%	0.31%
Pu241	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.21%	0.00%	0.00%	0.30%
Pu242	0.00%	0.00%	0.01%	0.00%	0.19%	0.00%	0.19%	0.19%	0.00%	0.00%	0.30%
Ra226	0.00%	0.00%	0.01%	0.00%	0.19%	0.00%	0.19%	0.19%	0.00%	0.00%	0.30%
Sr90	0.00%	0.03%	0.03%	0.02%	0.19%	0.00%	0.19%	0.19%	0.00%	0.00%	0.30%
Tc99	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.21%	0.00%	0.00%	0.30%
Th230	0.00%	0.00%	0.01%	0.00%	0.19%	0.00%	0.19%	0.19%	0.00%	0.00%	0.30%
U234	0.00%	0.00%	0.01%	0.00%	0.19%	0.00%	0.19%	0.19%	0.00%	0.00%	0.30%
U235	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.19%	0.21%	0.00%	0.00%	0.31%
U238	0.00%	0.00%	0.01%	0.00%	0.19%	0.00%	0.19%	0.19%	0.00%	0.00%	0.30%
Zr93	0.00%	0.00%	0.00%	0.00%	0.30%	0.00%	0.30%	0.30%	0.00%	0.00%	0.30%
H Canyon	**Ingestion**						**Inhalation**	**External**			
Parent	Water	Vegetable	Meat	Milk	Soil	Fish	Soil	Soil	Swim	Boat	Shore
Nuclide	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr	mrem/yr
Am241	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.21%	0.00%	0.00%	0.30%
H3	0.01%	0.06%	0.07%	0.07%	0.31%	0.01%	0.31%	0.00%	0.01%	0.00%	0.00%
I129	0.00%	0.00%	0.00%	0.00%	0.30%	0.00%	0.30%	0.30%	0.00%	0.00%	0.30%
Np237	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.21%	0.00%	0.00%	0.30%
Pu239	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.19%	0.21%	0.00%	0.00%	0.31%
Pu241	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.21%	0.00%	0.00%	0.30%
Tc99	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.21%	0.21%	0.00%	0.00%	0.30%
U235	0.00%	0.00%	0.00%	0.00%	0.20%	0.00%	0.19%	0.21%	0.00%	0.00%	0.31%

8.0 Conclusions and Further Model Development

The following items require further development:

- To perform uncertainty analysis the model must include parameter distributions. The only parameter distributions included in the initial version of the model released under this User Guide are for the soil properties: density, porosity and saturation. The CA dose module developed by Neptune, Inc. (Perona and Tauxe, 2009) and the SRR dose model (2012) include distributions for various dose parameters that may provide a basis for developing distributions to be used in this model. It is assumed that uncertainties in dose coefficients, Maximum Concentration Limits, and radionuclide decay data are negligible and are therefore not to be defined with distributions in the next PA. As was done in the CA model, parameter distributions should be stored in an ACCESS database and can be added to the Dose_db.mdb database.
- The model reports dose by parent radionuclide, as was done for the 2008 PA, which requires making a separate calculation for each parent radionuclide. This is required for PA purposes because it is necessary to know the dose resulting from the burial of each parent radionuclide to determine disposal limits. On the other hand, the 2009 CA reported doses for radionuclides directly responsible for the dose and calculated doses from each disposal unit in a single transient calculation using the entire radionuclide inventory. While this was an efficient method of calculation, in many cases, the dose could not be traced to a unique parent. It would be desirable to report dose in terms of both the parent radionuclides and the radionuclides directly causing the dose. However, implementing this approach would generate a large amount of output that may not be used.
- A simplified version of the model could be created by removing the options to reproduce 2008 PA and 2009 CA results. Similarly, deciding between using interpolation and curve fits to calculate soil shielding dose conversion factors would simplify the model logic.
- The GoldSim Dose Model has been designed to be very general and any of the 1252 radionuclides in the database can be included in the calculations. It is anticipated that the screening process will reduce the number of radionuclides that must be considered in the PA and CA. Past experience indicates that on the order of 60 parent radionuclides with approximately another 60 daughters, about 10% of the database, produce any significant dose. The number of parents and daughters considered in future PA's and CA's may be reduced further based on known site inventories. In this case it may be desirable to create a simplified version of the dose model than can be streamlined for "production" use. This might be especially useful for sensitivity and uncertainty analysis.

