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U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

USER'S MANUAL FOR RESRAD-OFFSITE CODE VERSION 4

Vol. 2 – User's Guide for RESRAD-OFFSITE Version 4

Office of Nuclear Regulatory Research

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User's Manual for RESRAD-OFFSITE Code Version 4

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ABSTRACT

The RESRAD-OFFSITE computer code can be used to evaluate the radiological dose and or the excess cancer risk to an individual who is exposed while within and/or outside the area of initial (primary) contamination.

This user's guide presents the basic information necessary to install and use the RESRAD-OFFSITE code. It describes how to download and install the code and then verify the installation of the code. It shows ways to navigate through the input screens to simulate various exposure scenarios and to view the results in graphics and text reports. It contains screen shots of each input form in the code and provides basic information about each parameter to increase the user's understanding of the code. It outlines the contents of all the text reports and the graphical output. It also describes the commands in the two output viewers. It provides basic information about the probabilistic and sensitivity analysis tools available in the code and points to other documents that provide more detailed information and illustrate the use of these tools. It mentions the commands to facilitate inputting of externally edited data. It details the various ways of obtaining help in the code and points to the other documents that provide more detailed information about the inputs, the input forms and features/tools in the code. It describes the commands and features of the RESRAD Dose Conversion Factor Editor and illustrates how to create, export and import a user library.

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1 INTRODUCTION

The RESRAD-OFFSITE code was initially developed to extend the capability of the RESRAD-ONSITE code for modeling offsite receptor exposure scenarios (Yu et al. 2007). The transition from RESRAD-ONSITE to RESRAD-OFFSITE, including benchmarking of RESRAD-OFFSITE code against peer codes, was documented in DOE/EH-0708 (Yu et al. 2006). The capability of RESRAD-OFFSITE code was further enhanced in the modeling of the source release term for handling containerized waste materials. This source term model was documented in NUREG/CR-7127 (Yu et al. 2013) for potential application to low-level radioactive waste disposal facility performance assessment. The source term model is further improved with additional features such as time-distributed source releases, diffusion-controlled releases, and solubility-controlled releases to handle more complex source terms. The code was also updated to add complexity to the surface water model. These improvements allow RESRAD-OFFSITE to be potentially used for complex decommissioning sites, including sites pursuing restricted release, sites with non-soil like source materials, and sites with critical groups that may be located offsite. The methodology and models used in RESRAD-OFFSITE Version 4 is documented in Volume 1 of this NUREG/CR report. This is Volume 2, which serves as the User's Guide for using the RESRAD-OFFSITE code Version 4.

1.1 Purpose of User's Guide

The primary purpose of this user's guide is to help users understand and use the RESRAD-OFFSITE code Version 4. It describes how to download and install the code, as well as how to navigate through the input screens to simulate various exposure scenarios and view the results in graphics and text reports. This user's guide not only describes the features of RESRAD-OFFSITE Version 4, it also provides additional information about the input parameters to increase the user's understanding of the code. Some advanced features, such as the use of probabilistic and sensitivity analysis, and use of the Dose Conversion Factor (DCF) Editor are also included in this user's guide.

1.2 Organization of User's Guide

This information is organized into the following major sections:

- Section 2. Installation: Installation procedures and system requirements.
- Section 3. Navigation: Instructions for moving around the interface to accomplish various tasks and to save input and output.
- Section 4. Input forms: Description of each input form, information on how to use each form, and parameters in the input forms.
- Section 5. Results: Instructions on how to find results in the textual and graphical output.
- Section 6. Enhancements: Explanation of the probabilistic/uncertainty analysis and sensitivity analysis features.
- Section 7. Help: Various ways of obtaining help.

- Section 8. References: List of references.

- Appendix A. RESRAD Dose Conversion Factor Editor: Discussion of dose coefficients, slope factors, and creating, exporting, and importing of DCF libraries.

2 INSTALLATION

The RESRAD Family of Codes, including RESRAD-OFFSITE Version 4, is distributed through the RESRAD website (http://resrad.evs.anl.gov/). The code requires a Windows 7 or later operating system and about 100 MB of disk space. The procedure for downloading and installing RESRAD-OFFSITE code is described in Section 2.1, the procedure for checking the installation is outlined in Section 2.2, and the procedure for uninstalling RESRAD-OFFSITE code is described in Section 2.3.

2.1 Installing from the RESRAD Website

1. Connect to the RESRAD website at http://resrad.evs.anl.gov/.

2. Click on “Download.”

3. Fill in and submit the requested information.

4. Use the credentials that you receive to download the installation program; note that the credentials have an expiration time.

5. Install the program; the code/user needs writing privileges in the directory where the code is installed and in its subdirectories.

6. If the default installation selections are used, the files needed to execute RESRAD-OFFSITE Version 4 will be installed in C:\RESRAD_Family\OFFSITE\4.0\.

7. The installation will also create the following subdirectories:

   ..\Metfiles\: The STAR format meteorological files will be installed here.
   ..\Userfiles: The input and output files are saved in this directory.
   ..\QAfiles\: The QA files from the RESRAD website can be copied here.

8. After installation, a new RESRAD-OFFSITE icon will appear on the computer desktop. Double-click this icon to start RESRAD-OFFSITE.

2.2 Checking the Installation

9. Connect to the RESRAD website at http://resrad.evs.anl.gov/download/.

10. Click on “User Center.”

11. Save the QA_RESRAD_OFFSITE_4.0.zip file to the QA subdirectory.

12. Follow the instructions in the ReadMe file, which is in the zip file.

2.3 Uninstalling

1. To uninstall, use the program utility, “uninstall,” in the Windows control panel.

3 NAVIGATION

Four methods are available to navigate the RESRAD-OFFSITE interface to input and access information and to access results (Figure 3-1):

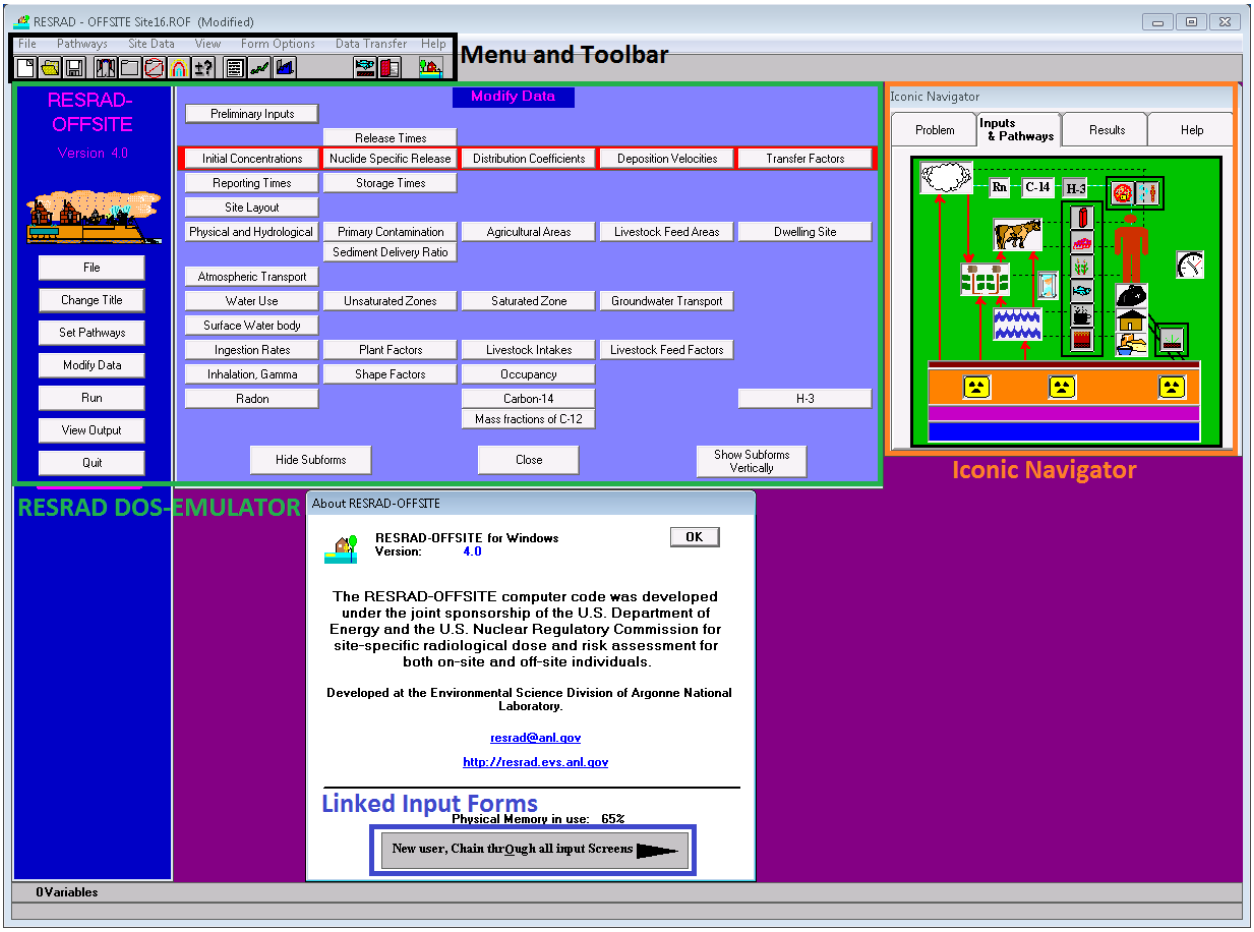

Figure 3-1 Navigating the RESRAD-OFFSITE Interface

Menus and Toolbars: These are the standard Windows tools used to manipulate files, input forms (i.e., screens), and output forms. Shortcut and hot keys are available to activate the menu commands from the keyboard. These are described in Section 3.1.

Linked Input Forms: All input forms, starting with either the About form or the Title form and ending with the last relevant input form, are linked together by two buttons in each input form. These buttons save the data in that input form and then open either the next input form or the previous one (Section 3.4).

RESRAD DOS-Emulator: This set of textual command buttons is similar to the set of buttons used in the interface of the early DOS versions of RESRAD-ONSITE (Section 3.2).

Iconic Navigator Window: This tabbed window provides access to input forms and results using graphical cues (Section 3.3).

3.1 Menus and Toolbars

3.1.1 Menus

The menu on the main RESRAD-OFFSITE window (i.e., the Main Menu) gives complete access to all the forms, functions, and features of the code. The Main Menu and the submenus that branch from it are shown below (Figure 3-2).

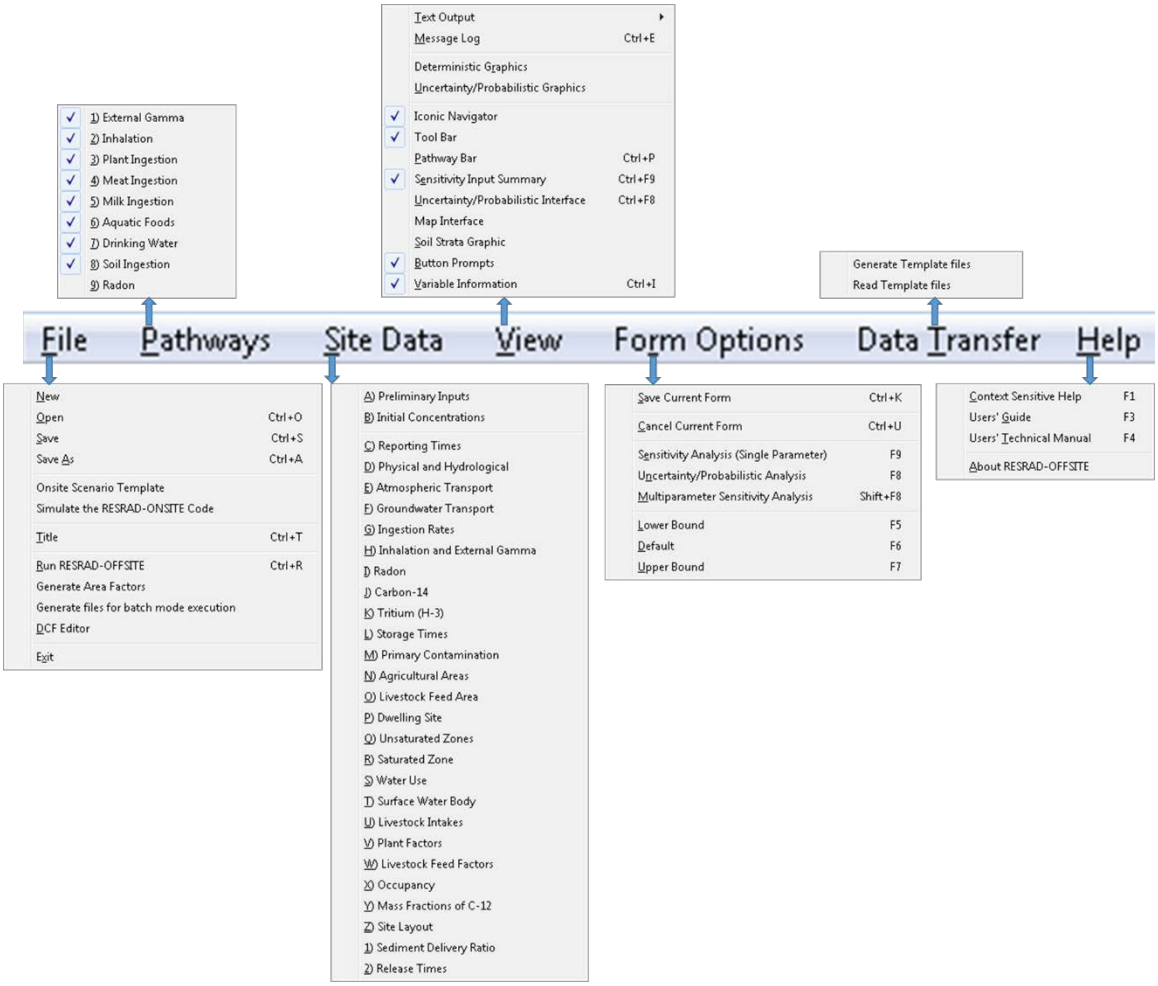

Figure 3-2 Main Menu and Submenus

The menu operations can be performed by clicking the mouse, by pressing the hot (underlined) keys after activating them with the Alt key, or by using the shortcut keys shown next to the submenu commands.

File Submenu: The first block of four commands performs common file operations. The next two commands facilitate the modeling of onsite scenarios. The remaining six commands can be used to access the Title window, to perform an analysis using the current inputs, to initiate the process of generating area factors, to generate all the files that are necessary to execute the computational code in batch mode, to launch the Dose Conversion Factor Editor, and to exit the code.

- **New:** This starts the interface afresh with a set of default or placeholder values for all parameters.

- **Open:** This brings up the dialogue box to open a previously saved input file.

- **Save:** This saves the current input file.

- **Save As:** This brings up the dialogue box to save the current inputs under a different filename.

- **Onsite Scenario Template File:** This menu provides a starting point to use the RESRAD-OFFSITE methodology to model an onsite exposure scenario. As described in Appendix L of Volume 1 of the User's Manual, all relevant capabilities of the RESRAD-OFFSITE code are retained under this option.

- **Simulate the RESRAD-ONSITE Code:** This command mimics the RESRAD-ONSITE code to the extent possible by altering the forms in the interface and by turning on the RESRAD-ONSITE formulation in the computational code while turning off the corresponding RESRAD-OFFSITE formulations, as detailed in Appendix K of Volume 1 of the User's Manual.

- **Title:** This displays the Title form.

- **Run RESRAD-OFFSITE:** This command saves the input file, generates all the data files that are necessary to execute the computational code, and launches the computational code.

- **Generate Area Factors:** This initiates the process of generating area factors. The process of generating area factors is discussed in Appendix O of Volume 1 of the User's Manual.

- **Generate Files for Batch Mode Execution:** This command saves the input file and generates all the data files that are necessary to execute the computational code but does not launch the computational code.

- **DCF Editor:** This launches the Dose Conversion Factor Editor, a stand-alone program that is common to some of the RESRAD codes. This is described in Appendix A of this volume of the User's Manual.

- **Exit:** This closes the RESRAD-OFFSITE code after prompting the user to save the last input file, if it has not been saved since it was modified.

Pathways Submenu: This is used to activate, deactivate, or verify the status of each exposure pathway. A checkmark next to a pathway indicates that it is currently active. The radon pathway can be activated only if a radon precursor is specified as being present at the site.

Site Data Submenu: All but five of the forms that are needed to define the scenario being simulated are directly accessible from this submenu. The shape and area factor form for external radiation is accessible from the inhalation and external gamma form. The four nuclide-dependent property forms—the radionuclide specific release form, the distribution coefficients form, the deposition velocity form, and the transfer factors form—are accessible after the

radionuclides have been selected from the initial concentrations form. Any forms that are currently open (i.e., being displayed) are indicated by a checkmark on the submenu.

View Submenu: This submenu has two functions: it provides access to the various text and graphical output windows, and it is used to set the display options for a number of features of the code. The first two subgroups display the text and graphical outputs of a RESRAD-OFFSITE analysis, which are discussed in Section 5. The last group of commands on this submenu is used to set the user's preference to display (indicated by a checkmark) or hide (no checkmark) the following functions of the code:

- **Iconic Navigator:** This is the Iconic Navigator window, which can be used to access the forms, to perform the analysis, and to view the output. This is discussed in Section 3.3.

- **Toolbar:** This is the primary toolbar, shown in Section 3.1.2.

- **Pathway Bar:** This is the pathways toolbar, shown in Section 3.1.2.

- **Sensitivity Input Summary:** This is the sensitivity analysis (one parameter at a time) information bar, shown in Section 3.1.2.

- **Uncertainty/Probabilistic Interface:** This form, which details any probabilistic analysis that is to be performed for the current input file, is discussed in Section 6.2. This form can also be used to perform step-by-step probabilistic analysis and to view plots of the results.

- **Map Interface:** This is the form that displays the plan view of the locations of the primary and secondary contamination. Section 4.13 describes the map interface. Unlike in the other cases where the user's preference is a simple show or hide, there are three possibilities in this case. The user may indicate a preference to see the map only when the site layout form is displayed in the sequence of forms (to set this, click view map interface while the layout form is displayed), to see the map at all times (to set this, click view map interface when the layout form is not being displayed), or to never see the map.

- **Soil Strata Graphics:** This is a sketch of the cross-section of the ground below the primary contamination. It shows the relative thickness of the onsite soil strata vertically; the horizontal dimension scales to reflect the area of the primary contamination.

- **Button Prompts:** A button prompt is a short help message about a control on the toolbars, on the Pathways/Inputs tab of the Iconic Navigator window, or in the map interface. The prompt is displayed when the mouse cursor moves over the control and lingers there for a short while.

- **Variable Information:** This is the variable information bar, shown in Section 3.1.2.

Form Options Submenu: The first two commands on the Form Options submenu, Save current form and Cancel current form, are used to save or cancel the changes made to an open form(Section 4). The remaining six commands perform operations on the input boxes contained in the forms, as follows:

- **Sensitivity Analysis (single parameter):** This is used to activate “one-parameter-at-a-time sensitivity analysis” (Section 6.1) on the input parameter and to set the range of the parameter for the analysis.

- **Uncertainty/Probabilistic Analysis:** This is used to include the input parameter in the probabilistic or uncertainty analysis (Section 6.2). It can also be used to display the uncertainty/probabilistic analysis form, if it is not visible.

- **Multi-Parameter Sensitivity Analysis:** This is used to include the input parameter in the probabilistic or uncertainty analysis with the uniform or log-uniform distribution of a selectable range about its current value and to display the uncertainty/probabilistic analysis form, if it is not visible.

- **Lower Bound:** This is used to set the input to the lowest value accepted by RESRAD-OFFSITE. The lowest value may be a physical bound (i.e., the lowest value that is applicable for the parameter because of physical considerations) or simply a numerical bound imposed to prevent the code from crashing.

- **Default:** This is used to set the input to the default value assigned in the RESRAD-OFFSITE code. While some default values (e.g., ingestion rates, inhalation rates) are generally accepted values, others (e.g., field capacity, distribution coefficient) are merely placeholder values. It is up to the user to ensure that default values are acceptable for use.

- **Upper Bound:** This is used to set the input to the highest value accepted by RESRAD-OFFSITE. The highest value may be a physical bound (i.e., the highest value that is applicable for the parameter because of physical considerations) or simply a numerical bound imposed to prevent the code from crashing.

- **Data Transfer Submenu:** This is used to generate and read template files. This submenu has two commands: Generate Template files and Read Template files.

- **Generate Template Files:** This command is used to generate template files, which can be modified externally in a text or spreadsheet editor. A number of files are saved with various extensions to the filename specified by the user; three are relevant to the data transfer. The first is a RESRAD-OFFSITE input file with a ROF extension, containing all the data currently specified in the interface. The second is a comma-separated text file with the extension NID.CSV, containing most of the radionuclide-independent deterministic data currently specified in the interface. The third is a comma-separated text file with extension the NDP.CSV, containing some of the radionuclide-dependent deterministic data currently specified in the interface. Before generating files, the user is prompted to change the transformation database, the cutoff half-life, and the conceptualization of primary contamination, if necessary, and to specify the radionuclides present at the site. The template files can be modified by the user in a spreadsheet or text editor and must be saved back in the “comma-separated values” CSV format so that they can be read by the RESRAD-OFFSITE code.

- **Read Template Files:** This is used to read the previously saved template files after they have been modified by the user in a text or spreadsheet editor. The edited files must have been saved in the comma-separated value format.

Help Submenu: This is used to obtain context-sensitive information about the inputs, forms, and features in RESRAD-OFFSITE; to access PDF versions of this user's guide and the user's technical manual; and to display the About RESRAD-OFFSITE form.

- **Context-Sensitive Help:** Information about a specific input parameter, form, or feature in RESRAD-OFFSITE can be obtained by pressing the F1 function key while the input control is in focus (box, option buttons, drop-down box, etc.). The input control is in focus when the cursor is in the field of the control.

- **User's Guide:** This opens the PDF version of this document.

- **User's Technical Manual:** This opens the PDF version of the User's Manual.

- **About RESRAD-OFFSITE:** This displays the About RESRAD-OFFSITE form (i.e., the About form). This form shows the version of the RESRAD-OFFSITE software installed on the computer, the percentage of the physical memory in use, and the e-mail to which to send questions about the RESRAD-OFFSITE code; it also provides a link to access the RESRAD website.

3.1.2 Toolbars

Primary Toolbar

The primary toolbar below (Figure 3-3) is displayed if the user preference is set to display it in the View submenu (Section 3.1.1). The operations that can be performed by clicking on the icons on the primary toolbar are shown below. If the Button Prompts option was selected from the View submenu on the Main Menu, a message prompt appears as the cursor lingers over an icon to display what the icon means.

Figure 3-3 Primary Toolbar

- Files
  - Reset all input parameters to default values
  - Open an existing input file
  - Save data currently in all input forms to a file

- Input
  - Perform calculations
  - Save changes to current input form
  - Cancel changes to current input form
  - Display sensitivity analysis input form
  - Display uncertainty analysis input form

- Results
  - View summary report
  - View deterministic graphics
  - View uncertainty/probabilistic graphics

- Display Preferences
  - Display/hide pathway button bar
  - Display/hide sensitivity analysis summary bar

- RESRAD-ONSITE
  - Simulate the RESRAD-ONSITE code

Pathways Toolbar

The pathways toolbar below (Figure 3-4) is displayed if the user preference is set to display it in the View submenu (Section 3.1.1). The pathways toolbar is used to toggle between active and inactive for each pathway, and it displays the status of the pathways.

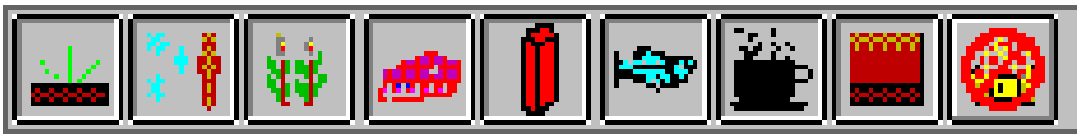

Figure 3-4 Pathways Toolbar

Sensitivity Analysis Input Summary Bar

The Sensitivity Analysis Input Summary Bar (shown in the upper half of Figure 3-5 below) is displayed if the user preference is set to display it in the View submenu (Section 3.1.1). It shows the number of variables selected for one-parameter-at-a-time sensitivity analysis (Section 6.1) and contains a button for each of those variables. The buttons display the FORTRAN variable name and the range factor for the sensitivity analysis of the variable. Left-click the mouse with the cursor on the sensitivity button to access the Sensitivity Analysis form for the variable. Right-click the mouse with the cursor on the sensitivity button to remove that variable from sensitivity analysis. The height of the bar depends on the number of variables selected for sensitivity analysis and should not be adjusted by the user. Up to fifty inputs can be selected for sensitivity analysis in an input file.

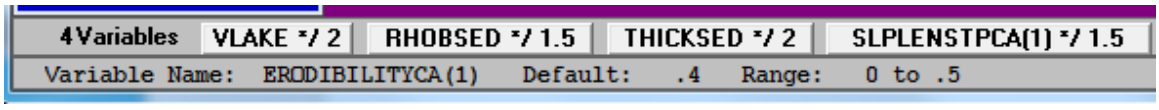

Figure 3-5 Sensitivity Analysis Summary Bar and Variable Information Toolbar

3.2 RESRAD DOS-Emulator

All applicable input fields can be accessed by following the command buttons in the RESRAD DOS-Emulator found on the left side of the interface. Some of the command buttons are linked directly to forms, while other commands lead to a group of second-level commands that appear

to the right of the primary command list. All the buttons (Figure 3-6) can be followed sequentially except for the Radon pathway button; it can be turned on only after a radon precursor has been selected from the Source form. The forms that are linked to these command buttons are discussed in Section 4.

There are three layouts of the commands to modify data: a vertical layout of commands to all the forms, a compact vertical layout of commands to some of the forms from which the remaining forms can be accessed, and a two-dimensional layout of commands to all the forms.

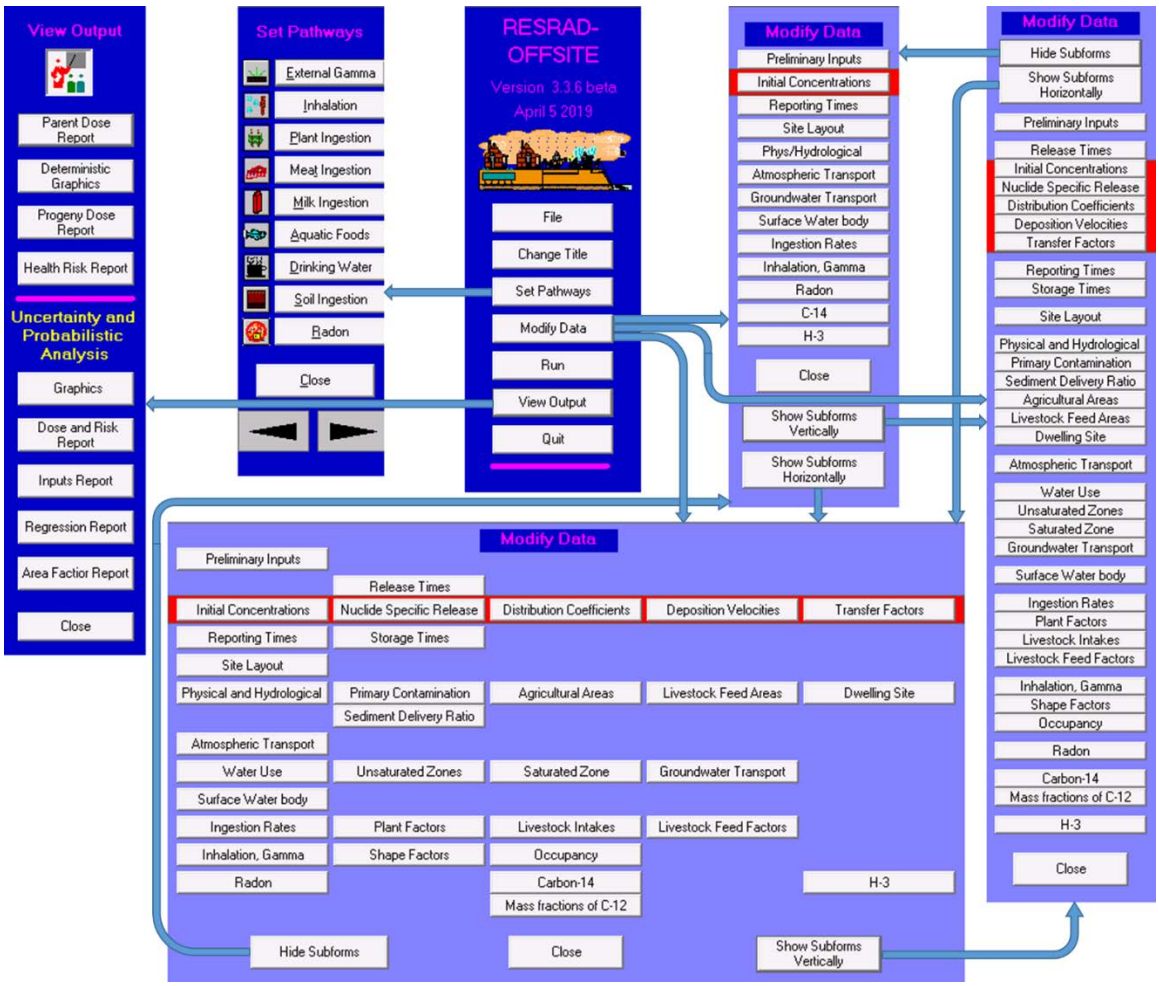

Figure 3-6 Forms Associated with the DOS-Button Emulator

3.3 Iconic Navigator Window

The Iconic Navigator window (Figure 3-7) will be displayed if that user preference has been set using the View submenu. It has four tabs. The first tab, Problem, gives the broad outline of the sequence to be adopted to perform the analysis. Buttons on the tab lead to the second tab, Inputs & Pathways, which is for specifying the site-specific scenario being analyzed, and to the third tab, Results, for viewing the results. Prompts displaying a descriptive name will appear as the cursor lingers over the buttons on the Inputs & Pathways tab. This feature is turned on and off using the Button Prompts option from the View submenu.

- **Problem:** This tab guides the user to set up a case in RESRAD-OFFSITE. Each button brings up windows or forms to continue with the process.

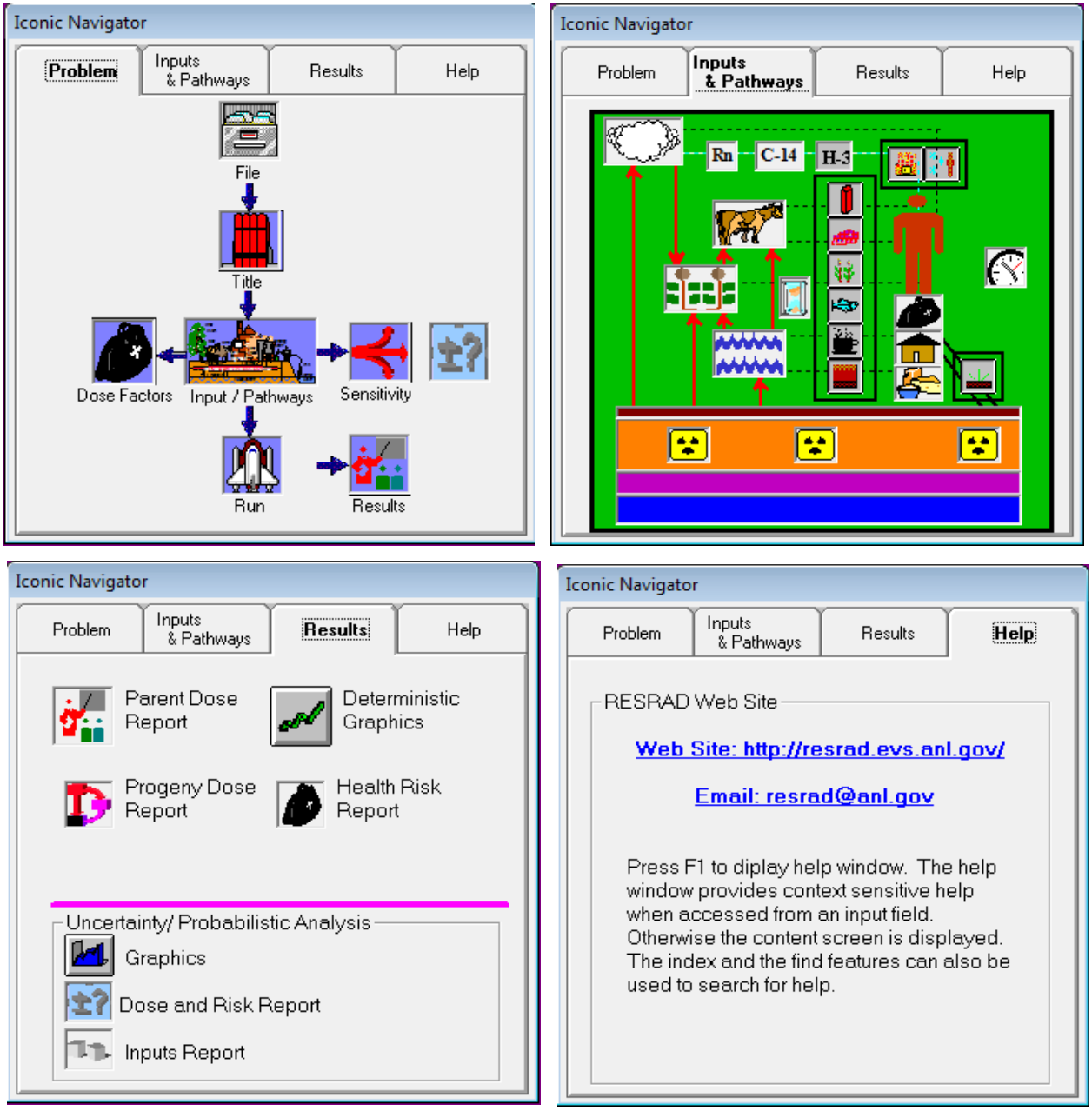

Figure 3-7 The Four Tabs of the Iconic Navigator

- **Inputs & Pathways:** This tab allows the user to view and activate pathways and access input forms. Buttons for the pathways can be found in the three sets of black boxes shown in the top right screen shot of Figure 3-7. Inhalation pathways are above the person icon, and ingestion pathways are to the left. The single external pathway is at the lower right. Input forms are accessed by clicking on icons not enclosed within the black

boxes. Prompts appear to display what the icon represents if the Button Prompts option is turned on in the View submenu.

- **Results:** The top two buttons give access to the main deterministic results in report and graphical formats. The next two buttons open supplementary reports. If an uncertainty/probabilistic analysis was run, three more buttons below the pink line provide access to the two uncertainty/probabilistic reports and a set of uncertainty/probabilistic graphics.

- **Help:** If the user operating system is connected to the Internet, this tab gives the user access to the RESRAD website and provides the address to which users can e-mail questions for the RESRAD team.

3.4 Linked Input Forms

All the input forms that are relevant to the current analysis can be displayed in sequence by clicking the forward or backward arrows in each form. The Alt-O and Alt-K key combinations can also be used to move forward and backward through the linked sequence of forms. The linked sequence begins in the About RESRAD-OFFSITE window, which is displayed every time RESRAD-OFFSITE is launched. The Title form is the first in the linked sequence, which accepts user input. The last form in the sequence has the Run command instead of a forward arrow; it issues the command to perform the RESRAD-OFFSITE analysis using the current set of inputs. The sequence of the forms is as follows:

- Title & Radiological Data,

- Preliminary Inputs,

- Times at Which Release Properties Are Specified (not applicable to the “Use RESRAD-ONSITE exponential release model” conceptualization),

- Initial Concentrations,

- Radionuclide Specific Release,

- Distribution Coefficients,

- Deposition Velocities,

- Transfer Factors,

- Set Pathways,

- Reporting Times,

- Storage Times,

- Site Layout (and map interface),

- Physical and Hydrological,

- Primary Contamination,
- Fate of Material Eroded from the Primary Contamination by Runoff,
- Agricultural Areas,
- Livestock Feed Growing Areas,
- Offsite Dwelling Area,
- Atmospheric Transport,
- Water Use,
- Unsaturated Zone Hydrology,
- Saturated Zone Hydrology,
- Groundwater Transport,
- Surface Water body,
- Ingestion Rates,
- Plant Factors,
- Livestock Intakes,
- Livestock Feed Factors,
- Inhalation and External Gamma,
- External Radiation Shape and Area Factors,
- Occupancy,
- Radon (if a radon precursor is selected),
- Carbon-14 (if ^{14}C is selected),
- Mass Fractions and Concentrations of Carbon-12 (if ^{14}C is selected), and
- Tritium (if ^{3}H is selected).

4 INPUT FORMS

There are more than 30 input forms for entering the parameters that define the site data, assumptions, site identification, and calculation specifications. Sections 4.1 through 4.33 describe each form in detail and have a description of each input on the form. Additional information about each input can also be obtained by clicking the Help command, F1, when the cursor is in that input field. The RESRAD-OFFSITE predictions of dose and risk depend on the values specified for the inputs on these forms. The sensitivity of the predictions to the value of an input depends on the scenario being considered and the values of the other inputs. Hence it is imperative that site-specific or site-appropriate values be used for all the inputs except for those that are defined by the standard receptor. Most input is entered by keying numbers into boxes, but some input is entered through list boxes, check boxes, and option boxes. Some features common to all input forms are described here.

Saving Information to Memory

There are two levels at which information can be saved in RESRAD-OFFSITE. The first level is to temporarily save the information in the forms to memory. This can be done with any of the following commands:

- **Command Buttons:** Click on the Save button, Forward button (Alt-O), or Backward button (Alt-K) on the form.
- **Menu:** Select Form Options, then Save current form (Ctrl-K).
- **Toolbar:** Click on the Folder button.

Saving Information to File

The second level is to save the information in memory and in any open forms to a file. This can be done with any of the following commands:

- **DOS-Emulator:** Press the File button on the DOS-Emulator to activate the File Options form. Then select Save or Save As.
- **Menu:** Select File, then either Save (Ctrl-S) or Save As (Ctrl-A).
- **Run:** If any input form was exited with a save operation (as opposed to a cancel operation), then the file will need to be saved to disk before calculations are performed. The code will save the data to a file with the consent of the user; this will be a save operation, not a save as operation.

Canceling Changes Made to a Form

The changes to the inputs in a form can be canceled if they have not yet been saved to memory. Changes made in forms that do not have a Cancel button are saved to memory as soon as they are made; these changes cannot be canceled.

- **Function Keys:** Press the ESC key.
- **Command Button:** Click on the Cancel button on the form.
- **Menu:** Select Form Option, then Cancel current form (Ctrl-U).
- **Toolbar:** Click on the Canceled Folder button.

Saving Information to Memory and Opening the Next or Previous Form

The information in a form can be saved to memory, and the next or previous form can be opened by pressing the forward arrow or the backward arrow on each form, as appropriate. The key combinations Alt-O and Alt-K also have the same effect as clicking the forward or backward arrows, respectively.

Entering Numbers

Some input boxes may be grayed out (disabled) because they are not applicable to the current case, either because some pathways have been turned off or because the pertinent radionuclide was not chosen. Values representative of the site should be entered in all input boxes that are active.

The default value and the bounds (upper and lower) of the selected parameter will be displayed in the variable information bar. The value in the input box may be set to the default value or to an upper or lower bound, as described below.

- **Default:** To set the selected parameter to its default, either select Form Options and then Default from the Main Menu or press the F6 function key. While some default values (e.g., ingestion rates, inhalation rates) are generally accepted values, others (e.g., field capacity, distribution coefficient) are merely placeholder values.
- **Bounds:** To set the selected parameter to its upper (or lower) bound, either select Form Options and then Upper Bound (or Lower Bound) from the Main Menu or press the F7 (F5) function key. These may be a physical bound (i.e., the highest or lowest value that is applicable for the parameter because of physical considerations) or simply a numerical bound imposed to prevent the code from crashing.

Obtaining Help

Context-specific help will be shown anytime the F1 function key is pressed. For additional sources of help, please refer to the Help section (Section 7) of this user's guide.

Selecting a Parameter for Probabilistic or Uncertainty Analysis

Input parameters can be selected for inclusion in a probabilistic or uncertainty analysis by pressing the F8 key while the cursor is in the input box for that parameter (see Section 6.2, Uncertainty and Probabilistic Analysis). Some parameters are ineligible for uncertainty analysis, either because it does not make sense to perform the analysis on those parameters, or because of unmanageable constraints imposed by interrelationships with other parameters.

Selecting a Parameter for One-Parameter-at-a-Time Sensitivity Analysis

Input parameters can be selected for deterministic one-parameter-at-a-time sensitivity analysis by pressing the F9 key while the cursor is in the input box for that parameter (see Section 6.1, One-Parameter-at-a-Time Sensitivity Analysis). Some parameters are ineligible for sensitivity analysis because it does not make sense to perform a sensitivity analysis on those parameters.

Selecting a Parameter for Multi-Parameter Sensitivity Analysis

Input parameters can be selected for inclusion in a multi-parameter sensitivity analysis by pressing Shift-F8 while the cursor is in the input box for that parameter. The selected parameters can have a uniform distribution with a half-range of 99%, 50%, 25%, 10%, 5%, or 0.1% of the deterministic value on either side of the deterministic value, or a log-uniform distribution ranging from 1/10 to 10, 1/5 to 5, 1/3 to 3, 1/2 to 2, 2/3 to 3/2, or 1/1.001 to 1.001 times the deterministic value (see Section 6.2, Uncertainty and Probabilistic Analysis), subject to the bounds on the input. Only the parameters that are eligible for uncertainty analysis can be included in the probabilistic multi-parameter sensitivity analysis. The sensitive parameters can be ranked using the standardized regression coefficient or the standardized rank regression coefficient. Multi-parameter sensitivity analysis is discussed in Section 6.3 of this guide.

4.1 Title & Radiological Data

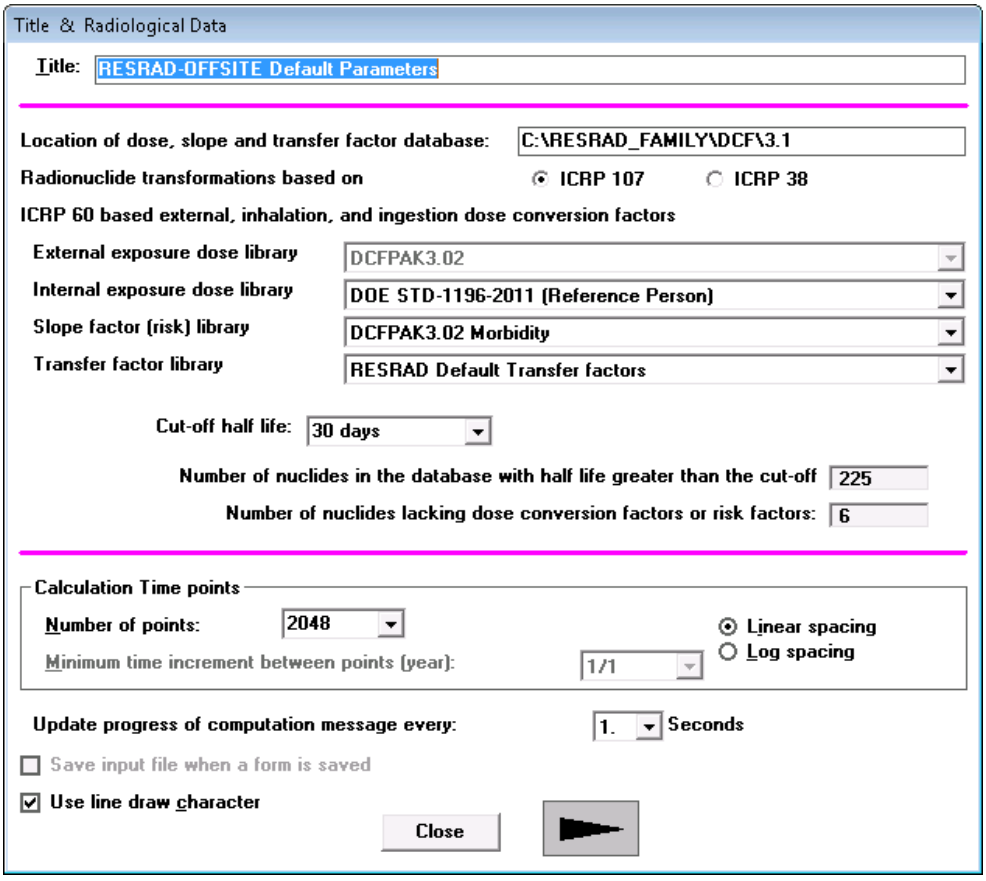

Figure 4-1 Title and Radiological Data Form

The Title & Radiological Data form (Figure 4-1) does not have a cancel feature. Any changes made to this form can be reversed only by re-inputting the original inputs. None of the parameters in this form are eligible for uncertainty analysis or for deterministic single-parameter sensitivity analysis.

Title: This box shows the text that describes the site/scenario being modeled. This identification text will appear at the top of each textural report page. Note that the apostrophe character (') cannot be used in the Title field (if used, the code will crash). The code will display a warning when an apostrophe is detected in the title.

Location of Dose, Slope, and Transfer Factor Database Library: This is the directory in which the RESRAD dose, slope, and transfer factor database and editor are located. A common dose, slope, and transfer factor database can be used by many of the RESRAD codes (RESRAD-ONSITE, RESRAD-BUILD, RESRAD-OFFSITE), which makes any user-created library accessible to all the codes. Therefore, the database file need not reside in the OFFSITE directory; instead, it can be in a directory that is shared by the RESRAD family of codes. If you have installed the database files in multiple locations, double-click on this input box to activate a file dialog form, then navigate to the directory in which the database that you want to use is located. Open the database you want to use, and the libraries available in that database will be displayed in the appropriate drop-down lists.

Radionuclide Transformation Based on: The user has an option to select the International Commission on Radiological Protection (ICRP) 107 (ICRP 2008)-based or ICRP 38 (ICRP 1983)-based radionuclide transformation database. If the ICRP 107 radionuclide transformation database is selected, only ICRP 60 (ICRP 1991)-based external, inhalation, and ingestion dose coefficients are available. If the ICRP 38 radionuclide transformation database is selected, the ICRP 26 (ICRP 1977)-based external, inhalation, and ingestion dose coefficients are also available.

External Exposure Library and the Internal Exposure Dose Library: The dose coefficients in these libraries will be used for the current analysis. Libraries of dose coefficients can be set up by using the RESRAD Dose Conversion Factor Editor, which is a standalone utility program common to the RESRAD family of codes (Appendix A). The libraries are stored in a database file. The second drop-down list contains all the internal exposure dose coefficient libraries that are available in the current database based on the radionuclide transformation database selection. For example, if the ICRP 38 radionuclide transformation database is selected, these include the standard Federal Guidance Report (FGR) 11 (Eckerman et al. 1988) and age-dependent ICRP 72 (ICRP 1996) libraries and any libraries created by the user. The library displayed in the first drop-down box for external exposure depends on the library chosen in the second drop-down box for internal exposure. If the ICRP 26-based internal exposure library, FGR 11, is chosen, then the external exposure dose factors will be from FGR 12 (Eckerman and Ryman 1993). Both the internal and external exposure dose factors will come from the user-created library when a user-created library is selected.

Slope Factor Library: The slope factors (risk) in this library will be used for the current analysis. Libraries of slope factors can be set up by using the RESRAD Dose Conversion Factors Editor, which is a standalone utility program common to the RESRAD family of codes (Appendix A). The libraries are stored in a database file. The drop-down list contains all the slope factor libraries that are available in the current database: the standard FGR 13 morbidity (Eckerman et al. 1999), FGR 13 mortality, the Health Effects Assessment Summary Tables (HEAST) 2001 morbidity libraries (EPA 2001), and any created by the user.

Transfer Factor Library: The transfer factors in this library will be used for the current analysis unless the values are changed in the nuclide-specific transfer factor form (Section 4.8). Libraries of transfer factors can be set up using the RESRAD Dose Conversion Factor Editor (Appendix A), which is a standalone utility program common to the RESRAD family of codes. The libraries are stored in a database file. The drop-down list contains all the dose conversion factor libraries that are available in the current database, including the standard RESRAD default transfer factor library and any libraries created by the user. The RESRAD transfer factor library contains only one soil-to-plant transfer factor for each nuclide, whereas the RESRAD-OFFSITE code can accept and use different factors for the vegetation in each of the four different agricultural and farmed areas. The transfer factors are site- and species-specific; the transfer factor form (Section 4.8) allows these values to be changed for each input file without having to create a different library for each site.

Cutoff Half-Life: The fate and transport of nuclides with half-lives larger than the specified half-life are modeled explicitly by the code. Progeny nuclides with a half-life equal to or shorter than the specified value are assumed to be in secular equilibrium with their immediate parent. The user can select from the values in the list (180, 30, 7, or 1 day[s]) or type in any value, both a numeric and its units, that is not less than 10 minutes. Only the nuclides that have a half-life greater than the cutoff half-life are listed in the right scroll box on the Initial Concentration form.

Informational Boxes: There are two informational boxes in this form. The first shows the number of radionuclides in the current ICRP107 (ICRP 2008) database that have a half-life greater than the current cutoff half-life. The second shows the number of such nuclides that are lacking at one or more dose conversion or slope factors.

Calculation Time Points

- **Number of Points:** This shows the number of time points at which releases, transfers across media boundaries, concentrations, doses, and risks are computed. Because RESRAD-OFFSITE computes concentrations and transfers at any time on the basis of the concentrations and transfers computed at preceding times, and because the code uses all the time points that fall within the appropriate exposure duration to perform time integration of dose and risk, this parameter determines the accuracy of the computed values. The number of points in the temporal graphics will be set to this number. Straight-line segments connect the points in the curve. A larger number of times enables the code to compute the concentrations, releases, transfers, and the time integrated dose and risk more accurately and will result in smoother plots. However, a larger number will also increase the execution time. Setting the number of calculation time points to twice the time horizon will ensure that the time integrated dose will be calculated using the dose rates at three calculation times. For most radionuclides, a number of time points equal to about one-tenth to one-fifth of the prediction time horizon should give results of sufficient accuracy. A greater number of calculation time points are required if the rate of release of a radionuclide changes rapidly over time. The number of points chosen must be such that a linear approximation between the values of releases and transfers at those times is a good representation of the actual temporal variation. The interval of time between the calculation time points must also not exceed the travel time in any of the groundwater transport zones. Choose from the values listed (powers of 2 from 32 to 16384 and 22000) or type in the desired number.

- **Linear Spacing or Log Spacing:** The spacing shows the manner in which the calculation time points are distributed over the time horizon. The time horizon is the sum of the maximum user-specified reporting time (Section 4.10, Reporting Times) and the exposure duration for risk (Section 4.2, Preliminary Inputs). The spacing may be linear or log.

    - **Linear:** If linear is chosen, the calculation time points are spaced uniformly (in an arithmetic sequence) between 0 and the time horizon. This choice is strongly suggested because the computations can be performed more quickly and the results will be more accurate.

    - **Log:** If log is chosen, the calculation time points are spaced in a geometric sequence (uniformly on a logarithmic scale) between the specified minimum time increment and the time horizon. The spacing in this case may be adjusted by the minimum time increment, as described below.

- **Minimum Time Increment between Points:** In addition to being the first calculation time point under the choice of log spacing, as described above, this is also the lower bound for spacing between calculation time points of a geometric sequence. Depending on the time horizon and the number of points, the spacing between the calculation time points can be very small at the beginning of the geometric sequence. In order to avoid unnecessary calculations, if the spacing is less than the specified minimum value, the sequence of time points will then be modified to a linear sequence with the minimum time increment, followed by a geometric sequence with a time increment that is never less than the specified minimum.

Update Progress of Computation Message: The time needed to perform the RESRAD-OFFSITE computations can range from a few minutes to a couple of hours, depending on the number of calculation time points, the number of radionuclides, the number and lengths of transformation chains, the groundwater transport characteristics of the nuclides, and, in the case of a probabilistic analysis, the number of realizations that are chosen. The FORTRAN computational code periodically writes out a message indicating the progress of the computation to reassure the user that computations are being performed and, in the case of a probabilistic analysis, to provide an estimate of the time required to finish the computations. This input box specifies the frequency at which this message will be updated by the computational code and the frequency at which it is read for display in the interface.

Writing the progress message can increase the total run time significantly. A “0.0” option is provided to turn off message writing by the computational code. This can reduce the run time of a probabilistic analysis. In this case, an estimate of the computation time will be made based on the size of one of the probabilistic output files. This option may not produce updates in some operating systems; viewing the contents of the RESRAD-OFFSITE directory prompts an update in some of these operating systems.

Use Line Draw Character: MS LineDraw Font is recommended for use in the reports. This font produces well-formatted tables and lines. If another font is desired, it is suggested that this box be unchecked to substitute minus signs for the lines.

Forward Arrow Button: Save the current values, hide the Title form, and open the next form (Section 4.2, Preliminary Inputs), all with one click of this button (or Alt-O). The same button appears on all input forms to facilitate rapid movement through all the relevant input forms.

Close Button: Use this button to close the Title form.

4.2 Preliminary Inputs

The Preliminary Inputs form mainly gathers input of parameters that determine the appearance of other input forms, the units of radioactivity and radiological dose, the conceptualization of primary contamination, the number of partially saturated zones, and the submerged fraction. The right side of the form provides a description of the conceptualization selected. Only one of the parameters in this form, the "submerged fraction of the primary contamination," is eligible for an uncertainty analysis or for a single parameter sensitivity analysis. Figure 4-2 through Figure 4-7 show the preliminary input forms with different conceptualizations of primary contamination.

Radiological Units

- **Activity:** The drop-down boxes allow the user to choose the desired unit of radiological activity. Available choices are curie (Ci), becquerel (Bq), disintegrations per second (dps), and disintegrations per minute (dpm); the first two can be combined with metric prefixes ranging from atto (10^{-18}) through exa (10^{18}).

- **Dose:** The drop-down boxes allow the user to choose the desired unit of radiological dose. Available choices are roentgen equivalent man (rem) and sievert (Sv); these can be combined with metric prefixes ranging from atto (10^{-18}) through exa (10^{18}).

Basic Radiation Dose Limit: This is the annual radiation dose limit used to derive all site-specific soil guidelines.

Exposure Duration (for Risk): This is the length of time that the receptor is exposed to radiation at this site. Values reported for risk are time-integrated over this exposure duration. The risk is calculated by using the trapezoidal formula on radionuclide intake rates computed at all the calculation time points that fall within the exposure duration and, if necessary, at the calculation time point that is just outside the exposure duration. Dose is time integrated over 1 year or the exposure duration, whichever is less. (Given the current lower bound of 1 year on the exposure duration, dose is currently integrated over a 1-year period.)

Number of Unsaturated Zones: This is the number of partially saturated layers between the primary contamination and the saturated zone. The code has provisions for up to five different horizontal strata.

Submerged Fraction of Primary Contamination: This is the fraction of the primary contamination that is below the water table. A fully submerged primary contamination is constrained to have its top surface at the water table. When a non-zero value is entered for the submerged fraction, the code will set the number of unsaturated zone to zero and will disable that input.

