RASCAL 4.3 WORKBOOK

DRAFT

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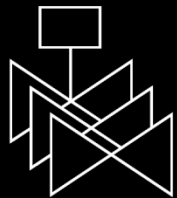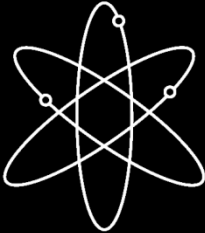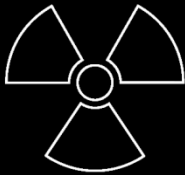
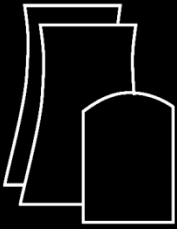Date of last revision: October 3, 2013

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ABSTRACT

The code currently used by NRC's Emergency Operations Center for making dose projections for atmospheric releases during radiological emergencies is the Radiological Assessment System for Consequence AnaLysis (RASCAL) version 4.3. This code was developed by the NRC. RASCAL 4.3 evaluates releases from: nuclear power plants, spent fuel storage pools and casks, fuel cycle facilities, and radioactive material handling facilities.

The workbook contains problems designed to familiarize the user with the RASCAL software through hands-on problem solving. The workbook is primarily for use by students in a RASCAL training course supervised by a qualified instructor.

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ACKNOWLEDGMENTS

The authors would like to acknowledge all the students who have used the workbook over the years. Your comments and suggestions have been invaluable.

INTRODUCTION

This workbook is designed to teach you how to use RASCAL 4.3 through hands-on problem solving. The problems described within were developed using RASCAL 4.3. The workbook may be used with other revisions of the software. However, the results from working the problems may appear different from those in the workbook.

Attempt to do each problem using the computer and answer all the associated questions. Blank tables are provided for you to record your results. A description of how the problem may be solved and a discussion of the results are included with each problem.

You must understand the risks and uncertainties inherent in dose projection models before using this tool.

Contact Information

Please direct any questions, suggestions, corrections or comments concerning this workbook to the following:

RASCAL_Help@nrc.gov

Distribution

The RASCAL 4.3 computer code and is available, for free, from the Radiation Safety Information Computational Center (RSICC).

WHAT IS RASCAL?

RASCAL, which stands for **R**adiological **A**ssessment **S**ystem for **C**onsequence Ana**L**ysis, is the software developed and used by the U. S. Nuclear Regulatory Commission (NRC) Emergency Operations Center to estimate projected doses from radiological emergencies.

RASCAL consists of the four primary tools and three additional tools described below.

Source Term to Dose

Use the Source Term to Dose (STDose) model when you want to enter information about plant conditions or accident conditions in order to estimate projected radiation doses from a plume to people downwind. The STDose model will first generate a time-dependent "source term." This is the release rate for each radionuclide from the facility as a function of time. This time-dependent release rate (the "source term") then provides the input to an atmospheric dispersion and transport model.

The atmospheric dispersion and transport model estimates radionuclide concentrations downwind, both in the air and on the ground due to deposition. The calculated concentrations are then use to estimate projected doses. The dose pathways are: cloudshine from the plume, inhalation from the plume, and groundshine from deposited radionuclides (assuming 4 days of exposure to groundshine).

Field Measurement to Dose

Use the Field Measurement to Dose (FMDose) model when the plume-phase of the accident is over and you are in the intermediate-phase. The FMDose model estimates doses based on measurements of the radionuclide activity in the environment. The FMDose model will use the ground concentration of radionuclides to calculate intermediate-phase doses.

Radionuclide Data Viewer

Use the Radionuclide Data Viewer to examine the contents of the RASCAL radionuclide database. This database contains information on individual radionuclides such as half-life, dose conversion factors, and inventories.

Decay Calculator

Use the Decay Calculator to evaluate the radioactive decay of a radionuclide mixture over a user specified decay time.

Create Reactor Inventory Base File

Use this tool to enter information about how a reactor has been operated so that a more realistic reactor core, RCS, and spent fuel inventories may be used in the STDose model.

Source Term Merge / Export

Use this tool to combine atmospheric source terms for two or more reactors on a single site into a common source term that may be used to assess the combined consequences of a **multi-reactor event**.

Download Meteorology from Internet

Use this tool to set up and run the program to retrieve weather data from the internet.

GETTING STARTED WITH RASCAL

RASCAL is started by selecting in Windows:

Start | All Programs | RASCAL 4.3

This will display the opening screen with version number and date of release.
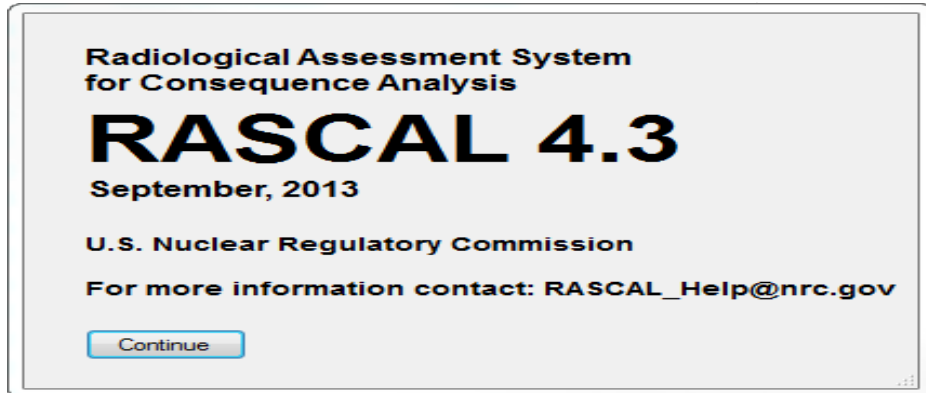
Click the **Continue** button to have the main RASCAL screen displayed.
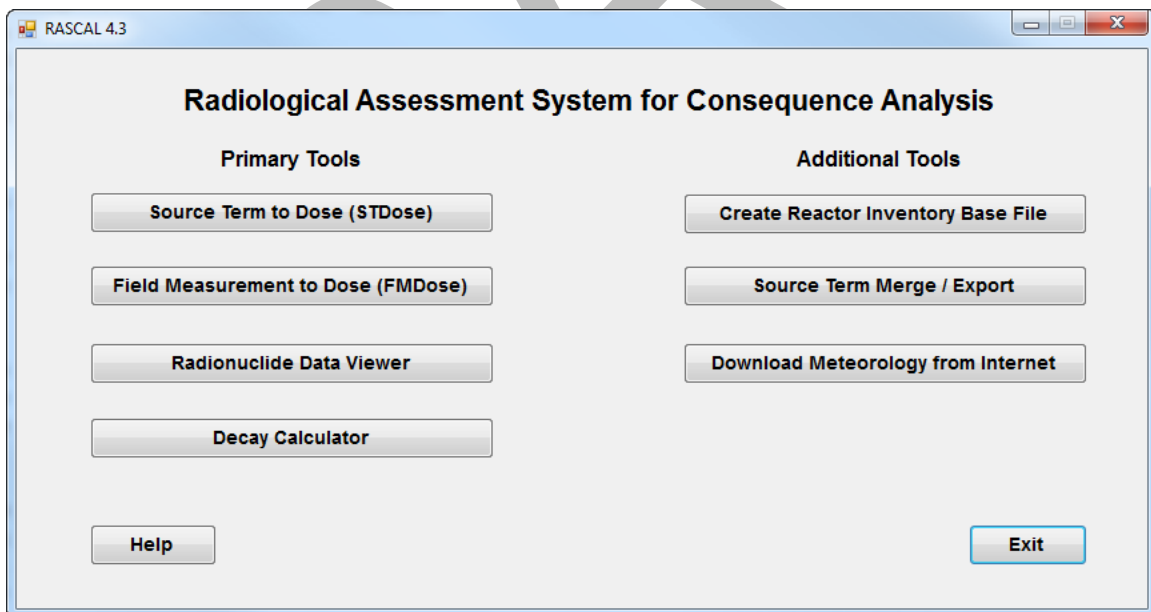
Since the first section of the workbook deals primarily with the **Source Term to Dose (STDose)** model, click that button.

Basic Features of the User Interface

This is the main screen of the **Source Term to Dose (STDOSE)** model as seen when first starting up the program.
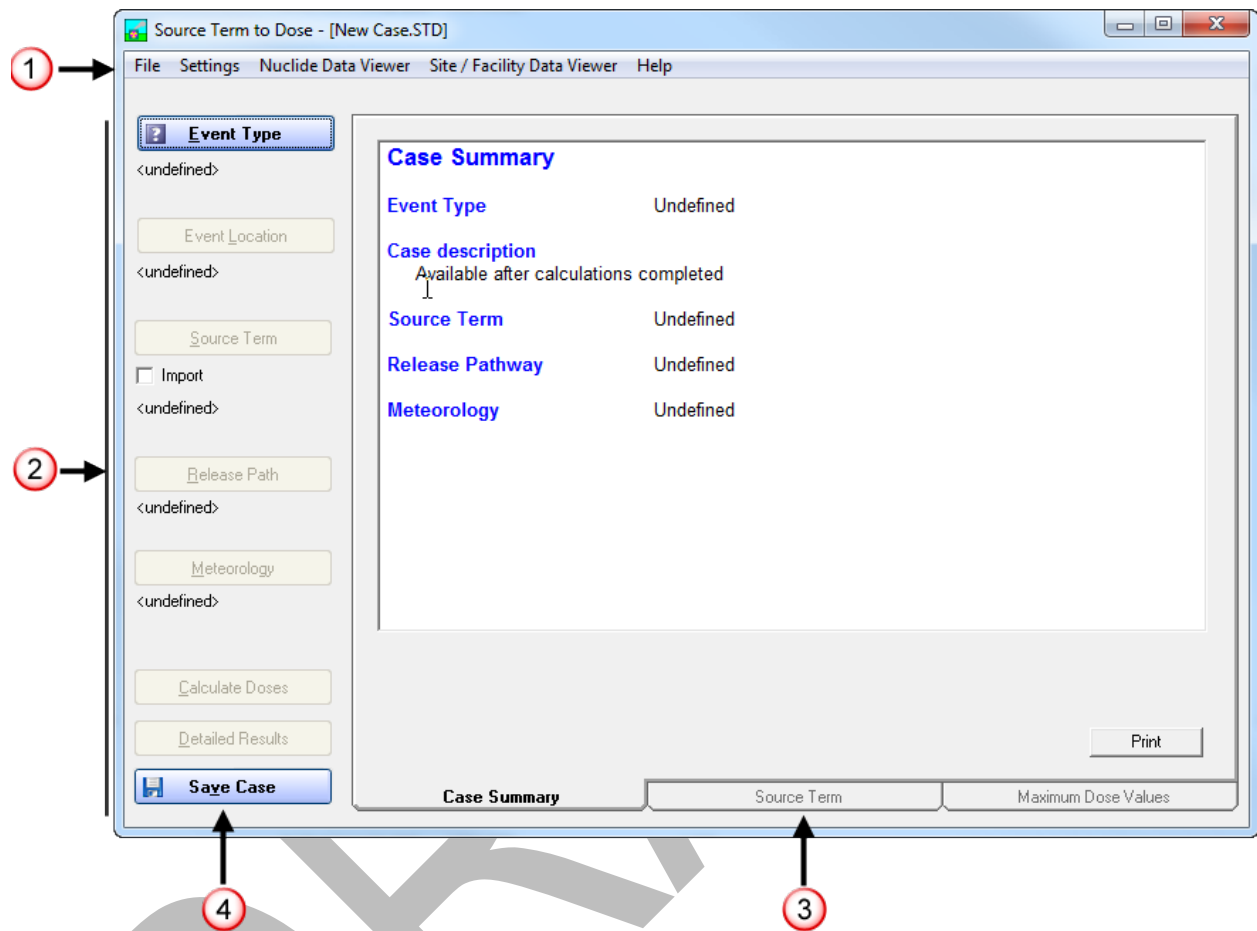
1. The menu bar at the top provides the standard Windows functions such as file management and help as well as access to two data viewers.

    The **Setting** function sets up options such as case naming and dose factors.

    The **Nuclide Data Viewer** can be used to examine the contents of the RASCAL radionuclide database. The database contains nuclide specific information such as inventories, dose conversion factors, and half-lives.

    The **Site / Facility Data Viewer** can be used to display data on each of the facilities in the RASCAL database. This includes geographic coordinates and a brief location description plus details about the facility. For reactors it includes parameters used by the model such as volumes, pressures, and leak rates.

2. The main input to the program is controlled via the buttons on the left side; starting from the top and working downward. The buttons are blue with a question mark when they are available but

the topic area has not yet been defined. The buttons display a checkmark when the step has been completed.

3. The right portion of the screen contains a set of three tabs. These tabbed areas provide easy viewing of the inputs and some of the generated results. Initially, only the case summary tab is active and updates as the problem is defined. After a set of calculations has been completed, the **Source Term Summary** and **Maximum Dose Values** tabs become active to show results. More results are accessed via the **Detailed Results** button.

4. The **Save Case** button is used to create a single file containing all the inputs and results from a single modeling run. (The save file is really just a zipped archive containing all the input and output files generated during the building and running of the case. You could use an unzip utility to extract and examine files in the saved case.)

All the user inputs are remembered after the calculations. Thus, it is very easy to go back and change a single input and recalculate without having to completely redo the case inputs.

USING RASCAL:
ASSESSING A PWR CORE DAMAGE ACCIDENT

This section of the workbook provides a detailed look at using the RASCAL STDose model to develop a protective action recommendation for a PWR core damage accident. It walks-through the entire process from start to finish.

The problems in this section should be worked in sequence as each depends on the previous work.

SOURCE TERM AND RELEASE PATHWAY

Purpose

To learn how to select source terms, release pathways and reduction mechanisms.

Background

Here are a few facts that you should know:

- Almost all the radioactive material at a nuclear power plant is in the fuel rods. Therefore, only major damage to fuel rods can cause a large release.

- The only plausible way to cause major damage to fuel rods is to remove the water covering the rods so that the heat produced by radioactive decay can no longer be removed effectively.

- If water no longer covers the fuel rods, the fuel cladding will first start to melt. Later, the fuel itself will start to melt. If the fuel remains uncovered, the molten fuel will eventually melt through the reactor pressure vessel.

- Any accident that leaves the fuel rods uncovered is a very serious accident that will cause large amounts of fission products to be released from the reactor core.

- It is a lot easier to predict when the uncovering of a reactor core will occur and how long the uncovering will last than it is to predict how much core damage will occur (for example, what percent of the fuel will melt). Therefore, RASCAL uses the time that the reactor core is uncovered as its primary method to assess offsite consequences of accidents involving core damage.

- When you use the "**time core is uncovered**" source term type, RASCAL will calculate the time-dependent release of fission products to the containment. The first fission products released from the core are noble gases and volatile elements like iodine and cesium. Non-volatile materials do not come out until later.

- The "**time core is uncovered**" source term option of RASCAL is likely to overestimate the speed and magnitude of the release and thus also overestimate the projected radiological doses. RASCAL users should inform decision makers of that fact.

Problem

You are provided with the following information:

- Arkansas Nuclear One, Unit 1 had been operating at full power

- At 10:00 A.M. the reactor tripped due to a major rupture in the primary coolant system (loss-of-coolant accident)

- Operators believe the core may become uncovered at 1:00 P.M. Further, they are concerned they may not be able to provide enough makeup water to recover the core.

- Plant operators report they are unable to activate the containment spray system. However, they expect the containment to remain intact and any release to the atmosphere will be at the design leak rate.

Use RASCAL to estimate potential consequences from the accident.

If needed, start the **Source Term to Dose (STDose)** model from the main RASCAL screen (see page 3). Then, input the information provided into the **Event Type**, **Event Location**, **Source Term**, and **Release Path** screens of the model.

Step by Step

We start with the main screen showing an undefined case and waiting for the event type to be selected.
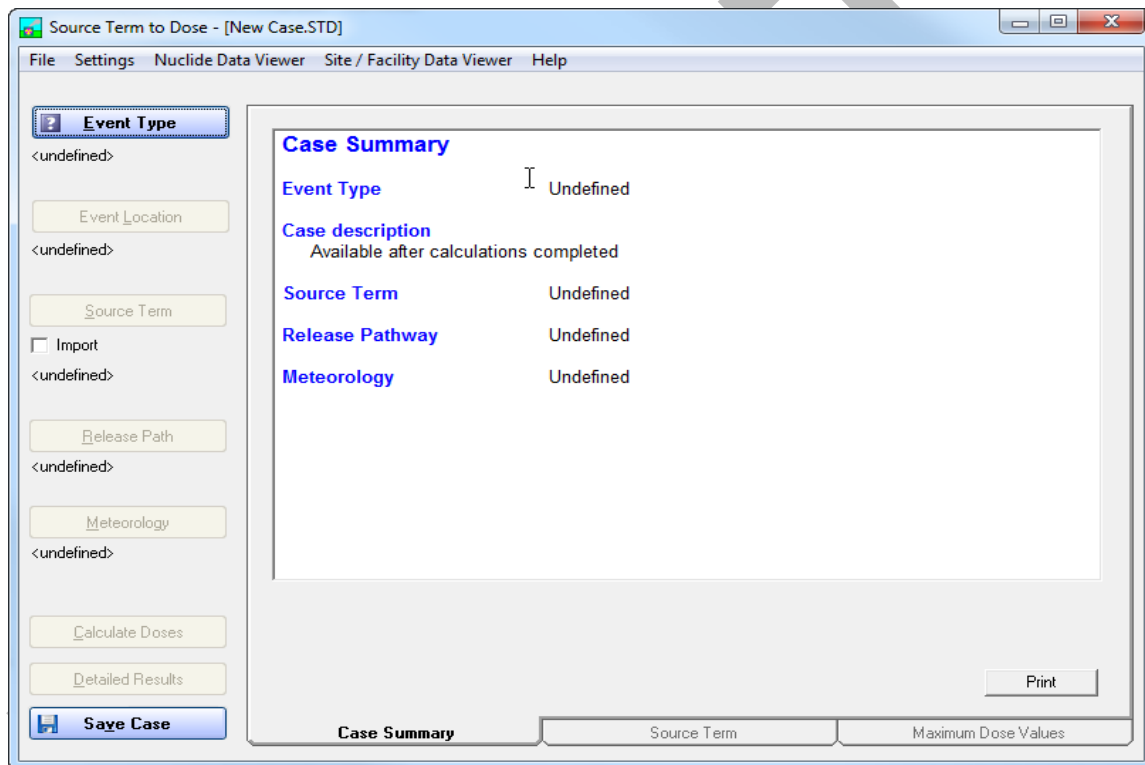
Event Type

Selection of the event type is easy. First, click the **Event Type** button. Since the problem is at Arkansas Nuclear and is a reactor accident - choose the option **Nuclear Power Plant**. Making this selection will limit the choices you have further down the line.
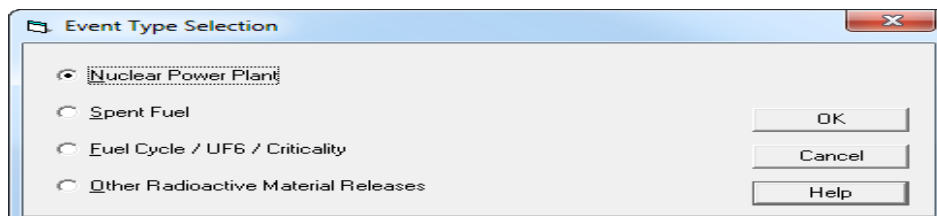
Click the **OK** button to return to the main screen. The **Event Type** button now has a checkmark indicating that the step has been completed. Also, the **Event Location** button color has now changed from grey to blue indicating it is active.

Event Location

Specification of the event location is also easy in this case. Click the **Event Location** button to bring up the **Location and Plant Parameters** screen.
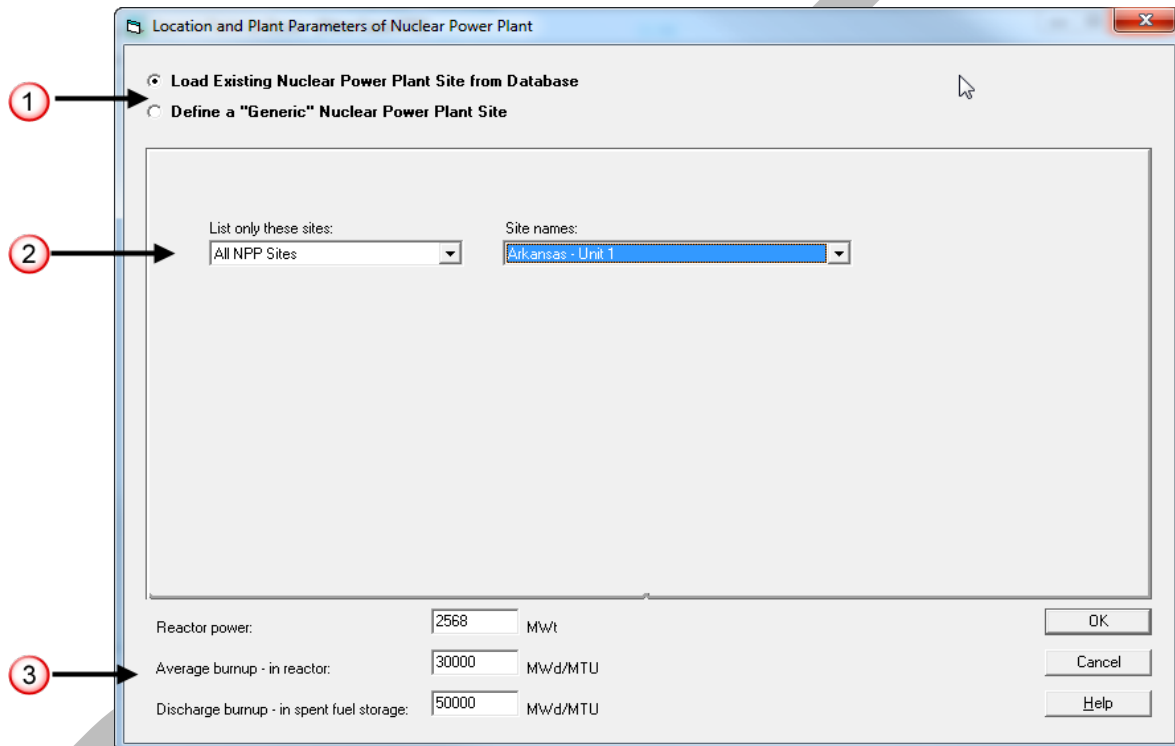
1. Select the option to **Load Existing Nuclear Power Plant Site from Database**

   RASCAL contains a database with information about all the commercial nuclear power plants in the U.S. The database contains unit specific information such as power and volumes as well as location and population information. The second option (**Define a "Generic" Nuclear Power Plant Site**) is available if needed. It can be used to define a site anywhere in the world.

2. Select **Arkansas - Unit 1** from the list of available site names

   The drop-down list has all the nuclear power plants available in the database.

3. Leave all the plant parameters unchanged

   This section displays some of the plant specific data from the database. The values can be changed if needed. However, the problem states that the reactor had been at full power so leave the power set to

the default value. Leave the peak rod burnup at the default value of 30,000 MWd/MTU because better information was not provided.

The reactor power has units of megawatts thermal (MWt). The thermal power is a direct measure of the energy produced by fission. Therefore, the fission product inventory will be proportional to the thermal power. Changing the reactor thermal power level affects the release quantity of all radionuclides.

(The electric power is the thermal power times the electrical generating efficiency of the plant. Typical efficiencies are usually between 30% and 35%, giving a rough conversion factor of 3 between MWe and MWt. All plants have slightly different efficiencies and the efficiency of a single plant can vary depending on operating conditions. Thus, fission product inventory is not exactly proportional to electric power output. It is usually close, but not exact.)

Fuel burnup is a measure of how much fission energy has been produced by the fuel elements that are currently in the core. The fission energy released per unit mass of the fuel has units of megawatt-days per metric ton of uranium (MWd/MTU).

A brand new core will have zero burnup. After several reloads of reactor fuel (generally replacing about one-third of the core per reload), the burnup will typically be about 20,000 MWd/MTU at the start of the cycle and will steadily increase to about 40,000 MWd/MTU at the end of cycle when the reactor shuts down to replace old fuel with fresh new fuel. The older fuel elements that are replaced will typically have a burnup of about 50,000 MWd/MTU. The reactor control room can determine the current fuel burnup at any point in the cycle, although this will not a have high priority during an actual emergency.

Radionuclides with relatively short half-lives (less than a couple of weeks) reach a steady-state equilibrium activity (quantity) fairly rapidly. Their activity in the core is largely unaffected by burnup.

But, the activities of long-lived radionuclides (half-life greater than one year) steadily increase as the reactor core produces power. Their activities never reach equilibrium. RASCAL uses peak rod burnup to adjust the core inventory for the long-lived radionuclides in the core fuel that never reach equilibrium. All long-lived radionuclides in the core inventory are scaled as needed based upon the actual burnup value entered.

Click **OK** to return to the main screen.

Note

The case summary is filled in as you proceed through the definition of the problem. This includes the information you enter as well as supplemental information pulled from the RASCAL databases. For example, the 2010 Census population at 2, 5, and 10 mile radii from the plant are shown. Also shown are, the design pressure and design leak rate.

Source Term

Now select the **Source Term** button. This will display the **Source Term Options for Nuclear Power Plant** screen. All the available source term types for a nuclear power plant accident are listed.
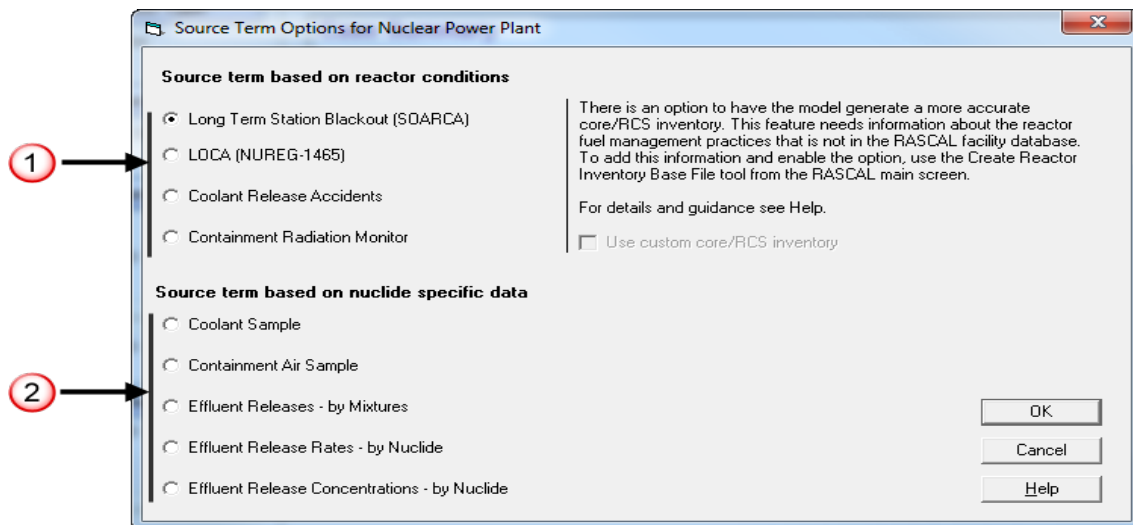
1. The top four options base the source term on an estimate of the amount of core damage.

2. The bottom five options base the source term on some form of measurement.

    Select the **LOCA (NUREG-1465)** option on this screen and then click **OK** to proceed.
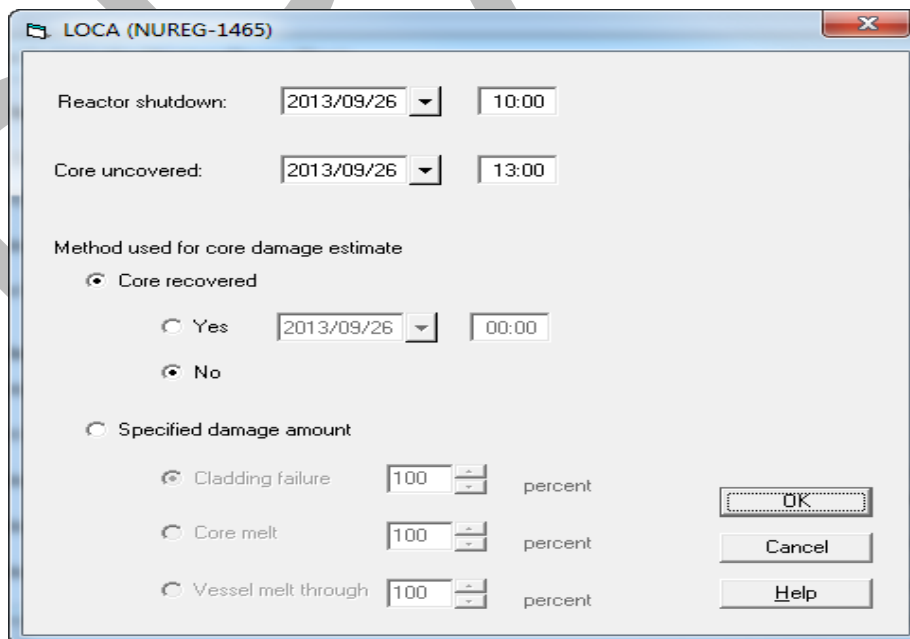
Enter the time of the reactor shutdown (**10:00**) and the time the core was uncovered (**13:00**).

There are two important things to understand here about times in RASCAL. **First**, RASCAL uses a 24 hour clock (instead of A.M. and P.M.). That is why we entered 13:00 instead of 01:00. **Second**, you should always work in *site time*. All information received from the plant will be in their local time. Trying to convert time zones can be confusing in an emergency and is not necessary if all parties have agreed to work with site time.

Leave the method option set to **Core recovered** with the setting of **No**. Click **OK** to complete the source term definition.

Release pathway

Now select the **Release Pathway** button on the main screen. This will display the **PWR Release Pathways** screen.

Each source term type will have one or more available release pathway. As shown below, there are three release pathway options for a PWR. Each option has an associated containment schematic which uses red lines to show pathways to the atmosphere.
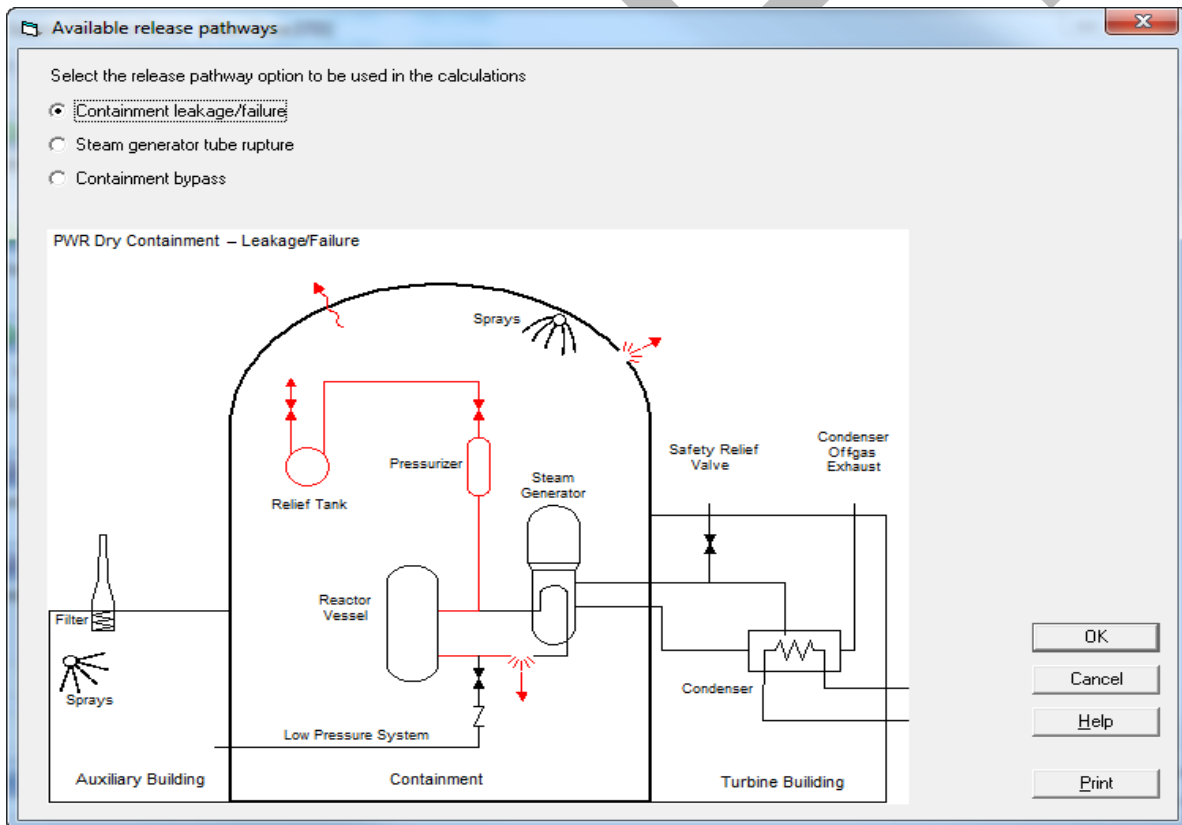
Select the option **Containment leakage/failure** and then click **OK** to display the containment release pathway definition screen.
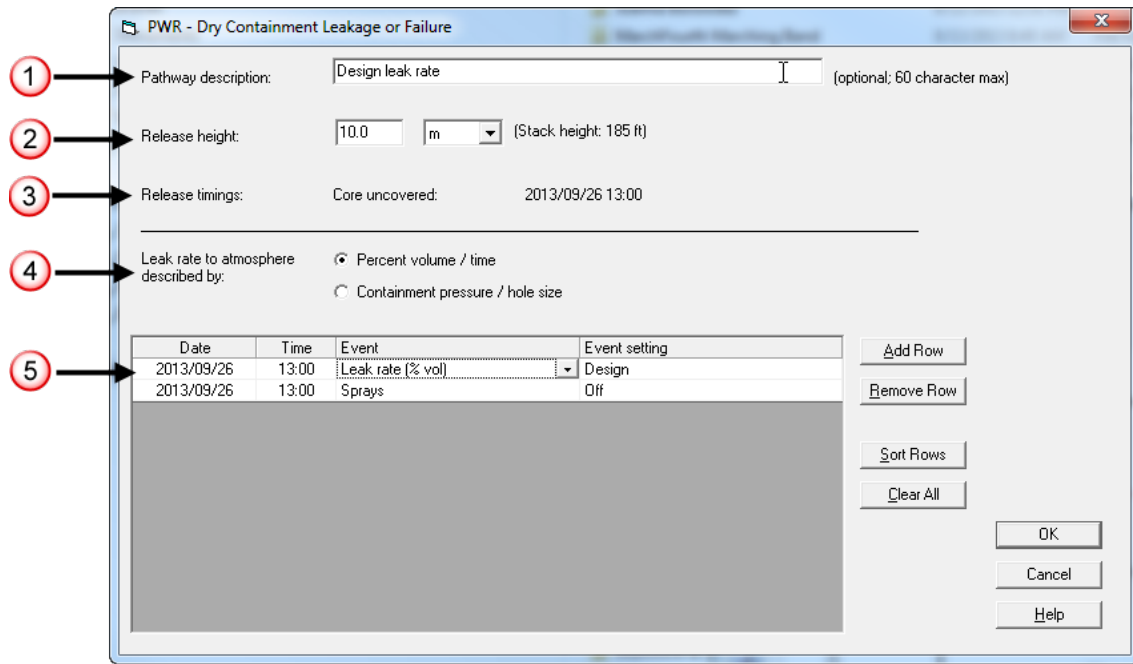
1. For the pathway description enter the text: **Design leakage**.

   This user-entered description is not used in the calculations but will appear on the case summary output. It should be used to clarify where or how the material is entering the atmosphere.

2. Release height: **10.0 m**

   If known, the height above ground level at which the material enters the atmosphere should be entered. This value may be adjusted upward if needed to represent an effective release height. For example, if a fire is forcing the material higher you might use an estimate of the height of the smoke as an effective release height. In our case we do not have a defined release point so leave the release height at the default value of **10.0 m**.

Note on building wake correction

Previous versions of RASCAL included an option to turn the correction for building wake on and off. RASCAL 4 no longer contains that option. The correction is always applied.

Historically, adjustments to the atmospheric dispersion parameters have been made to compensate for releases from buildings. These adjustments have been based on building dimensions and have not considered wind speed. RASCAL includes optional adjustments to the dispersion parameters that are functions of building area, wind speed, and distance downwind (Ramsdell 1990). The adjustments, which are inversely related to wind speed, start at zero at the release point and increase with distance downwind until a limit, based on building area, is reached.(The adjustments are actually a function of travel time.) When the wind speed exceeds about 4 m/s the adjustments become negligible. The adjustments have been referred to as building wake corrections. However, the adjustments are more sensitive to wind speed than building area and are only significant at low wind speeds. Therefore, it is more appropriate to refer to the correction as a low wind speed correction. More recent analysis of the experimental dispersion data (Ramsdell and Fosmire 1998a, 1998b) has yielded adjustments that are independent of building area.

3. The release timings line shows when the release to containment starts. In this case that is when the core is uncovered. This value cannot be changed here, but guides user on the dates and times to be entered in the grid for the release.

4. Leak rate to atmosphere described by: **Percent volume / time**

Leakage fractions for reactors can be described in two ways: 1) as a leak rate from containment in percent volume per time, or 2) as a leak rate set by a pressure and containment hole size. Both methods allow the leak rate to vary with time. The methods cannot be combined.

5. Leave the spray and leak rate events unchanged

The lower portion of the screen deals with describing the time dependent leakage of material to the environment. A leak type is selected and then release events are entered into a table. The default is for a leak rate type of percent volume, for there to be no active reductions (e.g. sprays, filters), and for the leak rate to be at design. The event grid already has 2 events defined: sprays off and design leak rate. The defaults are correct for the problem and do not need to be changed.

Click the **OK** button to accept the release pathway definitions.

In many of the later problems in the workbook the inputs are described in a much briefer format without all the discussion. However, when appropriate, the rationale for an input will be provided.

Following is the abbreviated input summary for the problem up to this point.

Event Type	Nuclear Power Plant
Event Location	Arkansas – Unit 1
Source Term	Type: LOCA (NUREG-1465) Shutdown: < date > 10:00 Core uncovered: < date > 13:00 Core recovered: No
Release Path	Type: PWR – Dry Containment Leakage or Failure Release height: 10.0 m Release events: < date > 13:00 Leak rate (% vol) Design < date > 13:00 Sprays Off

ENTERING SITE METEOROLOGICAL DATA

Purpose

To learn how to enter the basic meteorological observations obtained from the site.

Background

Meteorological data is needed to model the behavior of the radioactive plume in the atmosphere. The minimum required data is:

wind speed and direction	defines the downwind transport
atmospheric stability	governs plume horizontal and vertical growth
precipitation	defines wet deposition (a very important removal process)
air temperature	needed for some deposition processes and UF6 modeling

The goal is to provide the best representation of the weather conditions for the model run in both time and space. That is, capture how the conditions change with time over the period of the release and plume transport. And, capture how the conditions change in space as the plume moves away from the release point. You do this by combining observations and forecasts for both the release point and other locations in the modeling domain.

RASCAL requires that initial weather data be entered within a 2 hour window before the start of the release. The model will not allow the start of calculations until at least this weather data is provided. If no other data is provides, this initial set will persist throughout the duration of calculations.

The first step in creating a meteorological dataset for use with RASCAL is entering the meteorological data for the release point. This data should be either observed weather for that 2 hour window before the start of the release or a forecast for that same period. The data can be obtained from a variety of sources.

For nuclear power plants, weather observations for the site itself would be obtained via the Emergency Response Data System (ERDS) or by telephone from the licensee. The weather data are measured on a multi-level tower and consist of wind speed and direction, air temperature, and atmospheric stability. The reporting and averaging interval may vary but is usually 15 minutes. Note that precipitation is not measured or reported. Normally you will enter the data measured at the lowest tower level (typically 10 m or 30 ft). You can use elevated measurements but will need to change the measurement height in the program. RASCAL adjusts winds to the release height so using surface data is not an issue.

ERDS has some limitations with respect to weather data:

- it provides no forecast meteorological information
- it may not be connected when needed
- the data is from a single location and may not be sufficient to describe winds in complex terrain
- there are no ERDS connections at facilities other than nuclear power plants

Nevertheless, observed data from the onsite meteorological tower is still the best starting place. As time and data permit, add observation data from surrounding stations (e.g. National Weather Service). This information is used to improve the spatial representation of the wind fields. If you are planning on modeling for more than 3 hours past the last observation you should also add forecast weather information.

The observations and forecasts should be updated periodically. ERDS should be checked every 15-30 minutes. The National Weather Service generally updates observations hourly and forecasts every 3-6 hours.

Problem

For purposes of this problem, we will assume that ERDS and the plant operators have provided the following data:

Time	Wind direction (deg)	Wind speed (mph)	Stability class	Precipitation	Air Temp (deg F)
1100	10	6	B	No precip	65

Note that ERDS does *not* provide information on precipitation. That information would need to be acquired from another source.

Step by Step

Select the **Meteorology** button on the main screen. This will display the **Meteorology** screen.
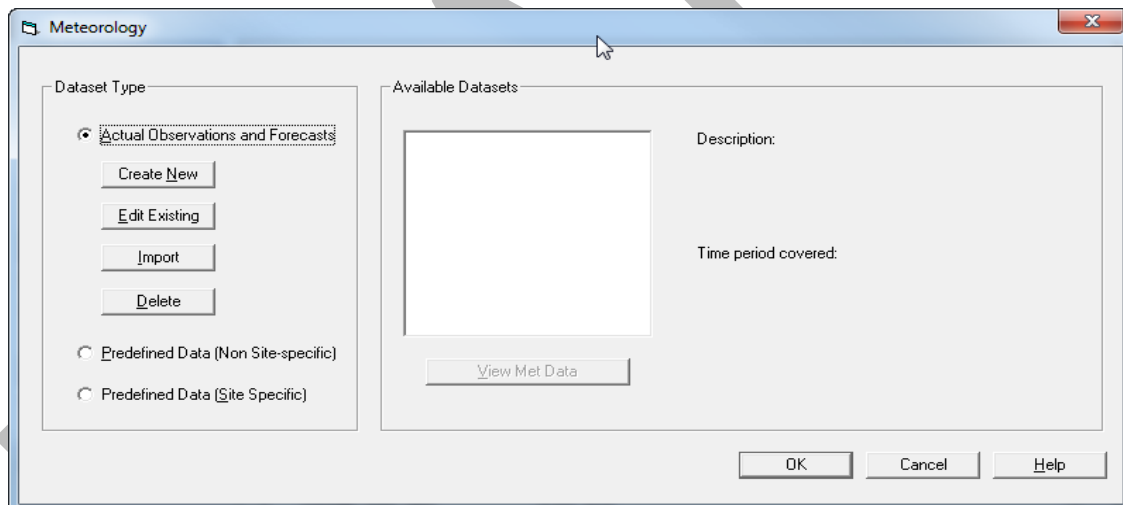
The default is to use **Actual Observations and Forecasts**. There are "generic" datasets available that can be used when actual data is not available. These are described further at the end of the workbook.

Actual Observations and Forecasts

This data type is both site-specific and date/time-specific. That is, it can be used only for releases from the site specified at the specified times. Since it is site-specific, it can correct for topographic effects. The date and times of the meteorological data must closely match the release times. Meteorological data must start within a 2 hour window before the release to the atmosphere starts. The dataset can be comprised of a mix of observations and forecast records. However, entering a set of observations for a station will cause any forecasts for that station at an earlier time to be deleted.

1. Select the **Actual Observations and Forecasts** dataset type.
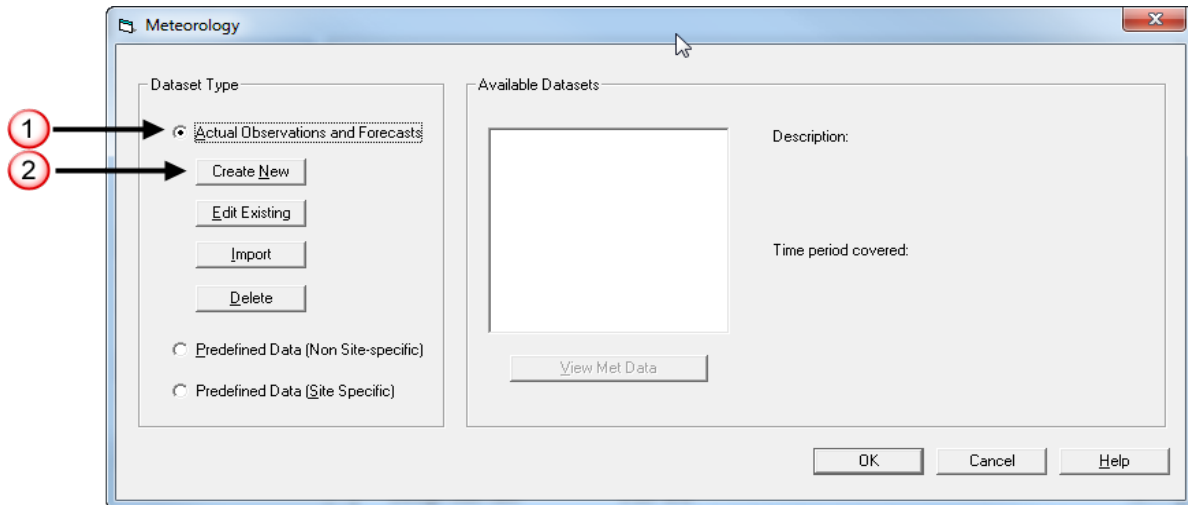
This will enable the buttons used to access the **Meteorological Data Processor** program. If no datasets have been previously created for this site, then the **Available Datasets** box will be empty.

Since we have not yet entered any weather data for this event, we want to create a new set. Using actual data requires that the times of the meteorological observations closely agree with the times of the release to the atmosphere.

2. Click the **Create New** button.

This will start the **Meteorological Data Processor** program and display the main screen.
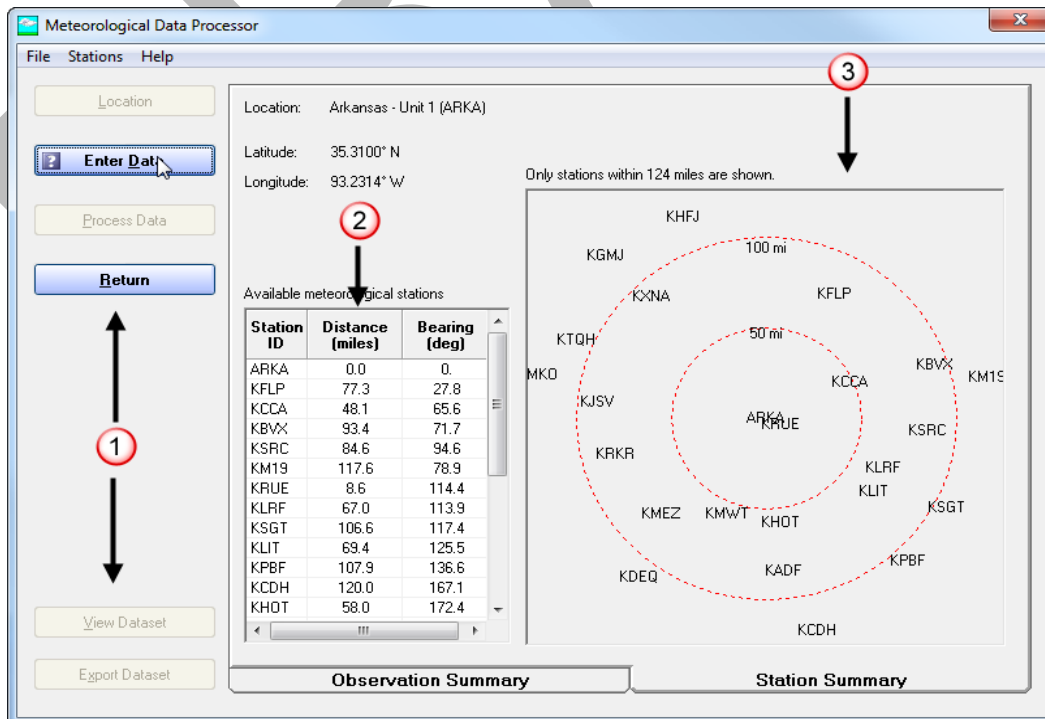
1. The main steps of the program are controlled via the buttons on the left side; starting from the top and working downward. The **Location** button is greyed out and unavailable because the program was started from within the source term to dose model. At this point the location has already been defined and thus doing it again is not necessary. The **Location** button is available only if the **Meteorological Data Processor** program is started in a stand-alone mode. The **Process Data**, **View Dataset**, and **Export Dataset** buttons are also unavailable since no data has yet been entered.

2. This is a list of the available weather stations surrounding the site. These are taken from the RASCAL database. The display shows the distance and the direction of the station from the release point.

   The NWS is continuing to add observing stations. If you find other stations that you would like to use they can be added. Refer to "Adding Weather Stations" on page 76 for the steps.

3. A simple map show the relative positions of the stations to the release point.

Click the **Enter Data** button to display the data entry screen.

Data Entry Screen
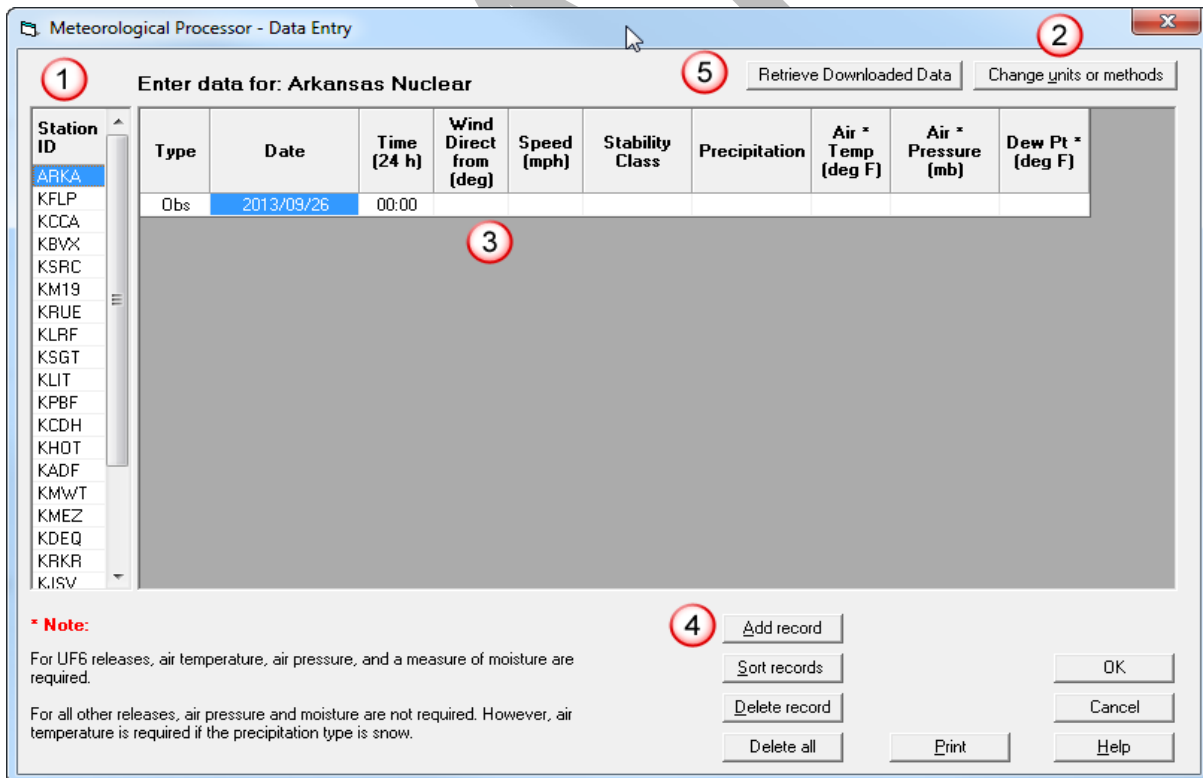
Note the following features of the data entry screen:

1. The default weather station (first in the Station ID list) is the on-site meteorological tower. For sites not in the RASCAL database, this station will be the release point. At least one observation

must be entered for this station. It should usually be at the first observation time. It is recommended that you always begin by entering the data for the release point before entering data for other stations.

You can change the station by clicking on any entry in the list. Try this to see how it works. Notice that the table of data will change as the station changes.

2. Use the **Change units or methods** button if the units of the data you are receiving do not match those currently displayed in the data entry grid.

3. Weather data for each station is entered into a separate grid. Do not combine data from multiple stations into one table. The table of data initially consists of a single, mostly blank record.

   Data can be entered for any date or time. However, there must be data before or at the same time as the start of the release to the atmosphere.

4. The **Add record** button is used to add records to the end of the data entry grid.

5. The **Retrieve Data** button can used to populate the data entry grid if the data downloader program has been run to download data from the internet.

Entering Data

Now, enter the following data for station ARKA:

Column header	User entry	Comments
Type	Obs	This means that the record is an *observation* and represents an actual set of measured values (in contrast to forecast)
Date	today	Use the default, which if the computer clock is correct, should be today.
Time	11:00	Enter the time using a 24-hour clock. The program will round the time to the nearest quarter-hour. For example, an entry of 12:07 would be changed to 12:00. Similarly, an entry of 14:23 would be changed to 14:30.
Direction from (deg)	10	This is the direction from which the wind is blowing. A wind from the north is 0 degrees, from the east is 90 degrees, from the south is 180 degrees, and from the west is 270 degrees.
Speed (mph)	6.0	
Stability	B	
Precipitation	No precip	
Air Temp (deg F)	65	Required if there is precipitation or a UF_6 release.
Air Pressure (mb)	<blank>	This is needed only if the release contains UF_6.
Dew Pt (deg F)	<blank>	This is needed only if the release contains UF_6.

The record will look like this:

Type	Date	Time (24 h)	Wind Direct from (deg)	Speed (mph)	Stability Class	Precipitation	Air * Temp (deg F)	Air * Pressure (mb)	Dew Pt * (deg F)
Obs	2013/09/26	11:00	10	6.0	B	No Precip	65		

Now click the **OK** button to return to the main form.

Meteorological Data Processor

File   Stations   Help

Station ID	Number of Observations	First Observation	Last Observation	Station Name
ARKA	1	2013/09/26 11:00	2013/09/26 11:00	Arkansas Nuclear
KFLP	0			Flippin, Marion County Regional Airport
KCCA	0			Clinton Memorial Airfield
KBVX	0			Batesville, Batesville Regional Airport
KSRC	0			Searcy, Searcy Municipal Airport
KM19	0			Newport, Newport Municipal Airport
KRUE	0			Russellville, Russellville Regional
KLRF	0			Little Rock Air Force Base
KSGT	0			Stuttgart, Stuttgart Municipal Airport
KLIT	0			Little Rock, Adams Field
KPBF	0			Pine Bluff, Grider Field Airport
KCDH	0			Camden / Harrell Field
KHOT	0			Hot Springs, Memorial Field Airport
KADF	0			Dexter B Florence Memorial Field
KMWT	0			Mount Ida
KMEZ	0			Mena, Mena Intermountain Municipal
KDEQ	0			De Queen, J Lynn Helms Sevier
KRKR	0			Poteau, Robert S Kerr Airport
KJSV	0			Sallisaw, Sallisaw Municipal Airport
KMKO	0			Muskogee, Davis Field
KTQH	0			Tahlequah, Tahlequah Municipal
KXNA	0			Fayetteville/Springdale, Northwest

Location

Enter Data

Process Data

Return

View Dataset

Export Dataset

Observation Summary   **Station Summary**

Observation Summary

Note that the **Observation Summary** tab is active when the screen is redisplayed after doing data entry. This summary shows in one place how much data has been entered. For each station, it shows the number of observations (or forecasts) and the date and time of the first and last entries. In this case, a single observation has been entered for the ARKA site.

Process Data

The RASCAL transport and diffusion models require gridded wind fields for their calculations. Just entering the observation data into the program is not enough. A final step is required to take the information at these observation points and generate the gridded data. Each time additions or changes are made to the data, the save and process step must be repeated.

The **Process Data** button is now active. Click it to display the **Process Data** screen.
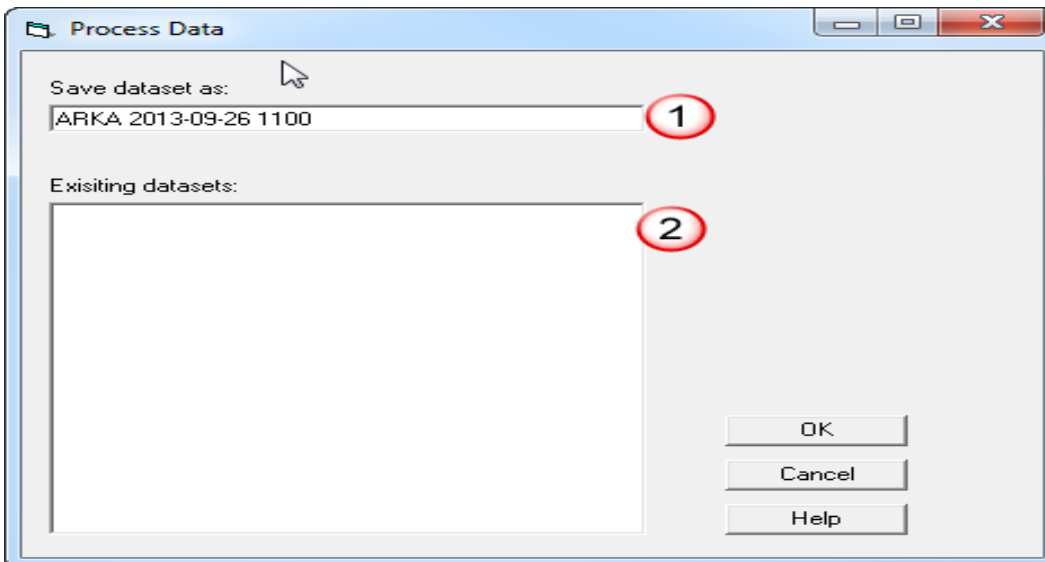
1. The field at the top of the screen is used to name the dataset. This name should uniquely identify the dataset to you and to others who will share the dataset. By default the program creates a name containing the date and time at which the data is processed. This will create a unique name for each dataset and allow users to quickly see which dataset is most recent.

   The dataset name must be a valid Windows filename. The following characters cannot be used: less and greater than, colon, double quote, forward and backward slash, vertical bar, question mark, and asterisk. Thus, for example, the default dataset name shows dates without slashes and times without a colon.

   For this first dataset, we are going to use a name that indicates when the dataset was created. Change the name suggested by the program to:

   ARKA < date > 1100   (Change the date in your name as needed)

   We are indicating that the dataset is based on the data available at 11:00. Later as we add more weather data we will change the name to use a later time.