In conclusion, a model to calculate doses and limits for PA groundwater pathways, PA intruder pathways, and CA surface water pathways has been developed. The model can also perform PA and CA screening calculations. Using GoldSim for model development allowed creation of a graphical user interface. An approach to automating the dose calculations using Excel workbooks and VBA macros is also furnished.

9.0 References

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Appendix A. Simulation Settings Used to Emulate 2008 PA and 2009 CA Dose Calculations

The starting time in the GoldSim model is set to 1960. Site closure is assumed to occur in 2040 or 80 years after the starting time. Following closure, a 100 year period of institutional control is assumed to be in place until 2140.

Slit Trench All-Pathways and Groundwater waste disposal is assumed to occur in year 2010. The 1000 year period for the All-Pathways assessment is from 2140 to 3140. The Groundwater protection assessment is made over the entire 1030 year disposal period 2010 to 3140. To calculate both sets of limits simultaneously, the printout must start in 2010 or 50 years after the starting time.

GoldSim settings for PA All-Pathways and Groundwater Protection limits for seven radionuclides with 0.2 year PORFLOW time steps

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Basic Step – 0.1 yr
Simulation Time – 180 yr
Print Frequency – 0.2 yr

For the short duration PORFLOW transport calculations, used for radionuclides with small k_d values that quickly elute from the waste, the All-Pathways limit is determined at 180 years (2140 PORFLOW calculation end time). Groundwater Protection limits are determined as the minimum values over 50 – 180 years (2010 – 2140).

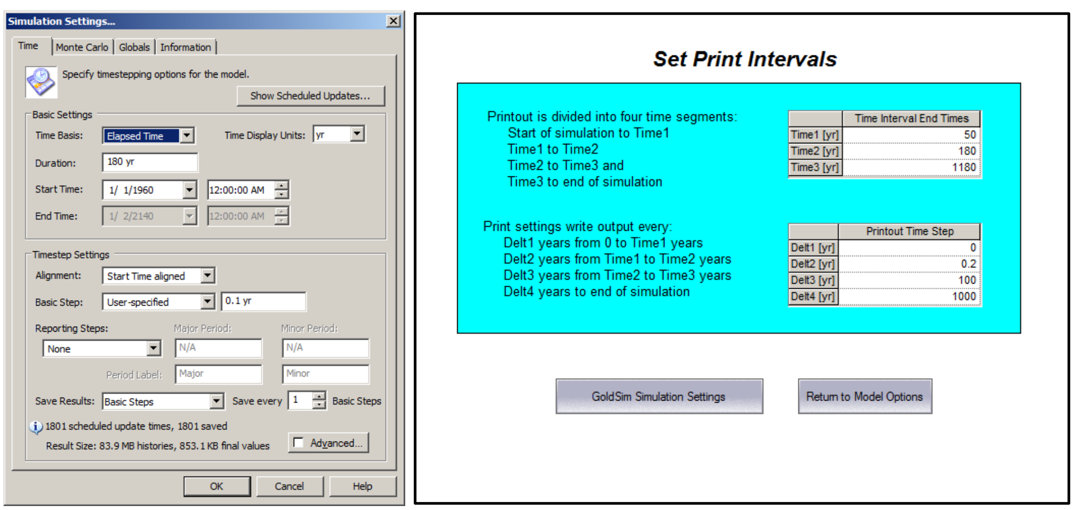

Figure A-1. GoldSim simulation and print control settings for seven PA doses and limits calculations with 0.2 year PORFLOW time steps.

GoldSim settings for PA All-Pathways and Groundwater Protection limits for 31 radionuclides with 2.0 year PORFLOW time steps

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Basic Step – 1 yr
Simulation Time – 1180 yr
Print Frequency – 2 yr

For the long duration PORFLOW transport calculations, the All-Pathways limit is determined as the minimum value over 180 – 1180 years (2140 – 3140). Groundwater Protection limits are determined as the minimum values over 50 – 1180 years (2010 – 3140).