Conceptualization of Primary Contamination: Four options are available. Select based on the waste type and design of the waste disposal facility. The choice of conceptualization applies to all radionuclides in the input file. Two of the conceptualizations have a sub-choice. The options are:

- Use RESRAD-ONSITE exponential release model (Figure 4-2);

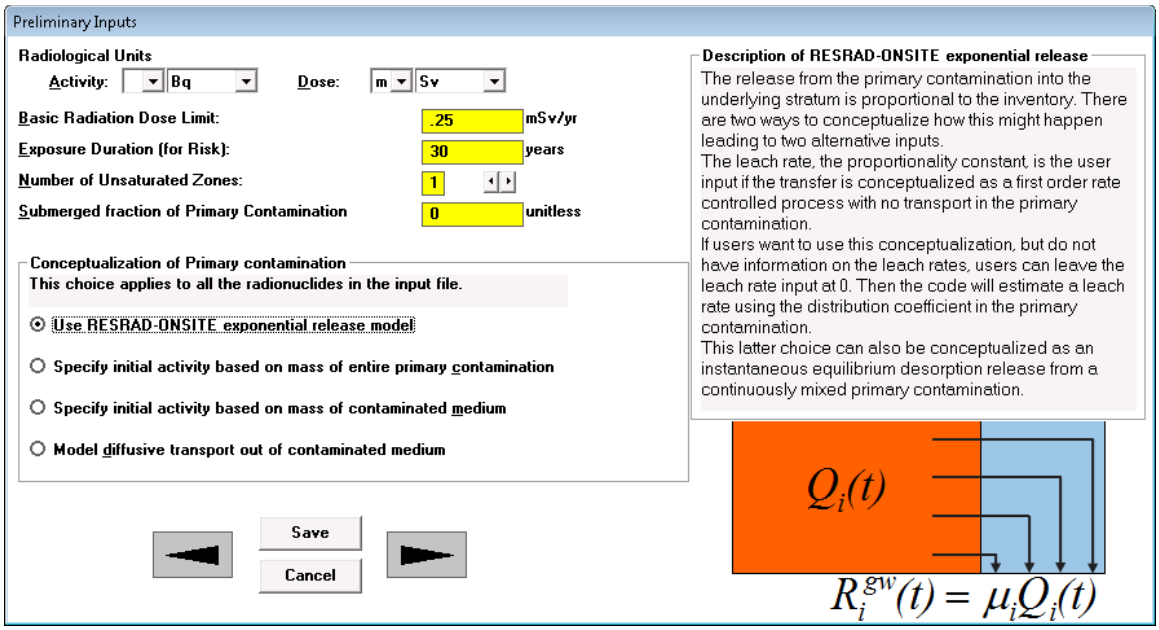

Figure 4-2 Preliminary Inputs Form—Conceptualization of Primary Contamination Option 1

- Specify initial activity based on mass of entire primary contamination (Figure 4-3);

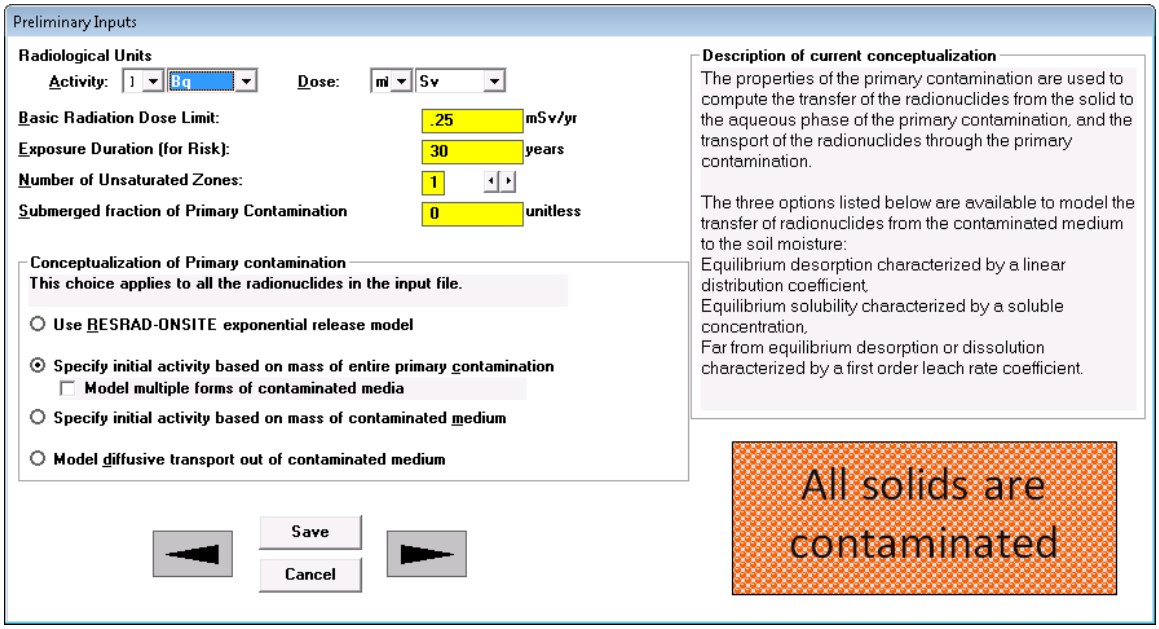

Figure 4-3 Preliminary Inputs Form—Conceptualization of Primary Contamination Option 2

o Model multiple forms of contaminated media (Figure 4-4);

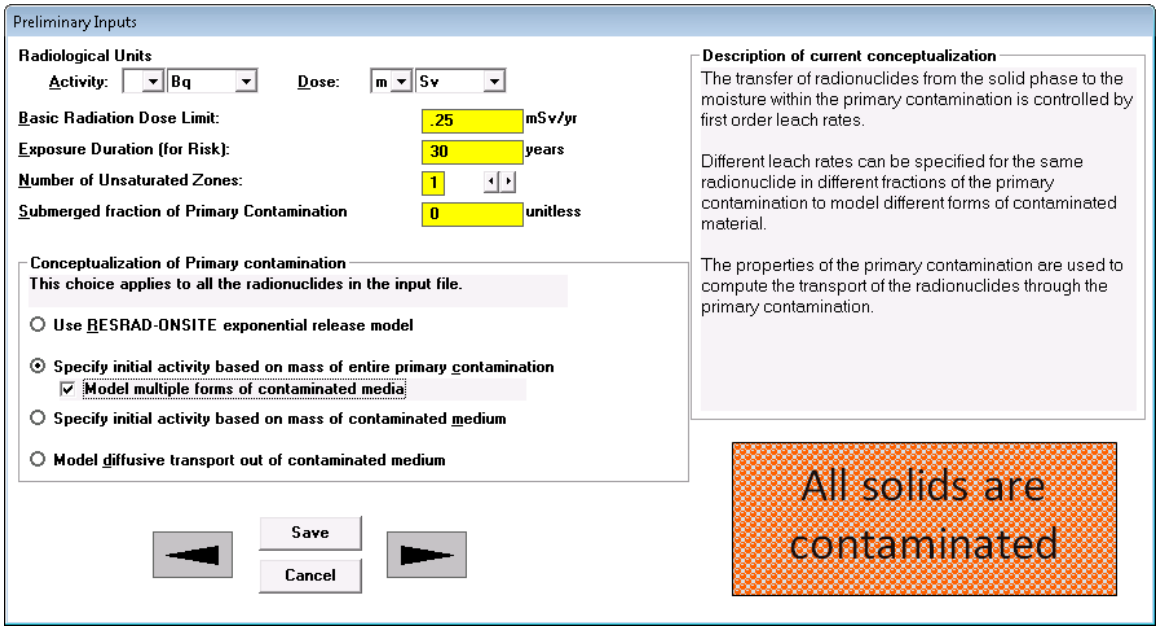

Figure 4-4 Preliminary Inputs Form—Conceptualization of Primary Contamination Option 2 with Multiple Forms of Contaminated Media

- Specify initial activity based on mass of contaminated medium (Figure 4-5);

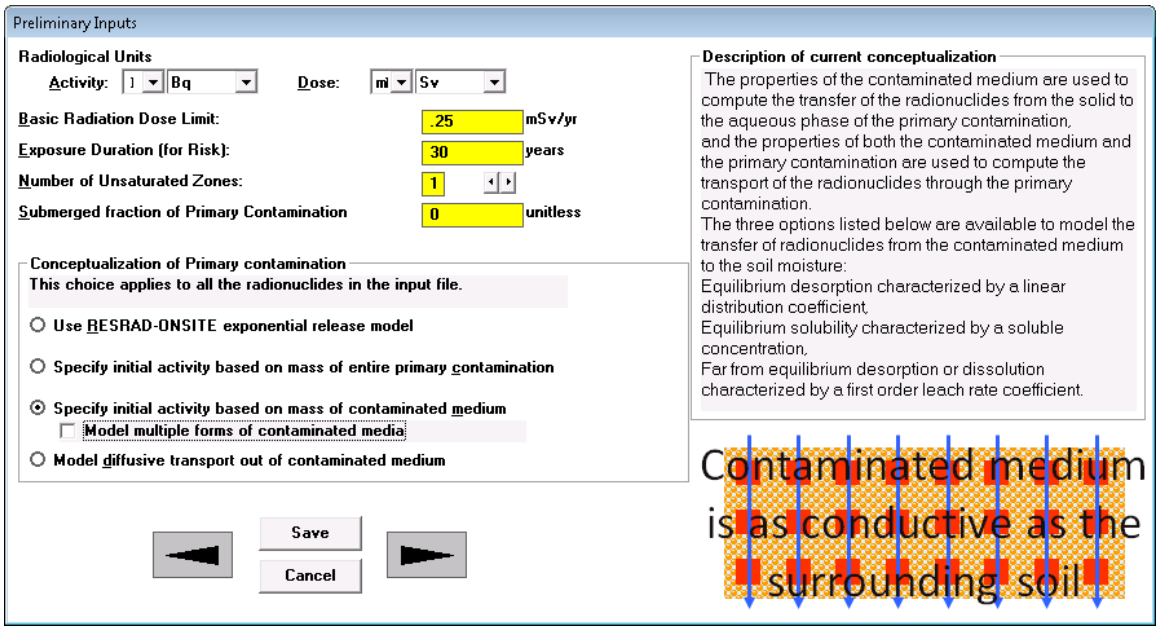

Figure 4-5 Preliminary Inputs Form—Conceptualization of Primary Contamination Option 3

o Model multiple forms of contaminated media (Figure 4-6); or

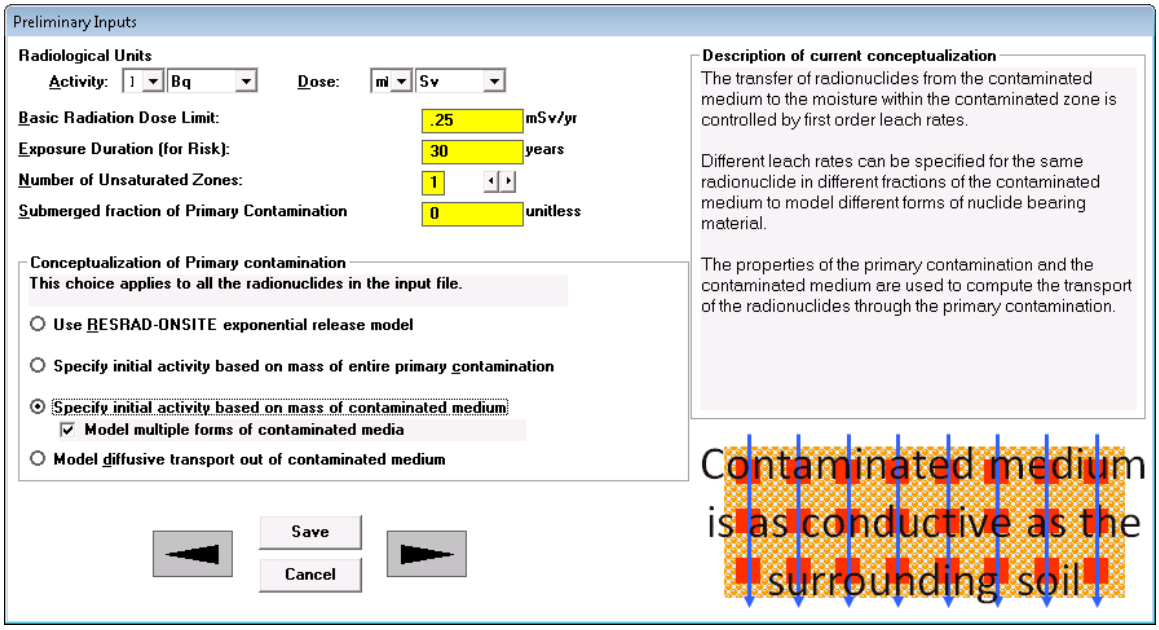

Figure 4-6 Preliminary Inputs Form—Conceptualization of Primary Contamination Option 3 with Multiple Forms of Contaminated Media

- Model diffusive transport out of contaminated medium (Figure 4-7).

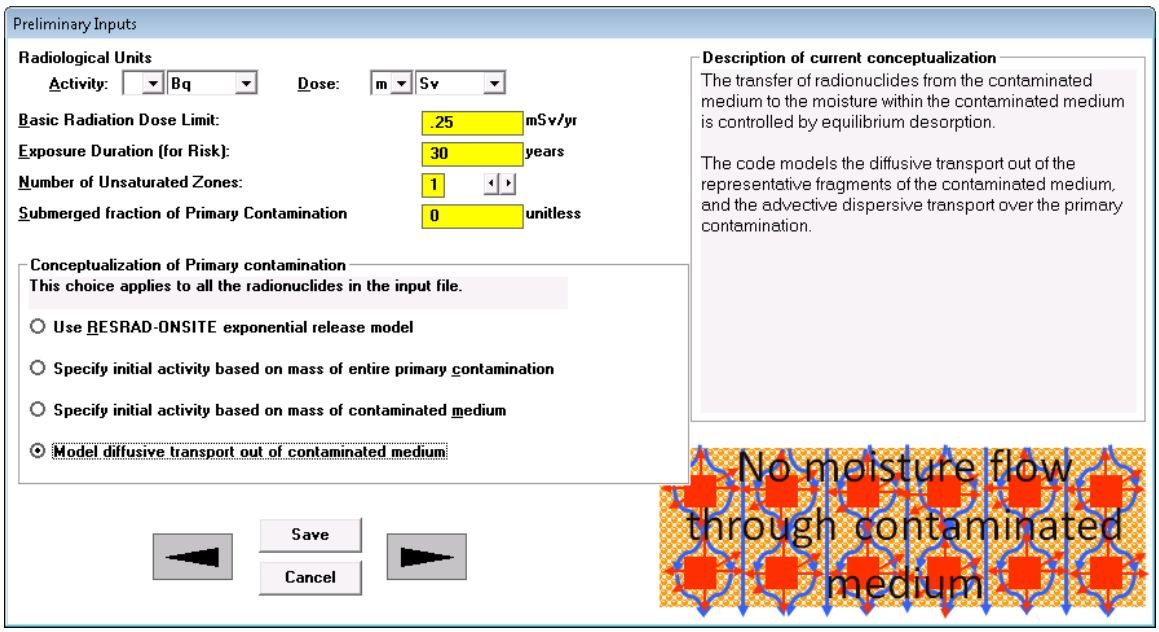

Figure 4-7 Preliminary Inputs Form—Conceptualization of Primary Contamination Option 4

4.3 Times at Which Release Properties Are Specified

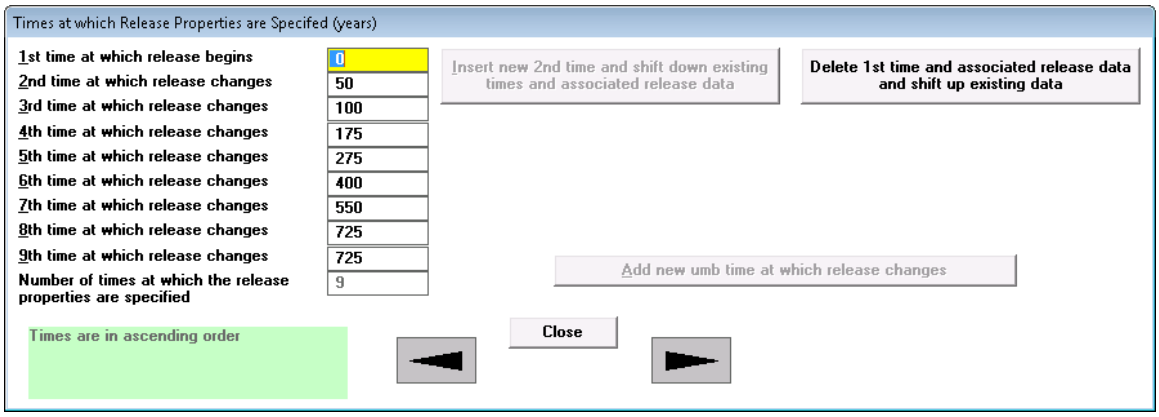

Figure 4-8 Times at Which Release Properties Are Specified Form-1

This form (Figure 4-8) allows input of the time at which the release begins and up to eight times at which the release properties change. The times must be in ascending order from the top to the bottom; no time can be less than the preceding time. These times are not radionuclide specific; the same times apply to all the radionuclides in an input file. The form is accessible with any of the three conceptualizations that model delayed and time-distributed releases, but not with the RESRAD-ONSITE exponential release model. The three command buttons on this form—add times at which release changes, delete these times, and insert times—are described below. The add command is the only one that is likely to be used when creating an input file; it is described first. The insert and delete commands can be useful when modifying a previously created input file.

Add New nth Time at Which Release Changes: Use this button to add new time at the *end* of the list of times at which the release changes. Times can be added if there are less than a total of 9 times (Figure 4-8). The value of each release time must be greater than or equal to the preceding release time Figure 4-9).

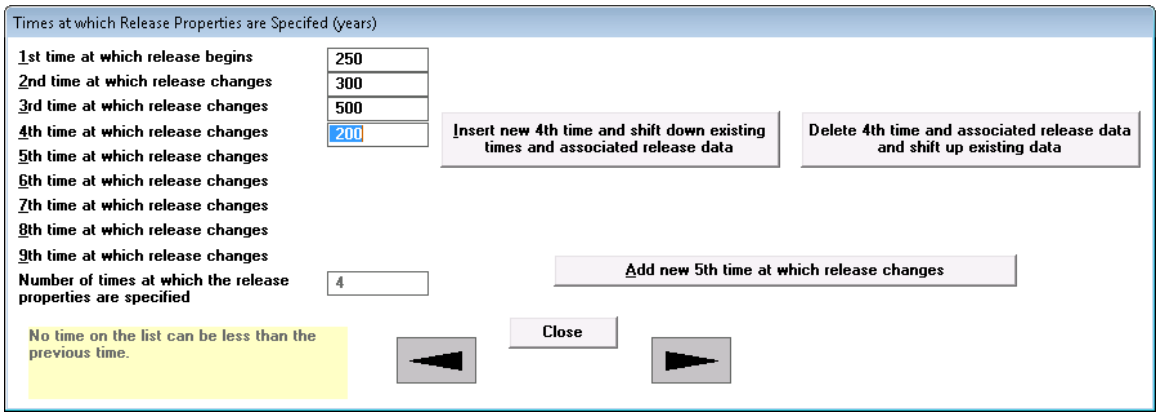

Figure 4-9 Times at Which Release Properties Are Specified Form-2

Insert New nth Time and Shift Down Existing Times and Associated Release Data: Use this button to insert a new "time at which release begins" at the *beginning* of the list or to insert a new "time at which the release changes" at any point *other than at the end* of the list (Figure 4-10). Times can be inserted if there are less than a total of 9 times (Figure 4-8). The ability to insert a time is useful when modifying a previously created input file. If the release properties (the releasable fractions, the manner in which the releasable fraction changes with time, the leach rate coefficient or the soluble concentration, the manner in which the leach rate coefficient or the soluble concentration changes with time) have already been input for the existing release times and it is desired to insert a new time with its associated release properties at any point other than at the end of the list, then this command is used to shift the succeeding times down and to move all the previously entered release properties to go with their times, in order to create space in the interior of the list and in the associated release properties data structure, for the new time and for the release properties associated with it.

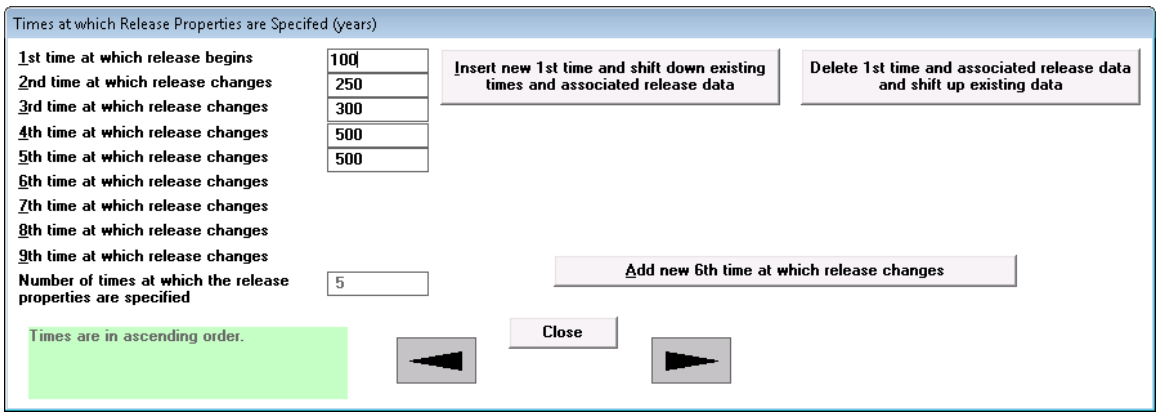

Figure 4-10 Times at Which Release Properties Are Specified Form-3

Delete nth Time and Associated Release Data and Shift Up Existing Data: Use this button to delete a time at which the release changes and associated release data; any succeeding release times and the release data associated with them are shifted up. Times can be deleted if there is more than 1 time (Figure 4-11).

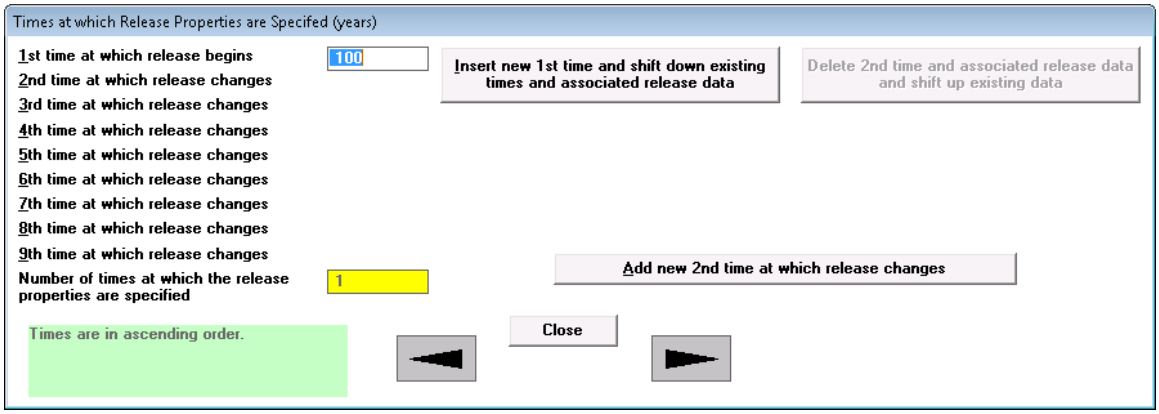

Figure 4-11 Times at Which Release Properties Are Specified Form-4

Number of Times at Which the Release Properties Change: This box shows the total number of times at which the release's properties are input. It is not a direct user input, but it changes as the release times are added, inserted, or deleted.

This form does not have a cancel feature. Any changes made to this form can be reversed only by re-inputting the original inputs for the release times and for the associated release data.

4.4 Initial Concentrations

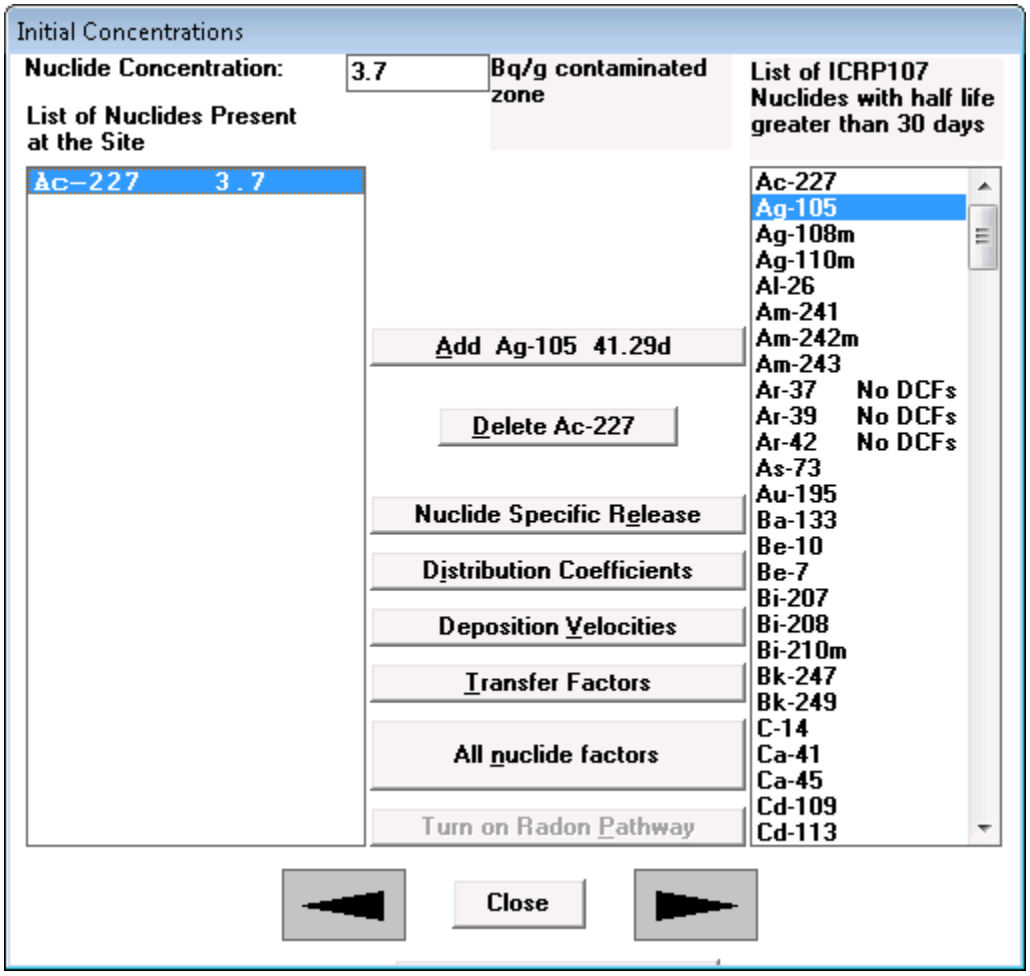

Figure 4-12 Initial Concentrations Form-1

The Initial Concentrations form does not have a cancel feature. Any changes made to this form can be reversed only by re-inputting the original inputs. Figure 4-12 shows the Initial Concentrations form under the RESRAD-ONSITE Exponential Release model conceptualization of the primary contamination.

Uncertainty analysis can be performed on the concentration of any nuclide that has a non-zero initial concentration. This can be done by clicking on the nuclide in the left scroll box (List of Nuclides Present at the Site) and then pressing the F8 key. Only positive values can be sampled for the concentration. A discrete distribution that produces a zero value should not be

used because it will cause the code to crash. A one-parameter-at-a-time sensitivity analysis cannot be performed on the concentration.

List of Nuclides in the Selected Nuclide Database with a Half-Life Greater Than the Cutoff: This list (in the right scroll box) shows all the radionuclides in the specified transformation database that have a half-life greater than the specified cutoff half-life. The list label shows the transformation database and cutoff half-life that were specified. Click on that list label to display the Title form where those two can be changed. Any nuclides that are lacking one or more of the dose or slope factors in the specified dose and risk libraries are flagged with a "No DCFs" comment on the side. This notifies the user that these nuclides cannot be analyzed unless a library with a non-zero dose and slope factors is selected.

List of Nuclides Present at the Site: This list (in the left scroll box) shows radionuclides that will be explicitly considered in the current analysis. It includes all radionuclides that were specified to be initially present at the site and their principal nuclide progeny (see cutoff half-life in the Title form, Section 4.1, or the context-sensitive help for this list). Although the fate and transport of any associated radionuclides will not be modeled explicitly, their contributions to dose and risk will be included based on the assumption that they are in secular equilibrium with their principal radionuclide parent.

Adding a Radionuclide to the List of Nuclides Present at the Site: The name of the radionuclide that is highlighted in the right scroll box and its half-life in the specified transformation database are included in the Add command button. Click on this button or type the hot key Alt-A to add the radionuclide highlighted in the left scroll box. Alternatively, double-click on the name of a radionuclide in the right scroll box to add it to the left scroll box. The radionuclide will be added to the left scroll box with a concentration specified in the top-center input box. All potential decay products will be added to the left scroll box with a concentration of zero if they are not already present. The transfer mechanism of the radionuclides being added will be set to the one selected in the transfer mechanism frame if it is visible.

Delete Nuclide: To delete a radionuclide, click on its name in the left scroll box. Then the name of the radionuclide that is highlighted in the left scroll box is included in the Delete command button. Click on this button or type the hot key Alt-D to delete the radionuclide highlighted in the left scroll box. All potential decay products that arise only from the deleted radionuclide and have an initial concentration of zero will also be deleted automatically.

Nuclide Concentration: This is the radionuclide concentration averaged over an appropriate depth and area. See the RESRAD Data Collection Handbook for more details.

- **To Change the Concentration of a Radionuclide That Is in the Left Scroll Box:** Click on the radionuclide in the left scroll box and type in the concentration.

- **To Change the Default Concentration When Adding New Radionuclides:** Click on the right scroll box, then enter the concentration in the top-center box. To add radionuclides with this concentration, see "Adding a radionuclide to the list of nuclides present at the site" above.

Accessing Other Related Forms

The four command buttons listed below provide access to the four forms that contain the radionuclide-dependent inputs. Alternatively, the first form can be opened by clicking on the forward arrow button on this form, and then the other three forms can be accessed by continuing to use the forward arrow buttons on the successive forms. If the computer monitor is large enough (17 inches or more diagonally), all these forms can be viewed simultaneously by clicking on the All Nuclide Factors button. All four forms can also be accessed by double-clicking on the radionuclide name in the left scroll box.

Nuclide Specific Release: Use this button to open the Radionuclide Specific Release form (Section 4.5).

Distribution Coefficients: Use this button to open the Distribution Coefficients form (Section 4.6).

Deposition Velocities: Use this button to specify the deposition velocity of the material with which the nuclide is being transported in the atmosphere (Section 4.7).

Transfer Factors: Use this button to access the Transfer Factors form (Section 4.8).

Turn on Radon Pathway Command Button: This command button is enabled only when a radon precursor radionuclide is added in the list of nuclides present at the site. This command button toggles the radon exposure pathway on and off.

Figure 4-13 shows the Initial Concentrations form under the “Specify initial activity based on mass of entire primary contamination” conceptualization of primary contamination. Three transfer mechanism: 1) equilibrium desorption, 2) equilibrium solubility, and 3) first-order rate controlled are available in this conceptualization. These offer a convenient way to pre-specify the release mechanism to be assigned to radionuclides before they are selected. The transfer mechanism of the radionuclide can be changed in the Radionuclide Specific Release form, Section 4.5, when the release characteristics are specified.

The initial concentrations form under the “Specify initial activity based on mass of contaminated media” conceptualization is similar; only the unit label of the nuclide concentration (activity/g of contaminated medium) will be different.

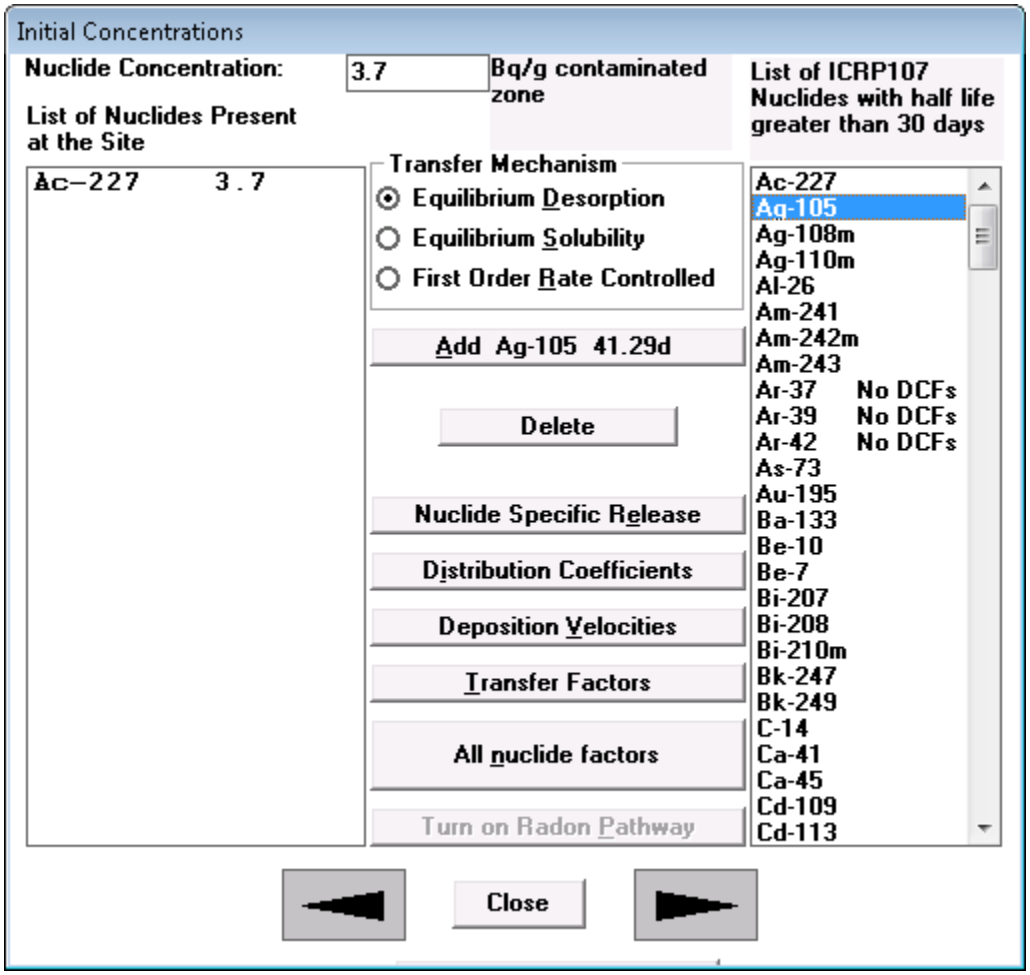

Figure 4-13 Initial Concentrations Form-2

Figure 4-14 shows the Initial Concentrations form when “Modeling multiple forms of contaminated media” under the “Specify initial activity based on mass of entire primary contamination” conceptualization of primary contamination. Only the first-order rate-controlled transfer mechanism is applicable for this option.

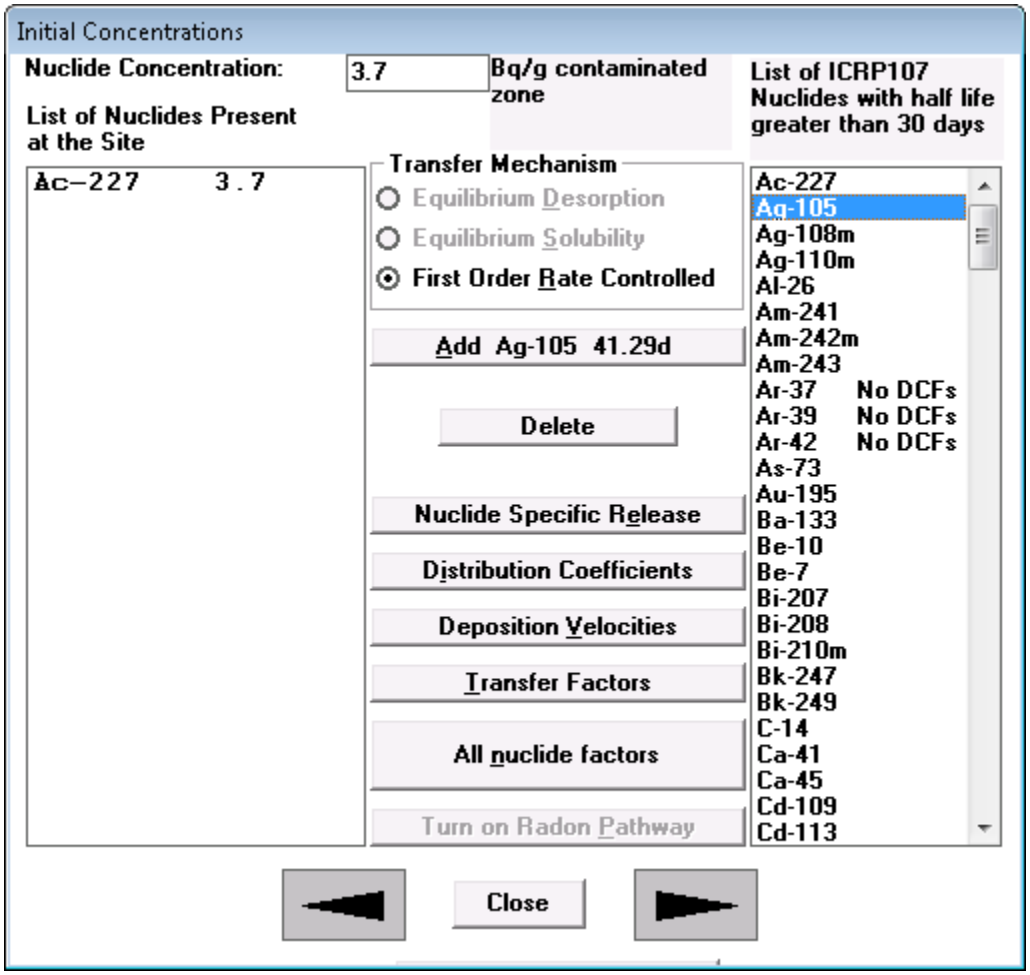

Figure 4-14 Initial Concentrations Form-3

Figure 4-15 shows the Initial Concentrations form under the “Model diffusive transport out of contaminated medium” conceptualization of primary contamination. Only the Equilibrium Desorption transfer mechanism is currently available under this option.

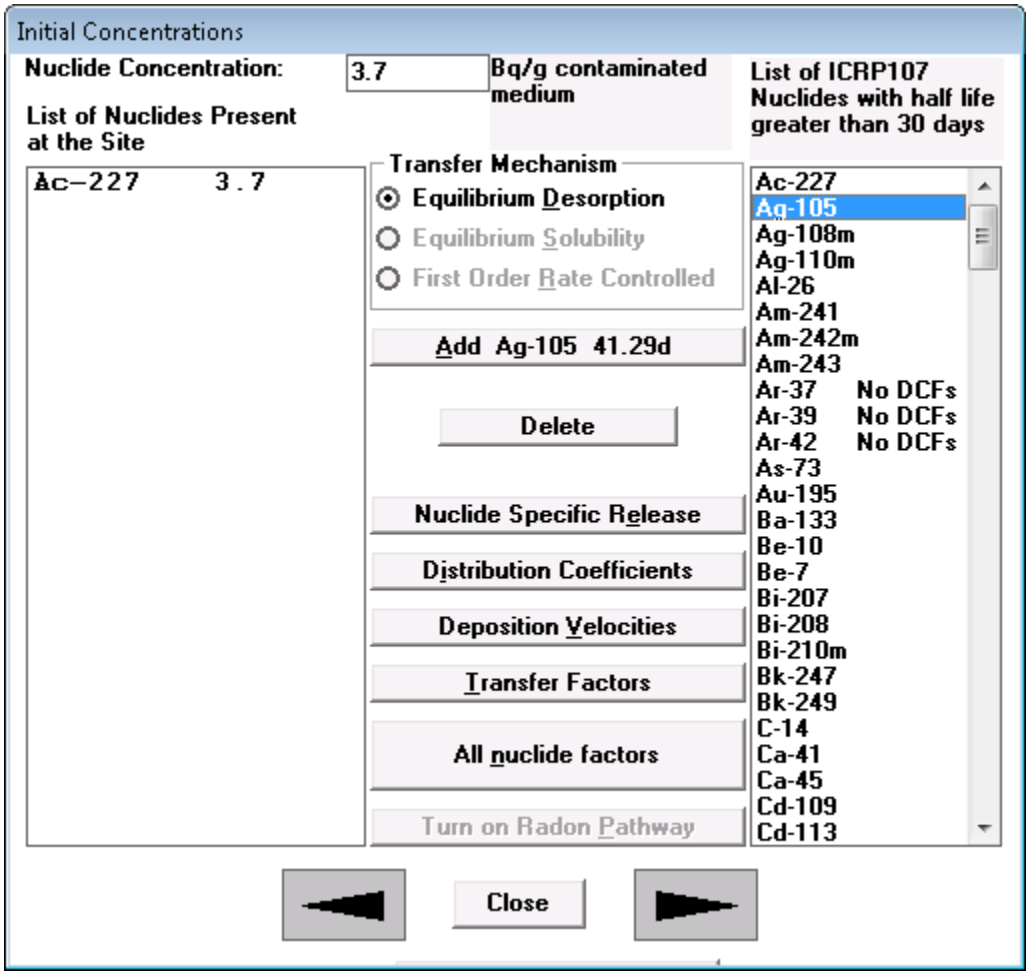

Figure 4-15 Initial Concentrations Form-4

4.5 Radionuclide Specific Release

Figure 4-16 through Figure 4-21 show the radionuclide specific release forms for different options available for the conceptualization of primary contamination. Figure 4-16 shows the inputs required under the RESRAD-ONSITE Exponential Release Model conceptualization of the primary contamination. If the non-zero first-order leach rate constant specified is less than the upper limit for the RESRAD-ONSITE Exponential Release Model described in the context-sensitive help, it will be used to compute the contaminant concentration in the region of primary contamination and the releases to groundwater. Because the contaminant concentration in the primary contamination contributes to the releases to the atmosphere and to surface runoff, the leach rate constant indirectly affects those two releases as well. If a zero or a value greater than the upper limit is entered, the code will estimate a leach rate constant based on the equilibrium desorption concentration using the specified distribution coefficient.

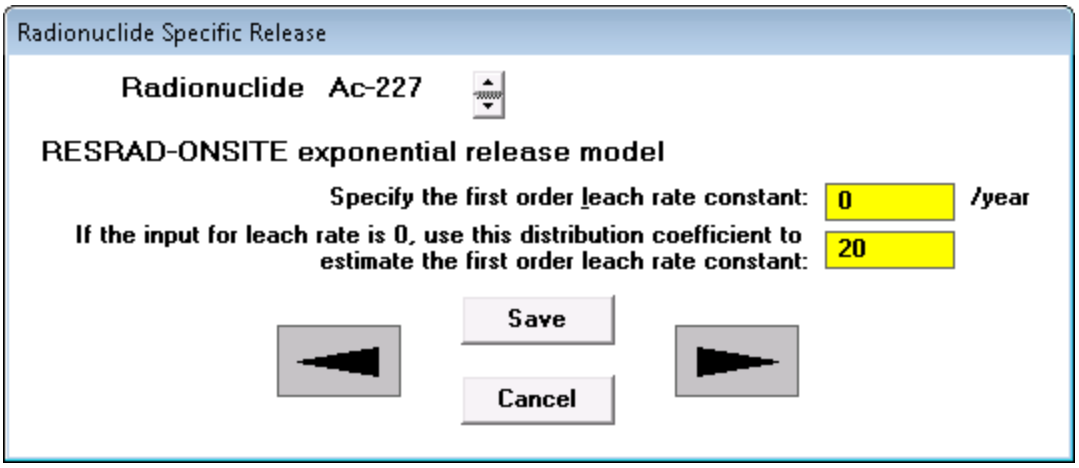

Figure 4-16 Radionuclide Specific Release Form-1

Click on the up or down arrow next to the radionuclide name to save the release properties of the current radionuclide and to view/specify the release properties of the next or previous radionuclide. Uncertainty and sensitivity analysis can be performed on the numerical inputs in the radionuclide specific release forms.

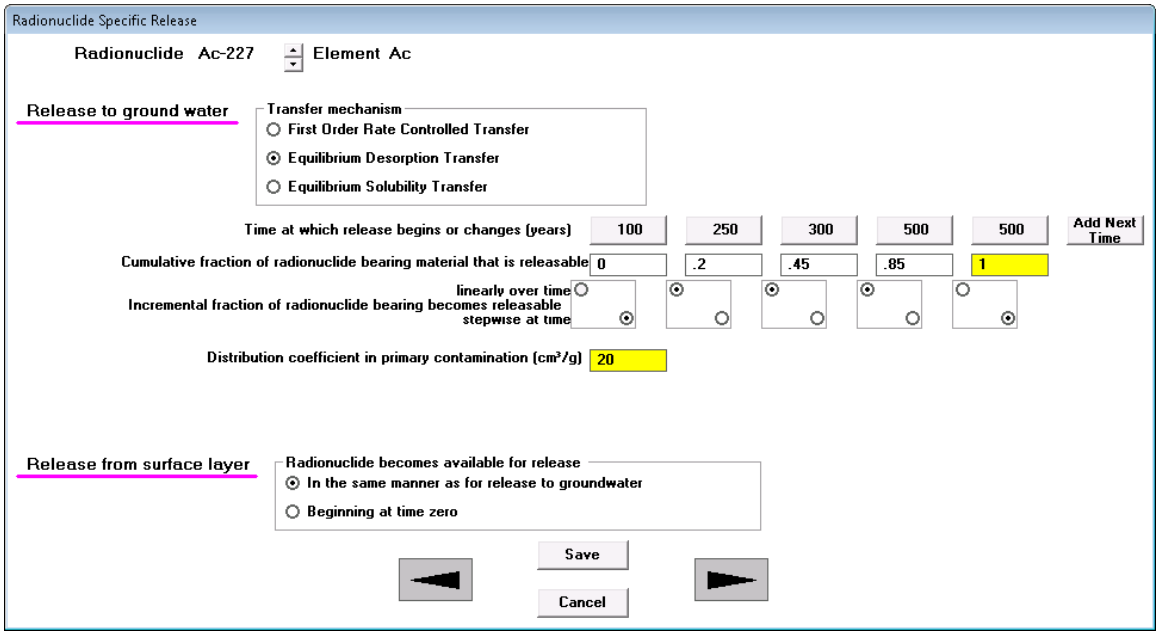

Figure 4-17 Radionuclide Specific Release Form-2

Figure 4-17 shows the transfer mechanisms available under the “Specify initial activity based on mass of entire primary contamination” or the “Specify initial activity based on mass of contaminated medium” conceptualization of the primary contamination, along with the inputs required when the equilibrium desorption transfer mechanism is selected. The transfer mechanism of the radionuclide can be changed on this form. When equilibrium desorption transfer option is selected, the distribution coefficient of the radionuclide in the primary

contamination and the temporal information about the part of the contaminated medium that is prone to release are required. The time at which the release begins and up to eight times at which the release properties change that were input as described in Section 4.3 are displayed in this form. They cannot be changed in this form because the same times apply to all the radionuclides in the input file. The releasable fractions of the radionuclide-bearing material must be specified at these times. The releasable fraction changes in a stepwise fashion at the beginning of the release. Different choices can be made for the manner in which the releasable fraction changes at the other times.

For the case illustrated in Figure 4-17, the ^{227}Ac is not transferred to the soil moisture during the first 100 years; the code models the changes in the concentration of ^{227}Ac in the primary contamination due to radiological transformations during this period and continues to model it during subsequent times. The ^{227}Ac in 20% of the radionuclide-bearing material is modeled as becoming releasable over the next 150 years, from year 100 to year 250, at a constant rate of the ^{227}Ac in 2/15 percent of the primary contamination per year. Not all the releasable ^{227}Ac is transferred to the soil moisture, only the quantity needed to raise the concentration of ^{227}Ac in the infiltrating moisture to the equilibrium concentration determined by the specified distribution coefficient is released from the upgradient portion of the primary contamination; the rest remains in a releasable state in the primary contamination. The ^{227}Ac in an additional 25% of the radionuclide-bearing material is modeled as becoming releasable over the next 50 years, from year 250 to year 300, at a constant rate of the ^{227}Ac in 1/2 percent of the primary contamination per year. The ^{227}Ac in an additional 40% of the radionuclide-bearing material is modeled as becoming releasable over the next 200 years, from year 300 to year 500, at a constant rate of the ^{227}Ac in 1/5 percent of the primary contamination per year. The ^{227}Ac in the final 15% of the radionuclide bearing material is modeled as becoming releasable at year 500 because the releasable fraction was specified to change in a stepwise manner at the last release time in Figure 4-17. In this illustration, it would have been modeled as a stepwise change regardless of the specification because the beginning and end of the final release period was of the same value, 500 years; a linear change over an instant is a stepwise change.

The releasable fractions and the manner in which the releasable fractions change over time are radionuclide specific. They need to be specified for each radionuclide.

The releases from the surface layer could either be delayed and distributed in time in the same manner as specified for the release to the groundwater, or they can be modeled as beginning at time zero.

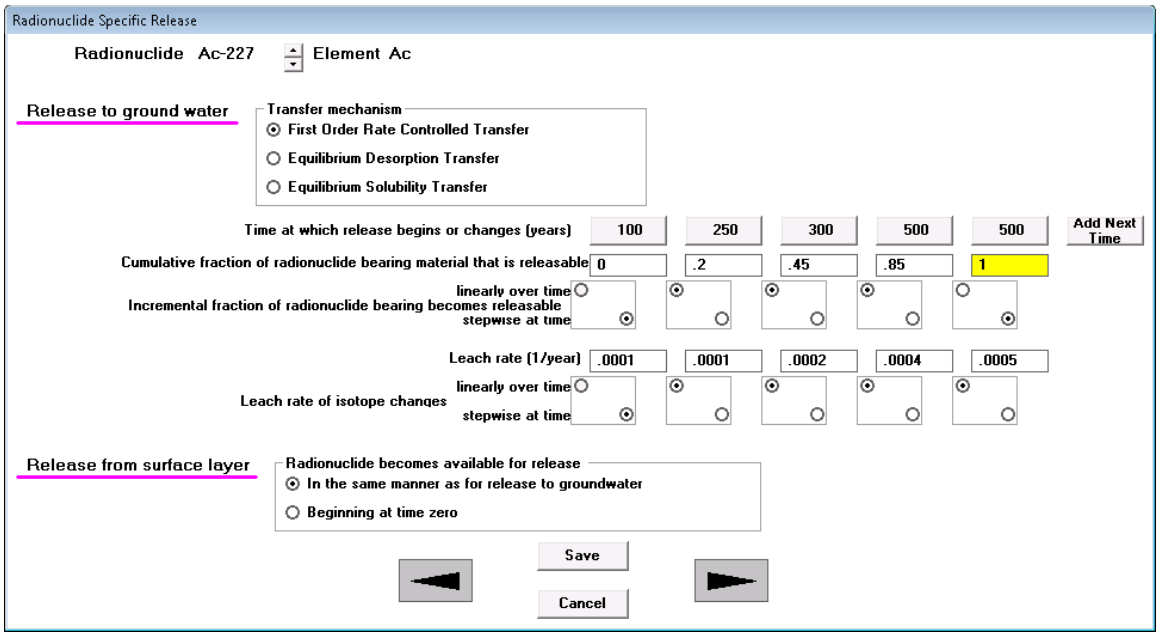

Figure 4-18 Radionuclide Specific Release Form-3

Figure 4-18 shows the transfer mechanisms available under the “Specify initial activity based on mass of entire primary contamination” or the “Specify initial activity based on mass of contaminated medium” conceptualization of the primary contamination along with the inputs required when the first-order rate-controlled transfer mechanism is selected. For this option, the temporal information on the leach rate coefficient of the radionuclide in the primary contamination and the temporal information about the part of the contamination that is prone to release are required, as shown in Figure 4-18.

Figure 4-19 shows the transfer mechanisms available under the “Specify initial activity based on mass of entire primary contamination” or the “Specify initial activity based on mass of contaminated medium” conceptualization of the primary contamination along with the inputs required when the equilibrium solubility transfer mechanism is selected. For this option, the temporal information on the soluble concentration of each element in the primary contamination and the temporal information about the part of the contamination that is prone to release are required, as shown in Figure 4-19. The soluble concentration is element-specific, not radioisotope-specific. If the equilibrium dissolution transfer option is selected for a radioisotope, it should be the transfer mechanism for all isotopes of that element. The soluble concentration must be specified in terms of gram atomic weights of the element per liter. The code displays the concentration in mg/L just above the value that is being entered in gram atomic weights/L to afford the user a check on the value being input.

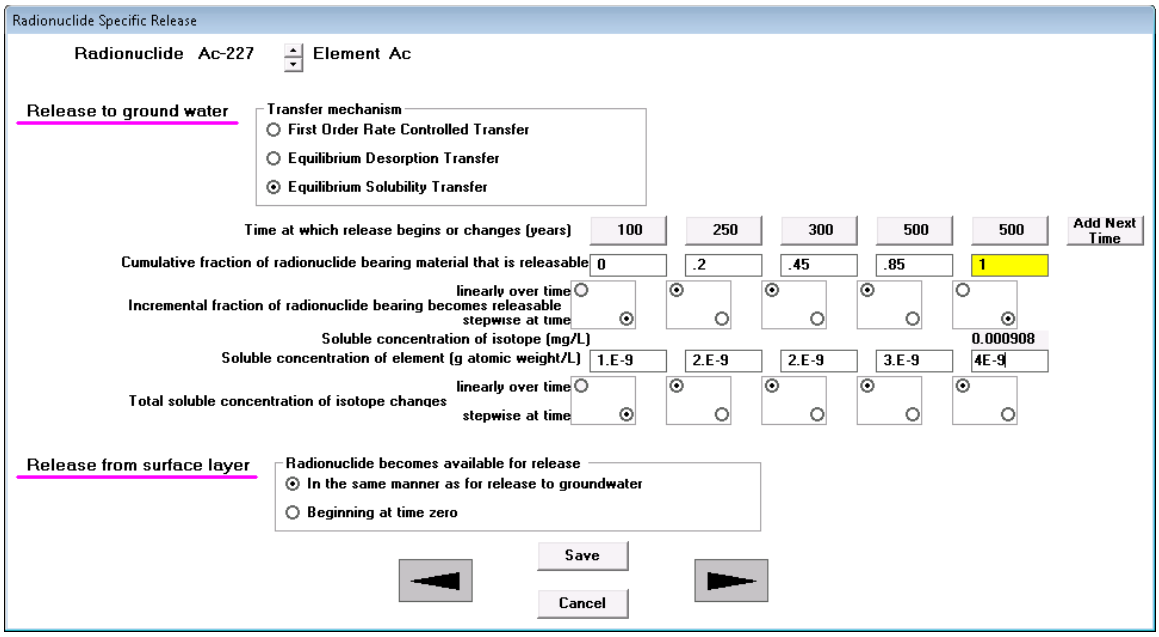

Figure 4-19 Radionuclide Specific Release Form-4

Figure 4-20 shows the transfer mechanisms available and the inputs required when "modeling multiple forms of contaminated media" under the "Specify initial activity based on mass of entire primary contamination" or the "Specify initial activity based on mass of contaminated medium" conceptualization of the primary contamination. Only the first-order rate-controlled transfer mechanism is applicable in this case.

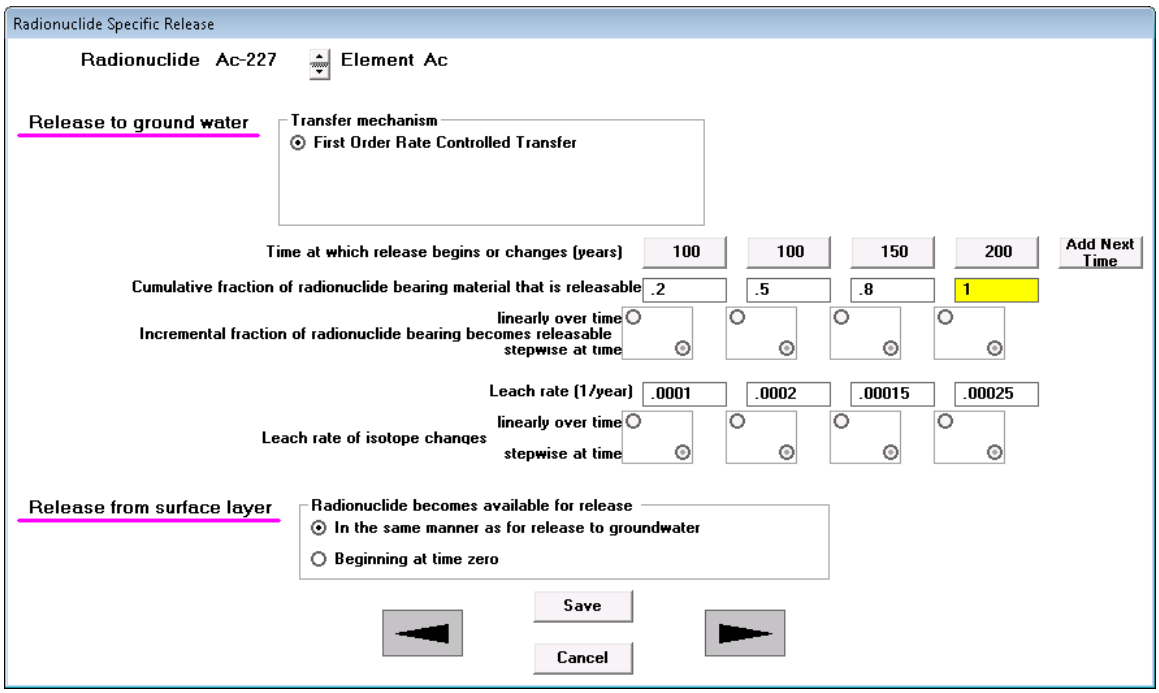

Figure 4-20 Radionuclide Specific Release Form-5

There are four distinct forms of radionuclide-bearing materials in the case illustrated in Figure 4-20. Two of the forms are releasable beginning at year 100. The form that contained 20% of the initial inventory is released with a constant leach rate coefficient of 0.0001 per year. The form that contained 30% of the initial inventory is released with a constant leach rate coefficient of 0.0002 per year. The third form that contained 30% of the initial inventory is released with a constant leach rate coefficient of 0.00015 per year beginning at year 150. The fourth form containing the final 20% of the initial inventory is released with a constant leach rate coefficient of 0.00025 per year beginning at year 200 in this example.

Figure 4-21 shows the transfer mechanism available and the inputs required when modeling diffusive transport out of a contaminated medium through which there is virtually no moisture flow. Only the equilibrium desorption transfer mechanism is currently available for this conceptualization. The diffusion coefficient of the radionuclide and the distribution coefficient of the radionuclide in the contaminated medium are required. While the interface expects input of the diffusion coefficient of the radionuclide, the *effective* diffusion coefficient[1] of the radionuclide in the contaminated medium can be input in place of the diffusion coefficient together with a zero value for the distribution coefficient of the radionuclide in the contaminated medium. Then the value computed by the code would be the effective diffusion coefficient that was input, as described in Equation G.63 of Volume 1 of the User's Manual and in the context-sensitive help. The temporal information about the part of the contaminated medium that is prone to release is also required.

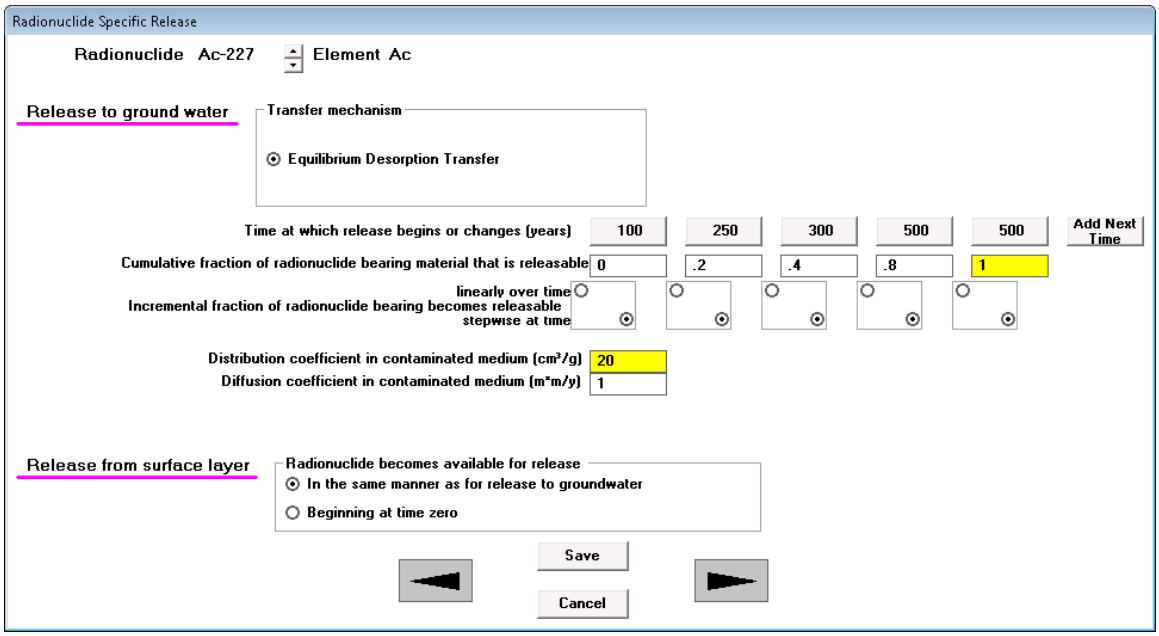

Figure 4-21 Radionuclide Specific Release Form-6

[1] The effective diffusion coefficient implicitly considers the distribution coefficient or "retardation" of diffusive transport due to interaction between the radionuclide and the contaminated material.

4.6 Distribution Coefficients

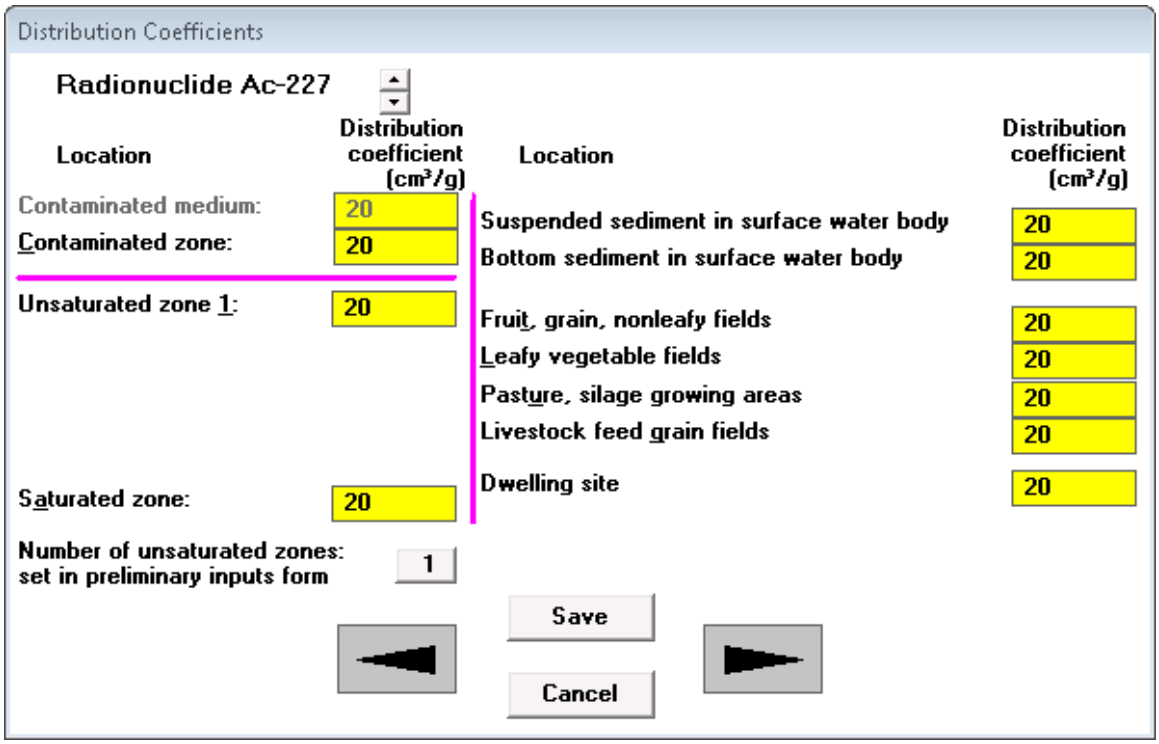

Figure 4-22 Distribution Coefficients Form for the RESRAD-ONSITE Exponential Release

In practical terms, the distribution coefficients are the ratios of the mass of radionuclide in the solid phase of the soil (per unit of dry mass) to the radionuclide concentration in the liquid phase in the different transport zones and at the locations of accumulation. Default values are provided for each radionuclide; however, site-specific values should be used because literature values can vary over many orders of magnitude, depending on the chemical form, soil type, pH, redox potential, and the presence of other ions. The distribution coefficients in the different transport zones and regions of accumulation are input in the form shown in Figure 4-22. Uncertainty and sensitivity analysis can be performed on the distribution coefficients.