2. Existing datasets are listed here. You may select one of these if you wish to overwrite it with the new data.

Previous versions of RASCAL required the user to set some advanced options. RASCAL 4 no longer has those options. Instead the options are fixed as described below:

- Missing stabilities are filled in with an estimated value based upon wind speed, time of day, and precipitation.

- The wind fields are modified for topography for sites in the RASCAL database

- There are no longer adjustments to stabilities that might be unrealistic. If a stability class is entered the program uses it.

Click the **OK** button. When the calculations are completed you will be returned to the main screen on the **Observation Summary** tab.
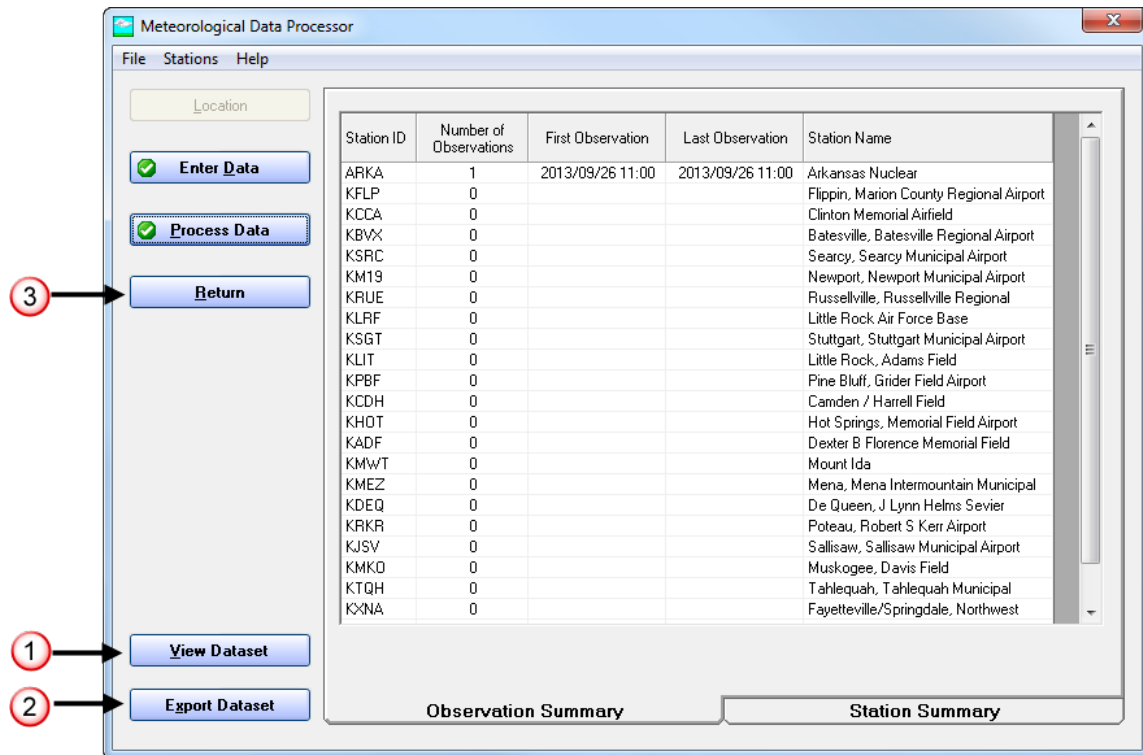
1. The **View Dataset** button will launch a separate program for viewing both the entered data and the generated gridded data to be used by the models.

2. The **Export Dataset** button can be used to create a single file containing all the meteorological information in the current dataset. This file can be saved in any location and can be copied or e-mailed. There is an import button on the meteorological data selection screen that allows this type file to be imported. The export/import functionality allows the jobs of dose analyst and weather data collection and entry to be separated.

3. The **Return** button exits the Meteorological Data Processor and returns control to the Source Term to Dose model user interface.

Before returning to the model to use this dataset, click the **View Dataset** button.

Viewing the Meteorology

This is the **Meteorological Data Viewer** main screen.
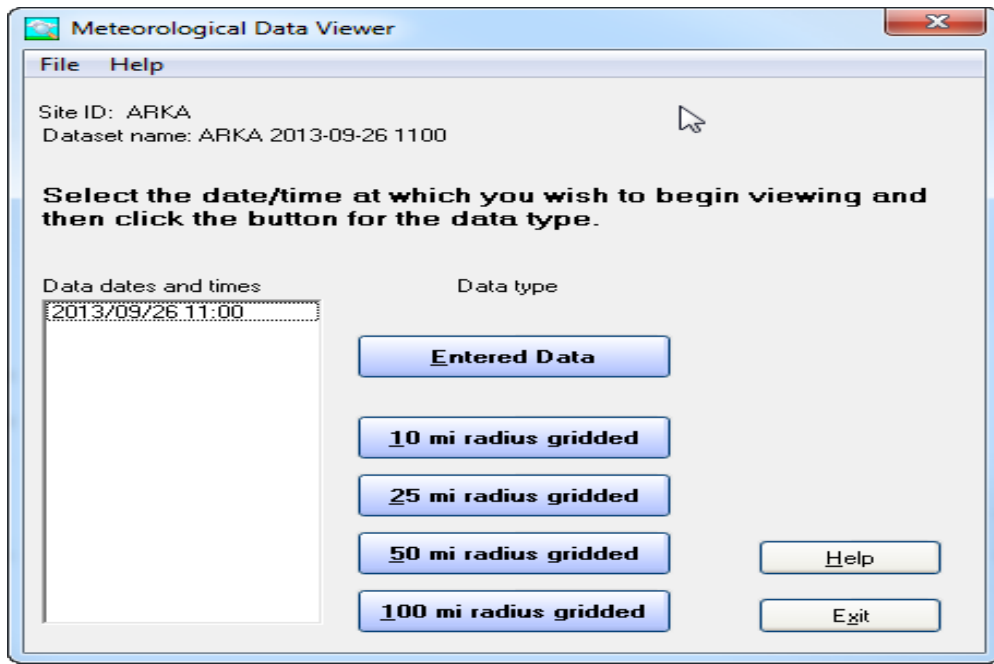
The viewer program provides both text and graphics displays of both the entered data and the processed data.

Click the **Entered Data** button.
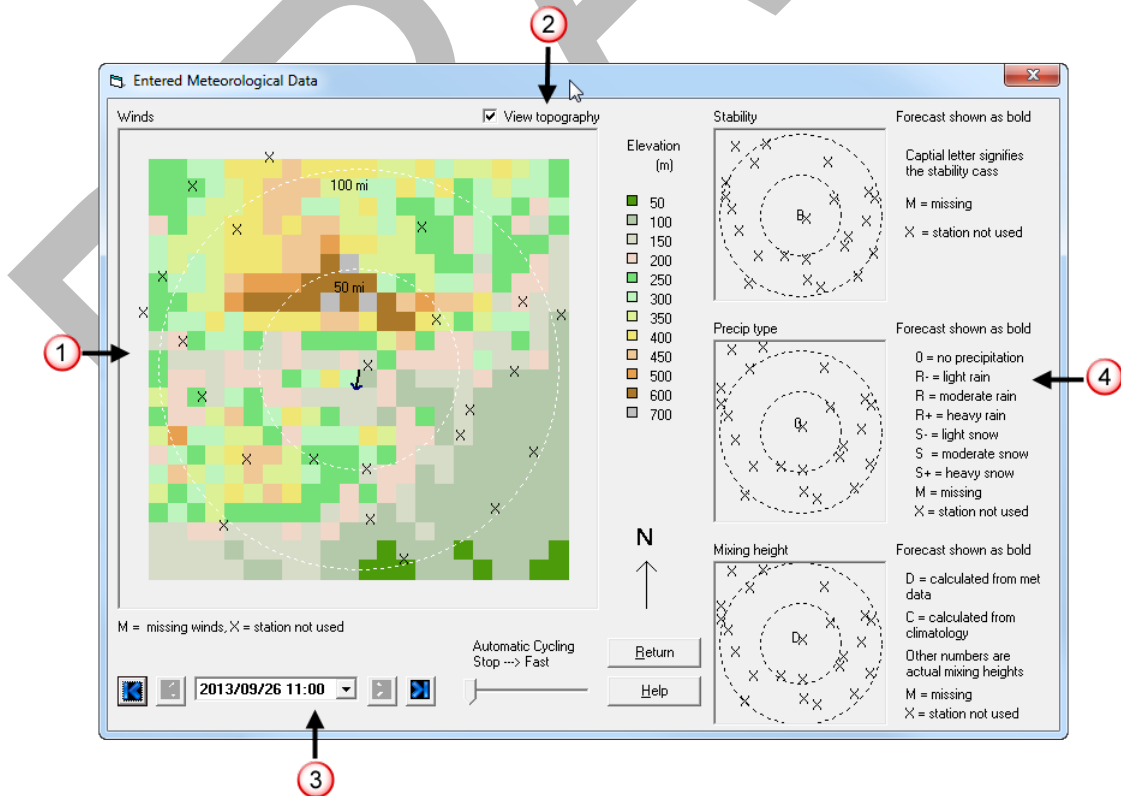
This screen provides a set of pictures to summarize the entered data at each time.

1. The large image on the left shows the winds. Arrows represent the direction in which the wind is blowing. In our case, the wind direction was 10 degrees (from the north). The length of the arrow is proportional to the wind speed. Since we entered only data for the site, there is no other station data to display and they are represented by an X.

2. The **View topography** check box controls whether a colored representation of terrain heights is displayed beneath the wind arrows.

3. The viewer can cycle through the data in 15 minute time steps. Since there was only a single measurement time there is only one time to display.

4. The 3 smaller images on the right reflect the data entered for stability, precipitation, and mixing height.

Click **Return** to go back to the data selection screen.

Click the **10 mi radius gridded** button.
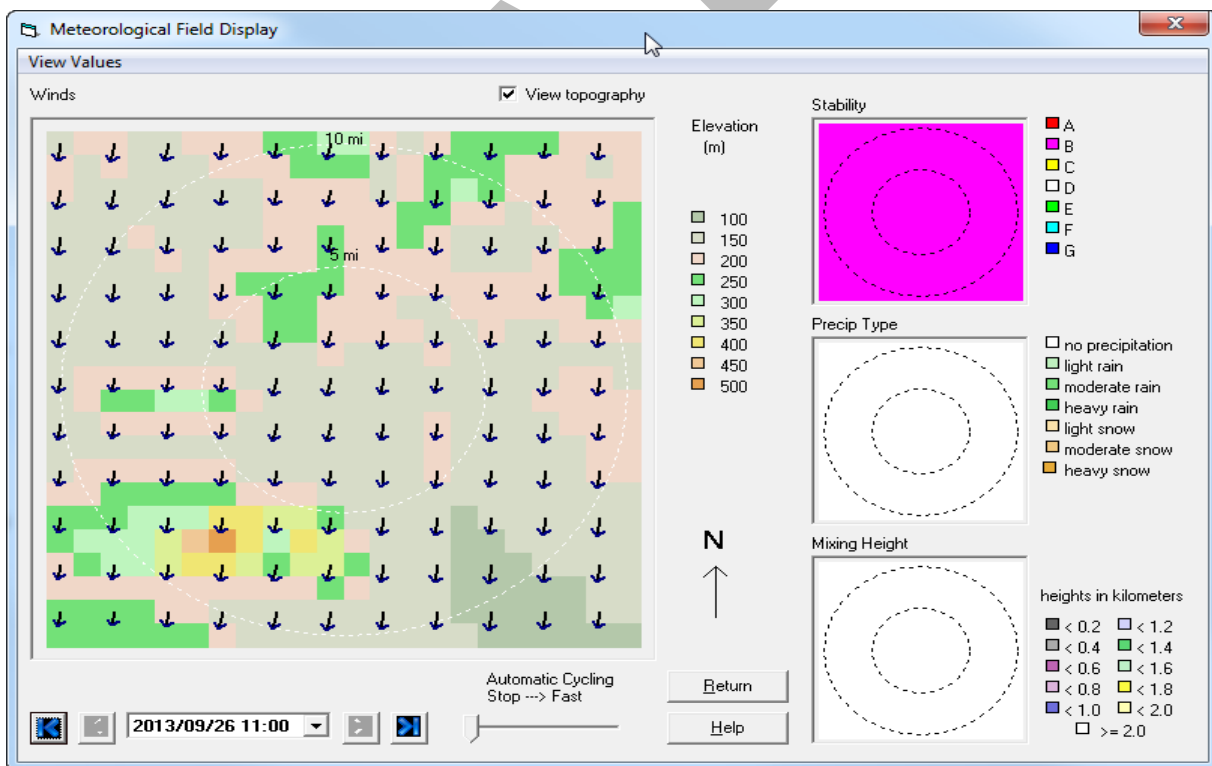
Now displayed in the large box on the left are arrows representing the wind field generated by the program from the single data record entered. Recall that the wind direction was 10 degrees. Wind direction is given as the direction *from* which the wind is blowing. Thus, the arrows show the direction material would be transported.

The three smaller boxes to the right show the stability, precipitation type, and mixing height. The first two are as entered with the data. The mixing height was calculated by the program.

We now have a group of files that include the user entered data and the processed wind fields to be used by the transport and diffusion models. This dataset will work only with the Arkansas site and on the date specified. This dataset can be recalled at any time for editing. However, each time the data is changed, you must again **Process Data**.

Click the **Return** button to close the wind field display. Then, click the **Exit** button to close the Meteorological Data Viewer. Finally, click the **Return** button of the Meteorological Data Processor. This returns to the meteorological dataset selection screen. Notice that the dataset just created is selected for use.
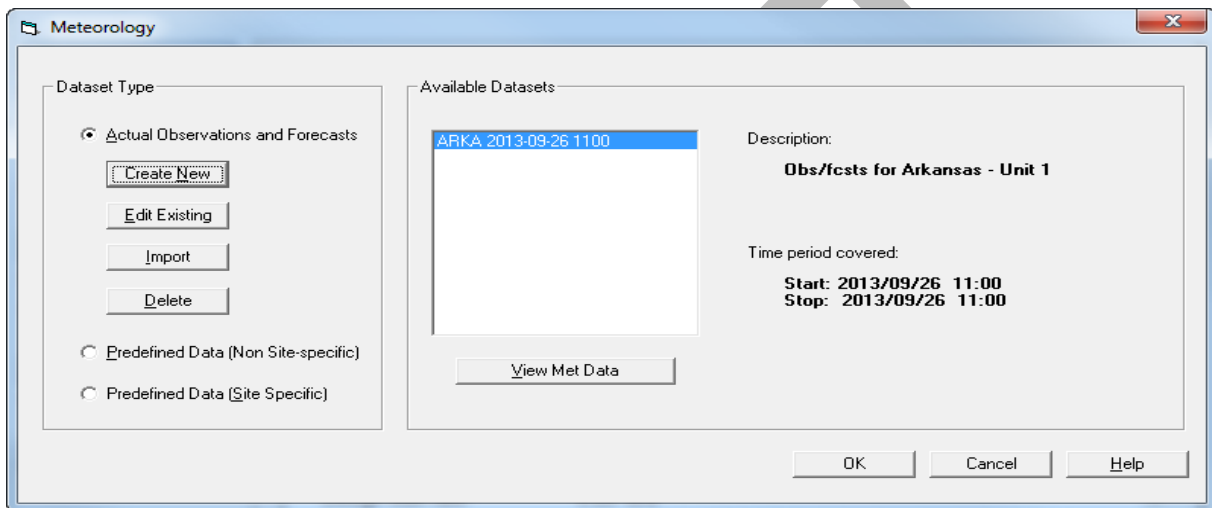
Click the **OK** button to return to the main screen.

CALCULATE DOSES

Purpose

To learn how to calculate dose.

Background

The last information to be entered before starting the calculations is the distance to which doses are to be calculated and when to stop the calculations.

Setting the **Distance of calculation** determines which models are run and the locations for the model receptors. In addition to defining the distance to which doses should be calculated, you also need to specify when the calculations should be terminated. This is essentially the end-of-exposure. Doses are accumulated up to this time (with the exception of 4-day groundshine which always goes to 4 days). Setting this value is discussed more fully starting on page 49, Time for End of Calculation.

Problem

Recall that you have been asked to evaluate the appropriateness of the protective action recommendation. In order to do this you will need to determine the projected total effective dose equivalent (TEDE) and the thyroid dose (thyroid committed dose equivalent or thyroid CDE).

Step by Step

Click the **Calculate Doses** button on the main screen to display the **Start the Calculations** screen.

1. Distance of calculation: **Close-in + out to 10 miles (16 km)**

Always select close-in plus out to 10 miles for the initial run. If there is a subsequent interest in doses at distances beyond 10 miles, run the calculations again selecting a greater distance. (Hint: if you save the case after you run it the first time, you will not have to re-enter all the data. You will just have to change a single entry on the **Start the Calculations** screen.)

2. End of calculations: **Start of release to atmosphere plus 8 hours**

The default of 8 hours is sufficiently long that, even if the wind speed was low (e.g. 2 mph), some material would reach the default distance setting of 10 miles. You should always evaluate whether this "end-of-calculation" provides enough time given the wind speed and final distance of interest for the material transport.

3. Inhalation dose factors to use in calculations: **ICRP 26/30**

4. Case title: **Core uncovered, design leak rate**

This is just a short unique description which will appear on all the outputs.

5. Case description: **Initial case of the workbook**

This area provides up to 600 characters that can be used to further describe the scenario being model. It is a good place for things like assumptions, rationale, etc. that will help others understand the thinking that went into the model run.

6. Analyst: **Dose Analyst**

Select the default text shown (controlled from the Settings menu) or use the other option to enter some other name and contact information.

7. Click the **OK** button to start the calculations.

Status windows will indicate the progress of calculations. The sequences of calculations are: source term, close-in model, and if needed the puff model to the specified distance. (The transport and diffusion models are described starting on page 58).

At the end of the calculations, the **Maximum Dose Values** tab of the main screen will be displayed.
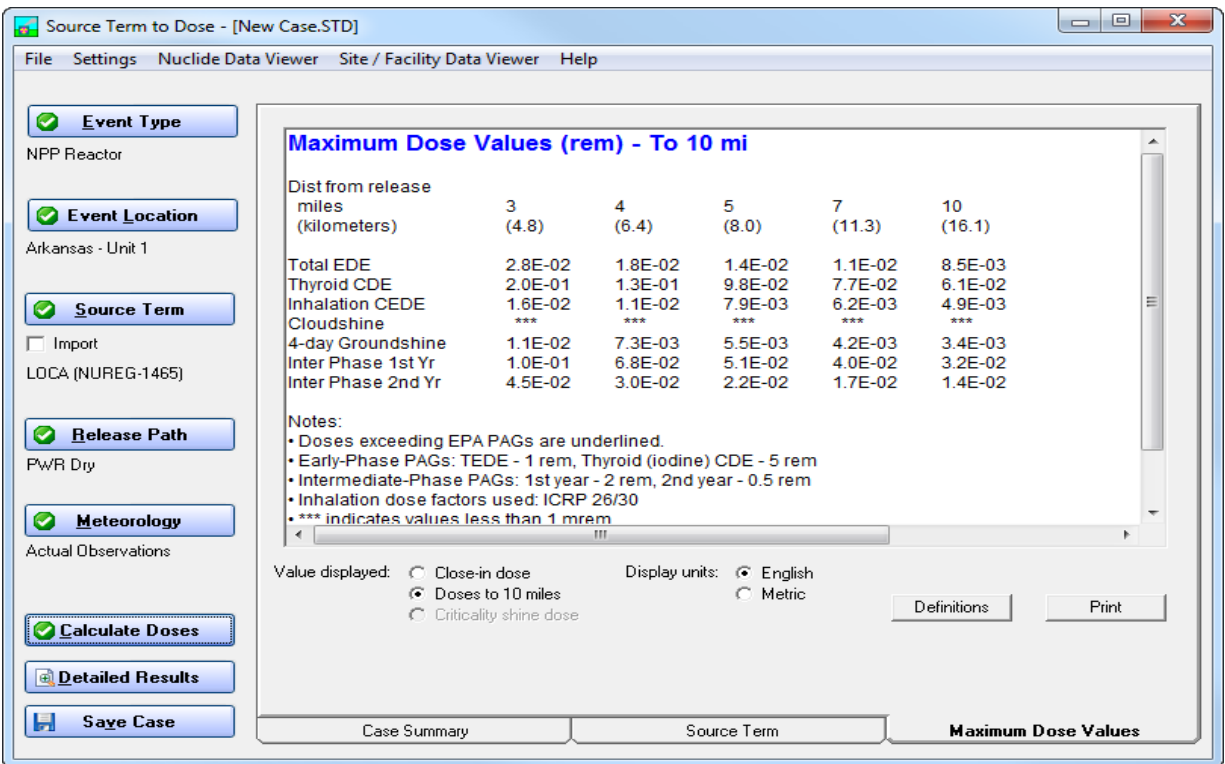
Save the Case

This is the time to save all your work so that it can be recalled later. Click the **Save Case** button in the lower, left of the main screen or select **File | Save Case** from the menu.

This will display one of two screens depending on the settings. The default setting when installed is for RASCAL to automatically generate the file name from the case title entered on the start calculations screen. If that is the setting you will see the following screen:
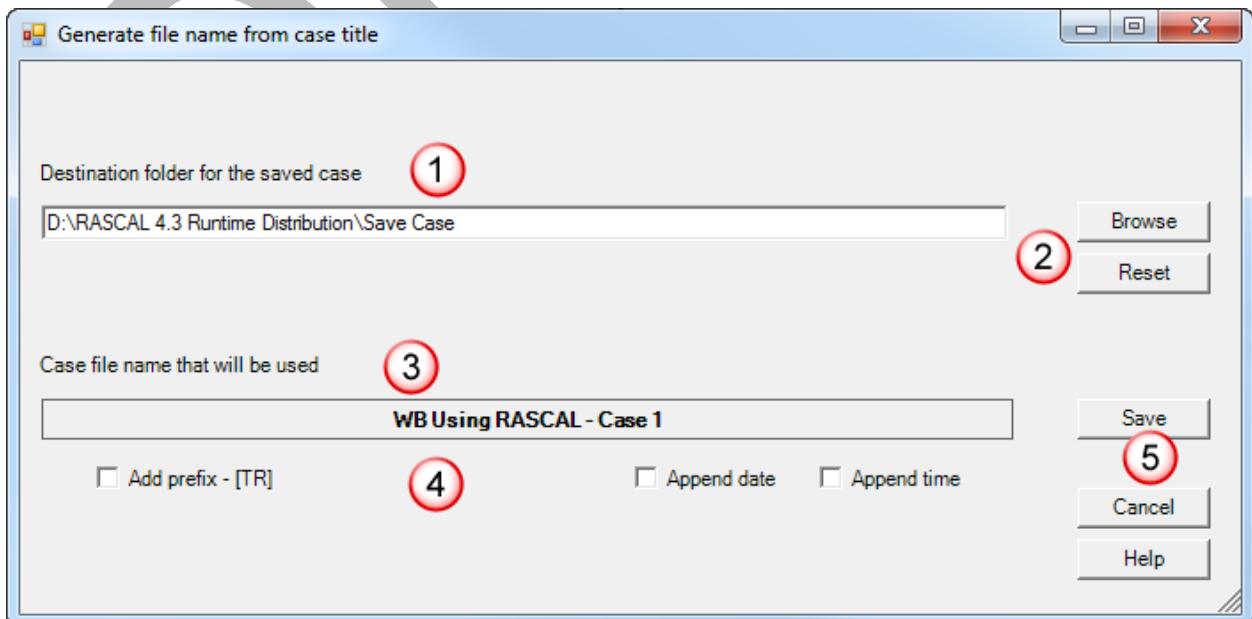
1. Destination folder is where the file will be saved. The default is the \Save Case folder under the main RASCAL folder.

2. Change or reset to the default using these 2 buttons.

3. This is the name that will be used, for this example use the name "**WB Using RASCAL – Case 1**." The base portion is what was entered for the cast title on the start calculation screen.

4. You have the option of adding a prefix. This is defined on the settings screen. You may also append the date and time to help make the file name unique.

5. Click the Save button to complete the process.

The other method for naming is the more traditional one where you have full control and must define the full case name. This has more flexibility but does require that you maintain some coherent naming scheme,

In both methods all the input information and all the results will be saved in a single file that can be backed-up, copied, and distributed.

Note

The saved case file is really a zipped archive that consolidates all the input, meteorology, and results into a single file. This file can be archived to other drives or e-mailed to other users. One note of caution, the file size can get quite large (many MBs) as the calculation duration increases and as more meteorology data is added.

USING THE MAXIMUM DOSE VALUES

Purpose

To learn how to use the RASCAL maximum dose values tables.

Discussion of PAGs

Chapters 2 and 5 of the EPA *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents* (EPA 400-R-92-001) discuss the protective action guides (PAGs) for the early phase. The following material is from those chapters.

Protective Action	PAG (projected dose)	Comments
Evacuation (or sheltering)	TEDE 1-5 rem Thyroid CDE 5-25 rem	Evacuation (or for some situations, sheltering) should normally be initiated at 1 rem TEDE or 5 rem thyroid CDE.
	TEDE is the sum of inhalation dose and the external doses from cloudshine and 4-days of groundshine.	

"Although the PAG is expressed as a range of 1-5 rem, it is emphasized that, under normal conditions, evacuation of members of the general population should be initiated for most incidents at a projected dose of 1 rem." (page 2-5)

"Sheltering may be preferable to evacuation as a protective action in some situations. Because of the higher risks associated with evacuation of some special groups in the population (e.g. those who are not readily mobile), sheltering may be the preferred alternative for such groups as a protective action at projected doses up to 5 rem. In addition, under unusually hazardous environmental conditions, use of sheltering at projected doses up to 5 rem to the general population (and up to 10 rem to special groups) may become justified." (page 2-5)

"Illustrative examples of situations or groups for which evacuation may not be appropriate at 1 rem include: a) the presence of severe weather, b) competing disasters, c) institutionalized persons who are not readily mobile, and d) local physical factors which impede evacuation." (page 2-6)

"No specific minimum level is established for initiation of sheltering. Sheltering in place is a low-cost, low-risk protective action that can provide protection ..." (page 2-7)

"The projected dose comparison to the early phase PAGs is normally calculated for exposure during the first four days following the projected (or actual) start of a release. The objective is to encompass the entire period of exposure to the plume and to deposited material prior to implementation of any further, longer-term protective action, such as relocation. Four days is chosen here as the duration of exposure to deposited materials during the early phase because, for planning purposes; it is a reasonable estimate of the time needed to make measurements, reach decisions, and prepare to implement relocation." (page 5-6)

Problem

Use the calculation results from the **WB Using RASCAL – Case 1 exercise** to assess the doses relative to the PAGs. Answer the questions at the end of the problem.

Step by Step

The first results screen displayed is the **Maximum Dose Values** table.

1. Use the **Value displayed** options to select which set of doses you want to see. The sample screen shown above is for the doses beyond the close-in area. A sample screen of close-in doses is shown on the next page.

   The doses shown are the highest doses at fixed distances from the release. The screen only shows at one time the "close-in" doses or the doses beyond the close-in area. The "close-in" doses are the doses calculated by the straight-line Gaussian plume. The doses beyond the close-in area are calculated using the Lagrangian puff model.

2. The tab contains a **Print** button which combines both sets of dose values with the case summary into a single printed report.

   The early phase (plume phase) doses that RASCAL calculates are for people who are outdoors during plume passage and who remain outdoors exposed to ground shine from deposited radionuclides for four days after the radionuclides have been deposited. Thus, the early phase doses that RASCAL calculates are larger than the doses that would be expected for people engaged in normal activities (spending much time indoors). In addition, people who evacuated or relocated within four days after plume passage would receive lower doses than RASCAL calculates.

This overestimation of the early phase doses by RASCAL is intentional. The purpose of the RASCAL dose calculation is to determine if protective actions are needed, not to provide realistic estimates of the doses that people would actually receive. The need for protective actions is based on the doses that would be received if no protective actions of any type were taken, even actions such as simply spending some time indoors. The RASCAL dose estimates should not be used as an estimate of the doses that would be received by people who did not intentionally take protective actions because even performing normal everyday activities will reduce doses to below those estimated by RASCAL.

The TEDE and Thyroid CDE numbers will appear underlined if the value exceeds the lower end of the EPA PAG range. Following the table of numbers is a "notes" section which defines the PAG thresholds and provides other information about the values shown. The maximum values table has a minimum dose of 1 mrem. Doses falling below that threshold are not shown. However, these low numbers can be examined by using the numeric values option for display under **Detailed Results**.

Question	Your answer
What are the TEDE's at 2 and 5 miles?	
What are the thyroid doses at 2 and 5 miles?	
To what distance does the TEDE exceed the PAG?	
To what distance does the thyroid dose exceed the PAG?	
At what time does the plume first reach 5 miles? (Hint: what was the wind speed?)	
At what time have you assumed the release to end? (Hint: On the "calculate doses" screen, look at the "end calculation at ..." entry)	
What was the time for the latest weather data that you entered?	

Optional question

Should the results of this RASCAL run be used to prepare the briefing?	

Results

See page 200 for the answers to the above table.

OBTAINING OBSERVED WEATHER DATA FROM THE INTERNET

Purpose

To learn how to obtain observed weather data from the Internet.

Background

Weather data from only the release point is not really good enough for dose projections to 10 miles.

As discussed earlier, site meteorological towers (e.g. those required at nuclear power plants) provide the best initial weather data for use by the RASCAL models. To supplement the on-site data and improve the representation of wind fields, we should use additional sources of weather data. The more data you have to represent the meteorological conditions in the modeling area, the better the wind field representation. Whenever possible, use data from multiple stations, especially stations downwind of the release point. This becomes especially important at greater distances (25 and 50 miles).

The National Weather Service operates both manned and automated observing stations. The information is reported hourly usually very close to the hour. The data reported includes wind speed and direction (2 minute average), air temperature, dew point temperature, and weather conditions (e.g. precipitation). Atmospheric stability is not reported.

For sites in the RASCAL Database

As we saw when using the Meteorological Data Processor, the RASCAL facility database provides the names and codes for National Weather Service stations surrounding the site.

To quickly obtain weather observations at these defined stations, use the following URL:

weather.gov/data/obhistory/K???.html

You replace the ??? with the three letter code for the weather station that you want. The station identifiers are case sensitive and must be all capital letters. The "html" must be lowercase.

For example, the page with the current weather for Billings, Montana would be:

weather.gov/data/obhistory/KBIL.html

As you can see on the sample on the next page, the web page provides the following information:

- The date (day of month) and time of the observation
- Wind direction and wind speed
- Weather (this is where you would find precipitation type if any)
- Temperature (air and dewpoint)
- Relative humidity (useful for UF6 releases)
- Air pressure (useful for UF6 releases)
- Precipitation amount

Much of this data can be entered into RASCAL directly. Note that there is no stability class provided. For the stability, set the field to **Unknown** and the model will estimate it from other conditions.

As you can see, this page contains the observations for the past 3 days. This data is useful if you are attempting to model a release that happened in the past and need historical weather.

For sites not in the RASCAL database

If you do not have the 3 letter ID code for the weather stations, begin at the **weather.gov** website. You can navigate to the area of interest by either 1) entering some location information and using the **Go** button, or 2) using the finger cursor to pinpoint a location on the map and clicking.

If using the cursor to zoom the map, several clicks will be needed to reach the required location.

Shown below is an example of the current conditions and forecast web page for a specific location. Note the following three areas:

1. These are the currently measured conditions. They were measured at the Harrisburg airport. This is the closest measurement to the location selected. This measured information can be entered into RASCAL. You can also use the **3 Day History** link to see past conditions.

2. This identifies the specific point selected. This is not where the measurements were taken.

3. This identifies the NWS forecast office creating the weather forecast and provides location information for the point selected.

National Weather Service Support
The National Weather Service is prepared to offer direct assistance if requested. They can provide observations as well as detailed forecasts. They will be able to give you additional insights on the data

and tell you how reliable they think it is. In addition, they can provide stability class predictions and more exact information on precipitation.

The NWS requests that NRC staff contact the local forecast office (LFO) nearest the release. NRC Protective Measures Team procedures provide details on how to make contact and a list of offices and telephone numbers. The old procedure of first contacting the Senior Duty Meteorologist has been discontinued.

Non-NRC responders will need to establish their own relationship with the NWS.

Practice

Do the following if you have an Internet connection, otherwise skip down to the problem section.

To supplement the weather data from the Arkansas site, obtain the current weather observations for KRUE (Russellville) and KMWT (Mount Ida). The Russellville station is 8.5 miles from the plant and will provide good additional data for computations to 10 miles. The Mount Ida station is 56 miles away but at least is in the downwind direction (currently).

If the wind speed units are not given, assume that they are in miles per hour (mph). You will find that the NWS does not provide stability on their web pages. You will need to get it from the NWS directly (call the LFO) or just enter "unknown" and let the code estimate it.

Fill in the table below with the current data obtained from the Internet:

Station	Type	Date	Time	Direction (from)	Speed	Stability	Precipitation
KRUE	Obs						
KMWT	Obs						

Problem

Normally, you would enter the information, as recorded above, into RASCAL. However, to avoid an inconsistency with the previous workbook data, enter the values below.

Station	Type	Date	Time	Direction (from)	Speed (mph)	Stability	Precipitation
KRUE	Obs	today	1100	340	5	unknown	No precip
KMWT	Obs	today	1100	320	3	unknown	No precip

Step by Step

Begin by clicking the **Meteorology** button to display the screen for selecting the dataset.
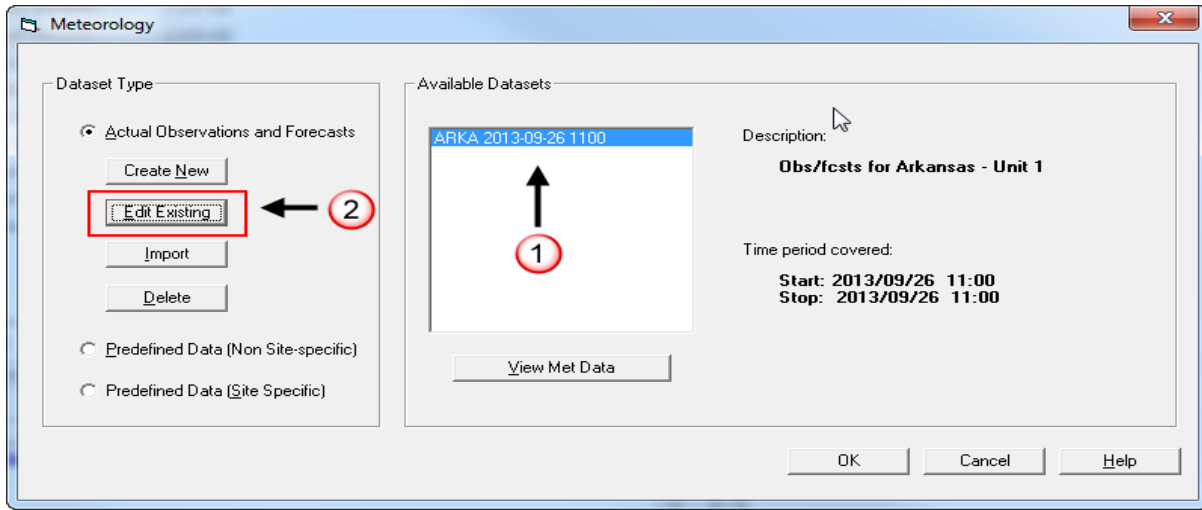
Click the **Edit Existing** button this time as we want to make additions to the dataset not create a brand new one.

When the Meteorological Data Processor has started, select **Enter Data**. You will see that the single ARKA observation entered previously is still there. Now, we want to add the observations from the two NWS stations.

Remember that each station has its own data table. In the Station ID section, select **MWT** to display the Mount Ida table. Enter the provided data into the grid.
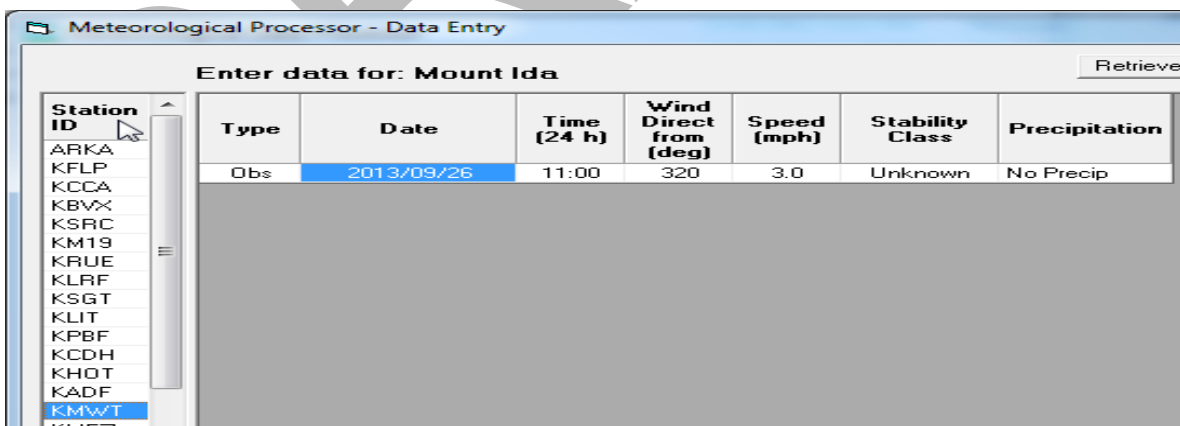
Repeat the process for Russellville (RUE). When both the RUE and MWT data has been entered, click the **OK** button. The **Observation Summary** tab now shows that data for 3 locations has been entered.

Remember that the final step after changing any data is to process and save. Click the **Process Data** button.

For this exercise, continue the naming scheme using the site ID and the date and time the data is updated. Assume that we are updating this data about half an hour later than before.

Set the dataset name to: **ARKA < date > 1130**.

By updating the time in the name we can always tell which dataset was created last and presumably contains the "best" estimate of the conditions.
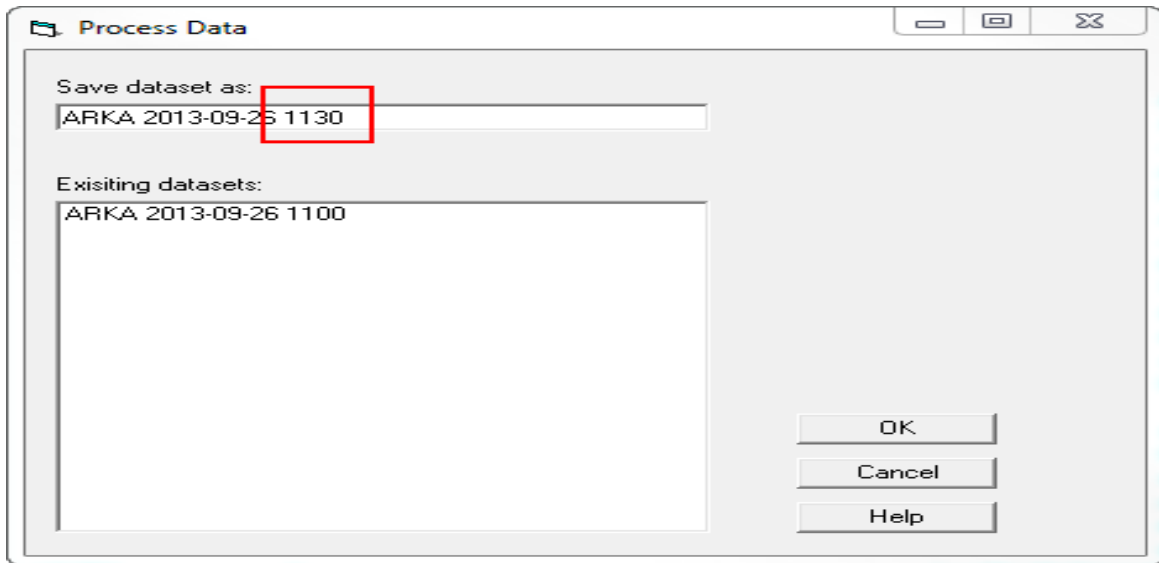
After processing this new set of meteorological data, exit the meteorological data processer and return to the source term to dose model.

Notice that there are now 2 meteorological dataset shown.
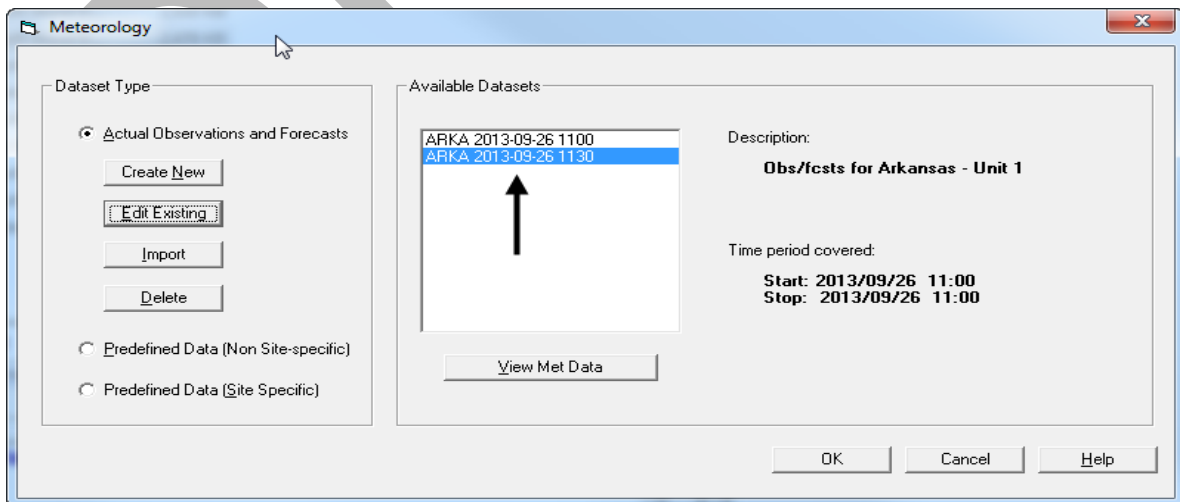
The '**1100**' set is the first one you created using just the Arkansas ERDS data. This '**1130**' set is the new one, just created, the includes the MWT and RUE data. Either dataset can be used for calculations.

However, at this point we want to use the more recent set (later time stamp) because it contains out best estimate of the weather at this time. Make sure the "1130' dataset name is highlighted and click **OK**.

Recalculate the doses using this new dataset to see if including more meteorological data makes a difference. Provide a new set of answers to the questions below.

Question	Previous answer (single station)	New Answer (3 stations)
What are the TEDE's at 2 and 5 miles?	1.0E-01 and 1.4E-02 rem	
What are the thyroid doses at 2 and 5 miles?	7.7E-01 and 9.8E-02 rem	
To what distance does the TEDE exceed the PAG?	To between 0.5 and 0.7 miles	
To what distance does the thyroid dose exceed the PAG?	To between 0.7 and 1.0 miles	

Save This Case

For consistency in the workbook, use the name: **Using RASCAL - Case 2**. You do not want to overwrite the previous case.

Results

See page 201 for the answers to the above table.

OBTAINING FORECAST WEATHER DATA FROM THE INTERNET

Purpose

To learn how to obtain forecast weather data from the National Weather Service.

Background

Observed data is of course the best to use as input to the models. These are conditions that have actually been measured. This is fine if the release has already occurred and your job is to estimate where the material went. However, you may be doing an assessment of potential consequences at some future time. The release may not yet have taken place but you want to run scenarios based on possible future meteorology. Or, the release may be occurring now and you want to predict the movement of the plume for more than the next few hours.

Over short periods of time (a couple of hours) assuming the current observed conditions will persist may be adequate. For longer times, the uncertainty increases. Therefore, you should add forecasts to the meteorological dataset.

Note that RASCAL will delete any forecast records that are followed by a later observation. Forecast records are only used for times later than the last observation.

To obtain forecast weather data

1. Go to the website: **weather.gov**

2. Navigate to the site area by either 1) entering location or 2) by clicking on the map.

Then, as needed, zoom further in to get as close to the site as possible. This will display the **7-day forecast** in both graphics and words.

This information could be used to create the needed forecast data for RASCAL but there is an easier method.

1. Scroll to the bottom of the displayed web page until you see the heading **Additional Forecasts and Information**. Note the display of the **Hourly Weather Graph** on the right. We will return to that later. For now, click the link for **Tabular Forecast**.

4. Here is a much more usable format of the needed forecast data. For each hour, there is an estimate of the temperatures, winds, and precipitation.

Date	08/02															
Hour (CDT)	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22
Temperature (°F)	79	83	88	93	98	102	106	108	109	110	110	109	106	102	96	93
Dewpoint (°F)	65	64	63	63	62	61	60	59	58	57	57	57	56	58	59	61
Heat Index (°F)	81	84	89	94	99	103	107	109	110	110	110	108	105	100	94	91
Wind (mph)	9	10	10	10	11	11	10	11	11	11	11	13	13	13	13	13
Wind Dir	S	S	SSW	SSW	SSW	SSW	SW	SSW	SSW	SSW	S	S	S	S	S	S
Gust													22	26	26	24	22
Sky Cover (%)	22	22	21	21	21	21	21	21	21	21	21	23	24	27	29	32
Pcpn. Potential (%)	5	5	5	5	5	5	5	5	5	5	5	5	7	7	7	7
Rel. Humidity (%)	63	55	45	37	32	27	24	22	21	19	19	19	20	24	30	35
Thunder	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Rain	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

5. The rows **Temperature (°F)**, **Wind (mph)**, and **Wind Dir** are straightforward to use.

The **Pcpn. Potential (%)** needs to be evaluated to decide what should go into RASCAL.

Pcpn. Potential (%)	Expression of uncertainty	Equivalent areal qualifiers
10 percent	---	isolated or few
20 percent	slight chance	widely scattered
30 - 50 percent	chance	scattered
60 - 70 percent	likely	numerous
80 - 100 percent	definite	(none used)

The following is general guidance on using the **Pcpn. Potential (%)** information in making RASCAL runs.

Probability of Precipitation (POP)	What to do in RASCAL
Slight chance of less	Set the precipitation class to "No Precip" and don't worry about it.
Chance or likely	Create two meteorological datasets, one without precipitation and the other with precipitation. Run the RASCAL scenario with both datasets and compare the doses. It is not appropriate to average the doses from the two runs. Either precipitation will occur or it won't but you will have considered both cases.
Definite	Enter the predicted precipitation

6. The next step to using this table of data is to decide which data to use. We want to best represent the changes with time. However, to do that may not require entering data for every hour. Instead, review the data to identify where there are significant changes.

One possible way to use this data:
- Start with the hour 07 data and record temperature, wind speed, wind direction, and precipitation: 79 °F, 9 mph, S, No precip
- Other than a slight change in temperature and wind speed, hour 08 is the same as 07. For convenience, do not enter that data into RASCAL.
- At hour 09 the wind direction has changed to SSW so enter that data.
- The next 3 hours remain essentially the same and can again be skipped (allowed to persist).

The National Weather Service sometimes gives wind direction in terms of compass directions (for example, N, NNE, NE, etc.) that the wind comes *from*. You will have to convert these to degrees.

N	= 000	E	= 090	S	= 180	W	= 270
NNE	= 023	ESE	= 112	SSW	= 202	WNW	= 292
NE	= 045	SE	= 135	SW	= 225	NW	= 315
ENE	= 067	SSE	= 158	WSW	= 248	NNW	= 338

7. If there is precipitation in the forecast, you will also have to go to the **Hourly Weather Graph** to get the amount of precipitation during each 6-hour interval. Return to the main weather page for the selected site and click on the **Hourly Weather Graph** to expand the display. Examine the precipitation forecast charts.
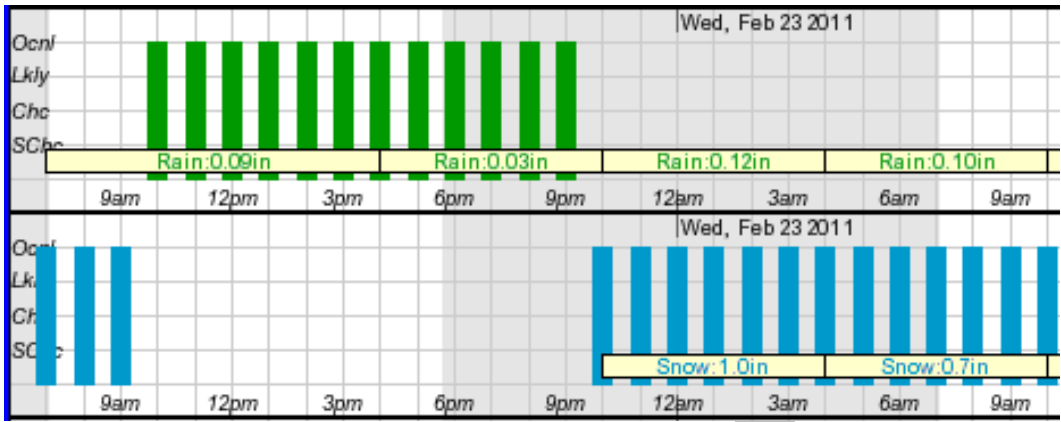
You need to translate this information into a precipitation rate that RASCAL understands: light rain, rain, heavy rain, light snow, snow, and heavy snow. For rain, translate into an hourly rainfall rate. In the case shown above, 0.09 inches over 6 hours is a rate of 0.015 inches / hour. From the table below you see that translates to a RASCAL precipitation class of **Light rain**.

Rainfall rate	Equivalent RASCAL precipitation class
< 0.04 in/h (< 1 mm/h)	Light rain
0.04 in/h - 0.2 in/h (1 - 5 mm/h)	Moderate rain
> 0.2 in/h (> 5 mm/h)	Heavy rain

For the snow portion, again divide the amount by the time period. In this case, 1.0 inch over 6 hours or 0.17 in/hr. From the table below, that translates into a RASCAL precipitation class of **Snow**.

Snowfall rate	Equivalent RASCAL precipitation class
< 0.1 in/h (< 2.5 mm/h)	Light snow
0.1 in/h – 1.0 in/h (2.5 - 25 mm/h)	Snow
> 1.0 in/h (> 25 mm/h)	Heavy snow

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Practice

Do the following if you have an internet connection, otherwise skip down to the problem section.

Obtain the weather forecast for the Arkansas plant for 3, 6, and 9 hours in the future. For example, if it is now 9:45 A.M., the nearest hour is 10:00 A.M. and thus you want forecasts for 13:00, 16:00, and 19:00. Start with examination of the Tabular Forecast and record the forecast data in the left-hand columns of the table below. If there is likely to be precipitation, also look at the Hourly Weather Graph and fill in the right-hand 2 columns as well.

Current Hour plus	Wind Dir		Wind (mph)	Pcpn Potential %	Precip type (rain or snow)	Precip likelihood	Precip amount & interval
	compass	degrees					
+3 hr							
+6 hr							
+9 hr							

Problem

For consistency with previous workbook problems, enter the data below into RASCAL. The Arkansas Nuclear site does not provide weather forecasts. However, the NWS does generate point forecasts and we can assume that the forecast information is for that specific location. Modify the latest meteorological dataset to add to the ARKA site data the three forecast records shown below:

Type	Date	Time	Direction	Speed	Stability	Precip	Air temp
Fcst	today	13:00	315	8 mph	B	None	68 F
Fcst	today	16:00	270	5 mph	D	None	76 F
Fcst	today	19:00	225	3 mph	E	None	75 F

Step by Step

Remember, you are *adding* 3 forecast records to the already existing observation for ARKA. On the dataset selection screen, use the **Edit existing** button again with the **1130** dataset selected. Then, in the meteorological data processor, click the **Enter data** button and add the forecast records.

The data grid for Arkansas will look like this:

Process the dataset and save with a new name (do not overwrite the previous file). In this case, use a time in the name of **ARKA 1200**.

Use the **View Meteorology** button to start the viewer program.

Note that there are now 33 dates and times shown. The processor has filled in the gaps between the hours with additional data.
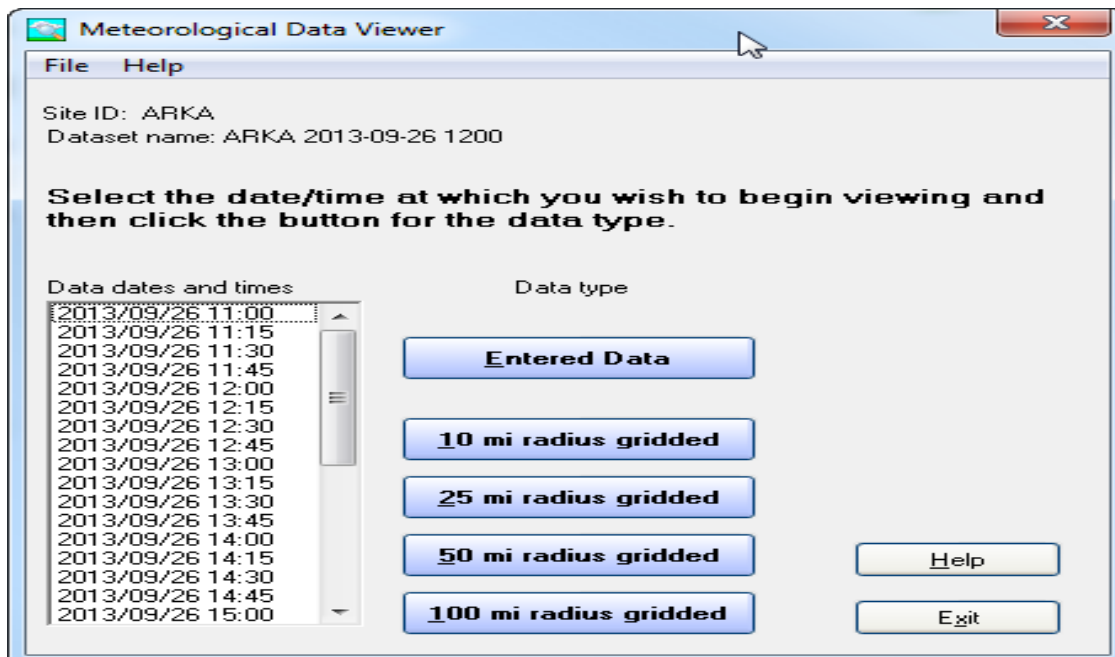
Click the **Entered data** button to examine the data.

Step through the data using the control buttons and observe the wind arrows. Note that the arrow direction changes with time. Also, note that the RUE and MWT arrows disappear at some point. We entered data for those stations only at 11:00. After a few hours of persistence, the met data processor sets those values to missing.

Exit the Meteorological Data Viewer program and then return from the Meteorological Data Processor program into the **Select Meteorological Dataset** screen. The dataset just created should be highlighted.

Run the calculations using this new dataset to estimate doses. Answer the set of questions again based on your results using observed *and* forecast weather.

Question	Previous answer (3 stations - obs only)	New Answer (3 stations- obs & fcst)
What are the TEDE's at 2 and 5 miles?	1.1E-01 and 1.6E-02 rem	
What are the thyroid doses at 2 and 5 miles?	9.1E-01 and 1.2E-01 rem	
To what distance does the TEDE exceed the PAG?	To between 0.5 and 0.7 miles	
To what distance does the thyroid dose exceed the PAG?	To between 0.5 and 0.7 miles	

Should this new RASCAL run be used to prepare the briefing?	

Save This Case

For consistency in the workbook, use the name: **Using RASCAL - Case 3**

Results

See page 202 for the answers to the above questions.
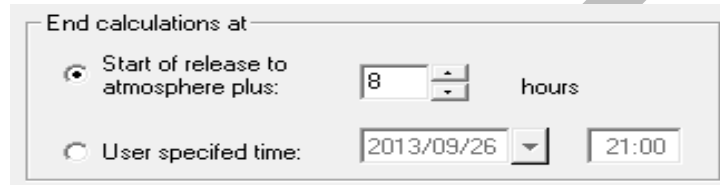
TIME FOR END OF CALCULATION

Purpose

To show how to select an appropriate time for the end of the calculations.

Background

On the start calculations screen you must specify the time after the start of the release at which you want to end the calculations.

The time can be specified as a number of hours after the start of the release to the atmosphere or as a specific date and time.

This is what happens at the time that the calculations end:

1. The release of material to the atmosphere ends (if it has not already ended).

2. The plume movement stops outside the close-in area.

3. Direct cloudshine dose from the plume stops.

4. Inhalation of radionuclides stops, but the full committed dose equivalent from radionuclides already inhaled is calculated.

5. Deposition of radionuclides on the ground stops, but the dose from 4-days of exposure to the radionuclides already deposited before the end of calculations is calculated.

Thus, if you end the calculations too early, projected doses may be too small because you have ended the calculations before the plume has delivered its dose. Conversely, if you end the calculations unnecessarily late, the computer run time will be unnecessarily long.

The diagram below illustrates the problem. Assume you have had a 1 hour release with a 4 mph wind speed. The ellipses represent the position of the plume in the air at various hours (H) after the release. The plume stretches for 4 miles. At H=1 the release has just ended. The leading edge of the plume has reached 4 miles (1 hr x 4 mph = 4 miles) and the trailing edge had just left the release point.

Plume location at hour H
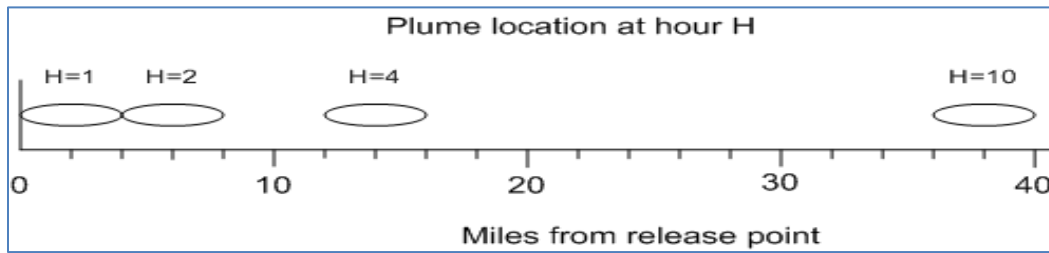
If you end the calculations 1 hour after the release starts, doses at 5 miles and beyond will all be zero. They will be zero not because no dose would be received but because insufficient time was allowed for material to be transported to those distances.

There is a simple rule of thumb that can be used for setting the calculation duration as long as the wind direction and speed are not going to vary too much over the model period.

$$Calculation\ Duration \geq \left(Release\ Duration + \frac{Calculation\ Distance}{Wind\ Speed} \right) \times 1.1$$

The x1.1 adds 10% to account for the backward diffusion of the material at the trailing edge of the plume. Round the calculation duration up to the nearest hour. However, try not to set a time much longer than necessary because it will increase the calculation time unnecessarily. Also, increase the duration if the wind directions are changing significantly and especially if they reverse directions. Remember not to mix incompatible units; use mph with miles or m/s with meters.

Remember:

The close-in calculation uses a straight-line Gaussian model. This is a steady-state calculation. That is, material is transported "immediately" to all distances. There is no consideration of the calculation duration. Receptors may report doses before the material has had time to be transported to the receptor. Use care when interpreting the results from the close-in model especially when using distances beyond 2 miles.