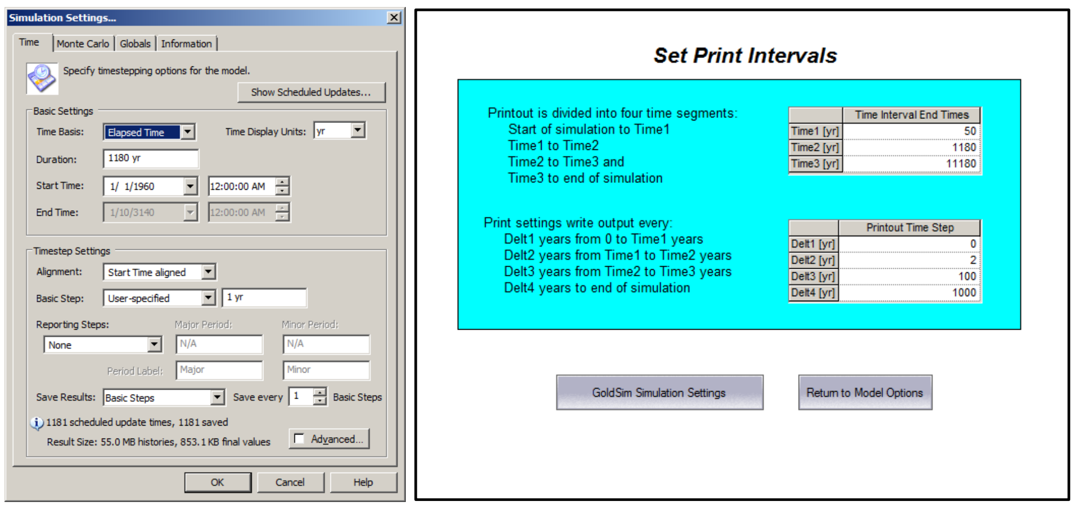

Figure A-2. GoldSim simulation and print control settings for 31 PA doses and limits calculations with 2.0 year PORFLOW time steps.

GoldSim settings for Inadvertent Intruder limits for all 38 radionuclides

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Basic Step – 1 yr
Simulation Time – 1080 yr
Print Frequency – 10 yr

Intruder waste disposal occurs at 2040 years. The 100 year period of institutional control was counted as part of the 1000 year period of assessment in the 2008 PA. Therefore, intruder limits are applied over the 900 year period from 2140 to 3040. The Inadvertent Intruder limit is determined as the minimum value over 180 – 1080 years (2140 – 3040).

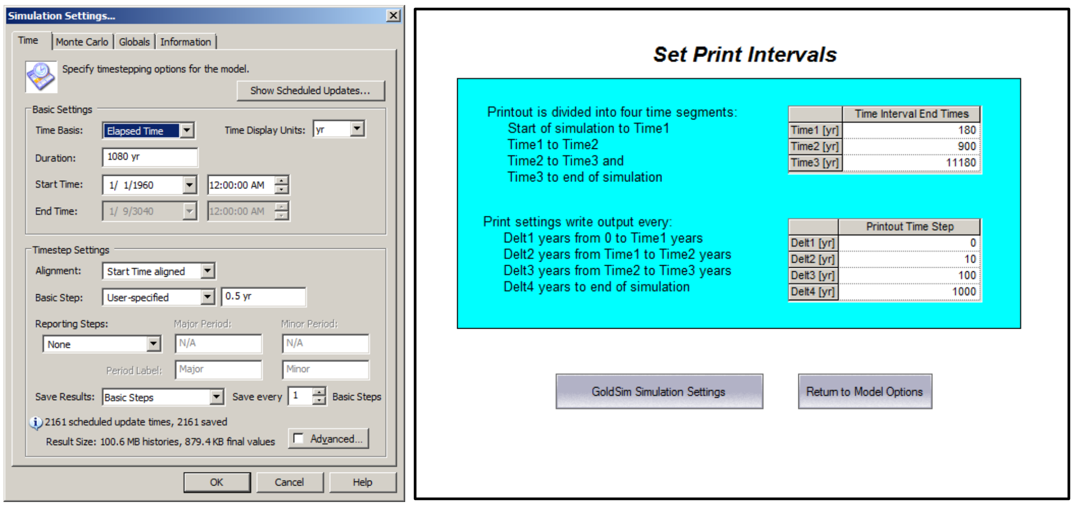

Figure A-3. GoldSim simulation and print control settings for Inadvertent Intruder doses and limits calculations.

GoldSim settings for CA doses for all 35 Slit_c and 8 H_Canyon radionuclides

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Basic Step – 1 yr
Simulation Time – 1180 yr
Print Frequency – 1 yr

CA waste disposal occurs at 2025 years. The CA disposal limit is determined as the minimum value over 65 – 1180 years (2025 – 3140).