Click on the up or down arrow next to the radionuclide name to save the distribution coefficients of the current radionuclide and to view the distribution coefficients of the next or previous radionuclide.

Contaminated Medium: The distribution coefficient for the contaminated medium is enabled only when the initial activity is based on the mass of contaminated medium. The distribution coefficient is used to model the transfer of contaminants from the solid phase of the contaminated medium to the water phase in the contaminated medium.

Contaminated Zone: If the RESRAD-ONSITE Exponential Release Model is used, this distribution coefficient is used to estimate a first-order release rate when the user does not specify a leach rate constant. In this case, the form has a pink horizontal line to differentiate the

distribution coefficient that is used to estimate the leach rate constant from the distribution coefficients that are used to model transport.

This distribution coefficient is used to compute the radionuclide transport rate within the primary contamination for the other release methodologies. In these cases, the distribution coefficient in the contaminated zone is used for the same purpose as the distribution coefficients in the unsaturated and saturated zones. There is then no need to separate the distribution coefficients of those zones in this case, and the pink horizontal line is not displayed, as shown in Figure 4-23.

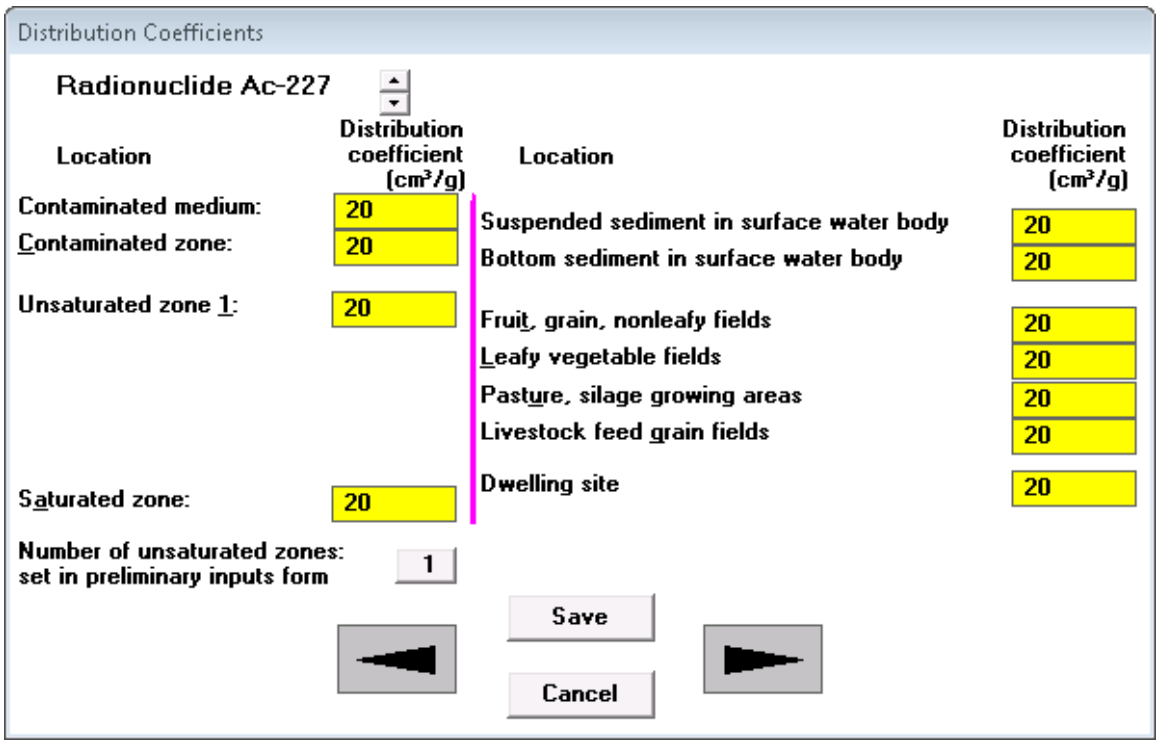

Figure 4-23 Distribution Coefficients Form for Other Releases

Unsaturated Zone and Saturated Zone: These distribution coefficients are used to compute the radionuclide transport rate for groundwater transport calculations.

Suspended Sediment in Surface Water Body, Bottom Sediment in Surface Water Body: These two distribution coefficients are used to compute the concentration of the radionuclide in the surface water body.

Fruit, Grain, Nonleafy Fields; Leafy Vegetable Fields; Pasture, Silage Growing Areas; Livestock Feed Grain Fields; Dwelling Site: These five distribution coefficients for agricultural fields, pastures, and dwelling sites are used to account for the adsorption on the soil when accumulation in the fields, pastures, and dwelling sites is being computed.

Clicking on the button displaying the number of unsaturated zones causes the Preliminary Inputs form (Section 4.2) to open, because the number of unsaturated zones can be changed only on the Preliminary Inputs form.

4.7 Deposition Velocities

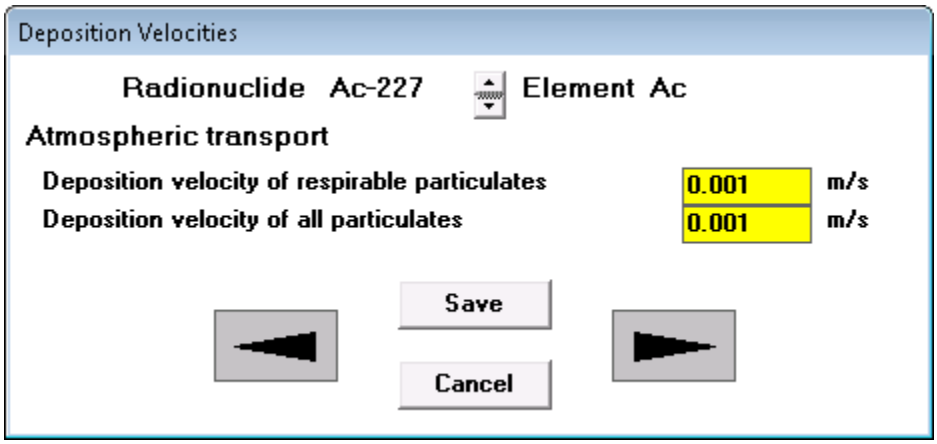

Figure 4-24 Deposition Velocities Form

Uncertainty and sensitivity analysis can be performed on the deposition velocities. The deposition velocities in RESRAD-OFFSITE are element-specific, not radioisotope-specific. The Deposition Velocities form (Figure 4-24) is linked to the list of radionuclides specified to be present at the site. Therefore, the deposition velocities are displayed for each radionuclide present at the site for both respirable particulates and for all particulates (Figure 4-24). However, the code will not accept different deposition velocities for different isotopes of the same element. The deposition velocity specified for a radionuclide will be used for all radioisotopes of the same element. The form displays the radionuclide name and the element name to remind the user that the deposition velocities are element-specific. The deposition velocities for each element and radionuclide that were specified for the site can be viewed by clicking on the up or down button next to the radionuclide name. The deposition velocities are used in the code to account for the loss from dry deposition along the atmospheric transport path and to compute the deposition flux at offsite locations.

Deposition Velocity of Respirable Particulates: This is the deposition velocity of the airborne respirable dust particulates. It is used to model the settling of the respirable particulates from the dust plume during atmospheric transport.

Deposition Velocity of All Particulates: This is the deposition velocity of the airborne dust particulates. It is used to model the settling of the particulates from the dust plume during atmospheric transport.

4.8 Transfer Factors

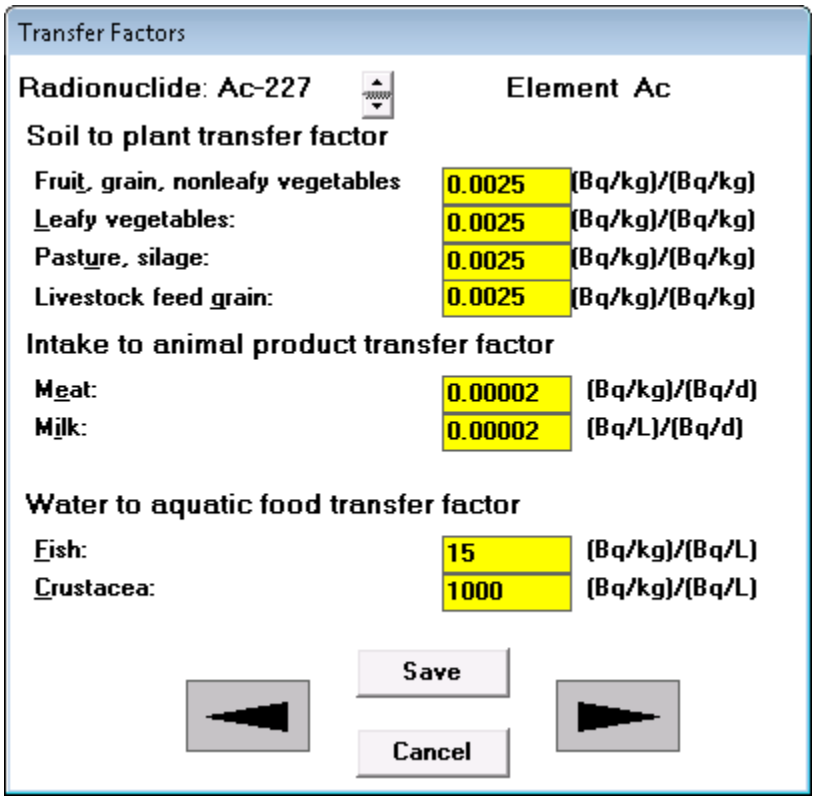

Figure 4-25 Transfer Factors Form

Uncertainty and sensitivity analysis can be performed on the transfer factors. The Transfer Factors form (Figure 4-25) is linked to the list of radionuclides specified to be present at the site. Therefore, it displays the transfer factors for each radionuclide that is specified to be present at the site. However, the transfer factors are element-specific; thus, any changes made to the factors of an isotope will be used for all the isotopes of that element. The form displays the radionuclide name and the element name to remind the user that the transfer factors are element-specific. The factors for each element and radionuclide that were specified for the site can be viewed by clicking on the up or down button next to the radionuclide name.

Soil to Plant Transfer Factor: This is the root uptake transfer factor, which is the ratio between the contaminant concentration in the edible plant and that in the soil upon which the plant is grown. The RESRAD database contains only one default value for each element. Values appropriate for site-specific vegetation must be entered in the four input boxes. Values displayed for tritium, ^{3}H, denoted by H-3 in the code (Figure 4-26), and for carbon-14, ^{14}C, denoted by C-14 in the code (Figure 4-27), cannot be changed by the user because the transfer factors are computed by the code (see Appendix F of the User's Manual).

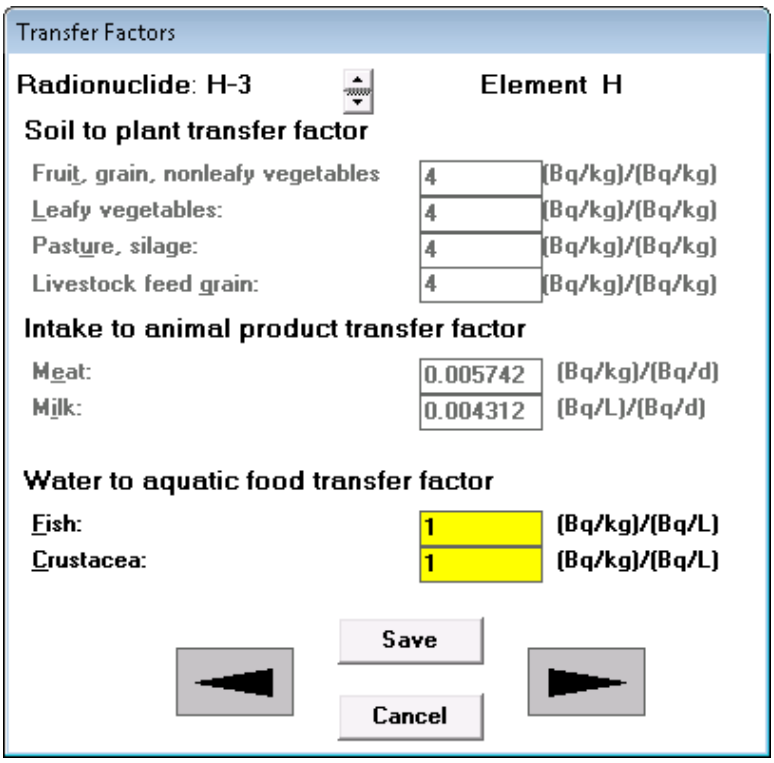

Figure 4-26 Transfer Factors Form for ^{3}H

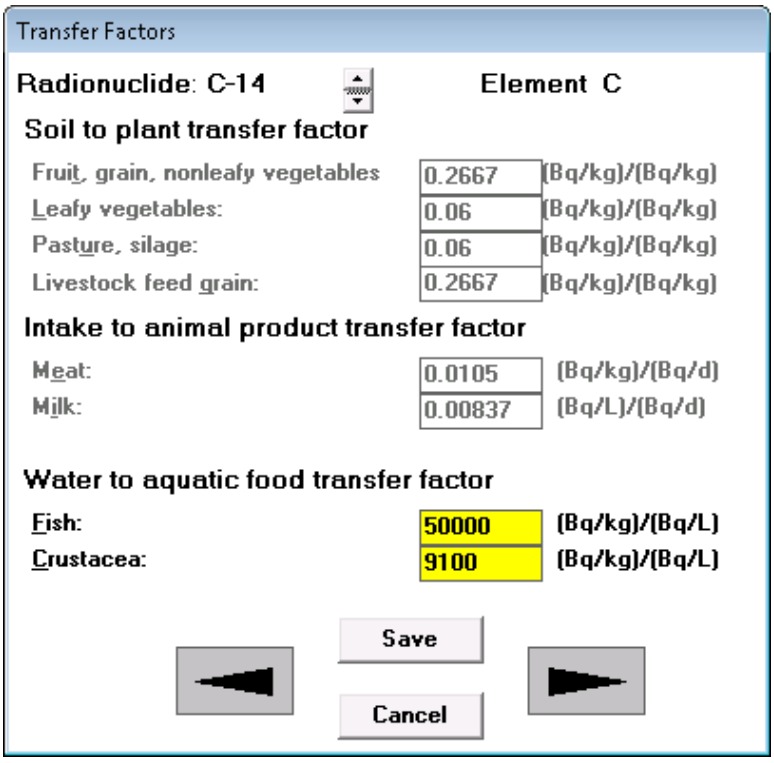

Figure 4-27 Transfer Factors Form for ^{14}C

Intake to Animal Product Transfer Factor: This is the ratio between the concentration of the radionuclide in meat or milk and the rate of intake of the radionuclide by livestock. Values displayed for ^{3}H and for ^{14}C cannot be changed by the user because the transfer factors are computed by the code (see Appendix F of the User's Manual).

Water to Aquatic Food Transfer Factor: This is the ratio between the radionuclide concentration in the edible parts of aquatic food and that in the water in which the aquatic food sources live.

4.9 Set Pathways

All pathways, except the radon pathway, are active by default but can be turned off. The user can activate the radon pathway after selecting a radon precursor. The pathway icons and the pathway command button toggle the pathways on and off.

An inactive pathway can be activated by clicking on either the crossed-out icon corresponding to the pathway or the name of the pathway, or by using the hotkey (Alt + underlined letter) corresponding to that pathway (Figure 4-28).

An active pathway can be deactivated by clicking on either the icon corresponding to the pathway or the name of the pathway, or by using the hotkey (Alt + underlined letter) corresponding to that pathway.

Figure 4-28 Set Pathways DOS-Emulator

4.10 Reporting Times

None of the inputs on the Reporting Times form (Figure 4-29) are eligible for uncertainty analysis or for sensitivity analysis.

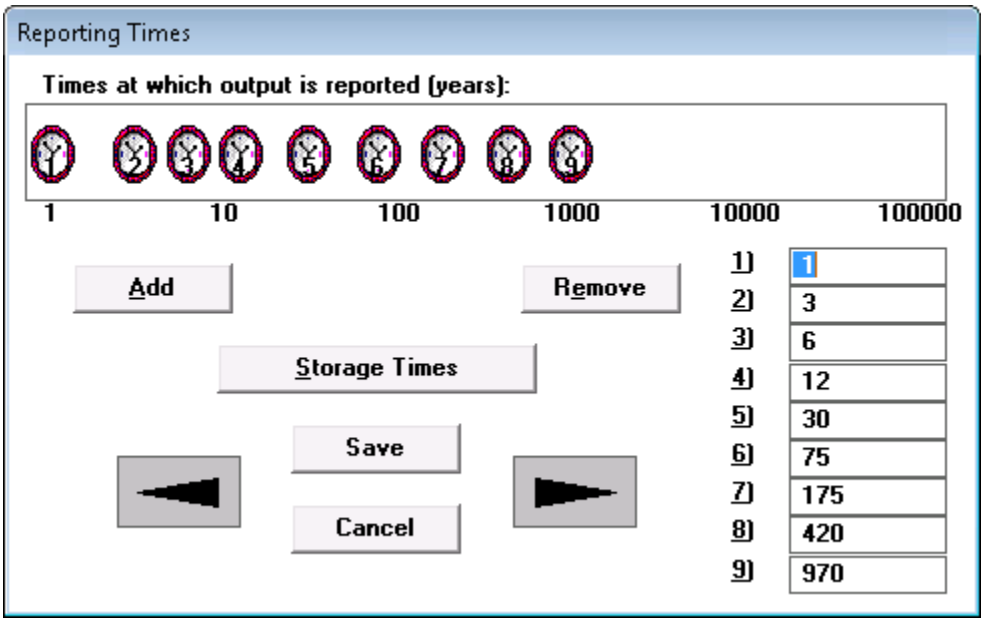

Figure 4-29 Reporting Times Form

Times at Which Output Is Reported: These are the times after the radiological survey when results are to be reported in the textual output. A time horizon of 1,000 years is commonly used; however, calculations can be carried out to longer periods to identify potential problems from delayed contributions from the groundwater or other pathways. The forecast time horizon is the sum of the last reporting time and the exposure duration for risk. Results are always calculated and reported for year 0.

The code predictions are available at each of the calculation time points generated by the specification in the Title & Radiological Data form (Section 4.1). Interpolation is performed between those time points to produce the textual report at the times specified in this form.

To add a time:

- Click on the Add button and a new clock icon and time box will appear. Set the time following the change-time procedure, or
- Click the right mouse button while the cursor is in the frame containing the clock icons.

To remove a time:

- Click on the appropriate time box, then click on the Remove button.

To change a time:

- Click on the appropriate time box and enter a new value, or
- Click on the appropriate clock icon and drag to the desired time location.

Storage Times: The Storage Times form can be assessed by clicking on this button. The Storage Times form is the next linked form, so the forward arrow can also be used to get to it.

4.11 Storage Times

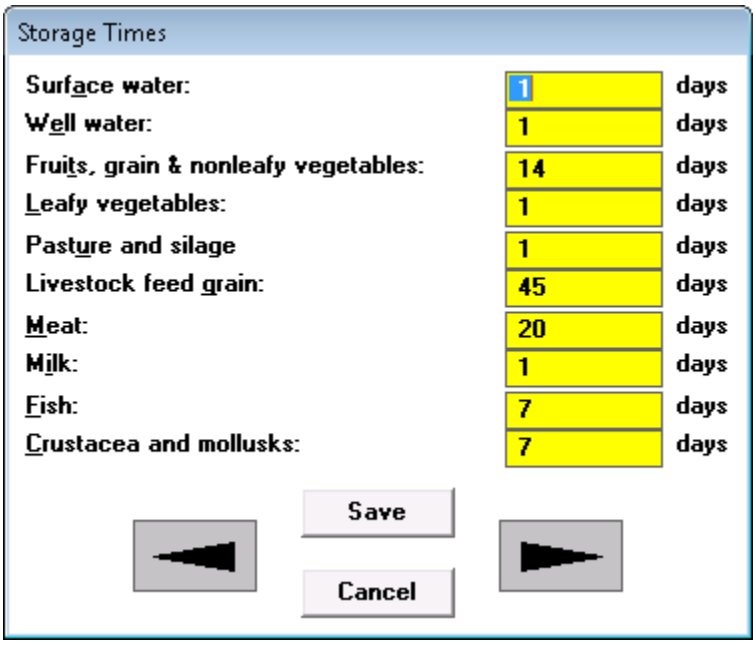

Figure 4-30 Storage Time Form

Uncertainty and sensitivity analysis can be performed on the storage times.

Storage Times: These are the various amounts of time over which foodstuffs and water are stored before being consumed or used (Figure 4-30). The concentrations of radionuclides in food and water are adjusted for decay and ingrowth during this period. See Appendix E.3 of Volume 1 of the RESRAD-OFFSITE User's Manual for details.

4.12 Site Layout

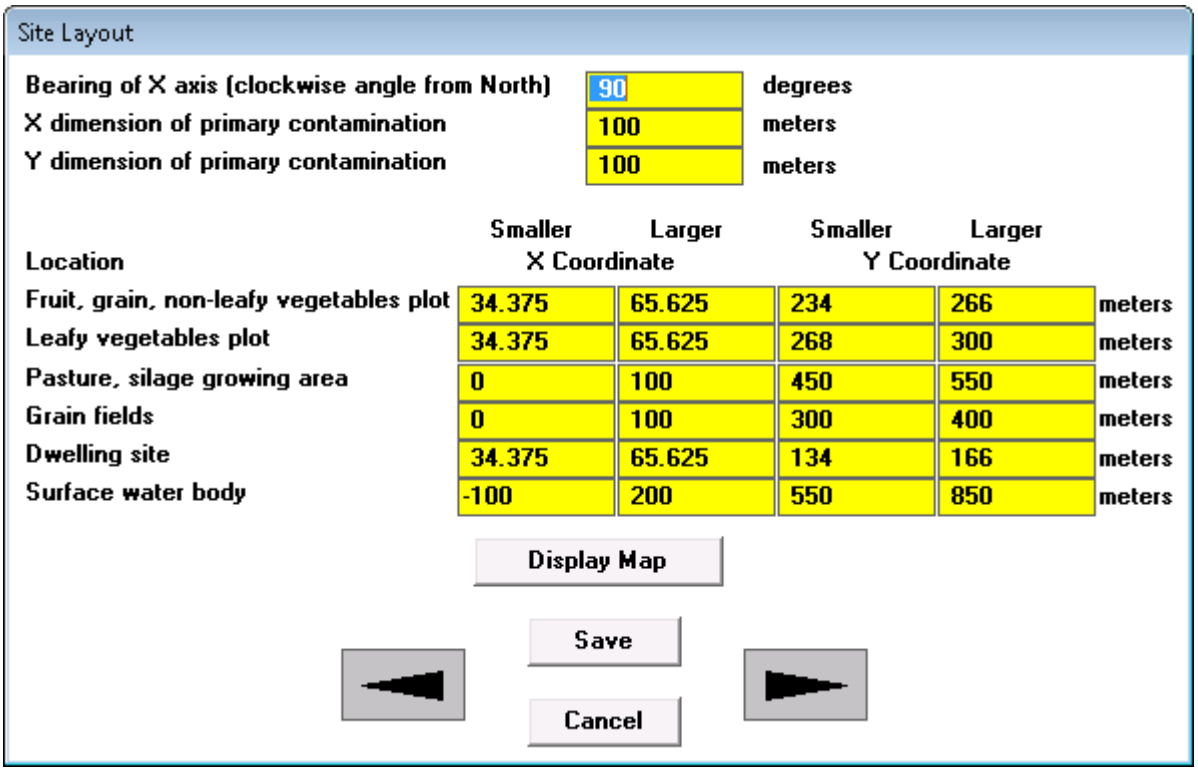

Figure 4-31 Site Layout Form

The Site Layout form (Figure 4-31) allows numerical input of site dimensions. The map interface (Section 4.13) can be used to input the same information in an interactive graphical fashion. The site layout form is appropriate when measured or computed lengths are available, and it is likely to be a quicker way to specify the dimensions of the site. The interactive map interface is appropriate when visible features in the map are to be used to define the various areas. Uncertainty and sensitivity analysis can be performed on any parameter on this form.

The inputs on this form are used by the atmospheric transport module and the direct external exposure from the primary contamination module and to compute the areas of primary contamination and the offsite locations of secondary contamination. The atmospheric transport model assumes that the primary contamination and the offsite locations of secondary contamination are rectangular in shape and that a pair of sides of each of the rectangles is oriented in the same direction. The two sides of the primary contamination that meet at the lower-left corner are the axes of the coordinate system. Each offsite area is defined by the four coordinates, as shown in Figure 4-32. These can be thought of as the coordinates of the sides of the offsite area.

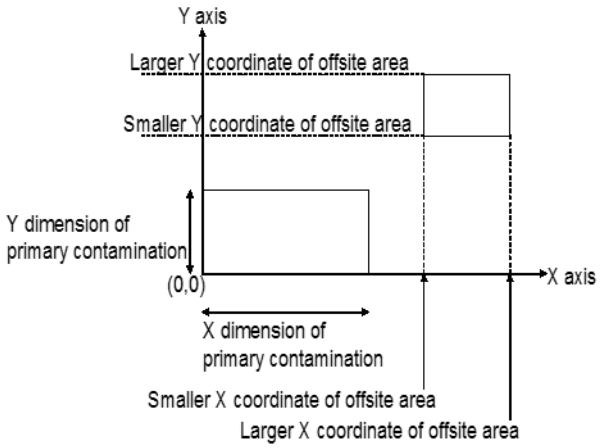

Figure 4-32 The Coordinate System Used in RESRAD-OFFSITE

Bearing of X-Axis: This is the clockwise angle from north to the direction of the positive X-axis.

X Dimension of the Primary Contamination: This is the length of the side of the idealized primary contamination that is parallel to the X-axis, the length of the lower side.

Y Dimension of the Primary Contamination: This is the length of the side of the idealized primary contamination that is parallel to the Y-axis, the length of the left side.

The X Coordinates of an Offsite Area: These are the X coordinates of the two sides that are parallel to the Y-axis. When the Save command or one of the form's linking arrow commands is issued, the code will compare the two X coordinates of each area and interchange them, if the larger value is entered in the column for the smaller value, and vice versa.

The Y Coordinates of an Offsite Area: These are the Y coordinates of the two sides that are parallel to the X-axis. When the Save command or one of the form's linking arrow commands is issued, the code will compare the two Y coordinates of each area and interchange them, if the larger value is entered in the column for the smaller value, and vice versa.

All the information that has been entered and saved in the Site Layout form will be reflected in the display map. Conversely, the position and size that have been set and accepted in the map interface will be reflected in the Site Layout form.

4.13 Map Interface

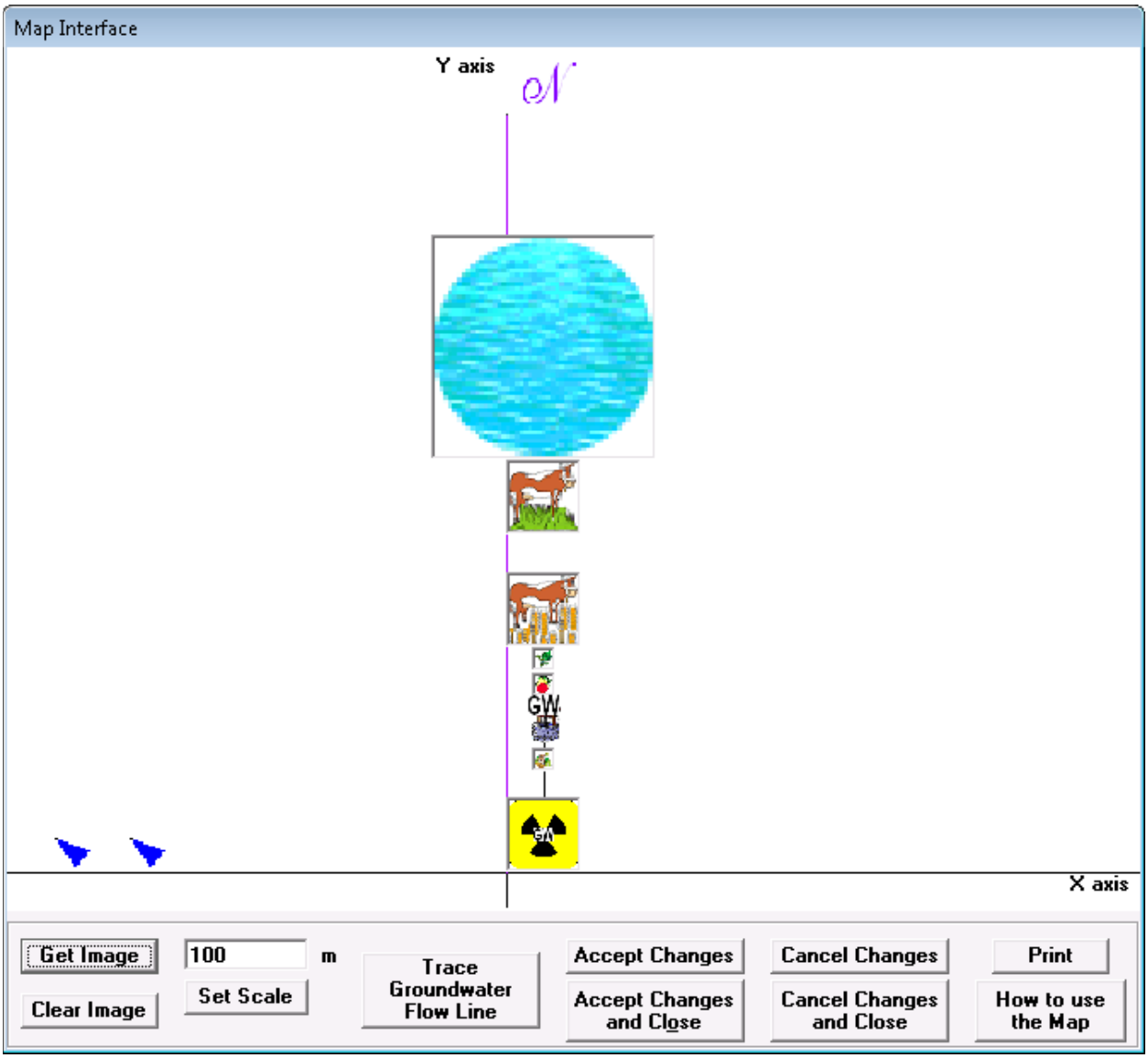

Figure 4-33 Map Interface

The map interface (Figure 4-33) can be used to position and, where appropriate, size the objects and directions of interest in RESRAD-OFFSITE (primary contamination, offsite dwelling, well, surface water body, agricultural fields, direction of groundwater flow, and direction of north), either by dragging and dropping or by resizing the corresponding icons. Alternatively, the map interface can be used to view the layout that was specified in the standard input forms (Site Layout form, Section 4.12, and Groundwater Transport form, Section 4.23). It can also be used to access the forms specifying the properties of the locations represented by each icon; right-clicking the icon opens the corresponding form. The forms that are linked to the icons are in Table 4-1.

Table 4-1 Icon Identification

Icon	Form, Section in User's Guide
N	Site Layout, Section 4.12
Radioactivity	Primary Contamination, Section 4.15
Cow	Livestock Feed Growing Areas, Section 4.17
Leaf or fruits	Agricultural Areas, Section 4.17
House	Offsite Dwelling Area, Section 4.18
Well	Saturated Zone Hydrology, Section 4.22
Blue circle/ellipse	Surface Water Body, Section 4.24
GW	Groundwater Transport, Section 4.23

The process for using the map interface is as follows:

1. View Map Interface form.

2. Add a background image (using Get Image button).

3. Set the scale (using the Set Scale button) based on a known distance in the background map.

4. Move and size the Radioactivity icon to define the location of the primary contamination.

5. Move and size the other icons to define the corresponding locations. The GW (groundwater flow direction) and N (North) icons indicate direction; they cannot be resized, because size has no meaning for the direction. The well cannot be resized because the diameter of the well is not an input.

6. Trace the groundwater flow line passing through the center of the primary contamination, if that information is available.

7. Click on the Accept Changes button.

8. The image location, scale, and object locations will be written to the input file when the RESRAD-OFFSITE file is saved. This information is used to display the map image and the icons when the input file is opened later.

Details on Using Map Interface

Steps 2 through 8 are described in greater detail below.

Step 2 (in detail): To get an image, click on the Get Image button and navigate to an image (bitmap, metafile, enhanced metafile, JPEG, or GIF file) of the site that is large enough to contain all the objects of interest and open it.

- Click on the Get Image button on the map interface. A file dialog box will pop up (Figure 4-34).

- Use the file dialog box to navigate to the directory containing the image, typically the same folder that contains the RESRAD-OFFISTE input files (for example, the highlighted folder, “Userfiles,” in Figure 4-34).

- Double-click the file to be opened (for example, the highlighted file, “HypotheticalSuburbanResidentGroundwaterFlog.jpg,” in the Figure 4-34).

Step 3 (in detail): Find the scale on the map or find two points on the map that are a known distance apart (these points should be as far apart as possible). Move each of the two blue arrows to a different point; if using the scale, move each blue arrow to a point on either end of the scale. Enter the distance (in meters) between the arrows in the entry box above the Set Scale button, then click the Set Scale button. In the example illustrated in Figure 4-35, it is better to set the scale using the Y-axis and the right edge of the surface water body (a distance of 1250 m) than to use the two points denoting the scale distance of 106 m on the map. This reduces the error that results from not placing the blue arrows exactly where you intended.

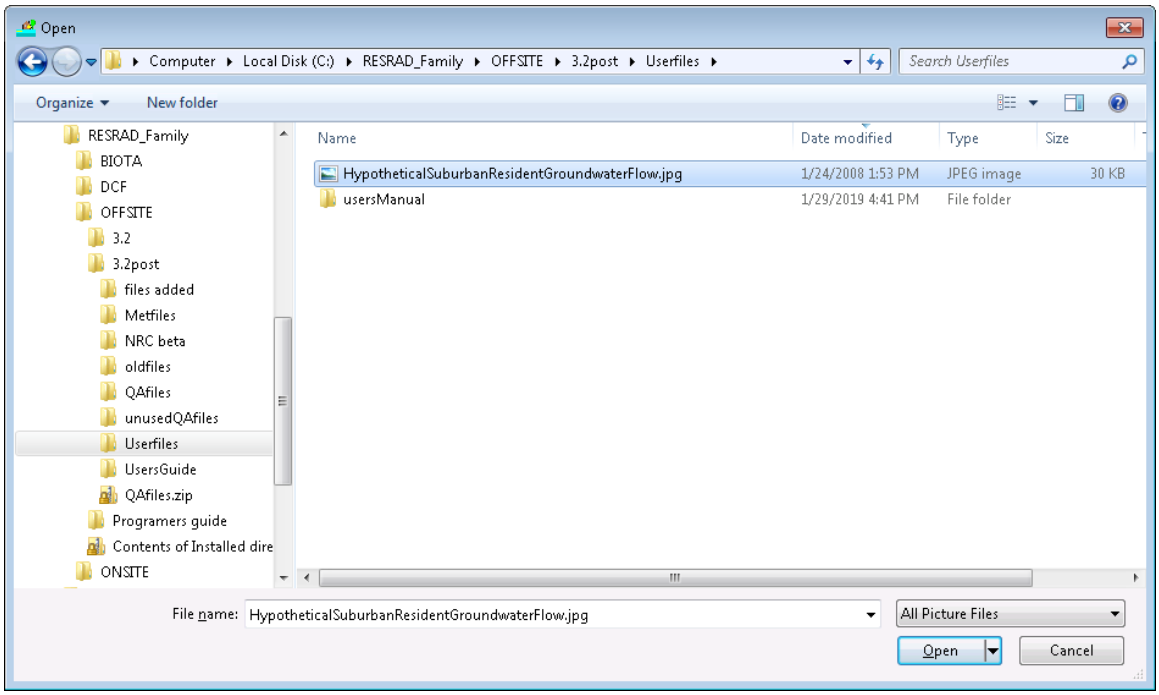

Figure 4-34 Map Interface Dialog Box

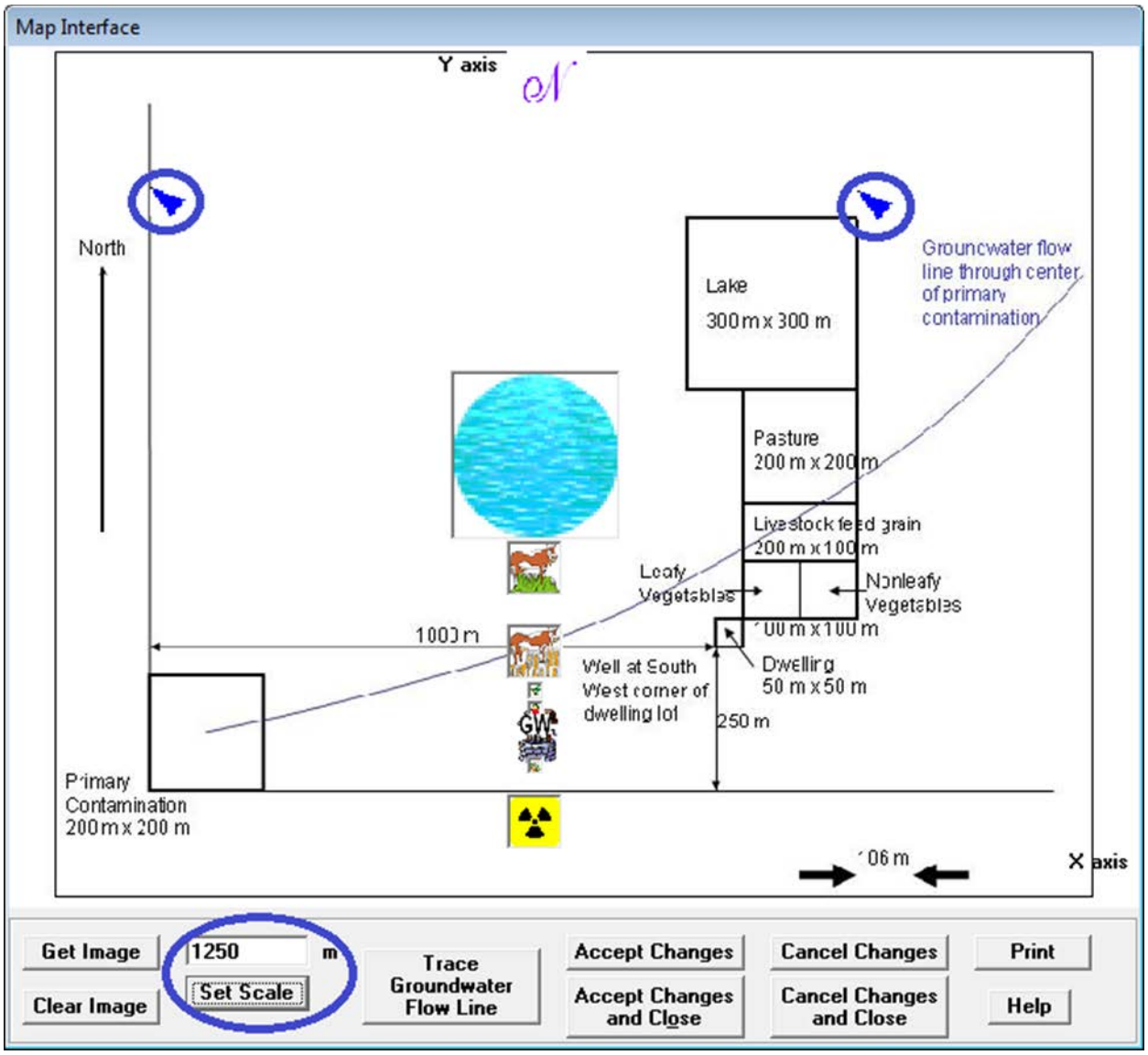

Figure 4-35 Setting the Scale in the Map Interface

Step 4 (in detail): Left-click on the source icon (the yellow and black radiation symbol) and drag it to the location of the primary contamination. Move the sides of the icon to expand or shrink it to cover the entire primary contamination. Notice that all the other icons that represent exposure locations and directions move with the source icon (Figure 4-36). This is why it is necessary to locate the primary contamination before locating any of the other icons.

Step 5 (in detail): Left-click on each of the other objects in turn and drag them to the appropriate locations (Figure 4-37). Expand or shrink each icon (by moving its sides) to cover the entire area it represents. The GW icon, which indicates the direction of the groundwater flow from the source; the N icon, which indicates North; and the Well icon cannot be resized. If an icon does not appear on the map interface, it can be moved onto the map by specifying its location in the Site Layout form (Section 4.12).

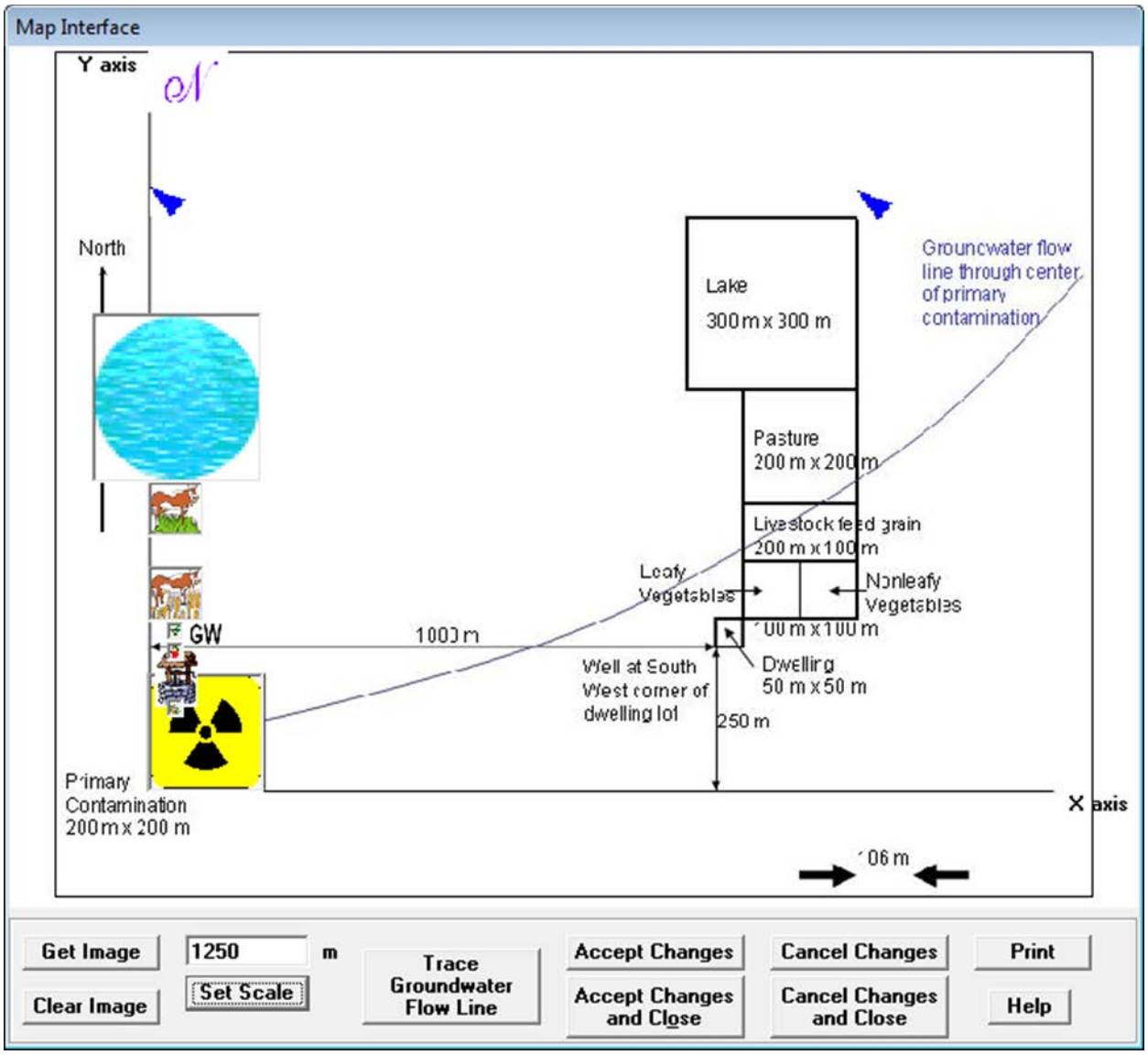

Figure 4-36 Locating and Sizing the Primary Contamination on the Map Interface

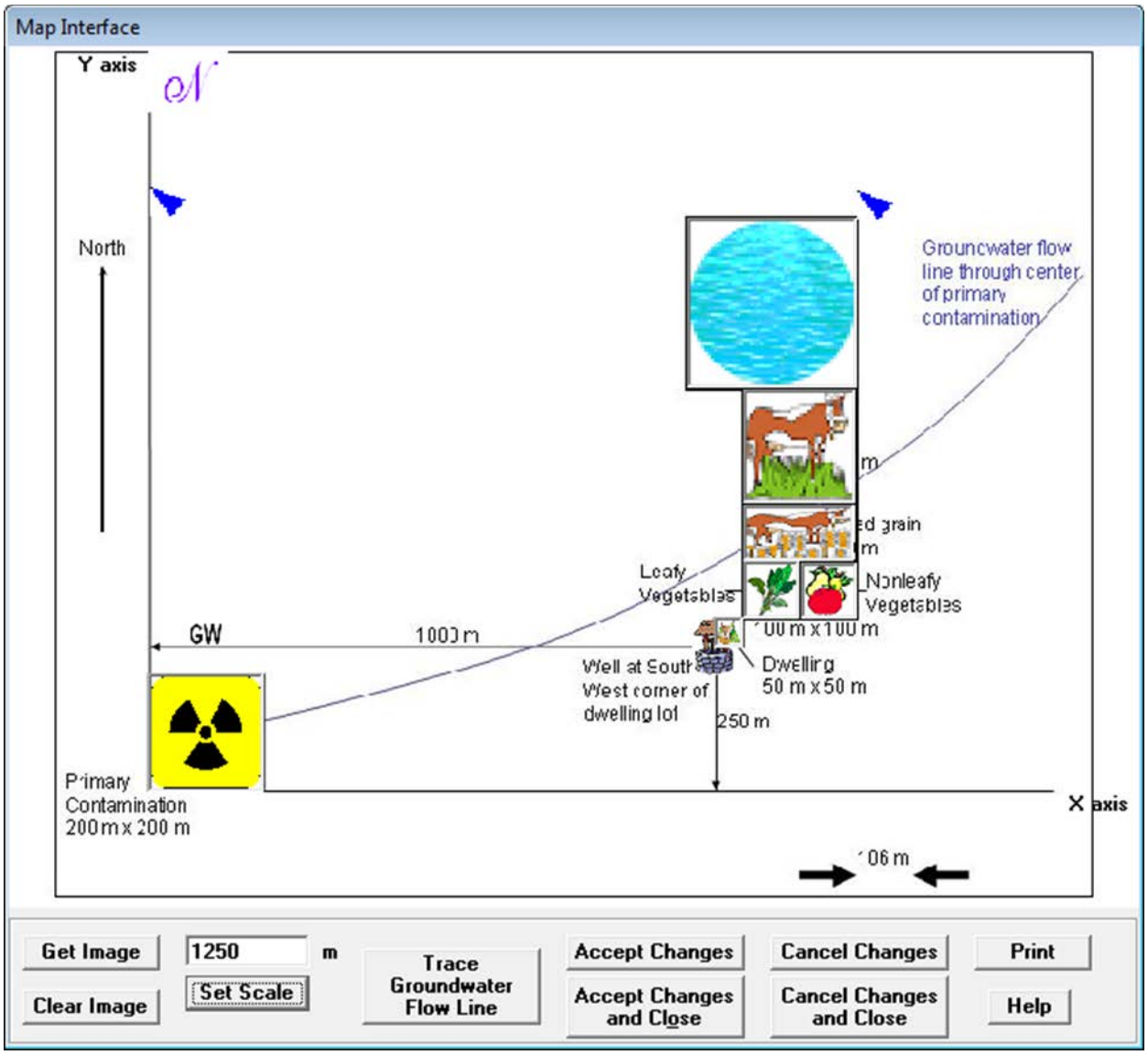

Figure 4-37 Locating and Sizing the Offsite Icons on the Map Interface

Step 6 (in detail): Click on the Trace Groundwater Flow Line command button, if the path of the groundwater flow line through the center of the primary contamination is available. The icons representing the various locations will be removed, providing a clutter-free map on which to trace the flow line (Figure 4-38). A curved groundwater flow line must be approximated by up to 10 linear segments. Use the following procedure to trace the curved path on the map interface.

- Grab the large GW icon and move it to the first approximately linear portion of the flow line; the small GW icon is anchored to the center of the primary contamination and cannot be moved.

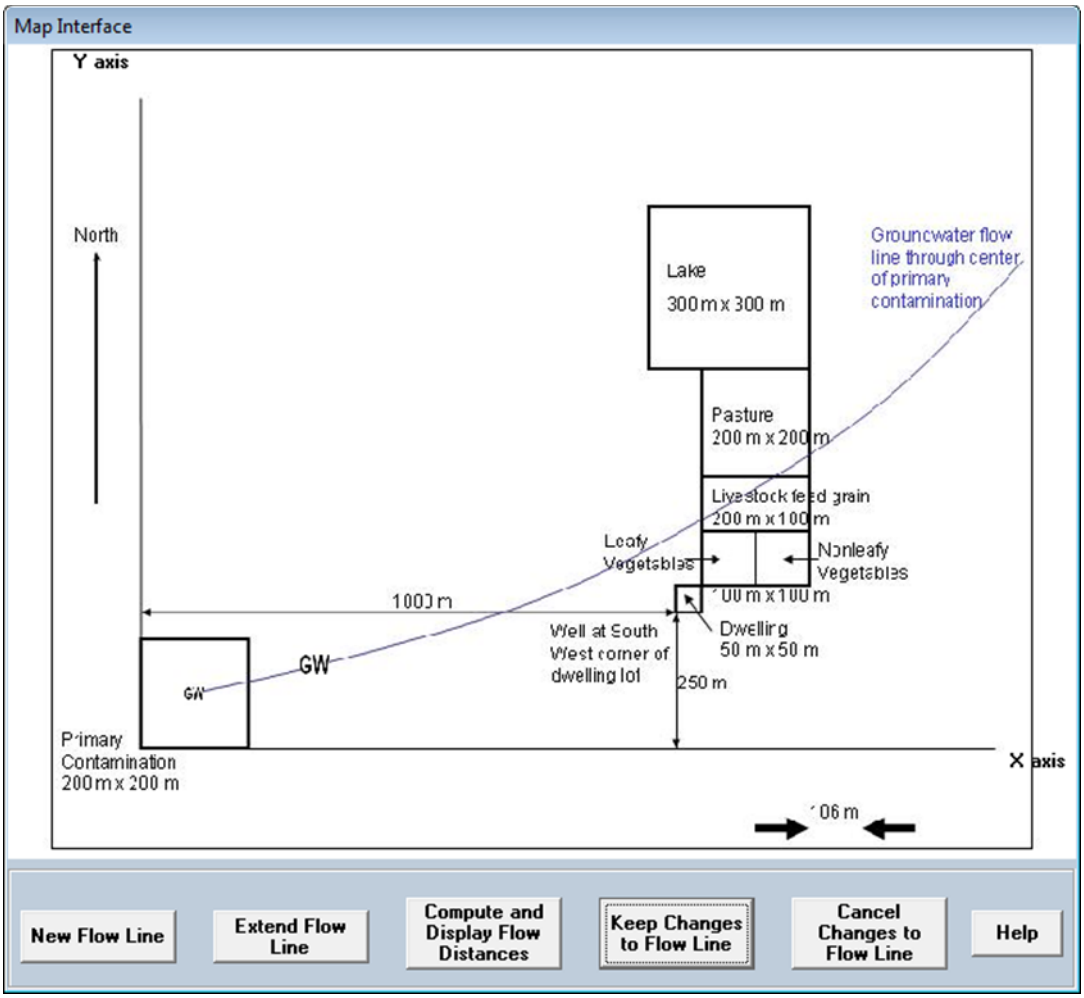

Figure 4-38 Tracing a Groundwater Flow Line on the Map Interface, First Segment

- Click on the Extend Flow Line command button to fix the position of the GW icon that you just moved and use it to define the next linear approximation of the flow line; grab and move the new large GW icon to define the second approximately linear portion of the flow line. Continue in this fashion to define the flow line with up to 10 linear segments (Figure 4-39).

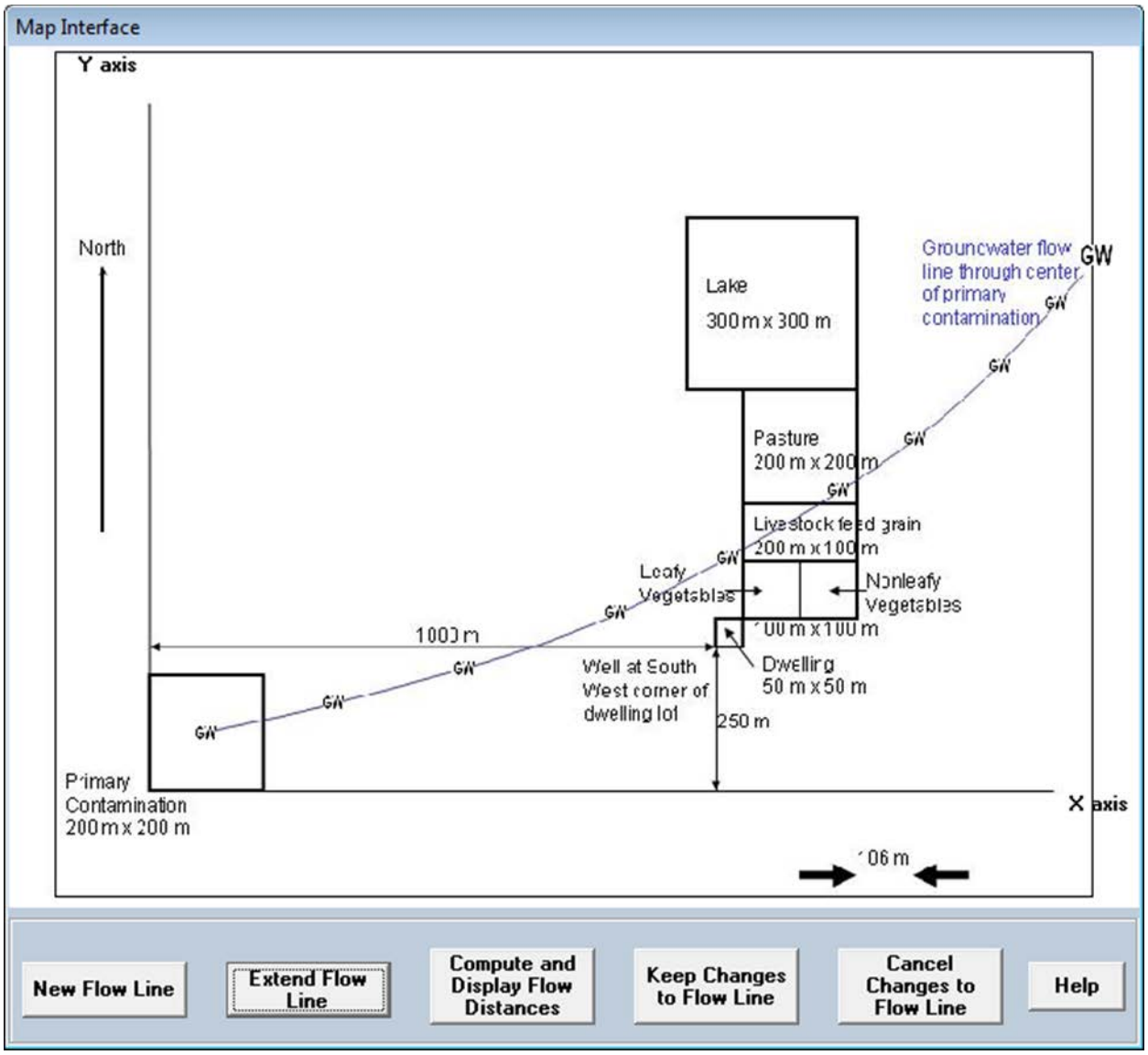

Figure 4-39 Tracing a Groundwater Flow Line on the Map Interface, Last Segment

- Click on the Compute and Display Flow Distances command button, if you wish to see the lengths and locations of the transport distances. If not, skip to the next step.

The transport distances to the well and the surface water body will be displayed on top of the corresponding icons (Figure 4-40).

- Click on the Well option and then on the up-down arrow control to see the bottom of the perpendicular from the well to the flow line. If it is possible to draw perpendiculars from the well to more than one of the line segments, the up-down arrow control can be used to scroll over all these possibilities and to view the corresponding distances.

- The same procedure can be repeated after clicking on the Surface Water Body option to see the bottom of the perpendicular from the center of the surface water body to the flow line.