Problem

Assume that 12 hours after the projected start of release (core uncovered), the pressure in the containment will be reduced to zero. This will effectively end the release to the atmosphere.

Re-compute the doses based on these assumptions. You will need to make changes on the release pathway screen to end the release, enter more forecast weather data, and increase the duration of the calculation.

Modify the latest meteorological dataset to add to the Arkansas data the two additional forecast records shown below:

Type	Date	Time	Direction	Speed	Stability	Precip	Air temp
Fcst	today	23:00	230	2 mph	E	None	63 F
Fcst	next day	02:00	270	4 mph	E	None	59 F

Run the calculations again and then fill in the table below:

Question	Your answer
What are the TEDE's at 2 and 5 miles?	
What are the thyroid doses at 2 and 5 miles?	
To what distance does the TEDE exceed the PAG?	
To what distance does the thyroid dose exceed the PAG?	

Step by Step

1. First we need to modify the inputs to end the release to the atmosphere. This is done on the **Release Pathway** screen.

   Add a record to the release pathway events. Set the following parameters in this new event:
   Date = next day (we are adding 12 hours to the starting time of 1:00 p.m.)
   Time = 01:00
   Event type = Leak rate (% vol)
   Value = 0. % / h (this stops the release)

2. Next, edit the ARKA 1200 meteorological dataset to add the two forecast records. Process the data and save the meteorological dataset under a new name using the time: **1230**.

3. Finally, we need to extend the end of calculation time. We have a 12 hour release. Adding 3 additional hours provides adequate time for the material to be transported. Use 15 hours.

Save This Case

For consistency in the workbook, use the name: **Using RASCAL - Case 4**

Results

See page 203 for answers to the above questions.

For very long release times

You may wonder how to handle a situation in which the release time is very long. For example, consider a reactor containment leaking at the design basis leak rate, which is likely to be under 1%/day. The leak rate is so small that the leakage will effectively be nearly constant over many weeks. Thus, you might think that you should end the calculations many weeks or even months after the start of the release. However, this is not the case. First, there is a limit of 96 hours on the calculation duration.

In addition, two other factors should be considered. First, the pressure in the containment will decrease with time as heat is removed. This will cause the release rate to decrease to lower than the rate used in RASCAL. Second, the projected doses being calculated by RASCAL are being used for early decisions on protective actions. When a release continues beyond a day it is no longer in the early phase of the emergency. RASCAL is designed primarily for early decisions that can be implemented before a release starts. Decisions about protective actions for long term releases can be made later as the situation becomes better understood and field measurements become available.

In conclusion, for the projected doses to be properly applied, the end of calculations for RASCAL should seldom exceed 24 hours from the start of the release. In fact, there is a limit on the calculation duration of 96 hours after the start of the release to the atmosphere.

DISPLAYING PLUME FOOTPRINTS

Purpose

To learn how to obtain a picture so that plume direction and area exceeding PAGs can be evaluated.

Problem

Now we would like to see the spatial extent of the doses and the direction of the maximum doses.

Step by Step

To do this we need to generate plume plots. Begin by selecting the **Detailed Results** button on the left side of the main screen.

This will display the **Detailed Results of Dose Calculations** screen. The screen is divided into four main sections: 1) Result Type, 2) Time Period for Exposure, 3) Display Format, and 4) Display Units.
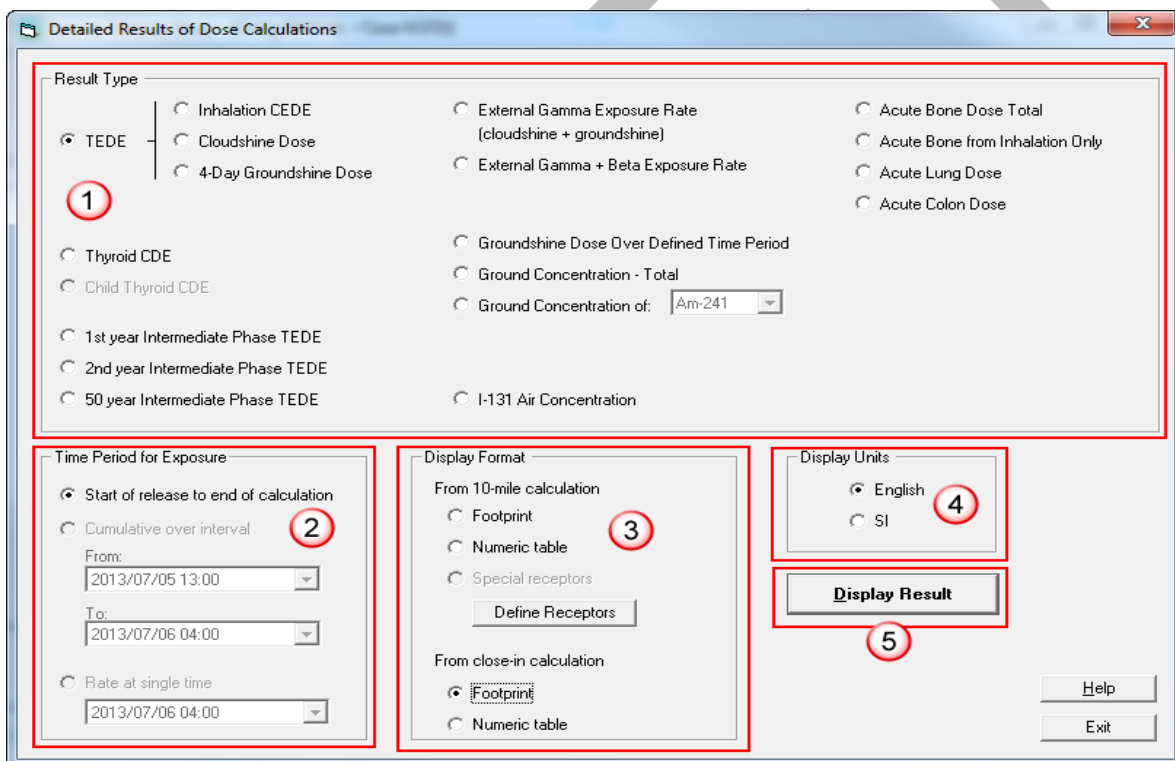
The **Result Type** section contains an option button for each of the 18 results calculated by RASCAL. Note that we have additional result types not shown in the maximum dose values table.

The **Time Period for Exposure** section has three possible settings. With the **Start of release to end of calculation** option, the doses shown are a result of exposure for the full available period. Some doses (such as TEDE) can only use this option as they are composite doses which cannot be separated. The **Cumulative over interval** option allows examination of the doses accumulated over a subset of the full interval. It is defined in 15 minute steps. Finally, the **Rate at single time** option shows a dose rate over a single 15 minute period. Some result types (e.g. gamma exposure rate) can use only this option.

The **Display Format** section controls how the information is presented. Results can be displayed as either a numeric table or as a graphic "footprint." We must also choose whether we want to see the results from the close-in calculation or from the 10-mile calculation. We must look at them separately.

The **Display Units** section controls whether the units are standard U.S. (e.g. rem, Ci, feet) or SI (e.g. Sv, Bq, m).

To get a footprint of the thyroid CDE from the close-in calculation, select the following options:

- Display format: **From close-in calculation - Footprint**
- Result type: **Thyroid CDE**
- Time period: **Start of release to end of calculation**
- Display units: **English**

Select the **Display Result** button.
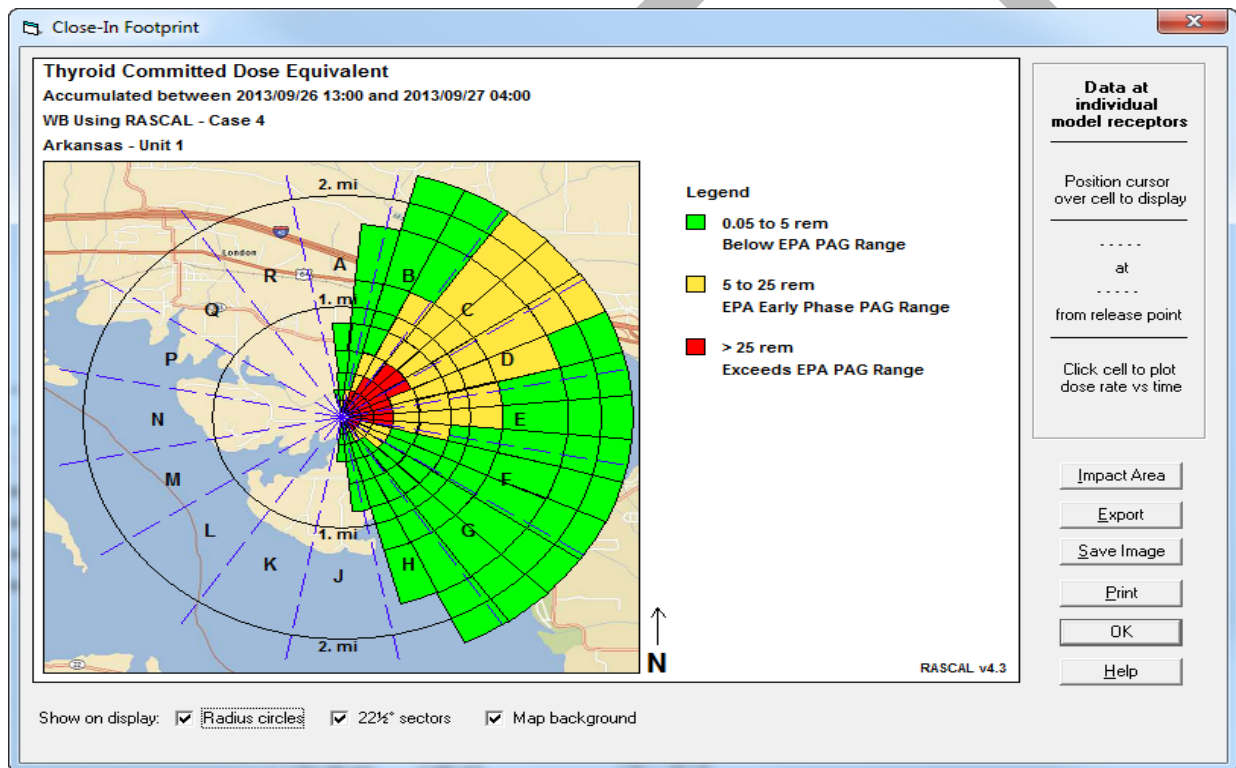
Note that the close-in footprint shape reflects the polar receptor grid used by the straight-line Gaussian plume model. Each colored area represents the dose at a model receptor point on the polar grid. This model is more fully explained starting on page 58.

Click **OK** to return to the **Detailed Results** screen. Now display the thyroid dose footprint for the 10-mile calculation. The footprint for the 10-mile distance reflects the rectangular Cartesian grid used by the puff model.
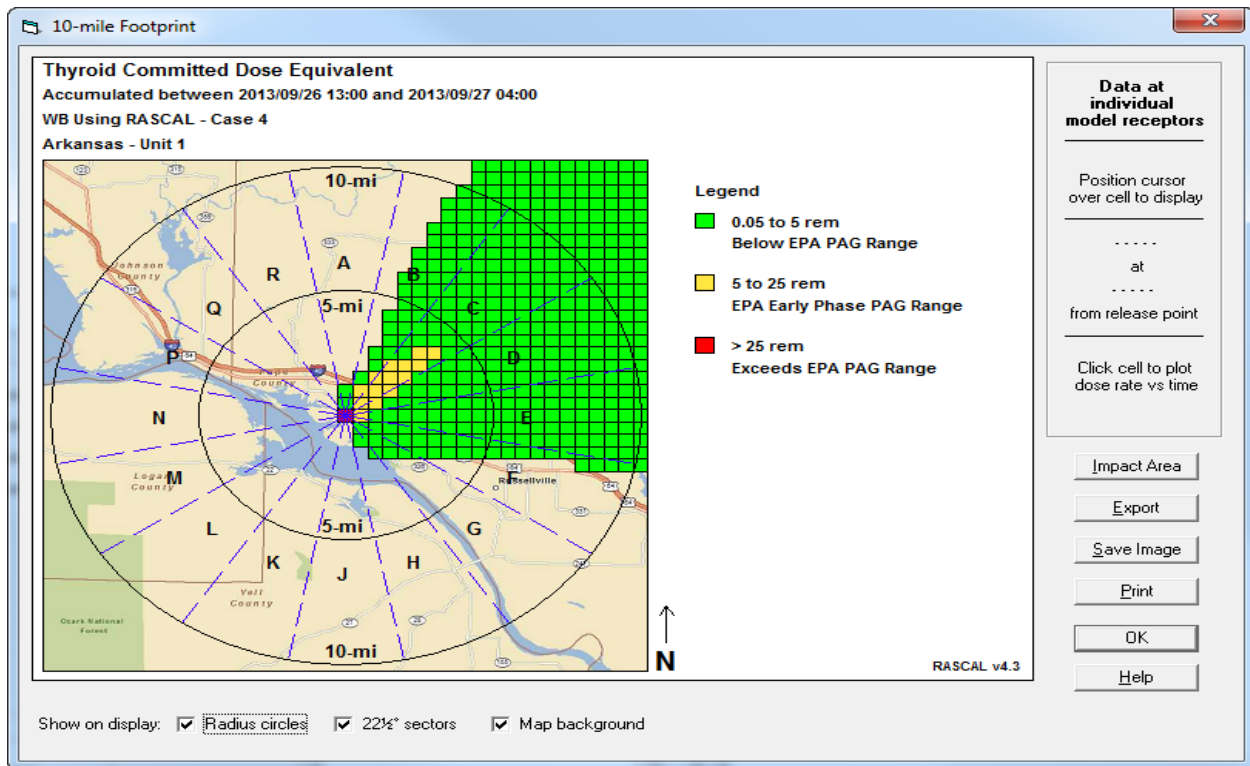
Examine details in the plume

Question	Your answer
In which compass direction from the release point are the doses greatest?	

Now, let's use the cursor to get some more detail about one of the individual cells on the footprint. You can see the location information and exact dose at any point and also examine the time history of the dose at a point.

Put the cursor in a colored cell of the footprint and note that the dose and location are displayed at the upper right of the screen. Follow the "centerline" out from the release point until you see:
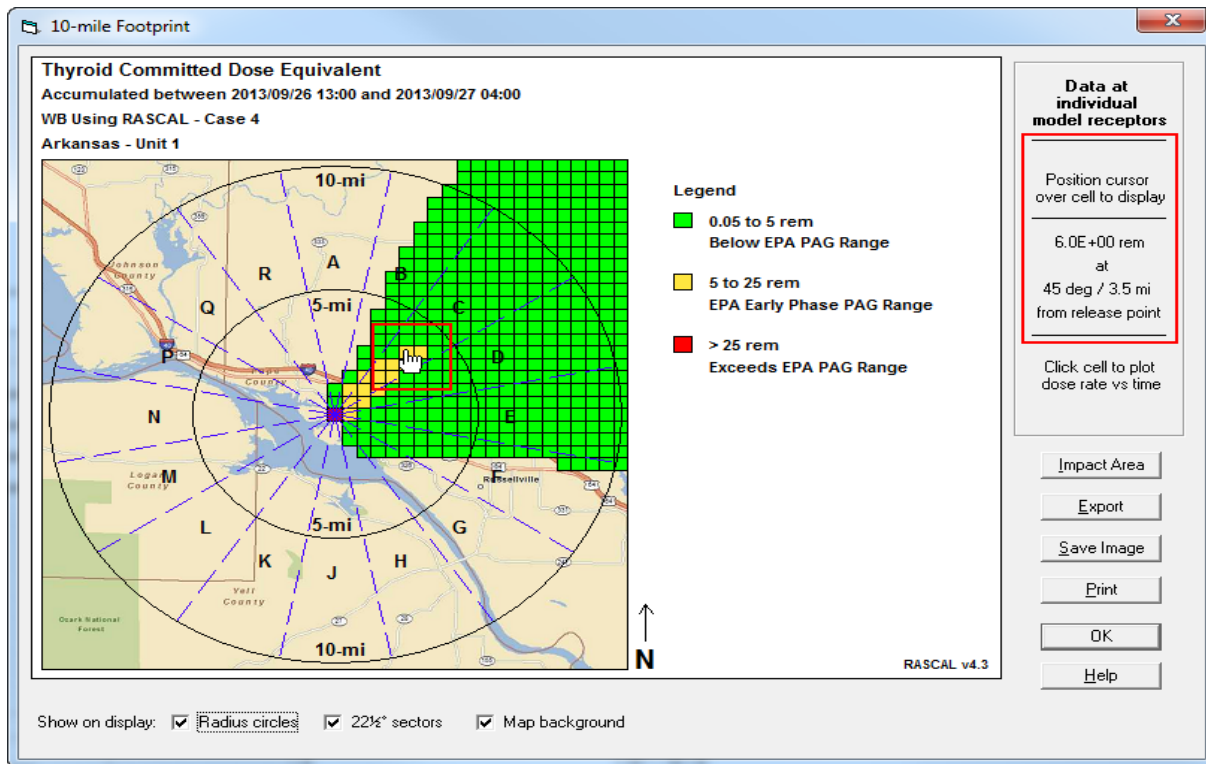
Here is the thyroid CDE of 6.0 rem at 3.5 miles northeast (45º) of the release point.

Click the mouse while the cursor is positioned over that cell to display a rate plot.
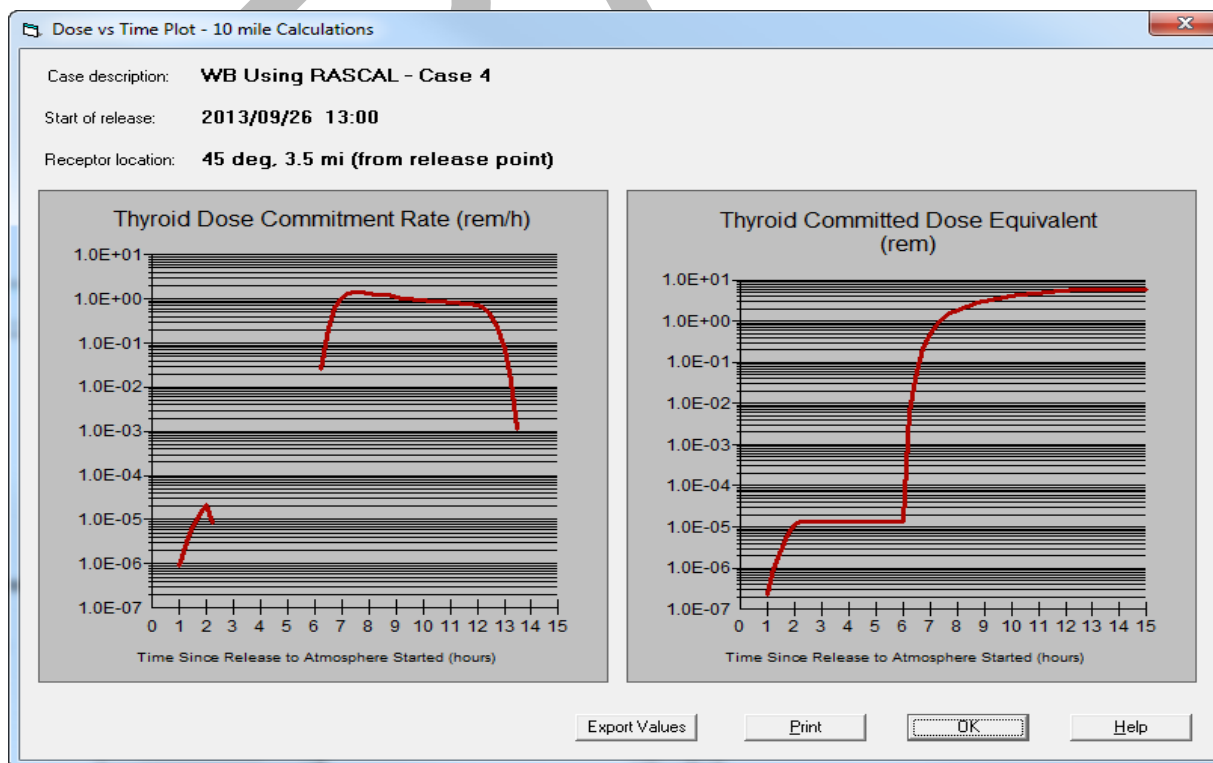
These graphs show us that 3.5 miles from the release point: the thyroid dose does not start to be delivered until about 1 hour after the start of the release. Then there is a gap of about 4 hours when the plume was not impacting the point (wind shift likely). Finally, the plume again shifts over the point and continues to deliver the dose until about 14 hours after the start of release.

TRANSPORT AND DIFFUSION MODELS

Purpose

To learn about the two transport and diffusion models used in RASCAL.

Background

Two transport and diffusion models are used in RASCAL for radiological releases (a separate plume model handles UF_6 releases).

Straight-line Gaussian plume model

Close to the release point a straight-line Gaussian plume model is used. This model is characterized by the following features:
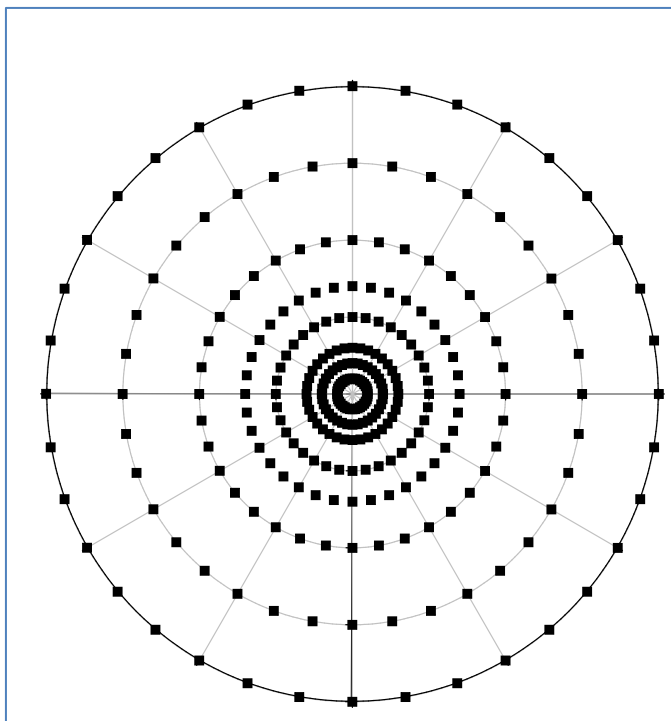
A polar grid of receptors is used. As shown in Figure 1, this grid consist of 8 concentric circles with receptors located every 10 degrees around the circles. There are default distance settings (see Table 1) for the circles or the 8 distances may be set by the user.

The model is steady-state. That is material is transported "immediately" to all distances. There is no need to allow for transport time on this grid. The disadvantage is that the receptors may report doses before the material has had time to be transported to the receptor.

The release point is always at the center and space between the receptors on a circle increases with distance from the release. Use care when interpreting the results from the close-in model especially when using distances beyond 2 miles.

Figure 1 Polar Receptor Grid for the Plume Model

Table 1 Default distances for close-in polar grid

Calculation distance setting	Distances in miles							
Close-in only or Close-in + 10 miles	0.1	0.2	0.3	0.5	0.7	1.0	1.5	2.0
Close-in + 25 miles	0.25	0.5	1.0	1.5	2.0	3.0	4.0	5.0
Close-in + 50 miles & Close-in + 100 mile	0.5	1.0	1.5	2.0	3.0	5.0	7.0	10.0

This receptor grid is evident when looking at dose footprints. Observe in the picture below how the footprint reflects the modeling domain. With the close in polar grid, the footprint consists of wedge-shaped pieces representing the area around a receptor point.
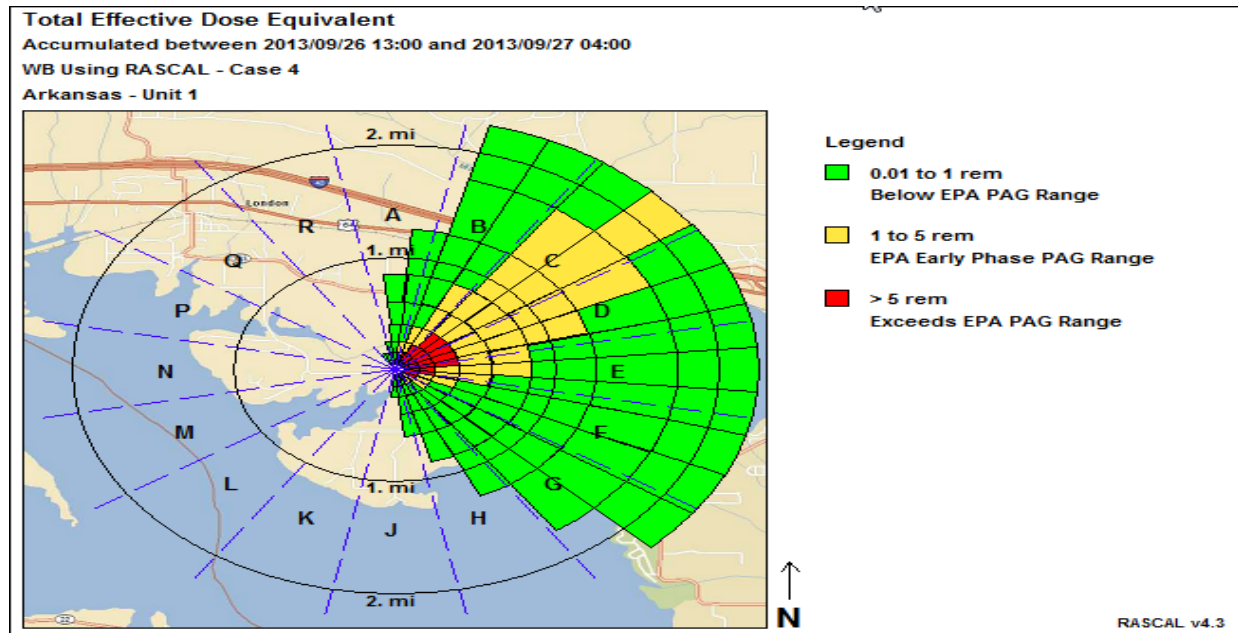
Lagrangian puff model

Further away from the release point, RASCAL switches to a Lagrangian puff model. This model has the following characteristics:
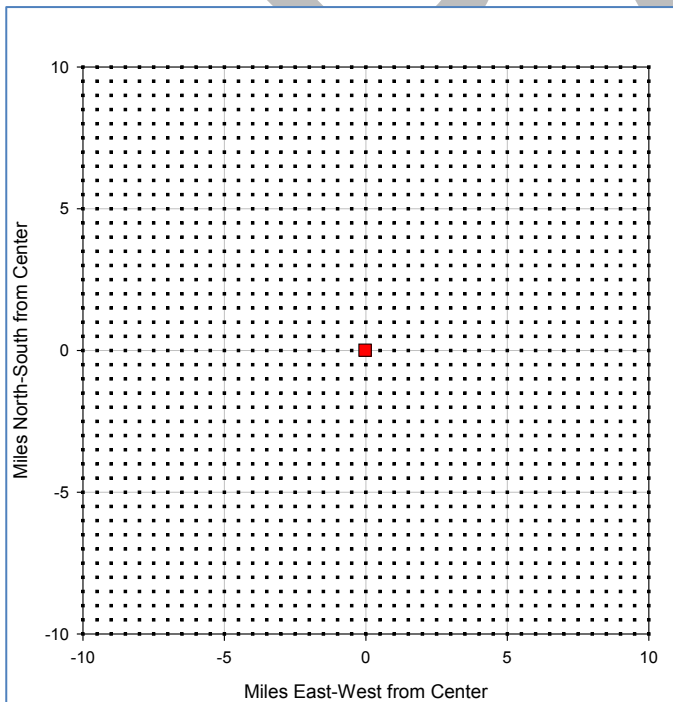
It uses a uniformly spaced Cartesian grid of 41 x 41 receptor points. Figure 2 illustrates this grid. The release point is always at the center.

The grid spacings are set by the user selecting from 4 different distances: 10, 25, 50 or 100 miles. The resolution of the grid decreases as the calculation distance selected is increased. The distance between receptors for each calculation distance is shown Table 2.

Time must be allowed for material transport time. For example, with a 4 mph wind speed, if the calculations are ended after only 2 hours, the material will not have had time to be transported to the 10 mile edge of the modeling area.

Figure 2 Cartesian receptor grid for the puff model

Table 2 Distances between Cartesian grid receptors

Calculation distance	Distance between receptor points
10 miles	0.50 miles
25 miles	1.25 miles
50 miles	2.50 miles
100 miles	5.0 miles

With the puff model, the footprint is represented by squares drawn around each receptor.
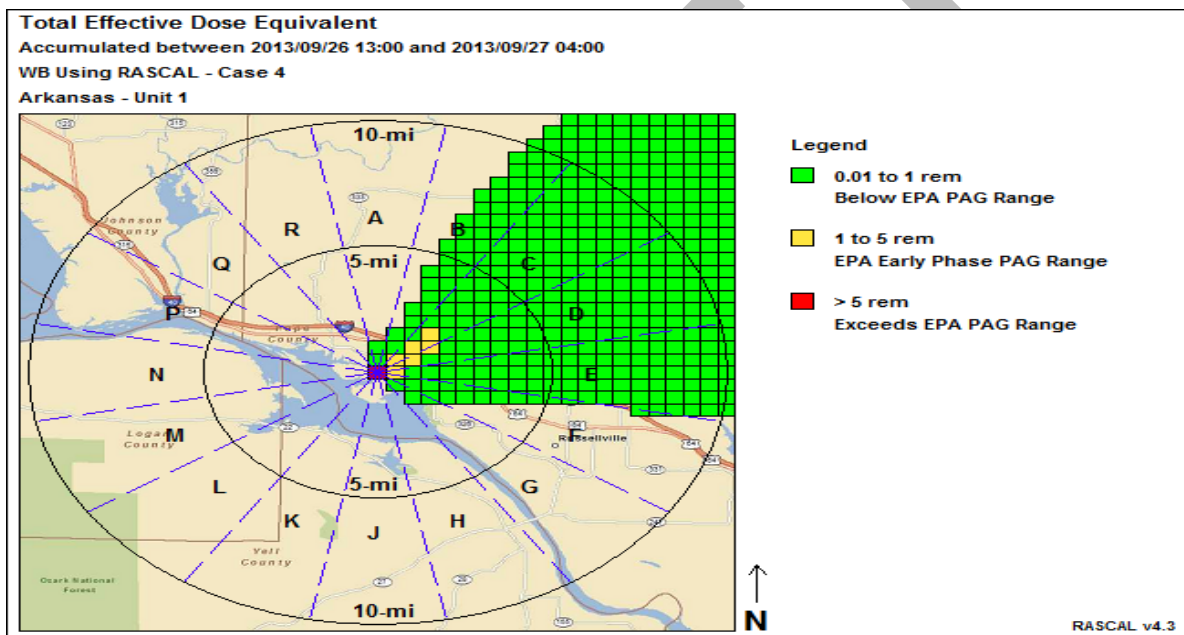
The New Atmospheric Dispersion Models

RASCAL 4 has changed from distance-based dispersion parameters to time-based parameters. Dispersion is now a function of: time since release, wind speed, atmospheric stability, and surface roughness. The old Pasquill-Gifford parameters were based on dispersion experiments in the 1950s. Atmospheric experiments on dispersion and boundary layer processes in the 1960s, 1970s, and 1980s have provided better methods for estimating the atmospheric dispersion.

Wind Speed

In RASCAL 3.0.5, concentration, deposition, and doses were relatively simply related to wind speed. Above a wind speed of about 4 m/s, concentration, deposition, and doses were inversely related to wind speed. If the wind speed doubled, the concentration, deposition and doses decreased by a factor of 2. The only deviations from this relationship were caused by the low wind speed meander correction at wind speeds below about 4 m/s, changes in the mixing-layer height associated, and changes in plume rise.

Normal atmospheric dispersion factors and deposition velocities were independent of wind speed. In RASCAL 4 things are not so simple.

In RASCAL 4, atmospheric dispersion is calculated as a function of atmospheric turbulence parameters and travel time, both of which are functions of wind speed. In addition in RASCAL 4, atmospheric deposition is a function of wind speed. When these dependencies are combined with the low wind speed meander correction and the variation of mixing layer height with wind speed, the range of conditions under which the inverse relationship between wind speed and concentrations, deposition and doses applies is limited. It is no longer realistic to use a rule of thumb such as double the wind speed decrease the concentration by a factor of 2. Under many conditions an increase in wind speed may not change or may even increase the concentration. Similarly, in other conditions, decreasing the wind speed may decrease the concentration.

Implications of the New Models

What are the implications of these changes to the models? In general, the RASCAL 4 dispersion parameters tend to be larger than the RASCAL 3 parameters. The X/Qs and doses for ground-level releases will tend to be lower. The X/Qs and doses for elevated-releases will tend to be higher near the release point. The footprints shown below illustrate the point.

Thyroid dose to 10 miles for 4 mph - D stability	
RASCAL v3.0.5	**RASCAL v4**
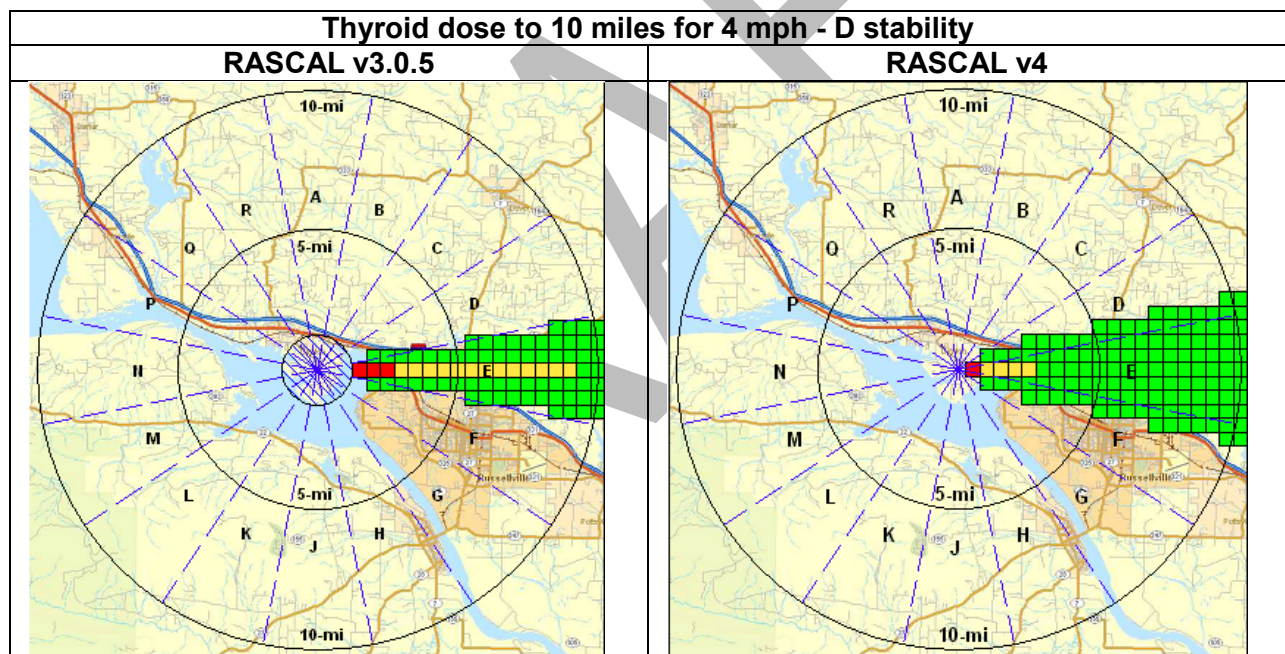
With RASCAL 4, the area impacted is larger and the doses are lower. Instead of the EPA PAG being exceeded to ~8 miles (left) it is exceeded only to ~3 miles (right). The following table summarizes the model differences for thyroid CDE under differing meteorological conditions.

Model differences in thyroid doses for a core uncovered scenario with differing met conditions	
Conditions	Ratio R4 / R3.0.5 at 5 miles
4 mph, D stability	27%
15 mph, B stability	31%
4 mph, G stability	16%
8 mph, D stability, Rain	24%

CREATING A GIS SHAPEFILE

Purpose

To learn how to export the plume footprint to a GIS compatible file and display it using the NRC GIS or Google Earth.

Background

RASCAL displays plume footprints over a static map background. You have no control over the map features displayed and can do no spatial analysis. RASCAL 4 adds the capability of exporting the plume footprint to a GIS compatible file format called a "shapefile." This shapefile can be added as a data layer in a GIS.

This GIS export function in RASCAL requires that the free, open source MapWinGIS control be installed. See the RASCAL installation instructions for details on obtaining and installing this component.

Problem

You are asked to work with the GIS operator to overlay the TEDE plume footprint on a map background in order to see impacted infrastructure such as schools and hospitals.

Step by Step

Begin with the footprint you want to export to the GIS displayed. Click the **Export** button.
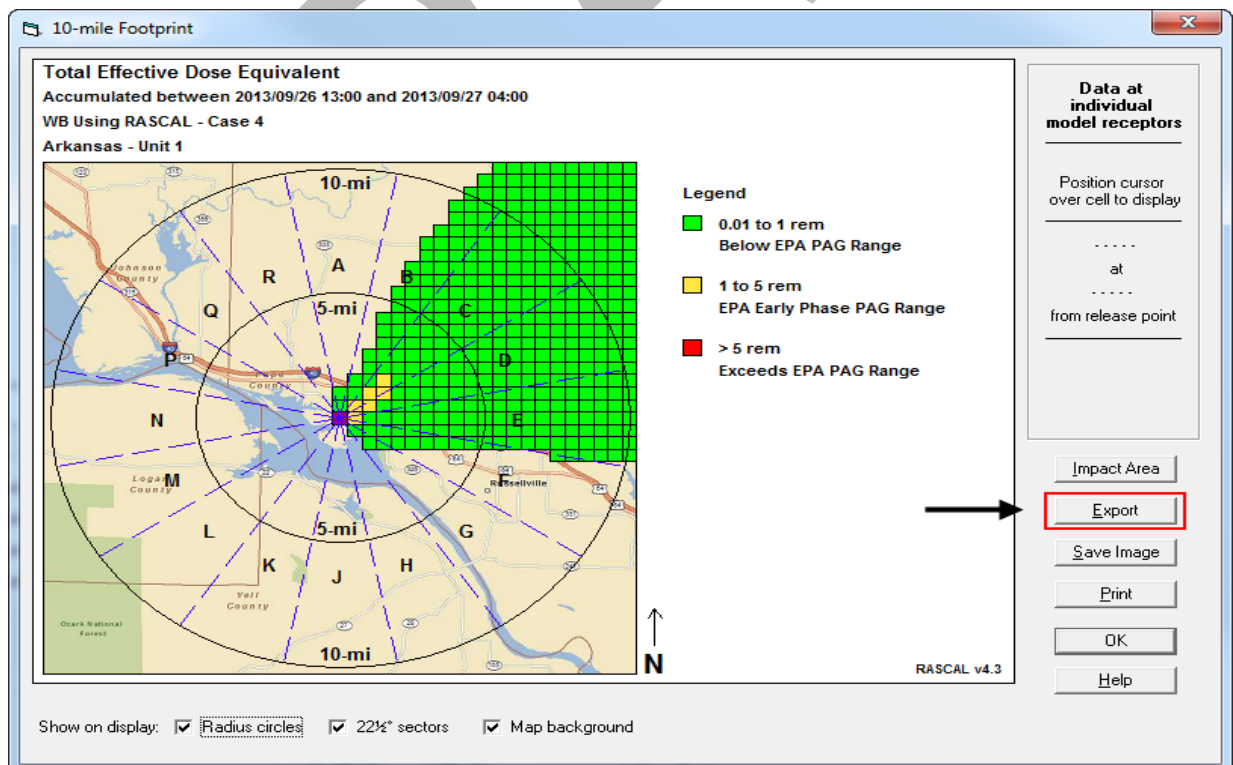
Select the **To GIS Shapefile** tab.
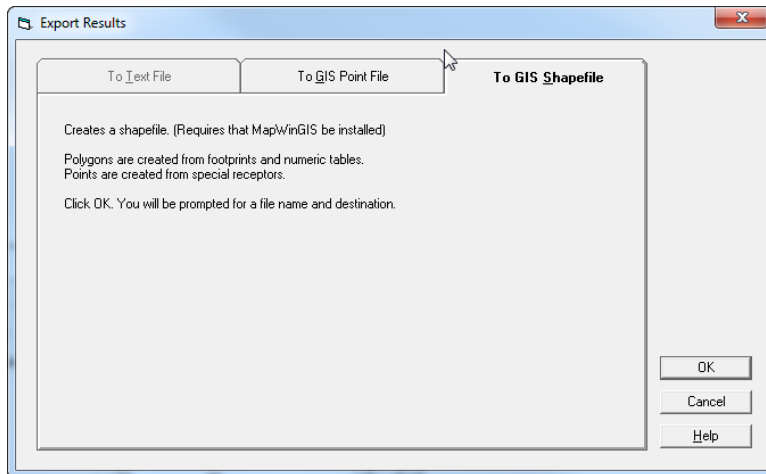
There are no options to select. Just click **OK** and then provide a file name and destination.

The default file name is the case description plus the result type plus the model type (plume or puff).
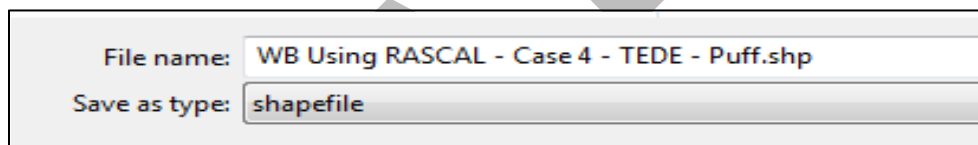
Change the file name and destination as needed. Remember the information as you will need it when adding the file to the GIS.

The following steps show the use of the NRC GIS (ESRI ArcMap v10). However, shapefiles are a common format for exchange of information and most GIS support their use.

With the GIS displaying the Arkansas site, select the **Add Data** button on the toolbar.
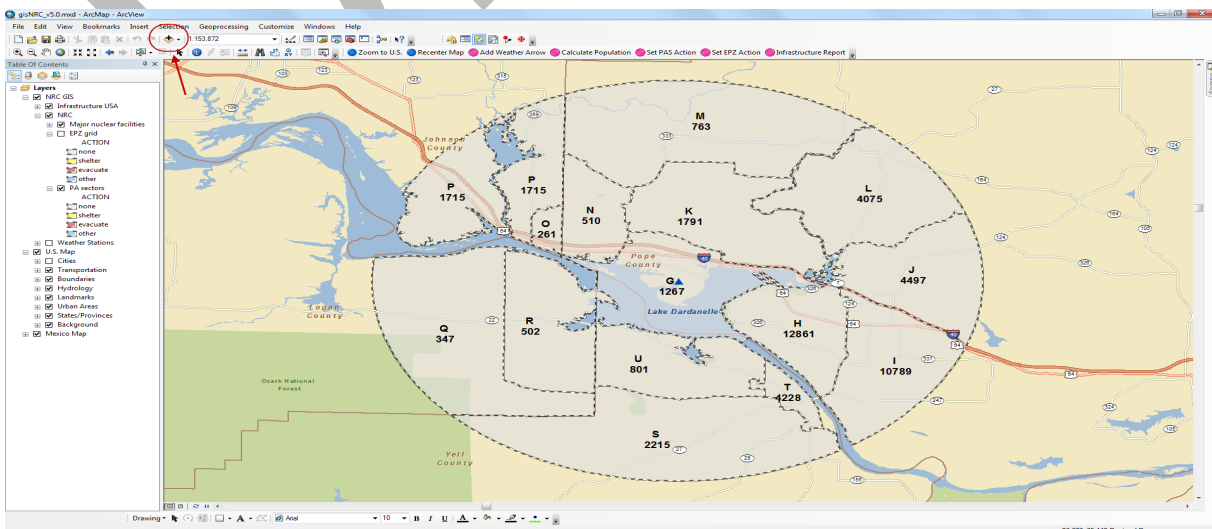
Navigate to the location where you saved the shapefile and select the correct .shp file. Click the **Add** button.
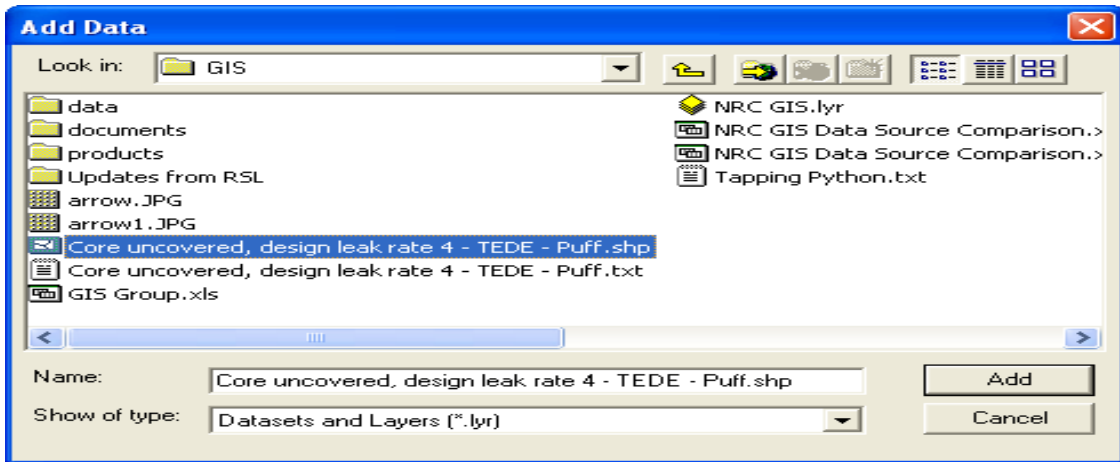
The data is added to the GIS at the top of the table of contents. Work with the GIS operator to set the symbology and transparency of the plume layer to match the colors and ranges used in RASCAL. To see what schools and hospitals are in the plume, turn on the infrastructure layer.
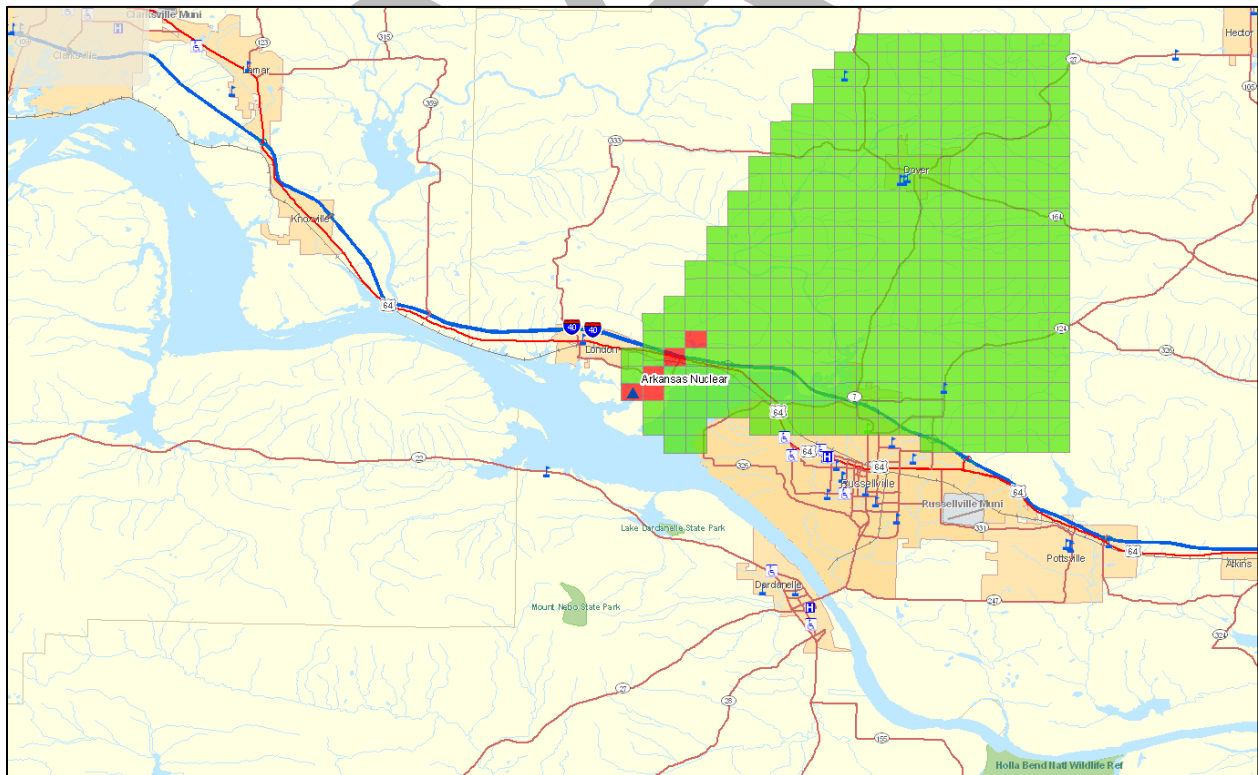
This plume can now be converted into a format displayable in Google Earth.

Open the **ArcToolbox**. Select **Conversion Tools | To KML | Layer to KML**. Fill in the fields:

- Enter the name of the shapefile
- Specify and output file name and destination
- Set the scale to what is being used in the ArcMap view

Click the **OK** button to create the file. The file can then be "dragged and dropped" into the Google Earth window.
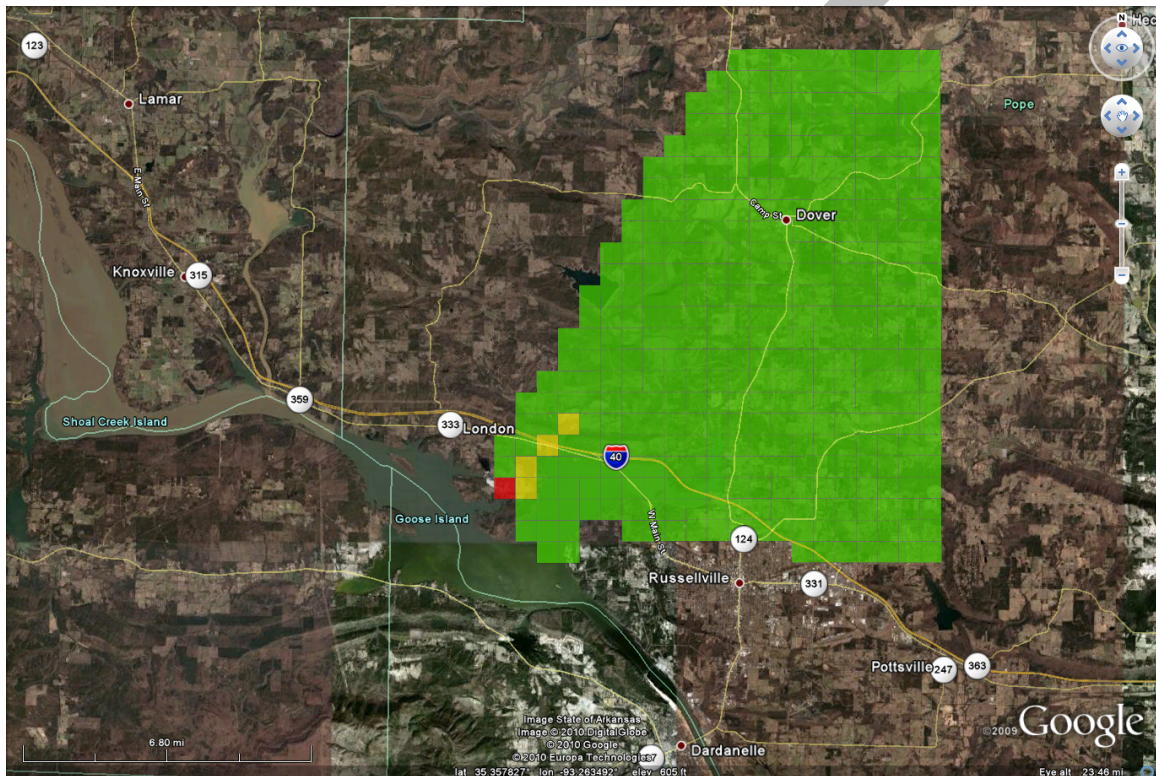
EXAMINING THE RASCAL SOURCE TERM

Purpose

To learn how to look at the details of the source term generated by RASCAL and how to export the source term information to the IMAAC.

Background

The RASCAL source term consists of a list of radionuclides and the associated amounts of activity released to the atmosphere over time. The source term summary report shows the sum of the total activity released by nuclide. The Release vs. Time shows the activity released in each time step by radionuclide.

The October 2004 Nuclear/Radiological Incident Annex of the National Response designates the Interagency Modeling and Atmospheric Assessment Center (IMAAC) as the single source for atmospheric dispersion and consequence prediction. During a radiological Incident of National Significance in which the NRC is the Coordinating Agency, RASCAL may be used to supply a source term to the IMAAC.

Source terms should be sent to IMAAC *only from NRC Headquarters*, not from the NRC Regions or the NRC site teams.

Problem

Load the first case saved. It should be *Using RASCAL - Case 1.*

1. Answer the following questions about the source term:

    a. Of the total activity released to the atmosphere, what fraction is noble gases?

    b. What is the ratio of noble gas to I-131? What does that tell you about the release?

    c. How much activity is still bottled up in the containment that might be available for future release if conditions change?

    d. What radionuclides are contributing most to the inhalation dose?

    e. Iodines are always a concern in a release. Describe the time dependence of the iodine release. At what time is the iodine release rate the greatest?

2. Prepare a source term export file for sending to the IMAAC.

Step by Step

Load the saved case.
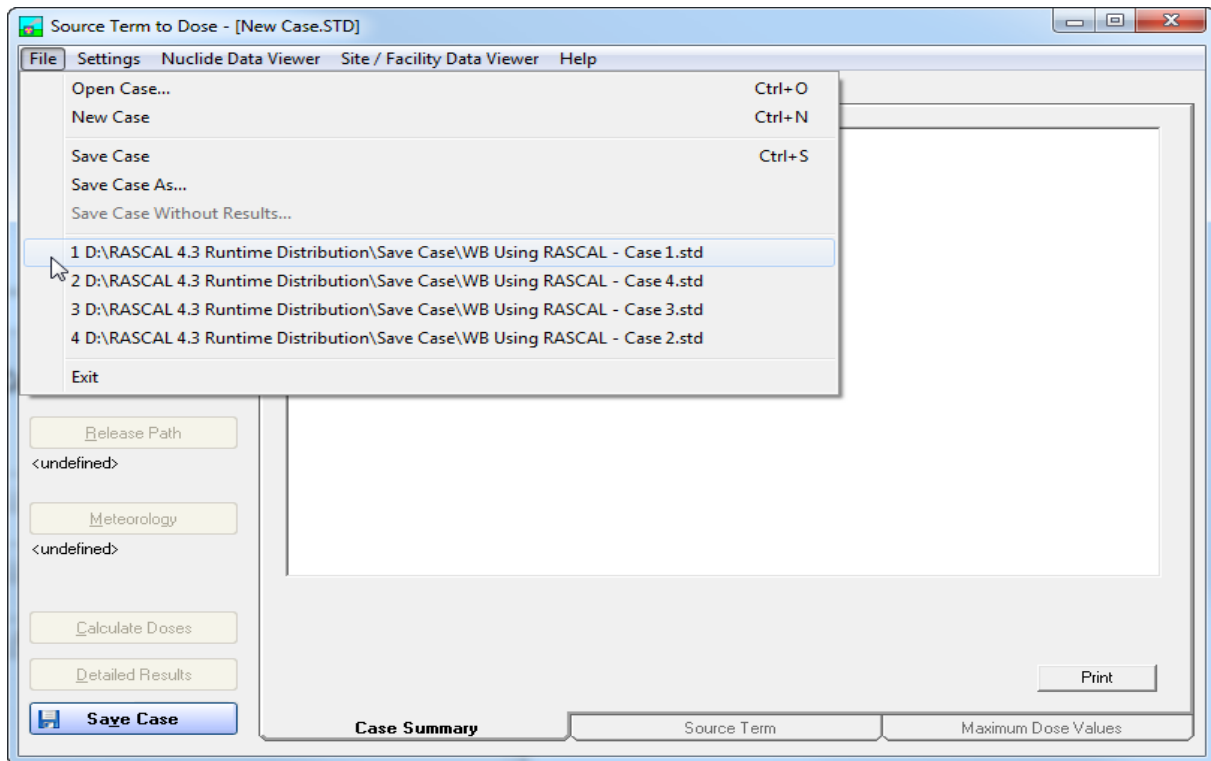
You can do this by selecting **File | Open Case** from the menu bar and then selecting the file name from the list.
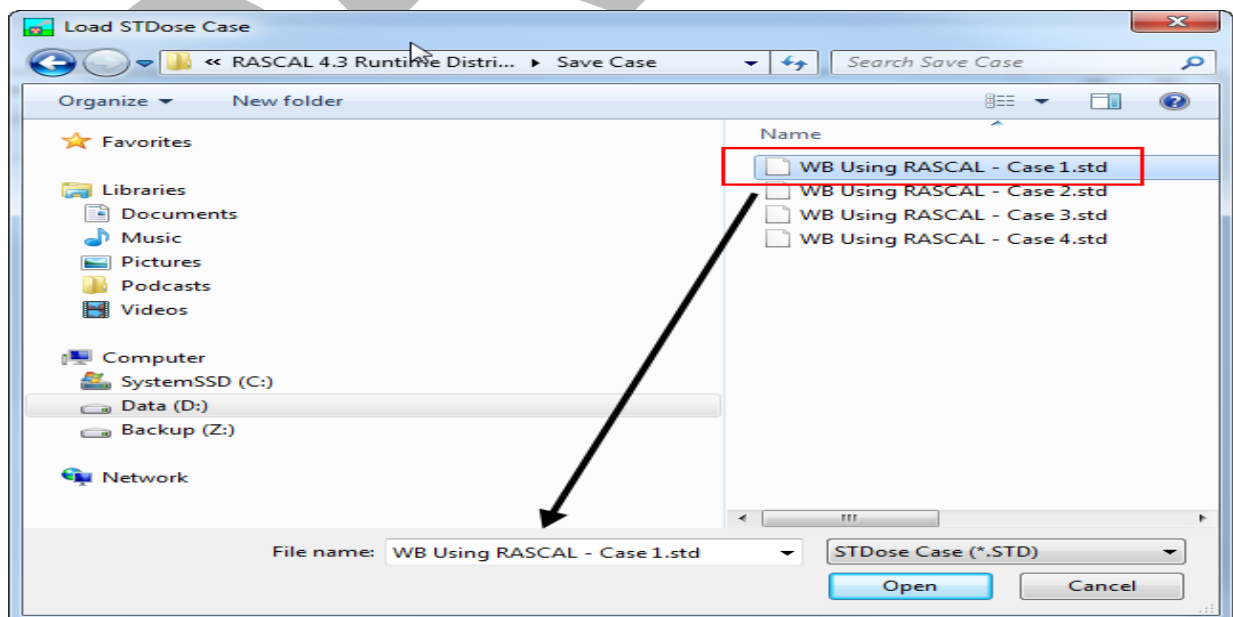
After the file loads, select the **Source Term Summary** tab.

a. The summary table shows the activity and percentage makeup of the release to the atmosphere. The total activity released to the atmosphere (1.9E+05 Ci) is small compared to the roughly 3 to 8 billion curies of activity in a typical reactor core. Iodines make up 21 percent of the release.

b. The ratio of noble gas to I-131 is 15:1. The noble gas to I-131 (primary thyroid dose contributor) ratio provides perspective on dose projections. During a release early after shutdown, without sprays in the release path, iodine concentrations will be high driving protective actions based on thyroid dose. If a release into containment is held up for a day or two or is subject to sprays, iodines will plate out or be washed out. The noble gas to iodine ratio will be much higher, maybe 1000/1 (a popular default) and the TEDE may transition to be the driver of protective actions, rather than the thyroid CDE dose. Having a feeling for the ratio, helps put the scenario into perspective. It can also be useful when comparing and contrasting results from other models. The ratio is only applicable to those scenarios that release noble gases and iodines.

c. There is still 2.7E+08 Ci of activity still in the containment. This table represents the approximate activities available at the end of the RASCAL projection, after the release has finished. This approximate activity summary will be helpful for seeing whether the bulk of activity available has been released or is still available for release. This provides perspective for consideration of subsequent threats. If significant activity is still held up in containment but there is no containment pressure or motive force to continue releasing it, then that should also be considered. For more information on how these results are derived, see Section 5, Activity Balance, of the Technical Supplement. For full details, use the **View Balance** button available in the Source Term Summary.