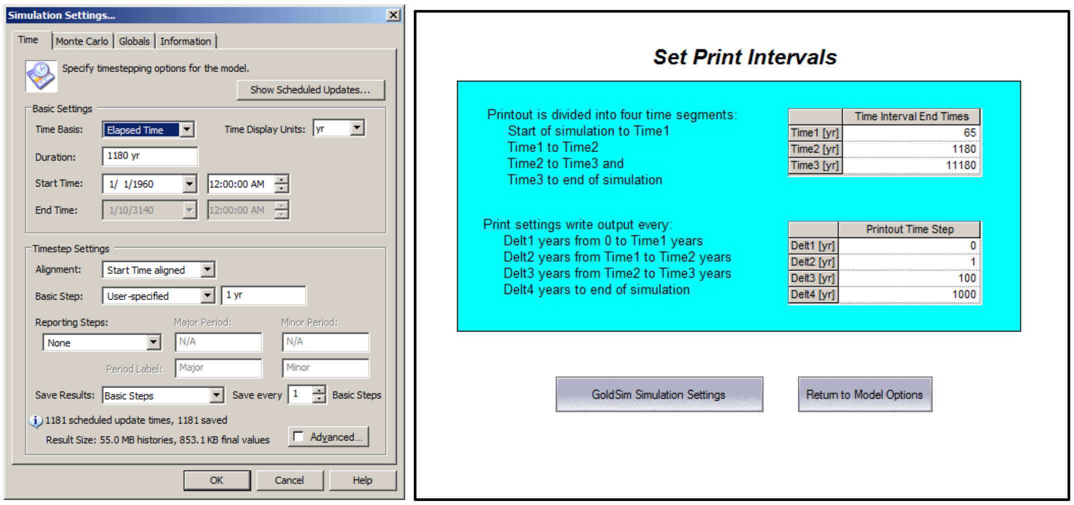

Figure A-4. GoldSim simulation and print control settings for CA doses and limits calculations.

Appendix B. Reconciliation of Differences in Dose Calculations

It would have been extremely inconvenient to change the basic radionuclide data in the dose model to account for differences in half-life and decay chains between data used in previous dose calculations and the new data established in the *SRNL_Rad_Data_Package*. Therefore, the GoldSim species list used the new radionuclide physical data for all model validation testing. Discrepancies remaining between the two sets of calculations for the E-Area Center Slit Trench were resolved by calculating the doses in a spreadsheet using radionuclide physical parameters from both calculations.

To summarize the results:

3.3% discrepancy in Post-Drilling limits for Mo-93 was traced to a difference in the decay chain:
2008 PA: Mo-93 → Nb-93m → Nb-93
New decay chain: Mo-93 → 0.88 Nb-93m + 0.12 Nb-93

1.0% discrepancy in Post-Drilling limits for Sr-90 was traced to a difference in the half-life:
2008 PA: Sr-90 $t_{1/2}$ = 28.90
New decay data: Sr-90 $t_{1/2}$ = 28.79

1.4% discrepancy in Post-Drilling limits for Zr-93 was traced to a difference in the decay chain:
2008 PA: Zr-93 → Nb-93m → Nb-93
New decay chain: Zr-93 → 0.975 Nb-93m + 0.025 Nb-93

4.1% discrepancy in Residential limits for U-238 was traced to a difference in the decay chain:
2008 PA: Pa-234m → 0.0013 Pa-234 + 0.9987 U-234
New decay chain: Pa-234m → 0.0016 Pa-234 + 0.9984 U-234

1.1% discrepancy in Residential limits for U-233 was traced to a difference in the decay chain:
2008 PA: Bi-213 → 0.0216 Tl-209 + 0.9784 Po-213
New decay chain: Bi-213 → 0.0209 Tl-209 + 0.9791 Po-213

It was also found that half-lives < 2.0E-09 must to be set to 2.0E-09 to avoid numerical errors in the GoldSim calculations. Making this change in the radionuclide data resolved some discrepancies in the intruder residential dose calculations. Differences in decay chain and half-life appear to impact intruder limits, where the material decays in place, more than all-pathways limits, where groundwater transport reduces relative isotopic concentrations.

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