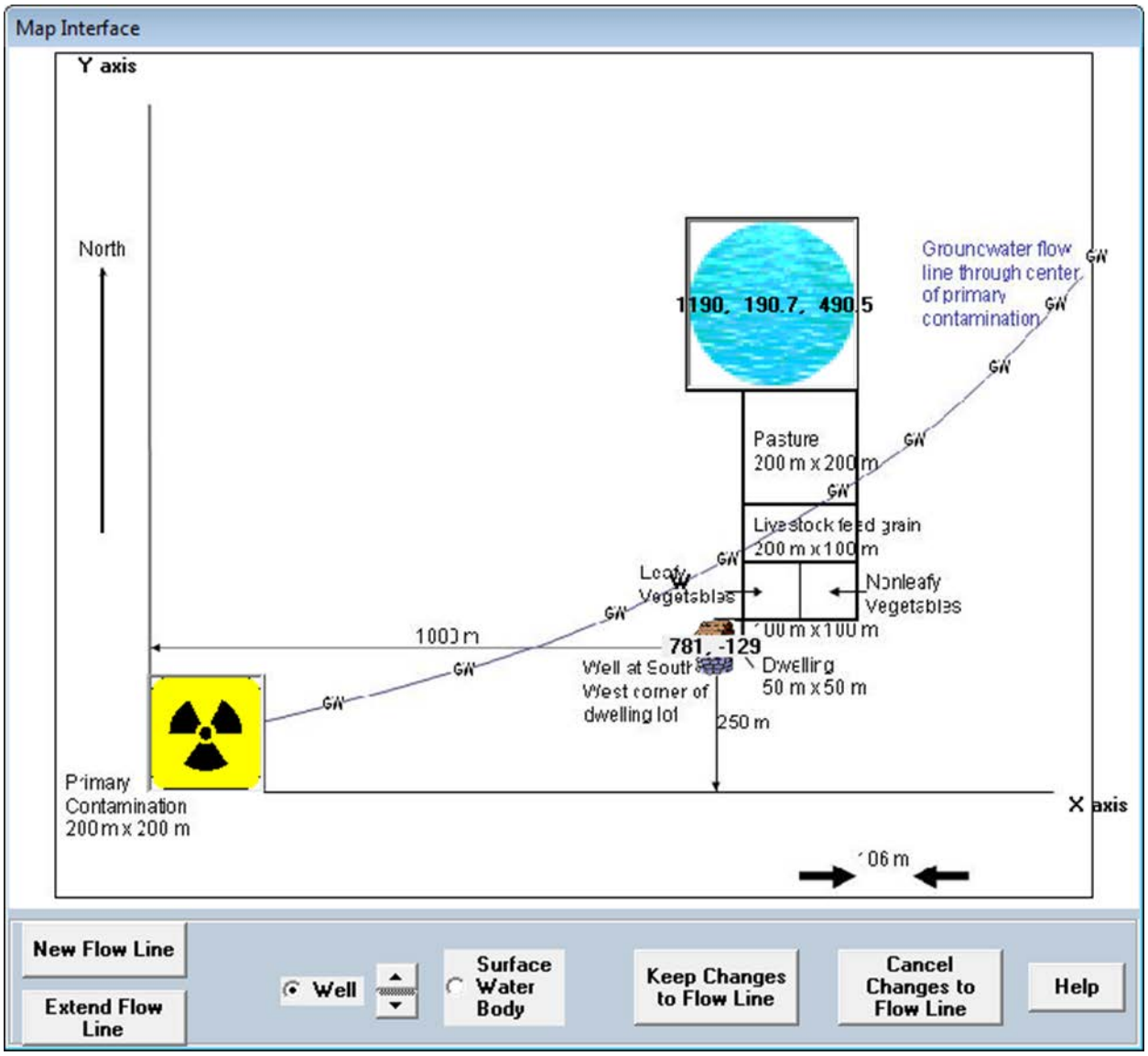

Figure 4-40 Groundwater Transport Distances Computed by Map Interface

- Click on the Keep Changes to Flow Line button (Figure 4-40) to preserve the flow line that was defined in the preceding steps and to return to the view of the map that displays all the icons.

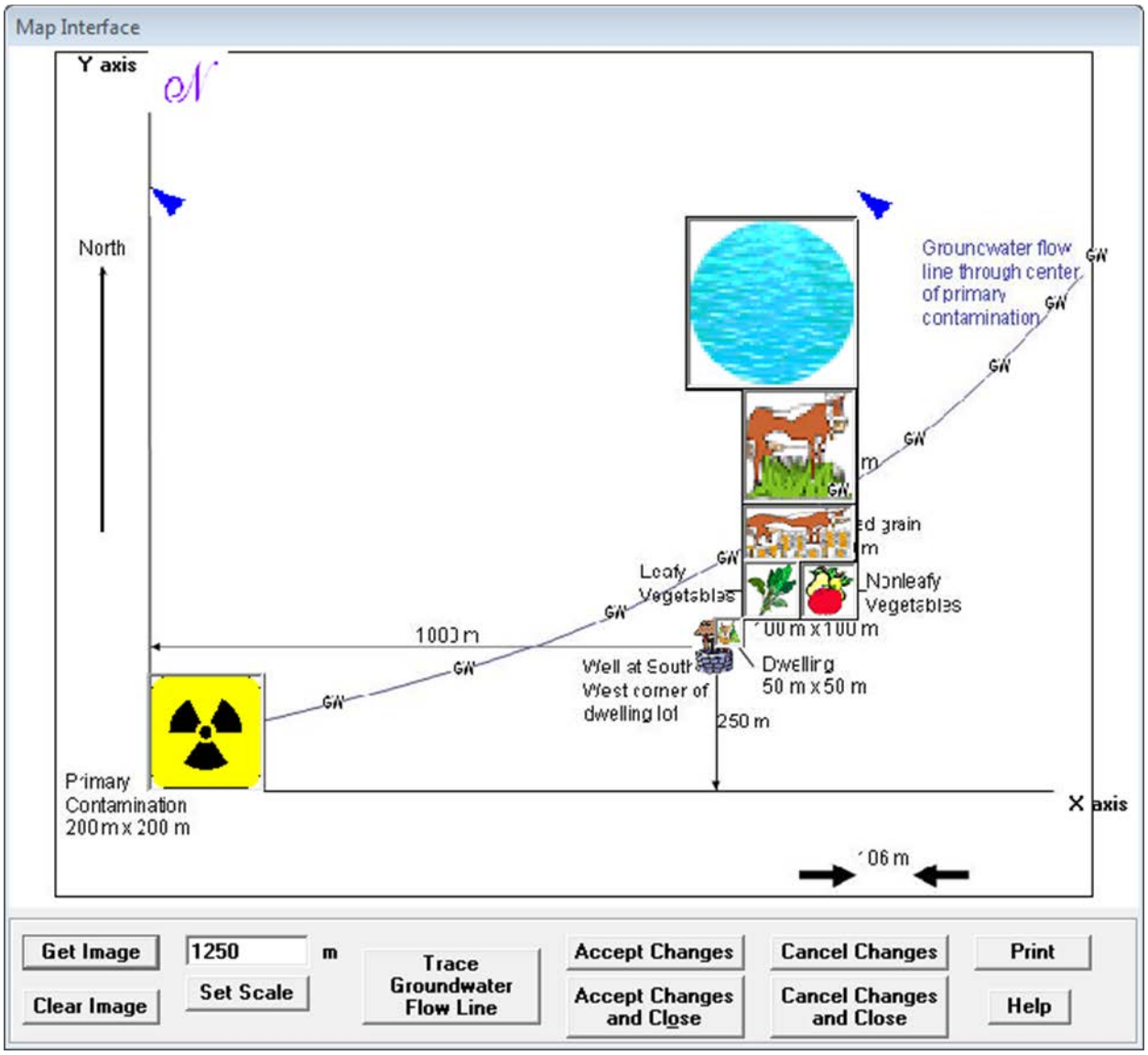

Figure 4-41 Fully Defined Map Interface

Step 7 (details): Be sure to click on either of the Accept Changes buttons (Figure 4-41) if you want to save all the locations and directions that you defined in the map interface.

- The location and transport distances specified in the map interface will be transferred to the appropriate forms when changes are accepted. These forms include the Site Layout form (Section 4.12), the Primary Contamination form (Section 4.15), the Groundwater Transport Parameters form (Section 4.23), and the External Radiation Shape and Area Factors form (Section 4.29). The numbers that were transferred to the Site Layout form for this example are shown in Figure 4-42 to illustrate their deviations from the dimensions used to draw the figure. These deviations occur because of the difficultly of placing the location and scale icons exactly in the correct positions.

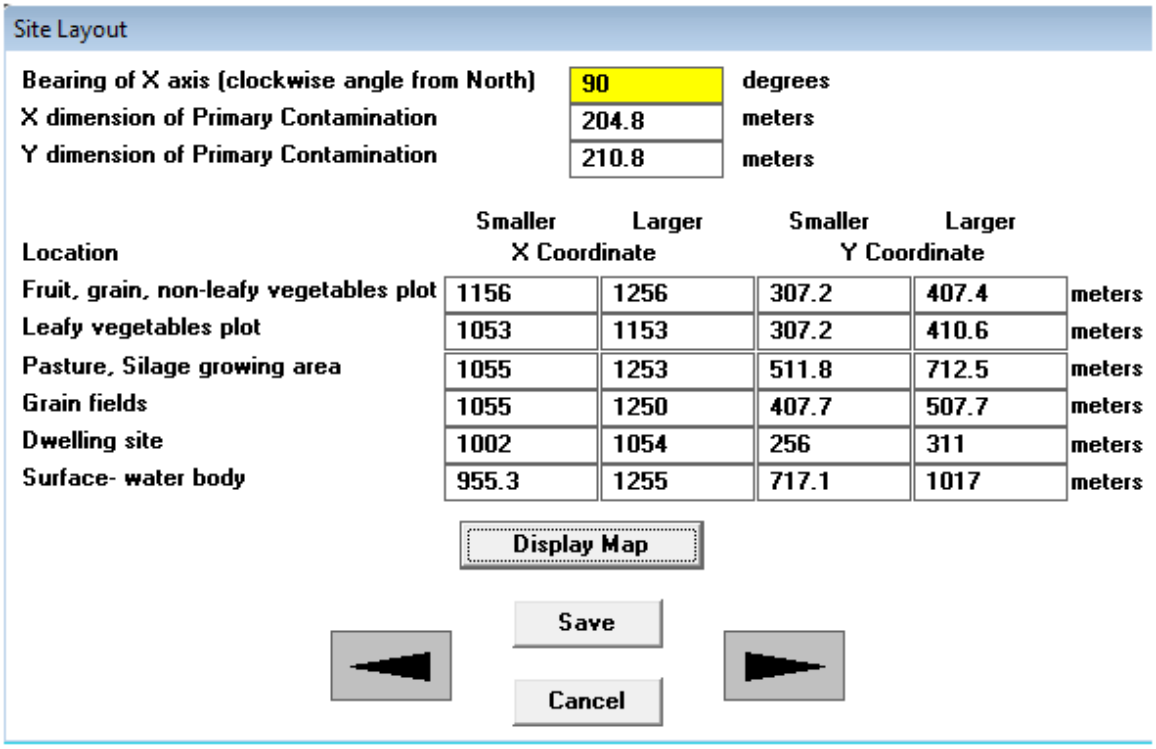

Figure 4-42 Site Layout Form-2

Any changes made in the map interface since they were last accepted will be lost if you click on either of the two Cancel Changes buttons (Figure 4-41).

Step 8 (details): The image location, scale, and object locations will be written to the input file when the RESRAD-OFFSITE file is saved. This information is used to display the map image and the icons when the input file is opened later. If the input file is being sent to a different computer, the image files should also be sent in order for it to be displayed on that computer. The Get Image command may need to be used on the receiving computer after opening the input file, if the structures and/or the names of the RESRAD-OFFSITE directories are different on the two computers. If the image file is not sent, the image of the map cannot be displayed; however, the icons will be in their specified locations, so the analysis will yield the same results.

4.14 Physical and Hydrological Parameters

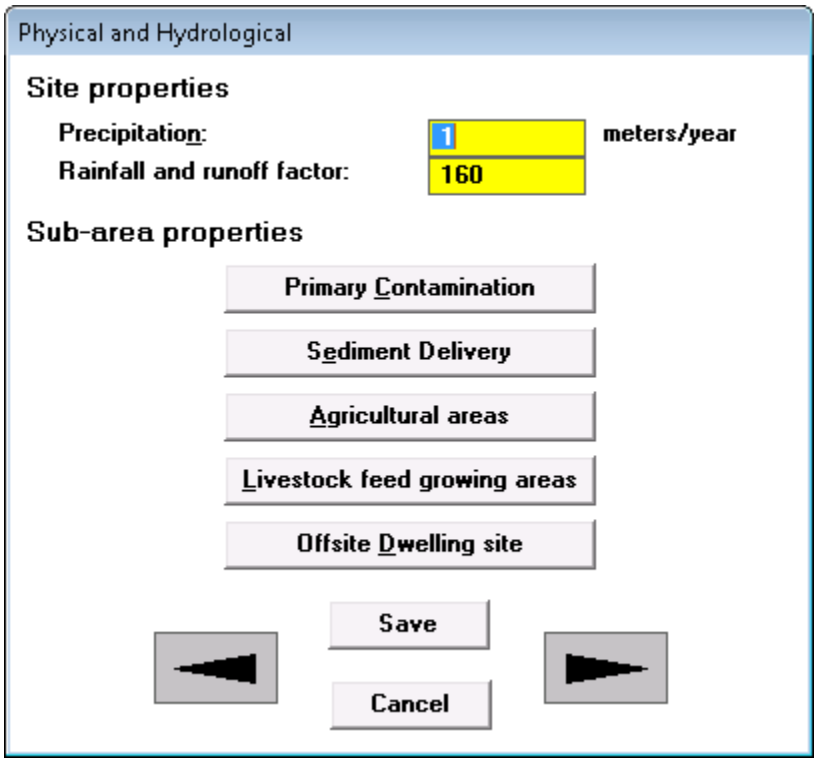

Figure 4-43 Physical and Hydrological Properties Form

Uncertainty and sensitivity analysis can be performed on the parameters listed on the Physical and Hydrological Properties form (Figure 4-43).

Precipitation: This is the annual average value of precipitation at the site. It is used to compute the infiltration rate in the primary contamination, the leach rates in all areas, and the evapotranspiration of tritium. The leach rate is used to compute contaminant concentration in soil in the agricultural, pasture, and dwelling areas and, in some cases, at the primary contamination site. The infiltration rate affects the rate of transport through the unsaturated zone and in the primary contamination.

Rainfall and Runoff Factor: This is a measure of the energy of the rainfall. It is used to compute the erosion rates of the primary contamination, of any cover above the primary contamination, and of the mixing layer at the offsite locations.

Accessing Other Related Forms

The five command buttons on this form (Figure 4-43), Primary Contamination, Sediment Delivery, Agricultural Areas, Livestock Feed Growing Areas, and Offsite Dwelling Site, provide access to the five forms that specify the physical and hydrological data on primary contamination and on the five subareas (see Sections 4.15, 4.16, 4.17, and 4.18). Clicking on any of these five buttons opens the respective form. The current parent form will not be closed and will remain in the background, and it will appear again when the other form is exited. Alternatively, the first form can be opened by clicking on the forward arrow button on this form;

the other four forms can be accessed by continuing to use the forward arrow buttons on the successive forms.

4.15 Primary Contamination

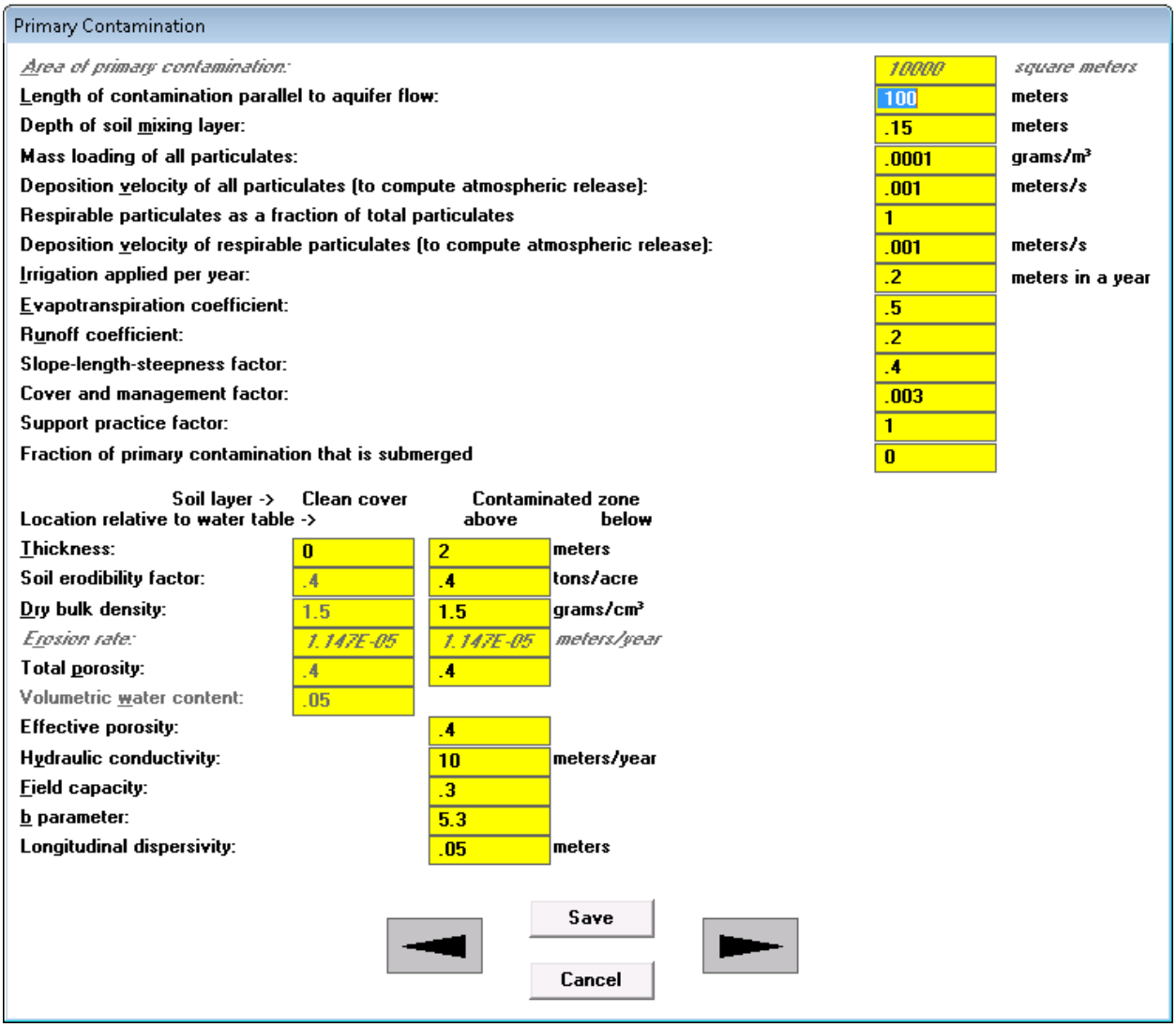

Figure 4-44 Primary Contamination Form-1

Uncertainty and sensitivity analysis can be performed on any parameter that is an input on the Primary Contamination form. The Primary Contamination form shown in Figure 4-44 relates to when the conceptualization of primary contamination uses the RESRAD-ONSITE Exponential Release model or the initial activity is specified based on the mass of the entire primary contamination. Parameters that are not inputs to the code are shown in gray italics for information only.

Area of Primary Contamination: This is not a direct input; it is computed using the information input in the Site Layout form. The primary contamination is a compact area that contains the locations of all soil samples with radionuclide concentrations that are clearly (i.e., two standard deviations) above background.

Length of Contamination Parallel to Aquifer Flow: This is the distance between two parallel lines that are perpendicular to the direction of the aquifer flow: one at the upgradient edge of the contaminated zone and the other at the downgradient edge. It is used in groundwater transport calculations. The code computes this value from the information input in the map interface. The user can change the value computed by the code. The connection between this form and the map interface is one-directional; the information entered in this form will not affect the map interface.

Depth of Soil Mixing Layer: This is the thickness of the surface soil at the location of the primary contamination, which may be assumed to be mixed uniformly from time to time as a result of anthropogenic or physical processes. It is used to calculate the concentration of contaminants in surface soil.

Mass Loading of All Particulates: This is the average mass of all particulates in a unit volume of air above the primary contamination. It is used to compute the rate of release of particulates from the primary contamination and the rate of release of radionuclide associated with the release of those particulates.

Deposition Velocity of All Particulates (to compute atmospheric release): This is the representative deposition velocity of all particulates at the location of primary contamination. It is used to compute the release rate of all particulates from the primary contamination to the atmosphere and the rate of release of radionuclide associated with the release of those particulates.

Respirable Particulates as a Fraction of Total Particulates: This is the mass fraction of respirable particulates/total particulates in the air at the primary contamination. It is used to compute the rate of release of radionuclide associated with the release of respirable particulates.

Deposition Velocity of Respirable Particulates (to compute atmospheric release): This is the representative deposition velocity of respirable particulates at the location of primary contamination. It is used to compute the release rate of respirable particulates from the primary contamination to the atmosphere.

The next three inputs and the precipitation rate are used to compute the infiltration rate and the evapotranspiration of tritium from the primary contamination. They affect all releases from the primary contamination as well as the transport rate through the unsaturated layers.

Irrigation Applied per Year: This is the volume of irrigation water that is applied over a period of 1 year per unit area of land. It is not the actual rate of irrigation during the growing season; instead, it is the irrigation rate averaged over 1 year.

Evapotranspiration Coefficient: This is the fraction of precipitation and irrigation water that penetrates the topsoil which is lost to the atmosphere by evaporation and by transpiration by vegetation.

Runoff Coefficient: This is the fraction of precipitation that does not penetrate the topsoil, and instead leaves the area of concern as surface runoff; no loss is assumed for irrigation water.

The next five inputs are used to compute the rate of erosion. Erosion rate is not an input in RESRAD-OFFSITE; it is displayed for the information of users.

Slope-Length-Steepness Factor: This factor accounts for the effect the profile of the terrain has on the erosion rate.

Cover and Management Factor: This factor (formerly called the Cropping-Management Factor) accounts for the effects land use, vegetation, and management have on the erosion rate.

Support Practice Factor: This factor (formerly called the Conservation Practice Factor) accounts for the effects conservation practices have on the erosion rate.

Dry Bulk Density (of soil in the contaminated zone and in clean cover): This is the mass of (dry) solids in a unit volume of soil in the respective layers of soil. In addition to being used to compute the erosion rate, this is also used to compute the exposure to external radiation. The density in the contaminated zone is also used to compute the release to groundwater, and thus the concentration in the primary contamination.

Soil Erodibility Factor: This is a measure of the susceptibility of the soil to erosion.

Fraction of Primary Contamination That Is Submerged: Part or all of the primary contamination can be below the water table. A fully submerged primary contamination is constrained to have its top surface at the water table. When a non-zero value is entered for the submerged fraction, the code will set the number of unsaturated zones to zero and will disable that input.

Thickness (of contaminated zone): This is the distance (in meters [m]) between the uppermost and lowermost soil samples with radionuclide concentrations that are clearly (i.e., two standard deviations) above background.

Thickness (of clean cover): This is the distance from the ground surface to the location of the uppermost soil sample with radionuclide concentrations that are clearly above background.

Total Porosity (of contaminated zone and clean cover): This is the fraction of soil (by volume) that is occupied by liquid and gaseous phases in the respective layers.

Field Capacity (of contaminated zone): This is the volumetric moisture content of soil at which (free) gravity drainage ceases. This is the amount of moisture that will be retained in a column of soil against the force of gravity. It serves as the lower bound for the total volumetric moisture content.

b Parameter (of contaminated zone): The soil-specific exponential b parameter relates the hydraulic conductivity of partially saturated soil to its moisture content.

Hydraulic Conductivity (of contaminated zone): This is the apparent flow velocity through the contaminated zone under a unit hydraulic gradient.

Effective Porosity: This is the fraction of soil (by volume) through which water flows. Part of the soil moisture may not contribute to the movement of contaminants. Therefore, the effective porosity will be less than or equal to the total porosity.

Longitudinal Dispersivity: This is the ratio between the longitudinal dispersion coefficient and pore water velocity. It has the dimension of length. This parameter depends on the thickness of the zone and ranges from one one-hundredth of the thickness to the order of the thickness.

Volumetric Water Content (of clean cover): This is the fraction of soil (by volume) that is occupied by water.

The Primary Contamination form shown in Figure 4-45 is displayed when the "Specify initial activity based on mass of contaminated medium option" is selected in the Preliminary Inputs form, Section 4.2. This form also requires the total mass and volume of contaminated medium.

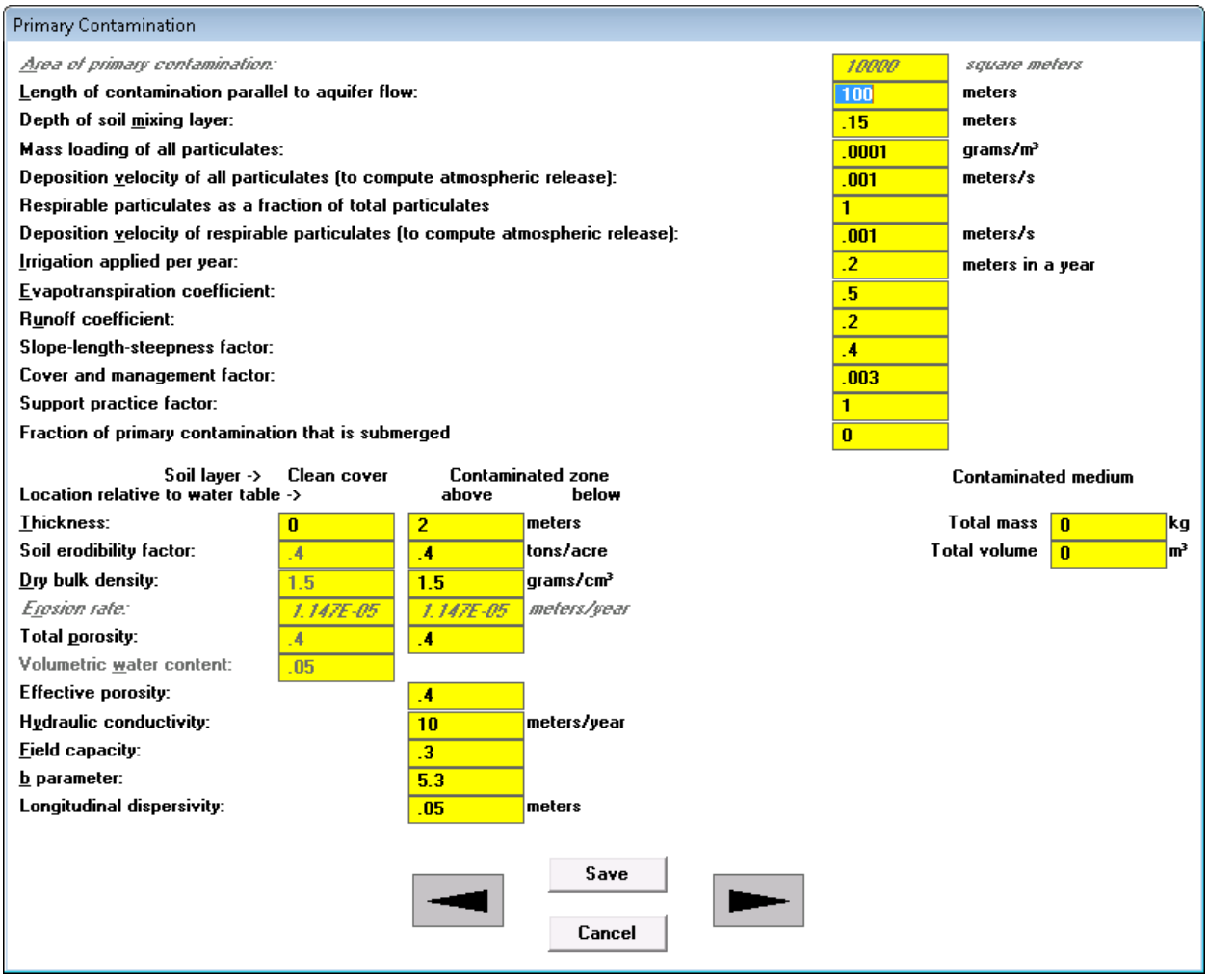

Figure 4-45 Primary Contamination Form-2 (for Initial Activity Based on Mass of Contaminated Medium)

Figure 4-46 shows the Primary Contamination form when the diffusive transport out of the contaminated medium option is selected in the Preliminary Inputs form, Section 4.2. This form requires total mass, total volume, and volumetric water content for the contaminated medium, and has the dimensions of an individual fragment of contaminated medium.

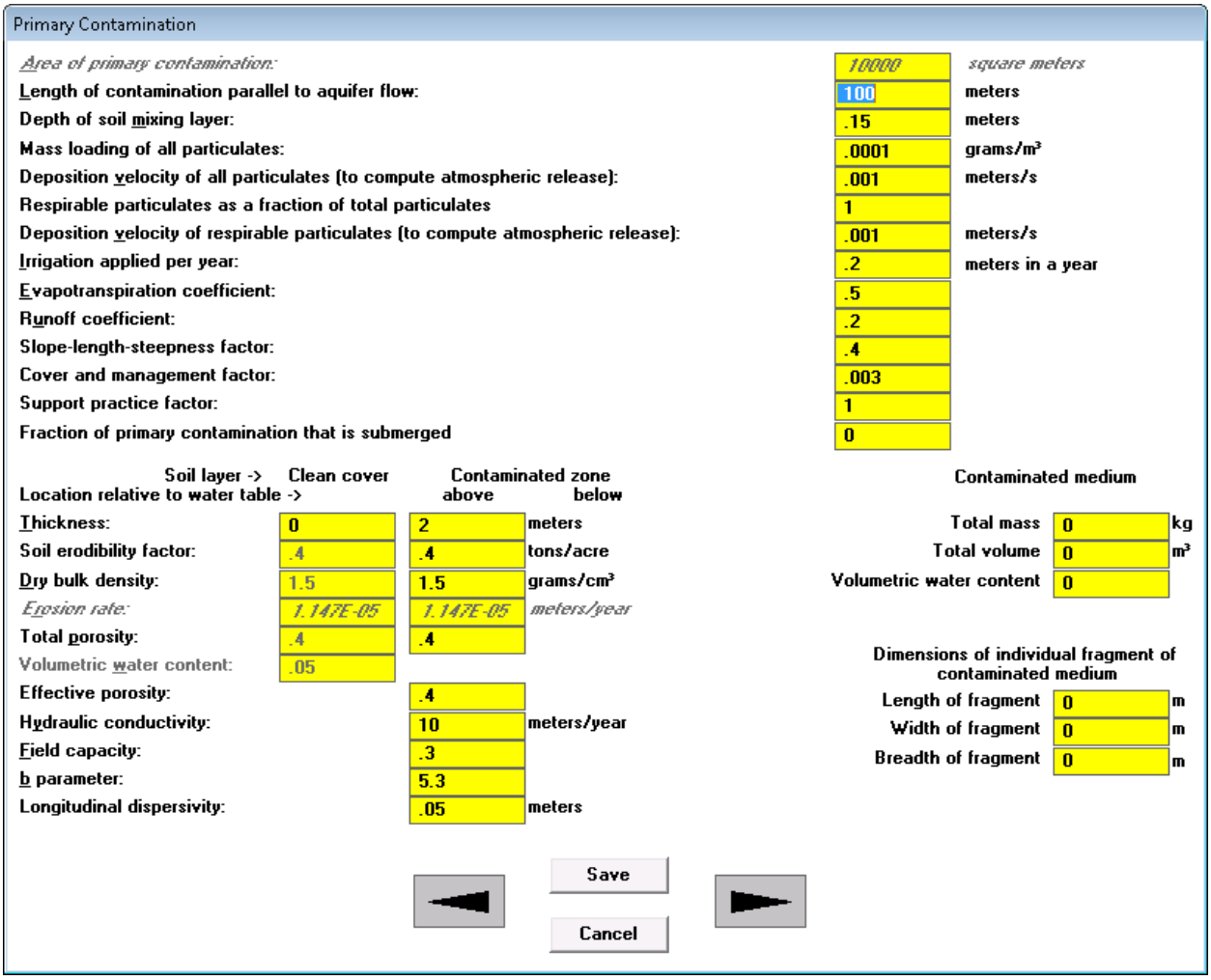

Figure 4-46 Primary Contamination Form-3 (for Diffusive Transport Out of Contaminated Medium)

4.16 Fate of Material Eroded from the Primary Contamination by Runoff

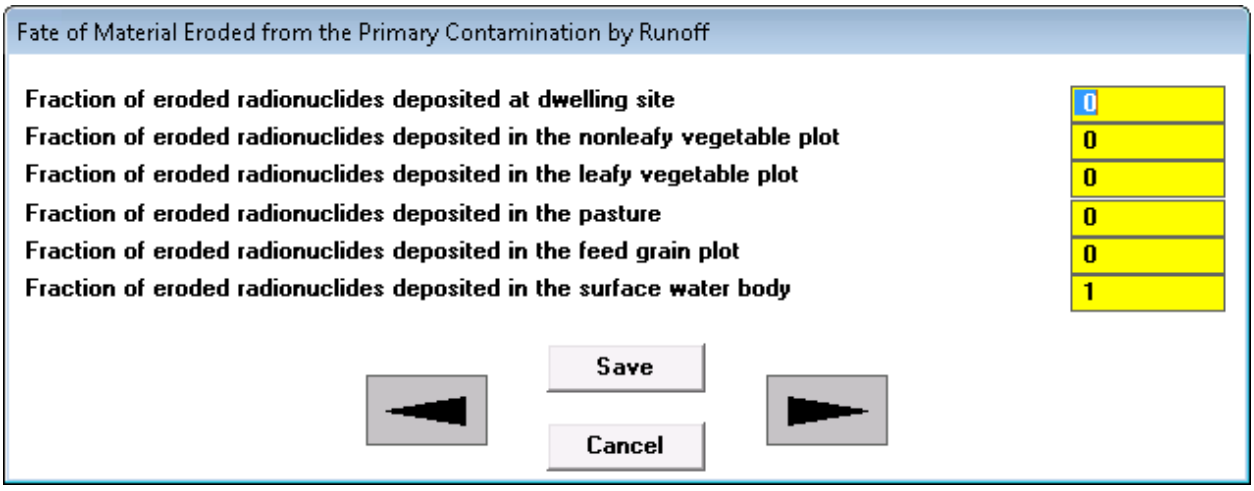

Figure 4-47 Fate of Material Eroded from the Primary Contamination by Runoff Form

Uncertainty and sensitivity analysis can be performed on any parameter that is an input on this form (Figure 4-47).

Fraction of Eroded Radionuclides Deposited at Dwelling Site: This is the fraction of the contaminated soil that was eroded from the area of primary contamination that is deposited at the dwelling site.

Fraction of Eroded Radionuclides Deposited in the Nonleafy Vegetable Plot: This is the fraction of the contaminated soil that was eroded from the area of primary contamination that is deposited at the nonleafy vegetable plot.

Fraction of Eroded Radionuclides Deposited in the Leafy Vegetable Plot: This is the fraction of the contaminated soil that was eroded from the area of primary contamination that is deposited at the leafy vegetable plot.

Fraction of Eroded Radionuclides Deposited in the Pasture: This is the fraction of the contaminated soil that was eroded from the area of primary contamination that is deposited at the pasture field.

Fraction of Eroded Radionuclides Deposited in the Grain Field Plot: This is the fraction of the contaminated soil that was eroded from the area of primary contamination that is deposited at the grain field plot.

Fraction of Eroded Radionuclides Deposited in the Surface Water Body: This is the fraction of the contaminated soil that was eroded from the area of primary contamination that reaches the surface water body.

4.17 Agricultural Areas and Livestock Feed Growing Areas: Physical and Hydrological Data

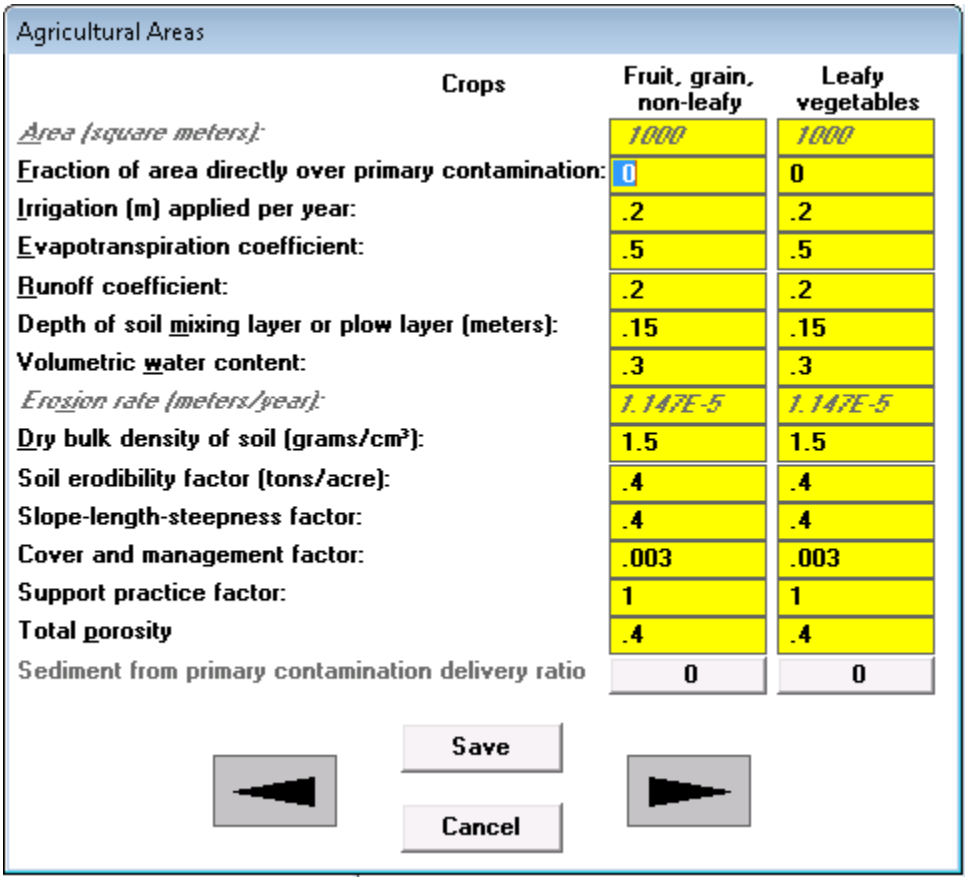

Figure 4-48 Agricultural Areas Form

Uncertainty and sensitivity analysis can be performed on any parameter that is an input on the Agricultural Areas and Livestock Feed Growing Areas forms (Figure 4-48 and Figure 4-49).

Area: This is the area of agricultural land on which the crop is cultivated, or the pasture land on which the livestock are allowed to feed. This is not a direct input but is computed based on the information input in the Site Layout form.

Fraction of Area Directly over the Primary Contamination: This is the areal fraction of the agricultural or pasture land that lies directly above the primary contamination. If the entire area is completely on the contamination, the fraction is one; if the entire area is away from the region of primary contamination, the fraction is zero. This fraction is used to account for direct root uptake of contaminants from the primary contamination.

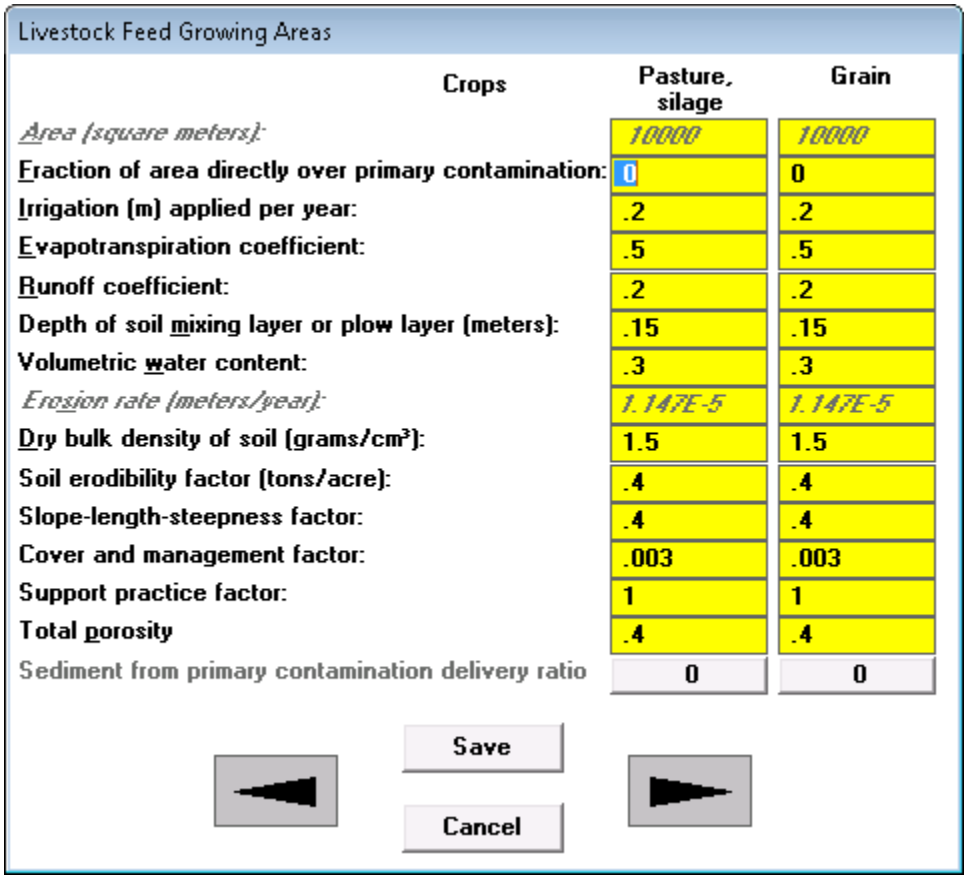

Figure 4-49 Livestock Feed Growing Areas Form

Irrigation Applied per Year: This is the volume of irrigation water that is applied over a period of 1 year per unit area of land. It is not the actual rate of irrigation during the growing season; it is the irrigation rate averaged over 1 year.

Evapotranspiration Coefficient: This is the fraction of precipitation and irrigation water that penetrates the topsoil and is lost to the atmosphere due to evaporation and transpiration by vegetation.

Runoff Coefficient: This is the fraction of precipitation that does not penetrate the topsoil but leaves the area of concern as surface runoff; no loss is assumed for irrigation water.

Depth of Soil Mixing Layer or Plow Layer: This is the thickness of the surface soil which may be assumed to be mixed uniformly from time to time as a result of anthropogenic or physical processes. It is used to calculate offsite accumulation.

Volumetric Water Content of Soil: This is the fraction of soil moisture by volume.

Dry Bulk Density of Soil: This is the mass of solids in a unit volume of soil.

Soil Erodibility Factor: This is a measure of the susceptibility of the soil to erosion.

Slope-Length-Steepness Factor: This factor accounts for the effect the profile of the terrain has on the erosion rate.

Cover and Management Factor: This factor (formerly called the Cropping-Management Factor) accounts for the effects land use, vegetation, and management have on the erosion rate.

Support Practice Factor: This factor (formerly called the Conservation Practice Factor) accounts for the effects conservation practices have on the erosion rate.

Total Porosity: This is the fraction of soil (by volume) that is occupied by liquid and gaseous phases.

Sediment from Primary Contamination Deliver Ratio: This command button displays the value entered in the Fate of Material Eroded from the Primary Contamination form, Section 4.16. That form will be displayed when this button is clicked.

4.18 Offsite Dwelling Area: Physical and Hydrological Data

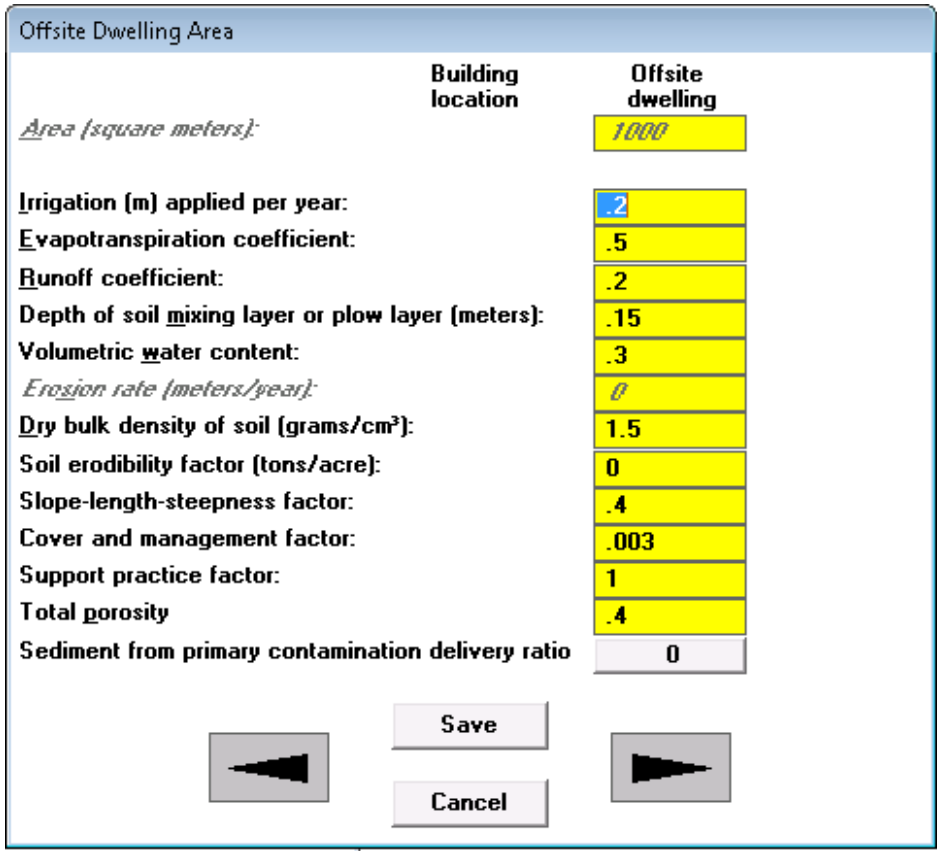

Figure 4-50 Offsite Dwelling Area Form

Uncertainty and sensitivity analysis can be performed on any parameter that is an input on the Offsite Dwelling Area form (Figure 4-50). The descriptions for most of these parameters are the same as the descriptions for the agricultural and pasture lands forms in Section 4.17.

Area: This is the area of the plot of land on which the offsite dwelling is located. This is not a direct input but is computed based on the information input in the Site Layout form.

Irrigation Applied per Year: This is the volume of irrigation water that is applied to the lawn or home garden over a period of 1 year per unit area of land.

4.19 Atmospheric Transport

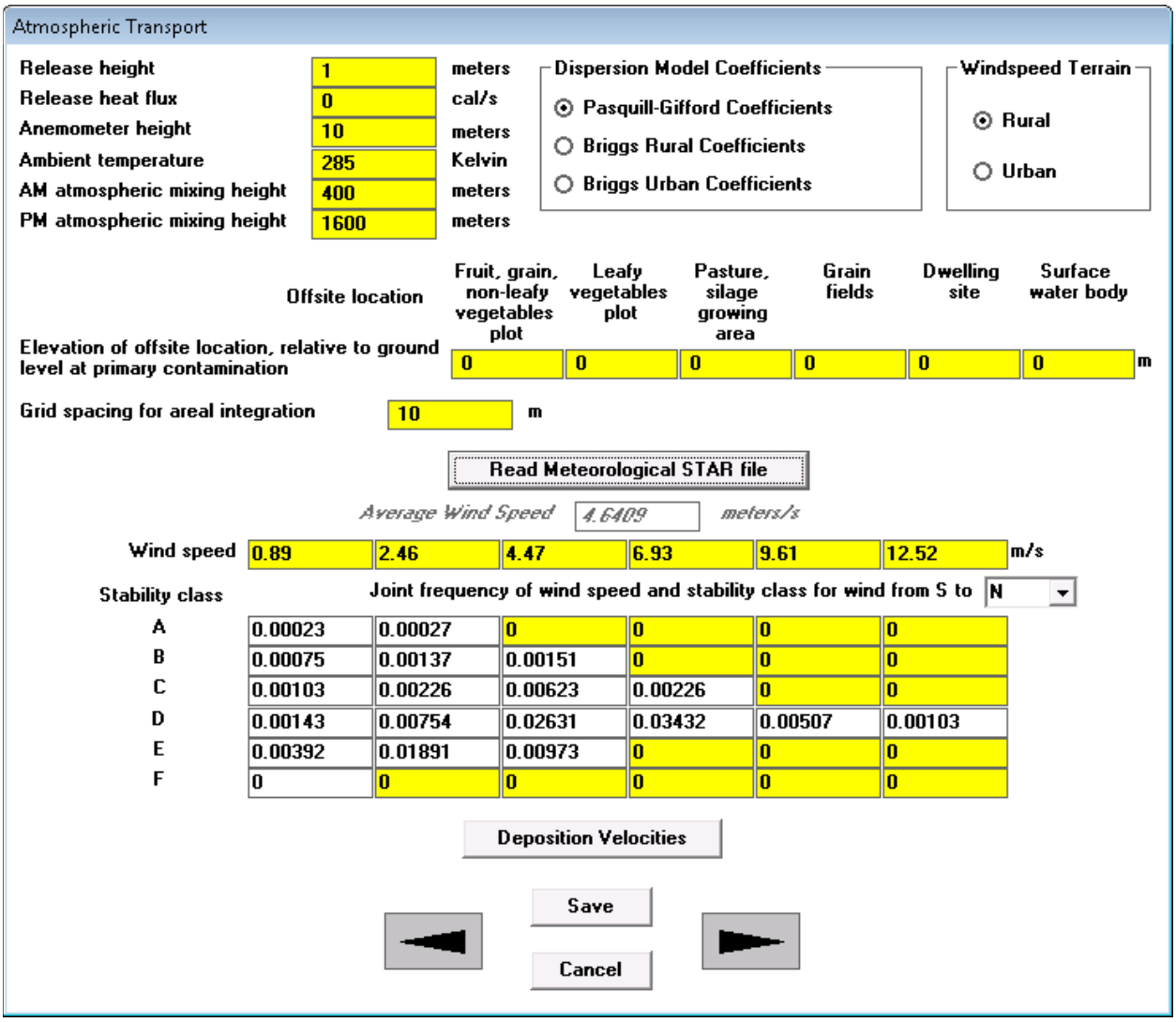

Figure 4-51 Atmospheric Transport Form

Uncertainty analysis can be performed on all but the following parameters on the Atmospheric Transport parameters form (Figure 4-51): Grid spacing for areal integration, the joint frequency, and the two parameters involving choices. One-parameter-at-a-time sensitivity analysis can be performed on all but the two parameters involving choices. The code will not check whether the sum of the frequencies of the joint frequency distribution equals one when one-parameter-at-a-time sensitivity analysis is performed on a joint frequency.

Release Height: This is the height of the release above the ground level at that location.

Release Heat Flux: This is the heat energy that accompanies the contaminant release. It is used to account for the rise of the plume.

Anemometer Height: This is the height at which the wind speed was measured.

Ambient Temperature: This is the temperature of the air at the location of release.

AM and PM Atmospheric Mixing Heights: The atmospheric mixing height is the thickness of the layer of air that is bounded by the ground surface and a layer of stable air above it. The spreading of the contaminants is limited to the thickness of the mixing layer. AM and PM refer to the portion of the day during which the measurement was taken.

Dispersion Model Coefficients: This is the formulation used to generate the dispersion coefficients for the atmospheric transport model.

Wind Speed Terrain: The choice of terrain determines the relationship between the wind speed and the elevation above the ground surface.

Elevation of Offsite Location, Relative to the Ground Level at Primary Contamination: When the ground level at the offsite location is above the ground level at the site of primary contamination, the code adjusts for the upward deflection of the wind. It is the difference in the height of the ground surface at the offsite location of contaminant accumulation and the height of the ground surface at the site of primary contamination.

Grid Spacing for Areal Integration: The primary contamination and the offsite receptor areas are assumed to be rectangular in shape (as defined in Section 4.12) when modeling the atmospheric transport. Rather than use a single transport distance from the center of the source to the center of the receptor, the code provides the option to subdivide the source and receptor areas into smaller squares or rectangles. The transport from each subdivision of the source to each subdivision of the offsite receptor area is computed and summed together to produce a better estimate of the atmospheric transport. A smaller grid spacing improves the accuracy of the calculations but requires a longer computation time. This input is the maximum dimension of each subdivided rectangle.

Read Meteorological STAR File: This button is used to select the data file that contains the joint frequency distribution of the wind speed and stability class in STAR format. Files containing the meteorological data at a number of airports are placed in the …\metfiles\ subdirectory during installation. This subdirectory also has two files containing the default joint frequency distributions for the RESRAD-OFFSITE and RESRAD-ONSITE default cases.

Average Wind Speed: When a STAR file is read, the code computes the average wind speed for that file and shows it in the corresponding input box. The input box is enabled when RESRAD-ONSITE is simulated and the user can enter an average wind speed or change the calculated value.

Wind Speed: This is the representative wind speed for the wind speed class interval. The joint frequency data in STAR format uses 6 wind speed intervals.

Joint Frequency of Wind Speed, Wind Direction, and Stability Class: This is the joint frequency distribution (i.e., it is the fraction of the time during which the atmospheric conditions fall within each wind speed interval, wind direction, and stability class combination). RESRAD-OFFSITE uses six atmospheric stability classes (A through F), six wind speed intervals, and 16 wind directions. If a STAR file containing data for class G is read, the frequencies in class G are added to the corresponding class F frequency. The form displays the joint frequency for the direction specified in the drop-down box. The information for each wind direction can be viewed and edited by selecting the desired direction from the drop-down box. Both the direction from which wind blows and the direction toward which it blows are shown in order to avoid confusion; customarily, wind is identified by the direction from which it blows rather than by the direction toward which it blows. Although only the joint frequency data for wind from one direction can be viewed at a time, the code uses data from all relevant wind directions.

4.20 Water Use

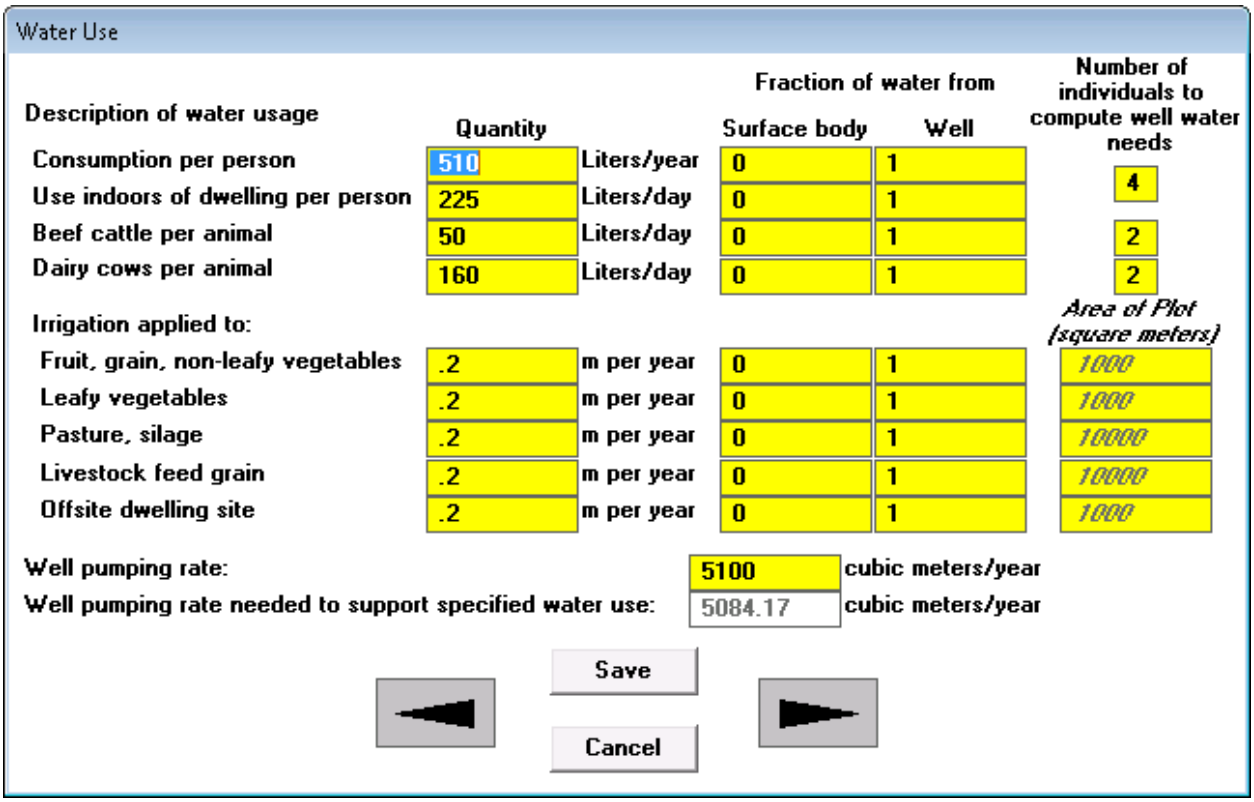

Figure 5-52 Water Use Form

The quantities of water obtained from the two sources of water are the focus of the Water Use form (Figure 4-52). The water needs of humans, livestock, and irrigation are in the first column. The water requirements also appear in other input forms; if they are changed in one form, the other forms will be updated immediately. The second and third columns are the fractions of these water requirements that are obtained from the contaminated surface water body and contaminated well. These fractions can add up to less than one, if water from uncontaminated sources is also used. Uncertainty and sensitivity analysis can be performed on any parameter that is an input on this form except the number of individuals, as noted below. The user must

ensure that the sum of the pair of fractions does not exceed unity when performing uncertainty analysis.

Water Consumption per Person: This is the total amount of water consumed by an individual; it includes water that is used in the preparation of and consumed with food.

Water Used in Dwelling per Person: This is the total amount of water used in the home. It includes water used for cleaning, washing, showering/bathing, and so forth. It is used to compute the dose from waterborne radon.

Water for Beef Cattle: This is the amount of water consumed by each individual animal raised for meat.

Water for Dairy Cows: This is the amount of water consumed by each individual animal raised for milk production.

Number of Individuals: These are the number of persons or livestock that obtain the specified water needs from the water source. These inputs are used only to compute the required minimum well pumping rate and are not used by the computational code. These inputs are not eligible for uncertainty analysis.

Irrigation Applied per Year: This is the volume of irrigation water that is applied over a period of 1 year per unit area of land. It is not the actual rate of irrigation during the growing season; it is the irrigation rate averaged over 1 year.

Well Pumping Rate Needed to Support Specified Water Use: This is the total volume of water that needs to be withdrawn from the well to satisfy the demand described in this form. It is provided to help the user select an appropriate well pumping rate. This value is computed every time a change is made to an input in this form. The well pumping rate is increased automatically, so it will never be less than this minimum required rate.

Well Pumping Rate: This is the rate at which water is extracted from the well. The interface will not accept a well pumping rate that is insufficient to meet the needs specified in this form. While the code performs this check for the deterministic case, the user is responsible for ensuring that this condition is not violated when performing sensitivity or probabilistic/uncertainty analysis.

4.21 Unsaturated Zone Hydrology

Uncertainty and sensitivity analysis can be performed on any parameter on the Unsaturated Zone Hydrology form (Figure 4-53) except the number of unsaturated zones.

Number of Unsaturated Zones: This is the number of partially saturated layers between the primary contamination and the saturated zone. The number of unsaturated zones can be changed only in the Preliminary Inputs form (Section 4.2). The code has provisions for up to five different horizontal strata. Clicking on the button displaying the number of unsaturated zones causes the Preliminary Inputs form to open. Because the distribution coefficients are likely to be different for each zone, the Distribution Coefficient form (Section 4.6) is also opened.

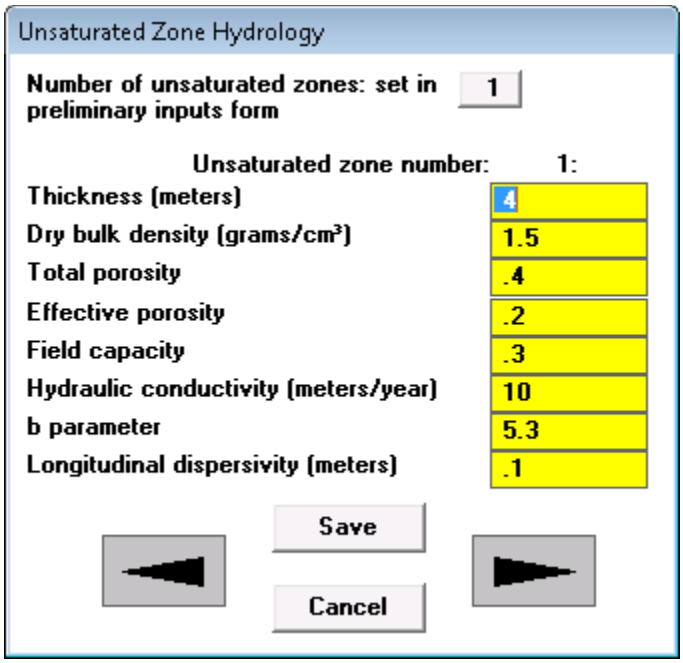

Figure 4-53 Unsaturated Zone Hydrology Form

Thickness: This is the thickness of the specific unsaturated zone.