Scroll down in the source term summary to the bottom.

Notice that some of the nuclide names have an asterisk (*) after them. This indicates that the nuclide includes daughters implicitly. For example, the Cs-137* includes the Ba-137m daughter.

d. Importance to inhalation in the center section. Over 50% of the inhalation dose comes from just 3 nuclides: I-131, Sr-90, and Pu-241.

The Importance table provides perspective on which radionuclides are contributing most of the dose while considering three pathways, Submersion, Inhalation, and Ground shine, for the post shut down time selected. The most important radionuclides will change over time for each of these categories. More details can be seen by selecting the Importance Button.

There are several reasons to consider a reduced radionuclide set. NARAC, when dispersing with a high resolution model can calculate results much more quickly. RASCAL calculation results can be expressed in smaller files and be more easily shared. Troubleshooting becomes simpler. When considering dose contributions by radionuclide, most of the impact can be assessed more quickly with fewer radionuclides, once the bad actors are known. Using just the essential radionuclides will save controllers time and energy when preparing sample injects for ingestion pathway exercises. Players will benefit also by not having to deal with insignificant contributors. Another benefit of the importance file is to know how certain radionuclides (like iodines), which are impacting specific embargos like milk, will trend over time.

For reference, the radionuclide releases from Three Mile Island and Chernobyl are show below.

Nuclide group	TMI (Ci released)	Chernobyl (Ci released)	Fukushima (Ci released)
noble gases	2.5 million	170 million	?
radioiodines	15	48 million	?
others	negligible	72 million	?

TMI reference: Table II-1 of "Three Mile Island: A Report to the Commissioners and to the Public," Nuclear Regulatory Commission Special Inquiry Group, Mitchell Rogovin, Director, 1980.

Chernobyl reference: Table 1 of "Chernobyl - Assessment of Radiological and Health Impacts," Nuclear Energy Agency, Organization for Economic Co-Operation and Development, 2002.

e. To see the time dependence, select the **Release vs. Time** button on the tab.
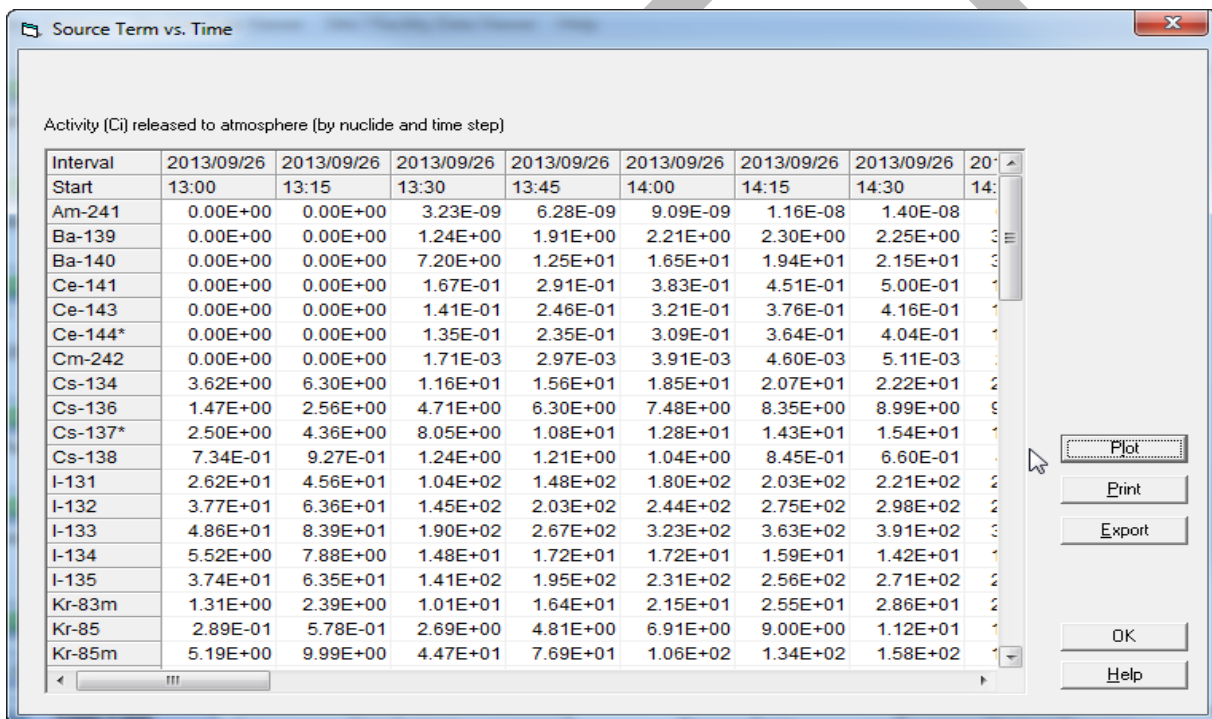
This shows the activity of each radionuclide released to the atmosphere each 15 minute time step. Examination of the iodine rows shows the amount released each time period increasing.

Next, click the **Plot** button. In the selection boxes on the right, select I-131, I -132, and I-133. Then, click the **Update Plot** button.
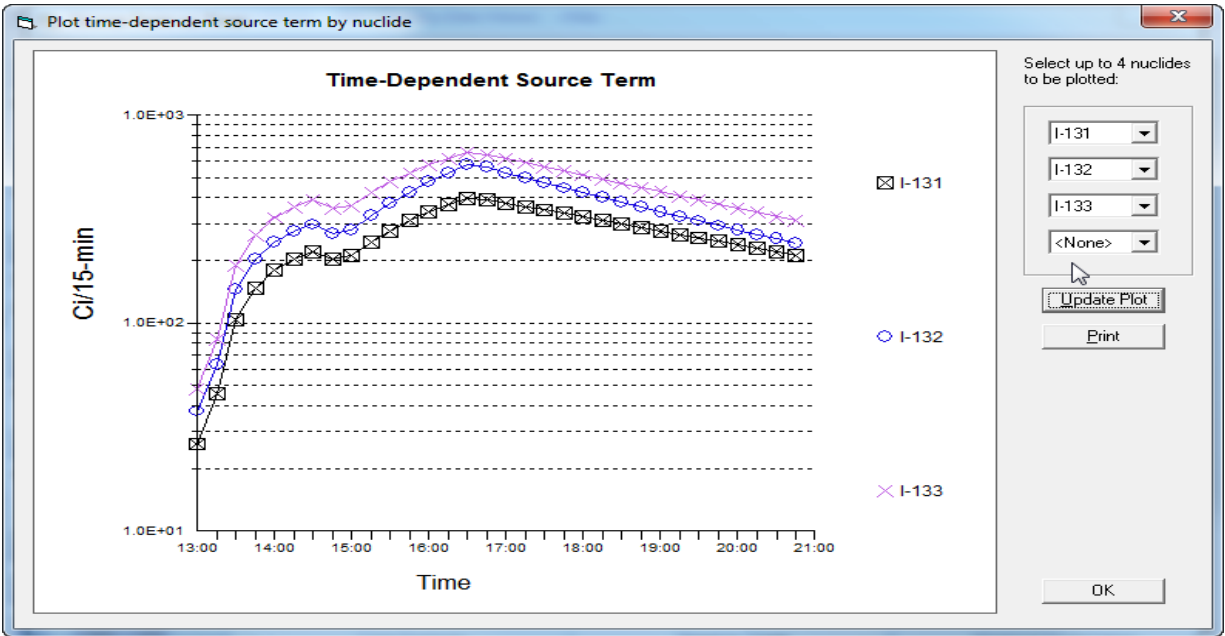
The graph shows the release rate of the selected iodines in units of curies per 15-minute time step. From the graph, the rate is greatest at about 16:30.

To create the IMAAC export file

1. Return to the **Release vs. Time** view of the source term.

2. Click the **Export** button to the right of the nuclides table.

3. Select the format: XML or CSV.

4. There is an option to strip the '*' character from the names of the nuclides with implicit daughters. This may help the importing program.

5. Navigate to the folder where you want to save the file. Enter a unique file name. Click the **Save** button.

6. There is an option to limit the nuclides that are exported. They can be filtered by importance to dose. Check the box if you want the filter applied. The full importance results can be viewed using the button.

7. Click the Export button, supply a destination and file name, then click the Save button.

The file can now be attached to an e-mail and sent to the IMAAC.

Note

NRC staff - Refer to Protective Measures Team procedures for IMAAC notification and additional information that needs to be in the e-mail. Source terms should be sent to IMAAC *only from Headquarters*, not from the NRC Regions or NRC site teams.

USING RASCAL PART 2: ASSESSING A MULTI–UNIT PWR CORE DAMAGE ACCIDENT

This section of the workbook provides a parallel approach to the first RASCAL Source Term to Dose model problem. It is a walk through the entire process using new options for characterizing a source term and an introduction to automated meteorology. The result will be a second source term which can be merged with the source term in the last problem. Protective actions and the implications of a multi-unit assessment will be explored and discussed.

The problems in this section should be worked in sequence as each depends on the previous work.

LONG TERM STATION BLACKOUT SOURCE TERM

Purpose

To study how this source term option, based on the State of the Art Reactor Consequence Analysis (SOARCA) study, improves assessment results by modeling the core damage sequence more realistically.

Background

The SOARCA Study extended over six years and resulted in a draft report for comment, NUREG 1935, published in January, 2012. The study revealed that core melt sequences progressed over longer time frames than were modeled in RASCAL using the NUREG 1465 (1995) methodology. In essence the core tends to heats up in its center first and damage progresses outwardly. Credit can be taken for emergency core cooling systems. In all likelihood more time will be available for offsite protective actions. Core damage sequences that modeled severe core melt when the core was uncovered for two hours in older RASCAL source term modules will be more realistically modeled over eight to ten hours or more.

RASCAL allows up to 48 hours of delay before the core begins to be uncovered due to battery life (usually about 4-6 hours) and potential passive cooling. During the Fukushima incident, the Unit 2 Reactor Core Isolation Cooling (RCIC) system was on when battery power was lost. A rough passive mode appears to have been maintained. Increasing and decreasing pressure in the reactor vessel supported some circulation. This on/off passive relief lasted several days. Some credit to heat removal, and the success of this unusual passive cooling, may be due to the U2 torus room being flooded in the case of the Fukushima accident.

There is also a delay of 8 hours from the time the core begins to become uncovered until it becomes fully uncovered and fission products begin to be released from the core. Until fully uncovered, steam cooling from the evaporating water will provide core cooling.

Problem

Arkansas Nuclear One (ANO), Unit 2, was shut down at the same as ANO 1, 10:00 AM, due to the earthquake which caused the Unit 1 LOCA. Offsite power was lost. Diesels provide power until 18 hours later when a strong aftershock incapacitates the diesels and causes total loss of AC power. This leaves the plant in a Station Blackout. The turbine driven, DC power governed, High Pressure Safety Injection (HPSI) and RCIC systems both activate. At this stage, the lower capacity RCIC pumps are all that are needed to supply enough cooling water. The batteries are expected to last 6 hours. After the batteries run down the core becomes uncovered. Eight hours later (32 hours after shutdown) fission products leak through a slightly damaged containment at 2.0 %/d with no sprays available.

Begin a new case. Choose Nuclear Power Plant for the Event and choose Arkansas Nuclear One, Unit 2, for the Event Location. Under the Source Term tab, choose the SOARCA option and complete the entries based on the information given. In this example, power is restored and the core is recovered after being uncovered for 5 hours at 23:00 on the second day. Next, set up the Release pathway.

Save the case as **Using RASCAL – Case 5**.

We will return to this problem after an introduction to Automated Meteorology.

AUTOMATED METEOROLOGY - SETUP

New to RASCAL 4.3 is a tool to download meteorological data from the internet in support of modeling release in the U.S. This tool can download both observed and forecast weather for both sites in the RASCAL facility database and sites defined by the user. Both the download tool and the facility database contain an optimized list of sites supporting the predefined locations. Forecasts are available for all the weather stations and the sites; observations are available only from the weather stations and not the site. The tool does not have access to the site meteorology tower or the ERDS.
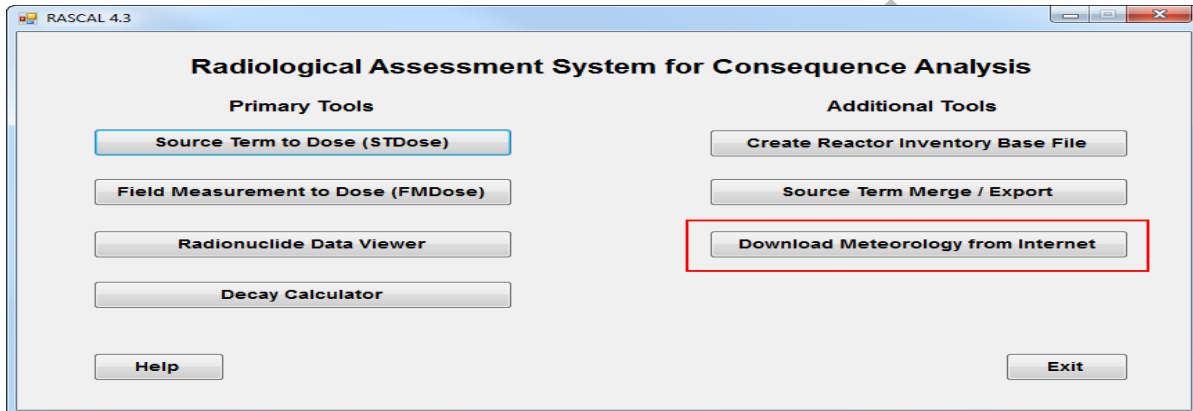
From the RASCAL main screen, choose **Download Meteorology from Internet**.

There is some setup involved before using the tool for the first time.

There are two tabs. We'll start with the second tab, **Meteorological File Settings**, first.
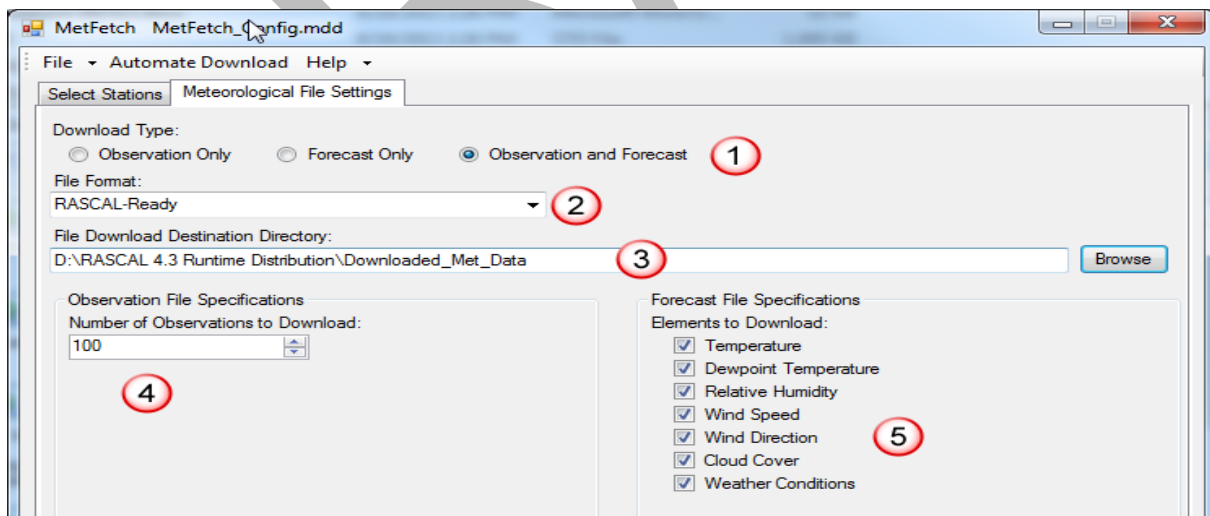
1. **Download Type** should be set to **Observation and Forecast**. We will want both types of data.

2. **File Format** should be set to **RASCAL-Ready**. We want the tool to create a file we can use as input to the RASCAL meteorological data processor. The other option just gets the data in its native XML format.

3. **File Download Destination Directory** is where the program will store the observations and forecasts. For RASCAL to be able to find them they need to be in the **\Downloaded_Met_Data** folder under the main RASCAL program folder.

4. **Number of Observations** can be left at **100**. This setting determines how far back in time the program goes for observations. For hourly reporting stations (e.g. NWS under normal conditions) this will be about 4 days. If a station reports more frequently, the limit of 100 observations will occur sooner.

5. All the **Elements to Download** should be checked.

Next, take a look at the **Select Stations** tab.

1. The **Station Database File Path** must point to the RASCAL facility database file. As needed, use the **Browse Path** button to locate the file. It is in the \Data folder under the main RASCAL program folder. This file contains site locations and met station lists.
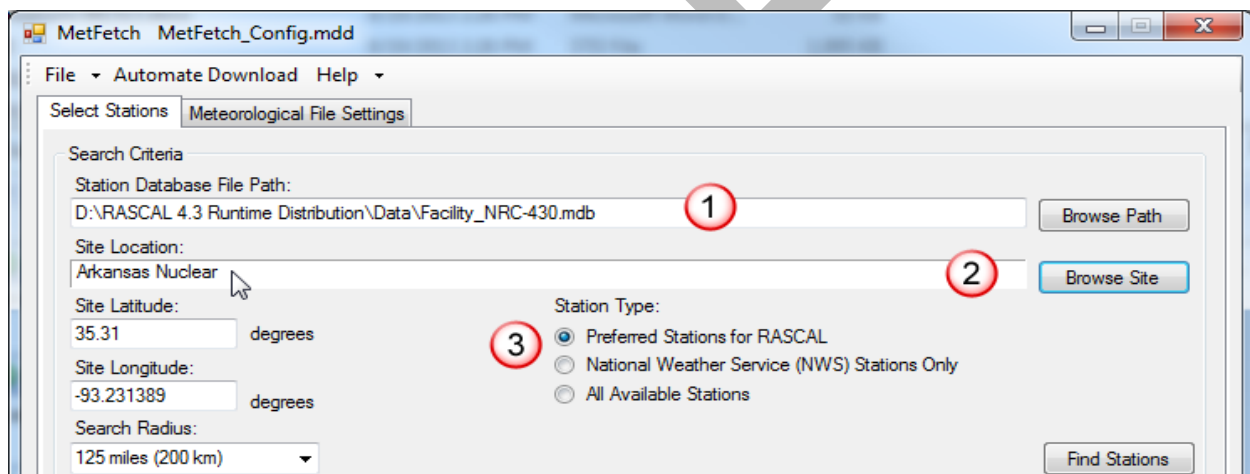
2. Use the **Browse Site** button to select Arkansas Nuclear.
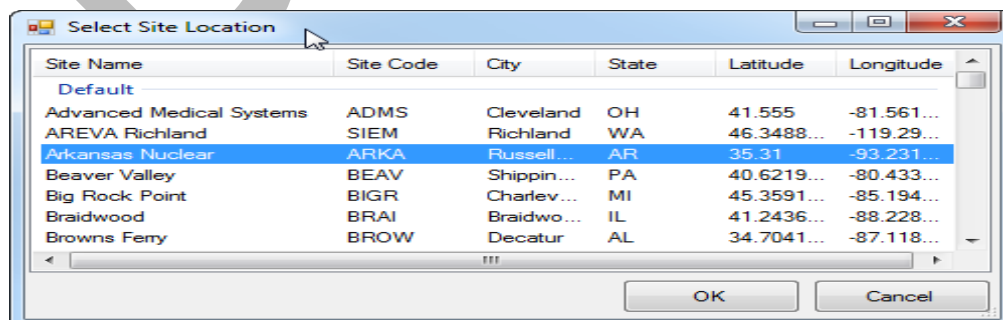
3. Make sure the **Station Type** is set to **Preferred Stations for RASCAL**. This option makes use of an algorithm to strategically choose the best stations throughout the region, without choosing many more stations than needed.

The final setup step is defining which meteorological stations should be polled for data.

1. Verify the **Search Radius**; 100 miles should be sufficient.

2. Click the **Find Stations** button.

3. This will populate the **Stations Available for Download** on the left.
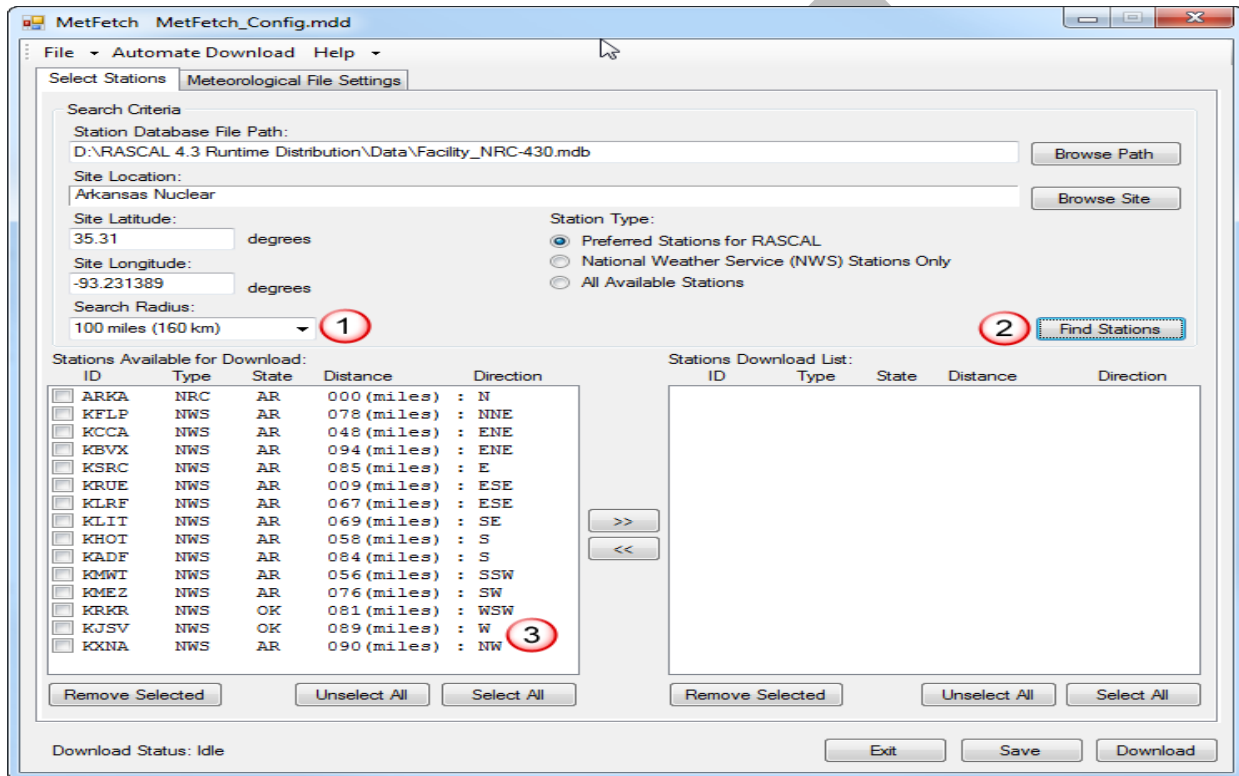
4. Select those of interest (usually all) by putting a checkmark in front or using the **Select All** button.
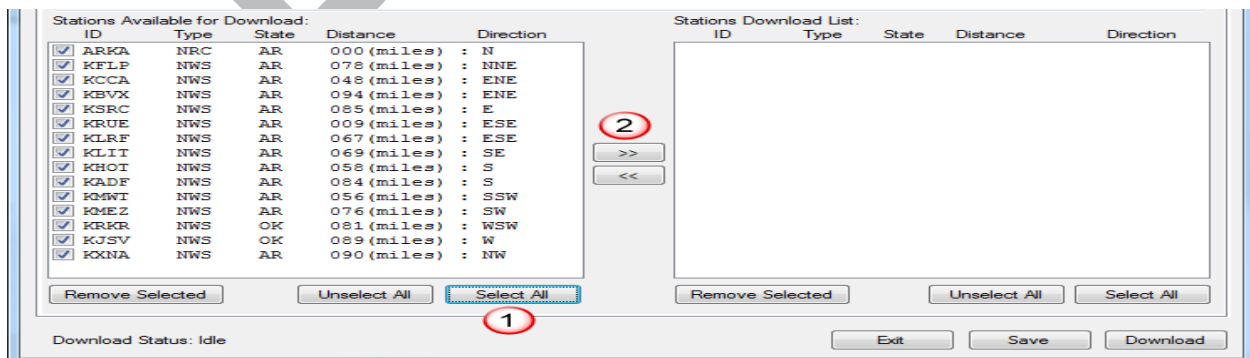
5. Move them to the **Stations Download List** on the right using the **>>** button.
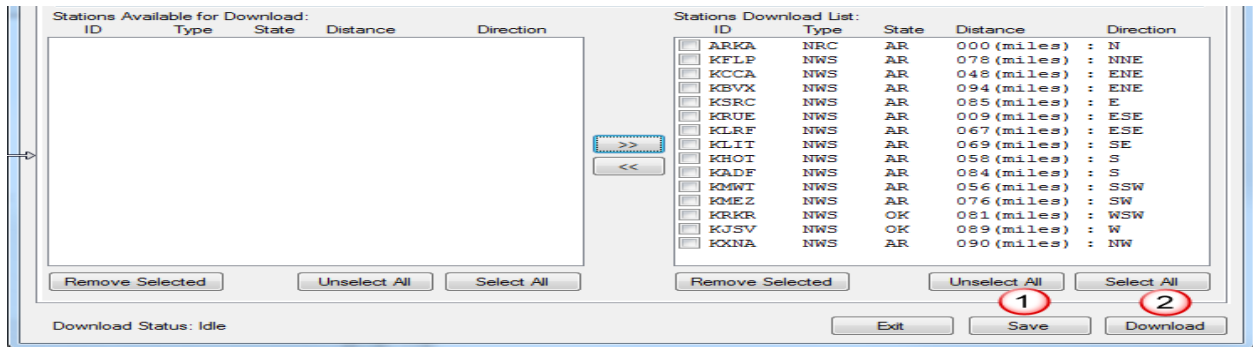
6. At this point, click the **Save** button (1) so the program remembers the configuration.

7. Finally, click the **Download** button (2) to obtain observation and forecast data for each station in the download list. Sometimes there is a slight delay before a progress bar appears. The weather data will be saved in the **Downloaded_Met_Data** folder, identified above, and will be available when conducting RASCAL runs.

Note

If a NRC licensee site is in the list of stations (e.g. ARKA in the list above), you will receive a message that MetFetch is unable to download observations for it. This is normal as the program does not have access to the site met tower data either directly or via the ERDS. The message is basically a reminder that if you want to use observations from the site they must come from some other source. Since the site tower is the closest to the release point for nuclear power plants, you should make an effort to get the data and enter it manually.

8. Click the **Exit** button to exit the program. In normal operations you may choose to minimize the program to make is easier to access regularly. Typically, you would run the download process hourly at about 10 minutes past the hour. This coincides with the standard NWS reporting interval and allows some time for the hourly observations to make it into the NWS reporting system.

AUTOMATED METEOROLOGY – USE IN A RASCAL RUN

After setting up a Source Term and Release Pathway in the STDose model, proceed to the Meteorology module. If any of the past meteorology files are older than about two days, delete them when possible to avoid data range error warnings. Choose **Create New**, and choose **Enter Data**.

Station IDs in the left column are highlighted in green if there is data for them in the downloaded met folders. Using the **Retrieve Downloaded Data** button at the top of the input window, weather data is imported one station at a time.

Caution

Do not change units for weather data when automated meteorology (only U.S. data) is used.

With ARKA highlighted (blue) in the station ID list on the left, click the **Retrieve Downloaded Data** button.

Notice that there is a forecast folder (2) but no corresponding observation folder (1) for the same date and time. This is to be expected for the nuclear power plant site. As mentioned earlier, the MetFetch program does not have access to the site tower data either directly or via the ERDS. Observations from the site tower will need to be obtained from other sources (e.g. HPN, chronologies, etc.).
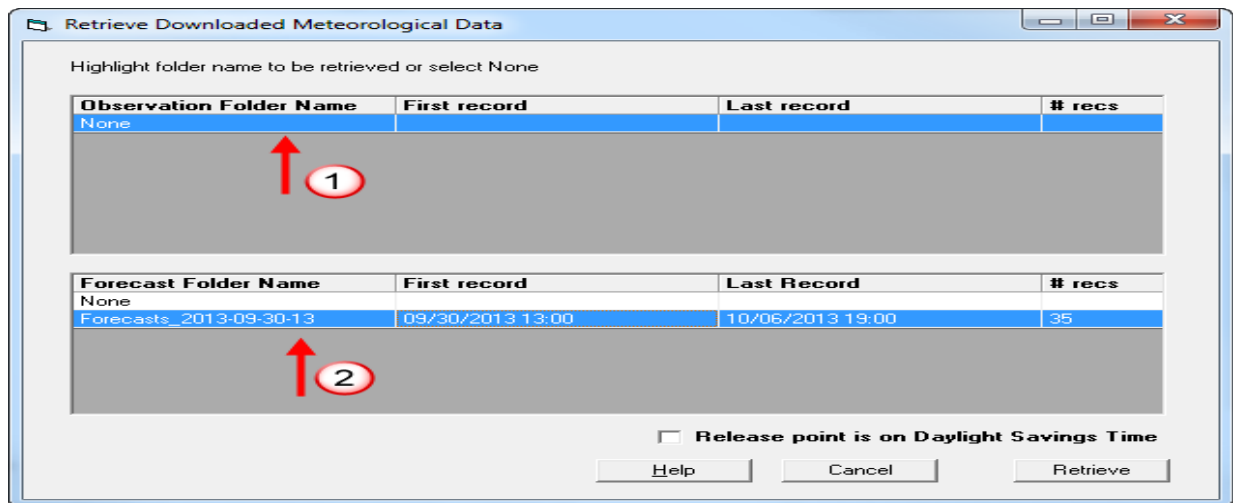
Highlight or select the most recent forecast folder (top of the list) and then choose **Retrieve**. Note, there is a check box for correcting the weather data to **Release point is on Daylight Savings Time**, if needed.
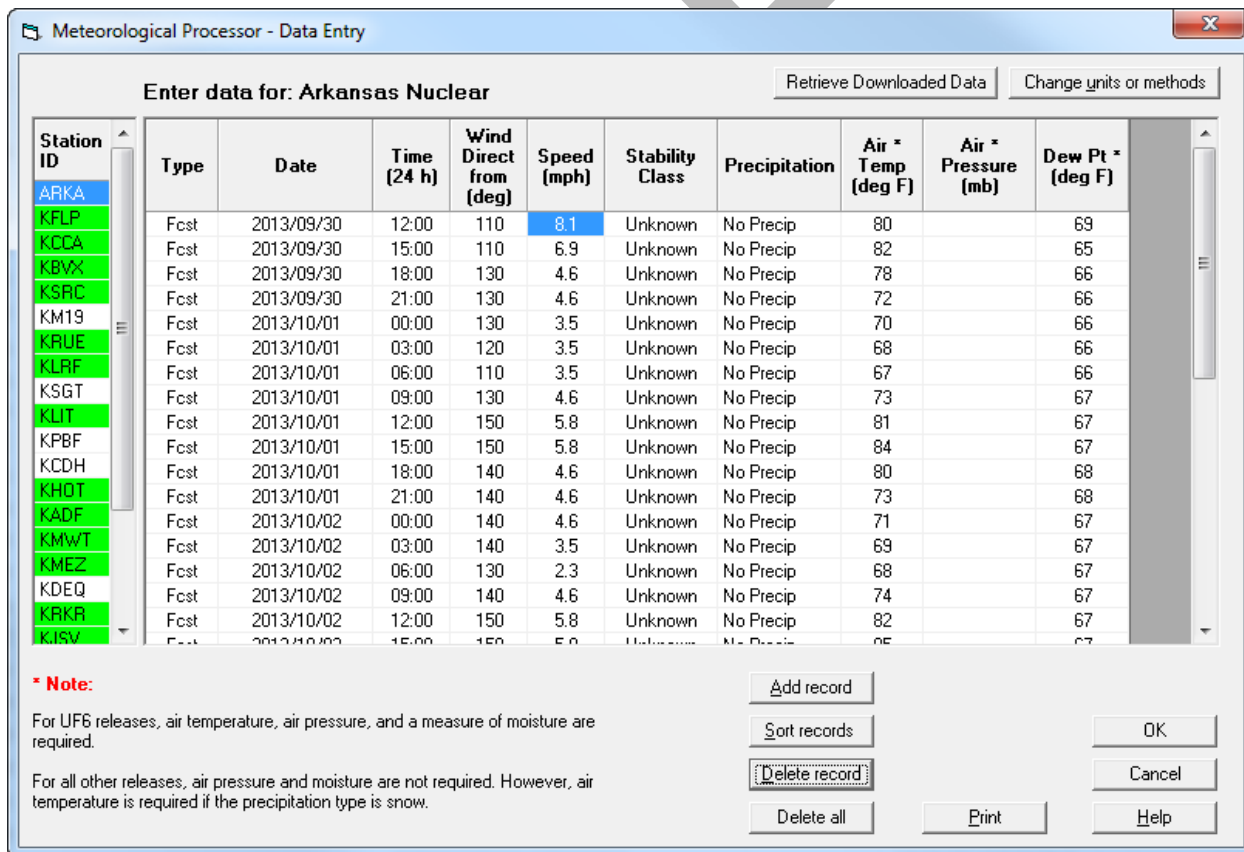
The forecast data is loaded into the data grid for ARKA.

Note

If any of the data rows look suspect because they have zeros that are not consistent, they can be deleted.

The process can be repeated for other stations in the list. Highlight the station ID then click the Retrieve button and select the observation and forecast folder to use.

Note

The more meteorological stations used the better the wind field representation but also the larger the files become and the longer the calculation time becomes. Complex wind fields can effectively disperse plumes more realistically.
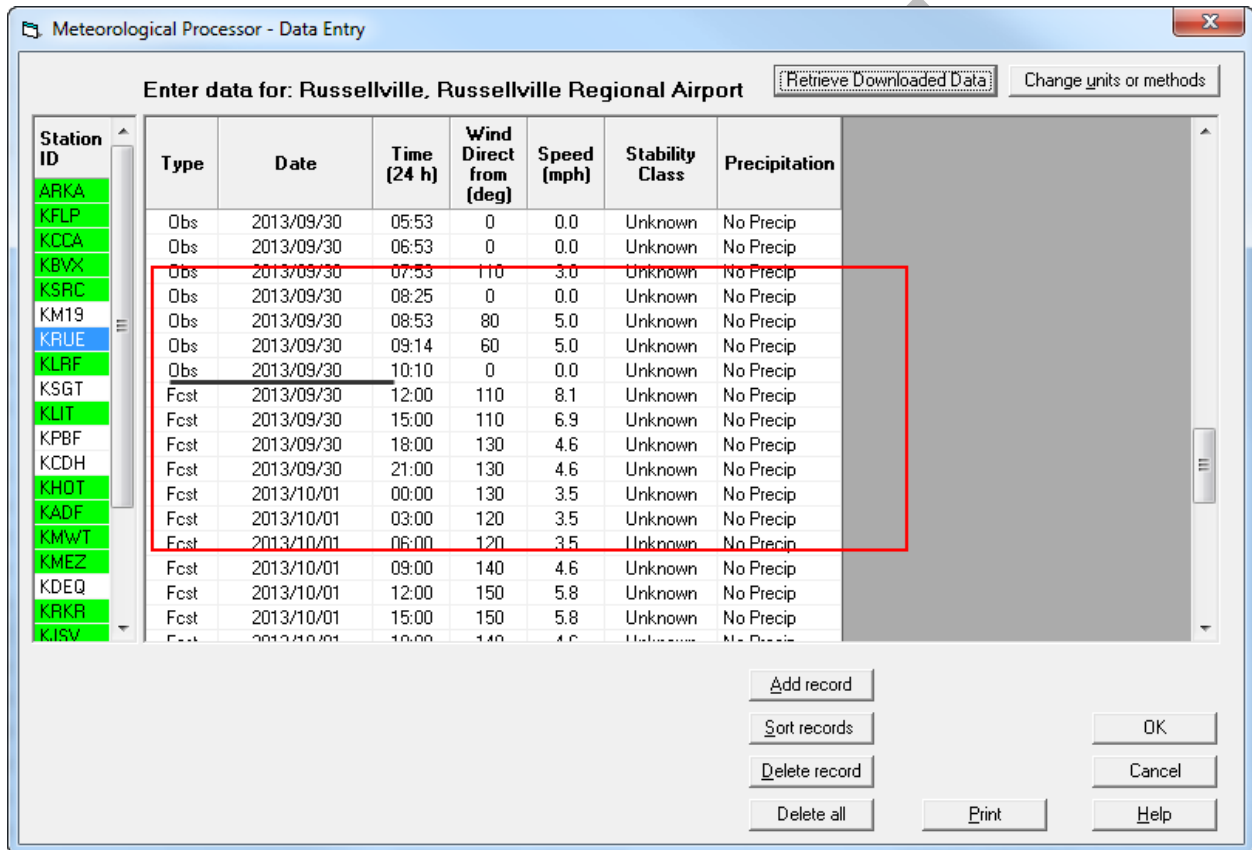
Notice in the example above for KRUE, that both observations and forecasts were retrieved. Because of the setting to get 100 observations, the observed data goes back several days before the release time and will really not be used. The forecast goes forward in time, initially at 3 hour intervals and later at 6 hour intervals.

If you have internet access, set up and download meteorology for Arkansas Nuclear. Process the Using RASCAL Case 4 result, with automated meteorology and save the file with a new name such as Using RASCAL Case 4 Auto Met. We'll use the original Using RASCAL Case 4 in the next example.

Results

Page 204 has a summary of the inputs used to get those answers shown.

LONG TERM STATION BLACKOUT SOURCE TERM – CONTINUED

It is projected that at 23:00 on the 2nd day after shutdown, offsite power will be restored. The Unit 2 core will have been fully uncovered for about five hours. Containment sprays will be activated when power is restored. It is estimated that containment pressure will be reduced to zero by 06:00 AM on the third day of the incident and the release will be stopped.

In order for the RASCAL class to come out with consistent results that match the answers in the back of the workbook, we must default back to manual meteorology entries.

You have already entered the meteorology for the site for a little more than the first 24 hours. Choose your last meteorology file and edit it to enter the upcoming forecast data. When we merge the Unit 1 and Unit 2 source terms in the next problem, we'll want a meteorology file available that begins before the Unit 1 release and extends beyond the Unit 2 release timeframes.

Type	Date	Time	Direction	Speed	Stability	Precip	Air temp
Fcst	Day 2	18:00	35	9 mph	D	None	73 F
Fcst	Day 2	21:00	55	8 mph	D	None	64 F
Fcst	Day 3	00:00	75	6 mph	E	None	60 F
Fcst	Day 3	03:00	95	5 mph	E	None	55 F

Enter the meteorology update and process the data using the phrase 'Case 5' in the met file name. Calculate the result being sure to choose a reasonable distance and duration for the calculations that will provide a RASCAL result that characterizes the present hazard from a Unit 2 release, and would provide a good basis for protective action decisions. It may take a few tries to obtain a satisfactory result.

In addition to the default dose calculations, a **Child Thyroid CDE** result is now available, when choosing the ICRP 60/72 option before calculating. The 5 rem child thyroid CDE protective action limit is identified in the EPA 2013 Interim PAGs and is only for consideration of KI administration. The RASCAL dose calculation is based on the most sensitive population, a one year old child.

Question	Your answer
From what time does the meteorology need to be available?	
At about what distance is the TEDE exceeded? Thyroid CDE?	
Using the Source Term tab, and Release vs Time option, does the release interval extend as expected? What types of radionuclides are being released near the end?	
At what distance does the Child Thyroid dose exceed the 2013 EPA Interim PAG for KI ingestion? Adult CDE, same distance?	
Projecting doses over 25 miles, how does the **TEDE** dose compare at **3 miles** for ICRP 26/30 versus ICRP 60/72?	
How does the **adult Thyroid CDE** dose compare at **3 miles** for ICRP 26/30 versus ICRP 60/72?	
How does the **TEDE** dose compare at **10 miles** for ICRP 26/30 versus ICRP 60/72?	
How does the **adult Thyroid CDE** dose compare at **10 miles** for ICRP 26/30 versus ICRP 60/72?	

Results

Page 205 has a summary of the inputs used to get those answers shown.

Notice that for the SOARCA case, impacts can be similar, but there is much more time at the beginning of an event to take protective actions if needed. Notice the low noble gas/I-131 ratio. It correlates to the Thyroid CDE driving protective actions (exceeds EPA PAGs furthest out). During your spare time, you can explore various calculations and perspectives by changing the parameters that are set up in this problem.

Save the case as **Using RASCAL – Case 5**.

MERGING SOURCE TERMS FOR TWO UNITS

Merging

Choose **Source Term Merge/Export** on the RASCAL start up screen.
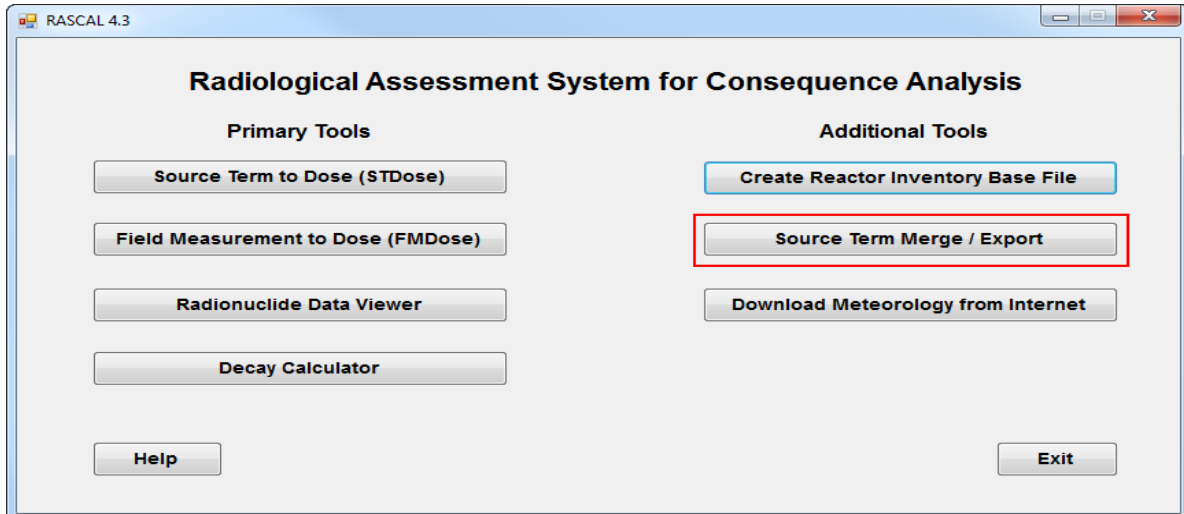
As the RASCAL user works through the merge results screen shown below several steps take place.

1. A 'Merge Results' folder can be created or another folder chosen for processing temporary files. Set up the first entry field by browsing to this base folder

2. After the case files to be merged are loaded (viewing options are available), the Merge **Source terms** button is chosen.

3. The bottom portion of the window remains inactive while an intermediate entry screen opens. The user identifies and labels the appropriate **release height**, **latitude and longitude**, **Case Title** for the merged file run, **analyst**, and **Title** for the units affected. After clicking **OK**, and the files are merged successful, the message below appears, and the bottom portion of the screen becomes active.
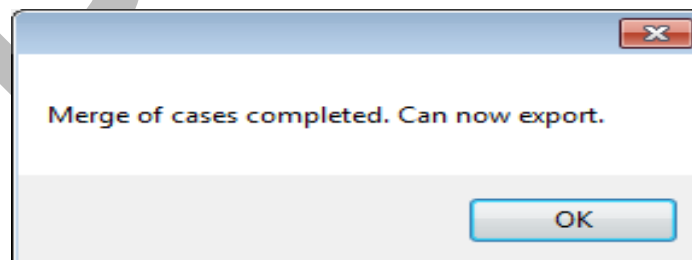
4. Considerations for the Export options include the following:
    a. XML source term files contain additional information about the RASCAL run such as release height, meteorology, and other relevant run parameters.

b. Default source term values for the Pathway, Time Period, and Method are recommended for NARAC. The top 20 radionuclides will generally contribute almost the entire dose.

c. Over time the specific radionuclides that contribute the most to the dose will change. As an incident progresses through the various time phases, different Time Periods can be selected to identify the top 'bad actors' at that time.
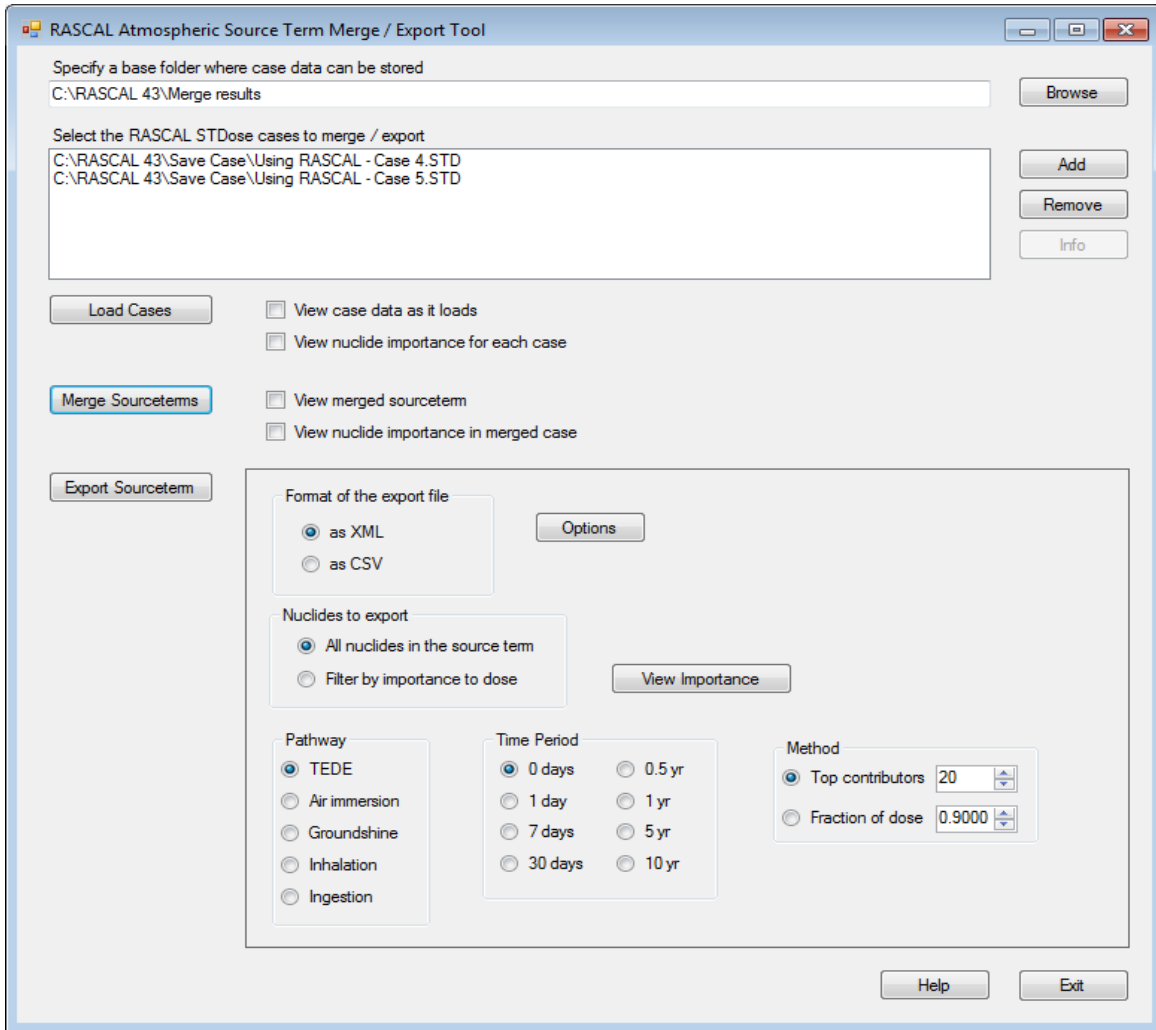
5. Choose Export **Source term** to complete the process and exit the screen.

Processing a Merged Source Term

Begin a normal RASCAL run by selecting the **Source Term to Dose (STDOSE)** option on the main menu screen. Choose **Nuclear Power Plant** and **OK.** Click the **Event Type** button, choose one of the affected units, in this case ANO 1. Notice that the Source Term tab in RASCAL 4.3 has a check box for importing a source term. Check the **Import checkbox** then select the **Source Term** button.
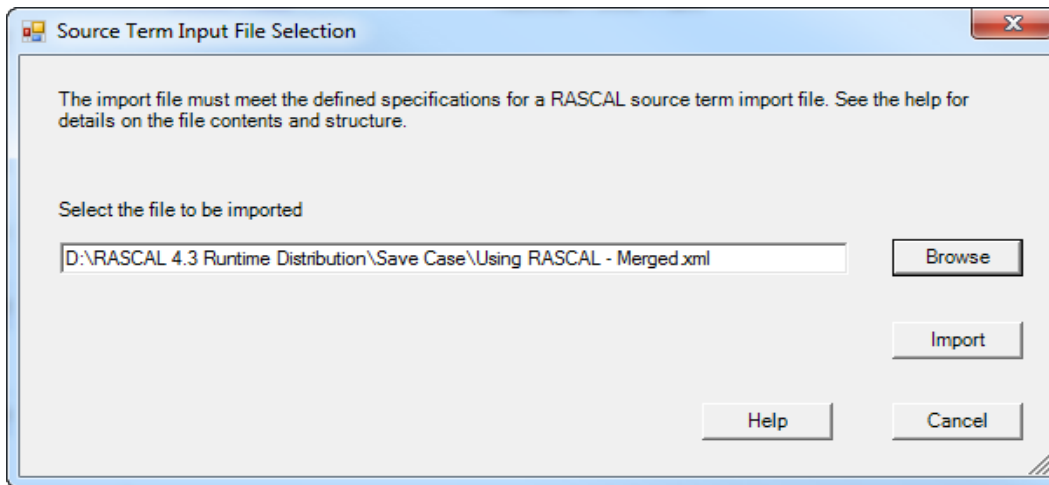
Browse to the merged source term file location and select it. Remember to choose the file type, **xml** or **csv**, when browsing to be sure the file reveals itself. Next choose the **Import** button. After a short delay a Report Status is shown.
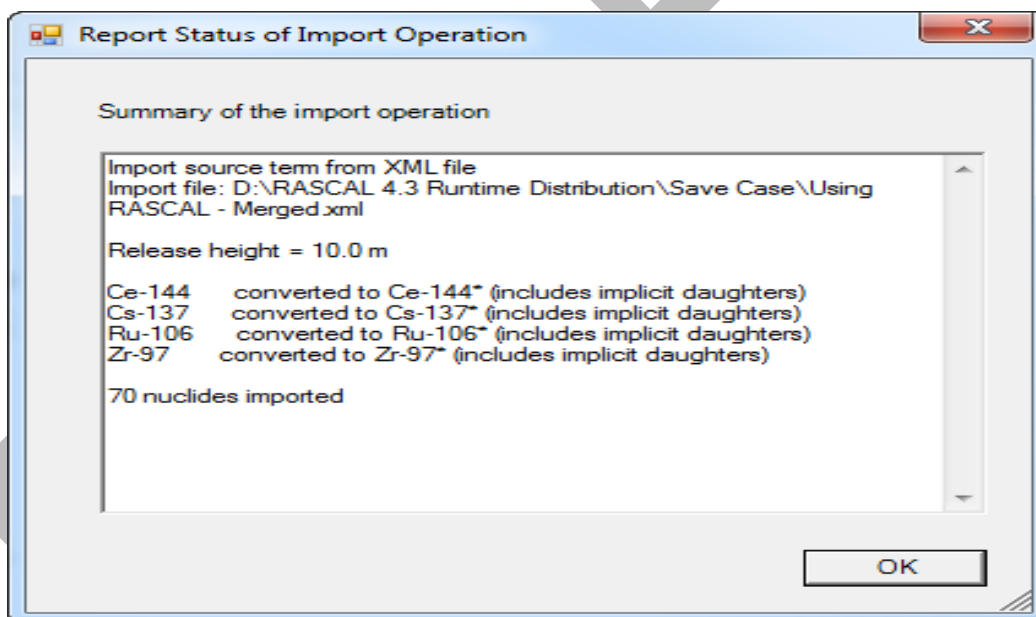
Choosing **OK** imports the combined source term and also sets the release parameters as they were for each case. The meteorology file will need to cover the entire range of weather over both the Unit 1 and Unit 2 release scenarios. An example is shown below.

When the meteorology file has been prepared, and selected, proceed to the Calculation tab.

Caution!

The 'time' for the end of calculations must extend over the release duration for both Unit 1 and Unit 2 scenarios plus enough time to be transported adequately to the zones of interest. In this case, the second release ends at the start of the 1st release plus 39 hours. 50 hours will allow enough time to see impacts out to 50 miles or more, if they exist.

The EPA PAGs are not exceeded beyond 10 miles, the impact plot desired. Do the 50 (may calculate for 10 minutes) or 100 mile impact plots add valuable perspective?

Thyroid Committed Dose Equivalent
Accumulated between 2013/09/26 13:00 and 2013/09/28 15:00
Using RASCAL Merged Cases 4 and 5
Arkansas - Unit 1

Legend

■ 0.05 to 5 rem
Below EPA PAG Range

■ 5 to 25 rem
EPA Early Phase PAG Range

■ > 25 rem
Exceeds EPA PAG Range

Data at individual model receptors

Position cursor over cell to display

. . . . .
at
. . . . .
from release point

Click cell to plot dose rate vs time

Impact Area

Export

Save Image

Print

OK

Help

RASCAL v4.3

Show on display: ☑ Radius circles ☑ 22½° sectors ☑ Map background

NUCLEAR POWER PLANTS

The section "Using RASCAL: Assessing a PWR Core Damage Accident" ran through the entire code for one particular reactor core damage accident to teach you many of the details of the code. This section on Nuclear Power Plant Problems has short problems, each illustrating some specific aspect of the code. These problems primarily explore reactor source terms and release pathways.

CREATE REACTOR INVENTORY BASE FILE

Reactor accident impacts will vary depending on how fresh the reactor's fuel is and other considerations. RASCAL uses general characteristics like average fuel burn up being 30,000 MWd/MTU. In a real incident it is likely that information will be available to better characterize the reactor's state. If this is the case, RASCAL 4.3 permits creating a Reactor Inventory Base File that can help predict better results. How much difference will it make? Let's use Using RASCAL Case 5 and consider one example. In Case 5, we found EPA PAGs exceeded at about 8 miles. The Case 5 Source Term information indicated about 1.6 E6 curies released. What would be the case if the very fresh fuel was used and the burn-up rate was lower? Remember, generally only one batch (1/3 of core) is generally exchanged during refueling, so refining the reactor parameters may only result in small differences.

1. Choose the **Create Reactor Inventory Base File** option from the main menu.
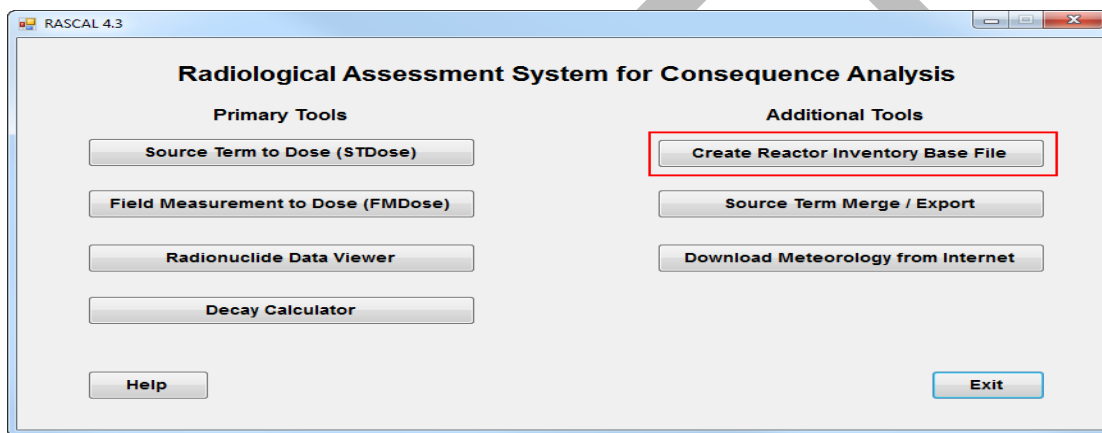
2. Set the date of the last refueling outtage about 6 weeks before the accident date, then choose **Create**.

3. An updated inventory is created and can be used in the STDose module.
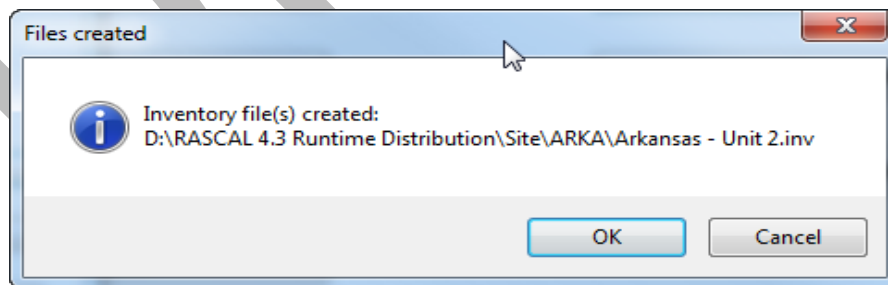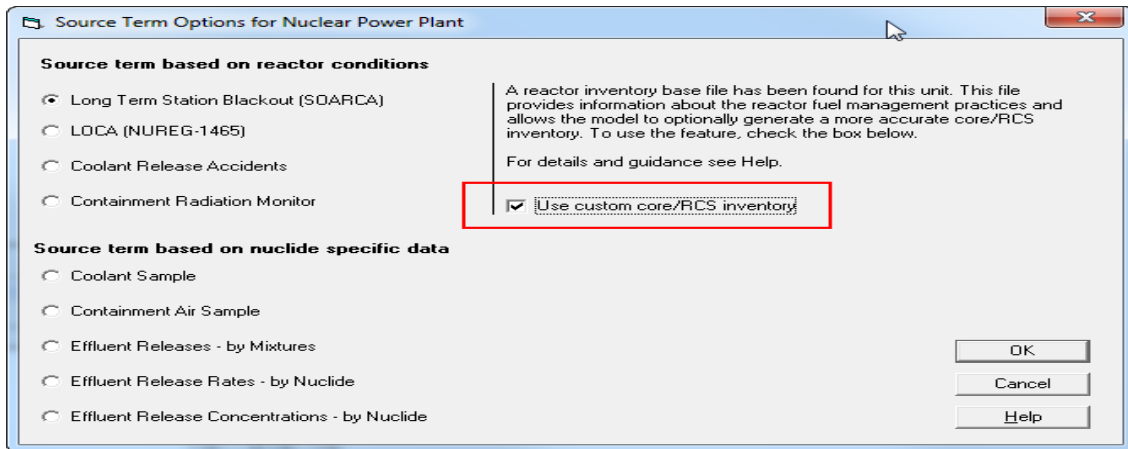
4. In this case, we find the activity released slightly lower, 1.5E6 versus 1.6E6 Ci, and the PAGs are exceeded at a relatively insignificant smaller distance. Nevertheless, RASCAL 4.3 provides the capability to improve the reactor characterization for a wide range of refueling circumstances.
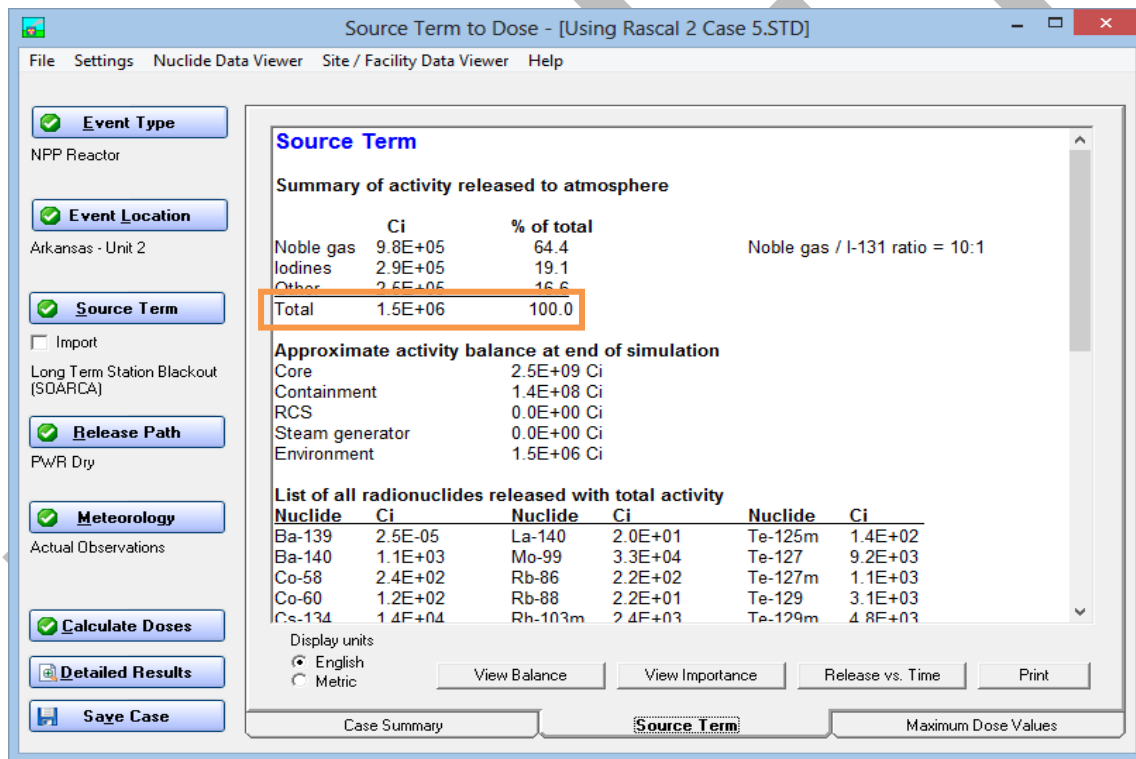
5. If the option to also run inventory model and view files created is selected, a summary report is provided with a radionuclide activity list for core activity at the time of the incident.

6. Experiment with the custom inventory module. See if you can find circumstances that will result in significant differences in calculation results when a custom inventory is used.

RELEASE PATHWAY REDUCTION MECHANISMS

Purpose

To study how to use release pathway reduction mechanisms to obtain an appropriate release.

Background

The magnitude of the leakage rate of radioactive material to the atmosphere is an important consideration when estimating doses. One way to define leakage is by a containment pressure and a containment hole size. Reducing either will reduce the rate at which material enters the atmosphere.

Various reduction mechanisms are modeled by RASCAL. The reduction of the source term by sprays is treated as an exponential function with time. There is an initial effectiveness that is applied for the first 15 minutes that radionuclides are in the containment atmosphere and then a reduced effectiveness acting after 15 minutes. The reduction factor (RDF) is calculated as:

$$RDF = e^{-\lambda T}$$

where T is the total amount of time (h) that the sprays have been operating and lambda (λ) is 12/h for the first 15 minutes and 6/h after 15 minutes. Some PWRs use ice bed condensers to allow for smaller containment volumes. Such containments route hot gases through large ice baskets to condense steam and lower containment pressure. Factors to consider with this type of containment are whether the ice has been exhausted and whether the recirculation fans are available to provide multiple passes of the hot gases through the ice beds.

RASCAL 4.3 implements a new methodology for calculating the release to the environment. The methodology, which is described in Section 1.4 of the technical supplement, decreases the pressure and leak rate automatically with time. RASCAL 4.2 assumed that the pressure and leak rate remained constant unless changed by the user. The new methodology requires containment atmosphere temperature as well as pressure and hole size. The pop-up screen used in RASCAL 4.2 to enter the pressure and hole size has been modified to include containment temperature. Several default holes size options have also been added to the screen. If a user defined hole size is entered, the leak rate calculated with the pressure and hole size is compare with the containment design leak rate. The larger of the two leak rates is used to calculate the release to the environment.

Problem

The Catawba Nuclear Plant, Unit 1 (a PWR with an ice condenser containment) had been operating at full power. The reactor scrammed at 10:45 A.M. local time. At 1:30 P.M. local time the core was uncovered (LOCA). It was recovered after 45 minutes but there was a direct release path through the pressurizer relief tank. We assume that the release to the environment started as soon as the core was uncovered.

We will first run this problem with none of the active reduction mechanisms operating and with a 4-inch diameter opening in the containment with the containment at the maximum design pressure of 15 lb/in^2. It is assumed the opening will remain open for 3 hours (until 16:30) and then be completely closed. (Hint: you need to set the diameter to zero.) In all the modeling runs, use the predefined **Standard Meteorology** dataset. This met dataset is found under the **Predefined Data (Non Site-specific)** option.

After the initial run, we will make changes to the release pathways to reduce the size of the release. Run the following six cases and fill in the source term and doses in the table.

Case 1: Initial case described above (with sprays off, ice bed exhausted, and recirculation fans off)

Case 2: Reduce the containment pressure by a factor of 3; from 15 lb/in^2 down to 5 lb/in^2

Case 3: Reduce the hole size to 2 inch diameter (leave pressure at 5 lb/in^2)

Case 4: Assume that the ice bed is not exhausted

Case 5: Turn on the recirculation fans

Case 6: Turn on the sprays

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Sprays	Off	Off	Off	Off	Off	On
Recirculation fans	Off	Off	Off	Off	On	On
Ice bed exhausted	Yes	Yes	Yes	No	No	No
Hole size @ 13:30	4" dia	4" dia	2" dia	2" dia	2" dia	2" dia
Containment pressure @ 13:30	15 lb/in^2	5 lb/in^2	5 lb/in^2	5 lb/in^2	5 lb/in^2	5 lb/in^2
Total source term (Ci)						
TEDE at 1 mile (rem)						

Results

Page 207 has the answers and a summary of the inputs used to get those answers.

This is a good "button pushing problem" to get you comfortable with the user interface. It also illustrates how easy it is to go back, change one entry, and then recalculate doses.

The base case (#1) had all the reduction mechanisms removed (e.g. sprays off and ice bed exhausted) and a leak rate based on a containment pressure and hole size. Each subsequent case reduced the leak rate or added back in a reduction mechanism. As you would expect the total number of curies release decreased as did the TEDE.

Optional questions:

Why, with an overall reduction of less than a factor of 10 in total source term (3.1E+05 to 4.5E+04), is there a more than 2 order of magnitude reduction in the TEDE (0.71 to 0.0041)?

Why is there such a significant reduction in the source terms released from RASCAL 4.2 to RASCAL 4.3? (Using RASCAL 4.2, the total source term for case 1 is 3.0E+07 Ci)

MONITORED MIXTURES

Purpose

To show how to determine projected doses based on effluent monitor readings.

Background

When a nuclear power plant effluent monitor detects a release, the release is likely to be a mixture of many radionuclides (fission products) rather than just a single radionuclide. However, the effluent monitor cannot identity the specific radionuclides present. Instead, the effluent monitor will usually be able to provide only the noble gas activity release rate, the radioiodine activity release rate, and sometimes a particulate activity release rate.

The effluent monitor may provide a reading in terms of some number of counts per second. The counts per second reading cannot be used by RASCAL because RASCAL does not know the efficiency of the effluent monitor. Therefore, RASCAL cannot convert the count rate in terms of counts per second to a concentration in terms of curies per second. However, every plant has a conversion factor that will permit the conversion of counts per second to curies per second.

Sometimes, the plant may use this conversion factor and report the release rates to you directly in terms of curies/second. Other times it may not be easy to obtain this conversion factor from the plant because the factor has been buried in the plant's dose projection software, and the users of the software may enter the monitor reading in terms of counts per second without knowing the value of the conversion factor that is being used. Nevertheless, the plant has this conversion factor, and you should be able to get it if you are persistent. Once you have the conversion factor, you can convert counts per second to curies per second.

If the plant provides you with an effluent concentration in terms of curies per unit volume and the effluent flow rate, you can multiply these two numbers together to determine the effluent activity release rate in terms of curies/second.

Monitored releases will be filtered so they should be mostly noble gases but with a small proportion of iodines and particulates. RASCAL estimates the composition of the noble gas component of the release by starting with the equilibrium proportions of each noble gas radionuclide that will be present in the reactor core while it is operating. Then the proportions of each that will be present at the start of the release will be determined by multiplying the initial proportion by the radiological decay factor and renormalizing the proportions to the time of the release start. The same is done for radioiodines.

For particulates a different technique is used because there is really no practical way to determine the composition of the particulate mixture. The particle composition used in the model includes all radioactive species of Cs and I and changes with time.

Problem

A malfunction at the North Anna, Unit 2 nuclear power plant caused the plant to shut down at 3:50 P.M. Shortly thereafter (4:00 P.M.) , an effluent release through a monitored pathway was detected.

The effluent release rate was reported to be 95 Ci/s for noble gases, 1.2 Ci/s for radioiodines, and 0.03 Ci/s for particulates. The plant's technical requirements state that the release duration must be limited to no more than 30 minutes.

Determine the projected TEDE and Thyroid CDE at 1 mile. Since this is a monitored release, use the stack height for the height of the release. Assume standard meteorology.

Dose type	Distance from release 1 mile
TEDE (rem)	
Thyroid CDE (rem)	

Results

Page 208 has the answers and a summary of the inputs used to get those answers.

CONTAINMENT RADIATION MONITOR

Purpose

To learn how a containment radiation monitor reading can be used to generate a source term.

Background

RASCAL can use a reading from a containment radiation monitor to estimate the amount of core damage. For example, RASCAL might calculate that the monitor reading you entered corresponds to 37% core melt. RASCAL will then use 37% core melt to calculate the activity released to the containment based on the core inventory and the core release fractions.
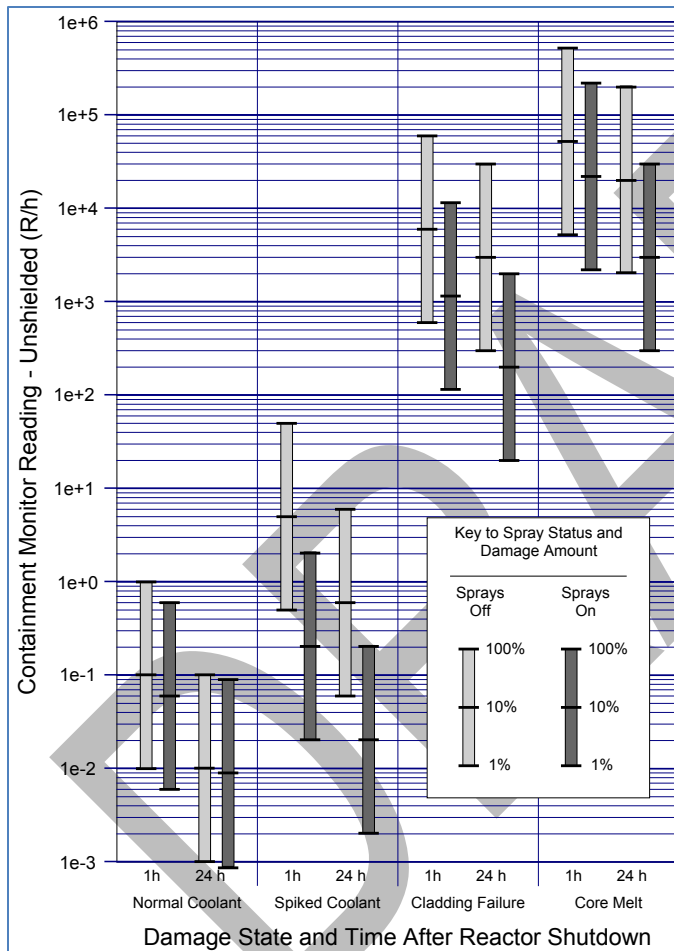
The factors that RASCAL uses to estimate core damage consider whether the sprays are on or not. If the sprays are operating, they will wash out most of the particulates so that a given monitor reading would correspond to more core damage than if the sprays were off. Figure 3 shows the containment dome monitor response for a PWR.

The RASCAL code will not use a monitor reading to estimate a coolant release. Only cladding failure and core melt are estimated. Where a reading could indicate either damage state, the more severe is used.

Figure 3 PWR Containment monitor response

There are advantages and disadvantages to this source term method. The advantage is that the core damage estimate is based on real measured data instead of a calculation of how much core damage is likely to occur based on how long the core is uncovered. Used together, the two methods can complement each other and allow a better understanding of what is really happening. The disadvantages are that 1) the method is not predictive, and 2) the radiation monitor is a lagging indicator of damage.

There are several cautions in using this method. First, the monitor must "see" more than 50% of the area being monitored (see Figures A-3 and A-4 in the RTM). If the monitor does not see this much, do not use this method.
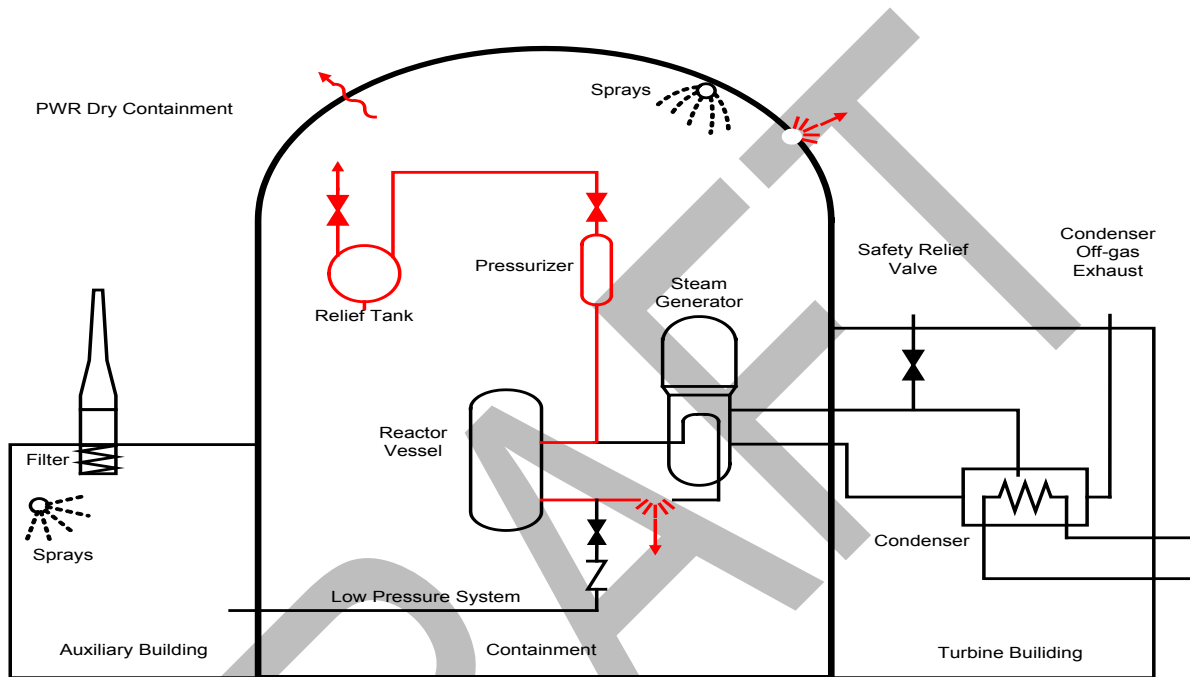
Second, in interpreting the RASCAL results, remember that there will be a time delay before fission products released from the core can affect the monitor reading. When there is a delay in the movement of fission products from the core to the containment or a delay in mixing within the containment, containment radiation monitor readings may start out low and then steadily increase with time. Thus, the maximum reading will give the best estimate of true core damage.

Third, the actual radionuclide mix in the containment may be different from that assumed in the calibration of the monitor. This can be especially significant for high dose rates when a shielded detector is used.

Finally, the RASCAL code does not look at decreasing readings. Each reading is treated discretely as an indication of the amount of core damage that has occurred. It would not make sense to specify 50% core melt from a reading and then later say that there was only 10% core melt.

Problem

An accident occurred at Waterford Unit 3. The reactor scrammed at 12:00 P.M. By 12:45 P.M. some of the core was uncovered. The release from the core passed into the containment building. Release from the containment was via design leak rate. The sprays are off.

During the course of the event, you receive periodic readings from the containment dome radiation monitor. Perform a RASCAL calculation (with Standard Meteorology) based on the containment radiation monitor readings in the table below:

Time	PWR containment monitor reading, R/h
12:45 P.M.	14
1:30 P.M.	50,000
3:00 P.M.	300,000

After calculating, look at the **Case Summary** tab and fill in the table below.

Containment radiation monitor reading	Indicated core damage
12:45 P.M.	
1:30 P.M.	
3:00 P.M.	

Results

Page 209 has the answers and a summary of the inputs used to get those answers.

CONTAINMENT BYPASS

Purpose

To learn how to estimate projected doses when there is a release of coolant and when the release pathway bypasses the containment.

Background

We have to distinguish between "source term" and "release pathway." A "bypass accident" means we have specified the release pathway. The release pathway for a bypass accident is one in which coolant escapes to the atmosphere without going through the containment.

There are four source term types that can be used with the bypass release pathway. The "LTSBO" and "LOCA" source term types can estimate the activity entering the coolant if the core is uncovered. The "coolant release accident" source term type can estimate coolant activity for normal coolant and for spiked coolant. The "coolant sample" source term type can estimate coolant activity based on sample data.

Problem

The Peach Bottom Unit 2 nuclear power plant experienced a leak in a containment penetration pipe that could not be isolated (closed). The resulting drop in reactor coolant system pressure and water level caused the reactor to automatically shut down at 11:45 A.M.

There are indications of increased fuel pin leakage due to the rapid shutdown. Best estimates suggest a spiking factor of 30. The pumps being used to maintain the water levels in the reactor coolant system are injecting 300 gallons/minute.

The leak is into an auxiliary building where the coolant immediately flashes into steam. The steam can escape the building to the atmosphere without any filtering. Plant operators expect to have the leak stopped by 1:00 P.M.

To end the release, you will need to set the bypass flow rate to zero. This tells the code that since make-up flow is no longer needed to maintain the water level, the leak has been stopped.

Calculate the projected TEDE and thyroid CDE at 2 miles assuming standard meteorology.

Dose type	Distance from release
	2 miles
TEDE (rem)	
Thyroid CDE (rem)	

Results

Page 210 has the answers and a summary of the inputs used to get those answers.

STEAM GENERATOR TUBE RUPTURE WITH COOLANT RELEASE

Purpose

To learn how to determine projected doses due to a steam generator tube rupture and to understand coolant spiking.

Background

A steam generator tube rupture (SGTR) in a PWR allows primary system coolant to escape rapidly to the secondary system. The rapid loss of coolant causes the pressure to drop in the primary system, which in turn causes the reactor to automatically "scram" (shutdown).

Rupture Location

The RASCAL user must specify whether the rupture to the tubes is above or below the water level in the steam generator. When the leak is below the water level on the secondary side of the steam generator the generator is said to be "partitioned." The water from the primary system that leaks into the steam generator mixes with the water in the steam generator. When the radionuclides are "partitioned," the concentration of radionuclides in the steam will be less than their concentration in the steam generator water by a "partitioning factor." When the leak is above the steam generator water level the generator is "Not partitioned." In this situation, most of the primary coolant will flash into steam and most of the radionuclides will be available for release.

Partitioning is assumed to have no effect on noble gases. Noble gases in the primary coolant leakage are assumed to immediately be available for release without any reduction or holdup. If the user selects "below the water," RASCAL reduces the release of all radionuclides that are not noble gases by a factor of 50. If the user selects "above the water," RASCAL reduces the release of all radionuclides that are not noble gases by a factor of 2.

How does the RASCAL user know whether to select "above" or "below"? Although the actual tube break location may be unknown, the steam generator water level relative to the top of the tube bundle should be available. If the water level is near or above the top of the tubes, the user should select "below." If the reactor has a once-through steam generator, RASCAL does not allow "partitioning" because most of the tube length in a once-through steam generator is not covered by water.

Setting the leak rate

The RASCAL user must also specify the rate of primary coolant loss to the secondary system and the loss of steam from the generator. The rate of primary coolant loss can be described in one of two ways.

One method is to specify the actual rate of coolant loss from the ruptured tubes. This loss can be estimated by the amount of water being added to the primary, from whatever source, to try and balance the flow into the secondary system. For a typical steam generator leak, the normal charging system flow may be enough to keep up with the leak. In this case, the difference between the letdown flow rate and the charging flow rate is the rate of leakage. Some plants have an "excess makeup flow rate" meter that displays this difference.

The other method is by specifying the number of steam generator tubes that have ruptured. RASCAL then assumes that the rate of primary coolant loss is the number of tubes that have failed multiplied by 500

gpm/tube. It is reasonable to select one tube unless the coolant makeup rate is so large that it indicates that more than one tube might be ruptured.

If the tube leak exceeds the normal charging capacity, then safety injection may actuate when the pressurizer pressure decreases. The operators can estimate the coolant makeup rate from the safety injection flow meter. Note that there was an event at a plant a few years ago, in which the operator detected the leak and started a second charging pump. This prevented the automatic actuation of safety injection and the reactor trip as the two pumps kept up with the leakage.

The bottom line is to enter the rate at which water is being added to the primary coolant system, from whatever source. The program labels it "charging flow" but it might be more aptly labeled "makeup flow."

The user must also specify a rate at which the steam is lost. As long as the steam generator is not isolated, the steam will continue to remove radionuclides from the steam generator water. The activity removal rate for the steam is the nuclide concentration in the steam times the flow rate of steam. The default for the steaming rate in a steam generator is 34,019 kg/h (75,000 lbs/h). This value is the amount of steam needed to remove decay heat soon after shutdown. The user can change this value with time if better information is available.

Release pathways

The RASCAL user must also specify whether the release to the atmosphere is through the condenser off-gas exhaust or the safety relief valves on the secondary system that are used to relieve high pressure. Usually the release will be through the condenser off-gas exhaust.

The primary-to-secondary leakage may cause pressures to briefly exceed the safety relief valve set-point, but the main steam dump valves should quickly relieve the pressure. The response of the steam dump valves may not be quite fast enough to handle a load rejection without a little steam release through the safety relief valves, but this release is generally less than a minute, which is negligible.

When the release is through the condenser off-gas exhaust, RASCAL assumes a reduction factor of 20 for non-noble gases. When the release is through the safety relief valves, there is no reduction. A release through the condenser off-gas exhaust is likely to be a monitored release. In that case, it would be useful to do another RASCAL run using the "Monitored Releases - Mixtures" source term option.

If the main condenser is not available, for example, because of loss of offsite power, the secondary system pressure will increase until the safety relief valves open. Thus, if the main condenser is not available, the RASCAL user should assume the release is through the high-pressure safety relief valves.

As time progresses, the pressure difference between the primary and secondary will decrease and the movement of fission products to the secondary will stop after several hours. Thus, the release is essentially self-terminating.

Coolant "spiking"

The rapid drop in pressure in the primary system causes an increase in the rate at which the radioactive fission products in the fuel rod cladding gap escape to the coolant. The concentration of fission products in the coolant rises rapidly. Originally, it was noticed that radioiodine concentrations rose and the phenomenon was first called "iodine spiking." Later it was found that the concentrations of all radionuclides rose with the possible exception of noble gases. Now we call this phenomenon "coolant

spiking" or simply "spiking." RASCAL assumes that the concentrations of only the halogens and alkali metals fission products in the coolant increase by the spiking factor.

The RASCAL user must specify the "spiking factor" using the **Specified Core Damage Endpoint** screen. At the start of an accident there will be no way to determine what the actual spiking factor is. After some time, it should be possible to analyze a coolant sample and estimate the spiking factor be comparing its activity to normal coolant activity. Thus, we recommend running RASCAL initially using the spiking factor default value of 30 and then adjusting the spiking factor after a primary coolant sample has been analyzed.

Problem

The Crystal River Unit 3 nuclear power plant experienced a sudden drop in primary system pressure and a sudden rise in secondary pressure at 12:36 A.M., shortly after midnight. The reactor immediately scrammed (shut down) in response to the sudden drop in primary system pressure.

The operators assumed that a steam generator tube rupture had occurred. The operators estimated that the makeup flow (including safety injection) was about 500 gpm. Assume that the sudden drop in primary system pressure will cause coolant spiking. Use the default spiking factor of 30.

The increase in pressure on the secondary side caused the high-pressure safety relief valves to open briefly, but after that the release was through the condenser off-gas exhaust. Assume the break is above the water line (worst case) and given no other information that the steaming rate is at the default value.

The release point is 30 meters above ground level.

Determine the TEDE and the thyroid CDE at 0.5 mile.

Dose type	Distance from release
	0.5 mile
TEDE (rem)	
Thyroid CDE (rem)	

Results

Page 211 has the answers and a summary of the inputs used to get those answers.

Notes on how we work the problem:

- Since the release through the safety relief valves was brief, we elected to ignore it.

- Offsite doses from a steam generator tube rupture accident are low compared to offsite doses from core damage accidents. A steam generator tube rupture accident without core damage releases only coolant activity. The curie content in coolant without core damage is low compared to the activities that might be present if there were core damage.

CONTAINMENT HOLDUP

Purpose

To learn how to model holdup in containment and better understand how that process affects source term and dose.

Background

Material released into the containment is subject to a variety processes that will reduce the amount available for release to the atmosphere. Particulates are reduced by natural processes including plateout. The longer particulates are held up in containment before release the more are removed. RASCAL models this removal process using exponential reduction factors based on NUREG-1228 and NUREG-1150.

Problem

The Wolf Creek plant has been operating at 80% of full power for the past year. Unexplained vibration problems were occurring and an administrative limit was imposed to try and reduce the occurrence of reactor trips. The plant shutdown at 2:15 P.M. when the vibration problems reoccurred. Additional complications resulted in the core being uncovered at 3:25 P.M. for 20 minutes. The core has since been recovered. The sprays are inoperative. It is postulated that the containment will reach design pressure and begin to leak at 100%/day (failure to isolate) within the next 12 hours. What would be the effect on the TEDE and thyroid doses if the containment were to begin leaking immediately versus 12 hours from now? Assume that the leak from containment is stopped after 3 hours. Use the Standard Meteorology dataset. For simplicity, ignore the fact that the containment would likely leak at the design rate during the holdup period.

Determine the TEDE and the thyroid CDE at 2, 10, **and 25** miles for the two scenarios and fill in the following table.

Dose type	Holdup (hrs)	Distance from release		
		2 miles	10 miles	25 miles
TEDE (rem)	0			
	12			
Thyroid CDE (rem)	0			
	12			

Also examine the source term for both scenarios and record the total curies released and the number of curies of Cs-137* released.

	Holdup (hrs)	Ci
Total	0	
	12	
Cs-137*	0	
	12	

Results

Page 212 has the answers and a summary of the inputs used to get those answers.

The plot below shows the thyroid doses with distance for the two scenarios.
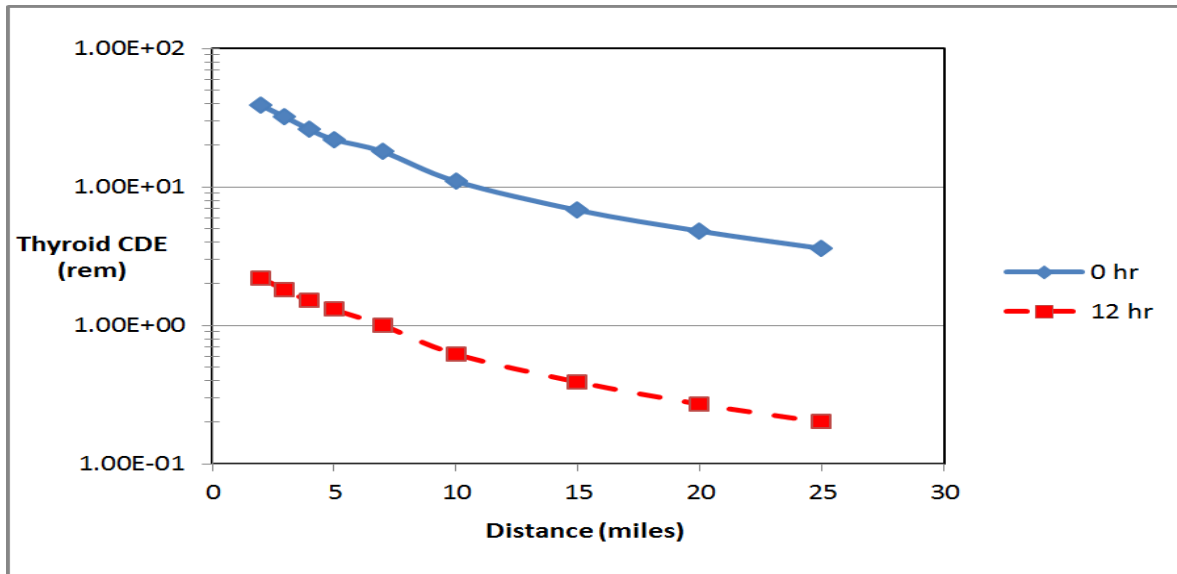
Even without sprays, if the release can be held up to allow natural processes to reduce the airborne amounts of the non-noble gases (e.g. I, Cs), the consequences of the release will be greatly reduced. This is seen in NUREG-1150 where significant reductions of dose impacts are predicted for late containment failure.

COOLANT SAMPLE

Purpose

To show how to use radionuclide activities measured in a coolant sample to determine the source term.

Background

The coolant sample source term option can be used only when coolant is being released directly to the environment. Thus, this source term option can be used for containment bypass release paths and steam generator tube rupture release paths.

The analysis of coolant activities will normally take a couple of hours to complete. Thus, the coolant sample source term option cannot be run early in the accident sequence. Since our objective is to make protective action decisions as early as possible, the coolant sample source term option is not likely to be available in time to be used for making protective action decisions. Other source term options will have to be used instead. However, the coolant sample source term option can be used as a way to improve the accuracy of previous estimates of release size. But, coolant sampling systems are designed for routine sampling and may not be able to measure the high activity concentrations that might result after significant core damage.

Problem

For the previous SGTR problem, assume that the post-accident sampling system (PASS) collected a coolant sample 15 minutes after reactor shutdown. The activity in the coolant was measured as the equivalent to 311 µCi of I-131 per milliliter (after being corrected for radiological decay back to the time the sample was collected).

Determine the TEDE and the thyroid CDE at 1 mile and fill in the following table.

Dose type	Distance from release
	1 mile
TEDE (rem)	
Thyroid CDE (rem)	

Results

Page 214 has the answers and a summary of the inputs used to get those answers.

SPECIFIED CORE DAMAGE AMOUNT

Purpose

To learn how to use the Specified Core Damage Amount option with the LOCA source term.

Background

The Specified Core Damage Amount source term option with the LTSBO and LOCA types allows you to specify how much fuel/core damage you expect. The same timings are used in the model for the methods but the code will calculate an effective time of core recovery to reach the specified damage state.

Problem

At 8:30 P.M. the Comanche Peak Unit 1 nuclear power plant reactor scrammed when it experienced a sudden drop in primary system pressure. A sudden rise in containment pressure and containment radiation levels indicate that a leak of coolant to the containment atmosphere had occurred. Failure of a pump supplying coolant caused that water level to drop temporarily causing some fuel rods to overheat.

At 09:00 P.M. a coolant radiation monitor indicated that the cladding on 4% of the fuel rods had been damaged.

Assume that the containment sprays were not activated. It is assumed that the containment will remain intact. Estimate off-site doses.

Dose type	Distance from release
	0.1 mile
TEDE (rem)	
Thyroid CDE (rem)	

Results

Page 215 has the answers and a summary of the inputs used to get those answers.

Notes on how we work the problem:

- We used the specified core damage point option with the LOCA source term type since we had an estimate of the total amount of fuel damage that occurred. We wanted to get to 4% clad damage and go no further.

- We assumed that the sprays were not activated and that with an intact containment the leak rate would be at design.

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FIELD MEASUREMENTS & DECISION MAKING

This section contains five exercises that deal with field measurements. The first problem uses field data to produce a RASCAL run that helps validate (or not) a protective action recommendation (PAR). The next two describe ways to use field data to validate or improve the source term to dose model projections. The fourth problem describes the use of the field measurement to dose model to calculate intermediate phase doses. The final problem in the section discusses comparing RASCAL results with NARAC and making a decision as to whether results are acceptable for release to other agencies.

PAR Evaluation

Purpose

To evaluate the protective action recommendation of a plant message and learn to use the field team dosimeter projection tool.

Background - Part I

When an NRC licensee declares a General Emergency Classification, there is always a protective action recommendation (PAR) issued for the public. This licensee PAR is required to be submitted to the State or local decision makers within 15 minutes of the declaration. States or local authorities will make a protective action decision (PAD) based on the licensee's and their own assessment. This is typically followed by a protective action order (PAO) issued by the Governor or a County Judge. Each 10 mile emergency planning zone (EPZ) is typically divided up into areas with geographical boundaries that can accommodate evacuation or sheltering decisions out to 2 miles, 5 miles, or 10 miles. Typical PADs are likely to be two miles all the way around (in all directions) and 5 miles in the downwind direction, or if severe, 5 miles in all directions and 10 miles downwind. This approach defines a 'keyhole' pattern and a licensee PAR identifying several areas will usually conform to protect the public in the entire keyhole area.

For each nuclear power plant, the EPZs and the areas that they're broken into are identified in the customized NRC Geographic Information System (GIS). Evacuated or sheltered areas can be highlighted and displayed with appropriate labels (wind direction, and whether it shows a PAR or PAD). The GIS areas usually include the population estimates for each area. EPZ plots can also be found in the State and licensee emergency plans found in eLibrary.

Since the State or Local decisions occur within about 15 minutes of a PAR, it is important for NRC dose assessors to anticipate this and be prepared with their own assessment for comparison and contrast. A completed RASCAL run will show if total effective dose equivalent (TEDE) and thyroid committed dose equivalent (CDE) EPA dose limits have been exceeded to any distance downwind. This will help define what and where protective actions should be taken. In this problem, we will need to first use field team data to complete a RASCAL run, then assess whether the areas impacted are consistent with the areas that the licensee is recommending for protective action.

Problem - Part I

You are given the following scenario data:

The Comanche Peak Unit 1 reactor was shut down at 8:37 A.M. At 10:54 A.M. a plant vent monitor (30 m above ground level) registered a noble gas release rate of 52.2 Ci/s. That is all you know at this time about the release.

Weather data

9:00 A.M.   Winds from 202°, 10 mph, stability class E, no precipitation, 78 °F
12:00 P.M.   Winds from 250°, 10 mph, stability class E, no precipitation, 83 °F

Field team readings

At 12:15 P.M. the following field team readings are reported:
Team 1 measures an I-131 concentration of 2.3E-6 uCi/cc at 0.5 miles downwind (centerline)
Team 2 measures an external gamma of 38 mR/h at 1 mile downwind (centerline)
Team 3 measures an external gamma of 16 mR/h at 2 miles downwind (centerline)

You are given Plant Message 8 and a map showing the protective action sectors (see following pages). Make a RASCAL run and using the results decide whether the PAR in the plant message is correct.

COMANCHE PEAK NUCLEAR POWER PLANT
NOTIFICATION MESSAGE FORM

Roll call: _____   _____   _____   12:31
          DPS   Somervell County   Hood County   Time

1. **Communicator:** (name)

2. [x] This is a drill   [ ] This is NOT a drill

3. **Message Number** 8   , **Originating From:** [ ] CR   [ ] TSC   [x] EOF

4. **Emergency Classification:** [ ] New   [x] Unchanged
    Declared at: Date: 02/10/2009   Time: 1054

 [ ] Unusual Event   [ ] Alert   [ ] Site Area Emergency   [x] General Emergency   [ ] Terminated

5. **Event Description:** [ ] New   [x] Unchanged
 Classification Path/EAL No. 2a, 2b, 2c, 2d, 2e
 Explain: Reactor coolant leak with fuel damage, radioactive containment breach has occurred or is likely.

6. **Radiological Data:** [x] New   [ ] Unchanged
 Radiological release in progress: [x] Yes   [ ] No
 A. If Yes: Expected Duration: 12.5 hrs. Started: Date: 02/10/2009   Time: 1054
 B. [ ] Radiological release has ended: Duration: _____ hrs. Terminated: Date: _____ Time: _____

7. **Recommended Protective Actions:** [ ] New   [x] Unchanged
   A. [ ] No recommended protective actions at this time
   B. [x] Recommended protective actions are:
      1. Evacuate from zones: 2A, 2B, 1A, 2D, 2E, 4A, 1B
      2. Shelter in zones: 1C; 2G; 2F
      3. Sectors affected: C, D, E

8. **DSHS - Radiation Control concurs with Recommendations in 7 above:**
    [x] Yes   [ ] DSHS Not Contacted   [ ] No

9. **Meteorological Data:** [ ] New   [x] Unchanged

   A. Wind Speed   10 MPH; Wind direction From   250 Degrees
   B. Stability Class (Check One): [ ] A   [ ] B   [ ] C   [ ] D   [x] E   [ ] F   [ ] G
   C. Precipitation (Check One): [x] None   [ ] Rain   [ ] Sleet   [ ] Snow   [ ] Hail   [ ] Fog

10. **Remarks:** Expected duration of radiation release is 12.5 hours. Advise remainder of EPZ to continue listening to the EAS network for updates.

11. **Approved:** _____   (Emergency Coordinator) Date: 02/10/2009   Time: 1230
         Print / Sign

EPP 203-8 Rev. 12

Plant Message 8

Comanche Peak Protective Action Recommendation
Evacuate Red – 1A, 1B, 2A, 2B, 2D, 2E, 4A
Shelter Yellow – 1C, 2F, 2G

Steps in the Solution to Part I

To be able to compare downwind values with the I-131 air concentration there must be some iodine in the source term released. Since no iodine release rate value was provided, assume initially that the I-131 release rate is 1000 times less than the noble gas rate. Plant Message 8 – Item 6A provides the release duration of 12.5 hours. Given that duration, the end of calculations should go at least 15 hours to ensure the plume trailing edge passes 10 miles. Do an initial calculation run.

We want to see how the model predicted I-131 air concentration compares with that measured by Field Team 1 at 0.5 miles. Go to **Detailed Results**. We want to look at the **I-131 Air Exposure or Concentration** result type for the close-in calculation footprint. The time closest to the measurement time should be selected. In this case that is 12:09.

Move the cursor over the centerline cells and find the one for 0.5 miles. On the right-hand side of the screen read off the concentration. 6.0E-07 µCi/cc.
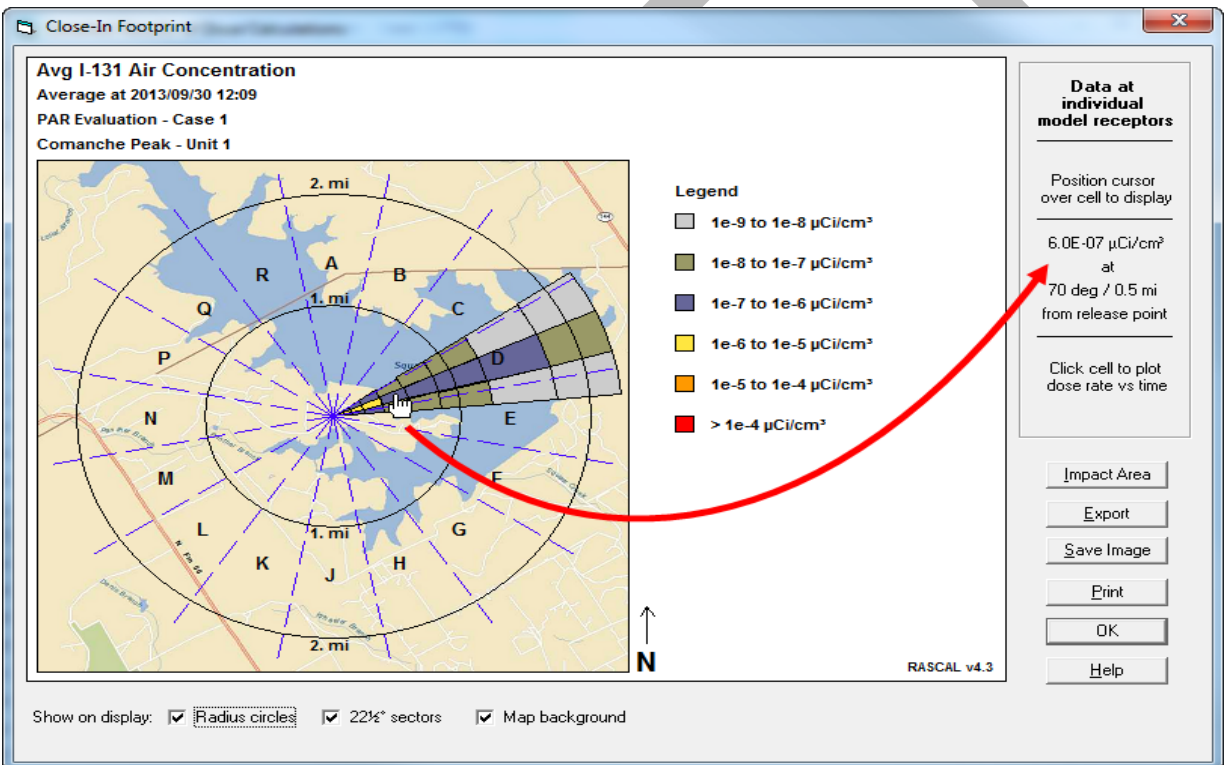
That is lower than the measured concentration of 2.3E-6 µCi/cc. Go back and adjust the iodine release rate (up by about a factor of 4) to get a better match of the model prediction to the field team I-131 reading.

Before finalizing the RASCAL result, double check the expected gamma readings at the known centerline distances. Discretion will have to be used to balance or choose the best of several gamma measurements at various distances to align the RASCAL result with. It's important to have several measurements to insure that the trends in place make sense and lend confidence to the measurements.

Results

After the RASCAL run has been made consistent with the field measurements given, your results should be similar to the following results. The inputs to these results are shown on page 216.

There is a screen shot for each field measurement given. Each screenshot has been annotated to show which footprint cell was queried and the reported cell value.
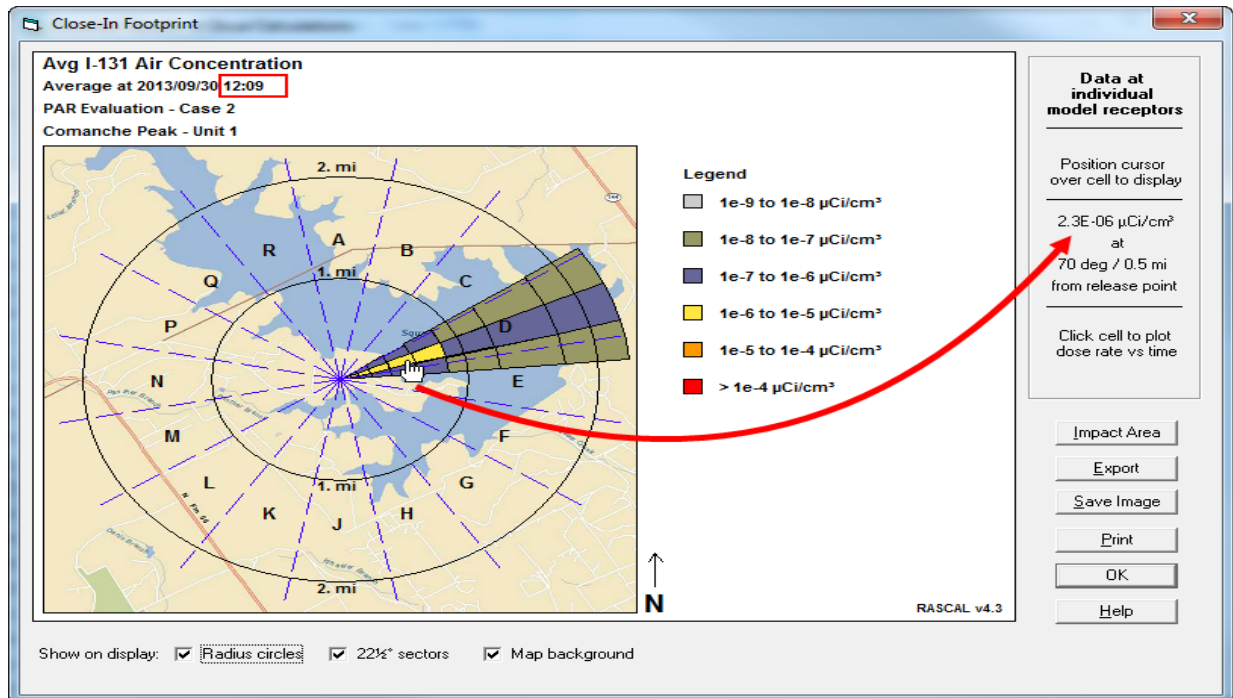
I-131 air concentration at 12:09, 0.5 miles on centerline (70 deg): **2.3E-6 μCi/cm³**. (Team 1 reported 2.3E-6 μCi/cm³)
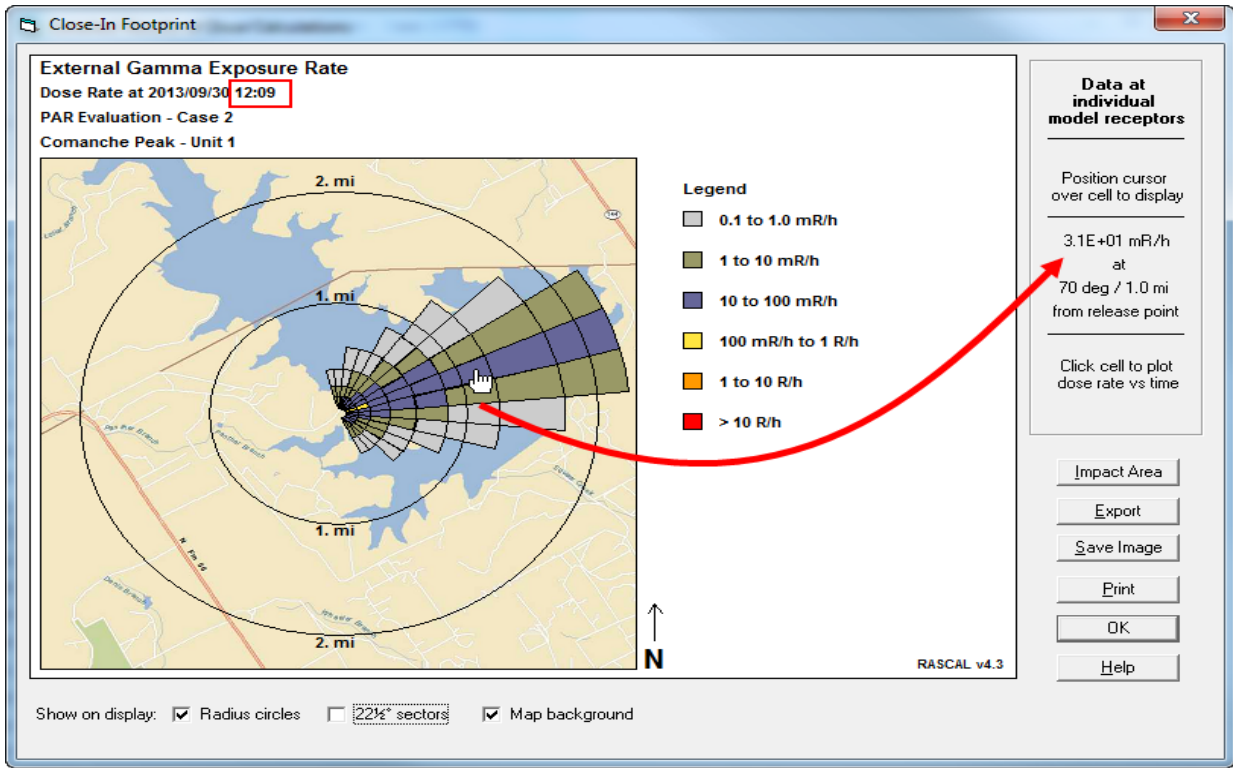
External gamma at 12:09, 1.0 miles on centerline (70 deg): **3.1E+1 mR/h.** (Team 2 reported 38mR/h)
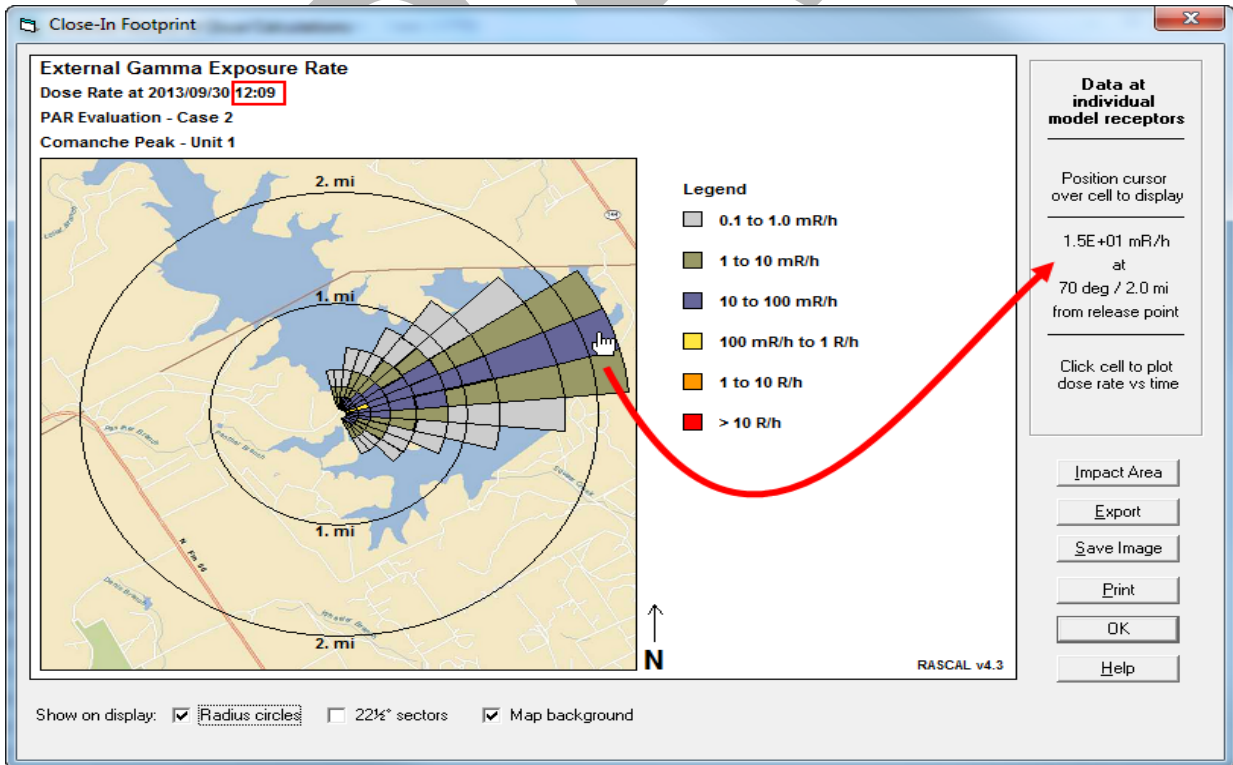
External gamma at 12:09, 2.0 miles on centerline (70 deg): **1.5E+1 mR/h**. (Team 3 reported 16 mR/h)

The following screen shots represent the TEDE and thyroid CDE results from the final RASCAL run. Your results should be similar. In this case, the thyroid CDE should drive the PAR. Notice that it exceeds the EPA limit of 5 rem, beyond 2 miles. (Note that 5 rem is exceeded in the plume model, but not in the puff model at two miles).
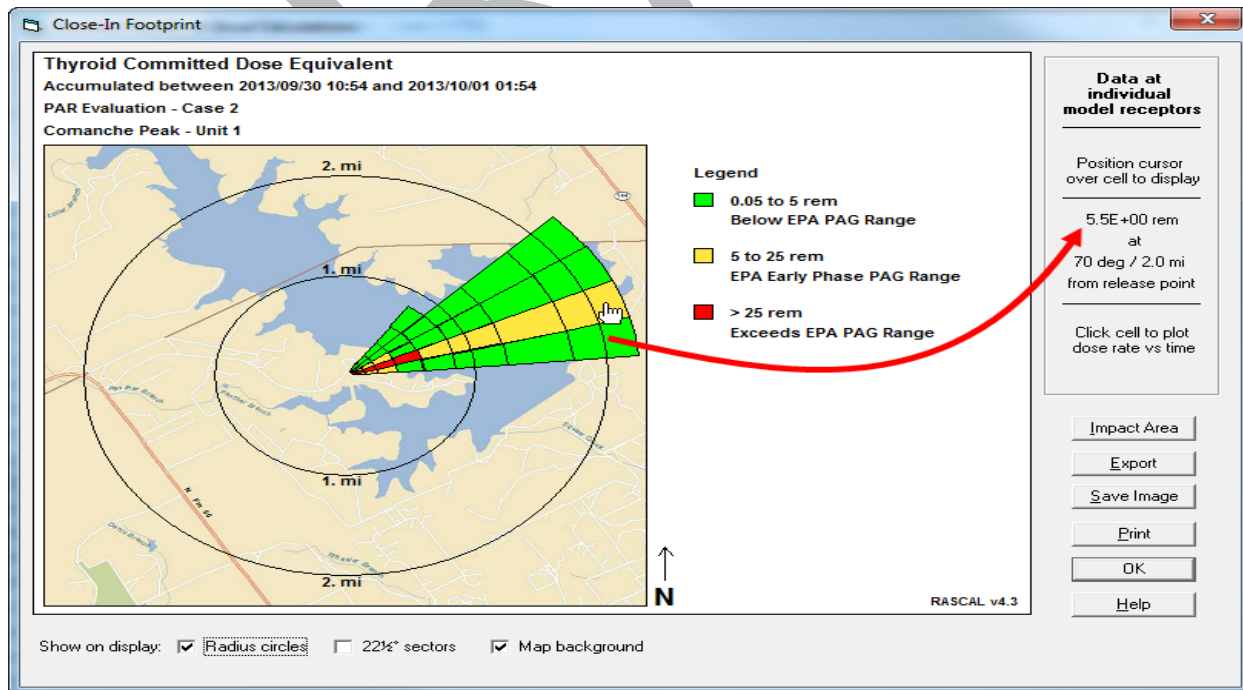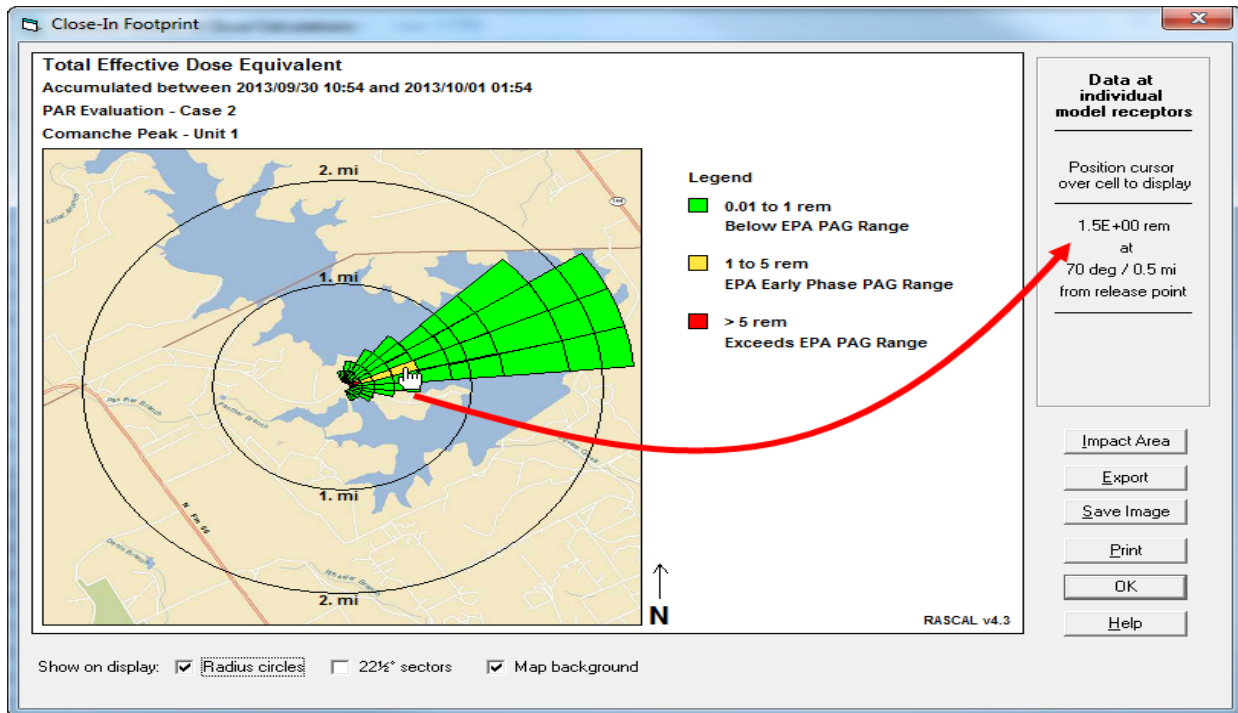
Results - Part I

Page 216 has the answers and a summary of the inputs used to get those answers.