Dry Bulk Density: This is the mass of solids in a unit volume of soil in the specific unsaturated zone.

Total Porosity: This is the fraction of soil (by volume) that is occupied by liquid and gaseous phases.

Effective Porosity: This is the volume fraction of soil through which water flows. Part of the soil moisture may not contribute to the movement of contaminants.

Field Capacity: This is the volumetric moisture content of soil at which (free) gravity drainage ceases, or the amount of moisture that will be retained in a column of soil against the force of gravity. This is the minimum moisture content of the unsaturated layer in the absence of evapotranspiration and root uptake.

Hydraulic Conductivity: This is the apparent flow velocity of water through the contaminated zone under a unit hydraulic gradient.

b Parameter: The soil-specific exponential b parameter relates the hydraulic conductivity of partially saturated soil to its moisture content.

Longitudinal Dispersivity: This is the ratio between the longitudinal dispersion coefficient and pore water velocity. It has the dimension of length. This parameter depends on the thickness of the zone and ranges from one one-hundredth of the thickness to the order of the thickness.

4.22 Saturated Zone Hydrology

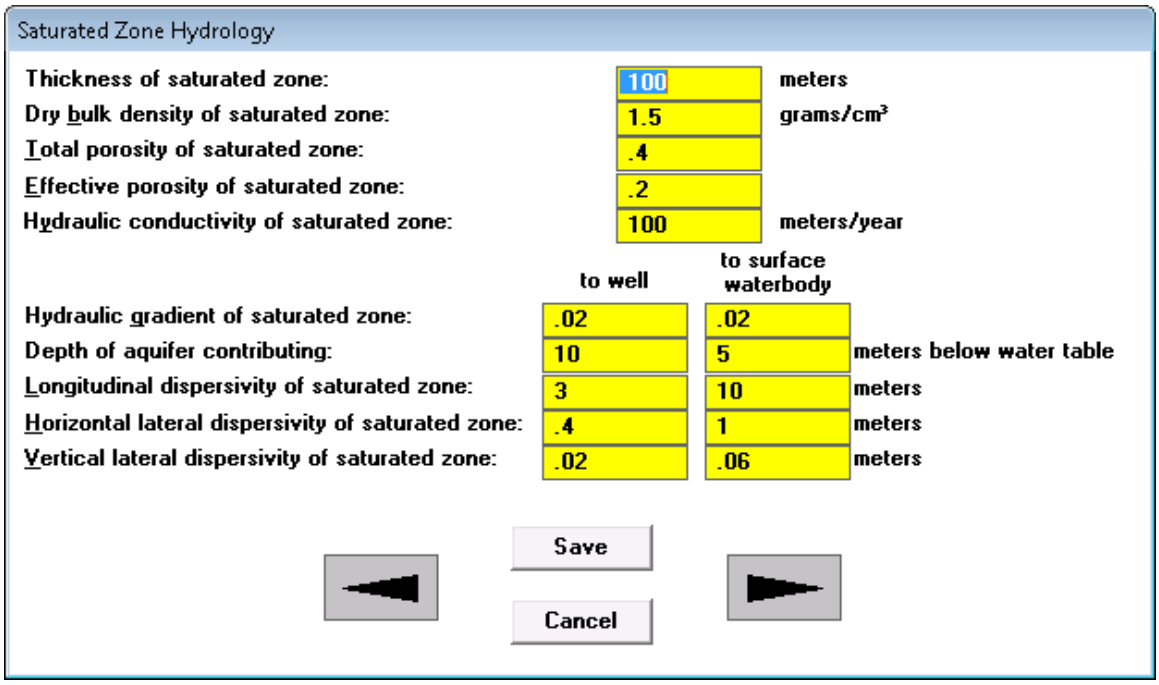

Figure 4-54 Saturated Zone Hydrology Form

Uncertainty and sensitivity analysis can be performed on any parameter whose value can be input on the Saturated Zone Hydrology form (Figure 4-54).

Thickness of Saturated Zone: This is used when the dispersion in the vertical direction in the saturated zone is being modeled. It is also used to check that the total groundwater flow under primary contamination exceeds the inflow from infiltration through the primary contamination.

Dry Bulk Density of Saturated Zone: This is the mass of solids in a unit volume of soil in the specific unsaturated zone.

Total Porosity of Saturated Zone: This is the fraction of soil (by volume) that is occupied by liquid and gaseous phases.

Effective Porosity of Saturated Zone: This is the fraction of soil (by volume) through which water flows. Part of the soil moisture may not contribute to the movement of moisture and contaminants.

Hydraulic Conductivity of Saturated Zone: This is the apparent flow velocity of water through the contaminated zone under a unit hydraulic gradient.

There are two columns for the remaining properties specified in the form, the first for transport from the primary contamination to the well and the second for transport to the surface water body.

Hydraulic Gradient of Saturated Zone: This is the slope of the surface of the water table.

Depth of Aquifer Contributing: Water flowing through the specified depth of the aquifer is assumed to be intercepted by the well or surface water body. This parameter is used to calculate the contaminant concentration in well water or the contaminated flux into the surface water body.

Longitudinal Dispersivity of Saturated Zone: This is the ratio between the longitudinal dispersion coefficient and pore water velocity. It has the dimension of length. This parameter depends on the length of the saturated zone.

Horizontal Lateral Dispersivity of Saturated Zone: This is the ratio between the horizontal lateral dispersion coefficient and pore water velocity. It has the dimension of length.

Vertical Lateral Dispersivity of Saturated Zone: This is the ratio between the vertical lateral dispersion coefficient and pore water velocity. It has the dimension of length.

4.23 Groundwater Transport Parameters

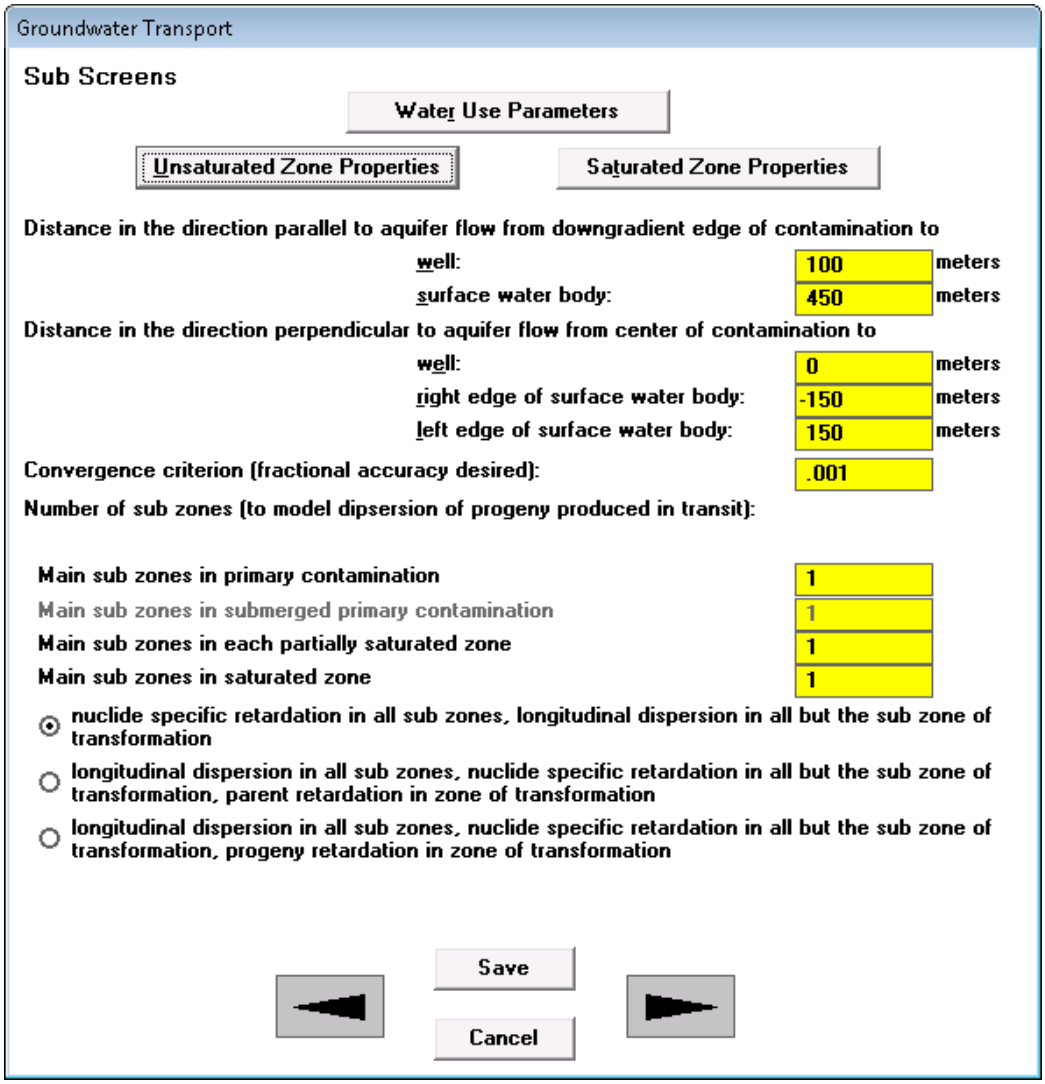

Figure 4-55 Groundwater Transport Form

Sub-Screens (Accessing Other Related Forms)

Three forms can be accessed by using the three buttons listed below. If the forward arrow buttons are being used to access each form in turn, the forms would have been accessed before this Groundwater Transport form (Figure 4-55) and need not be revisited from here.

Unsaturated Zone Properties, Saturated Zone Properties, and Water Use Parameters: These buttons can be used to open the respective forms. The current parent form will not be closed and will remain in the background. It will reappear when the other forms have been exited.

Uncertainty and sensitivity analysis can be performed on the distances that are inputs on this form. One-parameter-at-a-time sensitivity analysis can also be performed on the number of subzones, but not uncertainty analysis. Neither uncertainty analysis nor one-parameter-at-a-time sensitivity analysis can be performed on the convergence criteria. The code will compute the five groundwater transport distances, if the locations of the well and the surface water body relative to the primary contamination were specified in the map interface. The user can change the values computed by the code. The connection between this form and the map interface is one-directional; the information entered in this form will not affect the map interface.

Distance in the Direction Parallel to Aquifer Flow from Downgradient Edge of Contamination to Well: This is the distance (in meters [m]) along a groundwater flow line from the downgradient edge of the primary contamination to the well. It is used in the computation of transport in the saturated zone to the well. A negative value indicates that the well is either upgradient of or within the primary contamination. If this value is negative or if the combination of water and land usage and exposure pathways indicates that well water has no influence on dose, the computational code will skip the well water concentration computations in order to reduce computational time.

Distance in the Direction Parallel to Aquifer Flow from Downgradient Edge of Contamination to Surface Water Body: This is the distance (in meters [m]) along a groundwater flow line from the downgradient edge of the primary contamination to the upgradient edge of the surface water body. It is used in the computation of transport in the saturated zone to the surface water body. A negative value indicates that the surface water body is upgradient of the primary contamination. If this value is negative or if the combination of water and land usage and exposure pathways indicates that water from the surface water body has no influence on dose, the computational code will skip the surface water computations in order to reduce computational time.

Distance in the Direction Perpendicular to Aquifer Flow from Center of Contamination to Well: This is the distance (in meters [m]) between two groundwater flow lines, one through the center of the contamination and the other through the well. It is used in the computation of dilution due to dispersion in the saturated zone, and it applies to water extracted from a well.

Distance in the Direction Perpendicular to Aquifer Flow from Center of Contamination to Right Edge of Surface Water Body: This is the distance (in meters [m]) between two groundwater flow lines, one through the center of the contamination and the other through the right edge of the surface contamination. It is used to compute the contamination flux from the groundwater into the surface water body.

Distance in the Direction Perpendicular to the Aquifer Flow from Center of Contamination to Left Edge of Surface Water Body: This is the distance (in meters [m]) between two groundwater flow lines, one through the center of the contamination and the other through the left edge of the surface contamination. It is used to compute the contamination flux from the groundwater into the surface water body.

Convergence Criterion: This is the fractional accuracy desired in the Romberg integration used to calculate the contaminant flux or concentration in groundwater. A lower value will likely require the use of a larger number of points in this numerical integration technique and will thus have a longer computation time. For each Romberg refinement or cycle number, the number of integrand function evaluations is 2^N, where N is the cycle number. Therefore, if the convergence criterion is set too low, the computation time becomes excessive and convergence may not be achieved. If convergence is not achieved, RESRAD will indicate the failure in the QRFAIL.LOG file and the last estimate of the integral using 32,769 points will be used. If the convergence criterion is set at zero, Simpson's rule with 32 integration intervals will be used.

Modeling Transport of Progeny Produced in Transit

RESRAD-OFFSITE has two groundwater transport algorithms. One models the effects of the differences in the water-to-soil interaction of the parent nuclide and the progeny nuclides, and the other models the longitudinal dispersion. When one of these processes is clearly dominant, the user can choose the appropriate algorithm to model the transport of the progeny produced in transit. When both the longitudinal dispersion and the differences in the water-to-soil interaction are of comparable importance, the prediction of progeny nuclides produced in transit in the transport zones can be improved by breaking up the transport zones into a number of subzones; then both processes will be modeled over most of the transport path. Additional run time will be needed to do this.

Main Subzones in Primary Contamination: This is the number of subzones into which the primary contamination is to be divided in order to improve the predictions of progeny nuclides produced in transit.

Main Subzones in Submerged Primary Contamination: This is the number of subzones into which the submerged primary contamination is to be divided in order to improve the predictions of progeny nuclides produced in transit.

Main Subzones in Each Partially Saturated Zone: This is the number of subzones into which the partially saturated zone is to be divided in order to improve the predictions of progeny nuclides produced in transit.

Main Subzones in Saturated Zone: This is the number of subzones into which the saturated zone is to be divided in order to improve the predictions of progeny nuclides produced in transit.

Modeling Nuclide Specific Retardation or Dispersion

The two transport algorithms give rise to three choices for the algorithm to be used in the zones where the specific atom undergoes transformations. One of three options can be selected to do the following:

- Model the effects of the nuclide-specific distribution coefficients of the parent and progeny in the zone of transformation and ignore the effects of longitudinal dispersion,

- Model the effects of longitudinal dispersion and use the retardation factor of the parent nuclide for both the parent and the progeny produced in that zone and ignore the retardation factor of the progeny, or

- Model the effects of longitudinal dispersion and use the retardation factor of the progeny nuclide for both the parent and the progeny produced in that zone and ignore the retardation factor of the parent.

Anticlockwise Angle from X-axis to Direction of Groundwater Flow: This input will appear only if the GW icon in the map interface was used to specify a direction of groundwater flow that is other than 90 degrees.

4.24 Surface Water Body Parameters

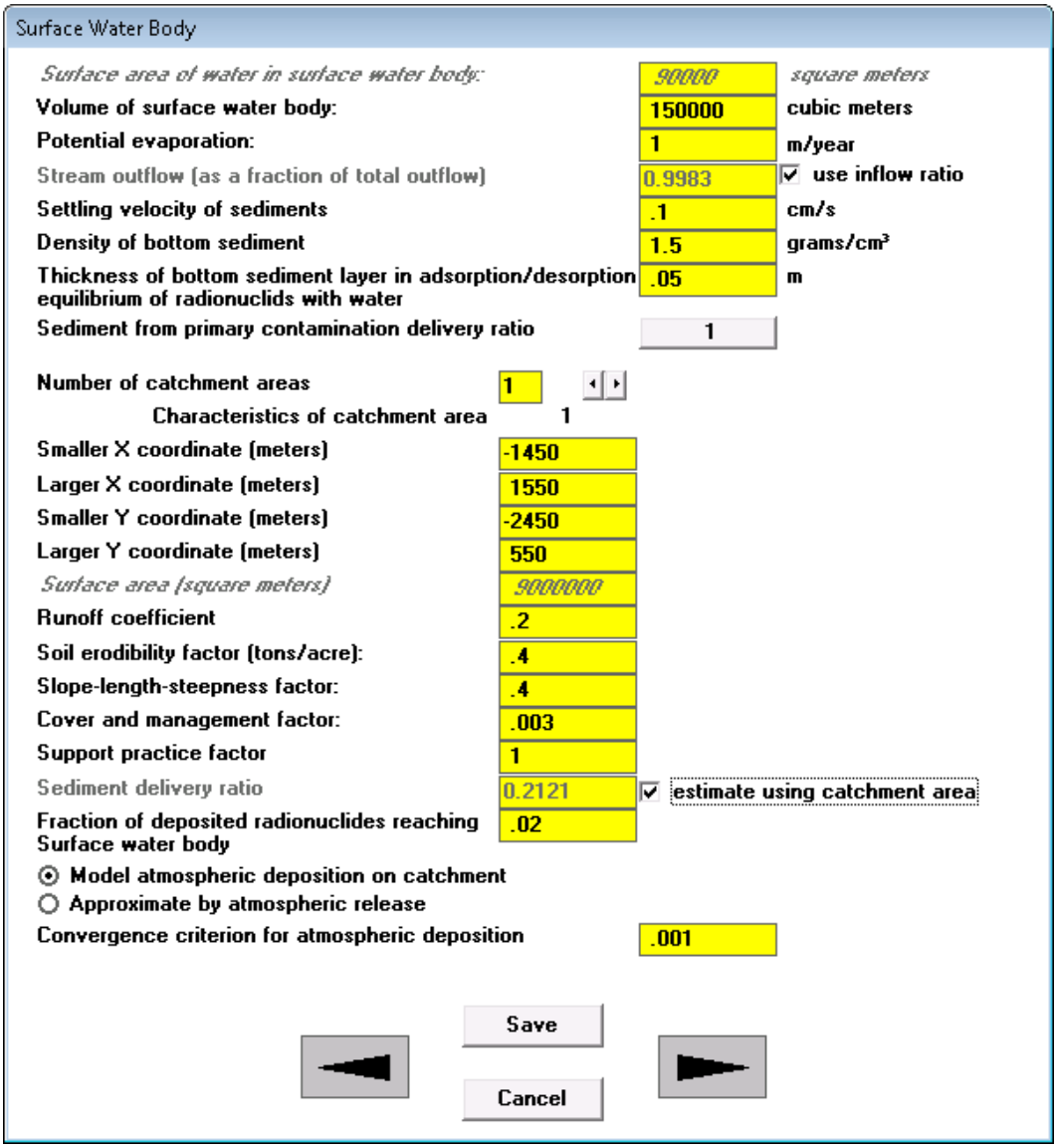

Figure 4-56 Surface Water Body Form

Uncertainty and sensitivity analysis can be performed on any parameter that is an input on the Surface Water Body form (Figure 4-56).

Surface Area of Water in Surface Water Body: This is the area of the surface water body. It is not a direct input but is computed based on the information input in the Site Layout form. It is used to compute the contaminant flux from atmospheric deposition and the precipitation and evaporation directly on and from the top of the surface water body.

Volume of Surface Water Body: This is the volume of water in the surface water body.

Potential Evaporation: This is the annual evaporation per unit surface area from the top of the surface water body.

Stream Outflow (as a fraction of total outflow): The value can be input or estimated using the inflow ratio. This is the quotient obtained by dividing the sum of the stream outflow and the water extracted for the receptor's use by the sum of all outflows other than evaporation.

Settling Velocity of Sediments: This is the representative rate at which suspended solids settle through the water to the bed of the surface water body.

Density of Bottom Sediment: This is the mass of solids in a unit volume of sediment.

Thickness of Bottom Sediment Layer in Adsorption/Desorption Equilibrium of Radionuclides with Water: This is the thickness of the top layer of the sediment that the radionuclides in this layer are in adsorption/desorption equilibrium with the radionuclides in the water.

Sediment from Primary Contamination Delivery Ratio: This is the fraction of the contaminated soil that was eroded from the area of primary contamination that reaches the surface water body. This command button displays the value entered in the Fate of Material Eroded from the Primary Contamination by Runoff form, Section 4.16. That form will be displayed when this button is clicked.

Number of Catchment Areas: This is the number of rectangular areas used to approximate the catchment area that drain into the surface water body.

Characteristics of Catchment Area: The catchment is modeled by one or more rectangles. The code requires input of the following characteristics of each rectangular region.

- **Coordinates of the Catchment:** The location and size of these rectangular areas are specified in the code by the coordinates of two opposite corners. The coordinates are specified with respect to a system of Cartesian axes on the left and lower sides of the primary contamination.

- **Surface Area of the Catchment:** The area is not an input and is obtained as the product of the length of two perpendicular sides.

- **Runoff Coefficient:** The fraction of precipitation that does not penetrate the topsoil but leaves the catchment area as surface runoff.

- **Soil Erodibility Factor:** This is a measure of the susceptibility of the soil to erosion.

- **Slope-Length-Steepness Factor:** This factor accounts for the effect the profile of the terrain has on the erosion rate.

- **Cover and Management Factor:** This factor (formerly called the Cropping-Management Factor) accounts for the effects land use, vegetation, and management have on the erosion rate.

- **Support Practice Factor:** This factor (formerly called the Conservation Practice Factor) accounts for the effects conservation practices have on the erosion rate.

- **Sediment Delivery Ratio:** This is the fraction of soil eroded from the catchment that reached the surface water body. The value can be input or, when the catchment is represented by a single rectangle, it can be estimated using the area of the catchment.

- **Fraction of Deposited Radionuclides Reaching Surface Water Body:** This is the fraction of radionuclide deposited on the catchment that is washed out into the surface water body.

Compute or Approximate the Deposition on Catchment: The atmospheric deposition on the catchment area can be modeled, or it can be approximated by its upper bound, the atmospheric release.

Convergence Criterion of Atmospheric Deposition: Convergence criteria for the areal integration of the deposition following atmospheric transport from the primary contamination to the catchment area.

4.25 Ingestion Rates

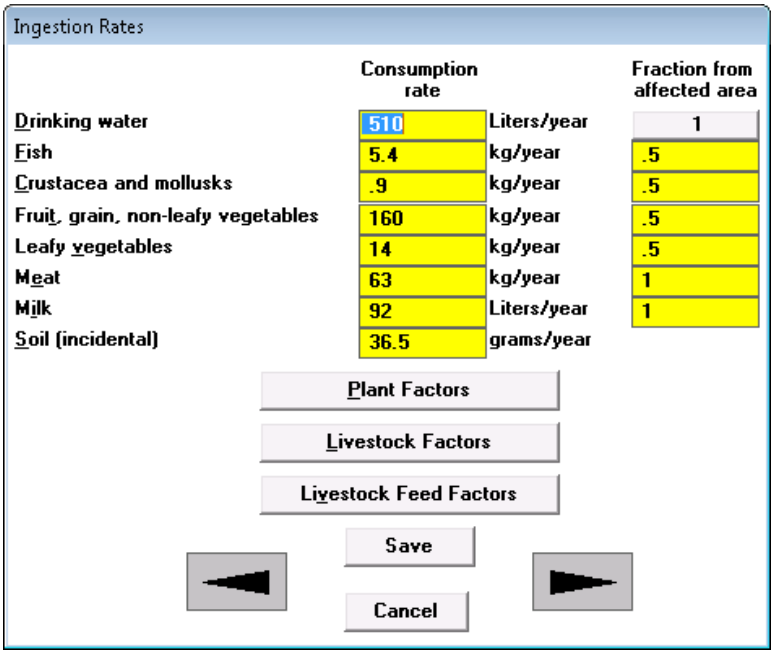

Figure 4-57 Ingestion Rates Form

Uncertainty and sensitivity analysis can be performed on any parameter that is an input on the Ingestion Rates form (Figure 4-57).

Consumption Rate: Consumption rates are national averages that are usually site-independent. Adjustments for regional differences in diet may sometimes be appropriate.

Fraction from Affected Area: This is the fraction of the consumption rates that is obtained from any area that is affected by the primary contamination. The entry for drinking water is the sum of the fractions obtained from the contaminated well and from the contaminated surface water body. Clicking on the entry for drinking water will open the Water Use form (Section 4.20); the fractions from each water source can be changed in that form.

Accessing Other Related Forms

Three forms can be accessed by using the three buttons listed below. Alternatively, the first form can be opened by clicking on the forward arrow button on this form; after that, the other forms can be opened by continuing to use the forward arrow buttons on the successive forms.

Plant Factors, Livestock Factors, and Livestock Feed Factors: These buttons can be used to open the respective forms. The current parent form will not be closed and will remain in the background; it will reappear when the form has been exited.

4.26 Plant Factors and Livestock Feed Factors

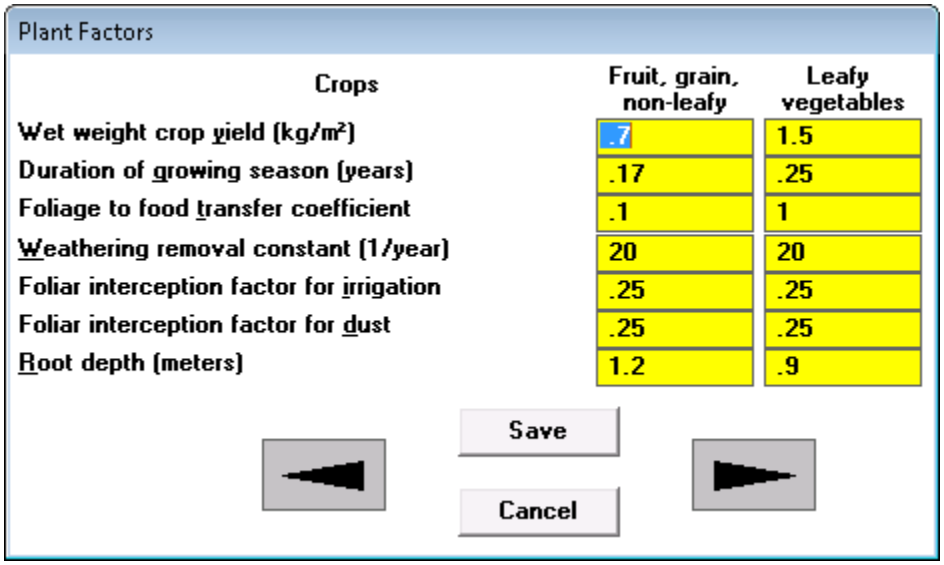

Figure 4-58 Plant Factors Form

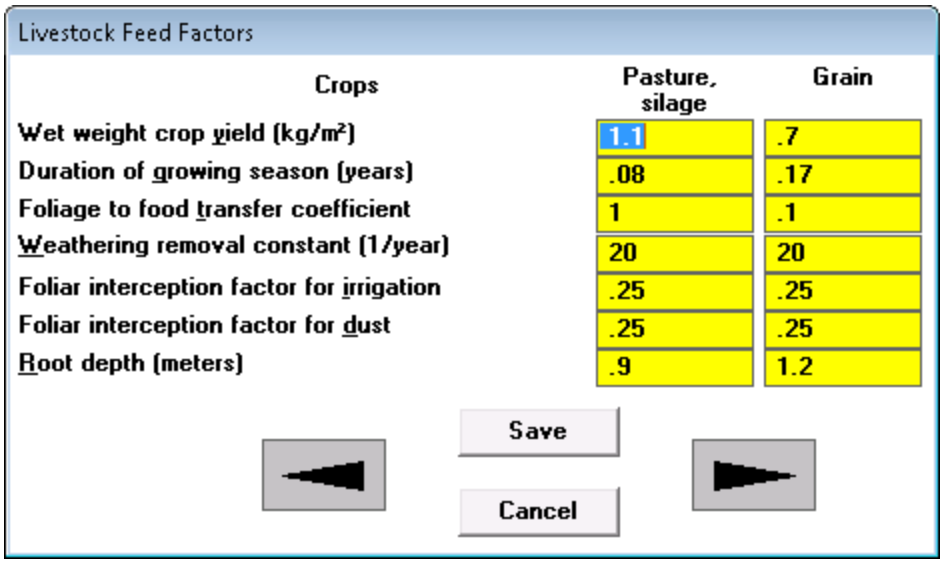

Figure 4-59 Livestock Feed Factors Form

Plant (i.e., vegetable and livestock feed) factors (Figure 4-58 and Figure 4-59) are related to growth and contaminant transfer. They depend on the mix of crops and on regional farming practices. Uncertainty and sensitivity analysis can be performed on any parameter that is an input on these forms.

4.27 Livestock Intakes (Factors)

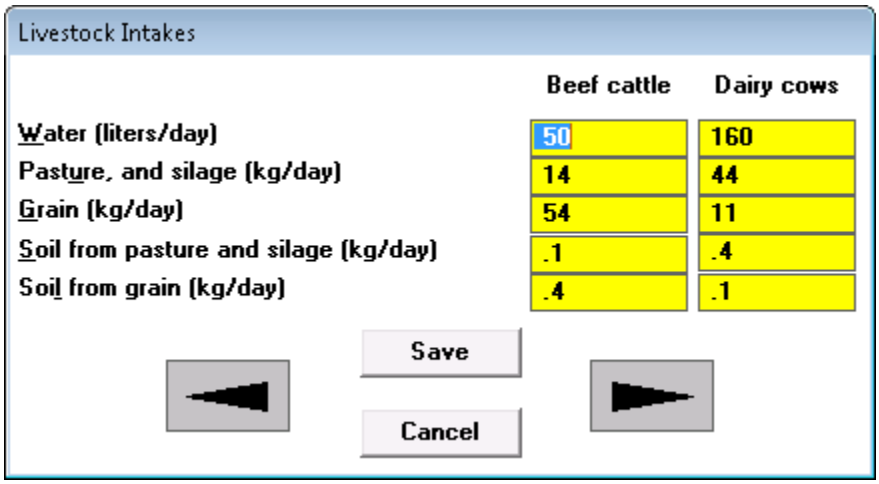

Figure 4-60 Livestock Intakes Form

Livestock intake (i.e., ingestion) rates (Figure 4-60) are national averages. Adjustments for regional differences in animal husbandry practices are necessary. The first column is the intake rates for each head of livestock raised for meat, while the second column is for each head of livestock raised for milk production. The incidental ingestion of soil associated with the ingestion of the two types of feed (grain or pasture/silage) must be specified separately because the

contaminant concentrations in the soils could be different. Uncertainty and sensitivity analysis can be performed on any parameter in this form.

4.28 Inhalation and External Gamma

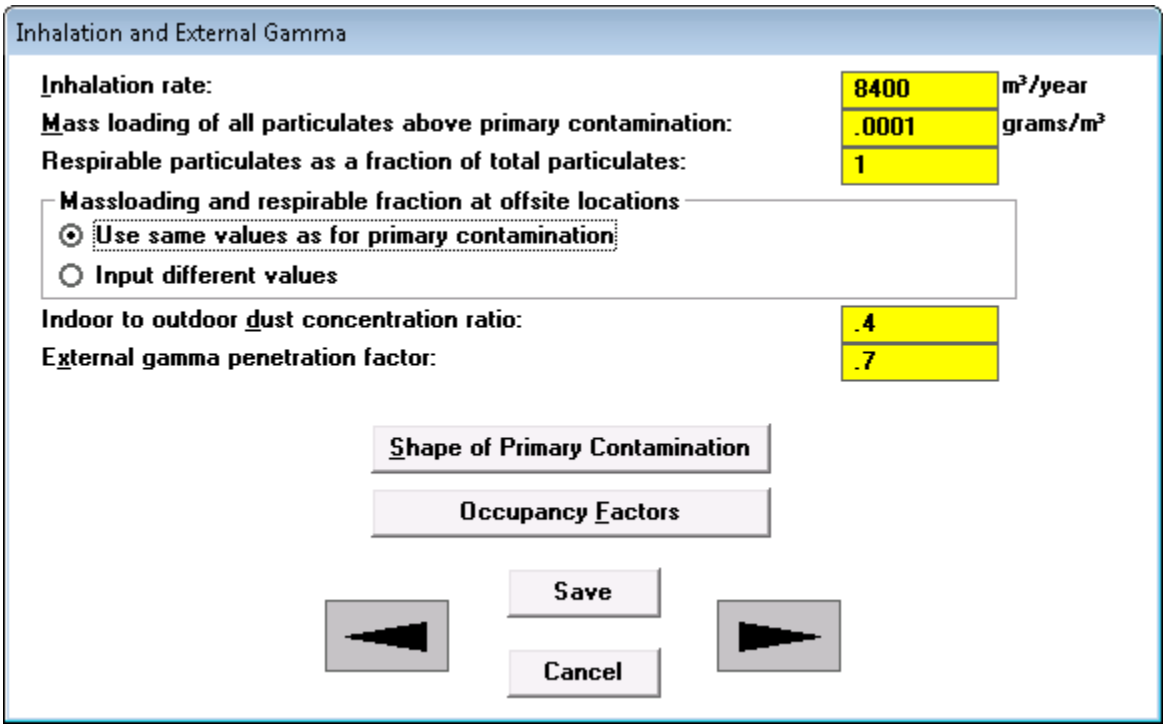

Figure 4-61 Inhalation and External Gamma Form-1

Uncertainty and sensitivity analysis can be performed on any input parameter on the Inhalation and External Gamma form (Figure 4-61).

Inhalation Rate: This is the annual air intake.

Mass Loading of All Particulates from Primary Contamination: This is the average mass of all particulates in a unit volume of air at the primary contamination, Section 4.15.

Respirable Particulates as a Fraction of Total Particulates: This is the mass fraction of respirable particulates/total particulates in air at the primary contamination.

Mass Loading and Respirable Fractions at Offsite Locations: The code provides an option to choose to use the same value of mass loading and respirable fraction at offsite locations as for primary contamination, or input different values (Figure 4-62).

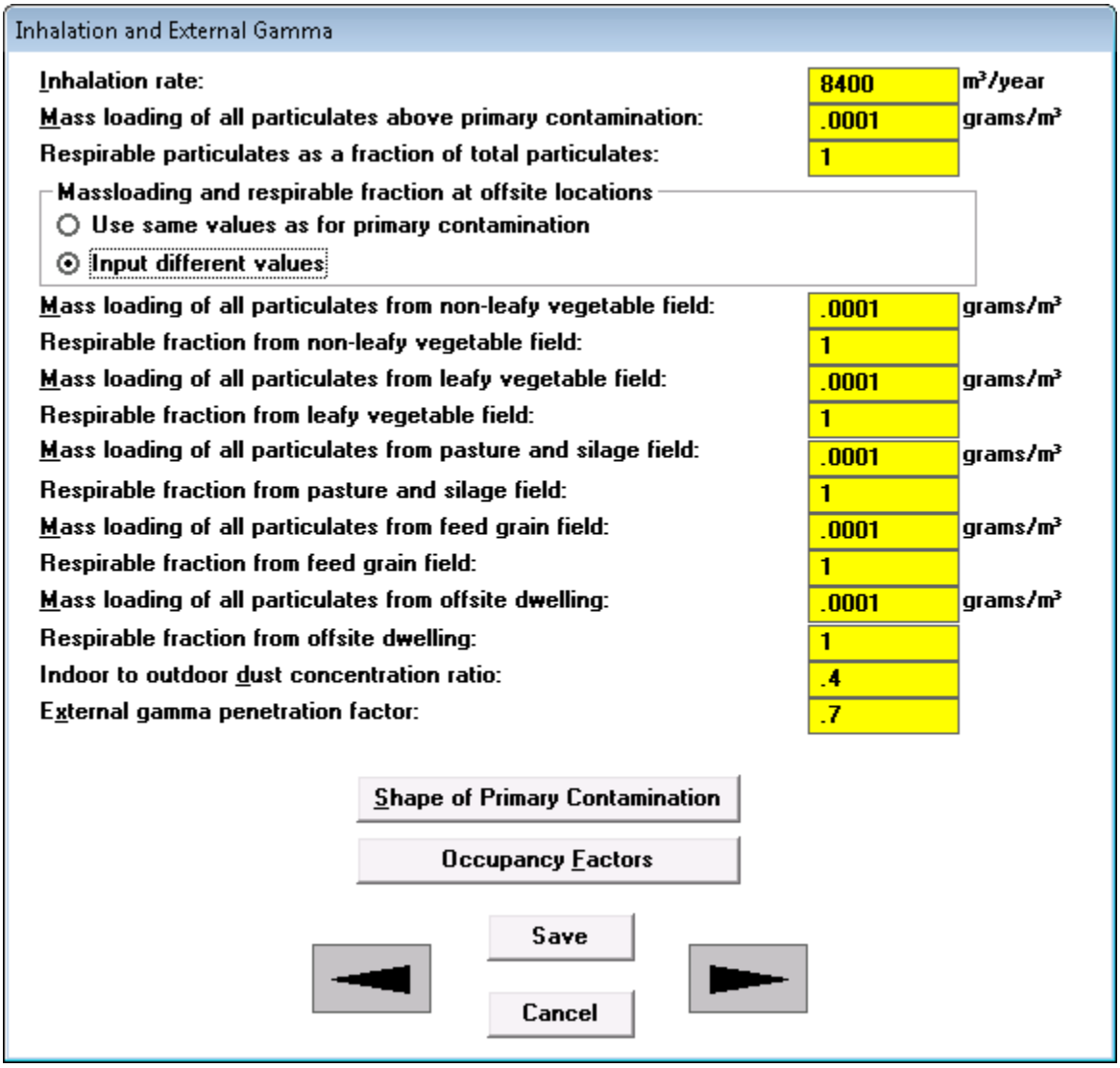

Figure 4-62 Inhalation and External Gamma Form-2

Mass Loading of All Particulates at Each Offsite Location: This is the average mass of all particulates in a unit volume of air above the offsite location. It is used to compute the resuspended radionuclide concentrations at the offsite locations.

Indoor to Outdoor Dust Concentration Ratio: This accounts for the effect of the building structure on the level of contaminated dust existing indoors. It is the fraction of outdoor contaminated dust that is present indoors.

External Gamma Penetration Factor: This factor accounts for the effect of the building structure on the level of gamma radiation existing indoors. It is the fraction of outdoor gamma radiation that penetrates the building.

Accessing Other Related Forms

Two forms can be accessed by using the two buttons listed below. Alternatively, the first form can be opened by clicking on the forward arrow button on this form, and then the other form can be opened by continuing to use the forward arrow button on the first form.

Shape of Primary Contamination and Occupancy Factors: These buttons can be used to open the respective forms. The current parent form will not be closed and will remain in the background; it will reappear when the form has been exited.

4.29 External Radiation Shape and Area Factors

The primary contamination is shown in black against a white backdrop in the picture box at the top left corner of the form (Figure 4-63). The primary contamination will change to pink if the Calculate Radii and Fractions button near the top of the right side is pressed (Figure 4-64).

Shape of the Plan of the Primary Contamination: As a default, the shape of the primary contamination and the centroid of the offsite dwelling specified in the site layout/map interface form are used to calculate the shape and area factors for the external radiation pathway. The onsite dwelling is assumed to be located at the center of the primary contamination. This form can be used to specify different locations for the dwellings and to define a polygonal shape for the primary contamination.

The user may override the radii and fractions. If the user overrides the computed values, the code will place a check in the check box as an indication of the override.

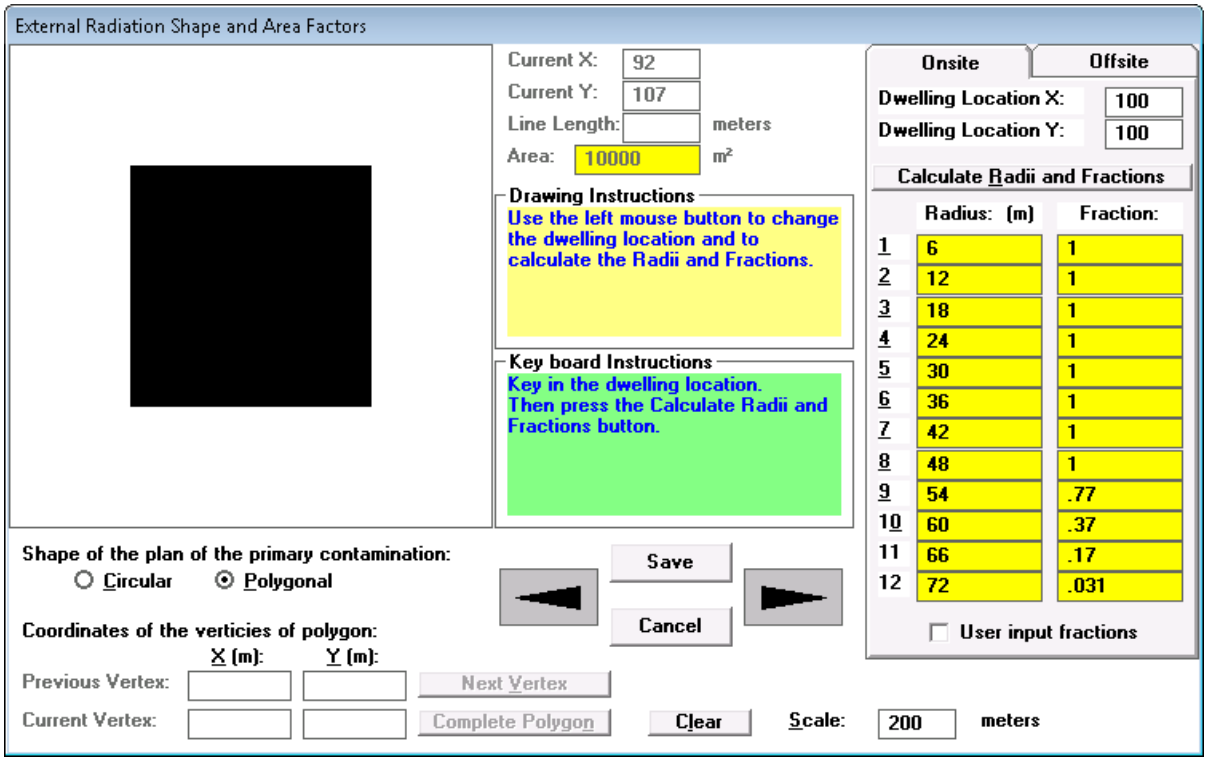

Figure 4-63 External Radiation Shape and Area Factors Form

Changing the Location of the Dwellings

If the primary contamination is not completely within the picture box, change the number in the box next to Scale (in the middle near the bottom of the form) until it is visible in its entirety. At the top-right, select the tab (Onsite tab or Offsite tab) corresponding to each dwelling in turn and specify its location, either by inputting the coordinates or by clicking on the location in the picture box. If the coordinates of the location are keyed in, the Calculate Radii and Fractions button must be pressed to compute the area fractions. This must be done before proceeding to the other tab (Onsite tab or Offsite tab). The coordinates of the position of the cursor are shown in the Current X and Current Y information boxes at the top-center of the form; this information is helpful when the cursor is being used to click on the location of the dwelling.

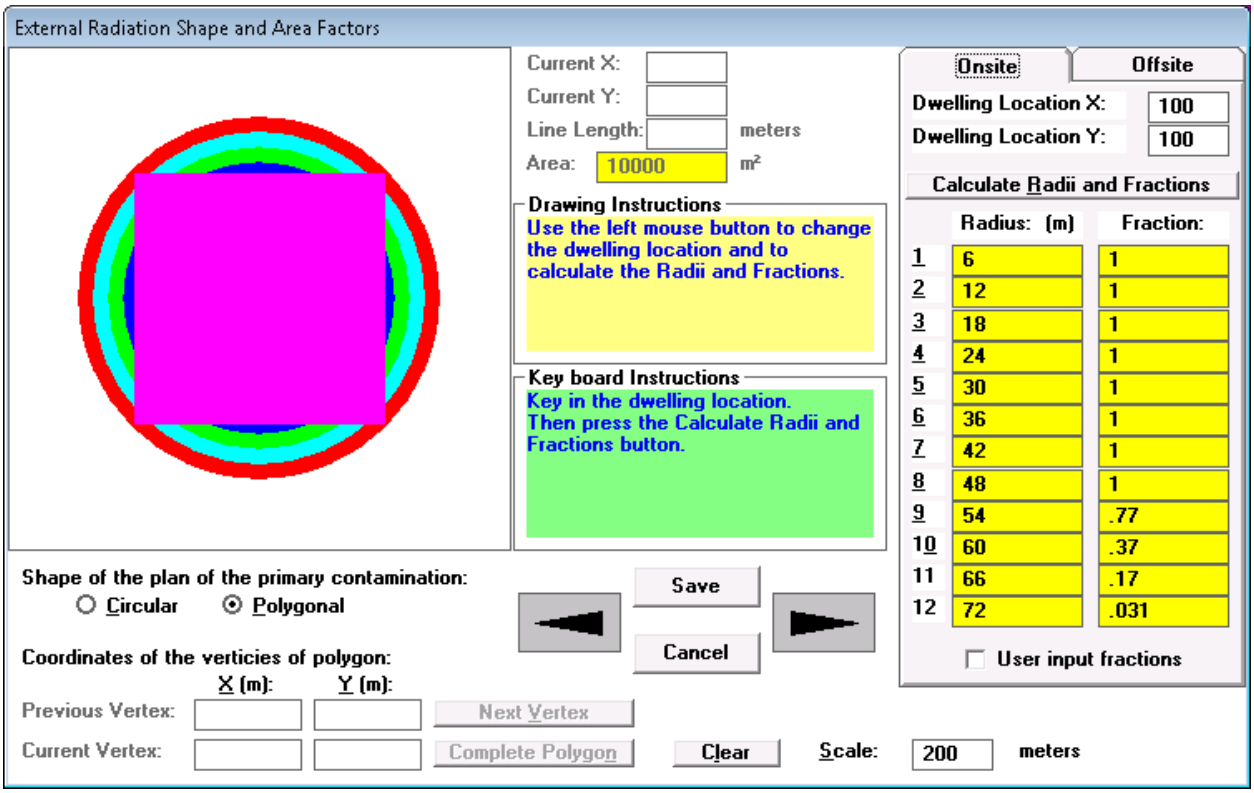

Figure 4-64 Polygonal Primary Contamination in External Radiation Shape and Area Factors Form

Changing the Shape of the Primary Contamination

Set the number in the box next to Scale to the length of the square enclosing the primary contamination and the two dwelling locations. Choose the Polygonal option; Clear the image if there is already a polygon in the drawing area. The polygon can be “drawn” using the mouse and following the drawing instructions given in the yellow information box on the form. Alternatively, the vertices of the polygon can be keyed in by following the instructions given in the green instruction box. After the polygon is completed, the location of the onsite and offsite dwellings must be specified, as described in the previous paragraph. The area of the polygon will be computed when the radii and area fractions are computed. The area is displayed in the box at the top-center of the form (Figure 4-64).

Because the fraction of each annular area that is contaminated is computed graphically in the interface, it is not possible to perform uncertainty or sensitivity analysis on any of the parameters on this form. However, it is possible to perform probabilistic analysis on the input on the Site Layout form (Section 4.12). The FORTRAN computational code will compute the appropriate radii and fractions for all exposure locations (onsite and offsite dwellings, agricultural areas, livestock feed growing area, and pasture) for the probabilistic runs using the rectangular shapes specified in the Site Layout form.

4.30 Occupancy Factors

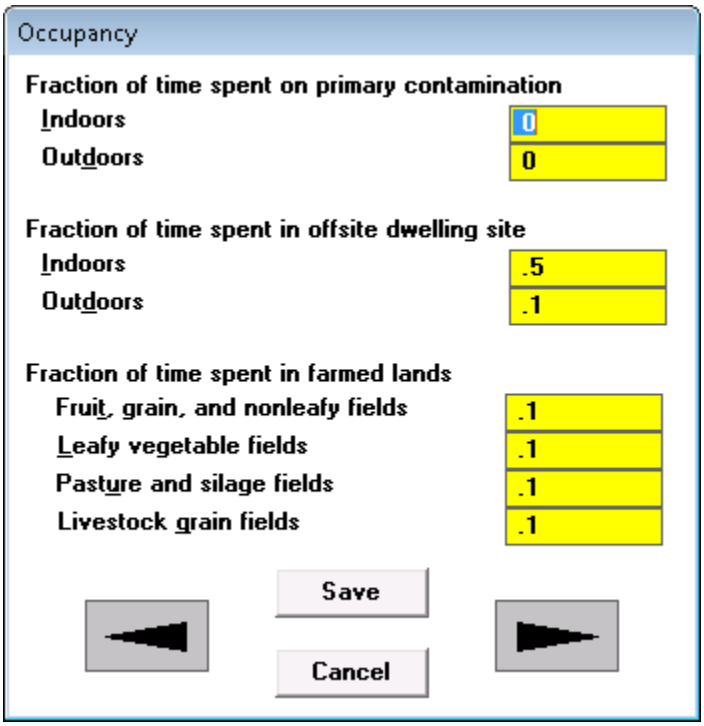

Figure 4-65 Occupancy Factor Form

The Occupancy Factor form (Figure 4-65) is used to input fractions of time spent in various locations.

Fraction of Time Spent on Primary Contamination

- **Indoors:** This is the fraction of time that the receptor spends in a building situated on top of the primary contamination.

- **Outdoors:** This is the fraction of time that the receptor spends outdoors on top of the primary contamination. If any agricultural or pasture land lies over the primary contamination, the time spent in that common area should be included in the entry for that agricultural or pasture land.

Fraction of Time Spent in Offsite Dwelling Site

- **Indoors:** This is the fraction of time that the receptor spends in a building situated away from the primary contamination.

- **Outdoors:** This is the fraction of time that the receptor spends outdoors of the offsite dwelling that is located away from the primary contamination.

Fraction of Time Spent in Farmed Areas: This is the fraction of time that the receptor spends outside in agricultural land and pasture land contaminated by irrigation or by atmospheric deposition. If any agricultural or pasture land overlies the primary contamination, the time spent in that common area should be included in the entry for the agricultural or pasture land, but not in the outdoor time fraction above the primary contamination.

Note: The sum of the time fractions spent indoors and outdoors on the primary contamination, in the offsite dwelling site and in the farmed areas, cannot exceed unity. Uncertainty and sensitivity analysis can be performed on any parameter on this form. The user must ensure that the combined occupancy limit is not violated during the uncertainty analysis.

4.31 Radon

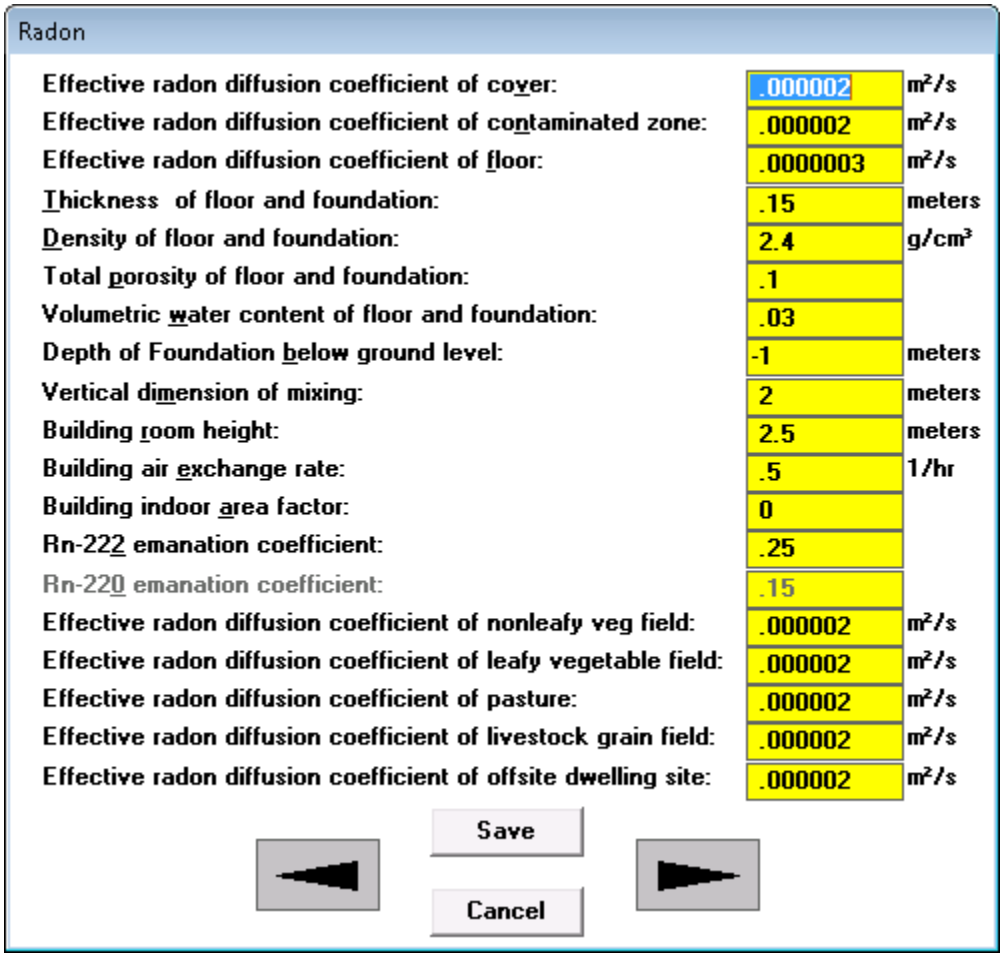

Figure 4-66 Radon Form

The radon model is discussed in Appendix D of the User's Manual. The radon parameters are activated only when the radon pathway is turned on. The radon pathway can be turned on only if a parent of either radon-222 (^{222}Rn) or radon-220 (^{220}Rn) is present as a contaminant. The wind speed found on the Atmospheric Transport form (Section 4.19), the volumetric water content of the clean cover on the Primary Contamination form (Section 4.15), and the total porosities in the offsite locations (Sections 4.17 and 4.18) are also used for the outdoor radon dose component calculation. Uncertainty and sensitivity analysis can be performed on any parameter on this form (Figure 4-66).

Effective Radon Diffusion Coefficient: This is defined as the ratio of the gradient of the radon activity concentration in the pore space to the diffusive flux density of radon activity across the pore area. Entering -1 for any diffusion coefficient will cause the code to calculate a diffusion coefficient based on the porosity and water content of the medium.

Thickness of Floor and Foundation: This is the average thickness of the building shell structure in the subsurface of the soil.

Density of Floor and Foundation: This defined as the ratio of the solid-phase mass to the total volume.

Total Porosity of Floor and Foundation: This is the ratio of the void space volume to the total volume of a porous medium.

Volumetric Water Content of Floor and Foundation: This in a porous medium represents the fraction of the total volume of the porous medium that is occupied by water contained in it. The value should be less than the total porosity of the porous medium.

Depth of Foundation below Ground Level: This is the depth from the ground surface to the bottom of the basement slab. The default value of -1 indicates that the slab will be placed directly on top of the contaminated zone.

Vertical Dimension of Mixing: This vertical dimension together with the area of the primary contamination are used to define the mixing volume used to compute the onsite concentrations of the short-lived radon progeny. The radon released from the primary contamination is assumed to be uniformly mixed with the air flowing through this mixing volume. This dimension is also used to define the onsite mixing volume for the computation of the concentrations of ^{3}H and ^{14}C in the air above the primary contamination for the onsite inhalation pathway.

Building Room Height: This is the average height of the rooms in the building.

Building Air Exchange Rate: This is the number of the total volumes of air in the building being exchanged with outside air per unit of time.

Building Indoor Area Factor: This is the fraction of the floor area built on the contaminated area. Values greater than 1.0 indicate a contribution from walls penetrating the contaminated zone. The default value of 0 indicates that the time-dependent area factor is derived from an assumed floor area of 100 m^2 and the amount of wall extending into the contaminated zone.

Radon Emanation Coefficient: This is the fraction of total radon generated by radium decay that escapes from the soil particles. This depends on many parameters such as particle size distribution, porosity, mineralogy, and moisture content.

4.32 Carbon-14

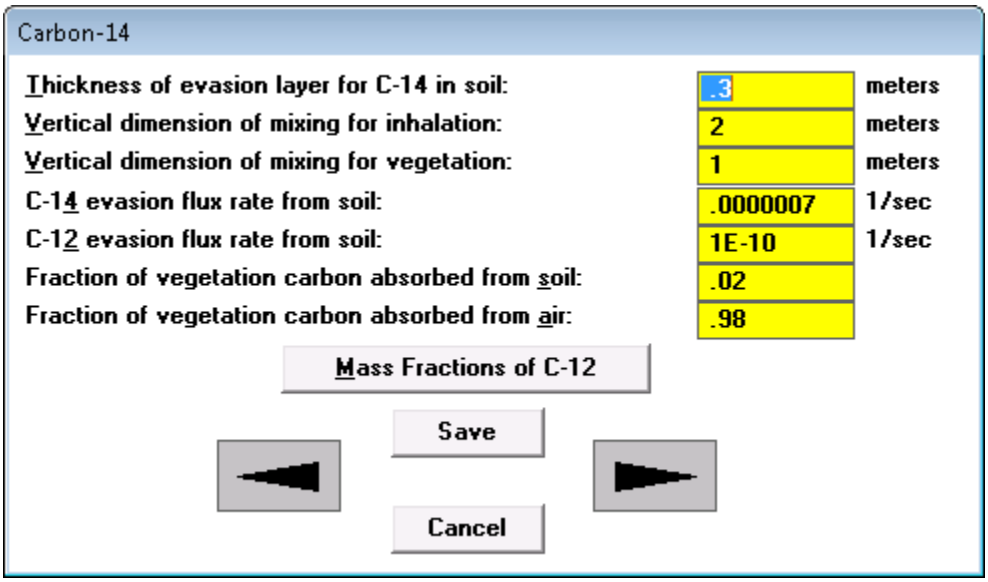

Figure 4-67 Carbon-14 Form

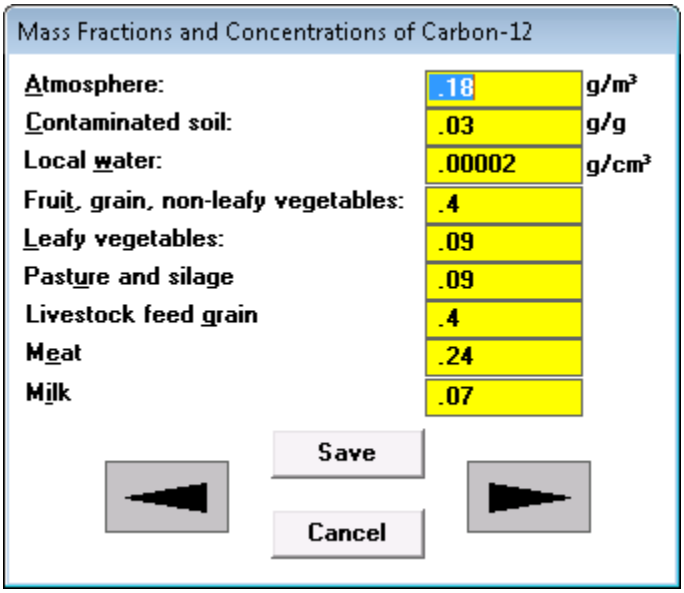

Figure 4-68 Mass Fractions and Concentrations of Carbon-12 Form

Appendix F of the User's Manual contains a description of the ^{14}C model. The Carbon-14 form and the Mass Fractions and Concentrations of Carbon-12 form are used to enter parameters for the ^{14}C model. Uncertainty and sensitivity analysis can be performed on any parameter on these forms (Figure 4-67 and Figure 4-68).

Thickness of Evasion Layer for C-14 in Soil: This is the maximum soil thickness layer through which carbon can escape to the air by conversion to CO_2. The carbon, including ^{14}C, below this depth is assumed to be trapped in the soil.

Vertical Dimension of Mixing for Inhalation: This vertical dimension together with the area of the primary contamination is used to define the mixing volume, which is used to compute the onsite concentrations of ^{14}C for the onsite inhalation exposure pathway. The ^{14}C released from the primary contamination is assumed to be uniformly mixed with the air flowing through this mixing volume. This dimension is also used to define the onsite mixing volume for the computation of the concentrations of ^{3}H and the short-lived radon progeny in air above the primary contamination for the onsite inhalation pathway.