A common approach would be a PAR to evacuate (or shelter) 2 miles all the way around (all directions) and 5 miles downwind. Some licensees will follow an evacuation recommendation with a recommendation to shelter those areas beyond the keyhole, out to 10 miles.

Is the RASCAL result consistent with the wind direction and supportive of the PAR on the licensee Notification Form?

Yes. Unless significant differences arise or it is apparent that the licensee has missed something, NRC will tend to support the licensee PAR. In this case, both results are consistent.

Background - Part II

States are responsible for calculating the potential internal dose that field team members may incur during plume transversals. Many field team procedures direct them to take a 10 minute air sample at centerline during plume passage. RASCAL calculates the external dose contribution based on the measured gamma rate (assuming it remains constant) over each 15 minute interval and uses the radionuclide mix to calculate the internal dose. RASCAL converts exposure rate to dose rate then adds in the internal dose. If a team's actual direct reading dosimeter is greater or less than the DRD reading that RASCAL predicts, the related doses can be scaled, based on what is actually measured. For this problem we will assume that the teams have taken KI before entering the vicinity of the plume.

Problem - Part II

Use the field team gamma rates for Teams 2 and 3, at their respective distances and times, answer the following questions:

1. Assume that each team is guided to take a 10 minute air sample at their location and are in the plume for 15 minutes to complete the process. What is each team members resulting dose from this exposure to the plume?

2. About what percent of that dose is internal dose? Note that RASCAL is using a conversion factor of 1 mR exposure to 0.7 mrem effective dose (EPA 400, P 7-11).

3. Is the internal dose contribution consistent for both Teams 2 and 3?

4. If two evacuating members of the public, not having taken KI, were to each inadvertently traverse the plume centerline for 15 minutes (same average gamma rate) at 1 and 2 miles downwind, what would be the associated total doses in each case?

5. What percentage would the internal dose contribution be in each of these cases?

6. If the release rate stays constant and Team 2 makes a number of passes, sometimes taking air samples, at 1 mile, such that their DRD at 5:00 pm reads 30 mR, can the team's total and internal dose contribution be easily calculated? Notice that the correction factor with KI at 12:09 is 0.9 mrem/mR while at 16:54 it is 1.0. By taking an average correction factor, 0.95, over this time interval, approximate but representative doses can be calculated.

Note

The correction factor changes over both distance and time for constant release rates. Significant increase in release rates can occur, so internal dose should be checked and logged regularly for response teams.

Steps to Part II Solution

Question 1: Begin by going back to the footprint display of the external gamma exposure rate for 12:09. Use the cursor to select the cell at 1.0 mile (Team 2).
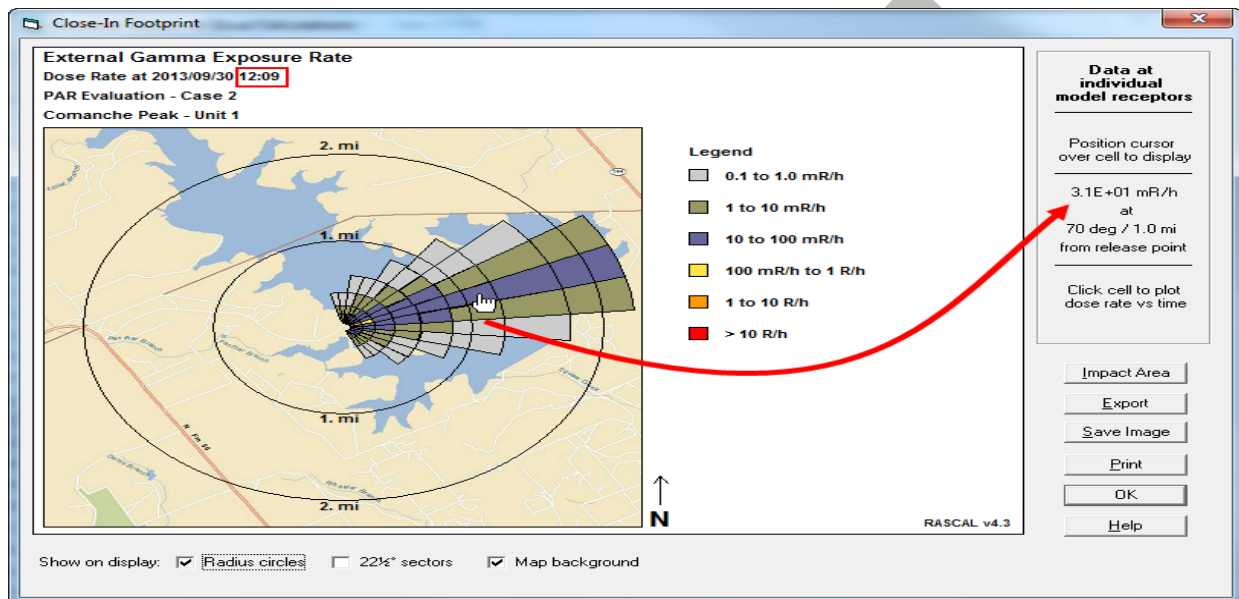
Click on the cell to display the dose rate vs time plot.
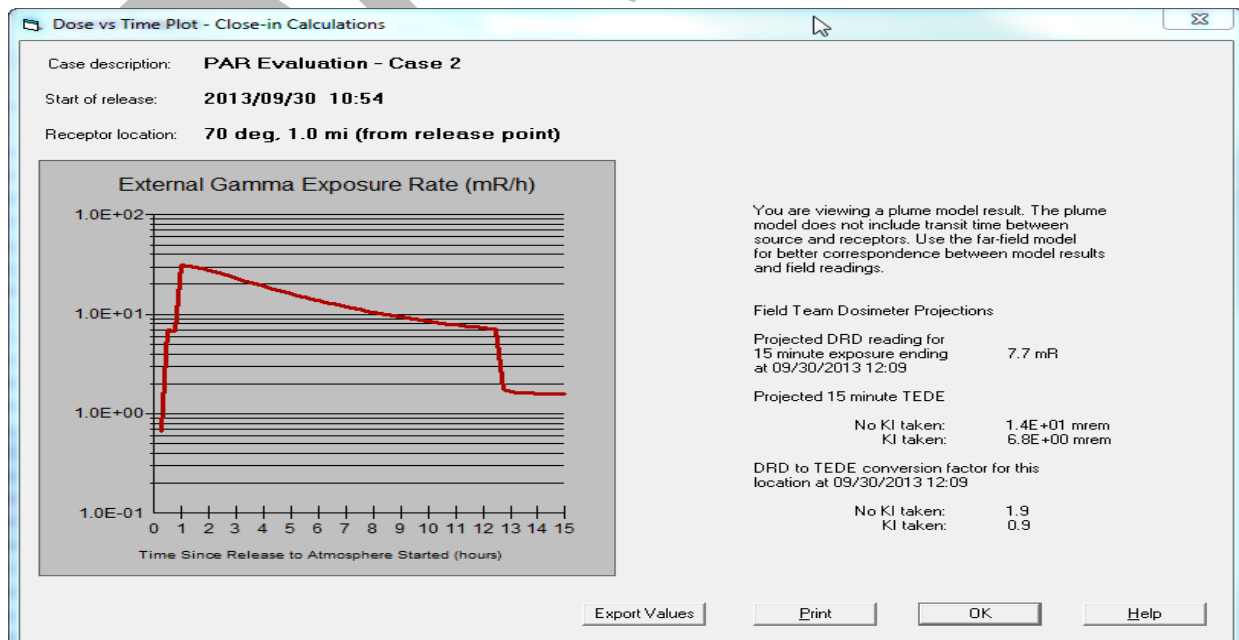
Note the **Field Team Dosimeter Projections** section on the right side of the display.

```
Field Team Dosimeter Projections

Projected DRD reading for
15 minute exposure ending        7.7 mR
at 09/30/2013 12:09

Projected 15 minute TEDE

          No KI taken:      1.4E+01 mrem
          KI taken:         6.8E+00 mrem

DRD to TEDE conversion factor for this
location at 09/30/2013 12:09

          No KI taken:      1.9
          KI taken:         0.9
```

The total dose (internal and external) for the 15 minute exposure period assuming KI was taken is 6.8 mrem.

Repeat the above process selecting the footprint cell at 2.0 miles (Team 3) to get the Team 3 total dose.

Question 2: RASCAL 4.3 provides a TEDE relative to the DRD reading so it can be determined if any dose limits are exceeded. What percentage of that is internal dose? The correction factors in RASCAL 4.3 have units of mrem/mR. If we divide the correction factor by 0.7 mrem/mR, inherent in RASCAL's calculation, we get relative dose with the external dose factor always 1.0.

So, for team 2 start with (0.9 mrem/mR)/(0.7 mrem/mR) = 1.3. 0.3 is internal dose contribution.
      Team 2: (1 - (1 / 1.3)) = 23% internal dose with KI

Repeat the calculation for Team 3 values.

Question 3: Compare the percentage values calculated for question 2.

Question 4: This time we assume no KI was taken and use the corresponding values for total estimated external and internal dose for the 2 and 3 mile points.

Question 5: Repeat calculations as done in question 2 using the no KI values.

Question 6: Use the DRD value provided in the problem, with the average correction factor, to calculate the estimated TEDE and the internal dose contribution in mrem. For Team 2 that would be:

      TEDE: 30 mR x 0.95 mrem/mR = 29.5 mrem
      Internal dose: (1-(1/1.4)) = 29%   29 mrem x 0.29 = 8.3 mrem

Repeat the calculation for Team 3 if their dosimeter reading is 15 mR after a similar series of plume passes.

Page 216 has the complete answers.

COMPARING FIELD MEASUREMENTS WITH RASCAL RESULTS

Purpose

To learn how to confirm that RASCAL results are consistent with field measurements (or not).

Background

Detailed results allow not only varying the result type but examining doses and dose rates at intervals during the modeling duration. For example, instead of looking at thyroid doses for the entire calculation period, you could look at the thyroid dose over an interval in the middle of that period. This can be useful when considering plume arrival times and duration at certain locations relative to protective action decisions.

RASCAL calculates exposure rates for closed window gamma meter readings taken at 1 m above ground level. When considering field measurements, one must use the wind speed and direction to anticipate when the plume will be in the vicinity of a particular measurement. Plume leading edges will typically ramp up readings over a short period of time. Plume trailing edges will yield a rapid decrease in readings in the model. For fairly stable release scenarios (release rates constant for an hour or more) using field team measurements to validate prior RASCAL dose projections is a recommended method for improving quality control. Two or more sets of field team data should be used. If fairly consistent, these data from a couple of locations can increase confidence in the RASCAL dose projections over the entire 10 mile EPZ.

Problem

At 10:00 A.M. the Fermi nuclear power plant reactor trips. An hour later (at 11:00 A.M.) a release through the stack begins. This is a monitored pathway so there is data on the release rates:

    Noble gas release rate 1000 Ci/s,
    Total iodine release rate 5 Ci/s, and
    Particulate release rate 0.5 Ci/s

The release is expected to continue for 4 hours. The onsite meteorological tower reports the following conditions at the time of release: winds from 190 degrees at 5 mph, stability class E, and an air temperature of 47° F.

At 1:00 P.M., Field Team 1 measures a centerline gamma reading, 3 miles downwind, of 300 mR/h. Five minutes later Field Team 3 calls in a centerline gamma reading, at 8 miles downwind, of 175 mR/h. Do these readings confirm that the RASCAL TEDE dose projections are representative of the impact (assuming that the release continues for 4 hours)?

Each of these field teams takes an air sample and within about 15 minutes moves to a background area to take measurements on the silver zeolite air sample cartridges. These measurements are translated to I-131 concentrations using their pre-calculated conversion factors. Team 1 report an I-131 air concentration at centerline, 3 miles downwind, of 1.9E-06 µCi/cc. Team 3 report 1.0E-06 µCi/cc for the centerline reading at 8 miles downwind.

Do these readings confirm that the RASCAL Thyroid CDE dose projections are representative of the impact (assuming that the release continues for 4 hours)?

Steps to make the comparison

First we need to make a RASCAL run using the given release information. Remember to use the stack height (168 feet) as the release height.

Once the calculations are complete, to get the reading needed for comparison with the field data, make the following selections on the detailed results screen.

1. For result type, select **External Gamma Exposure Rate**.

2. For time period for exposure, only the **Rate at single time** option is available. Select the time to match the field reading (**13:00**).

3. Select **Footprint – From 10-mile Calculation** as the display format.

4. Click the **Display Result** button.

We are interested in the gamma rate at a point 3 miles downwind of the release. Move the cursor over the colored cells and watch the display in the upper right. As you traverse the cells at some point the box will show 9º at 3.0 miles. This appears to be the closest model point to the sampling location of Field Team 1.
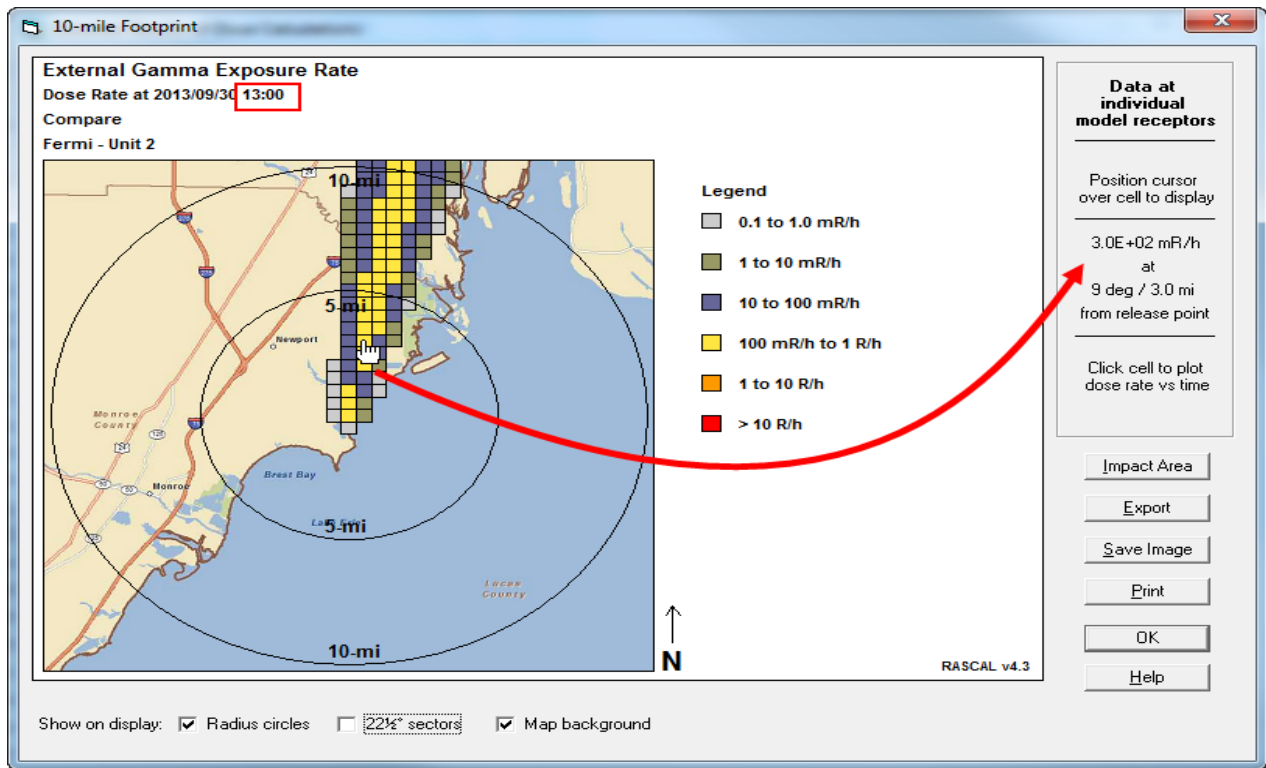
Record the gamma exposure rate for that point: 300 mR/h

Next, position the cursor at the centerline grid position, about 8.0 miles downwind.
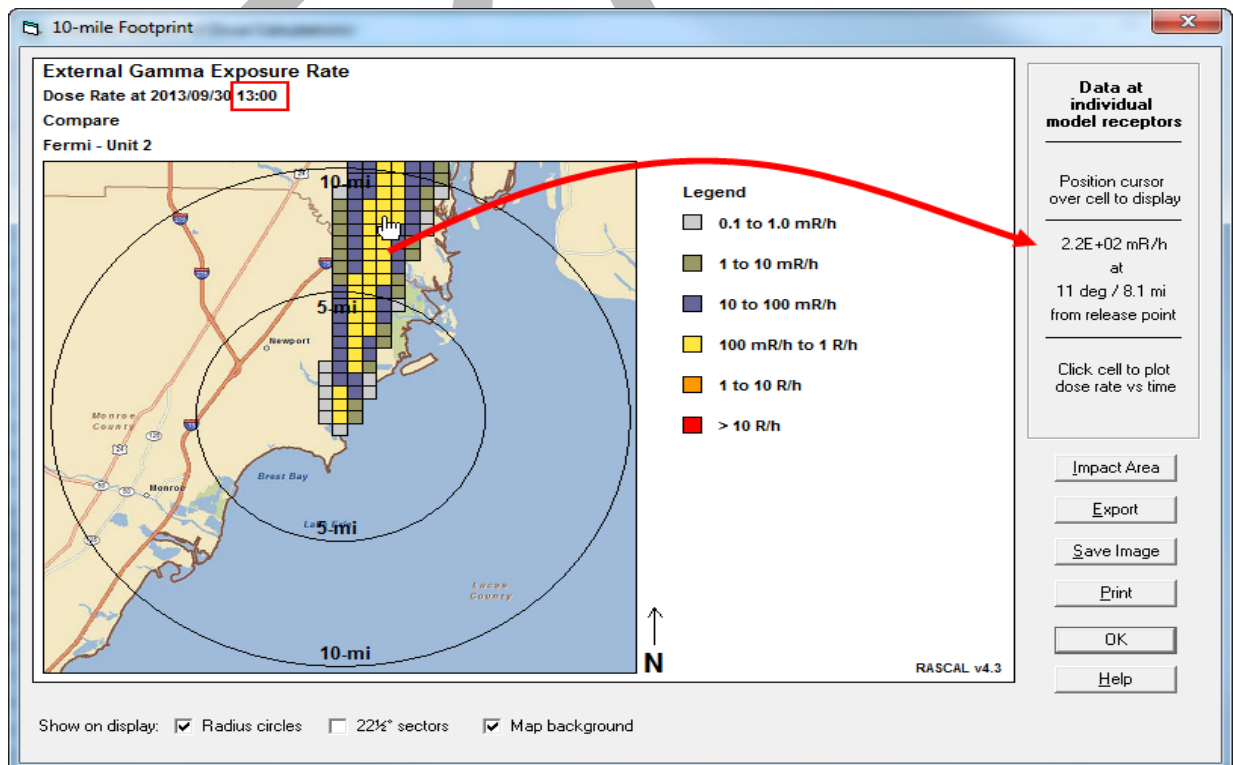
Again, record the gamma exposure rate: 220 mR/h

Switch the result type displayed to **I-131 Air Exposure or Concentration**. Position the cursor at the centerline grid position, about 3.0 miles downwind. Record the value: 1.6E-06 μCi/cc.
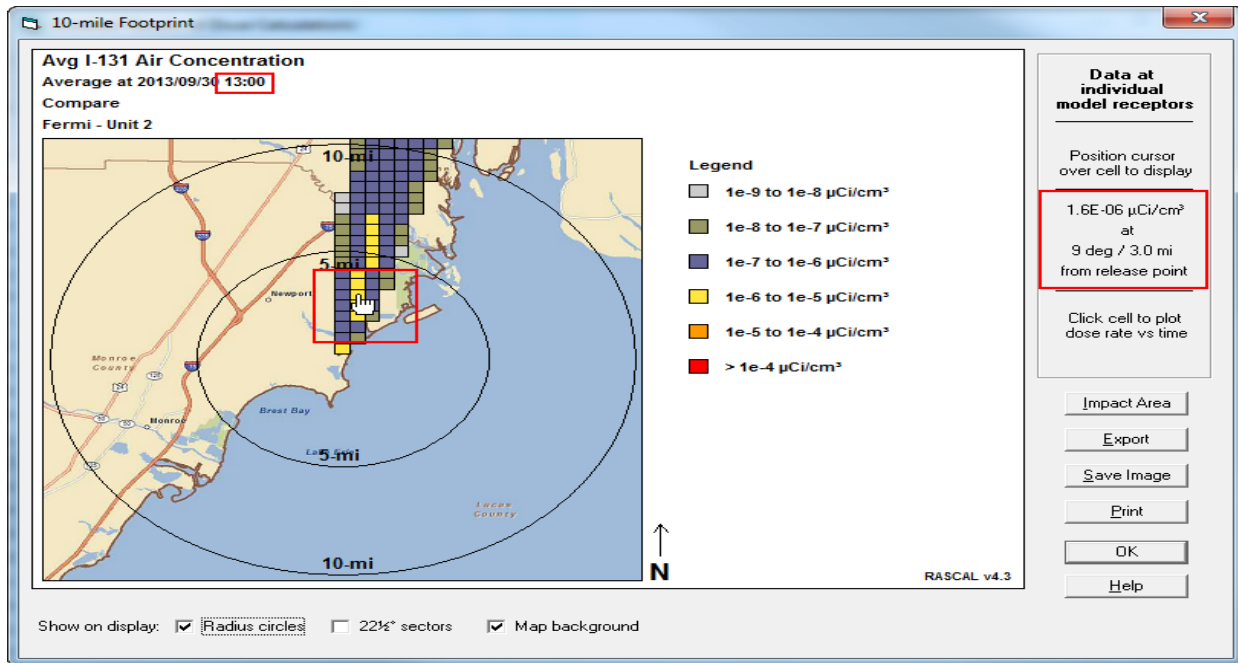
Position the cursor at the centerline grid position, about 8.0 miles downwind.
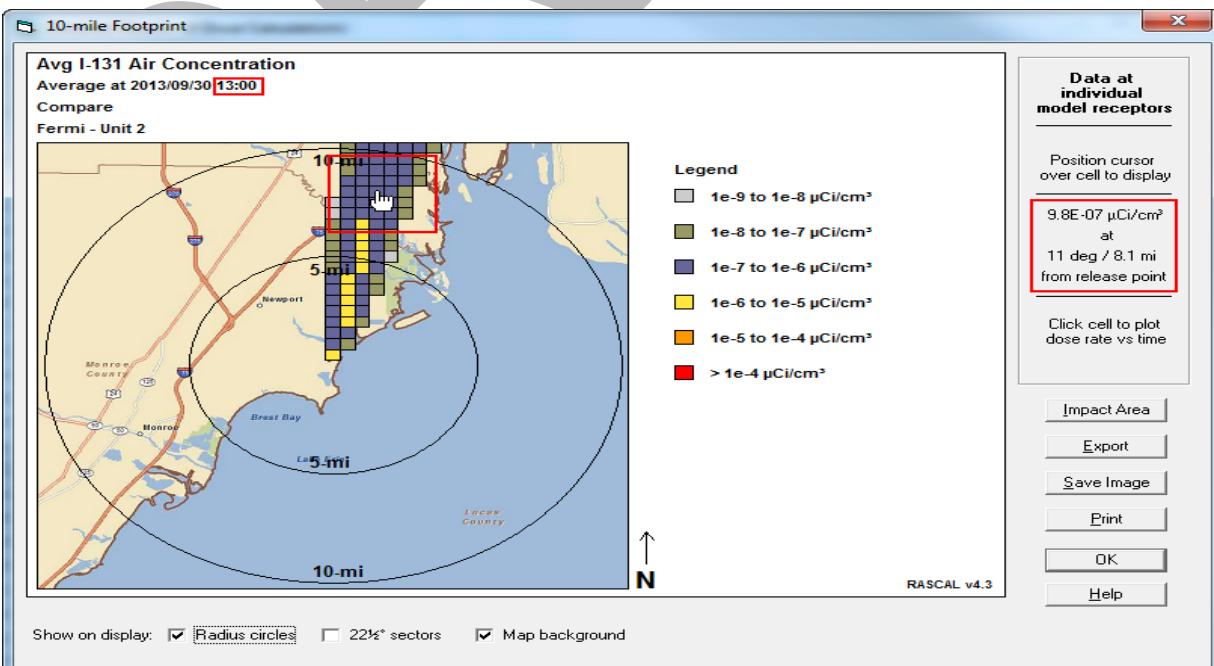
Record the value: 9.8E-7 µCi/cc

Results

Page 217 has the answers and a summary of the inputs used to get those answers.

The table below shows the field team and RASCAL values for gamma exposure rate and I-131 air concentration at 3 and 8 miles.

Distance	Measurement	Field Team at 13:00	RASCAL projection
3 miles	Gamma	300 mR/h	300 mR/h
	I-131	1.9E-06 µCi/cc	1.6E-06 µCi/cc (or Ci/m^3)
8 miles	Gamma	175 mR/h	220 mR/h
	I-131	1.0E-06 µCi/cc	9.8E-07 µCi/cc (or Ci/m^3)

These results are pretty close considering the uncertainties involved. The RASCAL results are nevertheless a modeled projection. In a real situation, greater variations are more likely than not. Be sure to confirm with checks of multiple field readings. In this case, we feel comfortable that the RASCAL run is representative of the projected impact. Tell the supervisors and decision makers that the field readings are consistent and add confidence to the model results.

If the field team results were consistently higher or lower than the RASCAL results, then the run could be scaled to model what is being measured in the field. This would improve dose projections for all areas in the EPZ and update decision makers.

Additional Questions

If you have several field teams all making field measurements in the plume, can you set up receptors at specific distances to project the gamma rates? Field team doses? Public doses?

NORMALIZING THE MODEL TO MATCH FIELD TEAM DATA

Purpose

To learn how to normalize RASCAL Source Term to Dose model results to match field team data.

Background

The basic method for normalizing the model results consists of two parts: obtaining the field measurements and then adjusting the model runs. Most States and nuclear power plants have field teams and practice them during drills and exercises. Teams will typically traverse the plume identifying the edges (maybe 10 times background) and taking centerline gamma readings. These readings are taken at some distance from the plant (release point) and located using a GPS. The centerline direction can be approximated by identifying the downwind azimuth.

If licensee or State dose projections are based on field measurements, then they are ***forward dose projections***. That is, they consider only the dose received from the sampling time forward. This needs to be considered when trying to normalize a RASCAL calculation with dose projections based on a field measurement.

Consider the plot below representing the hypothetical exponential decay trend of some reactor fission products available for release in a typical scenario.
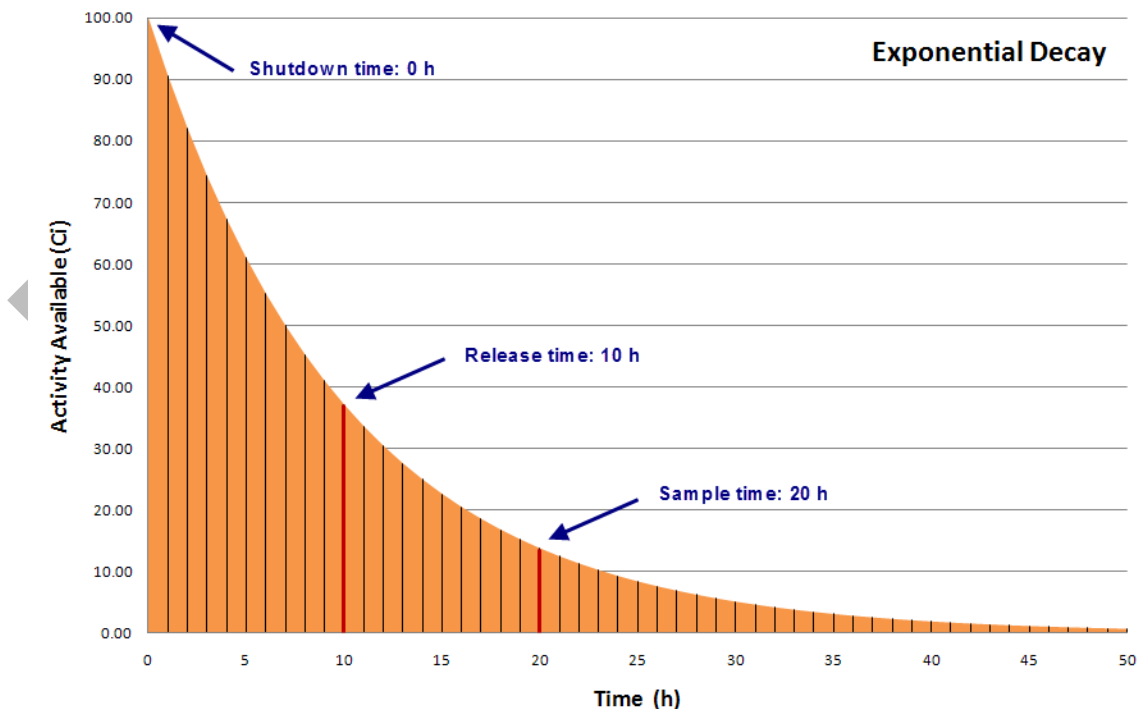
When we enter a shutdown time in RASCAL this would be represented as time zero.

When we enter a sample time (stack or field team measurement) this defines the radionuclide mix activity on the decay curve at that time. The sample time correlates to release rates at that time. The time can be the time of the stack flow rate measurement, the time of the latest licensee dose projection based on current release rates, or the time a field team is making measurements that will be used to back-calculate release rates.

The dose projections for the TEDE and Thyroid CDE will directly correspond to the area under the curve from the release time.

Therefore, if you want to compare RASCAL dose projections with licensee or State dose projections, and that report time is 20 h, then enter the sample time as 20 h and the release time as 20 h. Do not enter the start of release time, 10 h. The result will be a forward dose projection from 20 h and is appropriate for current licensee EOF or field team based dose projections. In a low level, gradually increasing release scenario, PARs will tend to be based on forward dose, not dose received.

In the above case, entering the (given) release start time of 10 h would result in a much larger dose projection related to the area under the curve from 10 h. This would not be applicable for a field team based dose comparison, but would be representative of total dose to a public member not evacuating the area.

Problem

There has been a release from the Palisades nuclear power plant. The **Nuclear Plant Event Notification** form and the **Nuclear Plant Event Technical Data** forms have just been received (next 2 pages). Given the field team readings in the notification form, produce a RASCAL result that correlates well to the field team readings taken at that location.

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Nuclear Plant Event Notification

☐ Actual Event   ☒ Drill

Plant Contact Information

Nuclear Power Plant: **PALLISADES**

Plant Communicator: _____

Time of Communication: County _____
S.O.M. _____
NRC _____

Calling From: ☐ Control Room   ☐ TSC   ☒ EOF   Other: _____

Call Back Telephone Number: _____

Plant Message Number: **9**

Current Classification

☐ Unusual Event   ☐ Alert   ☐ Site Area Emergency   ☒ General Emergency   ☐ Termination

This classification was declared as of: Date **8-16-06**   Time **11:18**

Reason for Classification

☐ Abnormal Rad Levels / Radiological Effluent   ☐ System Malfunction

☒ Fission Product Barrier Degradation   ☐ Hazards and Other Conditions Affecting Plant Safety

☐ Cold Shutdown/Refueling System Malfunction

IC Number **FG1**

☐ Independent Spent Fuel Storage Installation Events

①

Radiological Release in Progress Due to Event   **②**

☒ Yes   START **11:18 Am**   ☐ No

Protective Action Recommendations   **③**

☐ None

Evacuation of Area(s):   ☒ 1   ☒ 2   ☐ 3   ☐ 4   ☐ 5

In-Place Shelter of Area(s):   ☐ 1   ☐ 2   ☐ 3   ☐ 4   ☐ 5

PAR based on: ☒ Dose Calculations (Nuclear Plant Event Technical Data-EMD 32b required)   ☐ Plant Status   ☐ Security Event
☐ Other _____

Meteorological Data   **④**

Wind Direction (degrees): From **230** To **50**   Wind Speed (MPH): **2**

Stability Class: **F**   Precipitation: ☐ Yes   ☒ No

Recorder: _____   Date: _____   Time: **1156**

Authority: NUREG 0654
Compliance: Voluntary

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Nuclear Plant Event Technical Data

☐ Actual Event   ☒ Drill

Plant Contact Information

Nuclear Power Plant: __PALLISADES__

Plant Communicator: _____

Calling from: ☐ Control Room ☐ TSC ☒ EOF Other: _____

Call Back Telephone Number: _____

Plant Message Number: 9

Meteorological Data

Wind Direction (degrees): From __230__ To __50__ ① Wind Speed (MPH): __2__

Stability Class: __F__   Precipitation: ☐ Yes ☒ No

Reactor Information

Is the reactor shut down? ☒ Yes Time of shutdown: __0831 HRS__ ② ☐ No

Plant Status/Additional Information

_____ ☐ Attached

Release/Offsite Dose Data

Release pathway: ☒ Airborne ☐ Waterborne ③ MAIN STEAM LINE

Projected release duration (hrs): __2__ Effluent point(s): __STEAM LINE__

☒ Actual ☐ Potential Time of Calculation: __1150__

Based on: ☐ Monitor (in plant) ☐ Sample (in plant) ☒ Back Calculation of Field Data ☐ Other_____

④

Release Rates (Ci/sec)	
Noble Gas	1.310 E+1
Equivalent I -131	1.310 E-2
Particulate	

Projected Dose Rate

Distance	TEDE (mrem/hr)	Thyroid CDE (mrem/hr)
Site Boundary	3.920 E+2	5.461 E+3
2 Miles	1.059 E+2	9.987 E+2
5 Miles	4.225 E+1	2.842 E+2
10 Miles	2.181 E+1	1.085 E+2

⑤

Projected Dose

Distance	TEDE (mrem)	Thyroid CDE (mrem)
Site Boundary	7.841 E+2	1.092 E+4
2 Miles	2.118 E+2	1.997 E+3
5 Miles	8.449 E+1	5.684 E+2
10 Miles	4.361 E+1	2.169 E+2

Measured Offsite Radiation Levels

Distance	Time	Highest Reading (mR/hr)	Iodine Cartridge (NetCPM)	Sector
Site Boundary 0.5 miles	1145	210		C
( ) Miles				
( ) Miles		⑥		
( ) Miles				

Recorder: _____ Date: _____ Time: __1156__

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Step by Step

Review the Notification Forms

First let's see what information is available on the forms. The **Nuclear Plant Event Notification** form has the following key points:

1. A General Emergency was declared at 11:18 A.M. because of fission product barrier degradation.

2. The release started at 11:18 A.M.

3. The PAR is to evacuate areas 1 and 2 based on dose calculations.

4. The winds are from 230 degrees at 2 mph with stability class F and no precipitation.

Key points in this first form relevant to the RASCAL run are the start of the release and the weather. The event classification and PAR are interesting but not as input to the model.

The **Nuclear Plant Event Technical Data** form has much more information useful to the RASCAL run.

1. Weather data again (agrees with the data on the other form).

2. Time of reactor shutdown.

3. Expected release duration of 2 hours.

4. Release rates. Notice that the I-131 equivalent release rate is given as a factor of 1000 times lower than the noble gas release rate.

5. Projected dose rates and doses.

6. A single offsite gamma reading.

Run a RASCAL Calculation

Our task is to use trial and error adjustments to the release rates to match the dose rates given. The source term option of **Effluent Releases – By Mixtures** seems like a good place to start since we were given release rates for noble gases and iodines. However, remember that the projected doses are not based on them. Although no iodine concentration is given, in this case the I-131 release rate can be kept at the given percentage or ratio of the noble gas rate. (Be aware that partitioning, or changing chemical and physical forms, can occur with transport. Having iodine sample data from the measurement site is more optimum.)

When comparing RASCAL results from a field team reading, enter the release time as 11:45 (field measurement time) if desiring to project the dose to the public from that time forward. EPA would guide to do this. If we assume that the licensee dose projections are based on an 11:18 release start time, and we want to compare to their results, use 11:18 as the release time. It's more correct to use 11:45, so for this problem use 11:45 A.M. as the release time. In this case both times are relatively close, so will it make much difference?

Check dose projections

Compare projected TEDE and thyroid doses at 0.5, 2.0 and 5.0 miles from the event notification form and the RASCAL maximum dose values table.

Distance	TEDE (rem)		Thyroid (rem)	
	Form	RASCAL	Form	RASCAL
0.5 miles	0.78	0.054	10.92	0.57
2.0 miles	0.21	0.017	2.00	0.26
5.0 miles	0.08	0.006	0.57	0.07

There is not very good agreement. Why might this be?

The key here is the check box above the projected doses that indicates the projections are based on back calculations of the field data (#6 offsite reading with no iodine concentration). That means the doses and dose rates are not from the effluent release rates shown!

Compare model results with field measurement

Compare the gamma meter measurement at the time and location with the gamma reading provided on the report. Focus on the mid region distances, 2 and 5 miles. Ultimately we will arrive at a RASCAL 10 mile EPZ dose projection, based on the field team reading taken at 0.5 miles. Ideally this will be consistent with the licensee dose projections.

Note that the sample taken time is the time that the field team took their measurement. Note also that the release time is not the same as the sample time so the default does not apply. Assume the meteorology, including the forecast, does not change and is constant from 10:00 A.M.

After calculating doses, go straight to the **Footprints** tab and choose **External Gamma Exposure Rate** and set the rate at a single time close to the time of the field team measurement. Note that a two mile per hour wind would carry the release to a position 0.5 miles downwind in about 15 minutes, so data suggests that the team should see the plume at the time they indicated.

Display the result and position the cursor on the centerline at 0.5 miles.
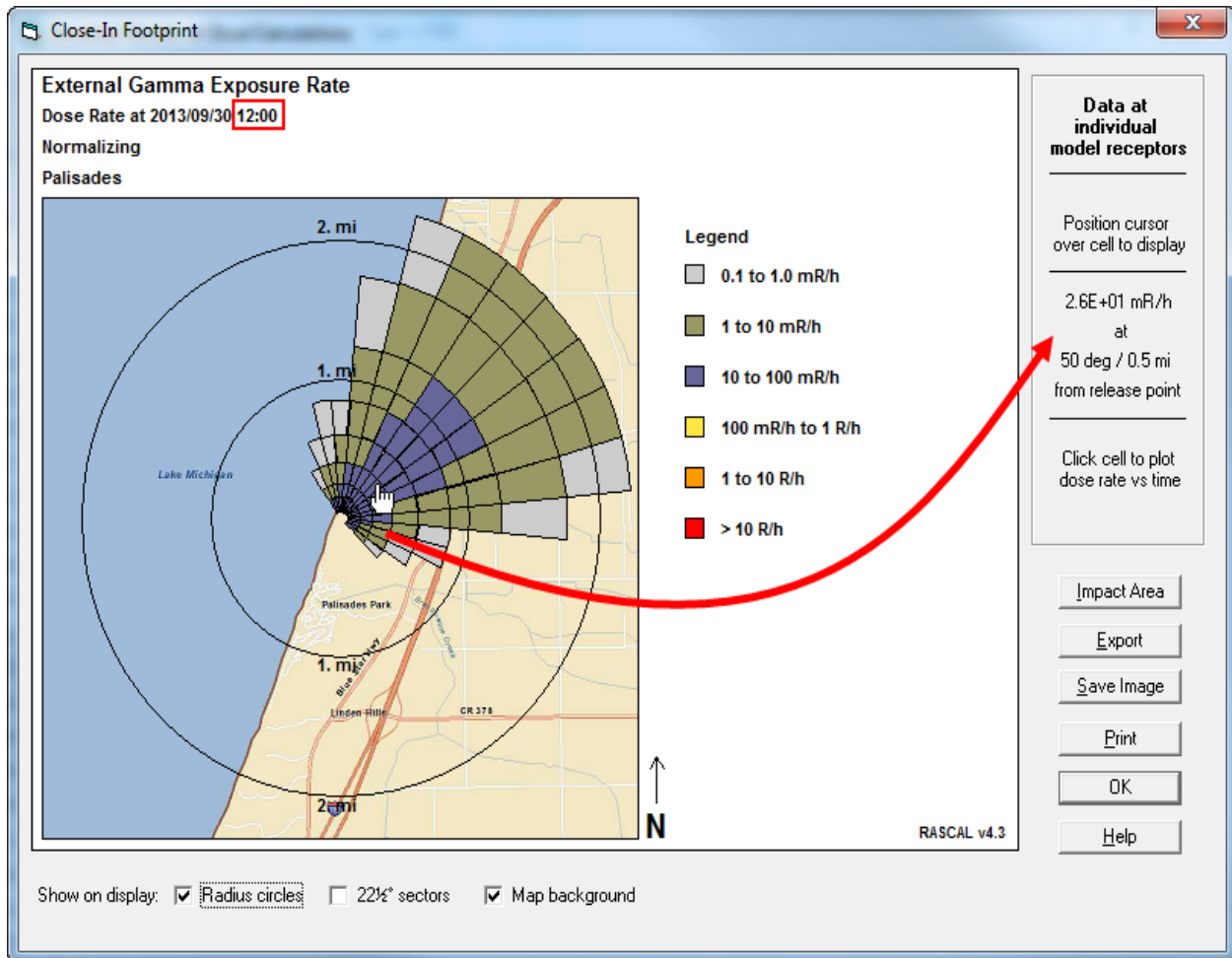
We see a gamma exposure rate of 26 mR/h at 0.5 miles downwind. This is roughly a factor of eight lower than the licensee reported value of 210 mR/h.

Adjust source term

Let's adjust our release rates in the source term definition. Since our results were about 8x low, increase both the noble gas and I-131 equivalent releases rates by 8x. The new values will be: 104.8 for noble gases and 0.104 for I-131.

Recalculate doses and check the gamma exposure rates again.
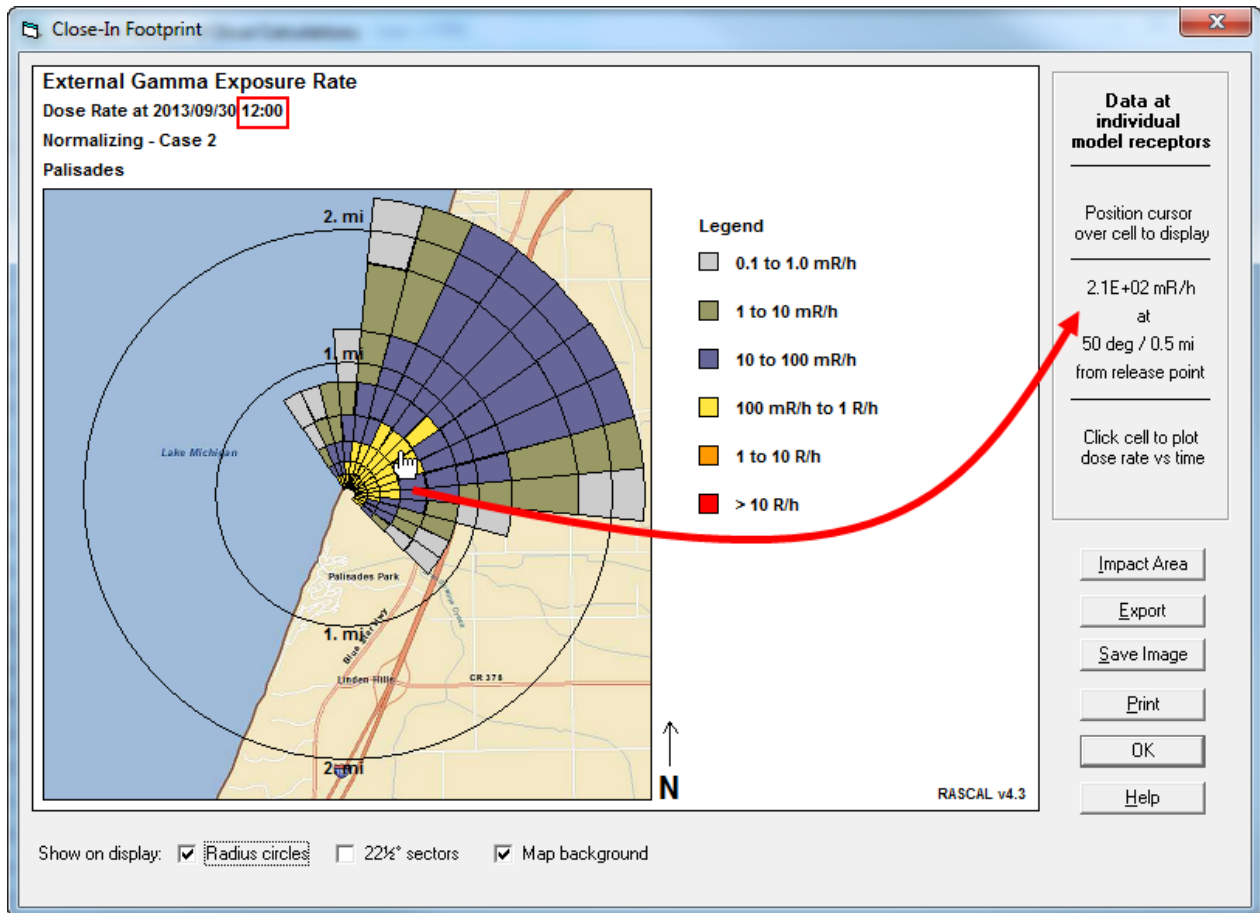
Now, we see a gamma exposure rate of 210 mR/h at 0.5 miles downwind. This is close to what the field team measured at this location. If we had an iodine concentration from an air sample, now would be the time to similarly calibrate the I-131 release rates by comparing against the **I-131 Air Concentration** plot at 0.5 miles downwind and scaling it. We could also check other field team gamma measurements at other distances and times to insure that our plot is representative, if they were available.

Check dose projections again

Finally, let's check the RASCAL dose projections again for consistency. From the Nuclear Plant Event Technical Data form and the RASCAL Maximum Dose Values table we see that the thyroid CDE and TEDE dose projections at select distances.

Distance	TEDE (rem)		Thyroid (rem)	
	Form	RASCAL	Form	RASCAL
0.5 miles	0.78	0.43	10.92	4.50
2.0 miles	0.21	0.13	2.00	2.00
5.0 miles	0.08	0.05	0.57	0.57

Conclusion

We would expect RASCAL to project lower doses for three reasons. The RASCAL 4 atmospheric dispersion and transport model results in greater dispersion and lower centerline dose projections. In addition, the RASCAL model takes into account radioactive decay and plume depletion during transport, factors not included in all other models. The TEDEs compare fairly well at 5 miles (RASCAL a little low), as does the RASCAL Thyroid CDE dose (568 mrem licensee vs 570 mrem RASCAL). Before sharing the result as final, it would be good practice to obtain an I-131 concentration or two from field measurements for verification that the RASCAL result is representative, as it may be in need of a further I-131 release rate adjustment.

FIELD MEASUREMENT TO DOSE MODEL

Purpose

To learn how to use the Field Measurement to Dose model to calculate intermediate phase doses based on measured ground concentrations.

Background

The Field Measurement to Dose model would normally be used after releases had ended to determine whether the area is habitable or do residents need long-term relocation. The model estimates doses based upon measurements of ground contamination. Within the NRC, the site team is the most likely user. The calculations can also be done using the Turbo-FRMAC code.

Two EPA pathways are considered: groundshine and inhalation due to resuspension. Both pathways are affected by weathering. The material becomes less accessible through time as natural processes work. The EPA (EPA, 1992) sets the following limits:

1st year PAG = 2 rem (20 mSv)

2nd year or any subsequent year objective = 0.5 rem (5 mSv)

50 year objective = 5 rem (50 mSv)

Problem

There has been a release from the Palisades nuclear power plant. The release started at 12:30 P.M. and lasted approximately 45 minutes. Field teams have been dispatched to determine where and how much radioactive material was deposited. The first report to come in provides:

Sample ID: ABC123

Location: a street corner in a subdivision downwind of the plant; bearing 145° at 4 miles

Sample data

Nuclide	Concentration microcuries/meter^2
Ba-140	1.4
Cs-134	0.6
Cs-137*	0.35
I-131	1.7
I-132	1.3
La-140	1.3
Sr-89	1.0
Te-132	1.2

The residents were evacuated early in the accident. Is it now safe for them to return to their homes?

Step by Step

Start the **Field Measurement to Dose** model from the main RASCAL screen.
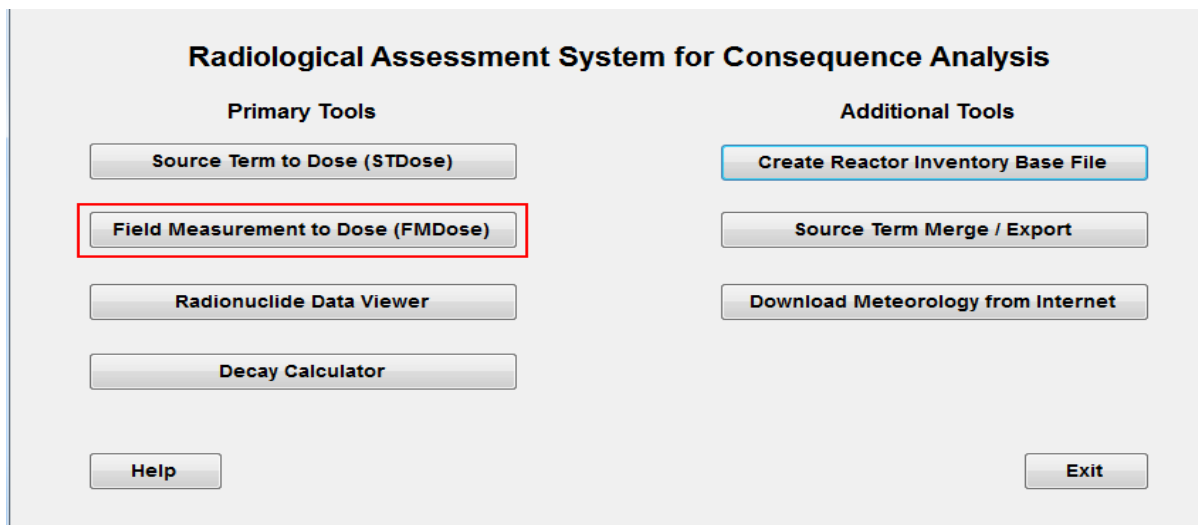
Operation of the user interface is similar to the Source Term to Dose model; buttons on the left, top to bottom. A tab area shows the summary of inputs and the results of the calculations.
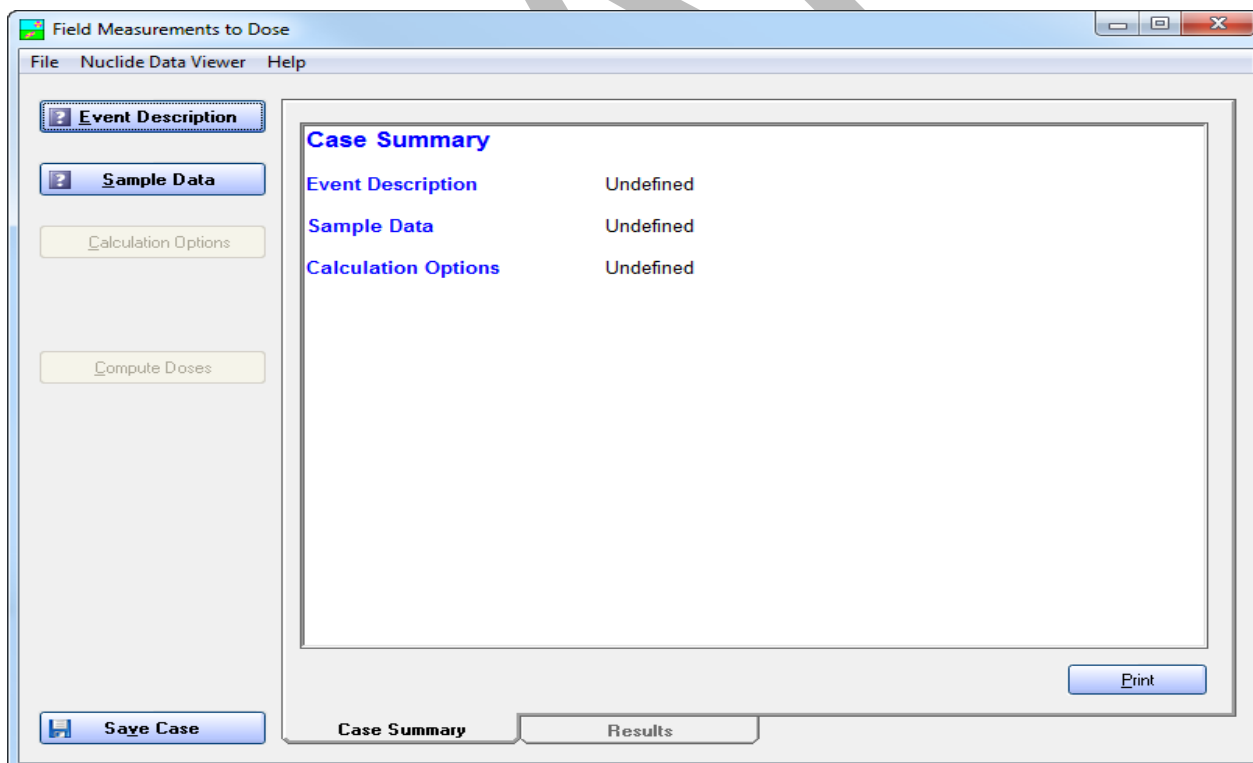
Begin by selecting the **Event Description** button on the main screen. That will display the following:

1. Event name: **Palisades NPP**
   An entry is required but the text is used for labeling only; it has no impact on the calculations.

2. Analyst name. Put a check in the box and enter your name.

3. Release started: put a check in the box, change the date if needed, and enter a time of **12:30.** This information is optional and is used only for labeling purposes.

4. We could also enter the latitude and longitude of the release point.

Click **OK** to return to the main screen. Note that the **Event Description** button now has a checkmark and the case summary has been expanded.

Next, select the **Sample Data** button.

1. Type in the sample ID provided: **ABC123**

   This entry is required and should uniquely identify the sample. It will be used to label the results.

2. The sample is a ground concentration with units of **μCi/m².** The defaults are correct so no change is needed.

3. If provided, you may optionally describe the location of the sample, the type of sample, and the time of deposition.

4. Enter the nuclide names and concentrations for the sample.

   You can speed up the data entry process by typing in the nuclide name without using the drop-down list and then tabbing to the next column to enter the concentration. Tabbing again gets you to the next row ready for the next nuclide name.

When the sample data is complete, click the **OK** button.

Finally, from the main screen, click the **Calculation Options** button.
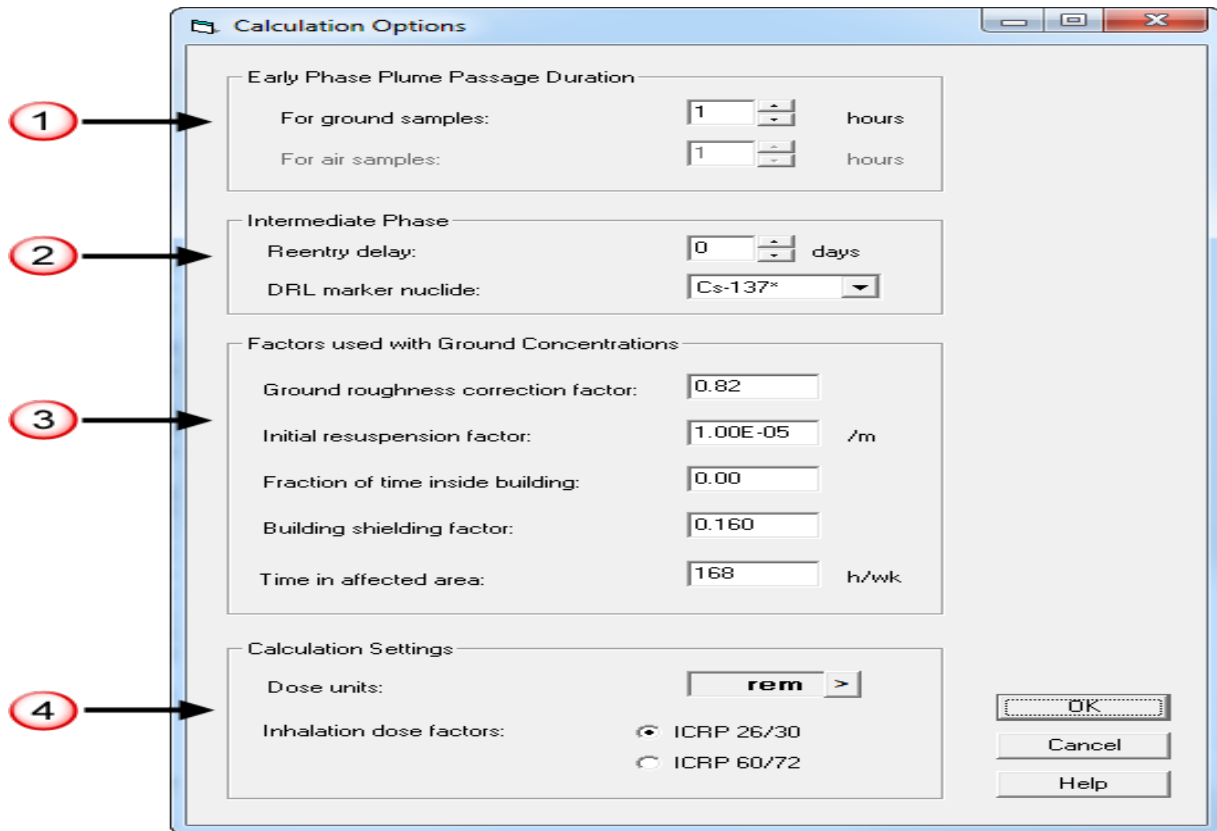
1. We are not interested in the early phase doses so the exposure period can be left at the default of 1 hour.

2. Leave the reentry delay at **0** days. Select **Cs-137*** as the DRL marker nuclide.

   The reentry delay is used for areas in which people have evacuated. For example, consider a case in which the measurements and analysis needed to define a relocation area will take a week. The EPA PAGs are based on the concept of averted dose - the dose that can be avoided by taking an action. To determine if an area is suitable for reentry a week after the accident, the dose that could be averted by not re-inhabiting the area is compared to the EPA IP protective action guides. Thus, the first year PAG would be compared to the dose not including the first week.

   In some instances it may be difficult to use the exposure rate DRL to identify areas where doses might exceed the protective action guides. Examples are when the exposure rate is near background levels or when there are no gamma-emitting radionuclides in the mix. In those instances, it may be easier to measure the surface concentration of a particular marker radionuclide rather than the exposure rate. You may select the marker nuclide to be used from the list of measured nuclides on the ground.

3. Leave the five factors at their defaults.

   The ground roughness correction factor accounts for the fact that the ground surface is not perfectly smooth. Some of the ground shine radiation will be intercepted by this uneven surface and cannot contribute to the dose. EPA used to use a value of 0.7 but now we use 0.82.

   Intermediate-phase inhalation doses are calculated assuming activity on the ground is resuspended and then inhaled. The resuspension process in the model begins with the user entered resuspension

factor and decreases with time. The default initial resuspension factor is **1.00E-06** /m and represents normal conditions for a temperate climate area. The value should be changed only if there is reasonable confidence that resuspension rates will be different. For example, with a very dry and windy area, the factor might be increased.

The fraction of time inside building value describes the percentage of time a person is assumed to be indoors and shielded from exposure to material on the ground. A value of 0.0 means the individual is always outside and received no shielding.

The building shielding factor is the amount by which being inside a building reduces the exposure. This is a function of the building construction type and materials.

The time in affected area is the number of hours per week that a person will be present in the contaminated area averaged over one year. The default value of 168 hours/week assumes people never leave the area.

4. Set the dose units to whatever is most useful. SI units can be used if desired. Also select which set of inhalation dose factors should be used.

Click the **OK** button to return to the main screen again.

Now the problem is fully defined and the program is ready to calculate the intermediate-phase doses.
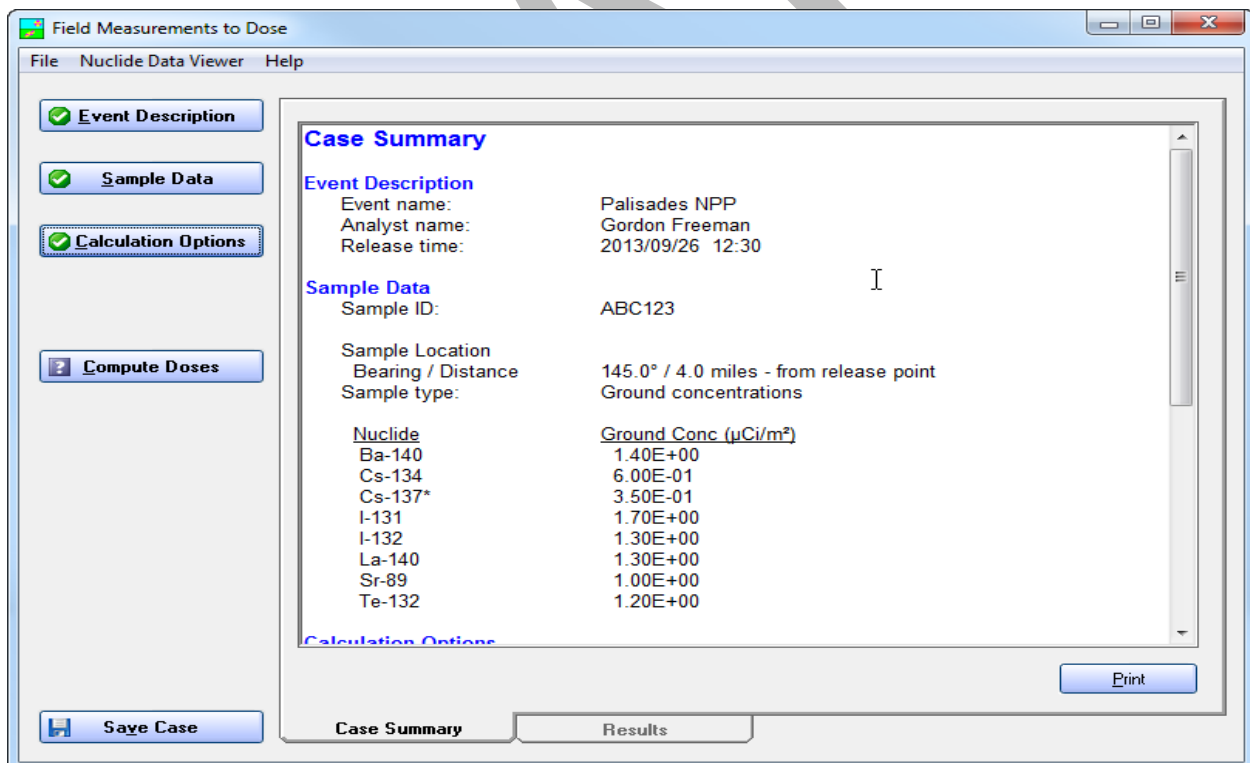
Click the **Compute Doses** button. The results will automatically be displayed.
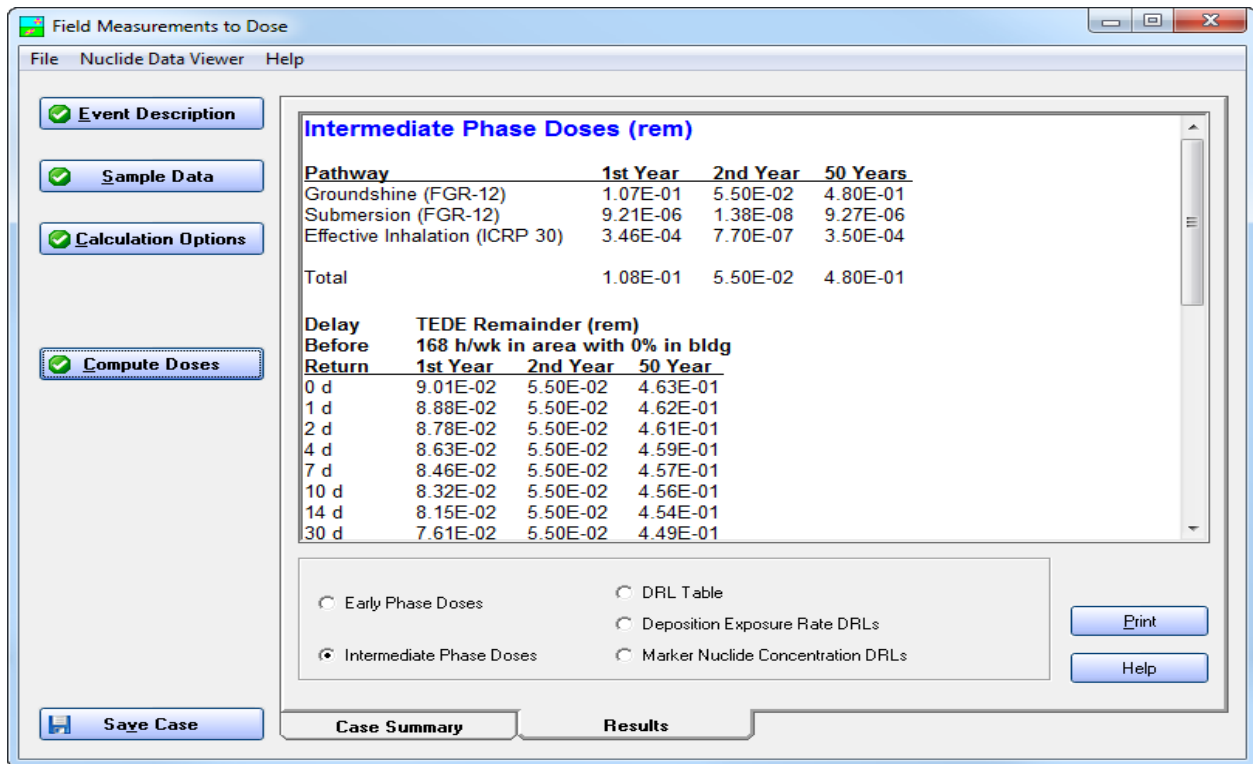
Results are far below the EPA PAGs for the intermediate phase. Based on that single result, people can immediately return to their homes in the area. However, measurements at only one location and/or only one sample are *not* enough data to make a decision.

For a typical "reactor mix" of radionuclides, if the first year dose is below the PAGs then the second and fifty years doses will be below PAGs as well. Also, the groundshine dose will usually dominate.

Results

Page 218 has the answers and a summary of the inputs used to get those answers.

Consider a Cs-137 RDD incident where the local population within the 500 mrem/yr contour (2nd year PAG) has been relocated. Cs-137 has a 30 year half-life. During subsequent consideration (after 60 days) of the 50y PAG (5 rem) it is determined that only about 100 mrem/yr should be allowed.

1. Should individuals in buffer zones less than 500 mrem be allowed to return?

2. Should individuals not relocated, but within a 100 mrem/yr contour, be relocated now?

RASCAL - NARAC Comparisons – Millstone 2010

Purpose

To determine whether NARAC (or IMAAC) products based on a RASCAL source term are complete, representative of the current scenario, and accurate for release to other Federal, State, and Local response agencies.

Background

The National Atmospheric Release Advisory Center (NARAC) is located at the Lawrence Livermore National Laboratory. It provides technical and scientific support and modeling for releases into the atmosphere. Under the National Response Framework, NARAC will become the host of the Interagency Modeling and Atmospheric Assessment Center (IMAAC). NRC Headquarters, and on occasion the NRC Regions, practice sending a scenario-representative RASCAL source term to NARAC for processing using their three-dimensional model and improved graphing capabilities.

Problem – Part I

The Millstone Exercise was held on October 19, 2010. Using the following scenario data from that exercise, do a RASCAL dose calculation and compare your results with those from NARAC.

Event Type	Nuclear Power Plant
Event Location	Millstone - Unit 2
Source Term	Containment Radiation Monitor Reactor shutdown: < date > 09:36 Monitor location: Containment Dome (not user selectable) Containment radiation monitor readings (R/h): < date > 11:20 100 < date > 11:27 1232 < date > 11:32 1373 < date > 11:36 1510 < date > 11:40 1655 < date > 11:45 1777 < date > 11:50 2307 < date > 12:00 2569
Release Path	Containment Leakage / Failure Release height: 10.0 m Leak rate events: < date > 11:50 Leak rate (% vol) 8% / day < date > 11:50 Sprays Off

Meteorology   Dataset type: Actual

Time	Type	Direction (Degrees)	Speed (mph)	Stability Class	Precipitation
09:45	Obs	177	8.8	A	None
10:00	Obs	190	8.7	A	None
10:15	Obs	191	9.0	A	None
11:00	Obs	191	9.0	A	None
12:00	Obs	190	9.0	C	None
13:00	Fcst	190	9.0	C	None
14:00	Fcst	190	9.0	C	None

Calculation   Distance of calculation: Close-in + to 10 miles
Options   End calculations at: Start of release plus 10 hours

As you are entering and using this scenario, consider the following questions :

- Does neglecting the first six containment monitor readings make a significant difference?
- Can you characterize the impact with just the last containment monitor reading?
- Consider whether adding the last two lines of met data changes anything.
- Use your source term tab to determine the duration of the release for this case.
- What might you do differently?

Then, after making you final calculations, consider the question:

Are the NARAC results for the TEDE and Thyroid CDE that follow representative of this RASCAL run and appropriate for further distribution to decision makers?

The two NARAC plots are shown on the following two pages.

EXERCISE EXERCISE EXERCISE

Radiological Release Dose Including Plume Passage
(Total Effective Dose Equivalent 0-96Hrs)

Actions and Long-Term Effects

	Description	(rem) Extent Area	Population
	Exceeds 1 rem total effective dose.	>1 161m 15,009m2	0

Note: Areas and counts in the table are cumulative.
Population Source = LandScan USA V1.0.

Effects or contamination from October 19, 2010 15:50 UTC to
October 23, 2010 15:50 UTC at or near ground level.
Release Location: 41.308600 N, 72.168100 W
Material: CS-134 + CS-136 + CS-137 + CS-138 + I-131 + I-132 + I-
133 + I-134 + I-135 + RB-88 + RB-86 + XE-138 + XE-131M + XE-
133M + XE-133 + XE-135M + XE-135 + KR-83M + KR-85 + KR-85M
+ KR-87 + KR-88
Generated On: October 19, 2010 17:27 UTC
Model: ADAPT/LODI
Comments:
Doses shown are total accumulated from the beginning of release.
Release starting at 10/19/2010 11:50:00 EDT for 10 hr
canned met at 10/19/2010 10:00:00 EDT;10/19/2010 11:00:00
EDT;10/19/2010 12:00:00 EDT
ICRP30 DCF's were used for this plot

Map Size: 1.1 km by 1.1 km   **Id:** Production.rcE18038.rcC1

EXERCISE EXERCISE EXERCISE

Radiological Release Early Phase Guidance (Radioiodine)
(KI Administration based on Thyroid Radioiodine CDE)

Effects and Actions

Description	Extent Area (rem)	Population
EPA Early Phase PAG for considering evacuation. Shelter in place if no evacuation.	>5 380m 62,536m2	0

Note: Areas and counts in the table are cumulative.
Population Source = LandScan USA V1.0.

Effects or contamination from October 19, 2010 15:50 UTC to October 23, 2010 15:50 UTC at or near ground level.
Release Location: 41.308600 N, 72.168100 W
Material: I-131 + I-132 + I-133 + I-134 + I-135
Generated On: October 19, 2010 17:27 UTC
Model: ADAPT/LODI
Comments:
Doses shown are total accumulated from the beginning of release. Release starting at 10/19/2010 11:50:00 EDT for 10 hr canned met at 10/19/2010 10:00:00 EDT;10/19/2010 11:00:00 EDT;10/19/2010 12:00:00 EDT
ICRP30 DCF's were used for this plot

©2005 Tele Atlas and/or LLNL   Globe GeoEye   **Id:** Production.rcE18038.rcC1

Map Size: 1.1 km by 1.1 km

The final RASCAL run produced the following close-in doses.

Using this run, compare the RASCAL TEDE and thyroid CDE close-in footprints with the NARAC plots.

The NARAC plots only extend for several hundred meters. The RASCAL close-in footprints go out to 2 miles (~3,200 meters). This makes it difficult to use the RASCAL plots for comparison. So, instead, use the maximum dose summary or the detailed results – numeric tables to get the RASCAL values for the comparison. The footprint can be used to confirm the plume direction.

EXERCISE EXERCISE EXERCISE
Radiological Release Dose Including Plume Passage
(Total Effective Dose Equivalent 0-96Hrs)

Map Size: 1.1 km by 1.1 km   Id: Production.rcE18038.rcC1

Actions and Long-Term Effects

	Description	(rem) Extent Area	Population
(yellow)	Exceeds 1 rem total effective dose.	>1 161m 15,009m2	0

Note: Areas and counts in the table are cumulative.
Population Source = LandScan USA V1.0.

Effects or contamination from October 19, 2010 15:50 UTC to October 23, 2010 15:50 UTC at or near ground level.
Release Location: 41.308600 N, 72.168100 W
Material: CS-134 + CS-136 + CS-137 + CS-138 + I-131 + I-132 + I-133 + I-134 + I-135 + RB-88 + RB-86 + XE-138 + XE-131M + XE-133M + XE-133 + XE-135M + XE-135 + KR-83M + KR-85 + KR-85M + KR-87 + KR-88
Generated On: October 19, 2010 17:27 UTC
Model: ADAPT/LODI
Comments:
Doses shown are total accumulated from the beginning of release.
Release starting at 10/19/2010 11:50:00 EDT for 10 hr
canned met at 10/19/2010 10:00:00 EDT;10/19/2010 11:00:00 EDT;10/19/2010 12:00:00 EDT
ICRP30 DCF's were used for this plot

The plume footprint shows good directional agreement.

The numeric table shows a dose of 1.06 rem TEDE at 160 m (0.16 km). Again, good agreement with the NARAC results.

NOT APPROVED BY NARAC
NARAC
National Atmospheric Release Advisory Center

EXERCISE EXERCISE EXERCISE
Radiological Release Early Phase Guidance (Radioiodine)
(KI Administration based on Thyroid Radioiodine CDE)

Set 1 - Initial Plots
Set 1 - Exercise

Effects and Actions			
	Description	(rem) Extent Area	Population
	EPA Early Phase PAG for considering evacuation. Shelter in place if no evacuation.	>5 380m 62,536m2	0

Note: Areas and counts in the table are cumulative.
Population Source = LandScan USA V1.0.

Effects or contamination from October 19, 2010 15:50 UTC to
October 23, 2010 15:50 UTC at or near ground level.
Release Location: 41.308600 N, 72.168100 W
Material: I-131 + I-132 + I-133 + I-134 + I-135
Generated On: October 19, 2010 17:27 UTC
Model: ADAPT/LODI
Comments:
Doses shown are total accumulated from the beginning of release.
Release starting at 10/19/2010 11:50:00 EDT for 10 hr
canned met at 10/19/2010 10:00:00 EDT;10/19/2010 11:00:00
EDT;10/19/2010 12:00:00 EDT
ICRP30 DCF's were used for this plot

Map Size: 1.1 km by 1.1 km   Id: Production.rcE18038.rcC1

The Thyroid CDE results also show good directional agreement.

NARAC shows the thyroid PAG of 5 rem being exceeded to a distance of 380 meters. RASCAL shows that same threshold exceeded at about 300 meters.

Thyroid Committed Dose Equivalent (rem)

Accumulated between 2013/09/30 11:50 and 2013/09/30 21:50

Distance		Bearing from release point				
mi	km	10°	20°	30°	40°	50
0.10	0.16	1.70E+01	1.25E+01	4.54E+00	5.97E-01	1.34E
0.20	0.32	4.57E+00	3.35E+00	1.21E+00	1.57E-01	3.49E
0.30	0.48	2.13E+00	1.55E+00	5.57E-01	7.16E-02	1.56E
0.50	0.80	7.99E-01	5.82E-01	2.05E-01	2.57E-02	5.39E
0.70	1.13	4.28E-01	3.10E-01	1.08E-01	1.32E-02	2.67E
1.00	1.61	2.14E-01	1.54E-01	5.27E-02	6.23E-03	1.19E
1.50	2.41	9.92E-02	7.07E-02	2.35E-02	2.63E-03	4.64E
2.00	3.22	5.59E-02	3.95E-02	1.27E-02	1.36E-03	2.21E

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Results

RASCAL and NARAC results were consistent (analysis post exercise) with the RASCAL and NARAC TEDEs each exceeding PAGs at about 160m. The RASCAL thyroid CDE exceeds at about 300m versus NARAC at 380m.

Problem - Part II Millstone Exercise Practice

A practice session for the Millstone exercise was held on October 18, 2010. The following RASCAL case was run: 10 m – ground level 2 hr release – RASCAL plume transport doses calculated for 8 hr – groundshine 96 hours – 1.1E6 Ci release.)

Compare the following RASCAL result with the associated NARAC results and determine whether the NARAC results are appropriate for release to other responding agencies and decision makers.

Source Term to Dose - [NARAC Compare - Part 2.STD]

File   Settings   Nuclide Data Viewer   Site / Facility Data Viewer   Help

Event Type — NPP Reactor

Event Location — Millstone - Unit 2

Source Term — ☐ Import — LOCA (NUREG-1465)

Release Path — PWR Dry

Meteorology — Actual Observations

Calculate Doses

Detailed Results

Save Case

Maximum Dose Values (rem) - Close-In

Dist from release miles (kilometers)	0.1 (0.16)	0.2 (0.32)	0.3 (0.48)	0.5 (0.8)	0.7 (1.13)	1. (1.61)	1.5 (2.41)	2. (3.22)
Total EDE	1.2E+02	3.7E+01	1.9E+01	8.2E+00	4.8E+00	2.6E+00	1.4E+00	9.2E-01
Thyroid CDE	1.9E+03	5.7E+02	2.9E+02	1.3E+02	7.4E+01	4.0E+01	2.1E+01	1.5E+01
Inhalation CEDE	8.2E+01	2.5E+01	1.3E+01	5.4E+00	3.2E+00	1.7E+00	9.1E-01	6.3E-01
Cloudshine	2.3E+00	1.1E+00	7.1E-01	4.0E-01	2.6E-01	1.5E-01	8.1E-02	3.0E-02
4-day Groundshine	3.6E+01	1.1E+01	5.5E+00	2.4E+00	1.4E+00	7.5E-01	3.9E-01	2.7E-01
Inter Phase 1st Yr	4.2E+02	1.3E+02	6.4E+01	2.8E+01	1.6E+01	8.7E+00	4.6E+00	3.2E+00
Inter Phase 2nd Yr	2.3E+02	6.8E+01	3.5E+01	1.5E+01	8.8E+00	4.8E+00	2.5E+00	1.7E+00

Notes:
• Doses exceeding EPA PAGs are underlined.
• Early-Phase PAGs: TEDE - 1 rem, Thyroid (iodine) CDE - 5 rem
• Intermediate-Phase EPA PAGs: 1st year - 2 rem, 2nd year - 0.5 rem
• Inhalation dose factors used: ICRP 26/30
• *** indicates values less than 1 mrem.

Value displayed: ● Close-in dose   ○ Doses to 10 miles   ○ Criticality shine dose

Display units: ● English   ○ Metric

Definitions   Print

Case Summary   Source Term   **Maximum Dose Values**

Source Term to Dose - [NARAC Compare - Part 2.STD]

File   Settings   Nuclide Data Viewer   Site / Facility Data Viewer   Help

Event Type
NPP Reactor

Event Location
Millstone - Unit 2

Source Term
☐ Import
LOCA (NUREG-1465)

Release Path
PWR Dry

Meteorology
Actual Observations

Calculate Doses

Detailed Results

Save Case

Maximum Dose Values (rem) - To 10 mi

Dist from release

miles	3	4	5	7	10
(kilometers)	(4.8)	(6.4)	(8.0)	(11.3)	(16.1)
Total EDE	7.5E-01	5.8E-01	4.5E-01	3.6E-01	2.7E-01
Thyroid CDE	1.0E+01	7.6E+00	5.8E+00	4.7E+00	3.5E+00
Inhalation CEDE	4.5E-01	3.2E-01	2.5E-01	2.0E-01	1.5E-01
Cloudshine	5.5E-02	3.9E-02	2.9E-02	2.2E-02	1.5E-02
4-day Groundshine	2.4E-01	2.1E-01	1.7E-01	1.4E-01	9.8E-02
Inter Phase 1st Yr	2.6E+00	2.1E+00	1.7E+00	1.4E+00	1.0E+00
Inter Phase 2nd Yr	1.4E+00	1.1E+00	9.0E-01	7.4E-01	5.5E-01

Notes:
• Doses exceeding EPA PAGs are underlined.
• Early-Phase PAGs: TEDE - 1 rem, Thyroid (iodine) CDE - 5 rem
• Intermediate-Phase PAGs: 1st year - 2 rem, 2nd year - 0.5 rem
• Inhalation dose factors used: ICRP 26/30
• *** indicates values less than 1 mrem

Value displayed: ○ Close-in dose   ● Doses to 10 miles   ○ Criticality shine dose

Display units: ● English   ○ Metric

[Definitions]   [Print]

[Case Summary]   [Source Term]   **Maximum Dose Values**

Radiological Release Dose Including Plume Passage
(Total Effective Dose Equivalent 0-96Hrs)

Case 1
Automated Report - Assessment
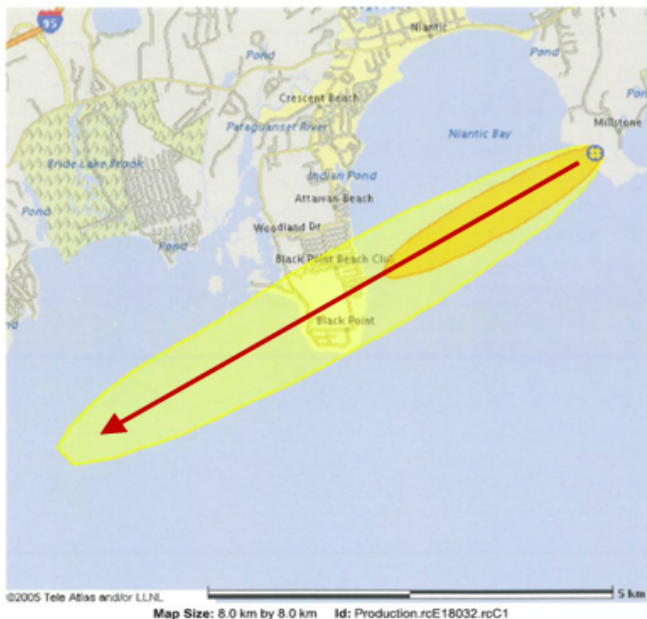
Actions and Long-Term Effects

	Description	(rem) Extent Area	Population
	Exceeds 5 rem total effective dose.	>5 3.1km 1.5km2	0
	Exceeds 1 rem total effective dose.	>1 7.7km 8.0km2	250

Note: Areas and counts in the table are cumulative.
Population Source = LandScan USA V1.0.

Effects or contamination from October 18, 2010 15:00 UTC to October 22, 2010 15:00 UTC at or near ground level.
Release Location: 41.308600 N, 72.168100 W
Material: AM-241 + PU-241 + BA-139 + BA-140 + LA-140 + CE-141 + LA-141 + CE-143 + PR-143 + CE-144 + PR-144 + CM-242 + PU-238 + CS-134 + CS-136 + CS-137 + CS-138 + I-131 + TE-131 + TE-131M + I-132 + TE-132 + I-133 + I-134 + I-135 + RB-88 + LA-142 + MO-99 + TC-99M + NB-95 + ZR-95 + NB-97 + ZR-97 + ND-147 + PM-147 + NP-239 + PU-239 + RB-86 + RH-103M + RU-103 + RH-105 + RU-105 + RU-106 + SB-127 + TE-127M + TE-127 + SB-129 + TE-129 + TE-129M + SR-89 + SR-90 + Y-90 + SR-91 + Y-91M + Y-91 + SR-92 + Y-92 + Y-93 + XE-138 + XE-131M + XE-133M + XE-133 + XE-135M + XE-135 + KR-83M + KR-85 + KR-85M + KR-87 + KR-88
Generated On: October 18, 2010 16:00 UTC
Model: ADAPT/LODI
Comments:
Doses shown are total accumulated from the beginning of release.
Release starting at 10/18/2010 11:00:00 EDT for 2 hr
canned met at 10/18/2010 11:00:00 EDT;10/18/2010 11:30:00 EDT
ICRP30 DCF's were used for this plot

©2005 Tele Atlas and/or LLNL.   5 km
Map Size: 8.0 km by 8.0 km   **Id:** Production.rcE18032.rcC1

NARAC Operations: (onDuty Assessor); narac@llnl.gov; 925-424-6465
Requested by: {NARAC Staff; NARAC; 925-424-6465; narac@llnl.gov }
Not approved for further distribution

Total Effective Dose Equivalent
Accumulated between 2013/09/30 09:00 and 2013/09/30 17:00
NARAC Comparison - Part 2
Millstone - Unit 2

Legend
- 0.01 to 1 rem — Below EPA PAG Range
- 1 to 5 rem — EPA Early Phase PAG Range
- > 5 rem — Exceeds EPA PAG Range

RASCAL v4.3
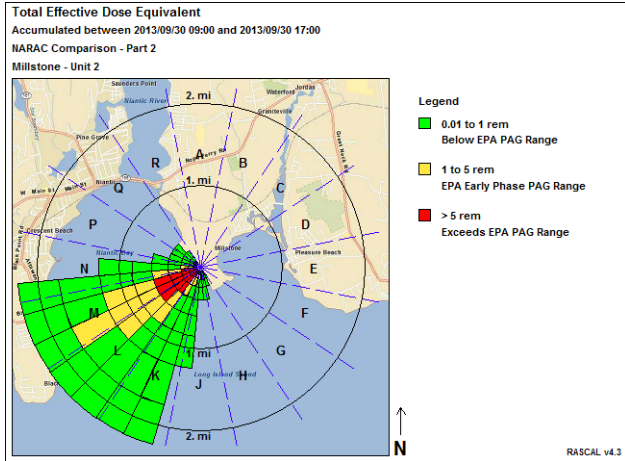
The TEDE results show good directional agreement with the NARAC plot.

Close-In Numeric Table

Total Effective Dose Equivalent (rem)

Accumulated between 2013/09/30 09:00 and 2013/09/30 17:00

Distance		Bearing from release point				
mi	km	230°	240°	250°	260°	27
0.10	0.16	9.15E+01	1.20E+02	8.46E+01	2.88E+01	3.85E
0.20	0.32	2.75E+01	3.65E+01	2.53E+01	8.25E+00	1.05E
0.30	0.48	1.39E+01	1.89E+01	1.28E+01	4.00E+00	4.69E
0.50	0.80	5.94E+00	8.23E+00	5.44E+00	1.51E+00	1.50E
0.70	1.13	3.37E+00	4.82E+00	3.08E+00	7.74E-01	6.10E
1.00	1.61	1.75E+00	2.62E+00	1.59E+00	3.35E-01	1.90E
1.50	2.41	8.35E-01	1.38E+00	7.45E-01	1.12E-01	3.56E
2.00	3.22	5.01E-01	9.22E-01	4.38E-01	4.60E-02	7.84E

The 1 rem TEDE is exceeded at 7.7 km for NARAC and at about 3 km in RASCAL.

The 5 rem TEDE level (not shown here) is exceeded at 3.1 km for NARAC and about 1 km in RASCAL.

Radiological Release Early Phase Guidance (Radioiodine)
(KI Administration based on Thyroid Radioiodine CDE)

Case 1
Automated Report - Assessment
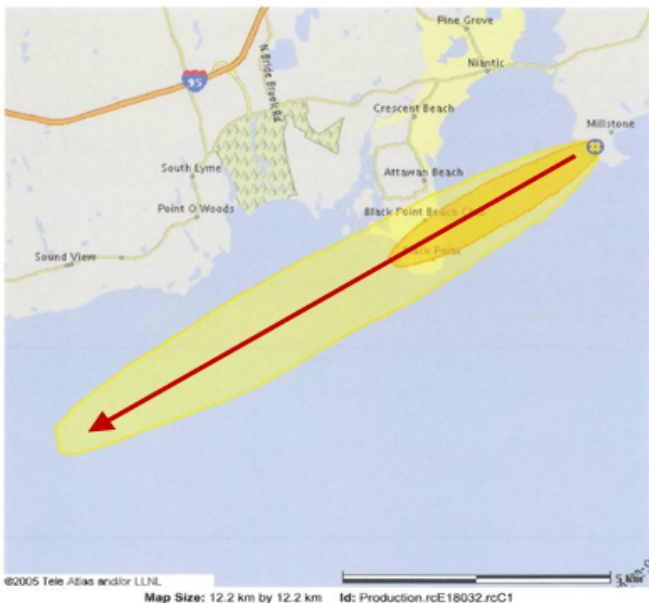
Effects and Actions

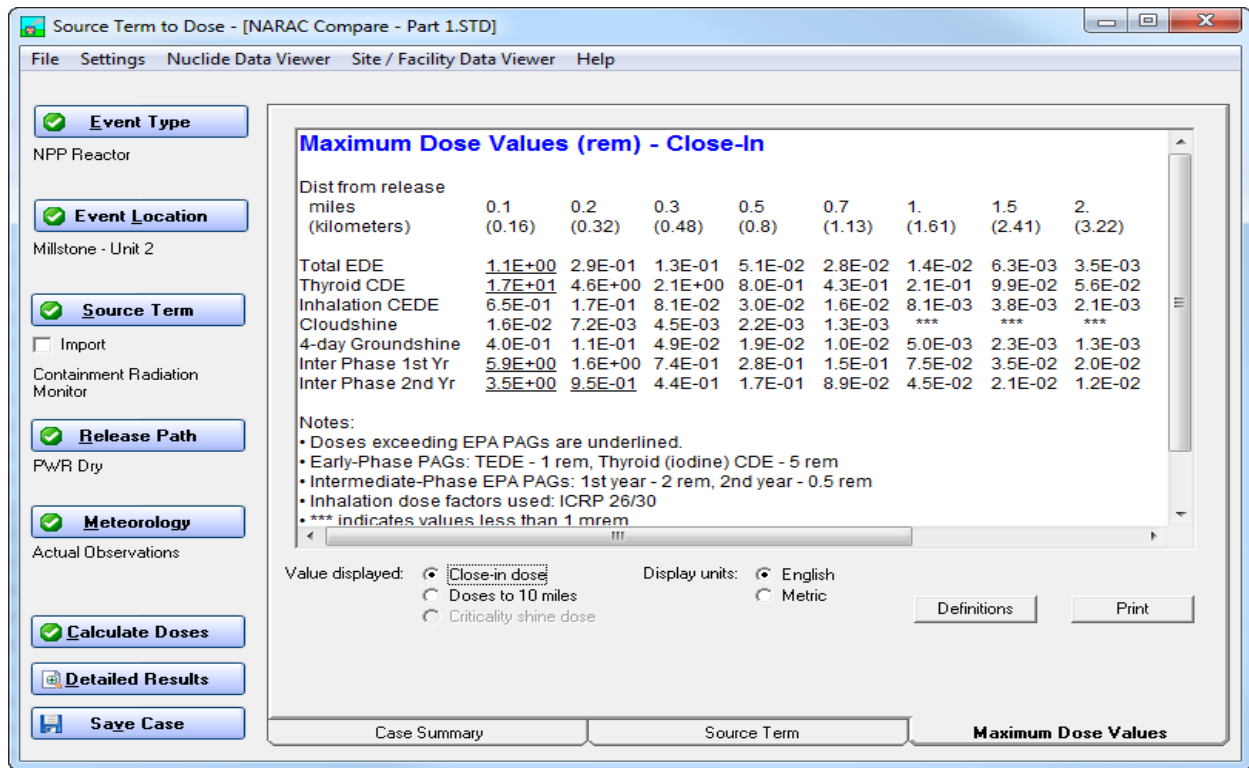|	Description	(rem) Extent Area	Population
	EPA early phase PAG for administering stable iodine (with state agreement).	>25 4.5km 3.4km2	130
	EPA Early Phase PAG for considering evacuation. Shelter in place if no evacuation.	>5 11.9km 17.6km2	310

Note: Areas and counts in the table are cumulative.
Population Source = LandScan USA V1.0.

Effects or contamination from October 18, 2010 15:00 UTC to October 22, 2010 15:00 UTC at or near ground level.
Release Location: 41.308600 N, 72.168100 W
Material: I-131 + TE-131 + TE-131M + I-132 + TE-132 + I-133 + I-134 + I-135 + SB-129 + TE-129 + TE-129M
Generated On: October 18, 2010 16:01 UTC
Model: ADAPT/LODI
Comments:
Doses shown are total accumulated from the beginning of release.
Release starting at 10/18/2010 11:00:00 EDT for 2 hr
canned met at 10/18/2010 11:00:00 EDT;10/18/2010 11:30:00 EDT
ICRP30 DCF's were used for this plot

©2005 Tele Atlas and/or LLNL.
Map Size: 12.2 km by 12.2 km   Id: Production.rcE18032.rcC1

Thyroid Committed Dose Equivalent
Accumulated between 2013/09/30 09:00 and 2013/09/30 17:00
NARAC Comparison - Part 2
Millstone - Unit 2

Legend
- 0.05 to 5 rem — Below EPA PAG Range
- 5 to 25 rem — EPA Early Phase PAG Range
- >25 rem — Exceeds EPA PAG Range

RASCAL v4.3
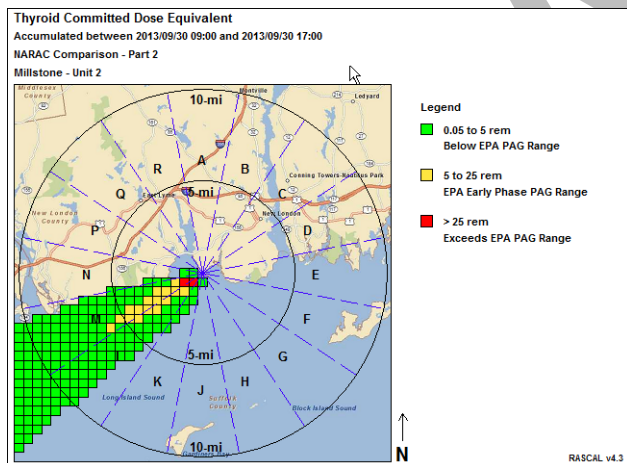
Again there is good directional agreement

The Thyroid CDE exceeds 5 rem at about 9 km (shown at left as 5.8 mi) in RASCAL and 11.9 km in NARAC.

Close-In Numeric Table

Thyroid Committed Dose Equivalent (rem)

Accumulated between 2013/09/30 09:00 and 2013/09/30 17:00

Distance		Bearing from release point				
mi	km	230°	240°	250°	260°	27...
0.10	0.16	1.46E+03	1.91E+03	1.33E+03	4.42E+02	5.05
0.20	0.32	4.32E+02	5.74E+02	3.93E+02	1.24E+02	1.30
0.30	0.48	2.19E+02	2.94E+02	1.98E+02	5.95E+01	5.71
0.50	0.80	9.17E+01	1.27E+02	8.28E+01	2.24E+01	1.80
0.70	1.13	5.19E+01	7.42E+01	4.66E+01	1.14E+01	7.64
1.00	1.61	2.68E+01	4.01E+01	2.38E+01	4.92E+00	2.48
1.50	2.41	1.28E+01	2.10E+01	1.12E+01	1.69E+00	4.98
2.00	3.22	8.02E+00	1.45E+01	6.85E+00	7.15E-01	1.15

The Thyroid CDE exceeds 25 rem at about 2.2 km in RASCAL and 4.5 km in NARAC.

Results – Part II

The trend for TEDE doses appears to be that RASCAL is lower by 2.6 - 3.1 times. The trend for thyroid doses appears to be about a factor of 1-2 lower for RASCAL.

What do we know about the new RASCAL 4.0 atmospheric dispersion model? Would we expect the RASCAL results to trend lower? If the NARAC result was used for protective action decisions, rather than RASCAL, would the protective action zone extend out further?

SPENT FUEL

RASCAL 4.3 calculates the spent fuel nuclide inventory from the fuel batches. As a default, the fuel is assumed to be from a reactor operating on 18 month refueling cycle with one third of the core replaced during each refueling. Thus there are 3 batches of fuel in the reactor core. When the reactor shuts down for refueling, one batch of fuel will have been exposed for 1 cycle, another for 2 cycles, the third for 3 cycles. If there is a full core offload during refueling all 3 batches of fuel are assume to be in the spent fuel pool, otherwise only the oldest batch of fuel off loaded. Once the reactor restarts, it is assumed that only the oldest batch of fuel remains in the spent fuel pool, whether there was a full core offload or not. If the custom fuel option is selected, the fuel management strategy (number of exposure cycles and cycle duration) can be adjusted. The custom fuel option is only available if a base file describing the recent reactor operation exists for the site.

The nuclide inventories of the fuel batches removed from the reactor at the last refueling are calculated from the number of exposure cycles and reactor power. The inventories are adjusted to account for decay since the last irradiation. Technical specifications limit the minimum time between reactor shutdown and the time that fuel can be removed from reactor. RASCAL 4.3 assumes a minimum time of 24 hours for BWRs and 72 hours for PWRs.

If the import source term option is selected on Source Term to Dose main screen, RASCAL 4.3 skips the calculation of source terms describe above and in the following discussions of specific spent fuel accidents. It also skips the calculation of release rates from the nuclide inventories. Instead, RASCAL 4.3 requests the name of a file that contains the nuclide release rates to the environment as a function of time following the accident.

There are three possible spent fuel source terms from spent fuel accident types: cold gap, hot gap, and cladding fire

Cold gap release

A "cold gap release" occurs when spent fuel elements are mechanically damaged but the temperature is low enough that the cladding does not suffer any thermal damage. Examples include mechanical damage to fuel elements damaged underwater in a fuel pool and mechanical damage to fuel elements in a dry cask storage. Radionuclides in the gap between the cladding and the fuel pellets will be released. The fractions of the inventory in the fuel element that will be released in a "cold gap release" are given in Table 3 for each radionuclide group.

Hot gap release

A "hot gap release" occurs when the fuel cladding ruptures due to heat build up releasing the gap inventory. If the spent fuel elements in a pool become uncovered, their temperature will rise. If the temperature reaches 1200 ℉, the fuel cladding will rupture due to the buildup up of internal pressure and will release the radioactivity in the gap between the cladding and the fuel pellets. The fractions of the inventory in the fuel element that will be released in a "hot gap release" are given in Table 3 for each radionuclide group.

Cladding fire

A "cladding fire release" occurs when the fuel elements remain uncooled and the temperature becomes high enough to cause the cladding to burn. The fractions of the inventory in the fuel element that will be released in a "cladding fire release" are given in Table 3 for each radionuclide group.

Table 3 Fuel activity release fractions used in spent fuel accidents

Nuclide group	Cold gap	Hot gap	Cladding fire
Noble gases (Xe, Kr)	0.4	0.4	1
Halogens (I, Br)	0.003	0.03	0.7
Alkali metals (Cs, Rb)	0.003	0.03	0.3
Tellurium group (Te, Sb, Se)	1×10^{-4}	0.001	0.006
Barium, strontium (Ba, Sr)	6×10^{-7}	6×10^{-6}	6×10^{-4}
Noble metals (Ru, Rh, Pd, Mo, Tc, Co)	6×10^{-7}	6×10^{-6}	6×10^{-6}
Cerium group (Ce, Pu, Np)	6×10^{-7}	6×10^{-6}	2×10^{-6}
Lanthanides (La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Y, Cm, Am)	6×10^{-7}	6×10^{-6}	2×10^{-6}

Reference: from Table 2.1 in NUREG-1940; originally from NUREG/CR-6451

Caution

The release fractions for spent fuel are for oxides, not metal.

RASCAL can analyze three types of spent fuel accidents as seen in the **Source Term Options for Spent Fuel** screen below:
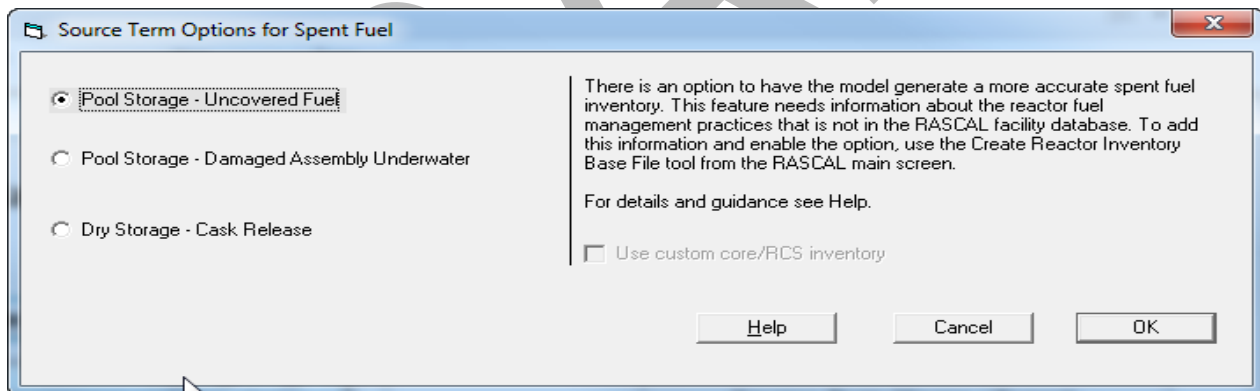
Pool Storage - Uncovered Fuel

RASCAL can analyze spent fuel pool accidents in which spent fuel pool water is lost and the fuel elements become uncovered. Spent fuel in a spent fuel pool must remain covered with water or otherwise cooled to remove decay heat or else the zirconium cladding may heat up and undergo rapid oxidation or "burning" that will propagate and eventually spread to all assemblies in the pool.

The user specifies:

- the date on which the reactor was last shutdown for refueling, which is assumed to be the date of last irradiation of the youngest batch of fuel in the spent fuel pool
- whether or not the whether the spent fuel pool contains a full core offload from this refueling

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- the number of batches that are in the pool (default = 10) prior to the last refueling offload
- whether or not cooling is restored and if it is when.

The spent fuel nuclide inventory is calculated as the sum of the nuclides in the most recently offloaded fuel (1 or more batches) plus the nuclides in older fuel batches. The batch inventories for the batches offloaded at the last refueling that are in the spent fuel pool are calculated as described above. RASCAL 4.3 assumes that the fuel batches in the spent fuel pool that were in the pool prior to the last refueling were removed at the end of a cycle and were exposed for the maximum number of cycles. The nuclide inventories of the batches are calculated starting with the youngest pre-existing batch by decaying the oldest fuel from the most recent refueling for the cycle period. The inventory for the second youngest pre-existing batch is calculated from the youngest pre-existing batch by decaying for a second cycle period. This process is repeated until inventories have been calculated for all pre-existing batches.

Iodines and noble gases except Kr-85 have essentially disappeared from all batches except possibly the batches offloaded during the last refueling outage. For the older batches, the Cs-137 is by far the most significant radionuclide and it decays very slowly with time because it has a half-life of more than 30 years.

If the cladding burns, radioactive materials may be released from the fuel using the release fractions in Table 3. The model assumes that clad burning will not start earlier than 2 hours after the fuel is uncovered and not otherwise cooled, such as from sprays or steam cooling.

The user also enters the time at which radionuclide release from the fuel (clad burning) starts. This time cannot be earlier than 2 hours after the fuel is uncovered. It is assumed that it takes 24 hours for the releases specified in Table 2.1 for clad burning to occur. Thus, 1/96 of the total release fraction listed in Table 3 will occur during each 15-minute time step. The release from the fuel terminates when the fuel is recovered or is otherwise cooled by sprays or steam cooling.

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Pool Storage - Damaged Assembly Underwater

RASCAL can evaluate the radiological consequences of mechanical damage to spent fuel in a fuel pool in which the fuel remains underwater and adequately cooled. The damage may occur to fuel being moved during refueling or to fuel already in the pool.

The user enters:

- the number of damaged fuel assemblies
- the percentage of fuel rods damaged in each assembly
- the exposure history of the damaged fuel
- the time of the damage.

If damage occurs to fuel in 2 different fuel batches, the consequences of damage to fuel in each batch must be assessed separately. The consequences for the accident would be the sum of consequences for the separate batches.

Fuel that is damaged underwater is assumed to remain cold but suffers cladding failure resulting in a cold gap release (see Table 3). Pool scrubbing removes 99% of the non-noble fission products released from the damaged fuel. If the release to the environment is filtered, a further reduction factor of 0.01 is applied to all radionuclides except noble gases.

Dry Storage - Cask Release

RASCAL has the capability to model an accident in which there is damage to the cladding of fuel assemblies stored in a cask and the integrity of the fuel cask is lost.
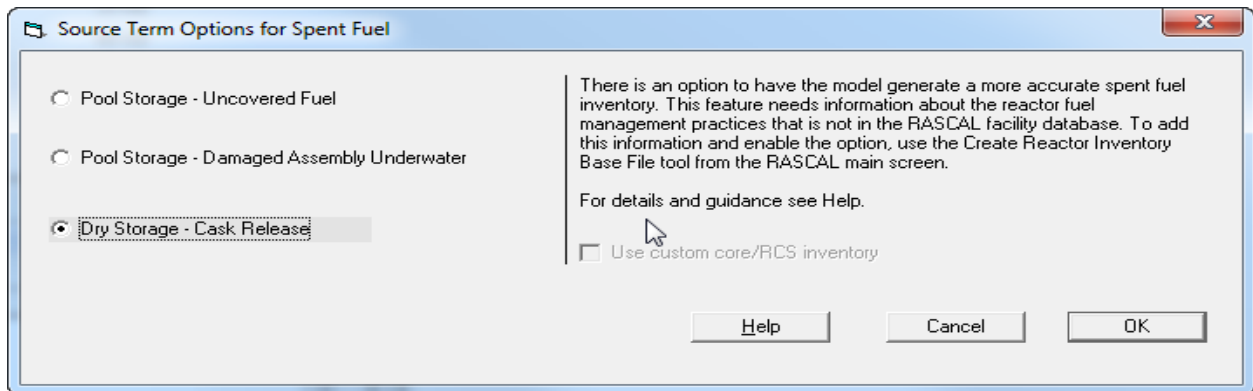
Only one cask can be involved but the user may vary the number of assemblies damaged.

The user enters:

- the type of cask and number of assemblies in the cask
- the age of the damaged fuel
- the type of damage and extent of damage if major damage.
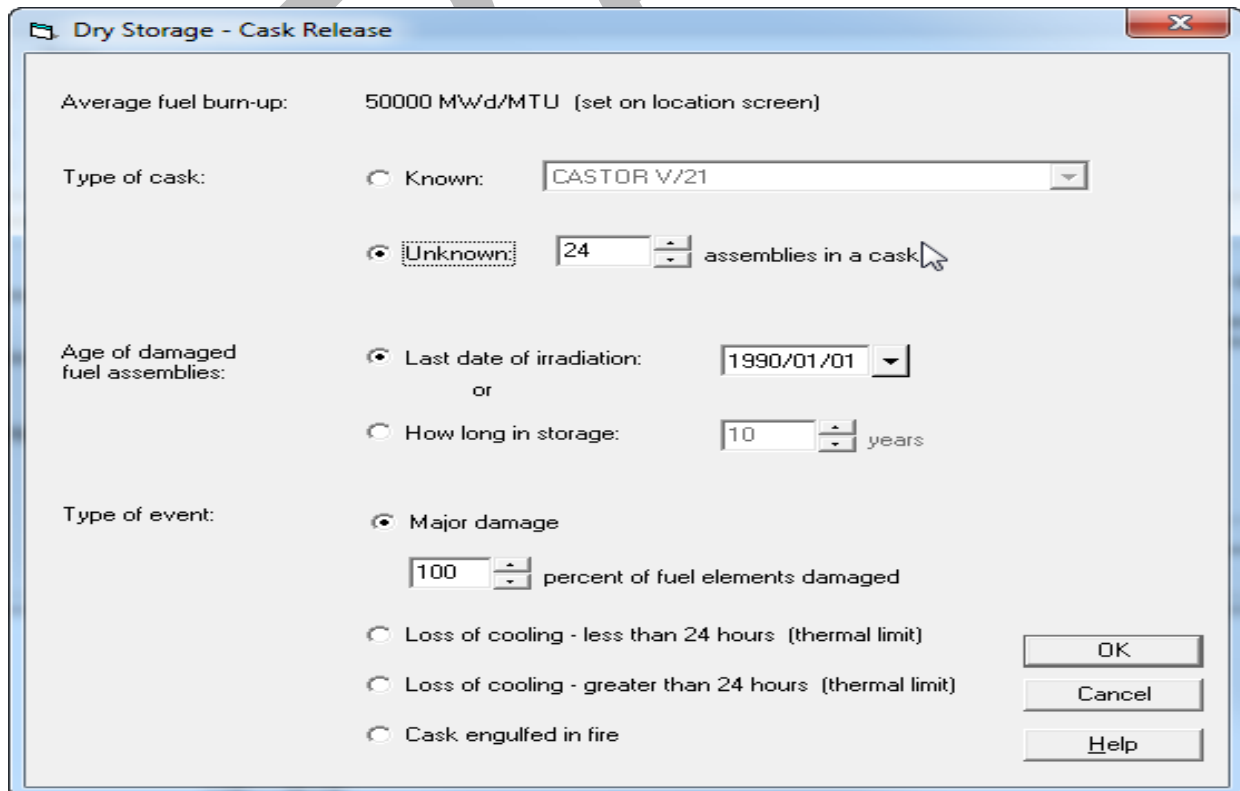
If the assemblies are damaged but have not lost cooling for greater than the thermal limit, a cold gap release fraction is used (see Table 3). If cooling has been lost long enough to allow the cladding to melt, then the hot gap release fraction is assumed. No release is assumed if the cladding does not melt or if the cask is engulfed in a fire.

Users also enter information related to the release location, release pathway, and release timing.

SPENT FUEL ASSEMBLY DAMAGED UNDERWATER

Purpose

To learn how to assess a spent fuel accident where the damaged fuel remains underwater.

Background

See the introduction to spent fuel source terms at the beginning of this section (page 141).

Problem

You are asked to make a dose projection for a fuel handling accident at the Crystal River nuclear power station. You are told that at 12:49 A.M., a fuel assembly that was being removed from the reactor to the fuel pool was smashed against another assembly in the pool and that both were severely damaged. The reactor had been shut down for 6 days. The assembly already in the pool had been there for over a year.

The fuel pool building is 20 meters high and has a filtered exhaust vent near the top. The building ventilation rate is 10 air changes/hour. Calculate the TEDE and thyroid CDE at 0.1 and 0.2 miles assuming **Standard Meteorology**.

What is the basic makeup of the radionuclides released to the atmosphere? How many radionuclides were represented in the source term?

Summary of activity release to atmosphere		
	Ci	% of total
Noble gas		
Iodines		
Other		
Total		

Dose type	Distance from release	
	0.1 mi	0.2 mi
TEDE (rem)		
Thyroid CDE (rem)		

Results

Page 219 has the answers and a summary of the inputs used to get those answers.

Notes on how we work the problem:

- Set the number of fuel assemblies damaged to 1. Although 2 assemblies were damaged, one had been recently irradiated and the other had been out of the reactor for much longer. The source term will be dominated by the recently removed fuel. If you want to compare the relative source terms you can run RASCAL separately for each assembly. If you run RASCAL for the older assembly, assume an age of 1620 days (about 3 cycles at 18 months/cycle) for the older assembly.

SPENT FUEL POOL DRAINED

Purpose

To learn how to model a spent fuel accident where the storage pool loses water and the fuel is uncovered.

Background

See the introduction to spent fuel source terms at the beginning of this section (page 141).

Problem

The plant staff are calling you from San Onofre, Unit 2 because there has been an earthquake in the vicinity. The spent fuel pool has lost much of its water due to a large crack possibly flowing into a sink hole. Due to a malfunctioning pump, it has not been possible to provide enough water to make up for the loss. The water dropped to the top of the fuel at 8:50 A.M., and appears likely to continue dropping. Estimates are that the fuel will be fully uncovered by 11:00 A.M. At this time there is no indication that the plant operators will be able to recover the fuel or provide alternate cooling methods. The pool contains one batch of fuel that was unloaded from the reactor only 2 weeks earlier. (A batch is defined as one-third of a core) There are 9 additional batches in the pool. The spent fuel building has been severely damaged and is in many places directly open to the atmosphere.

Assuming "Standard Meteorology," summarize the source term and estimate the TEDE and thyroid CDE at 1, 5 and 10 miles. Fill in the following tables:

Total activity released to atmosphere		curies

Dose type	Distance from release		
	1 mi	5 mi	10 mi
TEDE (rem)			
Thyroid CDE (rem)			

Results

Page 221 has the answers and a summary of the inputs used to get those answers.

Both TEDE and thyroid PAGs are exceeded at 10 miles. The model should be run again with a calculation radius of 25 miles. However, don't delay making protective action recommendations waiting for these additional model runs.

Notes on how we work the problem:

- A specific release height is not known. We only know that the building is open to the atmosphere in many places. It is likely that material is being released from multiple locations on the structure. We simply accepted the default release height of 10 m as a reasonable first number.

- Release duration of 2 hours. You might think you should put in 1 hour because at a rate of 100%/hour, all the fission products will have been released. But this is not true. The release rate is a rate, and like with radioactive decay, some always remains within the building. Using 2 hours as the time will get essentially all the material out of the building.

- Since the problem states that the building is open to the atmosphere, any filters are likely being bypassed or having very limited effectiveness.

Follow-up question

Make that first batch 1 year old instead of 2 weeks old and rerun the calculations. The doses are still high and the thyroid CDE still exceeds the PAG at 10 miles.

Look at the source term. What is creating the high thyroid doses? What are the implications in this case for the administration of KI?

Spent Fuel Pool Drained – Part B

(do this problem just before a break – it will require about 20 minutes to calculate)

RASCAL 4.3 has provisions to assess a full core off load (3 batches) from one unit and also consider a common spent fuel pool where fuel has been loaded in from a second reactor. Three fresh batches from a second reactor are not permitted in this version, although for a decommissioning site, this could occur.

Problem

Consider a highly unlikely, extreme spent fuel case, by modifying the scenario in Part A. With a spent fuel incident there would be much more time to implement protective actions than for an accidental reactor release, but the extent of long term low level contamination could be large. Use a full core offload for Unit 1, and include 5 batches from Unit 2 with the youngest batch having an age of 6 months. Download real meteorology for about 3-4 of the preferred weather stations. Find the distance at which the EPA 2nd year relocation PAG (500 mrem) would be exceeded. Don't forget to allow enough calculation time for the tail of the plume to progress past 100 miles.

Will the 2nd year relocation PAG be exceeded at less than 100 miles?

SPENT FUEL DRY CASK RUPTURE

Purpose

To learn how to model a spent fuel accident where a dry cask storage unit is ruptured.

Background

See the introduction to spent fuel source terms at the beginning of this section (page 141).

Problem

The RASCAL database contains information on a variety of dry storage casks. The user may select from the list of cask types to set the number of assemblies or manually enter a value. Table 4 lists the cask types defined and the number of fuel assemblies stored in each.

Table 4 Spent Fuel Dry Storage Cask Types

Cask name	# fuel assemblies	Cask name	# fuel assemblies
CASTOR V/21	21	NAC-STC	26
CASTOR X/32S	32	NAC-UMS	24
FuelSolutions	21	NUHOMS-24P	24
Hi-Storm 100	24	NUHOMS-32P	32
Holtec Hi-Star 100	24	SNC Transtor	24
NAC-C28 S/T	28	TN-24	24
NAC-I28 S/T	28	TN-32	32
NAC-MPC 24 GTCC	24	TN-40	40
NAC-MPC 36 Yankee	36	VSC-24	24
NAC-S/T	26		

In the late night hours and under cover of a heavy snowstorm, a terrorist entered the grounds of the Prairie Island Nuclear Power Station. Unable to gain access to the reactor buildings, he has barricaded himself in the dry cask storage yard. Law enforcement officials are in contact with him and believe he has attached some explosive device to one of the casks.

The current local time is 4:15 A.M. You are asked to make an assessment of the potential consequences of the explosive breaching of a single cask. The cask involved has been identified as a Castor V/21. This is a vertical metal cask on a concrete pad. The experts predict that the explosion will partially rupture the cask and estimate that roughly three-quarters of the assemblies within will be damaged by the shock. The snowstorm has stopped and current winds are reported as light.

Make your calculations and then fill in the tables below. Use an appropriate predefined meteorological dataset other than the standard one. You will need to make some assumptions about the leak rate and the release duration.

Total activity released to atmosphere	curies

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Dose type	Distance from release	
	0.1 mi	0.2 mi
TEDE (rem)		
Thyroid CDE (rem)		

Results

Page 222 has the answers and a summary of the inputs used to get those answers.