Vertical Dimension of Mixing for Vegetation: This vertical dimension together with the area of the primary contamination are used to define the mixing volume used to compute the onsite concentration of $^{14}CO_2$ for the uptake of ^{14}C by photosynthesis.

C-14 Evasion Flux Rate from Soil: This is the fraction of ^{14}C in soil within the evasion layer that escapes to the atmosphere per unit time.

C-12 Evasion Flux Rate from Soil: This is the fraction of stable carbon, ^{12}C, in soil within the evasion layer that escapes to the atmosphere per unit time.

Fraction of Vegetation Carbon Absorbed from Soil: This is the fraction of total vegetation carbon obtained by direct root uptake from the soil.

Fraction of Vegetation Carbon Absorbed from Air: This is the fraction of total vegetation carbon assimilated from the atmosphere through photosynthesis.

The Mass Fractions and Concentrations of Carbon-12 form can be assessed by using the Mass Fractions of C-12 button on this form. Alternatively, this form can be opened by clicking on the forward arrow button.

Mass Fractions and Concentrations of Carbon-12: This form is used to enter the ^{12}C concentrations in the atmosphere, contaminated zone, and in local water. This form is also used to enter the mass of ^{12}C in a unit mass of fruit, grain, and nonleafy vegetables; leafy vegetables; pasture and silage; livestock feed grain; meat; and milk.

4.33 Tritium

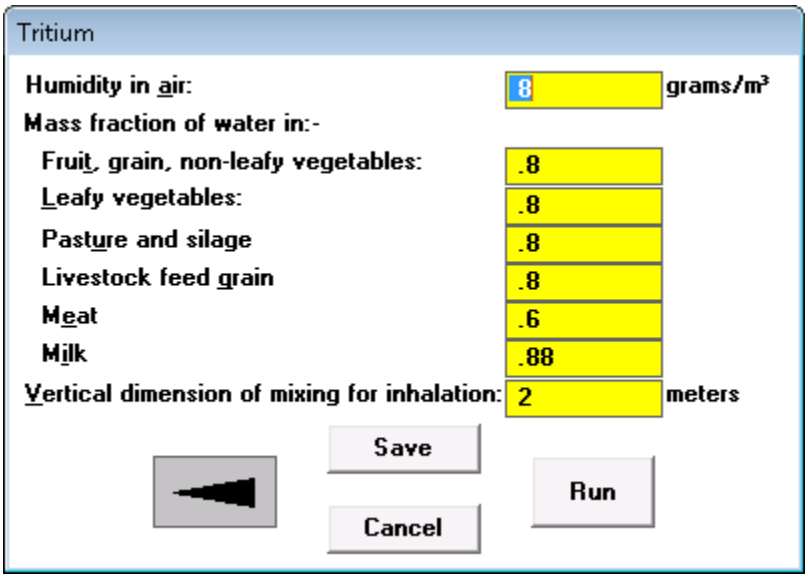

Figure 4-69 Tritium Form

Parameters for the tritium model can be input on the Tritium form (Figure 4-69). Appendix F of the User's Manual contains a description of the ^{3}H parameters and their use in the tritium model. It also contains a map of average U.S. humidity values. Uncertainty and sensitivity analysis can be performed on any parameter on this form.

Humidity in Air: Air humidity is used for the computation of tritium concentrations in air.

Mass Fraction of Water: Mass of water in unit mass of fruit, grain, and nonleafy vegetables; leafy vegetables; pasture and silage; livestock feed grain; meat; and milk are entered.

Vertical Dimension of Mixing for Inhalation: This vertical dimension and the area of the primary contamination are used to define the mixing volume, which is used to compute the onsite concentrations of tritium, ^{3}H, for the onsite inhalation exposure pathway. The ^{3}H released from the primary contamination is assumed to be uniformly mixed with the air flowing through this mixing volume. This dimension is also used to define the onsite mixing volume for the computation of the concentrations of ^{14}C and the short-lived radon progeny in the air above the primary contamination for the onsite inhalation pathway.

5 RESULTS

For each deterministic analysis, RESRAD-OFFSITE produces three textual reports and a data file that can be viewed by using the RESRAD graphics interface. The first few pages of each report list the table of contents of the report. The RESRAD graphics interface provides many options for viewing the results.

Sensitivity analysis (one-parameter-at-a-time) results are also viewed by using the RESRAD graphics interface. Uncertainty analysis results are produced in a report and in a number of data files that can be graphed in the uncertainty interface. The contents of the reports are as outlined below.

Textual Deterministic Reports

1. Parent Dose Report (.par)
    a. Inputs
        i. Dose conversion factors
        ii. Transfer factors
        iii. Site characteristics
    b. Pathway selections
    c. Total dose
        i. At user-specified reporting times
        ii. Peak and time of peak
    d. Pathway doses from transformation chain of initially present nuclides
        i. At user-specified reporting times
    e. Guideline information
        i. Dose/source ratios at user-specified reporting times, attributed to initially present nuclides
        ii. Single radionuclide soil guidelines at user-specified reporting times, when appropriate
        iii. Single radionuclide soil guidelines at time of peak dose from nuclide, when appropriate
        iv. Radionuclide soil guidelines at time of peak dose from all nuclides, when appropriate
    f. Run-time information
        i. Execution time
        ii. Conversion failures of numerical integration (groundwater transport)
2. Progeny Dose Report (.pro)
    a. Pathway doses from nuclides at point of exposure
        i. At user-specified reporting times
3. Cancer Risk Report (.rsk)
    a. Cancer risk slope factors
    b. Excess cancer risks
        i. Attributed to initially present nuclides
        ii. Attributed to nuclides at point of exposure
        iii. Radon and short-lived progeny contributions

Uncertainty and Probabilistic Analysis Reports

1. Dose and Risk Report (.prb)
    a. Inputs
        i. Summary of distribution of each point
    b. Minimum, maximum, mean, and standard deviation at reporting times
        i. Total dose from each initially present nuclide
        ii. Total risk from each initially present nuclide
        iii. Pathway dose from each initially present nuclide
    c. Cumulative distribution function
        i. Peak total dose
        ii. Peak pathway dose
        iii. Peak total risk
        iv. Peak pathway risk
    d. Correlation and regression coefficients (if requested by user)
        i. Peak total dose with inputs
        ii. Peak pathway dose with inputs
        iii. Peak nuclide dose with inputs
        iv. Peak total risk with inputs
        v. Peak pathway risk with inputs
        vi. Peak nuclide risk with inputs
2. Probabilistic Input Report (.smp)
    a. Input specification
        i. Distribution of each input
        ii. Rank correlation coefficient (RCC)
        iii. Warnings of incompatible input correlations
    b. Input samples
        i. Input vectors
        ii. Rank of input vectors
        iii. Correlation coefficients of raw data
        iv. Correlation coefficients of rank data
3. Output against Inputs Regression Report (.reg)
    a. Coefficient of determination
    b. Correlation and regression coefficients, the same as described in 1.d. above (if requested by user). But the inputs are sorted in the order of their influence on the variability of the output

5.1 Report Viewer

The Report Viewer (Figure 5-1) is launched automatically at the end of each run to display the Parent Dose Report (summary.rep). The Report Viewer may also be accessed at any time from the Main Menu, toolbar, DOS-Emulator, or Navigator to view any of the current reports or any reports from the past that were saved.

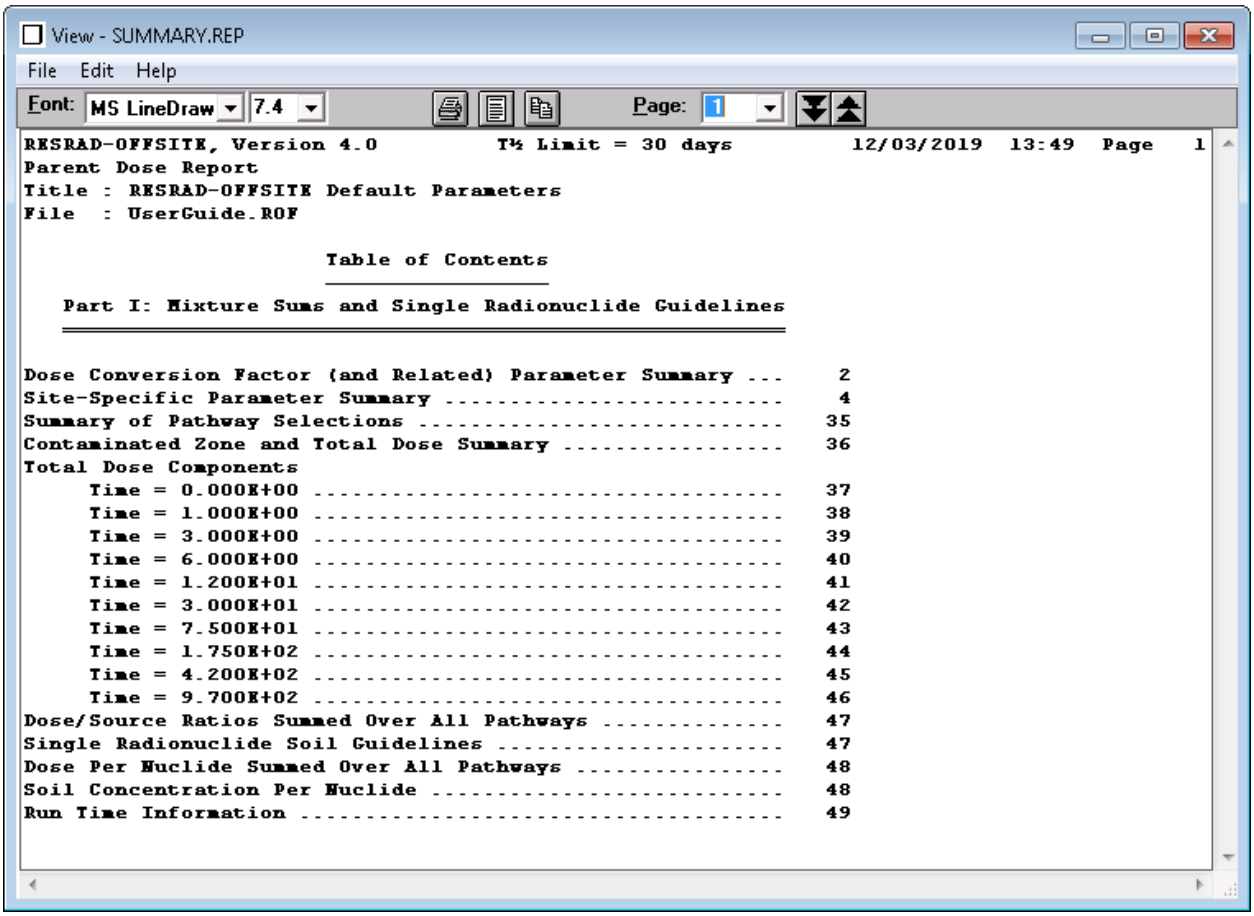

Figure 5-1 Report Viewer

Getting to Report Viewer

- **Menu:** Click on Select View, Text Output, and then any of the available choices: Parent Dose Report, Risk Report, Progeny Dose Report, Uncertainty/Probabilistic Dose and Risk Report, Uncertainty/Probabilistic Inputs Report, Linear Regression Report, and Area Factors Report.

- **Toolbar:** Only the Parent Dose Report can be accessed from the toolbar. Click on the report page icon (the left button on the third cluster).

- **DOS-Emulator:** Click on the View Output button and then the command button corresponding to the desired report.

- **Navigator:** Go to the Results tab and click on the command button corresponding to the desired report. The Linear Regression Report and the Area Factor Report cannot be accessed from the Navigator.

Viewing a Previously Saved Report

From within the Report Viewer, click on File and View another File (Ctrl-F) from the Report Viewer main menu. Point to the subdirectory where the input files are located. Select the file that you want to view. The saved files have the same root name as the input file. Three-character extensions identify the seven types of report files as follows:

- af = area factors report,
- par = parent dose report,
- prb = uncertainty and probabilistic dose and risk report,
- pro = progeny dose report,
- reg = regression report,
- rsk = cancer risk report, and
- smp = uncertainty-probabilistic input report.

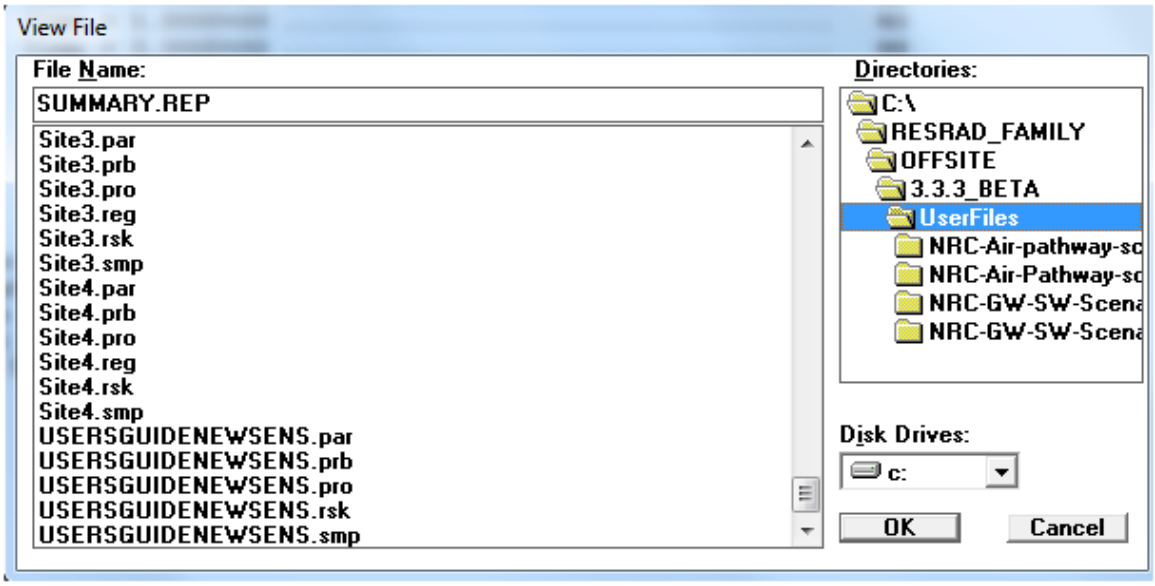

Figure 5-2 File Dialog Box of Report Viewer

The complete set of files that are saved for a particular input file can be viewed by typing in the input file name followed by a period and the wild card character in the View File dialog box (Figure 5-2). Some of the other file extensions of interest are as follows:

- chn = a file listing the transformation threads and principal nuclides for each initially present nuclide.
- pds or prk = formatted data file of peak probabilistic dose or risk for each simulation.
- pin = data file of probabilistic samples for each simulation.
- ptg = probabilistic temporal graphics for each repetition.
- rel = information on the related inputs.

Moving Around

- **Pages:** To go to another page, choose one of the following methods:
  - Enter the page number in the page text box and hit Enter.
  - Pull down the page list and click on the desired page.
  - Advance a page by pressing the Page Down key or by clicking on the double down arrows.
  - Go back a page by pressing the Page Up key or by clicking on the double up arrows.
- **Within a Page:** Use scroll bars to position text.
- **Between Reports:** Click on File and View another File (Ctrl-F) from the Report Viewer main menu to view another report. You can also close the Report Viewer and go back to the Main Menu to select a different file.

Saving Files

Every time a calculation is run, the previous reports and graphics files are overwritten. The results can be saved under different names, which allows for their retrieval later.

- **Saving All Files:** Click on File and Save All under the Report Viewer main menu. This will save all textual reports to files. If the input filename is filename.ROF, the reports will be saved as filename.yyy, where the extension yyy identifies the report as described in “Viewing a Previously Saved Report” above.
- **Saving the Open Report:** Click on File and Save under the Report Viewer main menu. This will prompt the user for a name under which to save the currently displayed report.

Copying Selections

- **Copy Highlighted Section:** Click on Edit/Copy under the Report Viewer main menu. The selected text will be placed on the Windows clipboard and can be placed into any document, such as a spreadsheet or word-processed text.

- **Copy the Current Page:** Click on Edit/Select All, followed by Edit/Copy. Another option is to click on the icon that looks like two pages.

Printing

- **Setting up the Printer:** RESRAD-OFFSITE uses the standard Windows printer. The setup for the printer can be accessed through the File/Printer Setup menu option. Options that can be selected include printer, paper size, and orientation.

- **Setting up the Report for Printing:** Click on the icon that looks like a single page to automatically select the best font size that will fit the report to a single page width.

- **Printing:** Select the File/Print menu option or click on the printer icon button. A dialogue box will appear for printing the whole report, sets of pages, or the current highlighted text.

5.2 Graph Viewer (Deterministic and Sensitivity Analysis)

Getting to Graph Viewer

- **Menu:** Click on View on the RESRAD-OFFSITE menu, then select Deterministic Graphics (Figure 5-3).

- **Toolbar:** Click on the middle icon in the third cluster, the one with the button prompt saying, “View Deterministic Graphics.”

- **DOS-Emulator:** Click on View Output to bring up the Output form. Click on Deterministic Graphics.

- **Windows Navigator:** Click on the Results tab, then click on the Deterministic Graphics icon.

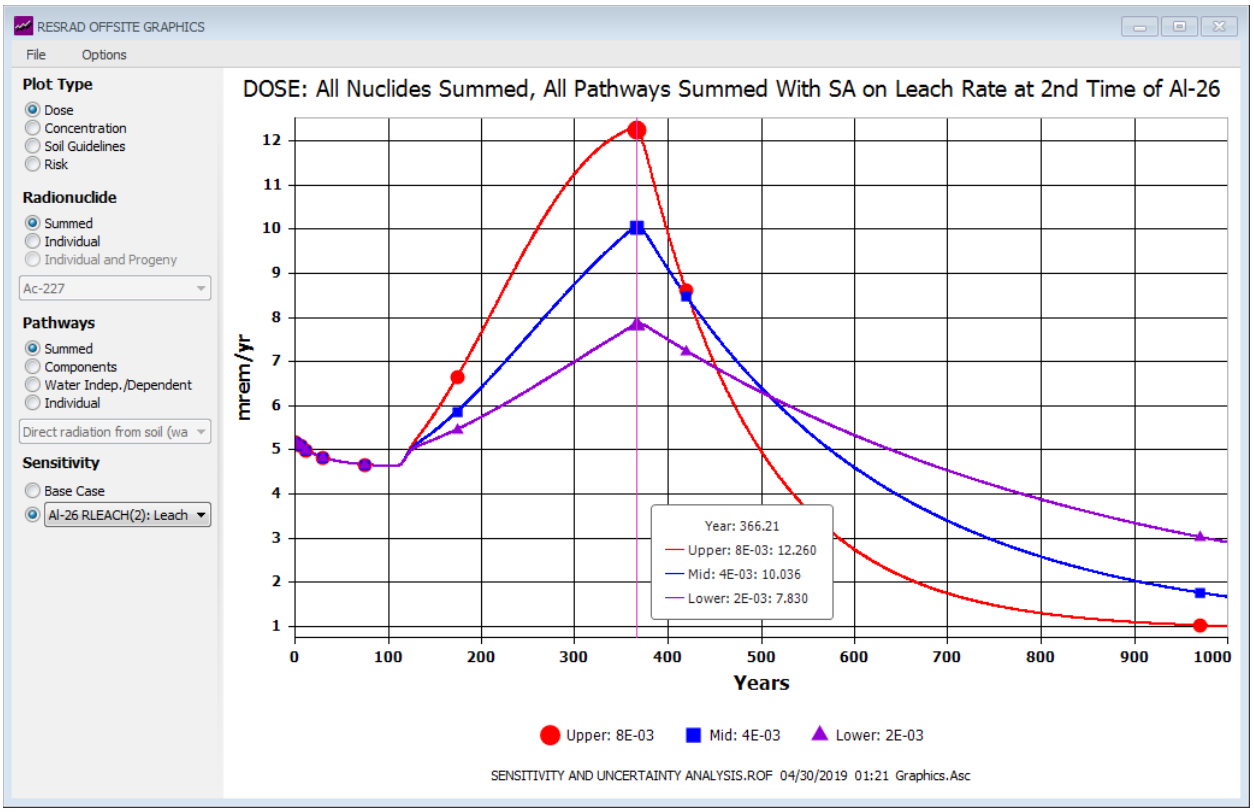

Figure 5-3 Graph Viewer

Choosing from the Plot Selection Palette

All dose, risk, and concentration data produced by RESRAD-OFFSITE for each radionuclide and pathway or media combination are available to the Graph Viewer. Thus, a wide choice of plots is available. The plots are selected by specifying the following:

- **Type (of Plot)**
    - **Dose:** Select Dose to view a graphical representation of the radiological dose over the user-specified time horizon.
    - **Concentration:** This displays a plot of the concentration of the selected radionuclide in various media over the user-specified time horizon.
    - **Soil Guidelines:** Select Soil Guidelines to view a graph of the initial radionuclide concentration in soil that will produce the specified basic radiation dose limit at that specific time as a function of time.
    - **Risk:** Select Risk to view a graphical representation of the excess cancer risk over the user-specified time horizon.

- **Radionuclide**
  - **Summed:** This option is available for Dose and Risk plots; it displays the dose or risk due to all the radionuclides specified to be present at the site.
  - **Individual:** This option is available for all five types of plots, but its definition depends on the type of plot. Select the radionuclide by using the drop-down scroll box.
    - When used with the concentration plots, it displays the concentration of the selected radionuclide (either an initially present nuclide or a progeny) in the selected media.
    - When used with the other four types of plots, it displays the total quantity due to the selected radionuclide (initially present nuclide) and its progeny.
  - **Individual and Progeny:** This option is available for Dose, Dose/Source Ratio, and Risk plots. It displays the individual dose, dose-to-source ratio, or risk due to the selected radionuclide (initially present nuclide) and each of its progeny.
- **Pathways:** Options are available for Dose, Dose/Source Ratio, and Risk plots.
  - **Summed:** This sums the selected quantity over all pathways and plots the sum.
  - **Components:** This plots the selected quantity from each pathway in one plot.
  - **Water Indep./Dependent:** This plots two lines on the graph. The first one shows the waterborne contribution, and the second one shows the airborne and any direct contribution from the selected quantity.
  - **Individual:** This plots a single selected pathway. The pathway is selected by using the drop-down scroll box.
- **Media:** This appears in place of the Pathways options when concentration plots are selected. Select the medium by using the drop-down scroll box.
- **Sensitivity:** This is displayed when a sensitivity analysis is performed.
  - **Base Case:** This shows only the results of the deterministic run.
  - **Sensitivity to a Parameter:** Select a parameter from the drop-down list to see the sensitivity of the output to that parameter.

Selecting from the Graph Viewer Menu

- **File**

  - **Open:** This command is used to open the deterministic graphics data file from a previous run. The deterministic graphics data file is stored in the same directory as the input files at the end of each run. These files have the same root name as their input files but end with the extension .grp.

  - **New Window:** This command displays another Graph Viewer window. Two plots from the same data file or plots from two different graphics data files can be viewed in the different windows.

  - **Save As:** The file can be saved as a graphic file *.grp or *.ASC file. When the file is saved as *.ASC, the X and Y values used in the plot are written in an ASCII (American Standard Code for Information Interchange) file format. A header row is printed after every 61 lines, making it easier to view the data over multiple pages.

  - **Print:** This command is used to produce a hard (paper) copy of the current plot.

  - **Print Preview:** This opens a window displaying the selected graph for preview.

  - **Export Graph:** This command exports the graph in Portable Document Format (PDF), Hyper Text Markup Language (HTML), Multipurpose Internet Mail Extension (MIME) HTML (MHT), and rich text format (RTF) document formats. The graphs can also be exported as images in bitmap image file (BMP), Graphics Interchange Format (GIF), Joint Photographic Experts Group (JPEG), Portable Network Graphics (PNG), and Tagged Image File Format (TIFF) formats.

  - **Export Data:** This command exports data in *.CSV format.

- **Options:** This menu is used to change the appearance of the plot. The following choices can be made: display either axis in linear or logarithmic scale, display or suppress grid lines, and run a chart designer to customize the display of the graph. The Chart Designer contains three main areas—the chart elements tree on the left, the chart appearance preview in the center, and customization tabs on the right. In the chart elements tree, the visibility of individual series and some chart elements (e.g., the chart title, axis labels, the legend) can be toggled by clicking the eye icon ( ) that appears when hovering over an element name. In addition, the chart elements tree and chart appearance preview areas allow selection of chart elements by clicking them, and the selected element can be reformatted using the Options and Properties tabs on the right.

6 ENHANCEMENTS

The influence of each input on RESRAD-OFFSITE predictions can be investigated by using two independent features available in the code. The sensitivity analysis option can be used to observe the independent influence of each individual parameter. The uncertainty and probabilistic analysis option can be used to study the variation in the prediction and the importance of each individual parameter when a number of parameters are varied simultaneously over their likely range. These analyses are discussed in Sections 6.1 through 6.3 and in greater detail in Appendix C of NUREG/CR-7127 (Yu et al. 2013).

6.1 One-Parameter-at-a-Time Sensitivity Analysis

Purpose

One-parameter-at-a-time sensitivity analysis is used to study the independent influence of each individual parameter on the predicted dose, risk, and concentrations. Each of the selected parameters is varied in turn by a factor, which is first higher than its deterministic (base) value, and then lower. Thus, two additional runs of the code are performed for each parameter selected for sensitivity analysis. Three curves are plotted to show the variation of the predictions over time for the three values (low, base, high) of the parameter, while all the other parameters are held at their base values.

Displaying the Sensitivity Analysis Range

- **Menu:** First click on the input box of the parameter of interest to put it in focus. Then click on Form Options on the RESRAD-OFFSITE menu and Sensitivity Analysis (F9 key).

- **Toolbar:** First click on the input box of the parameter of interest to put it in focus. Then click on the Set Sensitivity Button (fourth button in the second cluster on the toolbar).

- **Input Window:** First click on the parameter of interest, then press the F9 key.

- **Sensitivity Input Summary Bar:** The sensitivity input summary bar (shown if Sensitivity Input Summary under the View option is checked) will include a button for each parameter selected for sensitivity analysis. The title of the button includes the variable name, the symbols */, and the factor by which to multiply and divide. Right-click on any of these buttons to review, change, or remove a sensitivity analysis on the corresponding parameter.

Selecting a Parameter for Sensitivity Analysis

- First display the Set Sensitivity Analysis Range form (Figure 6-1) while the cursor is in the input box corresponding to the desired parameter. Then set the multiplication and division factor as described below.

- Choose one of the options for the multiplication and division factor. The resultant values for the two sensitivity runs will be shown at the right along with the base value. If you choose the last option, you can enter any value greater than 1 or accept the value of 10. If the selected factor causes a parameter value to exceed its bounds, a warning

message will be displayed with the option to set the factor to the maximum allowable value. If the base value specified for any variable selected for sensitivity analysis is changed, the sensitivity button corresponding to that factor should be revisited to ensure that the values for the sensitivity analysis will still be within the bounds.

- Click on the OK button to include the parameter in the sensitivity analysis. A button for this parameter will be added on the sensitivity input summary bar, and the parameter will be selected for sensitivity analysis.

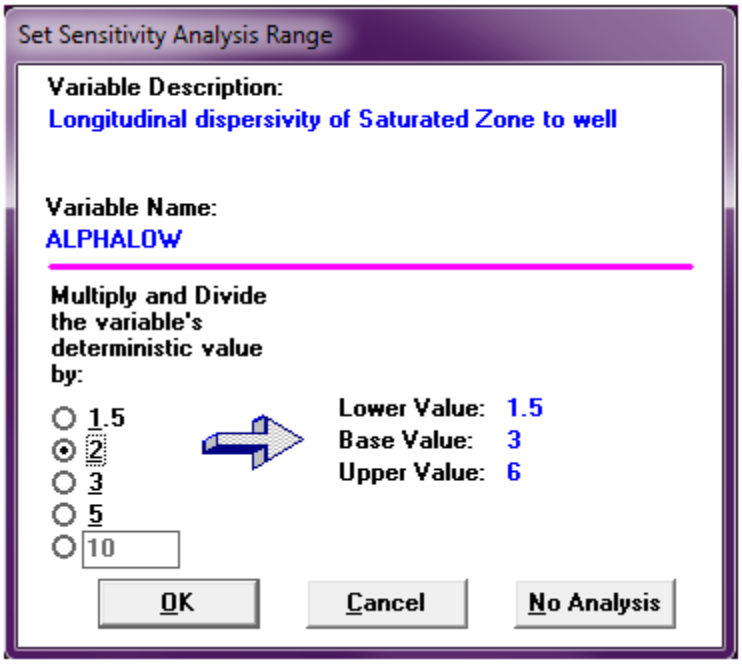

Figure 6-1 Set Sensitivity Analysis Range Form

Removing a Parameter from Sensitivity Analysis

- If a parameter has already been selected for sensitivity analysis, the button corresponding to it will be on the sensitivity input summary bar. Either right-click on that button or left-click and choose No Analysis to remove the sensitivity analysis. Clicking on Cancel will not remove the parameter from the sensitivity analysis in this case.

- If the parameter has not yet been selected, simply click Cancel on the Set Sensitivity Analysis Range form to disregard the information in the form.

Viewing Results of Sensitivity Analysis

- Sensitivity analysis results are shown only in a graphic format, not in any textual report. Launch the deterministic Graph Viewer after performing a sensitivity analysis on the selected parameters; the Sensitivity option will be displayed at the bottom of the plot selection palette (Section 5.2). Select a parameter from the drop-down box to see the sensitivity of the output to that parameter.

- More information on performing sensitivity analysis using RESRAD-OFFSITE is available in Appendix C of NUREG/CR-7127 (Yu et al. 2013).

6.2 Uncertainty and Probabilistic Analysis

Purpose

Uncertainty and probabilistic analysis is used to determine the variation in the predictions (dose, risk, or media concentrations) due to the uncertainty in the values of some parameters and the probabilistic nature of other parameters. It can also be used to identify the input parameters that are responsible for the major part of the variation in the output (Multi-Parameter Sensitivity Analysis, Section 6.3). Then the resources can be focused on reducing any uncertainty in those parameters in order to most efficiently reduce the variation in the predicted dose, risk, or media concentration.

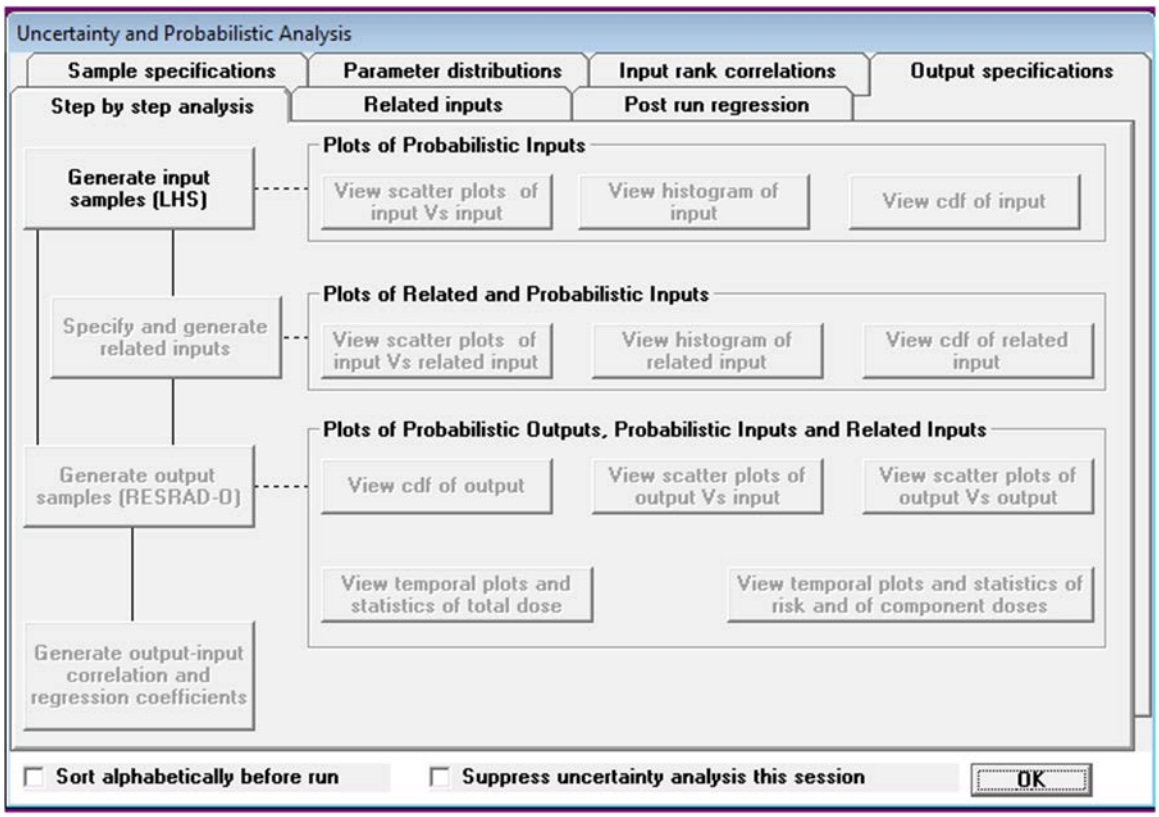

Figure 6-2 Uncertainty and Probabilistic Analysis Form

Selecting an Input Parameter for Uncertainty and Probabilistic Analysis

- **Menu:** First click on the input box of the parameter of interest to put it in focus. Then click on Form Options and the Uncertainty/Probabilistic Analysis (F8 key) (Figure 6-2).

- **Toolbar:** First click on the input box of the parameter of interest to put it in focus. Then click on the Uncertainty/Probabilistic Analysis button (farthest button on the right in the second cluster on the toolbar; it has a ±? symbol on it).

- **Input Window:** Press the F8 function key while the focus is on the input parameter to be included for uncertainty or probabilistic analysis.

The distribution of the selected variable is specified in the Parameter Distributions tab (Section 6.2.1) of the Uncertainty and Probabilistic Analysis interface form.

Displaying the Uncertainty and Probabilistic Analysis (Interface) Form

- **Menu:** Click on View and then the Uncertainty/Probabilistic interface (Ctrl-F8). This displays the form and sets the user preference to always display the form when the RESRAD-OFFSITE interface is launched.

The methods just described (Selecting an Input Parameter for Uncertainty and Probabilistic Analysis) will also display the form if it is not already visible. They are not included here because they also select the input that is in focus at the time they were invoked for uncertainty or probabilistic analysis.

The Uncertainty and Probabilistic Analysis form currently has one tab (Related Inputs) under development and six active tabs as follows:

1. **Parameter Distributions:** The uncertainty in the value of an input or the probabilistic nature of an input is specified in the form of a probabilistic distribution on this tab.

2. **Sample Specifications:** This tab is used to specify how the probabilistic input sets will be generated from the distributions specified in the previous tab.

3. **Input Rank Correlations:** This tab accepts the specification of correlations between pairs of uncertain/probabilistic inputs, if the appropriate choice is made in the Sample Specifications tab.

4. **Output Specifications:** This tab describes the different types of probabilistic display and analysis options that are available for the various outputs and is used to specify whether the component doses, risks, and concentrations for each realization of a probabilistic run need to be saved. It is also used to specify the desired output-input correlation and regression coefficients.

5. **Step-by-Step Analysis:** This tab allows the analysis to be carried out in sequence and provides an option to view the results of each step before proceeding to the next. It also allows viewing of the probabilistic graphics from a previous analysis.

6. **Post Run Regression:** This tab is used to obtain a specific selection of output-input correlation and regression coefficients.

These six tabs are described more fully in Sections 6.2.1 through 6.2.6.

6.2.1 Parameter Distributions Tab

All the input parameters that are selected for uncertainty and probabilistic analysis are listed in the Variable Description box at the left of the Parameter Distributions tab (Figure 6-3). Click on any of the entries in that box to display the distribution specified for that input parameter. When

an input parameter is selected for uncertainty and probabilistic analysis, it is added to the bottom of the list. The uncertainty in the value of the input parameter or the probabilistic nature of the input parameter can be specified on the right side of the tab. This is done as follows:

1. Select the type of distribution from the drop-down box.

2. Enter the statistics necessary to define the selected distribution in the input boxes below the drop-down box.

3. Save the distribution and its statistics by clicking on the Update Parameter Stats and Distribution button, the Previous Parameter arrow, or the Next Parameter arrow.

4. You can cancel any changes made to the distribution type or statistics, if they have not yet been saved by clicking on the Restore Parameter Stats and Distribution button or by simply clicking on a different input parameter in the list on the left.

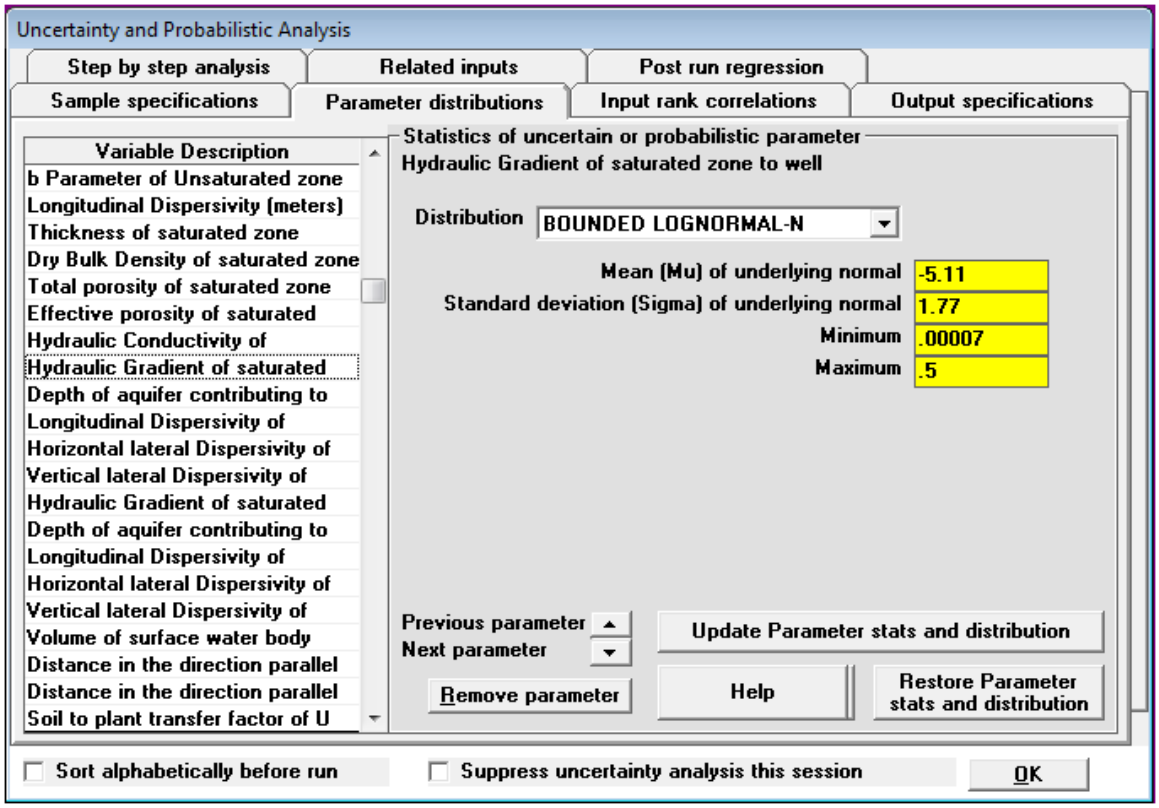

Figure 6-3 Parameter Distributions Tab of the Uncertainty and Probabilistic Analysis Form

Clicking on the Help button on this tab displays the Help on Statistical Distributions form for the selected distribution. This Help form (Figure 6-4) displays the probability density function of the selected distribution in the brown box on the right side of the form. Interrelationships among alternative forms for specifying the same distribution, or the definitions of the distribution statistics, are also included in the same box, where appropriate. Any conditions that must be satisfied by the distribution statistics are in the gray box at the bottom of the form. The

probability density function of the distribution is sketched on the left side of the form. The bounds of the input parameter are indicated by two red (vertical) lines, if they fall within the sketch. If the red lines are visible, the statistics for the distribution need to be changed to confine the distribution within these bounds.

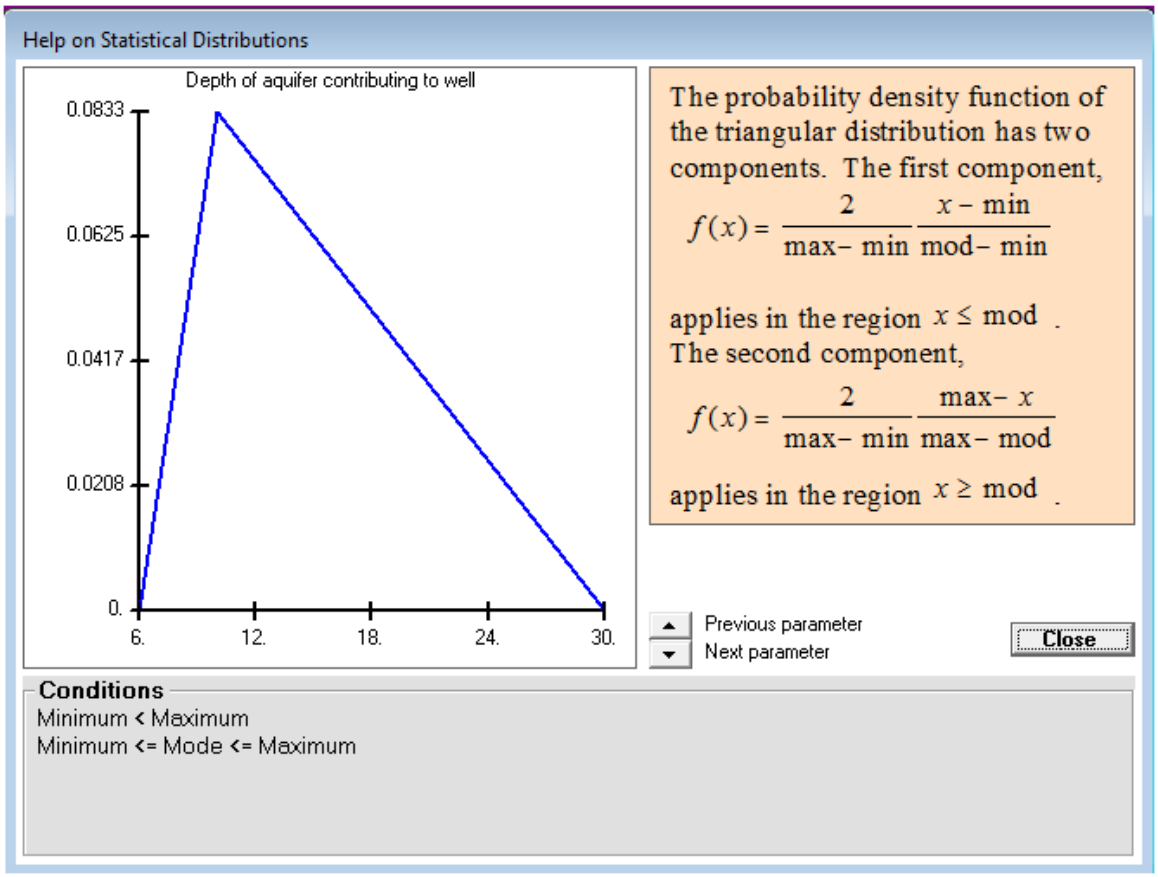

Figure 6-4 Help on Statistical Distributions Form

6.2.2 Sample Specifications Tab

This tab (Figure 6-5). specifies how the distributions specified in the previous tab are sampled and how the samples for the different inputs are to be combined to produce the set of inputs. The frame on the right side of the tab describes the purpose and effect of each of the items on this tab.

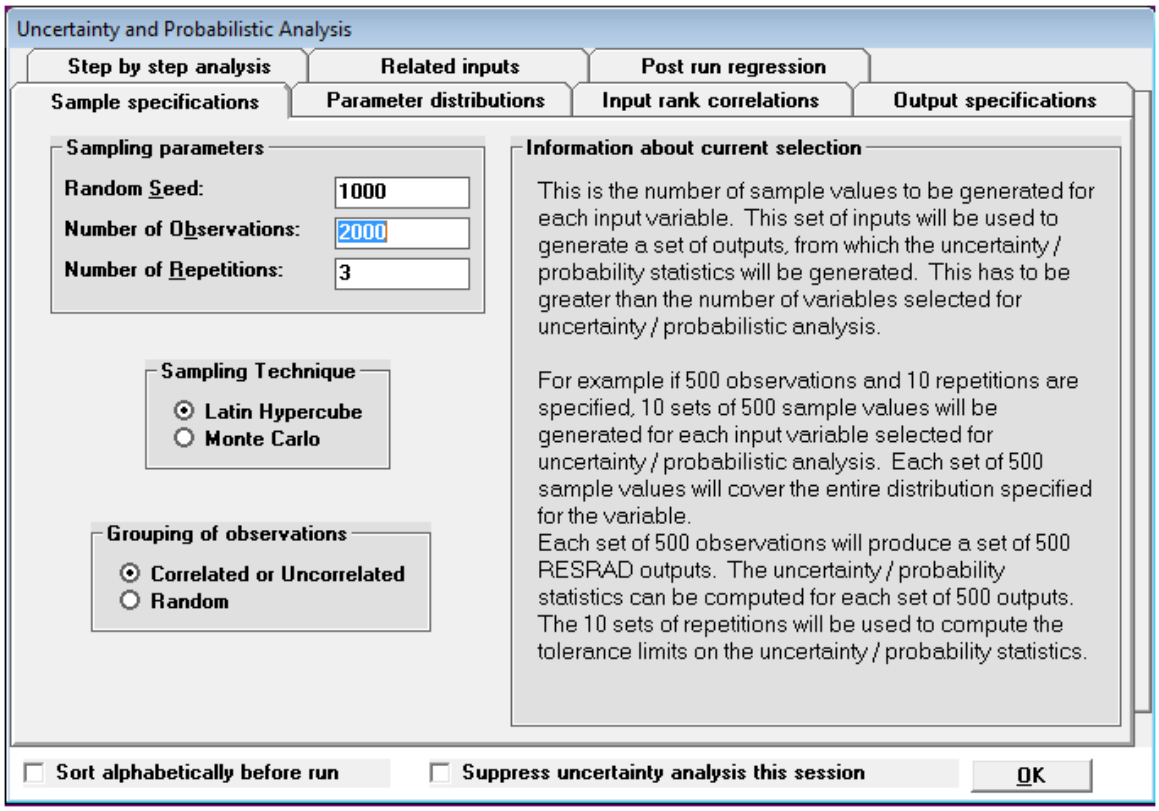

Figure 6-5 Sample Specification Tab of the Uncertainty and Probabilistic Analysis Form

- **Number of Observations:** This is the number of values that will be sampled from the distribution of each input parameter specified in the Parameter Distributions tab. This must exceed the number of input parameters, if correlations are specified between inputs or if regression statistics are to be produced. The accuracy of the probabilistic predictions can be improved by increasing the number of observations.

- **Sampling Technique:** The code offers a choice of two sampling techniques: Latin hypercube sampling (LHS) or Monte Carlo. In the LHS technique, the distribution is divided into equally probable segments, equal in number to the desired number of observations. Then a value is picked at random from each segment according to the probability density function within that segment. This ensures that the sample covers the entire range of the distribution, even when the number of samples is relatively small. In the Monte Carlo technique, the desired observations are each picked at random from the entire distribution according to the probability density function. When the number of samples is small, the sampled values do not represent the distribution as well as the values obtained by using the LHS technique.

- **Random Seed:** Both sampling techniques choose the sample value from the appropriate part of the distribution at random according to the probability density function. The sampling code has a random number generator to produce the pseudo-random numbers needed to do the random sampling. The random number generator produces a random number based on the seed it receives. It also increments the seed to

the next integer every time a random number is generated. Thus, the sequence of random numbers that is generated to obtain the sample can be exactly reproduced, if the same starting seed is used again. The Random Seed input is the starting seed; it allows the code to reproduce the same set of probabilistic inputs, should there be a need to rerun the same analysis at a later time on a different computer.

- **Grouping of Observations:** After the code obtains the required number of samples for each input parameter, it produces the probabilistic set of inputs. Each element of the set of inputs will contain one sample from each of the input parameters. The code offers two choices on how the samples from each input parameter are combined to make the set of inputs: (1) Random grouping or (2) Correlated or Uncorrelated grouping. If it is necessary to have correlations among some of the inputs, or if it is necessary to ensure that there is no correlation among some of the inputs (i.e., zero correlation), the correlated grouping must be used.

- **Number of Repetitions:** This is the number of times the analysis needs to be repeated in order to obtain a measure of the accuracy of the probabilistic predictions. Increasing the number of observations increases the accuracy of the probabilistic predictions, but a measure of the accuracy can be obtained only if the analysis is repeated. The closeness of the results, or the lack thereof, is an indication of the accuracy, or lack of accuracy, of the predictions.

6.2.3 Input Rank Correlations Tab

This tab (Figure 6-6) becomes active to accept input only if the Correlated or Uncorrelated grouping option on the Sample Specifications tab has been chosen. Correlations are specified among the ranks of the inputs, not the raw values of the inputs. The pair of inputs that are to be correlated are chosen from the two drop-down boxes, and the RCC is specified in the corresponding input box, all on the frame at the left. The Update Correlation Table button on the right frame saves the information in the correlation table at the left. Correlations that were saved can be deleted by first clicking on the corresponding line in the table at the left and then clicking on the Remove Correlation button on the right. The correlations can also be edited by clicking on the appropriate row in the table and then changing the value of the RCC. The revised correlation must be updated for it to take effect. A pair of uncorrelated inputs (i.e., a pair with a zero correlation coefficient) need not be specified in the table because the correlation between any pair of inputs that are not included in the table is implicitly set to zero in the sampling code.

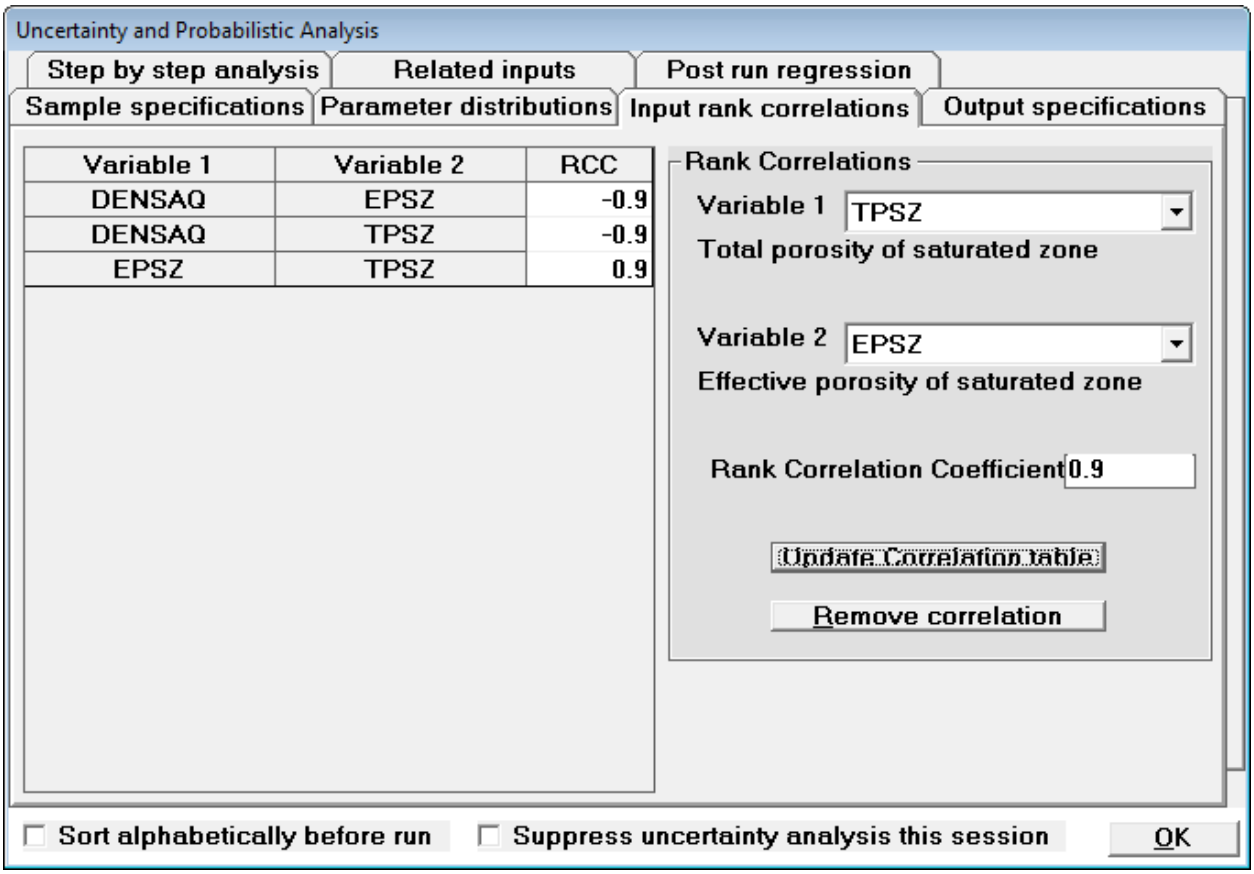

Figure 6-6 Input Rank Correlations Tab of the Uncertainty and Probabilistic Analysis Form

6.2.4 Output Specifications Tab

The frame at the top-left of this tab (Figure 6-7) shows the five categories of dose and risk for which probabilistic results can be obtained. Four of the five categories are always active; the user can choose whether to save the dose, risk, and concentration in a file at each graphical time for each realization (each observation of each repetition). The execution time increases when this option is checked. Clicking on the check box displays, in the frame at the right, the various forms of output that are available for each category. The frame at the lower left is used to select the output-input correlation coefficients to be computed during the analysis. Alternatively, these can be unselected before the run, and only the desired correlation and regression coefficients can be computed after the main computational code is run. This is done by using the Post Run Regression tab.

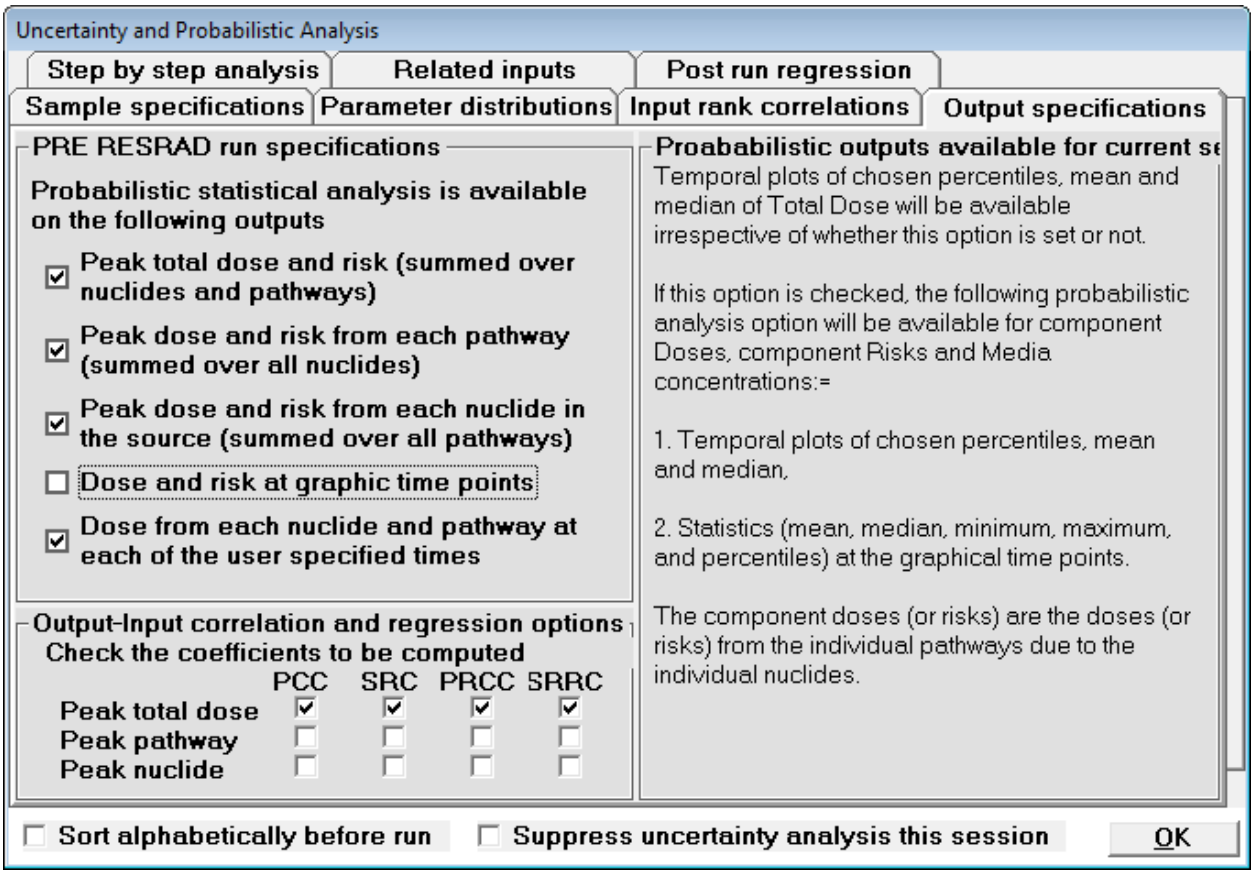

Figure 6-7 Output Specifications Tab of the Uncertainty and Probabilistic Analysis Form

6.2.5 Step-by-Step Analysis Tab

This tab (Figure 6-8) fulfills three main functions: (1) permits a step-by-step approach to performing probabilistic analysis, (2) serves as the starting point for viewing the probabilistic graphics, and (3) permits viewing of previously saved results. The different command buttons become active at the appropriate juncture.

The Generate Input Samples (LHS) command is the only button that is visible for a newly created uncertainty/probabilistic input file. Clicking on the button launches the probabilistic sample generating code (LHS). The remaining three buttons in the upper active (first) row become active when the input samples have been generated. The Generate Output Samples (RESRAD-O) button is also activated at this time. The three buttons in the first row are used to view the corresponding plots and to check the statistics of the input distributions. These plots can be viewed to confirm that the samples accurately represent the specified distribution and to visualize any correlations that were specified between the inputs.

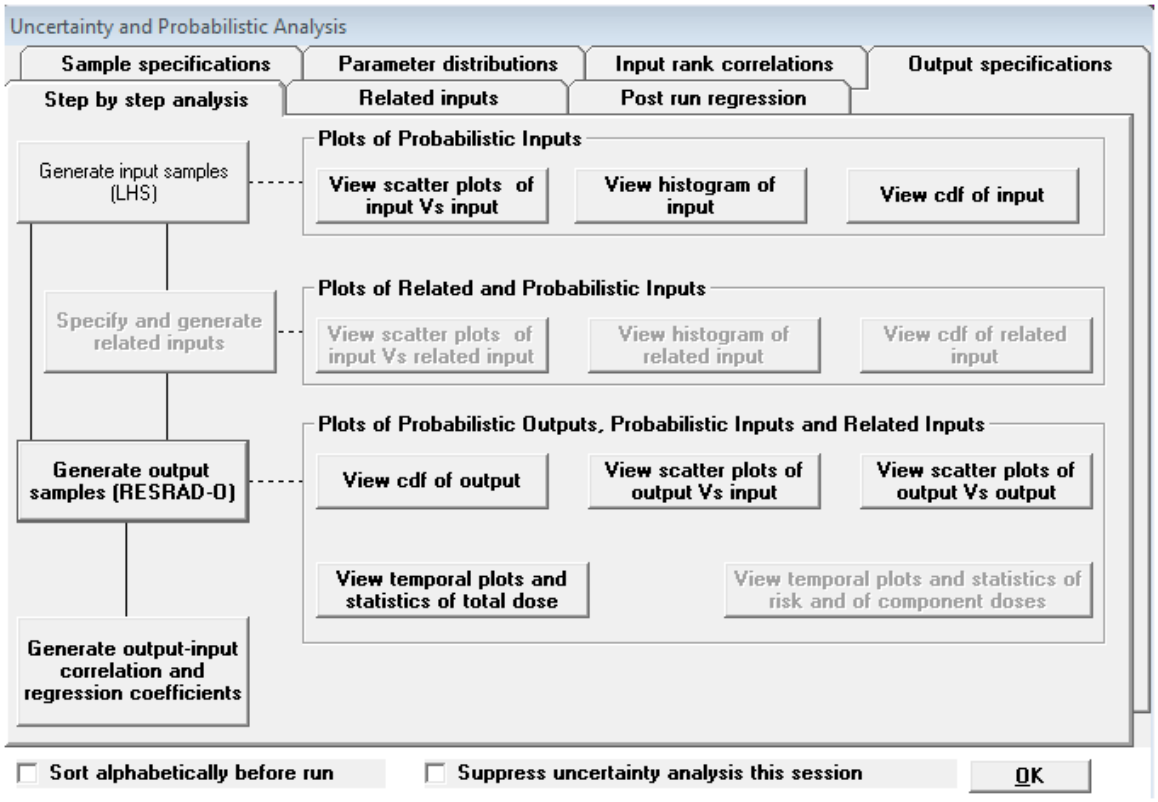

Figure 6-8 Step-by-Step Analysis Tab of the Uncertainty and Probabilistic Analysis Form

Clicking on the Generate Output Samples button launches the main computational code. The execution time can be significant for probabilistic analysis. While some simple cases might run in a few minutes, a typical analysis can run for hours. An estimate of the run time is displayed in the Run Time Feedback form (Run form, Section 7.4). The remaining command buttons become active when the output samples have been produced.

The other three buttons in the third row are used to view the probabilistic plots pertaining to the output. These are discussed in more detail in the following paragraphs. The buttons on the fourth row produce temporal plots. The left button produces temporal plots and statics for the total dose; the corresponding plots for the component doses, risks, and concentration have not yet been developed. Instead, the right button will produce a deterministic plot file for each of the realizations; these can then be viewed in the deterministic Graph Viewer. Clicking on the Generate Output-Input Correlation and Regression Coefficients button (bottom row) displays the Post Run Regression tab.

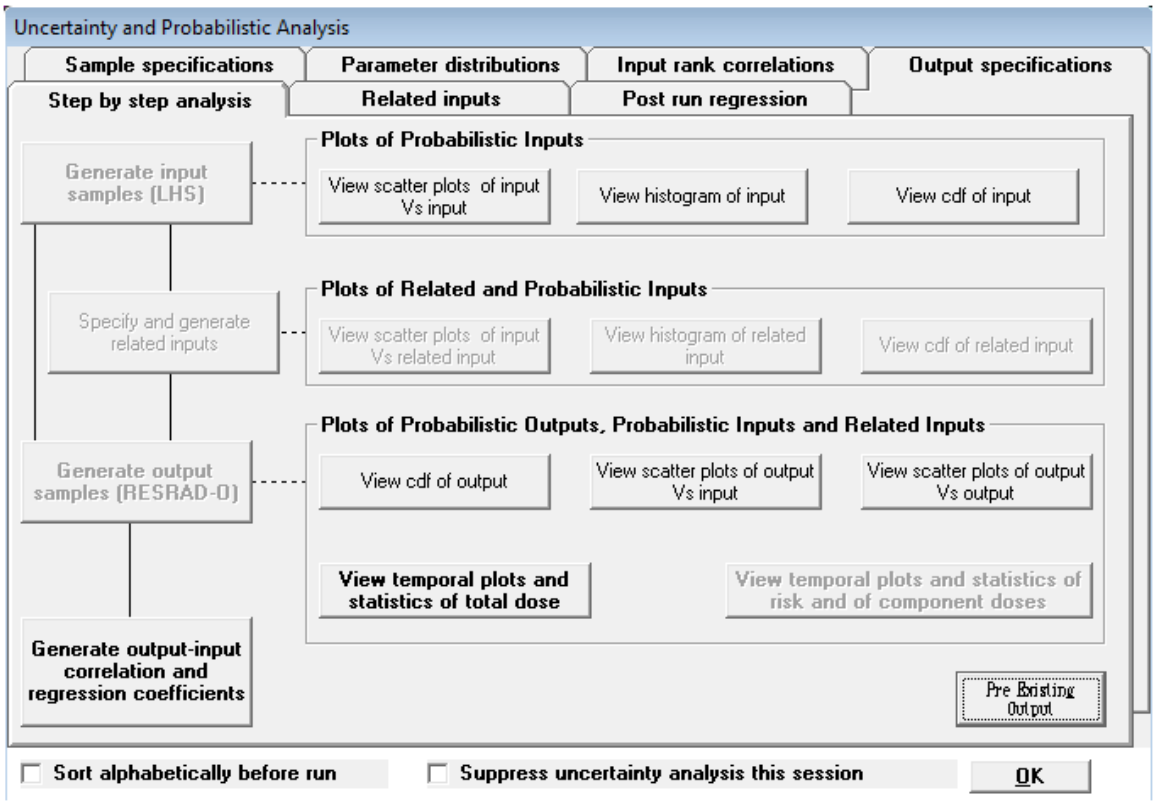

Figure 6-9 Step-by-Step Analysis Tab of the Uncertainty and Probabilistic Analysis Form When a Previously Executed Input File Is Opened

Plots from previous runs can also be viewed from this tab by opening the corresponding input file. When a preexisting input file is opened, the code checks for an indication that the file has been executed previously. If it has and if probabilistic results are available, the Preexisting Output button is displayed at the bottom-right of the tab (Figure 6-9). Click on this button to load the probabilistic input and output into the interface memory. This usually takes some time, so a Please Wait bar is displayed to ask for the patience of the user. The seven view plot buttons can then be used to view the three input plots (scatter plots of input against input, histogram of input, and CDF [cumulative distribution function] of input), the three output plots (CDF of output, scatter plots of output against input, and scatter plots of output against output), and the temporal plots for total dose. Input-output regression analysis can also be performed.

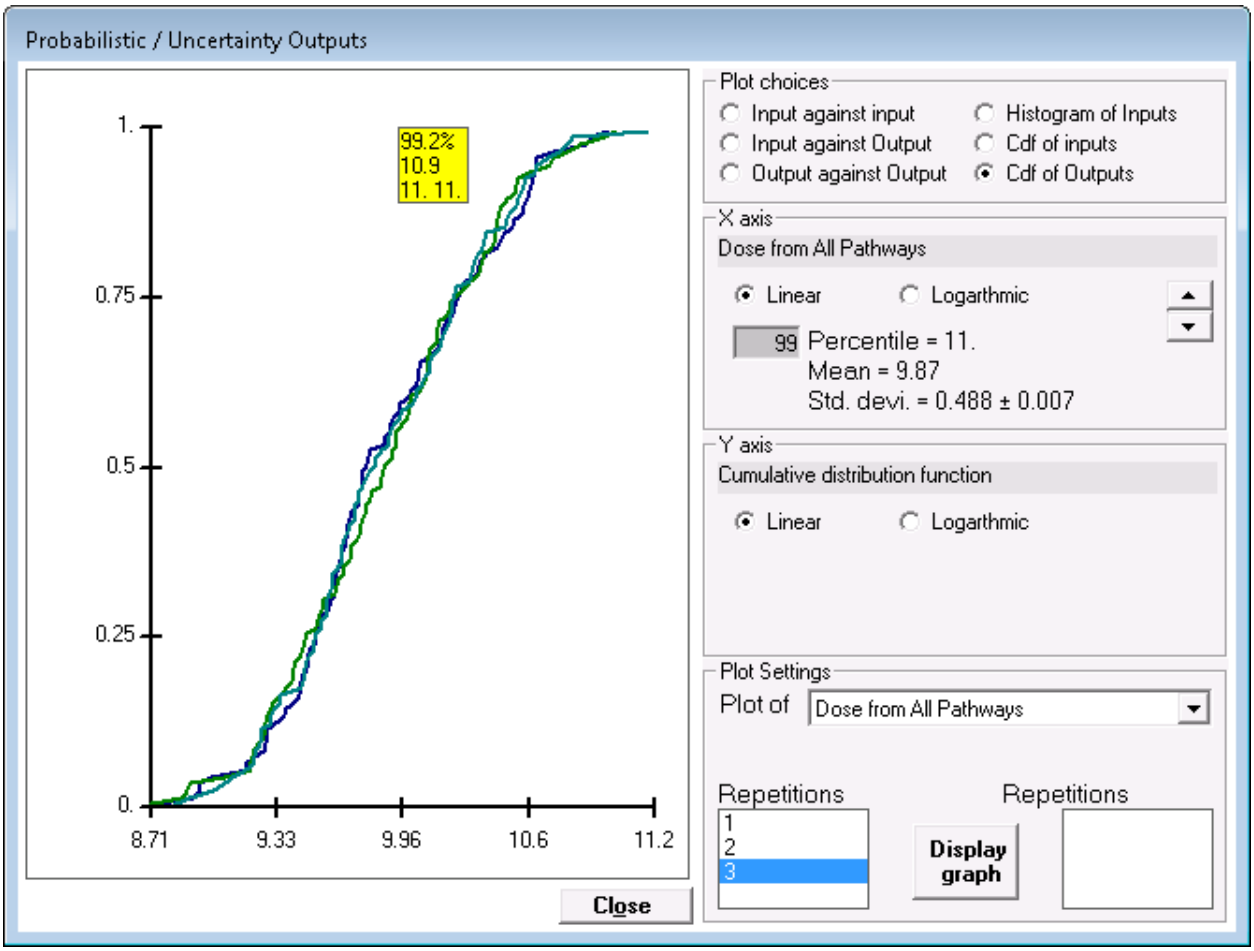

Figure 6-10 The CDF Output View of the Probabilistic/Uncertainty Graphics Output

The CDF of the output (Figure 6-10) can be used to obtain any desired percentile of the output (dose or risk). The value of the percentile can be obtained by keying in the desired percentile in the gray box in the X-axis frame on the right side of the Probabilistic/Uncertainty Outputs screen. This frame also displays the mean and the standard deviation of the output. Error ranges are shown, where appropriate, after a plus/minus symbol (±). (If the error range is less significant than the number of significant figures in the output, it will not be shown.) The value of the percentile for the different repetitions can also be displayed by clicking on the location of the desired percentile on the plot. This value is shown in the yellow tooltip that appears below the cursor. The tooltip disappears when the cursor moves away from the box. The up and down arrow buttons can be used to cycle over all the probabilistic outputs. One or more repetitions can be omitted from the plot, if needed to improve the clarity. At the bottom-right of the screen, the Display Graph button must be depressed to show the changes made in the Plot Settings frame. This form can be resized by expanding the sides or corners.

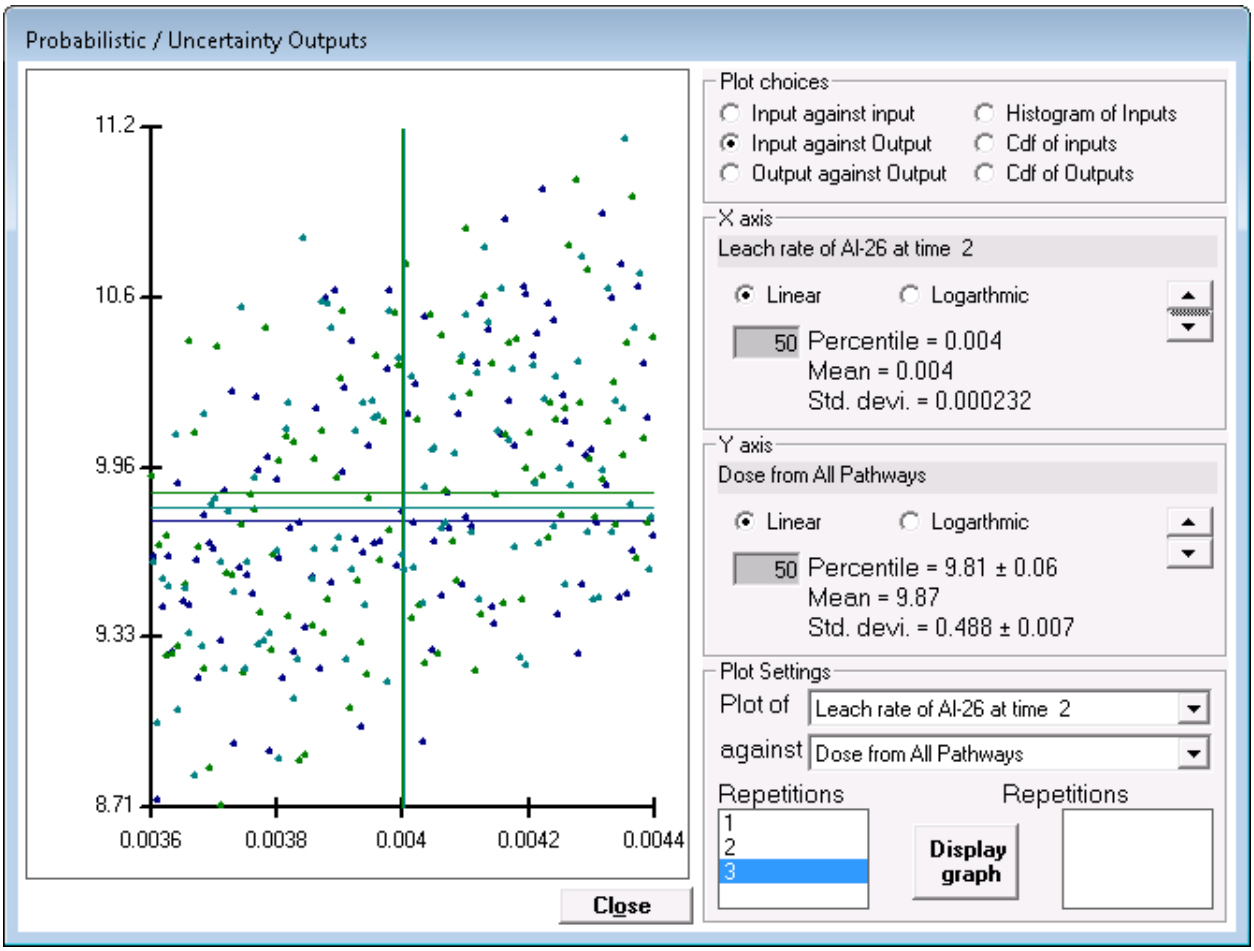

Figure 6-11 Scatter Plot of Output against Input View of the Probabilistic/Uncertainty Graphic Output

The scatter plots of output against input are helpful in identifying the input parameters that have a significant influence on the output, especially when there are few significant input parameters. However, as the case illustrated in Figure 6-11 shows, it is not easy to visually pick out the important parameters when they are masked by the compounding effects (interference) of other equally or more important input parameters. The important parameters can be identified by using the regression coefficients, as was done in the case illustrated in Figure 6-16 for the same case shown in Figure 6-11.

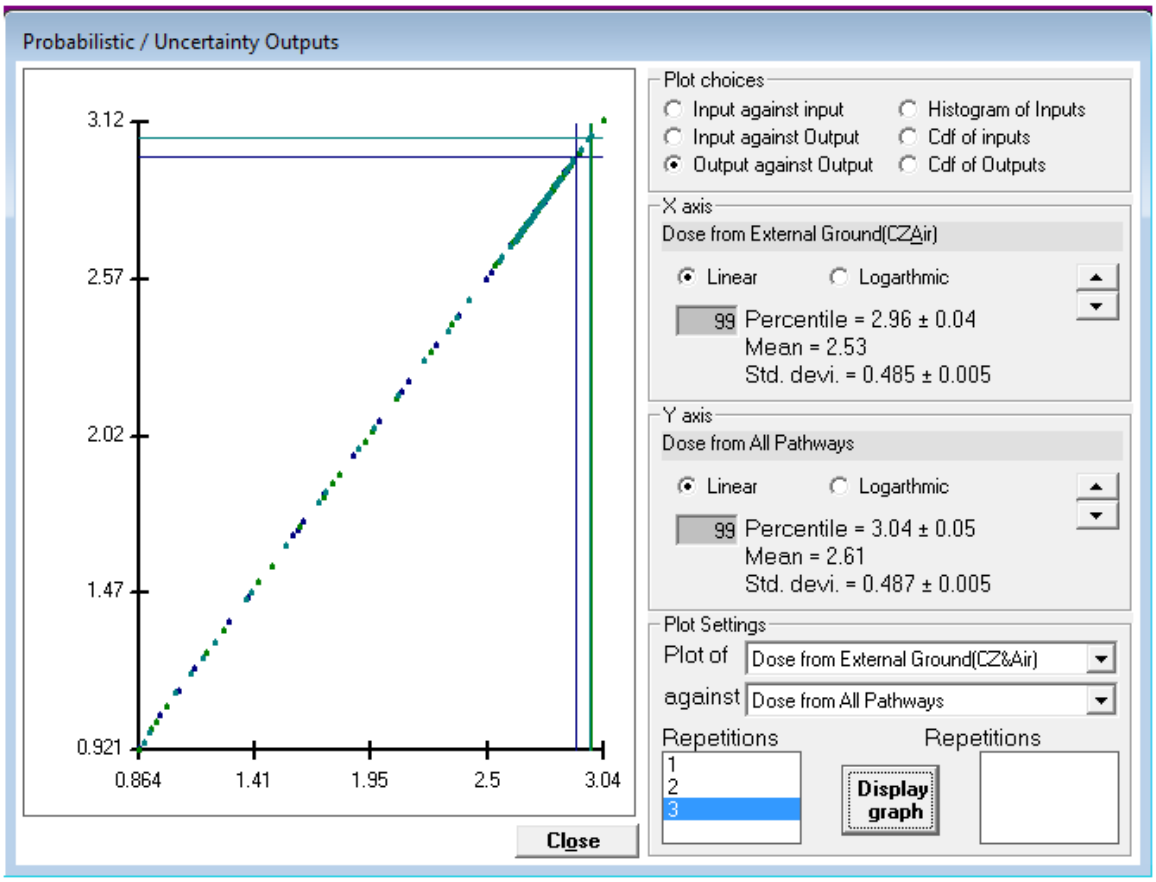

Figure 6-12 Scatter Plot of Output against Output View of the Probabilistic/Uncertainty Graphics Output

Scatter plots of output against output (Figure 6-12) are useful for identifying the pathways and nuclides that make a significant contribution to the variation in the dose or risk. They can also point to the importance of common parameters that affect the significant pathways.

The temporal plot shows the variation of the mean, median, and one other user-specifiable percentile of the total dose (dose summed over nuclides and pathways) with time (Figure 6-13). The plots for all repetitions can be displayed together, as shown above to see the variation among repetitions; plots of each repetition can be displayed for clarity. The coordinates of any location on the plot can be displayed in a highlighted box by moving the cursor to that point. The data from the plots for that corresponding year can be displayed by clicking the mouse; the data for each of the repetitions will be shown in the box at the lower right of the form.

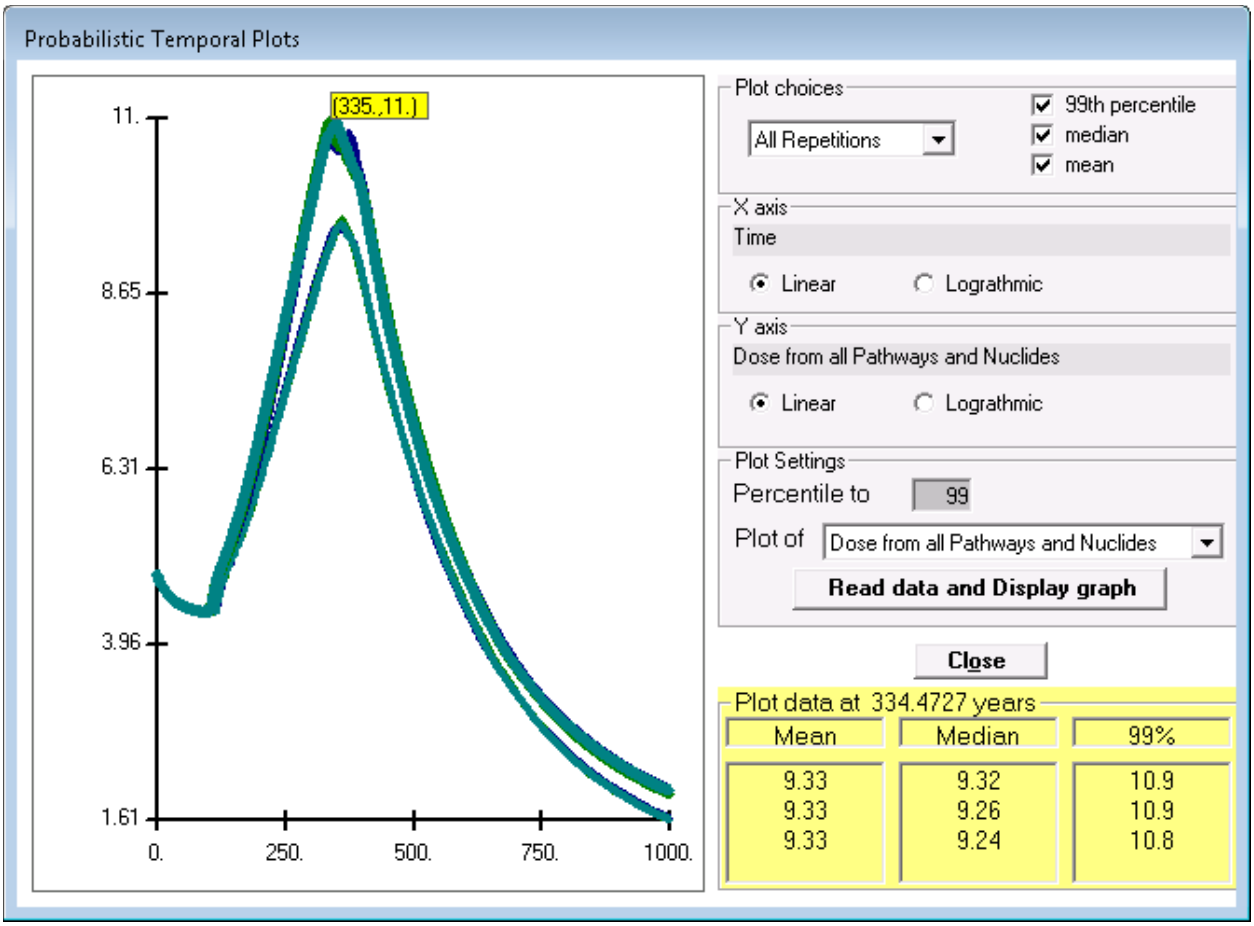

Figure 6-13 Probabilistic Temporal Plots

6.2.6 Post Regression Tab

This tab (Figure 6-14) is used to perform regression analysis among the desired outputs and the probabilistic inputs after the RESRAD-OFFSITE main computational code is run. Check the desired outputs (dose and/or risk and the pathways) and click on the Determine Correlation and Regression Coefficients button. The results are appended to the probabilistic dose and risk report. A separate regression report with the probabilistic inputs sorted in decreasing order of influence is displayed in the Report Viewer.

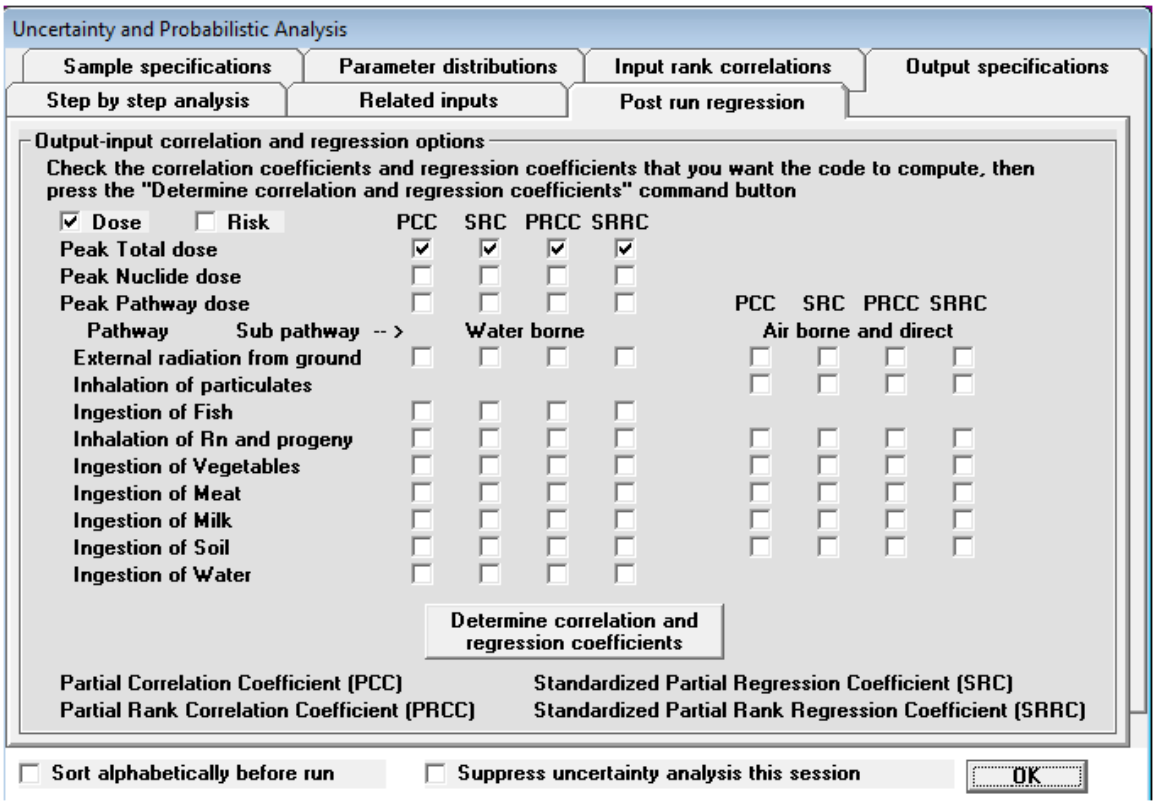

Figure 6-14 Regression Analysis Tab of the Uncertainty and Probabilistic Analysis Form

6.3 Multi-Parameter Sensitivity Analysis

Multi-parameter sensitivity analysis can be performed using the uncertainty feature (Figure 6-15) by allowing more than one parameter to vary at the same time. A parameter can be selected for this analysis by pressing Shift-F8 when the parameter has focus. The selected parameters can have a uniform distribution with a half-range of 99%, 50%, 25%, 10%, 5%, or 0.1% of the deterministic value on either side of the deterministic value, or a log-uniform distribution ranging from 1/10 to 10, 1/5 to 5, 1/3 to 3, 1/2 to 2, 2/3 to 3/2, or 1/1.001 to 1.001 times the deterministic value (see Section 6.2, Uncertainty and Probabilistic Analysis). The sensitivity of the dose or risk to the parameters is given by the standardized regression coefficient or the standardized rank regression coefficient (Figure 6-16).

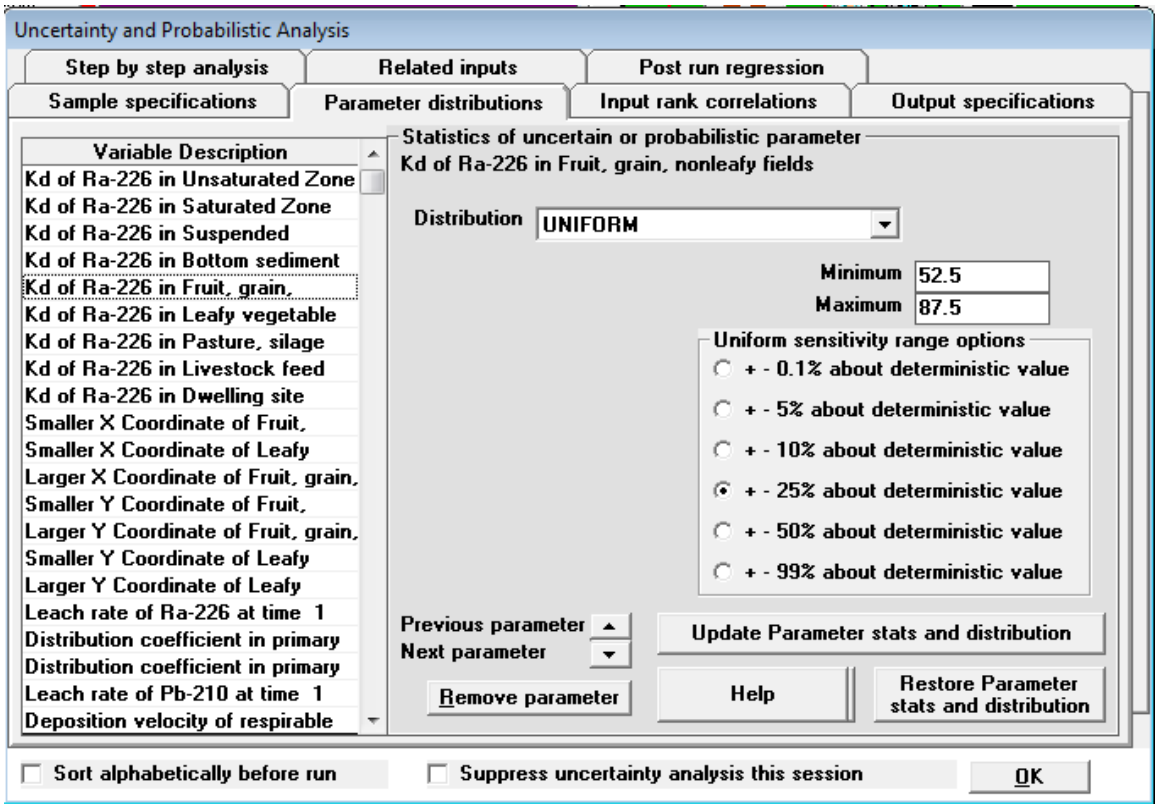

Figure 6-15 Multi-Parameter View of Parameter Distribution Tab of the Uncertainty and Probabilistic Analysis Form

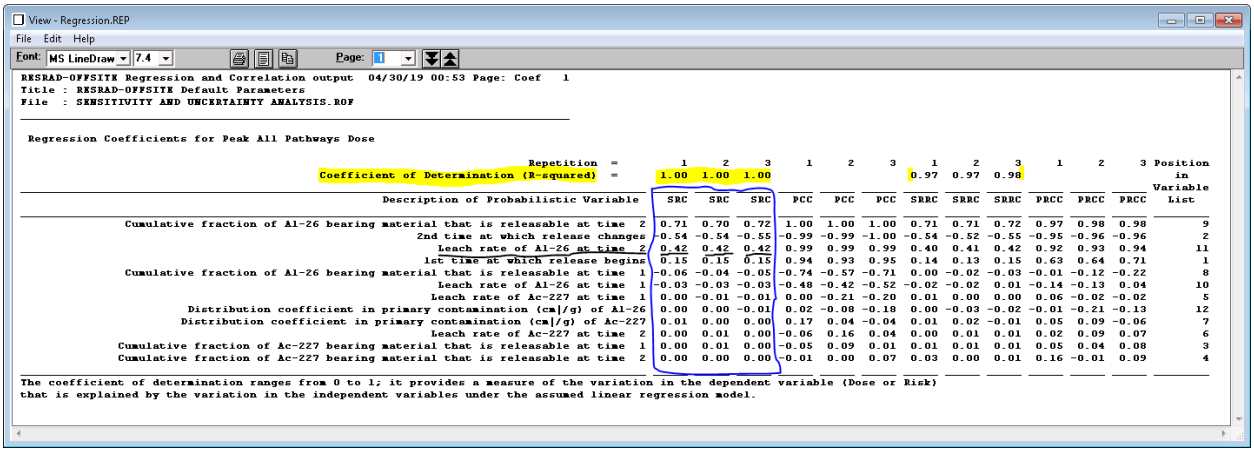

Figure 6-16 Regression Output

More information on performing sensitivity analysis using RESRAD-OFFSITE is available in Appendix C of NUREG/CR-7127 (Yu et al. 2013).

The uncertainty analysis feature can also be used to see the variation of dose over the range of one parameter at various levels of another parameter. The scatter plot of output against input is useful in seeing this variation and the interaction among the inputs, as shown in Figure 6-17. The coordinates of any point on the figure can be found by moving the cursor to that point; clicking the mouse will display the crosshairs. This is useful in finding the peak of a curve.

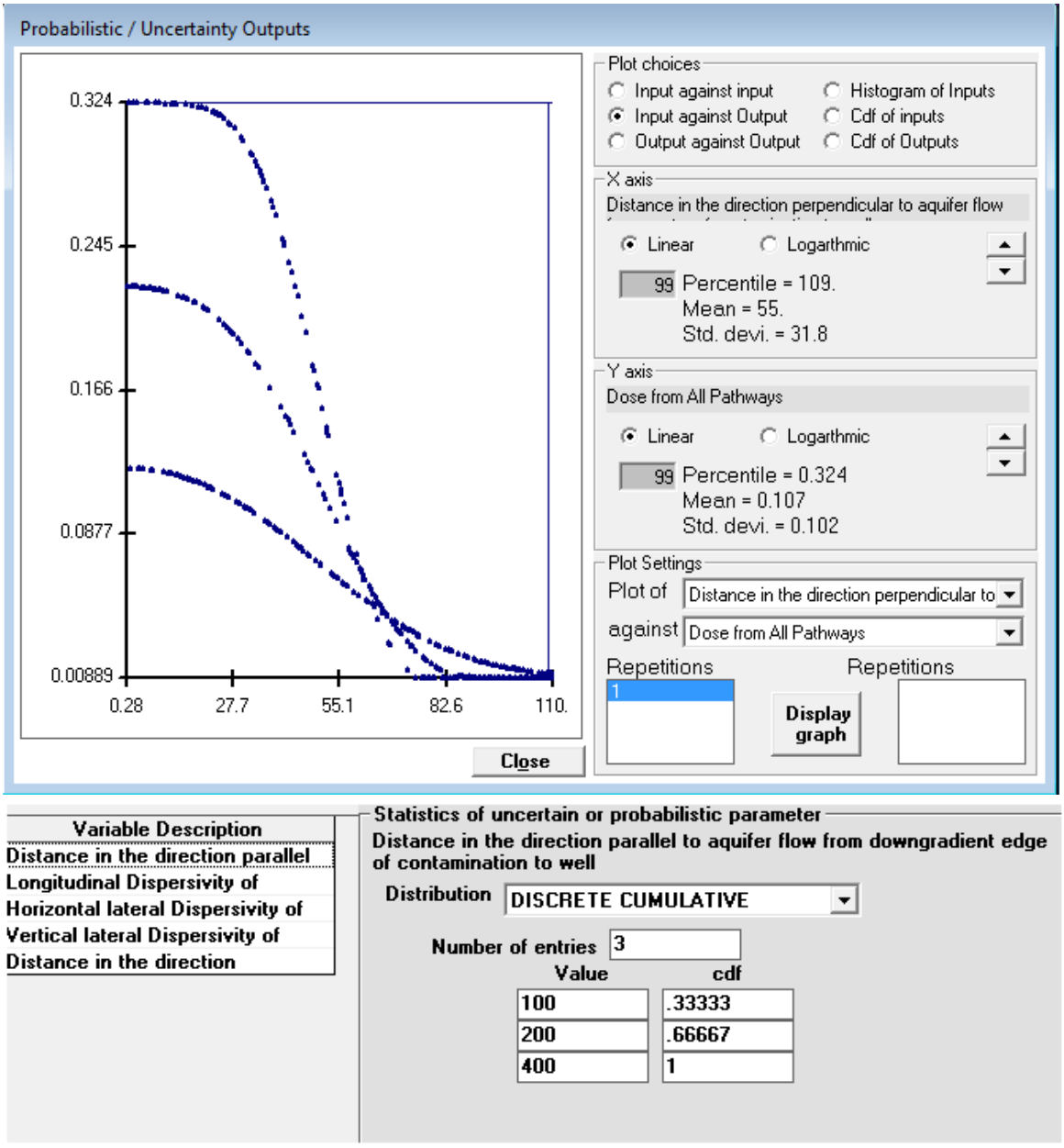

Figure 6-17 Output against Input Scatter Plot Showing the Variation of Output with One Input at Different Values of Another Input

6.4 Data Transfer

RESRAD-OFFSITE Version 4 allows the user to generate and read template files. The Data Transfer submenu has two commands: Generate Template Files and Read Template Files. Clicking on the Generate Template Files command opens the Formatted Data Transfer form (Figure 6-18). The form has instructions to generate and read template files. The radionuclide-dependent data files generated by the code also have additional information and instructions for modifying that data file.

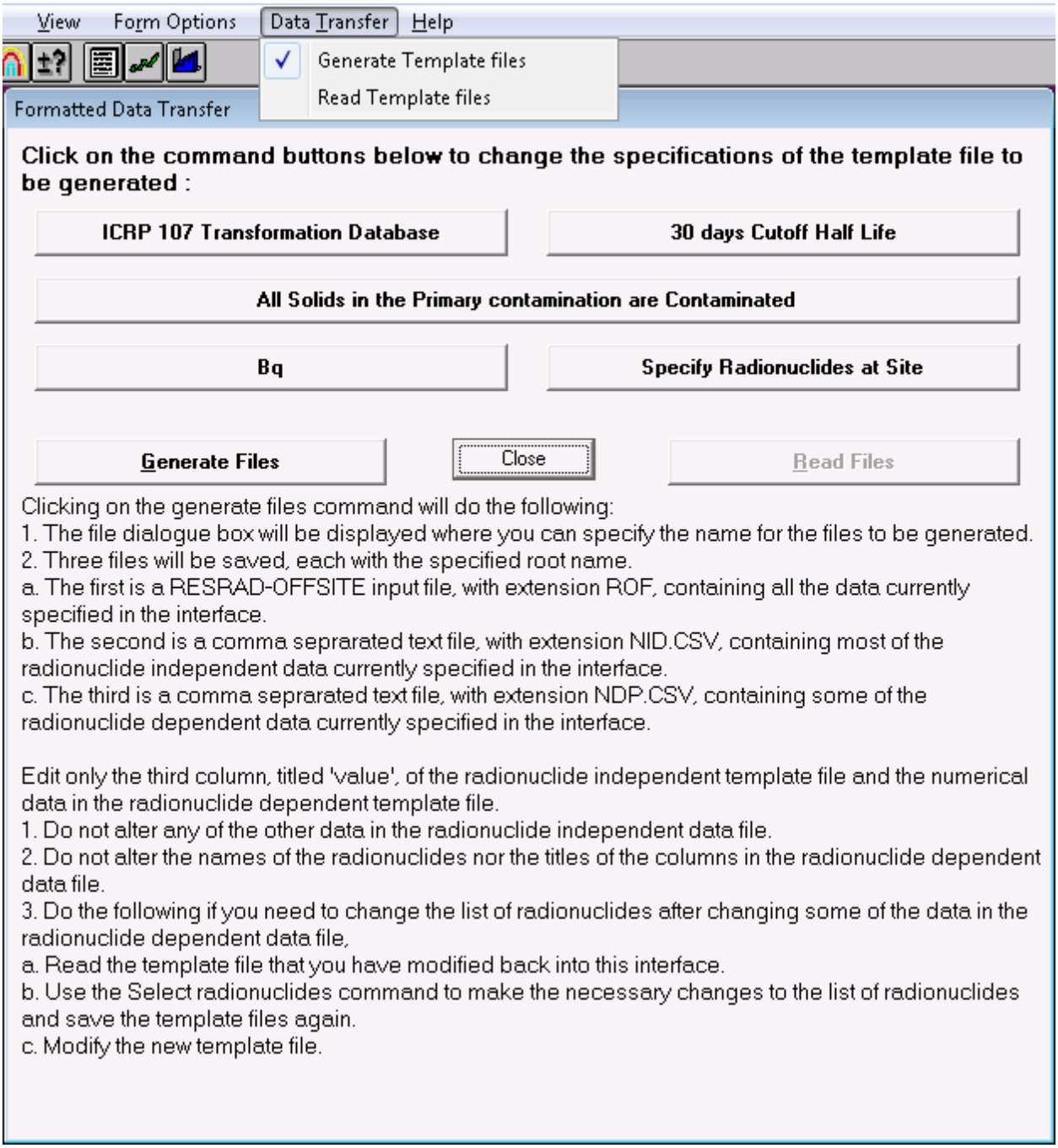

Figure 6-18 Formatted Data Transfer Form

7 HELP

Various levels of help are available in RESRAD-OFFSITE:

- **Application Help Form:** A help file that is accessible from the code gives a description of each input and explains how the parameter is used in the code.
- **Message Log (View - OUTPUT.FIL) Form:** A message log that is produced during the execution of the computational code is useful for debugging, if the code should terminate before completion.
- **RESRAD Website:** The RESRAD website has documents that relate to the RESRAD family of codes. The latest code is available for downloading from the site. The About RESRAD-OFFSITE form from the Help menu of the code contains a link to the RESRAD website and the e-mail address of the RESRAD team.
- **Run Time Feedback Form:** This gives information about the progress of the computation and a dynamic estimate of the run time for probabilistic cases.
- **PDF Versions of the User's Guide, the User's Manual, and Other Documents:** This guide, the technical manual, and the other reports that are listed in the menu can be accessed in PDF form.

7.1 Application Help (on Input Parameters)

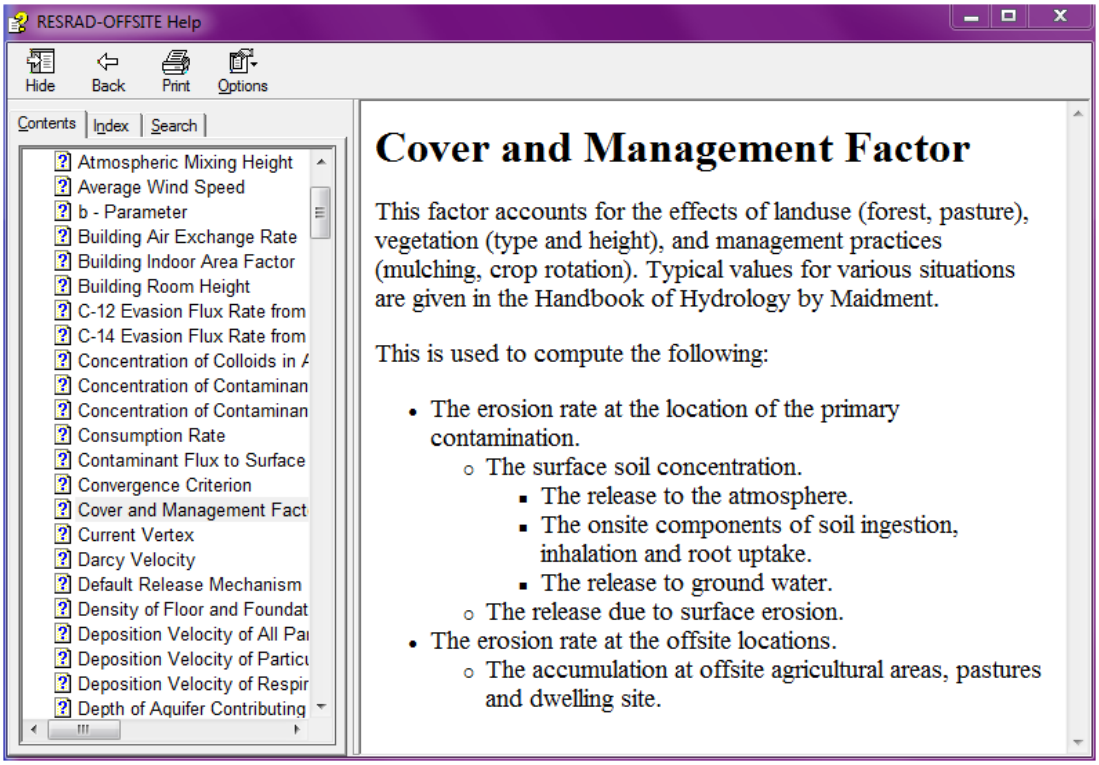

Figure 7-1 Context Sensitive Help

Getting Help

- **Figure Menu:** When the desired parameter is in focus, select context help from the Help submenu (press Alt-H, then press C) (Figure 7-1).

- **Input Window:** Press the F1 key.

- **From within the Help Window:**
  - Click on the desired parameter name on the Contents tab.
  - Search for a word in the Search tab.

The Help file has a simple description of the input parameter selected by the user and how the parameter is used in the code. For a more detailed description of the parameter and for information on how to obtain site-specific values, please refer to the RESRAD Data Collection Handbook.

7.2 Message Log

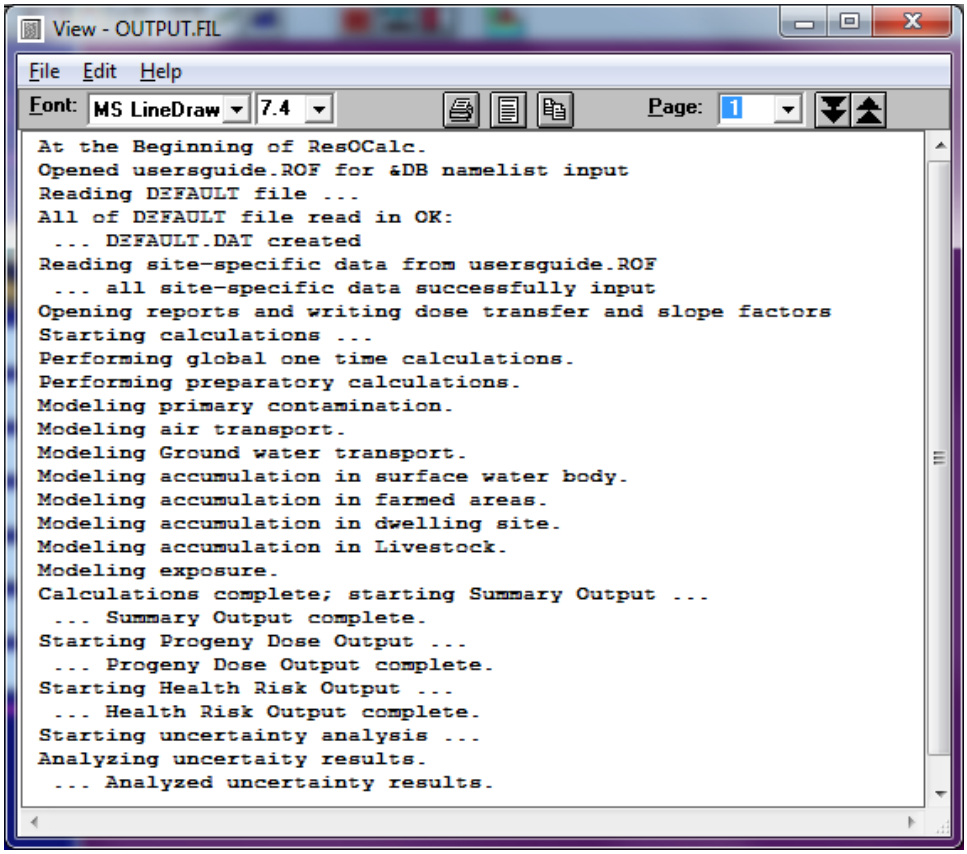

Figure 7-2 Message Log Generated by the Computational Code

Getting to the Log

From the Main Menu, choose View and Message Log. The message log (Figure 7-2) will also be displayed if the computational code encounters an error.

Interpreting the Log

This file lists the progress of the computational code as it completes each phase of the calculation and begins the next phase. If the computational code terminates before completing the calculations, the file will contain an error message that should be reported to the RESRAD team.

Reporting Problems

The e-mail address for communicating about problems and asking questions is resrad@anl.gov.

7.3 Website

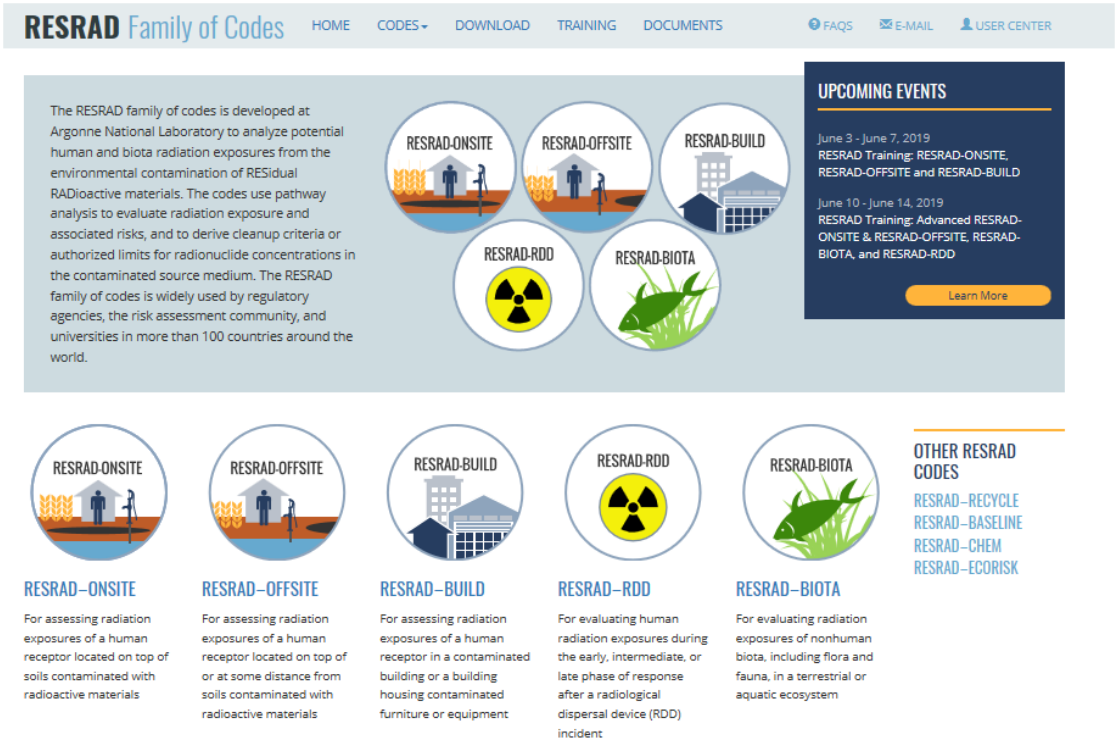

Figure 7-3 RESRAD Website

Getting to the Home Page

Type the RESRAD website address, http://resrad.evs.anl.gov, in your Web browser or click on the link to it in the code. The links are found on the About RESRAD-OFFSITE form (press Alt-H, then press A) and in the Help tab of the Navigator window.

The RESRAD website contains the following (Figure 7-3):

- Descriptions of the RESRAD family of codes;
- Downloadable version of the latest code;
- Table of current versions and release status;

- Information on upcoming training workshops and pictures from previous workshops;
- List of version releases and dates, along with a short description of the modifications included in the updated versions;
- E-mail contact; and
- Documents related to the RESRAD family of codes.

Getting to a RESRAD Document

Go to the Documents page of the website (Figure 7-4). These documents can be downloaded to your computer. Presently, 50 documents are available.

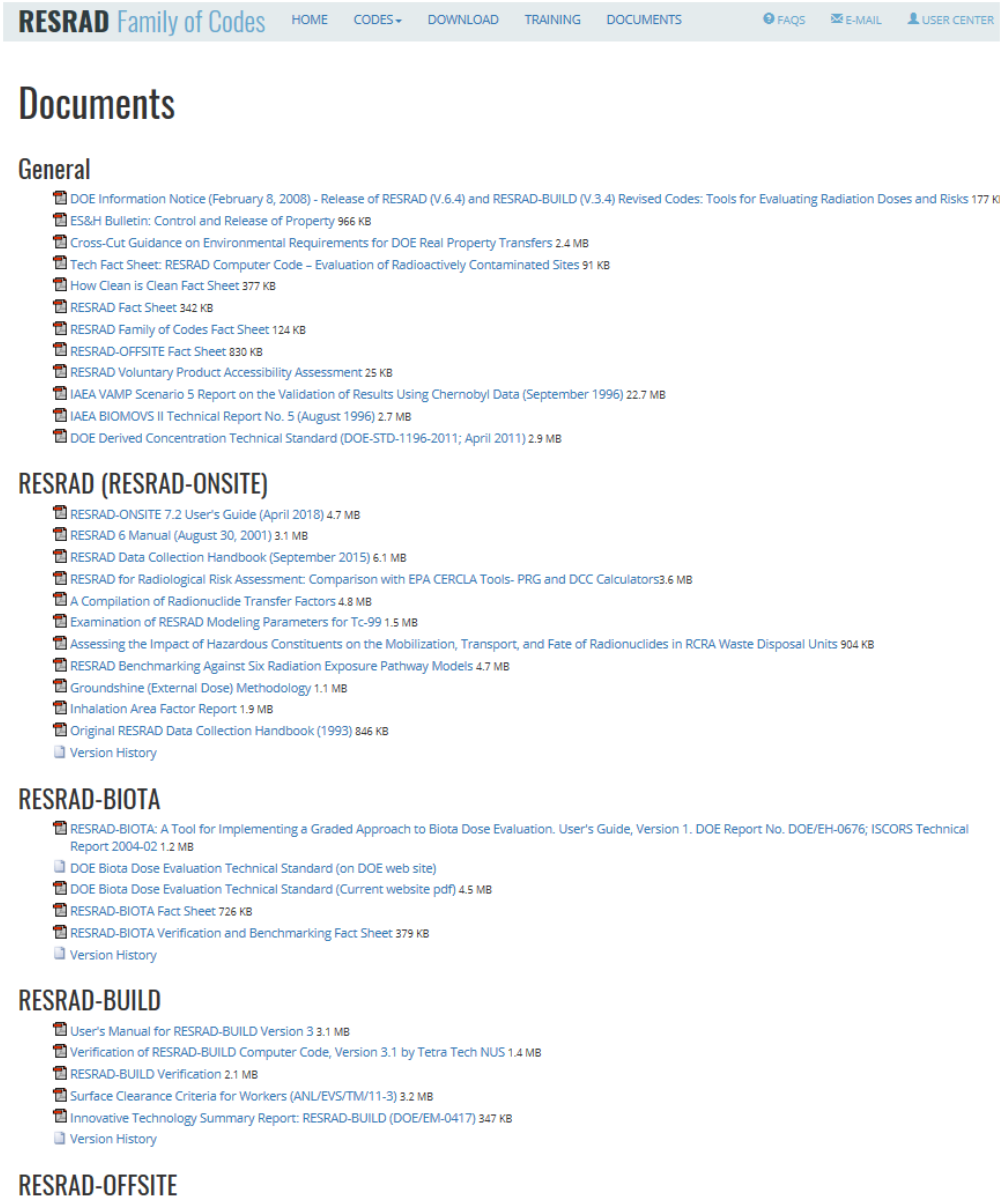

Figure 7-4 A Portion of Documents Page of the RESRAD Website

7.4 Run Time Feedback Form

The color-highlighted information bar displays the progress of the computation (Figure 7-5). The information bar cycles through yellow, blue, and green as it checks the progress of the computational code. For a deterministic run, both UNC (uncertainty) and SENS (sensitivity) will equal zero. If a sensitivity analysis is being performed, the SENS counter will show the index of the current sensitivity run; there will be two sensitivity runs for each input parameter selected for sensitivity analysis. The UNC counter displays the index of the current uncertainty/probabilistic run. The remainder of the information bar shows the code module being executed; the primary contaminant being considered; the transport layer or location, if appropriate, and, in the case of groundwater transport, the nuclides entering and leaving the transport layer and the current calculation time. The frequency at which this information bar is updated can be changed in the Title & Radiological Data form (Section 4.1). Frequent updates can increase the run time.

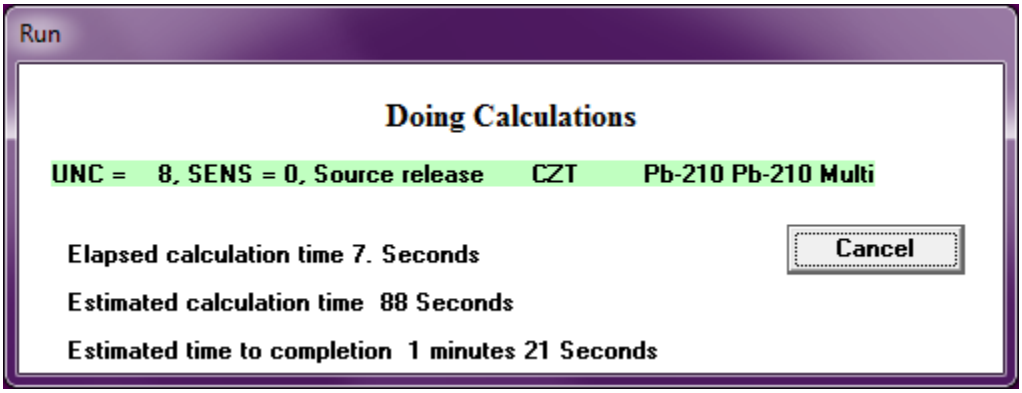

Figure 7-5 Run Time Feedback Form

The time that elapsed since the run command was executed is shown in the first line below the information bar. This is followed by two more lines that are displayed only when an uncertainty/probabilistic analysis is performed. The second line shows the estimated calculation time. It includes the time that has elapsed and the amount of time the code is likely to continue running. This line should stabilize after the first few probabilistic runs. The stability of the calculation time is an indication of the reliability of the estimated time to completion, which is shown in the third line.

While frequent updates from the computational program give the user a good idea of what the code is currently doing and how long it is likely to take before the run ends, this can come at the cost of increased run time. For probabilistic runs, it may be advantageous to shut off message writing by the computational code, as described in Update Progress of Computation Message in Section 4.1. The interface will still be able to display the UNC counter of the index of the current uncertainty/probabilistic run and will give estimates of calculation time and time to completion based on the size of the output files generated.

8 REFERENCES

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APPENDIX A
RESRAD DOSE CONVERSION FACTOR EDITOR

The RESRAD Dose Conversion Factor (DCF) Editor is a standalone utility program used to develop and edit the user-specific dose coefficient, transfer factor, and slope factor libraries for use in the RESRAD family of codes. Figure A-1 shows the RESRAD DCF Editor welcome page.

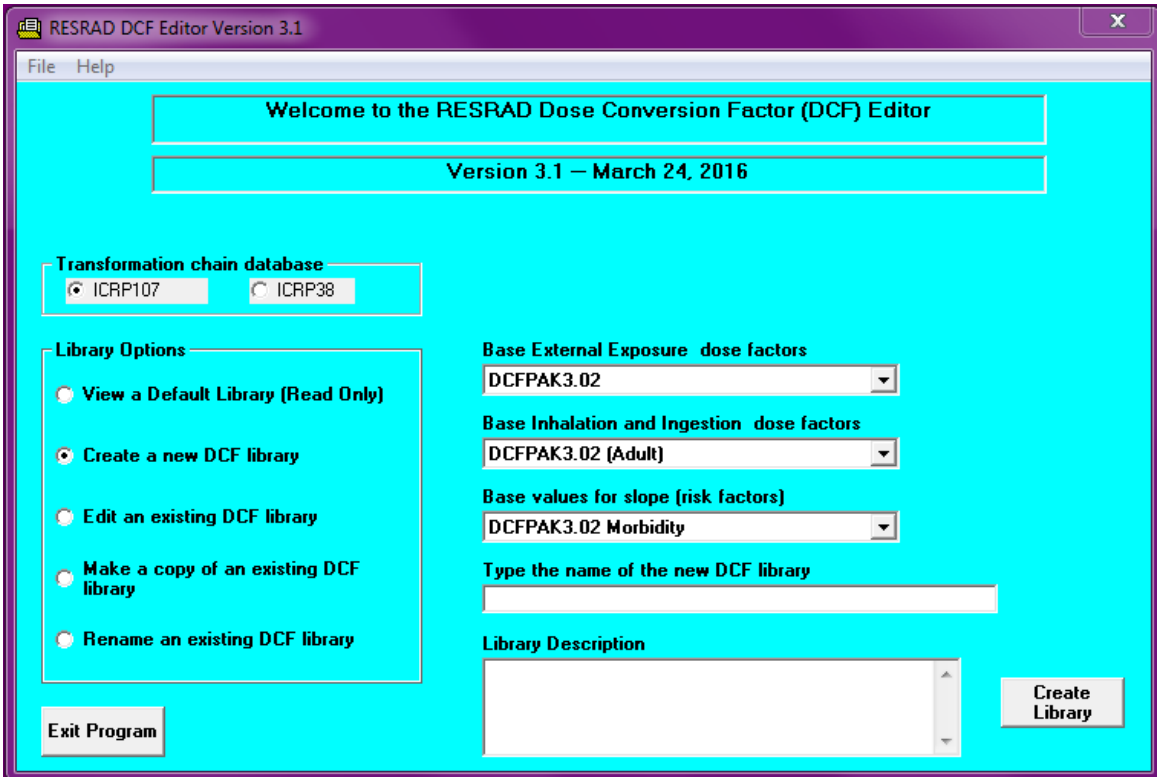

Figure A-1 RESRAD DCF Editor

Transformation Chain Database: The user has an option to select the ICRP 107-based or ICRP 38-based radionuclide transformation database. Multiple default libraries are available for ICRP 38 and ICRP 107; a drop-down box shows all the libraries available for a selected transformation database. Figure A-2 shows the partial list of the libraries available for the ICRP 38 transformation database. The library description provides information on the default dose and risk factors associated with the selected default library.

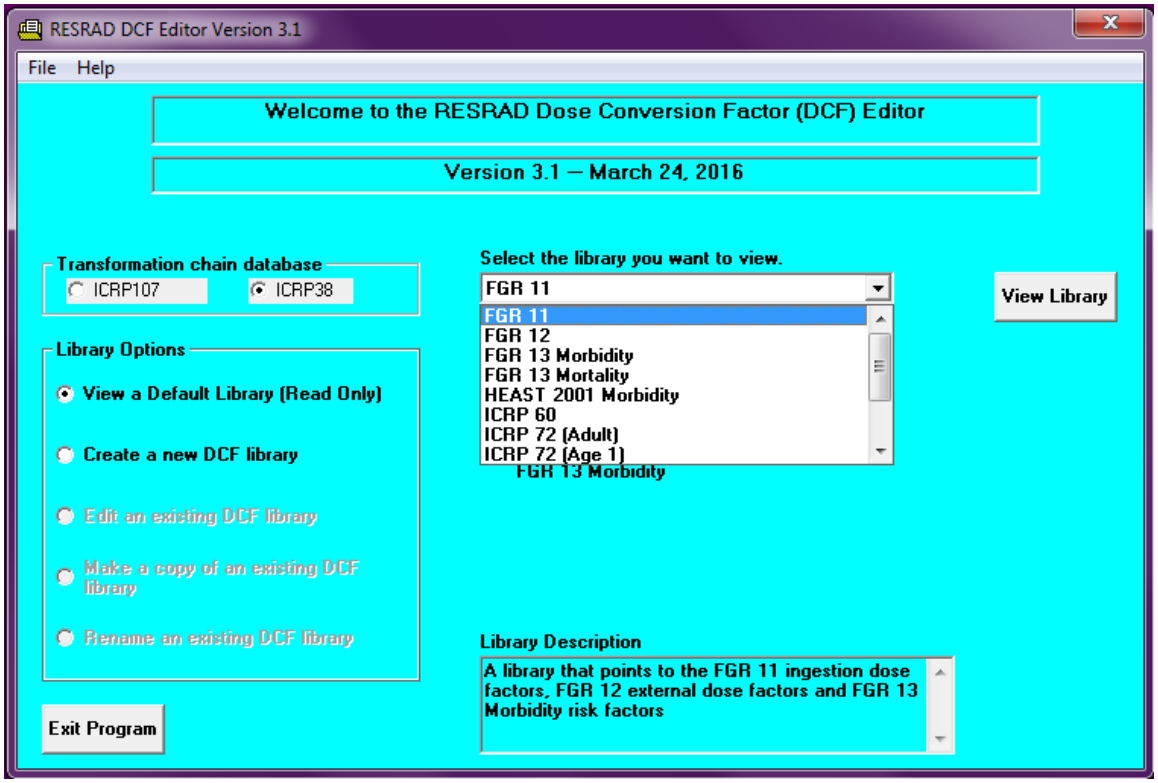

Figure A-2 Available DCF Libraries in ICRP 38 Transformation Database

Figure A-3 shows the multiple DCF libraries available when the ICRP 107 transformation database is selected. RESRAD-OFFSITE code also has a Reference Person DCF library. The reference person is defined as a hypothetical aggregation of human (male and female) physical and physiological characteristics arrived at by international consensus for standardizing radiation dose calculations. The reference person dose coefficients are derived using age-specific dose coefficients coupled with information on the age and gender structure of the U.S. population in 2000 census data and age- and gender-specific intakes (DOE 2011).

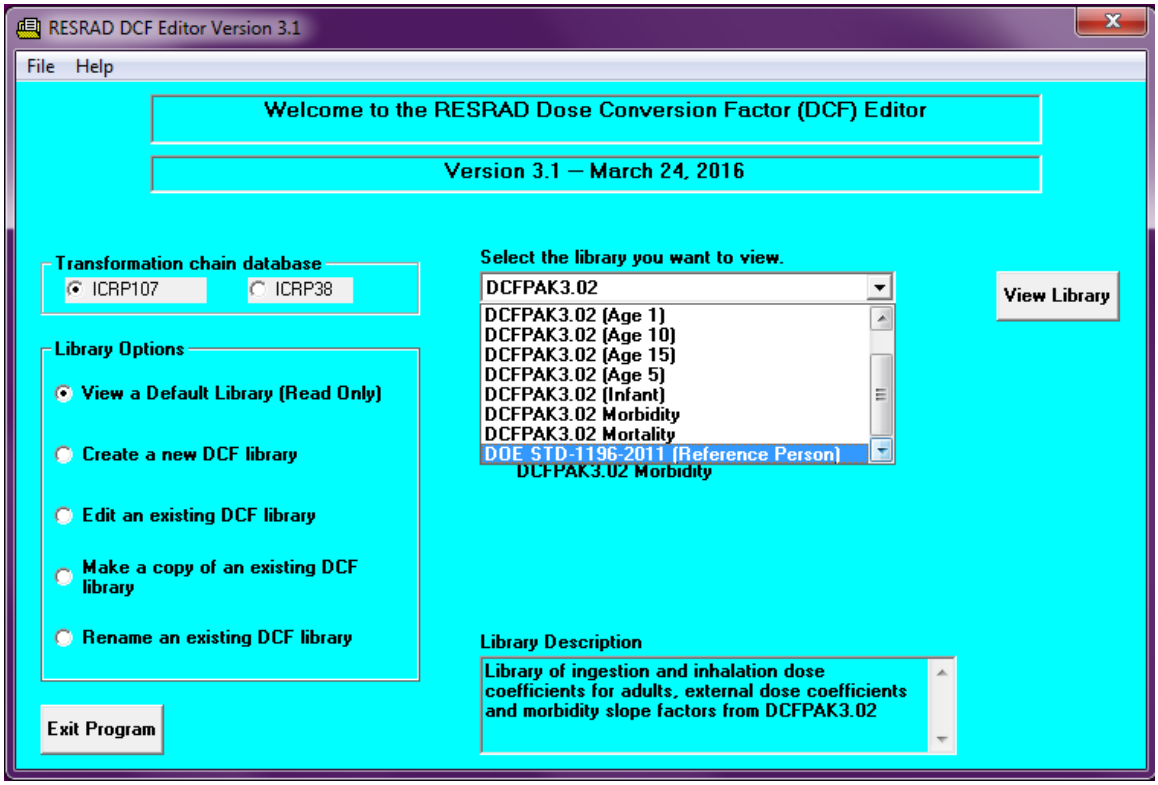

Figure A-3 Available DCF Libraries in the ICRP 107 Transformation Database

Library Options: The user has multiple library options: view a default library, create a new library, edit an existing DCF library, make a copy of an existing DCF library, or rename an existing DCF library.

To View a Default Library (Read Only): Select this option to view the default dose conversion, food transfer, and slope factors. The default values are contained in default libraries, which users cannot modify. New libraries created by the user automatically use data from one of the default libraries as a starting point. To view a default library, select the library you want to view and click View Library.

To Create a New DCF Library: Select this option to create a new DCF library based on the default values. You need to select base external, inhalation, and ingestion dose factors and risk factor libraries. You must provide a name for the new library. You can also enter a description of the library. The description may contain references or other helpful information. After entering the name and description, click the Create Library button to continue.

To Edit an Existing DCF Library: Select this option to edit a previously created DCF library (or one imported into the database). To edit an existing DCF library, select the library from the drop-down list. Edit the library description, if necessary, and click the Edit Library button.

To Make a Copy of an Existing DCF Library: Select this option to make a copy of an already existing DCF library. This option is similar to the "Create a New DCF Library" option. This feature is used to create a new DCF library based on another user-defined library. To copy an existing library, select the existing library from the drop-down list and enter the name of the new

library in the text box. Then press the Copy Library button to copy the dose conversion, transfer, and risk factors from the existing library to the new library.

To Rename an Existing DCF Library: Select this option to rename an existing DCF library. Select an existing DCF library from the drop-down list, type the name of the new library in the text box, and click the Rename Library button.

A.1 Dose Coefficients

As mentioned before, multiple DCF libraries are available in the ICRP 38 and ICRP 107 transformation databases. Figure A-4 shows the FGR 11 (Eckerman et al. 1988) internal dose conversion factors and the FGR 12 (Eckerman and Ryman 1993) external dose conversion factors, using the ICRP 38 transformation database.

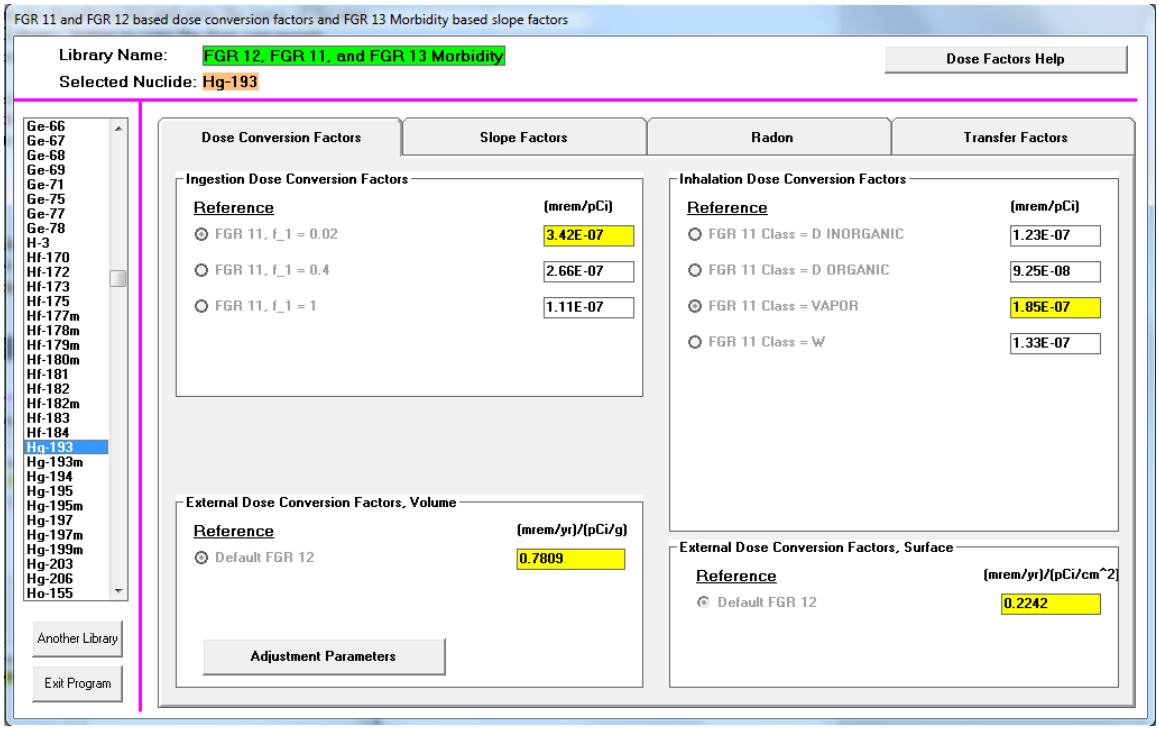

Figure A-4 Dose Coefficients from a FGR 12, FGR 11, and FGR 13 Library

Ingestion Dose Coefficients: FGR 11 (Eckerman et al. 1988) dose coefficients for various GI tract fractions are shown for Hg-203 in Figure A-4. The maximum value is selected as the default. When one selects Create a New DCF Library or Edit an Existing DCF Library option, one can select another DCF by clicking the option button for the DCF or enter a user-specific value. If a user-specific value is entered, a reference can be inserted into the text box.

Inhalation Dose Coefficients: FGR 11 dose coefficients for various lung clearance classes are shown for Hg-203 in Figure A-4. The maximum value is selected as the default. When user selects Create a New DCF Library or Edit an Existing DCF Library option, one can select another DCF by clicking the option button for the DCF or enter a user-specific value. If a user-specific value is entered, a reference can be inserted into the text box.

External Dose Coefficients: External dose coefficients from FGR 12 (Eckerman and Ryman 1993) for Hg-203 are shown in Figure A-4. The values are listed for volume and surface sources. When one selects a Create a New DCF Library or Edit an Existing DCF Library option, one can enter a user-specific value. If a user-specific value is entered, a reference can be inserted into the text box. For volume sources, adjustment parameters (Figure A-5) are also specified that include depth- and cover-fitted parameters and area- and shape-fitted parameters for each radionuclide. The adjustment parameters are used to calculate external dose coefficients for any size volume source. The adjustment parameter values cannot be changed by a user.

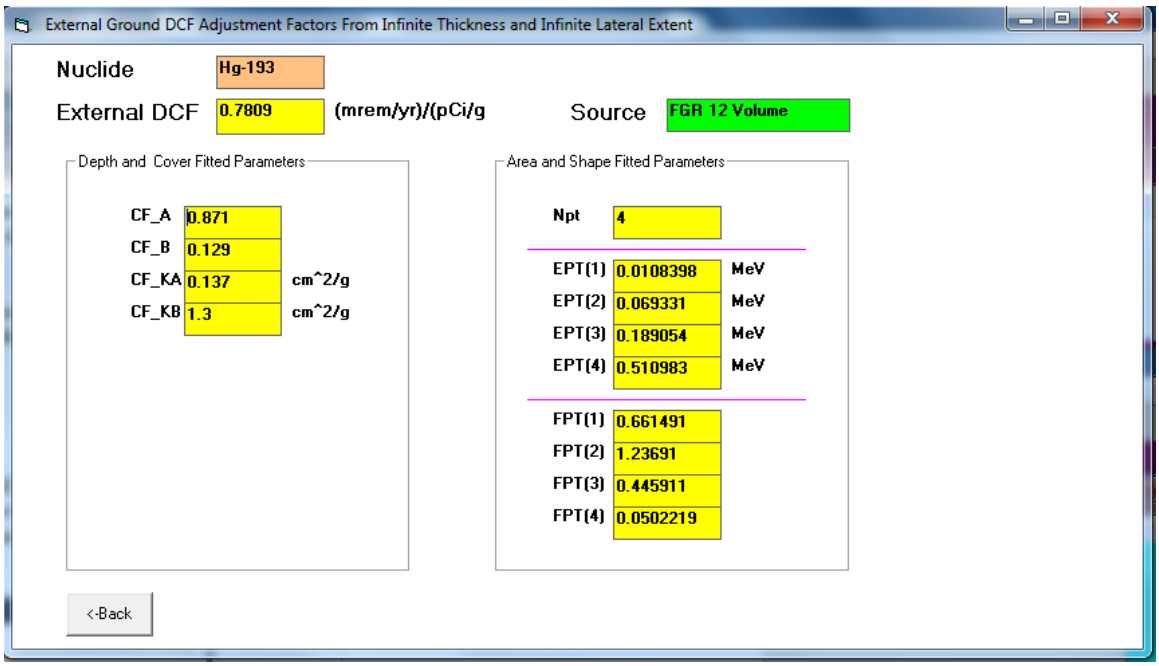

Figure A-5 External Pathway Adjustment Parameters from the FGR 12, FGR 11, and FGR 13 Library

To view dose coefficients for another nuclide, select that radionuclide. Section 4.1 discusses the other DCF libraries available.

A.2 Slope Factors

Clicking on the Slope Factors tab provides slope factor values in the selected library. Figure A-6 shows the FGR 13-based morbidity slope factor for Hg-203. Section 4.1 discusses the other slope/risk factor libraries available. The slope factors are available for the ingestion, inhalation, and external exposure pathways. The slope factor values shown are from the FGR 13 report (Eckerman et al. 1999). When the user selects a Create a New DCF Library or Edit an Existing DCF Library option, the user can enter a user-specific value. If a user-specific value is entered, a reference can be inserted into the text box.

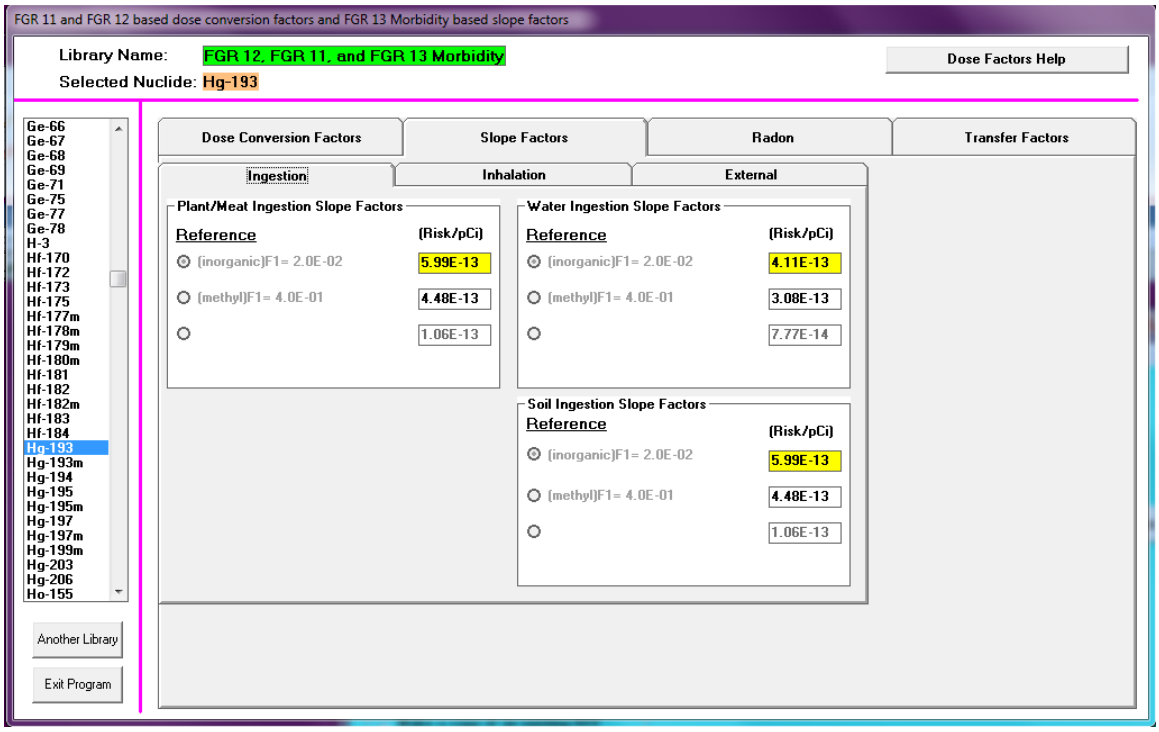

Figure A-6 FGR 13 Based Morbidity Slope Factors

A.3 Risk and Dose Factors for Radon

Clicking on the Radon tab on the top provides the radon progeny slope factors and the radon dose coefficients in the selected library (Figure A-7). Two sets of radon dose coefficients are available. One is based on the ICRP 26 methodology, and the other is based on the ICRP 60 methodology. For ICRP 26 methodology-based DCFs, the ICRP 26 methodology-based radon dose coefficients are used, and the ICRP 60 methodology-based radon dose coefficients are used with ICRP 60 methodology-based DCFs. Figure A-8 shows the radon dose coefficients based on the ICRP 60 methodology.

Radon Progeny Slope Factors: The values are from the EPA HEAST report (EPA 1994). When one selects a Create a New DCF Library or Edit an Existing DCF Library option, one can enter a user-specific value. To change the default values, enter a new value in the text box. To select the default value, click the D button; to enter references for user-specific values, click the R button.

Radon Dose Coefficients: Two sets of radon dose coefficients are available (Figure A-7 and Figure A-8). When a user selects a Create a New DCF Library or Edit an Existing DCF Library option, the user can enter a user-specific value. To change default values, enter a new value in the text box. To select the default value, click the D button; to enter references for user-specific values, click the R button.

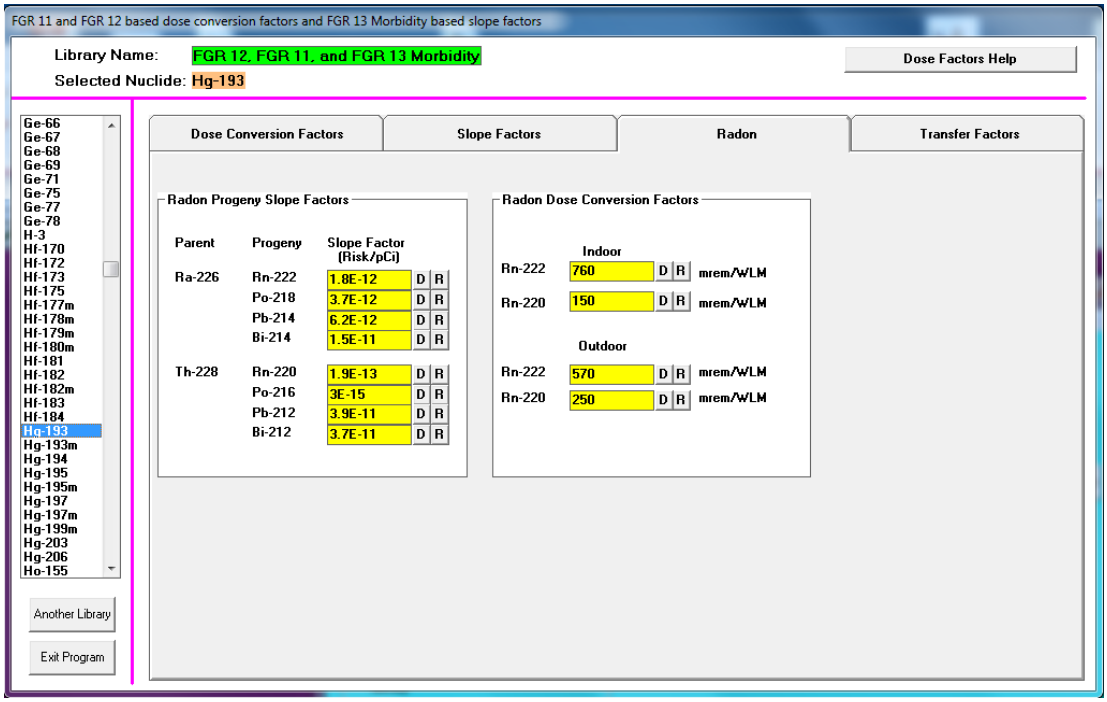

Figure A-7 Radon Progeny Slope Factors and ICRP 26 Methodology-Based Dose Coefficients

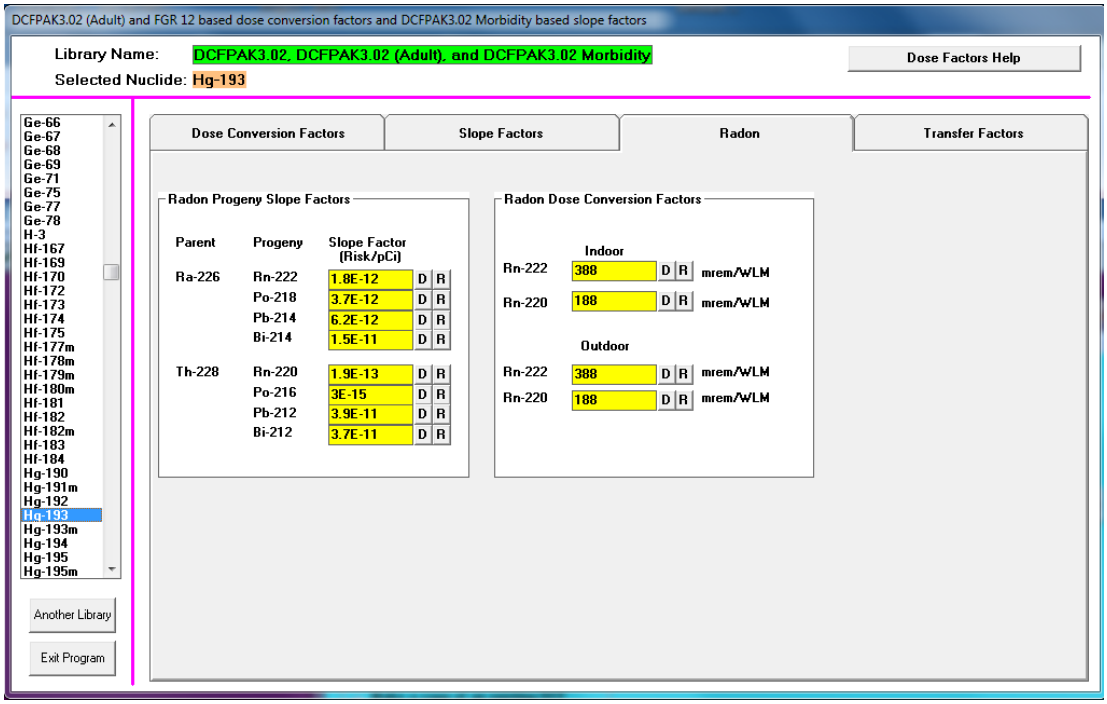

Figure A-8 Radon Progeny Slope Factors and ICRP 60 Methodology-Based Dose Coefficients

A.4 Transfer Factors

Clicking on the Transfer Factors tab provides transfer factors in the selected library (Figure A-9). Transfer factors are element-dependent. The transfer factors are provided for different food types (plant, meat, milk, fish, and crustacea).

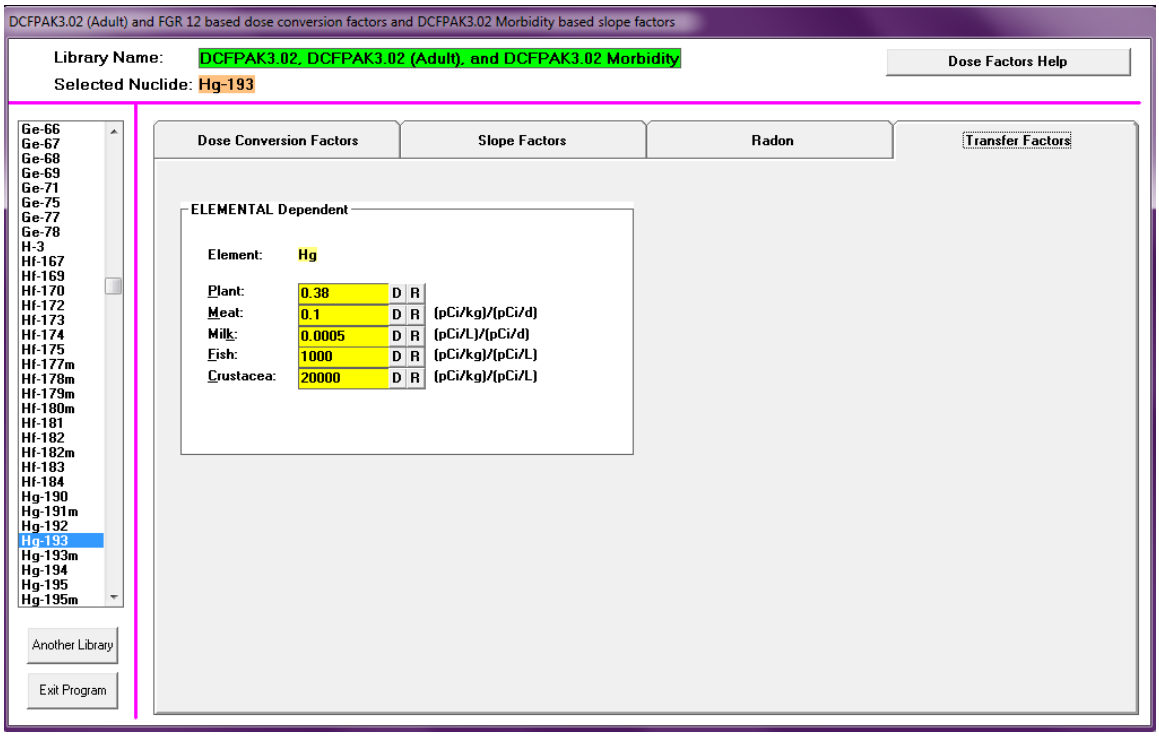

Figure A-9 Transfer Factors

Transfer Factors: See the detailed discussion in Section 4.8. When a user selects a Create a New DCF Library or Edit an Existing DCF Library option, the user can enter a user-specific value in the text box. To select the default value, click the D button; to enter references for user-specific values, click the R button.

A.5 Create New DCF Library

For radionuclides that lack dose conversion or slope factors, a value of -1 or -2 is assigned. The value -2 is assigned when the half-life is <10 minutes, and a value of -1 is assigned when the radionuclide half-life is greater than 10 minutes. For a radionuclide with an assigned value of -2, a zero value for the dose conversion and slope factor is used at run time. For a radionuclide with an assigned value of -1 for the dose conversion and slope factor, the code will not run and will tell the user that the DCF or slope factor is missing and ask the user to provide the missing data in the private dose factor library. For example, Xe-131m does not have internal dose conversion and slope factors (see Figure A-10). When the user selects I-131 as a principal radionuclide, the daughter Xe-131m DCFs and slope factors are required. Because the database does not have internal DCFs and slope factors for Xe-131m, the code will not allow selection of I-131 in the Source form and will request that a new DCF library that has internal

DCFs and slope factors be created (see Figure A-11) for Xe-131m. The following are the steps for creating and using the new DCF library:

- Select DCF Editor under the File menu.
- In the DCF Editor, select Create a New DCF Library (see Figure A-12).
- Give a name to the new DCF library such as “User I-131”; make sure the base library is the one you want to use for all other radionuclides (see Figure A-12). Note that there is a 20-character limit in the library name.
- Click on the Create Library button, then select “Xe-131m” and click the circle in front of the blank box (it is right under the line with the value -1 (see Figure A-13).
- Enter a value such as 0 in the value box (see Figure A-13).
- Make sure you do this for both the Dose Conversion Factors and Slope Factors tabs. Note that there are multiple tabs under the Slope Factors tab; remember to enter values there.
- Exit the DCF Editor program.
- Open Change Title in the main (DOS-Emulator) menu.
- Select the new created DCF library—“User I-131” in the example. Note that this library is now used for internal dose, external dose, and risk factors.

Now I-131 can be selected in the Source form and the code will run and use the Xe 131m user-defined internal DCFs and slope factors.

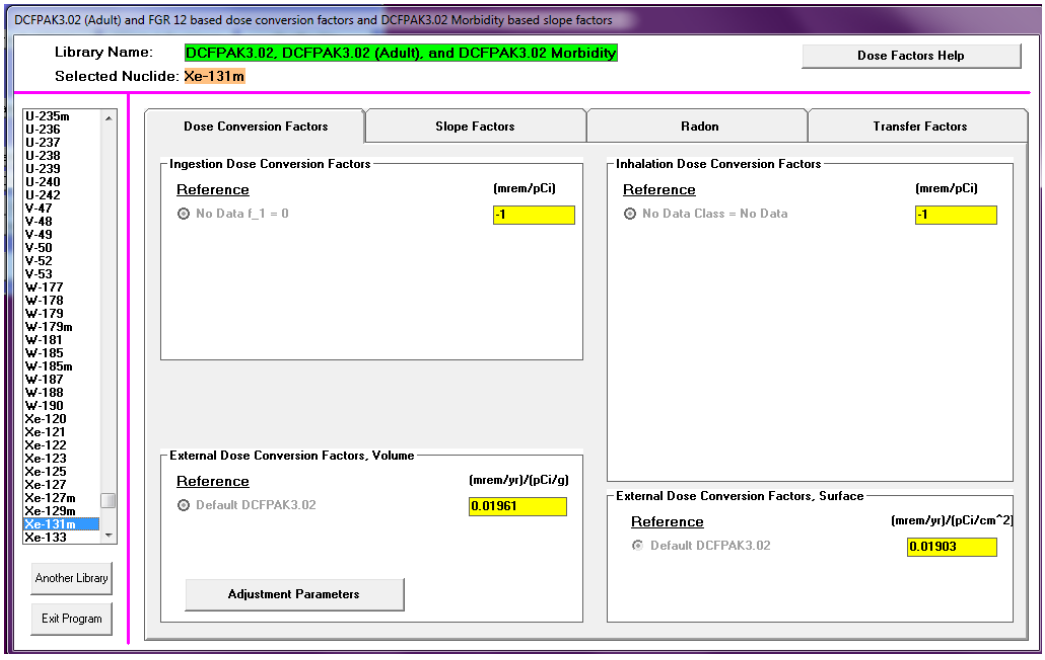

Figure A-10 Xe-131m Default Dose Conversion Factors in the Database

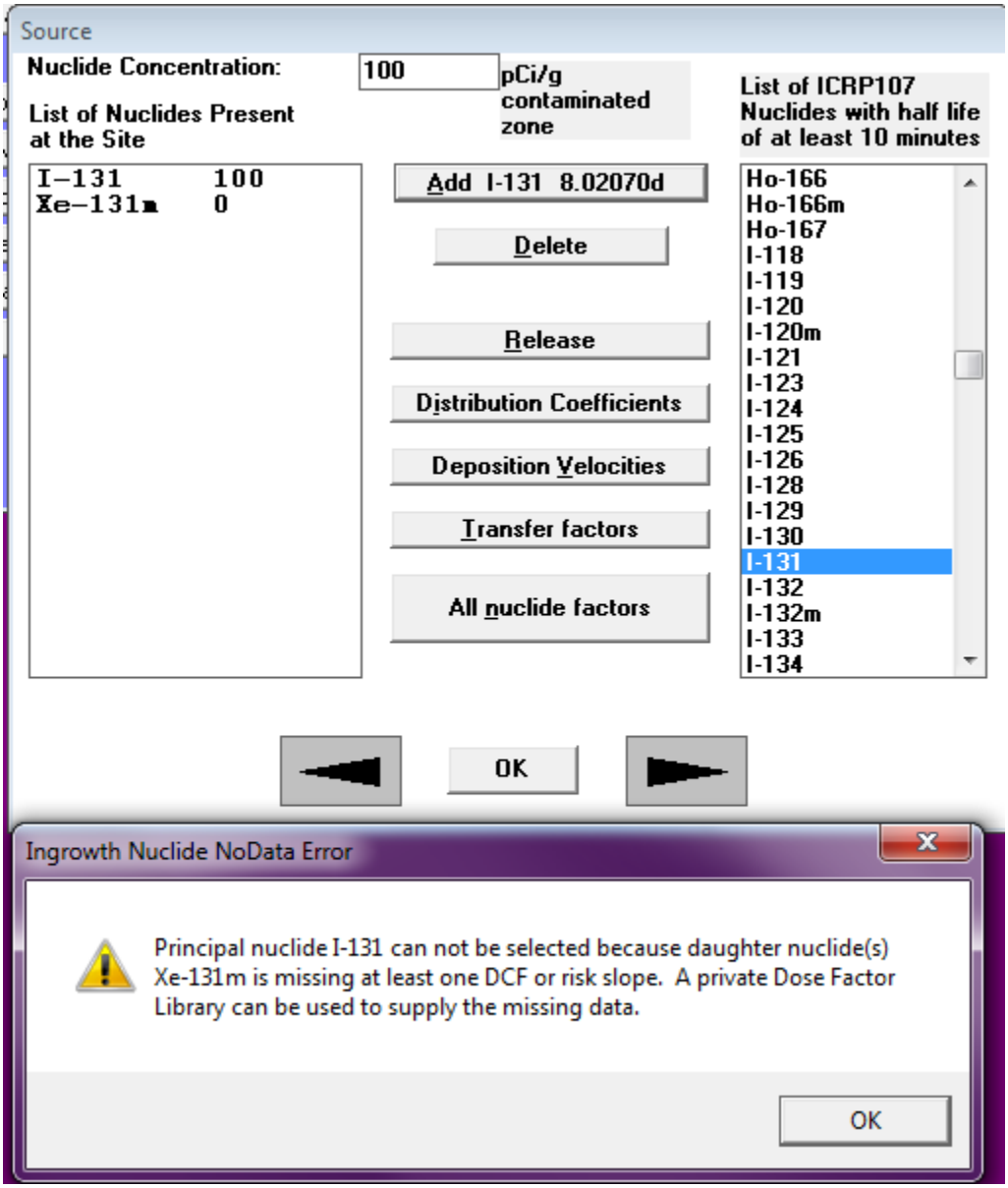

Figure A-11 Nuclide No Data Error Message

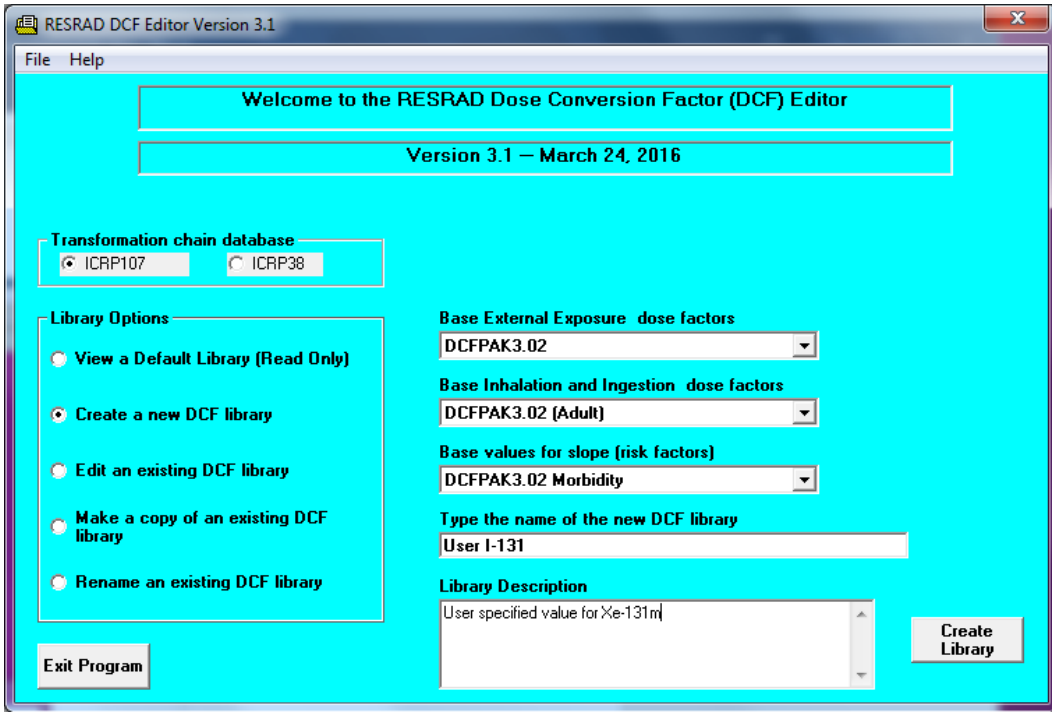

Figure A-12 Creating a New DCF Library

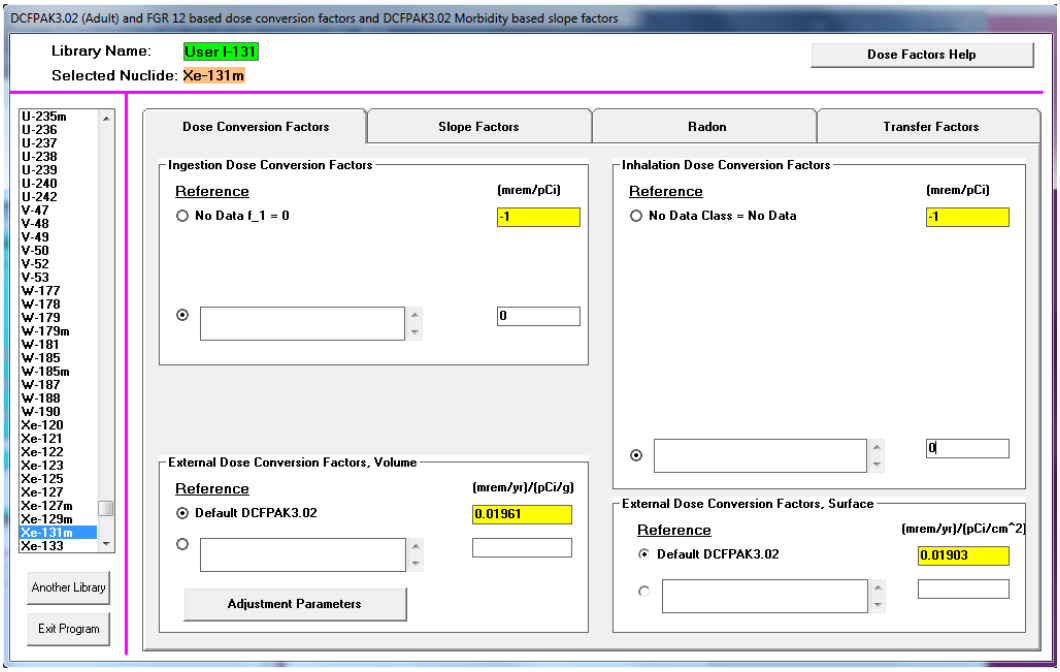

Figure A-13 Entering Nuclide Specific Dose Coefficients and Slope Factors in the New DCF Library

A.6 Import and Export of DCF Library

The DCF Editor allows users to import or export user-created DCF libraries. If an input file that uses a user-created library is to be shared with others, then the user library must be exported and shared with the input file that uses it. The users who receive the input file must import the library file, if they want to run the input file that uses the user-created library. Click File in the menu bar on top. Figure A-14 shows the Export and Import options available in the DCF Editor.

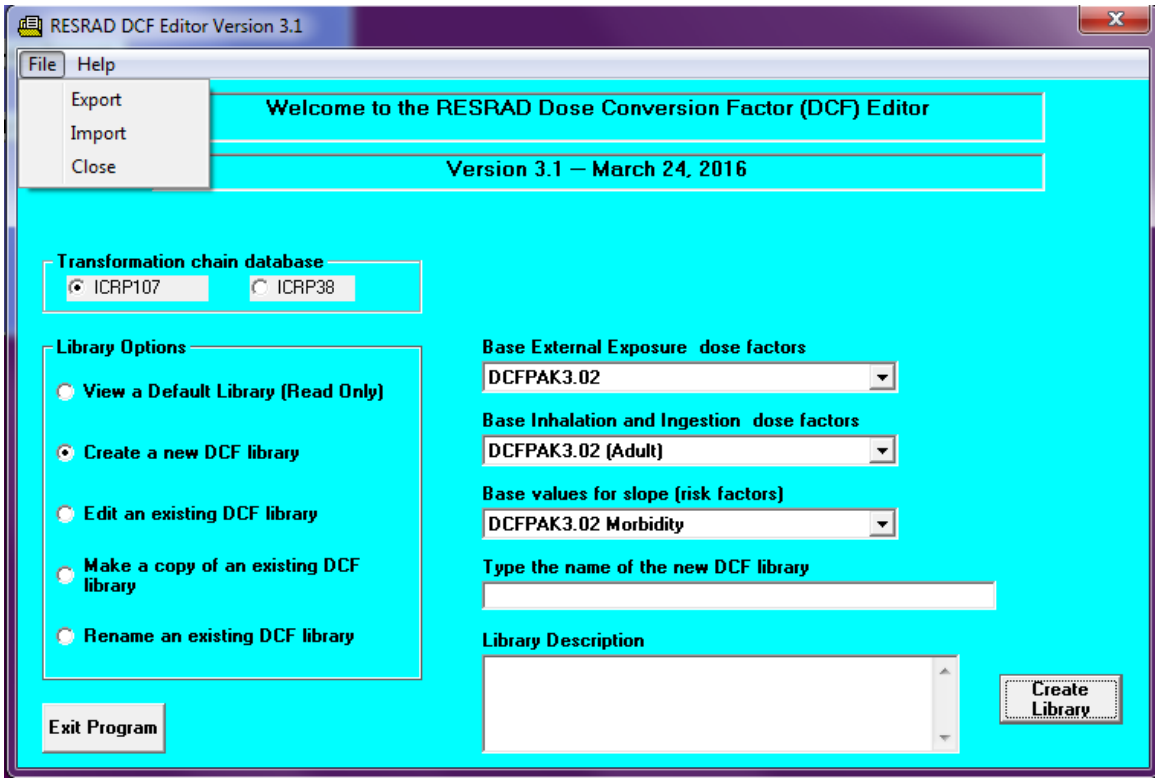

Figure A-14 Export and Import Options in the DCF Editor

For exporting a DCF library, select Export and click on it. Now select the library you want to export from the available user-created DCF libraries. Figure A-15 shows the User I-131 library selected.

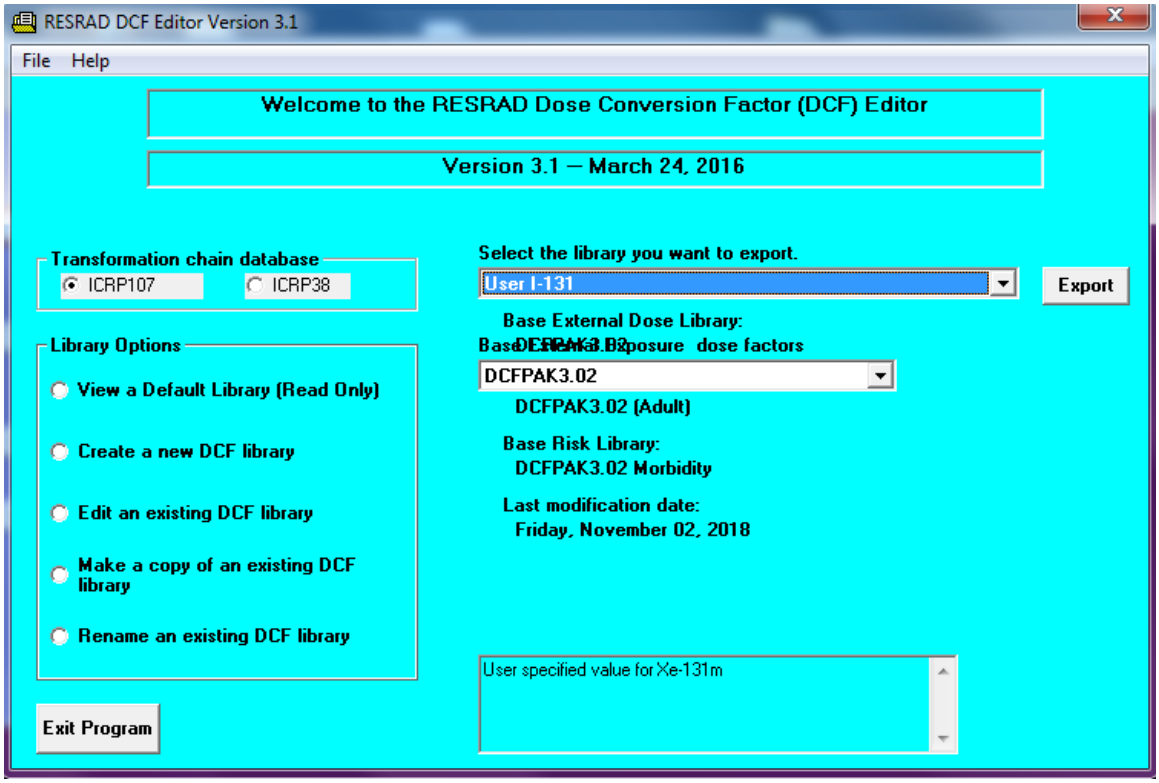

Figure A-15 Select the User Library for Export

Click the Export button.

Give a file name and select the location where you want to save the file, as shown in Figure A-16. The file will be saved with the new name “I131-DCFs” in the example.

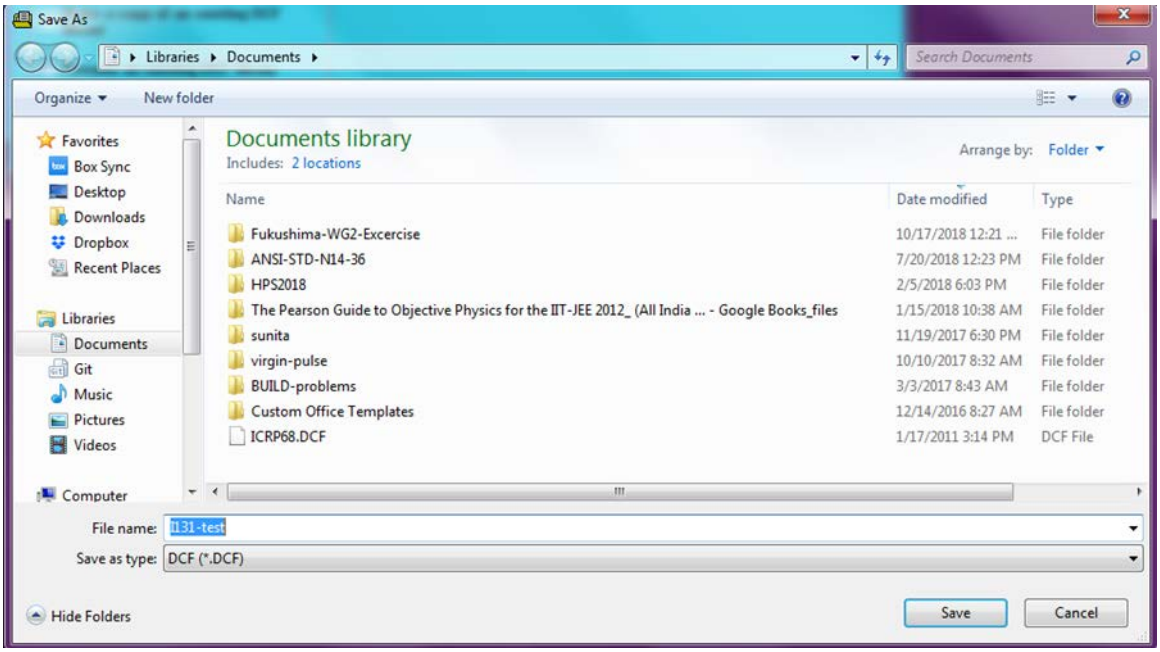

Figure A-16 Naming the Exported File

For importing a DCF library, select Import and click on it. Now go the location where DCF library file that you want to import is available. Select the library you want to import and open the file (Figure A-17). If the database on your computer already has a library with the same name as the one you are trying to import, you will get a message similar to the one shown in Figure A-18.

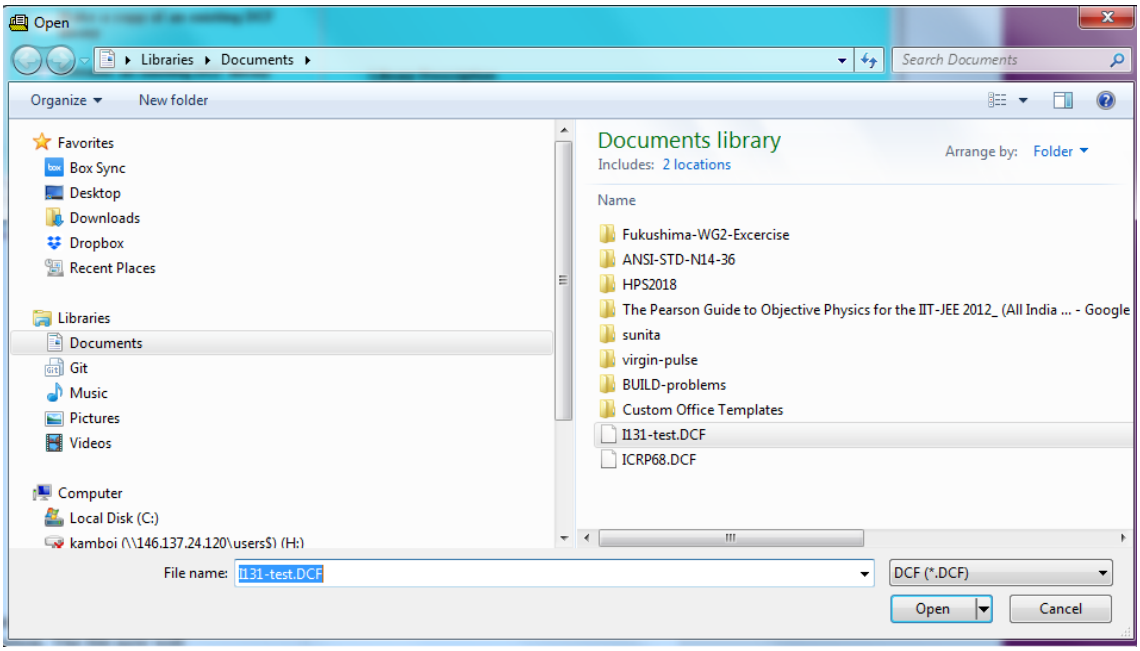

Figure A-17 Importing DCF Library

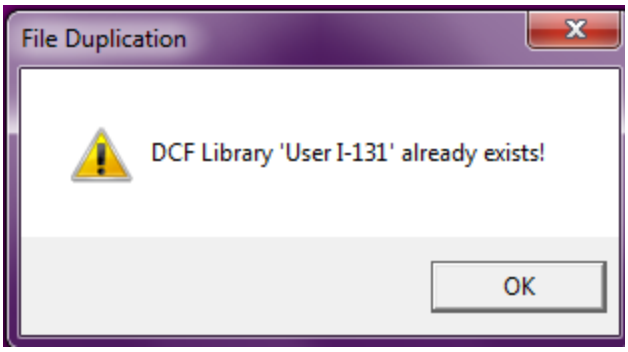

Figure A-18 DCF Library File Duplication Message

In this event, click OK and a new window will open (Figure A-19). Give a different name to be used for the library that you are trying to import and click Import. If you needed to change the name of the library when you imported it, be sure to make this change in the input files that were associated with the library that you imported. Go back to the DCF Editor and select the Edit an Existing File library option. The file now will be available in the DCF Editor (Figure A-20).

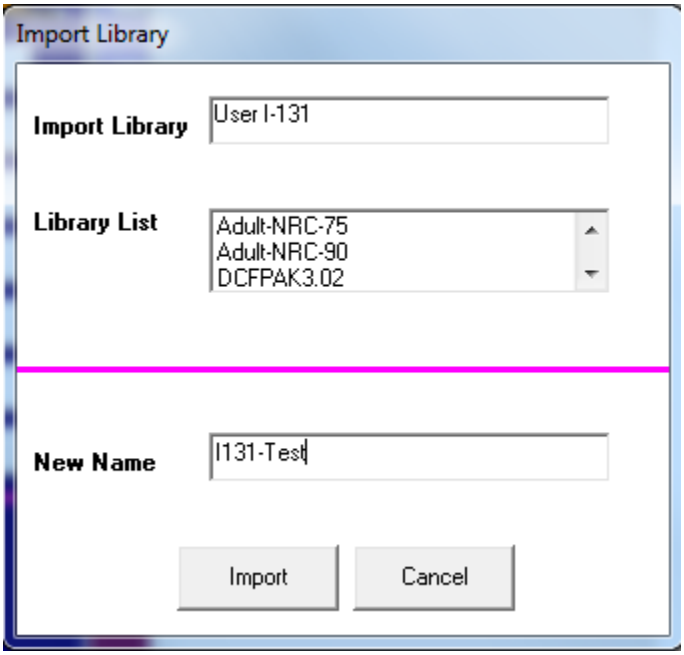

Figure A-19 Give Name to the DCF Library

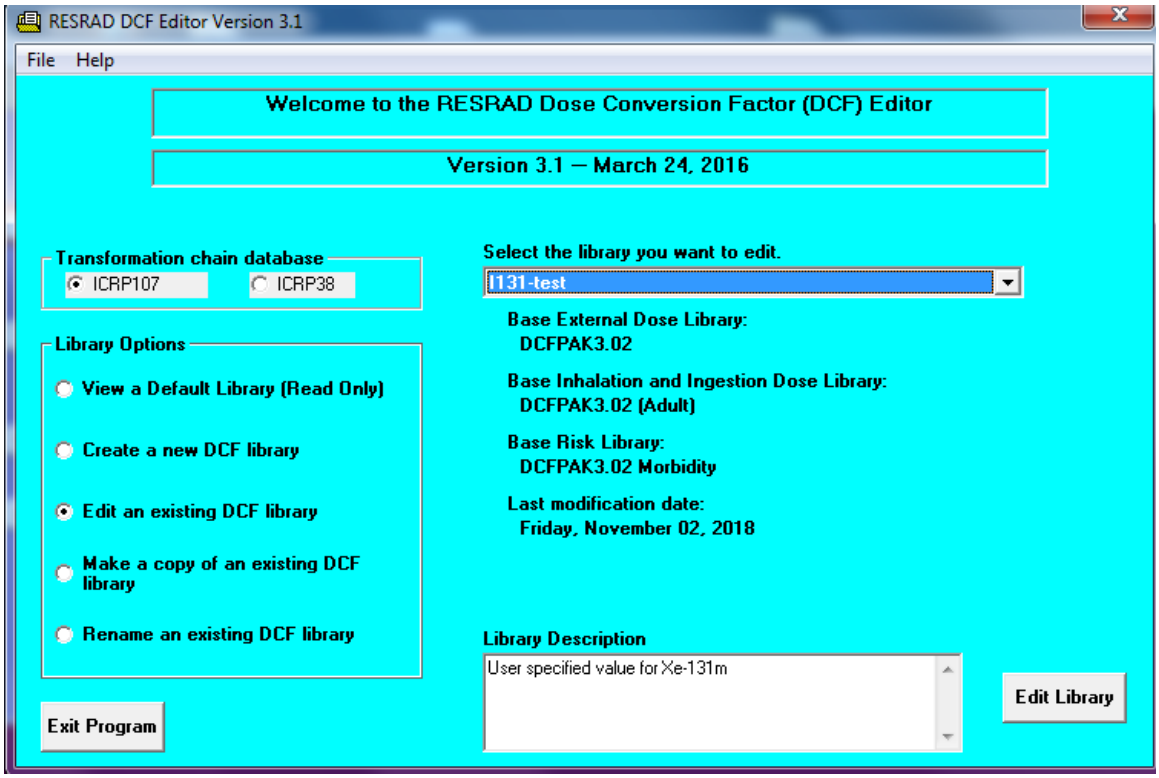

Figure A-20 Imported File Available in the DCF Editor