Notes on how we work the problem:

- Either unit could be selected as the fuel storage area serves both and as long as the fuel burnup value is appropriate to the stored fuel.

- The age of the fuel is unknown at this time but the worst case would be the minimum cooling time value of 5 years. This information would be available from technical staff.

- The leak rate will be the rate at which the material exits the ruptured cask and enters the atmosphere. The worst case option would be total failure.

- We are going to assume that the explosion ruptures the cask but has little effect on dispersing the material. Thus, a release duration of 2 hours provides enough time for the material to leave the cask.

- Make sure to change the date to an appropriate winter day. Any day will do.

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FUEL CYCLE / UF$_6$ / CRITICALITY

For fuel cycle facilities, RASCAL can calculate doses from: accidental criticalities, UF$_6$ releases, and releases caused by fires and explosions. The following problems show how to use RASCAL to analyze these types of accidents.

Because we want to focus on the fuel cycle accidents themselves and not meteorology, we will use the predefined **Standard Meteorology** dataset for all problems. This is easy to do and eliminates variability caused by differing meteorological conditions.

URANIUM PROCESS FIRE

Purpose

To learn about the options for modeling a fire at a uranium processing facility.

Background

Under the **Event Type: Fuel Cycle / UF6 / Criticality**, it is possible to model the release of uranium oxide resulting from a fire. Five separate fire scenarios are modeled: production process (wet and dry), HEPA filter, incinerator exhaust, waste, and milling. Each scenario may require further refinement of fire conditions by the user. Each combination of fire type and condition has a default airborne release fraction (ARF) and respirable fraction (RF) as shown in Table 5. These values may be changed by the user.

Table 5 Airborne release fractions and respirable fractions used in uranium oxide fires

Type of fire	Condition	ARF (Fuel cycle)	ARF (Other radioactive material fires)	RF
Production process	Dry process	0.001	0.001	1
	Wet process	3×10^{-5}	0.001	1
HEPA filter	At high temperature	1×10^{-4}	0.001	1
	Failure	1	NA	1
Incinerator exhaust		0.4	NA	1
Waste fire	Solid packaged in drums	5×10^{-4}	NA	1
	Solid loosely packed	0.05	0.001	1
	Combustible liquid	0.03	0.005	1
	Non-combustible liquid	0.002	0.001	1
Uranium mill	Drum in a fire	0.001	0.001	1
	Solvent extraction	0.03	0.005	1

Reference: from Table 3.7 of NUREG-1940 taken from *Airborne Release Fractions/Rates and Respirable Fractions for Non-Reactor Nuclear Facilities: DOE Handbook.* Vol. 1, 1994

It is also possible to model uranium release from fires using the **Event Type: Other Radioactive Material Releases**. The default airborne release fraction (ARF) for uranium is 0.001 based on the most commonly encountered forms of the material. However, a table gives alternate airborne release fractions based on the physical form of the material. For comparison of the two approaches, Table 5 also shows ARFs based on that table. In general, the two sets of ARFs are reasonably consistent considering that they came from two different sources and are based on different scenario descriptions and experimental data.

The differences do indicate that some judgment should be used when selecting ARFs. For fuel processing facilities, it is probably more appropriate to use the fire ARFs in the Event Type: Fuel Cycle / UF6 / Criticality than those in the Event Type: Other Radioactive Material Releases. The ARFs used for Fuel Cycle fires were generated specifically for uranium oxide processing. The ARFs for Other Radioactive Materials were generated on a more generic basis.

The source term is calculated using the airborne release fraction and the user specified material at risk (mass of uranium oxide). The mass of uranium oxide is converted to a mass of uranium by multiplying by 0.88. Then the mass of uranium is converted to an activity based on the user specified enrichment value. The respirable fraction is used during the dose calculations to reduce the amount of material inhaled and contributing to the inhalation dose.

Problem

A fire occurred at 9:47 A.M. in the powder preparation area of the UO_2 Building at the AREVA NP Richland facility. The fire lasted for 20 minutes and breached the building containment. Approximately 12,000 kg of UO_2/U_3O_8 powder (4% enriched) is located in the powder preparation area. All of the airborne material is assumed to be released through the airlock doors.

Fill in the following table:

TEDE at 0.1 mile	
Predominant dose pathway	

Results

Page 223 has the answers and a summary of the inputs used to get those answers.

Notes on how we work the problem:

- It would also be reasonable to lower the ARF. Experiments involving surface contamination on flammable material (wood) had ARFs of roughly 0.001. When the mass of the uranium is large relative to the mass of the flammable material, lower ARFs can be expected. For this problem an ARF of 10^{-4} or even 10^{-5} might not be unreasonable.

- If you expected that there would be significant deposition of the uranium oxide in the building you could decrease the available amount by assuming that the release was filtered.

- The release time affects only the rate at which material escapes, not the magnitude. Increasing the release time will leave the release magnitude unchanged, but will decrease the release rate. Remember not to end the calculations before the release has been completed.

EXPLOSION INVOLVING URANIUM OXIDE

Purpose

To learn about the options for modeling an explosion involving uranium oxide.

Background

RASCAL can model the release of uranium oxide from an explosion. First the user must characterize the explosion as one of the following:

- detonation; a shattering such as from a high explosive
- deflagration; enveloping with no shattering such as from a propane explosion
- venting; a result of over-pressurization such as a container rupture from high internal pressure

Next, the form of the uranium oxide material must be specified as liquid, solid, powder, or surface contamination. Each combination of type and form has a default airborne release fraction (ARF) and respirable fraction (RF) as shown in Table 6. These values may be changed by the user.

Table 6 Airborne release fractions and respirable fractions for explosions involving U oxide

Explosion characteristics	Material form	ARF	RF
Detonation (high explosive)	Liquid	1	1
	Solid	1	0.2
	Powder	1	0.2
	Surface contamination	0.001	1
Deflagration (fire)	Liquid	1×10^{-6}	1
	Solid	0	0
	Powder	0.005	0.3
	Surface contamination	0.001	1
Venting (sudden pressure change)	Liquid	0.002	1
	Solid	0	0
	Powder	0.1	0.7
	Surface contamination	0.001	1

Reference: from Table 3.8 of NUREG-1940, corrected and taken from *Airborne Release Fractions/Rates and Respirable Fractions for Non-Reactor Nuclear Facilities: DOE Handbook.* Vol. 1, 1994

The source term is calculated using the airborne release fraction and the user specified mass of material at risk (mass of uranium oxide). The mass of uranium oxide is converted to a mass of uranium by multiplying by 0.88. Then the mass of uranium is converted to an activity based on the user specified enrichment value. The respirable fraction is used in the calculation of inhalation dose.

Problem

You are asked to respond to an accident in the Research and Test Reactor Fuel Element area of Bay 15 at BWX NOG. At 3:35 P.M. local time, a boxline containing 3.6 kg of U_3O_8 explodes due to a loss of the inert atmosphere and a combination of aluminum and uranium which ignited. The explosion has destroyed the boxline and breached the roof of the building (estimated to be 12 meters above the ground level). The enrichment of the material is 93%.

How many total curies of activity were released to the atmosphere? Estimate the possible doses at the site boundary (540 m away) and to the nearest resident (1100 m away).

Total curies released	
TEDE & thyroid CDE at 540 meters	
TEDE & thyroid CDE at 1,100 meters	

Results

Page 224 has the answers and a summary of the inputs used to get those answers.

You will note that the doses are very small - so small that some are not shown on the **Maximum Dose Values** table. However, by selecting **Detailed Results** and then selecting the option of a **Numeric Table** for the Close-in Calculations these lower doses can be seen. Doses are small because the size of the release was very small. There was relatively little uranium involved and uranium has a low specific activity. Also, since uranium is not volatile, relatively little becomes airborne (recall the airborne release fraction was 0.005).

Notes on how we work the problem:

- Deflagration is the appropriate explosion type for the ignition of aluminum and uranium.

- The ARF and RF were left at defaults since have no basis for other values.

- The explosion occurred inside the building but since the roof has been breached assume that the release will not be filtered or sprayed. A 50% reduction will be applied due to the retention of material within the structure. Thus, you cannot just set the release as being outside to get the same effect.

- Use a fairly short release duration. Since it was an explosion, assume that the energetic release got everything out in 15 minutes. Either set the end time to 15:50 or the duration to 00:15.

UF$_6$ CYLINDER RUPTURE

Purpose

To learn about the result types available from the UF$_6$ plume model and how to model a release from a UF$_6$ cylinder.

Background

RASCAL can model the release of UF$_6$ from a cylinder (or other container). The user must specify the amount of UF$_6$ contained or the number and type of cylinders. The user must also specify a UF$_6$ release rate and the fraction ultimately released. The exception to this is for liquid UF$_6$ in a cylinder with a damaged valve. In this case, RASCAL estimates the fraction released based upon the position of the valve.

RASCAL uses a special model when treating the transport and diffusion of a UF$_6$ release. The model considers both the buoyancy of the plume due to the heat generated by its reaction with water vapor and the slumping of the plume caused by its high density. The model is described in detail in Chapter 5 of the RASCAL technical manual.

For UF$_6$ releases, only one meteorological observation can be entered. In other words, the weather cannot change during the release. This is only true for UF$_6$ releases and not for any other types of releases.

The model calculates 7 different types of results for UF$_6$ releases. The types are described below:

HF Concentration - 1-hour equivalent

The damage done by exposure to HF is <u>not</u> strictly proportional to its concentration times the time of exposure as it is for many other toxic gases. Instead, exposure to high concentrations of HF for short times has more effect than the same exposure spread out over a longer time. The **HF concentration 1-hour equivalent** provides a means of comparing the health effects of exposures by using a common time of exposure. (Reference: S. McGuire, NUREG-1391, *Chemical Toxicity of Uranium Hexafluoride Compared to Acute Effects of Radiation*, 1991). The 1-hour equivalent concentration $C_{1\,hr}$ is a measure of the degree of acute lung edema that may result and cause death. It is calculated in terms of the concentration C during the time of exposure t in hours:

$$C_{1\,hr} = C \times t^{0.5}$$

The implications of this relationship are that a doubling of concentration would require 1/4 the exposure time to maintain the same toxic load level. Or, to double the exposure duration would require the concentration to be about 71% of the original level to maintain effect.

Table 7 lists the health effects and ERPG levels for HF 1-hour equivalent concentrations.

HF Concentration - Average

The HF concentration averaged over the duration of the exposure.

HF Deposition

The HF concentration (g/m²) deposited on the ground. This result provides a measure of the potential hazard from contact with exposed surfaces. It may be used to reconstruct the path of the plume and the HF concentration in the plume. A dry deposition velocity of 0.3 cm/s is used in the calculations.

Table 7 Health effects due to HF exposure

Health effect due to HF exposure	HF concentration - 1 hr equivalent
ERPG-1: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing other than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.	2 ppm
ERPG-2: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.	20 ppm
ERPG-3: American Industrial Hygiene Association Emergency Response Planning Guideline -3: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.	50 ppm

(Source: AIHA Guideline Foundation; 2011 ERPG-WEEL Handbook)

Uranium Exposure

The uranium exposure (g-s/m³) equal to concentration times the time of exposure.

Uranium Intake

The uranium intake (mg) by inhalation. Uranium intake provides the best measure of potential acute kidney damage due to heavy metal poisoning as shown in Table 8. There are no known long term chemical injuries from uranium intakes that are sub-lethal.

Table 8 Health effects due to uranium intake by inhalation

U intake by inhalation	Health effect
below 5 mg	none
8 mg	threshold for clinically observable transient chemical changes in urine indicating renal distress
50 mg	threshold for permanent renal damage (speculative - never observed in humans)
230 mg	50% fatality without medical treatment

(From: S. McGuire, NUREG-1391).

Uranium CEDE

The committed effective dose equivalent (CEDE) from inhaled uranium (rem) provides the radiation dose to people in the plume. It is a measure of the long-term risk due to radiation exposure. There is essentially no external radiation exposure from airborne uranium so the CEDE will also be the TEDE.

Uranium Deposition

The uranium concentration (g/m²) deposited on the ground. This result provides a measure of the potential hazard from contact with exposed surfaces and from resuspension of uranium. It may be used to reconstruct the path of the plume and the uranium concentration in the plume. A dry deposition velocity of 0.3 cm/s is used in the calculations.

Problem

At 9:30 A.M. workers at AREVA NP Richland were moving a Model 30 cylinder full of hot, liquid, 4% enriched UF_6 to an outdoor storage area. The cylinder was dropped resulting in the rupture of the cylinder. Evaluate the impact of this release on a person standing on the plume centerline, at a distance of 0.2 miles. Assume **Standard Meteorology**.

Using the results shown in the maximum dose values table and Tables 7 and 8, fill in the table below:

Result type	Result at 0.2 miles	
	Value and units	Impact
HF conc 1 hr equivalent		
Uranium intake		
Radiation dose (U CEDE)		

Results

Page 226 has the answers and a summary of the inputs used to get those answers.

Notes on how we work the problem:

- There is no option to enter an elevated release as the UF_6 model handles only releases at ground level.

- The problem description says the cylinder is outside so the pathway should be direct to the atmosphere.

- The **Close-in only** distance is the only one available. For releases of UF_6, RASCAL automatically switches to the UF_6 plume model. The user may set specific distances at which doses are calculated

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UF$_6$ CASCADE RELEASE

Purpose

To learn how to model an accident in a cascade at one of the gaseous diffusion plant buildings.

Background

The UF$_6$ cascade release accident type is available only for the Portsmouth and Paducah gaseous diffusion plants. In addition, the cascade release source term option is available only for certain buildings of those facilities. Tables 9 and 10 list the building names and information about the default inventories and release rates.

Table 9 Paducah GDP buildings and default inventory and release rates

Building name	Cells per unit	Number of units	Avg cell inventory (lbs)	Release rate (lbs/sec)
C-331	10	4	4,400	130
C-333	10	6	9,500	130
C-335	10	4	4,600	130
C-337	10	6	8,400	130
C-310	10	1	150	130

Table 10 Portsmouth GDP buildings and default inventory and release rates

Building name	Cells per unit	Number of units	Avg cell inventory (lbs)	Release rate (lbs/sec)
X-326	20	2.5	1,000	130
X-330	10	11	5,000	130
X-333	10	8	5,000	130

Problem

You are called upon to make a dose assessment for an accident at the U.S. Enrichment Paducah gaseous diffusion plant. At 12:45 P.M. a block valve control failure resulted in a pressure increase which ruptured the primary containment of a cell. The problem occurred in the C-333 process building and operators have been unable to isolate the cell. The enrichment level is 5%.

It is a windy, summer afternoon with the process building operating in its summer flow configuration. What are the potential radiation and chemical doses to persons 2 miles downwind of the building?

Fill in the following table with values from the model and impacts taken from Tables 7 and 8.

Result type	Results at 2 miles	
	Numerical value	Impact
Radiation dose (U TEDE) Uranium intake		
HF conc 1 hr equi.		

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Results

Page 227 has the answers and a summary of the inputs used to get those answers.

The distance at which 100% of the UF_6 has reacted with the moisture in the atmosphere is 96.5 meters. (This is shown on the Maximum Dose Values tab of the main screen).

Notes on how we work the problem:

- Essentially, the radiation dose (U CEDE) is a TEDE since the cloudshine and groundshine doses are effectively zero. Thus, it can be compared to the EPA TEDE PAG.

- We are told that a single cell containment failed. Since we do not have information on the cell inventory, accept the default value.

- Since we have no additional information, accept the default value for the release rate.

- The worst case is for all the material to move from the cascade cell into the building so leave the default value unchanged.

- Problem states a windy, summer afternoon and no onsite weather data is available at this time.

CRITICALITY

Purpose

To learn how to use RASCAL to estimate consequences from a criticality accident.

Background

To estimate doses from a criticality accident, RASCAL first establishes the number of fissions that will occur. The user may either enter the number of fissions directly or may select the type of system being modeled, allowing RASCAL to determine the fission yield. The systems available and their assumed fission yields are shown in Table 11. The total yield assumes multiple bursts over 8 hours.

Table 11 Fission yields used in criticality calculations

System modeled in the scenario	Initial burst yield (fissions)	Total yield over 8 hours (fissions)
Solution <100 gal	1×10^{17}	3×10^{18}
Solution >100 gal	1×10^{18}	3×10^{19}
Liquid/powder	3×10^{20}	3×10^{20}
Liquid/metal pieces	3×10^{18}	1×10^{19}
Solid uranium	3×10^{19}	3×10^{19}
Solid plutonium	1×10^{18}	1×10^{18}
Large storage arrays below prompt critical	Steady state	1×10^{19}
Large storage arrays above prompt critical	3×10^{22}	3×10^{22}

Reference: from Table 3.9 of NUREG-1940 which were taken from NUREG/CR-6410

From the fission yield, RASCAL determines the fission product release to the atmosphere, the atmospheric dispersion of those fission products, and the doses from the plume. RASCAL also calculates the direct gamma and neutron shine dose. The user can reduce the amount of material released to the atmosphere by specifying release fractions for noble gases, iodines, and other radionuclides. Further reductions can be specified by having a filtered release pathway. The user can also specify shielding to reduce the direct shine dose.

Problem

At 1:45 P.M., criticality alarms sound at the AREVA NP Richland facility. The operators determine that a criticality excursion is occurring in a 125 gallon tank holding a solution of enriched UO_2 and water. Subsequently, radiation monitors detect a second burst indicating that the criticality is on-going. The room air is vented through an 18 meter high exhaust stack on the building roof.

1. How many total fissions will occur?

2. Fill in the following table:

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Dose (rem)	Distance	
	100 ft	500 ft (~0.1 mi)
TEDE from plume		
TEDE from criticality shine		
Total TEDE		

3. To what distances are the EPA PAGs exceeded?

4. What early health effects would we expect to a person standing 200 feet from the criticality when it occurred?

Results

Page 228 has the answers and a summary of the inputs used to get those answers.

Notes on how we work the problem:

- Multiple bursts is an appropriate choice since measurements suggest that the criticality is continuing.

- Left the ARFs at default as there is no other information that would cause us to change the settings.

- Left the shielding values all at 0.0. There is no information to cause a change from the defaults. You could assume no shielding which would be the worst case.

- The start of the release would be the start of the criticality. For the duration, the worst case would be if the criticality continues for the full 8 hours. The additional 2 hours will allow most fission products to escape the building. Stopping the release early effectively stops the criticality since the material can no longer be released.

- If you thought there would be some plate-out and deposition within the building and exhaust system, you could assume 50% reduction of non-noble gases during passage through the building and the exhaust system.

- Pick the worst case since there is no information about the flow rates of the exhaust fan.

OTHER RADIOACTIVE MATERIAL RELEASES

RASCAL can calculate doses from the release of radioactive materials from other types of facilities. Source terms can be produced for radioactive materials involved in fires or by measured or estimated radionuclide release rates or release concentrations.

Five licensed sites are included in the RASCAL facilities database. In addition, the user can describe a site not in the database.

All radioactive material licensees have much smaller radioactive material inventories than reactors. Thus, the size of potential releases is vastly less. In addition, reactor accidents generally take a long time to progress to a release. This is not always true at materials facilities. Thus, the RASCAL operator may be trying to estimate what *did* happen rather than what *will* happen.

RADIOACTIVE MATERIAL IN A FIRE

Purpose

To learn how to use RASCAL to model the consequences of radioactive material dispersed in a fire.

Background

The **Sources and Material in a Fire** source term option is used to model the consequences of radioactive material dispersed as a result of a fire. The user must specify the amount of material at risk and for each radionuclide set an airborne release fraction and respirable fraction. A default release fraction (see Table 12) is set by the code for each nuclide selected. These release fractions assume the material is on a completely combustible surface. For example, they would be appropriate for materials on a wooden laboratory bench. They would overestimate the airborne release fraction for material sitting on concrete or steel.

Table 12 Fire activity release fractions by element (based on the likely form of the compound)

Element	Activity Release Fraction	Element	Activity Release Fraction	Element	Activity Release Fraction	Element	Activity Release Fraction
H(gas)	0.5	Se	0.01	I	0.5	W	0.01
C	0.01	Kr	1.0	Xe	1.0	Ir	0.001
Na	0.01	Rb	0.01	Cs	0.01	Au	0.01
P	0.5	Sr	0.01	Ba	0.01	Hg	0.01
S	0.5	Y	0.01	La	0.01	Tl	0.01
Cl	0.5	Zr	0.01	Ce	0.01	Pb	0.01
K	0.01	Nb	0.01	Pr	0.01	Bi	0.01
Ca	0.01	Mo	0.01	Pm	0.01	Po	0.01
Sc	0.01	Tc	0.01	Sm	0.01	Ra	0.001
Ti	0.01	Ru	0.1	Eu	0.01	Ac	0.001
V	0.01	Rh	0.01	Gd	0.01	Th	0.001
Cr	0.01	Ag	0.01	Tb	0.01	Pa	0.001
Mn	0.01	Cd	0.01	Ho	0.01	U	0.001
Fe	0.01	In	0.01	Tm	0.01	Np	0.001
Co	0.001	Sn	0.01	Yb	0.01	Pu	0.001
Zn	0.01	Sb	0.01	Hf	0.01	Am	0.001
Ge	0.01	Te	0.01	Ta	0.001		

Reference: NUREG-1140

Guidance is provided in Table 13 for resetting the airborne release fraction if the element is in some other form.

Table 13 Fire activity release fractions by form of compound

Form of compound	Activity release fraction
Noble gas	1.0
Very mobile form	1.0
Volatile or combustible compound	0.5
Carbon	0.01
Nonvolatile compound / dispersible	0.01
Nonvolatile compound / less dispersible	0.001
U and Pu metal	0.001
Nonvolatile in a flammable liquid	0.005
Nonvolatile in a non-flammable liquid	0.001
Nonvolatile solid	0.0001

Reference: NUREG-1140

The release pathway settings control only the start and stop of the release to the atmosphere. It is assumed that all the material will be released from the facility. There are no provisions with this source term option for the application of sprays or filters.

Problem

You are tasked with estimating the doses resulting from a fire-induced release from a laboratory at the E.R. Squibb radiopharmaceutical facility. At 8:00 A.M. this morning, an electrical short apparently ignited some stored materials in the building and the fire has spread. It is reported that the laboratory may contain as much as 100 curies of I-131.

What is the source term? That is, what is the total activity of I-131 released to the atmosphere?

Estimate doses to persons within a 1 mile radius of the fire and then fill in the following table:

Dose type	Distance from release (miles)	
	0.1	1.0
TEDE (rem)		
Thyroid CDE (rem)		

Results

Page 230 has the answers and a summary of the inputs used to get those answers.

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Notes on how we work the problem:

- We have treated this plume as though it will not rise due to the buoyancy which might occur with a heated plume release from a fire. If observers from the site reported that the plume was rising and not being entrained in the building wake, it would be reasonable to increase the release height to the level estimated by the observers.

- We don't know how long the fire burned. For simplicity, until better information is available, assume the fire burns for one hour.

The thyroid dose at a tenth of a mile is less than 50% of the PAG of 5 rem. Persons closer may receive a dose which exceeds the PAG. However, to receive this dose the plume could not rise due to buoyancy and an individual would have to remain on the plume centerline (in the heaviest smoke) for the duration of the release. It is more likely that people would move out of heavy smoke.

When the I-131 is added, the default values for airborne release fraction and respirable fraction are entered automatically. These could be changed if you had additional information to support different values. For now, leave the ARF and IF for iodine (0.5 and 1.0) unchanged. Later credit could be given for other reductions such as fire suppression sprays or hold up in the structure.

TRANSPORTATION ACCIDENT

Purpose

To learn how to do an assessment for an accident location not in the RASCAL database.

Background

A unique feature of a transportation accident is that its location will not be in the RASCAL database. Thus, the RASCAL operator must enter a new site. This will also be true of accidents at smaller licensed facilities which are not in the RASCAL database. Another unique feature is that information from the site is likely to come from emergency responders with only limited knowledge of radioactive materials.

Most transportation accident scenarios will use the **Other Radioactive Material Releases** event type. However, for spent fuel transportation accidents, select the **Spent Fuel** event type instead.

Problem

At 2:00 A.M. a tractor trailer truck jack-knifed in central Pennsylvania near the intersection of I-80 and I-180 when the driver lost control on the icy road. The truck manifest says it was carrying 150,000 Ci of tritium gas and was bound for the Safety Light facility in Bloomsburg, PA. State highway patrol reports that the trailer slid at high speed into a bridge support and split open.

For this problem, assume that the GIS operator has given you the following site information:

latitude =   41.0495º N
longitude = 76.8400º W (enter west longitude as a negative number)
elevation = 153 meters
time zone = Eastern
nearby populated place = Milton, PA

In order to know how to handle the source term you will have to get a lot of information from other people. Communicators in contact with response personnel at the site will be obtaining information on the extent of the damage to the truck and its contents. Transportation and radioactive material experts will be determining the likely form of the material and how much might escape. Let us assume that they tell you that they estimate that 10% of the containers may have ruptured and that most of their contents are likely to leak out within 10-20 minutes and would quickly volatilize and become airborne.

Make a preliminary assessment of the risk to persons in the immediate vicinity of the crash. What doses may the first responders have received? What doses might nearby residents have received?

Dose type	Distance from release (miles)			
	0.1	0.2	0.5	1.0
TEDE (rem)				

As you probably understand, RASCAL results will play only a small part in answering those questions. Many other factors must be considered, some technical and some political. Nevertheless, RASCAL results can still be valuable.

Results

Page 231 has the answers and a summary of the inputs used to get those answers.

Notes on how we work the problem:

- Since this location is not in the RASCAL database, you need to use the option **Describe a Material Site not in the Database**.

- The exact location may or may not be important depending on how you will handle the meteorology. You can use "generic" weather (as will be described in the Meteorology section) or you may want the best weather data available. Most likely you will make the first RASCAL run with appropriate "generic" weather and then switch to obtaining actual observations as time permits and they are available. Initially, people will want your RASCAL results as soon as possible. Then, when they have your first results, they will start to ask how accurate the results are. At this point, generic weather is unlikely to be acceptable.

- A good way to locate nearby weather stations is by knowing the latitude and longitude of the release point. At the NRC, this information should be readily available from a GIS Operator on the Protective Measures Team. Alternatively, identifying close cities will help.

- When we worked the problem we used Effluent Release Rates – by Nuclide. We wanted to get 10% of the total inventory (10% of 150,000 = 15,000 Ci) out in 10 minutes. Thus we set a release rate of 1,500 Ci/min and a release duration of 10 minutes.

- The accident occurred outside with no holdup or reduction by other structures. The isotopic source term type being used assumes that the measured release rates are the rate the activity enters the atmosphere. We used the lowest allowed release height (10 m). This is basically ground level. We also used a release duration of minutes to match the source term.

- Even though we did not have actual measured weather data we could make some assumptions. It is the middle of the night and the roads are icy so winter, night calm seems likely.

- The TEDE and thyroid CDE values are well below the EPA PAGs even at 1/10 of a mile from the release point.

METEOROLOGY

This section presents a series of problems to provide more practice with the meteorological data processor and to illustrate how various meteorological conditions can affect resultant doses.

To simplify things, the following source term and release pathway will be used for all the problems:

Event Type	Nuclear Power Plant
Event Location	James A. Fitzpatrick
Source Term	Time Core is Uncovered Reactor shutdown: 03:30 Core uncovered: 06:00 Core recovered: No
Release Path	Pathway from dry well: Through the dry well wall Pathway to atmosphere: Direct from reactor building Release height: 10.0 meters Release events: < date > 06:00 Leak rate (% vol) 5% / day < date > 06:00 Sprays off

PRECIPITATION

Purpose

To understand how to deal with precipitation.

Background

Precipitation has a significant impact on projected dose. Precipitation washes particulates from the plume causing higher groundshine doses where the plume first encounters the precipitation. As the plume travels, depletion of the plume caused by precipitation will lower plume concentrations downwind. Thus, at greater distances, precipitation will cause lower cloudshine, groundshine, and inhalation doses.

RASCAL understands only seven precipitation types: none and 3 types each of liquid and frozen precipitation. The two classes are called rain and snow for simplicity. The precipitation in each class may be light, moderate, or heavy. The National Weather Service reports precipitation rates, but the format is not always uniform across the country. Rain includes drizzle, freezing rain, and freezing drizzle. Snow includes snow grains, snow pellets, ice pellets, ice crystals, and hail.

Precipitation Intensity

Precipitation intensity may be used if available. Some observations will report the rainfall rate. Forecasts normally include the predicted amount over 6 hour periods. Divide by 6 to get the hourly rate. Table 14 shows the appropriate conversion from rainfall rate to RASCAL precipitation class.

Table 14 Converting rainfall intensity to RASCAL precipitation class

Rainfall rate (intensity)	Equivalent RASCAL precipitation class
< 0.04 in/h (< 1 mm/h)	Light rain
0.04 in/h - 0.2 in/h (1 - 5 mm/h)	Moderate rain
> 0.2 in/h (> 5 mm/h)	Heavy rain

Doppler Radar

Doppler radar (NEXRAD) products display echo intensities in units of dBZ. These values correlate with precipitation type and intensity. However, the conversion varies by the area of the country and the type of precipitation that is occurring. Consult with a meteorologist if you wish to try and use these types of products as input to RASCAL.

Probability of precipitation

The probability of precipitation (PoP or POP) is described as the probability that a measurable amount of liquid precipitation (or the water equivalent of frozen precipitation) will occur. Measurable precipitation is defined as greater than 0.2 mm or 0.01 inch. The PoPs do not necessarily indicate precipitation intensity.

Forecasters often use the following worded qualifiers to express uncertainty or to qualify the area.

PoP percent	Expression of uncertainty	Equivalent areal qualifiers
10 percent	---	isolated or few
20 percent	slight chance	widely scattered
30 - 50 percent	chance	scattered
60 - 70 percent	likely	numerous
80 - 100 percent	definite	(none used)

The following is general guidance on using the PoP information in making RASCAL runs.

Probability of Precipitation (POP)	What to do in RASCAL
Slight chance of less	Set the precipitation class to "No Precip" and don't worry about it.
Chance or likely	Create two meteorological datasets, one without precipitation and the other with precipitation. Run the RASCAL scenario with both datasets and compare the doses. It is not appropriate to average the doses from the two runs. Either precipitation will occur or it won't but you will have considered both cases.
Definite	Enter the predicted precipitation

Problem

If needed, enter the initial conditions described on page 185 for source term and release path.

A. Create a meteorological dataset with the following conditions:

Time	Wind direction (deg)	Wind speed (mph)	Stability class	Precipitation	Air Temp (deg F)
0600	340	6	B	No Precip	50

Process the data and save with the new name: **FITZ No Rain**

Then, run the calculations using the following settings:

- Distance of calculation: Close-in + out to 10 miles
- End calculations at: Start of release to atmosphere plus: 8 hours

Record the **cloudshine** and **4-day groundshine** doses at 1, 5, and 10 miles in the tables provided.

B. Now, let's assume that the 06:00 observation included rain. Edit the meteorological dataset to change the precipitation type to **Rain**. Reprocess the data and save the dataset under a new name: **FITZ Rain**.

Recalculate doses and again record the cloudshine and 4-day groundshine doses in the tables.

Precipitation	**Cloudshine** (rem) at distance of:		
	1 mi	5 mi	10 mi
No rain			
Rain			

Precipitation	**4-day groundshine** (rem) at distance of:		
	1 mi	5 mi	10 mi
No rain			
Rain			

Results

Page 232 has the answers and a summary of the inputs used to get those answers.

1. Moderate rain removes most of the non-noble gases in about an hour.

2. Rainfall decreases cloudshine doses by washing material out of the plume.

3. Rainfall increases groundshine dose close-in but results in decreased groundshine dose farther out.

4. RASCAL dose not model isolated precipitation events (e.g. thunderstorms) well.

5. If the rain does not start until after the material has moved away from the release point, "hot spots" could be created.

CALM AND VARIABLE WINDS

Purpose

To learn how to deal with calm or variable winds.

Background

Calm is defined in the *Glossary of Meteorology* as "the absence of apparent motion of the air." It may be quantified as a wind speed of less than 1 mile per hour. It does not however mean that there is no motion of the air. Instead the air moves at low speed with lots of meander and no defined direction. Calm conditions present a problem for dispersion modeling. Since there is no defined direction and the wind speed is very low, the dispersion calculations cannot be based on plume movement.

The 3 models within RASCAL each treat calm conditions differently. The straight-line Gaussian plume model (used close-in) switches to a model that disperses radially. In the puff model (used for calculations to 10-50 miles), the puffs remain stationary but continue to disperse in place. In the UF_6 plume model, the wind speed is set to 1 mph and the plume is assumed to continue in the last defined transport direction.

Care should be taken when making protective action decisions based upon model runs using calm wind conditions. The low wind speeds and directional uncertainty may cause high doses in areas not predicted by the models. In some cases, a meteorologist may be able to provide a better value (speed and direction) by examining data from surrounding weather stations.

A good approach is to go to the weather.gov tabular forecast tables. These will generally include forecast wind speed and direction data for the current time. However, this data may be up to 12 hours old. It should not be used without first contacting the local forecast office.

Problem

Use the standard release scenario (page 185) for starting this problem.

Create a new meteorological dataset with the following conditions:

Time	Wind direction (deg)	Wind speed (mph)	Stability class	Precipitation	Air Temp (deg F)
0600	130	0	B	none	50

Process the data and save with the new name: **FITZ Calm**

Make a calculation run using this new dataset and the following settings:

- Distance of calculation: Close-in + out to 10 miles
- End calculations at: Start of release to atmosphere plus: 8 hours

Examine and describe the thyroid CDE footprints for both close-in and 10 miles. Record the thyroid CDE values at 0.2, 1.0, and 2.0 miles.

Met dataset	Thyroid CDE (rem) at distance of:		
	0.2 mi	1.0 mi	2.0 mi
Calm			

Results

Page 233 has the answers and a summary of the inputs used to get those answers.

This problem indicates the difficulty in predicting the direction of material movement under low wind speed conditions. The calm case is the extreme. Given no vector along which to move the material, the model diffuses it equally in all directions. Even with a measured direction, at low speeds that direction tends to vary considerably. At low wind speeds the material can move in unexpected directions and since it is moving slowly the concentrations can be high.

ELEVATED RELEASES

Purpose

To see how elevated releases affect downwind inhalation doses.

Background

Release Height

RASCAL uses a default release height of 10 meters. In terms of the models, this is essentially ground level. The entered release height can range from 10 to 200 meters (31 to 650 feet).

Release Height Winds

The Meteorological Data Processor program generates wind fields for a height 10 meters above the ground. If the actual release height of the material is greater than 10 meters a wind speed profile is used to adjust the transport wind speed to the release height. This profile is dependent on atmospheric stability and surface roughness. The equation and further discussion is provided in the RASCAL technical documentation.
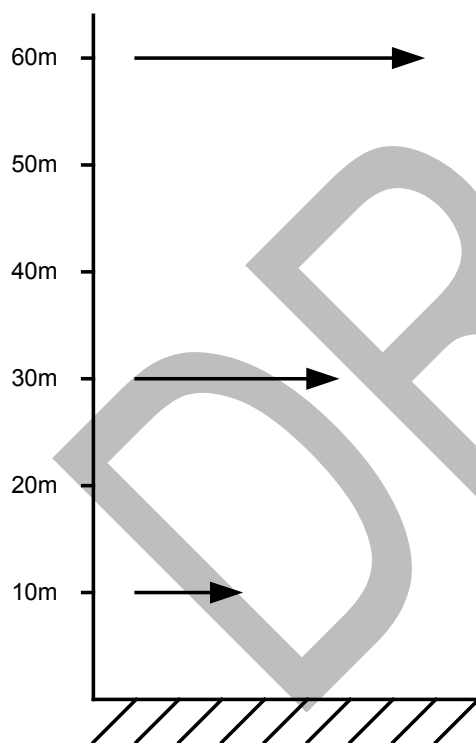
If the wind measurement height is between 8 and 12 meters, the wind measurement height will be assumed to be 10 meters. If a measurement height is specified outside this range the wind speed will be scaled to a height of 10 meters. To properly use data from elevated measurement heights you must make sure the "wind measurement height" setting for the station is set correctly.

To change the wind measurement height:
- Display the Station Summary tab
- Select a station ID from the available stations list
- On the menu, select Station and then Edit Station
- Change values as needed

Mixing Layer Thickness

Heating of the surface and surface friction combine to generate turbulence that mixes material released at or near ground level through a layer that varies in thickness from a few meters to a few kilometers in thickness. This layer is referred to as the mixing layer. The atmospheric models in RASCAL use the mixing height (also referred to as the mixing-layer depth or mixing-layer thickness) to limit vertical

diffusion. Elevated releases within the mixing layer disperse vertically and horizontally as the material is transported by the wind. As shown in the Figure 4, the material is reflected by the top of the mixing layer and the ground surface. At some distance downwind the material becomes uniformly mixed through the layer. With elevated releases, it may be some distance downwind before the actual plume of material intersects the ground surface.
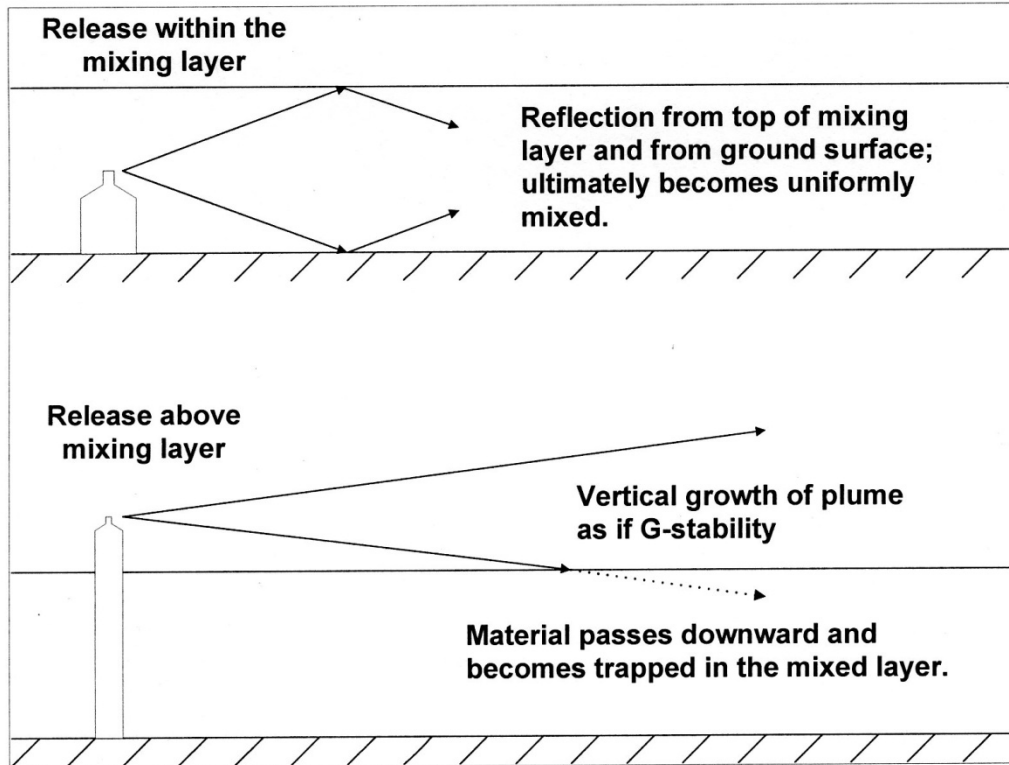
Figure 4 Plume interaction with mixing layer

Since mixing heights are rarely measured at nuclear power plants, RASCAL provides two ways of estimating the values: from current meteorological data or from climatological data. The first is the preferred option.

Problem

Using the standard initial conditions (Page 185) for starting these meteorology related problems, start a new case.

Investigate the differences in downwind doses for a ground level (10 m) and elevated (385 ft) release.

Create a new meteorological dataset with the following conditions:

Time	Wind direction (deg)	Wind speed (mph)	Stability class	Precipitation	Air Temp (deg F)
0600	340	3	F	none	50

Process the data and save with the new name: **FITZ F Stability**

Make a calculation using the following settings:

- Distance of calculation: **Close-in + out to 10 miles**
- End calculations at: **Start of release to atmosphere plus: 8 hours**

Record the thyroid CDE and cloudshine doses in the following 2 tables in the rows labeled **10.0 m**.

Release height	Thyroid CDE (rem) at distance of:		
	0.25 mi	2 mi	10 mi
10.0 m 385 ft			

Release height	Cloudshine (rem) at distance of:		
	0.25 mi	2 mi	10 mi
10.0 m 385 ft			

Next, go back into the release pathway section and change the release height to the stack height shown: 385 feet.

Repeat the calculations and record results in the tables in the appropriate rows.

Results

Page 235 has the answers and a summary of the inputs used to get those answers.

STABILITY CLASS

Purpose

To learn about stability classes and how they are estimated by RASCAL.

Background

Stability classes are determined on the basis of quantities that can be observed. For example, there is a direct relationship between the temperature profile in the atmosphere and turbulence. As a result, NRC has used temperature structure (ΔT/Δz) to define seven stability classes (see Table 15). Meteorological towers at nuclear power plants measure ΔT directly. However, they may report the stability class instead of the ΔT/Δz. ΔT/Δz is generally reported as °C/100 m or °F/100 ft.

At some nuclear power plants, ΔT is used to estimate the stability class for the vertical dispersion parameter, and the standard deviation of wind directions, which is a direct measure of turbulence, is used to determine a second stability class specifically for the horizontal dispersion parameter. RASCAL does not have a provision for two stability classes. If two stability classes are available, the stability class for the vertical dispersion parameter should be used.

Table 15 Selection of Pasquill-Gifford stability class by ΔT/Δz method

Stability class	Temperature change with height **	
	(ºC/100 m)	(ºF/100 ft)
A	< -1.9	< -1.0
B	-1.9 to -1.7	-1.0 to -0.9
C	-1.7 to -1.5	-0.9 to -0.8
D	-1.5 to -0.5	-0.8 to -0.3
E	-0.5 to 1.5	-0.3 to 0.8
F	1.5 to 4.0	0.8 to 2.2
G	> 4.0	> 2.2

** Negative values indicate a decrease in temperature with height

The National Weather Service does not include stability class in its reports, and they generally do not have temperature profiles. Therefore methods have been developed to estimate stability classes on the basis of more readily available weather variables such as wind speed, solar radiation, and sky cover along with time of the day (see Table 16).

Table 16 Selection of Pasquill-Gifford stability class by meteorological conditions

Surface wind speed		Daytime insolation [++]			Nighttime conditions	
m/s	mph	Strong	Moderate	Slight	Thin overcast or > 50% low clouds	<= 3/8 cloudiness
< 2	< 4	A	A - B	B		
2 - 3	4 - 7	A - B	B	C	E	F
3 - 4	7 - 9	B	B - C	C	D	E
4 - 6	9 - 13	C	C - D	D	D	D
> 6	> 13	C	D	D	D	D

++ Insolation = incoming solar radiation; i.e. strength of sunlight at ground level. Use slight insolation for mostly cloudy to overcast days or when it is near dawn or dusk. Use strong insolation for no clouds at mid-day during the summer. At all other times and conditions during daytime, assume moderate insolation.

The stability can be entered into RASCAL along with the other meteorological data. It may be entered directly as a class (A to G) or as a temperature change with height ($\Delta T/\Delta z$). There is an **Unknown** selection if the stability is not known.

When the stability is unknown, RASCAL will estimate it based on the time of day, wind speed, and the precipitation entered. Table 17 shows that estimated stability class for various conditions.

Table 17 How RASCAL estimates atmospheric stability class for missing stability classes

Wind speed (m/s)	No or light precipitation	Moderate or heavy precipitation
Daytime		
≤ 6.0	C	C
> 6.0	D	D
Nighttime		
≤ 3.0	F	E
3.1 - 5.0	E	E
> 5.0	D	D

Reference: NUREG-1940, Section 6.3.2

Daytime is defined as one hour after sunrise to one hour before sunset. Nighttime is defined as one hour before sunset to one hour after sunrise. The model computes the sunrise and sunset times based upon the date and the release point latitude.

PREDEFINED METEOROLOGICAL DATA

Purpose

To learn about the predefined meteorological data available with RASCAL.

Background

Predefined Data (Non site-specific) is an available meteorological dataset type. RASCAL is distributed with 18 such datasets. They were developed to cover a range of common weather conditions. These datasets have been given descriptive names such as *Summer- Afternoon - Windy*. Table 18 contains a summary of these datasets and their varying conditions.

There are pros and cons to using these predefined datasets.

Pros

- Each is a complete dataset that can be used with any location and any date and time of release.
- They are quick and easy to use especially when no actual observations are available. They can be used without needing to use the Meteorological Data Processor program.
- These datasets are good for comparing the plume and puff model results to see if the models are consistent.

Cons

- The wind fields are uniform in space as they are based on a single data record.
- They do not consider topography.
- They have a fixed wind direction of 270 degrees.
- They do not include any of the diurnal variations generally seen with actual conditions.

It is *always* better to use actual meteorological data.

Table 18 Summary of predefined meteorological datasets

Dataset name	Wind speed* mph	Stability class	Mixing layer* m	Precip code	Air temp deg F	Air press mb	Relative humidity %
Standard Meteorology	4	D	390	None	70	995	50
Summer - Afternoon - Calm	4	A	2000	None	85	995	40
Summer - Afternoon - Rainy	8	C	2000	Rain	70	995	95
Summer - Afternoon - Windy	15	B	1839	None	85	995	40
Summer - Morning - Calm	4	D	390	None	65	995	60
Summer - Morning - Rainy	8	D	780	Rain	60	995	95
Summer - Morning - Windy	15	D	1463	None	60	995	60
Summer - Night - Calm	4	F	123	None	55	995	80
Summer - Night - Rainy	8	E	333	Rain	50	995	95
Summer - Night - Windy	15	D	1463	None	50	995	85
Winter - Afternoon - Calm	4	C	1309	None	35	995	75
Winter - Afternoon - Windy	20	D	1951	None	35	995	75
Winter - Morning - Calm	4	E	236	None	30	995	80
Winter - Morning - Windy	20	D	1951	None	30	995	80
Winter - Night - Calm	4	G	47	None	20	995	90
Winter - Night - Windy	20	D	1951	None	20	995	90
Winter - Rain	10	D	976	Rain	35	995	95
Winter - Snow	8	D	780	Snow	25	995	95

*Notes - Wind direction in all cases is from the west (270 degrees).

The mixing layer depths were calculated by the Meteorological Data Processor and were not entered directly as observed data. If known, the mixing layer depth can be entered directly by the user.

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ANSWERS AND INPUT TO PROBLEMS

Following are the answers we got when we worked the problems. There may be variations in how you worked the problems that are valid. This section just shows you the numbers we got and provides all the inputs to the model that we used. This section only contains answers. Discussion of results is with the problem.

Using the Maximum Dose Values (page 33)

Results

Question	Your answer
What are the TEDE's at 2 and 5 miles?	1.0E-01 and 1.4E-02
What are the thyroid doses at 2 and 5 miles?	7.7E-01 and 9.8E-02
To what distance does the TEDE exceed the PAG?	To between 0.5 and 0.7 miles
To what distance does the thyroid dose exceed the PAG?	To between 0.7 and 1.0 miles
At what time does the plume first reach 5 miles?	About 2 P.M. (1hr after the release starts with 6 mph winds)
At what time have you assumed the release to end?	9 P.M. (Release start time of 1 p.m. plus 8 hours)
What was the time for the latest weather data that you entered?	11 A.M.

Inputs

Event Type	Nuclear Power Plant
Event Location	Arkansas – Unit 1
Source Term	Type: Time Core Is Uncovered Shutdown: < date > 10:00 Core uncovered: < date > 13:00 Core recovered: No
Release Path	Type: PWR – Dry Containment Leakage or Failure Release height: 10.0 m Release events: < date > 13:00 Leak rate (% vol) Design < date > 13:00 Sprays Off
Meteorology	Dataset type: Actual Observations Dataset: ARKA 1100
Calculation Options	Distance of calculation: Close-in + 10 miles End calculations at: Start of release plus 8 hours Case description: Core uncovered, design leak rate

Obtaining Observed Weather Data from the Internet (page 40)

Results

Question	Previous answer (single station)	New Answer (3 stations)
What are the TEDE's at 2 and 5 miles?	1.0E-01 and 1.4E-02 rem	1.1E-01 and 1.6E-02 rem
What are the thyroid doses at 2 and 5 miles?	7.7E-01 and 9.8E-02 rem	9.1E-01 and 1.2E-01 rem
To what distance does the TEDE exceed the PAG?	To between 0.5 and 0.7 miles	To between 0.5 and 0.7 miles
To what distance does the thyroid dose exceed the PAG?	To between 0.7 and 1.0 miles	To between 0.7 and 1.0 miles

Inputs

Event Type	Nuclear Power Plant
Event Location	Arkansas – Unit 1
Source Term	Type: Time Core Is Uncovered Shutdown: < date > 10:00 Core uncovered: < date > 13:00 Core recovered: No
Release Path	Type: PWR – Dry Containment Leakage or Failure Release height: 10.0 m Release events: < date > 13:00 Leak rate (% vol) Design < date > 13:00 Sprays Off
Meteorology	Dataset type: Actual Observations Dataset: ARKA 1130
Calculation Options	Distance of calculation: Close-in + 10 miles End calculations at: Start of release plus 8 hours Case description: Core uncovered, design leak rate

Obtaining Forecast Weather Data from the Internet (page 48)

Results

Question	Previous answer (3 stations - obs only)	New Answer (3 stations - obs & fcst)
What are the TEDE's at 2 and 5 miles?	1.1E-01 and 1.6E-02 rem	5.4E-01 and 9.9E-02 rem
What are the thyroid doses at 2 and 5 miles?	9.1E-01 and 1.5E-01 rem	4.5E+00 and 7.9E-01 rem
To what distance does the TEDE exceed the PAG?	To between 0.5 and 0.7 miles	To between 0.7 and 1.0 miles
To what distance does the thyroid dose exceed the PAG?	To between 0.7 and 1.0 miles	To between 1.5 and 2.0 miles

Adding the forecast information has resulted in increases in the projected doses. However, you are not seeing what direction the plume is moving.

Answer to optional question

Should this new RASCAL run be used to prepare the briefing?	No. You still do not have the information you need for your briefing.

Inputs

Event Type	Nuclear Power Plant
Event Location	Arkansas – Unit 1
Source Term	Type: Time Core Is Uncovered Shutdown: < date > 10:00 Core uncovered: < date > 13:00 Core recovered: No
Release Path	Type: PWR – Dry Containment Leakage or Failure Release height: 10.0 m Release events: < date > 13:00 Leak rate (% vol) Design < date > 13:00 Sprays Off
Meteorology	Dataset type: Actual Observations Dataset: ARKA 1200
Calculation Options	Distance of calculation: Close-in + 10 miles End calculations at: Start of release plus 8 hours Case description: Core uncovered, design leak rate

Time for End of Calculation (page 51)

Results

Question	Your answer
What are the TEDE's at 2 and 5 miles?	1.2 and 0.41 rem
What are the thyroid doses at 2 and 5 miles?	11 and 3.6 rem
To what distance does the TEDE exceed the PAG?	Between 2 and 3 miles
To what distance does the thyroid dose exceed the PAG?	Between 4 and 5 miles

Inputs

Event Type	Nuclear Power Plant
Event Location	Arkansas – Unit 1
Source Term	Type: Time Core Is Uncovered Shutdown: < date > 10:00 Core uncovered: < date > 13:00 Core recovered: No
Release Path	Type: PWR – Dry Containment Leakage or Failure Release height: 10.0 m Release events: < date > 13:00 Leak rate (% vol) Design < date > 13:00 Sprays Off < date+1 > 01:00 Leak rate (% vol) 0.00 %/h
Meteorology	Dataset type: Actual Observations Dataset: ARKA 1230
Calculation Options	Distance of calculation: Close-in + 10 miles End calculations at: Start of release plus 15 hours Case description: Core uncovered, design leak rate

Displaying Plume Footprints (page 82)

Results

Question	Your answer
In which compass direction from the release point are the doses greatest?	To the northeast

Inputs

Event Type	Nuclear Power Plant
Event Location	Arkansas – Unit 1
Source Term	Type: Time Core Is Uncovered Shutdown: < date > 10:00 Core uncovered: < date > 13:00 Core recovered: No
Release Path	Type: PWR – Dry Containment Leakage or Failure Release height: 10.0 m Release events: < date > 13:00 Leak rate (% vol) Design < date > 13:00 Sprays Off < date+1 > 01:00 Leak rate (% vol) 0.00 %/h
Meteorology	Dataset type: Actual Observations Dataset: ARKA 1230
Calculation Options	Distance of calculation: Close-in + 10 miles End calculations at: Start of release plus 15 hours Case description: Core uncovered, design leak rate

Long Term Station Blackout Source Term (page 84)

Results

Question	Your answer
From what time does the meteorology need to be available?	16:00-18:00 on day 2.
At about what distance is the TEDE exceeded? Thyoid CDE?	~2.8 mi, ~8 mi
Using the Source Term tab, and Release vs Time option, does the release interval extend as expected? What types of radionuclides are being released near the end?	Yes. Noble gases.
At what distance does the Child Thyroid dose exceed the 2013 EPA Interim PAG for KI ingestion? Adult CDE, same distance?	~18 miles, 2.4 rem
Projecting doses over 25 miles, how does the **TEDE** dose compare at **3 miles** for ICRP 26/30 versus ICRP 60/72?	0.88 rem, 1.3 rem
How does the **adult Thyroid CDE** dose compare at **3 miles** for ICRP 26/30 versus ICRP 60/72?	9.3 rem, 11 rem
How does the **TEDE** dose compare at **10 miles** for ICRP 26/30 versus ICRP 60/72?	0.36 rem, 0.54 rem
How does the **adult Thyroid CDE** dose compare at **10 miles** for ICRP 26/30 versus ICRP 60/72?	4.0 rem, 4.6 rem

Inputs

Event Type	Nuclear Power Plant
Event Location	Arkansas – Unit 2
Source Term	Type: Long Term Station Blackout (SOARCA) Shutdown: < date > 10:00 ECCS available and operating: Yes Expected duration of cooling: 24 h Method used for core damage estimate: Core recovered Core recovered: Yes at < date > 23:00
Release Path	Type: PWR – Dry Containment Leakage or Failure Release height: 10.0 m Release events: < date+1 > 18:00 Leak rate (% vol) 2%/d < date+1 > 18:00 Sprays Off < date+1 > 23:00 Sprays On < date+2 > 06:00 Leak rate (% vol) 0. %/d
Meteorology	Dataset type: Actual Observations Dataset: ARKA Case 5

Calculation Options	Distance of calculation: Close-in + 10 miles
	End calculations at: Start of release plus 15 hours
	Case description: Core uncovered, design leak rate

Release Pathway Reduction Mechanisms (page 95)

Results

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Sprays	Off	Off	Off	Off	Off	On
Recirculation fans	Off	Off	Off	Off	On	On
Ice bed exhausted	Yes	Yes	Yes	No	No	No
Hole size	4" dia	4" dia	2"dia	2" dia	2" dia	2" dia
Containment pressure	15 lb/in^2	5 lb/in^2	5 lb/in^2	5 lb/in^2	5 lb/in^2	5 lb/in^2
Total source term (Ci)	3.1E+05	2.4E+05	5.9E+04	5.2E+04	4.9E+04	4.5E+04
TEDE at 1 mile (rem)	7.1E-01	5.5E-01	1.4E-01	7.1E-02	3.7E-02	4.1E-03

Inputs

Event Type	Nuclear Power Plant
Event Location	Catawba Nuclear Plant, Unit 1
Source Term	Type: LOCA Shutdown: < date > 10:45 Core uncovered: < date > 13:30 Core recovered: < date > 14:15
Release Path	PWR Ice Containment Leakage or Failure Release height: 10. m Release events: *vary as needed for cases 1-6* < date > 13:30 Recirculation fans – Off < date > 13:30 Ice bed exhausted – Yes < date > 13:30 Sprays – Off < date > 13:30 Leak rate (press/hole) 15 lb/in2, 4 in diameter < date > 16:30 Leak rate (press/hole) 15 lb/in2, 0 in diameter
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours Description: Reduction mechanisms – Case 1

Monitored Mixtures (page 97)

Results

The following results are available from the **Maximum Dose Values** tab displaying the close-in doses.

Dose type	Distance from release
	1 mile
TEDE (rem)	5.0E-02
Thyroid CDE (rem)	3.9E-01

Inputs

Event Type	Nuclear Power Plant
Event Location	North Anna – Unit 2

Source Term	Effluent Releases – by Mixtures
	Shutdown: < date > 15:50
	Sample taken: < date > 16:00
	Release rates in Ci/s:
	  Noble gases – 95.0
	  Total iodines – 1.2
	  Particulates – 0.03

Release Path	Direct to Atmosphere Release height: 158 ft To atmosphere start: < date > 16:00 Release duration: 0 days, 00:30 hh:mm
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Containment Radiation Monitor (page 100)

Results

Examine the source term section of the **Case Summary** to see what amount of core damage was estimated based on the radiation monitor readings.

Containment radiation monitor reading	Monitor Reading (R/h)	Calculated core damage
12:45 P.M.	14	1.92 E-02% cladding failure
1:30 P.M.	50,000	7.2% core melt
3:00 P.M.	300,000	43.2% core melt

Inputs

Event Type	Nuclear Power Plant
Event Location	Waterford - Unit 3
Source Term	Containment Radiation Monitor
	Reactor shutdown: < date > 12:00
	Monitor location: Containment Dome (not user selectable)
	Containment radiation monitor readings (R/h):
	< date > 12:45 14
	< date > 13:30 50000
	< date > 15:00 300000
Release Path	Containment Leakage / Failure
	Release height: 10.0 m
	Leak rate events:
	< date > 12:45 Leak rate (% vol) Design
	< date > 12:45 Sprays Off
Meteorology	Dataset type: Predefined data (non site specific)
	Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in + to 10 miles
	End calculations at: Start of release plus 8 hours

Containment Bypass (page 101)

Results

The following results are available from the **Maximum Dose Values** tab displaying the close-in doses.

Dose type	Distance from release 0.2 miles
TEDE (rem)	3.0E-03
Thyroid CDE (rem)	4.8E-02

Inputs

Event Type	Nuclear Power Plant
Event Location	Peach Bottom - Unit 2
Source Term	Coolant Release Accidents Reactor shutdown: < date > 11:45 Coolant activity: Increased fuel pin leakage; Spike = 30 Time of coolant release: < date > 11:45
Release Path	Bypass of reactor building; direct, unfiltered Release height: 10.0 m Release events: < date > 11:45 Bypass flow rate 300 gal/min < date > 13:00 Bypass flow rate 0 gal/min
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Steam Generator Tube Rupture with Coolant Release (page 104)

Results

Dose type	Distance from release
	0.5 mile
TEDE (rem)	1.2E-03
Thyroid CDE (rem)	5.4E-03

Inputs

Event Type	Nuclear Power Plant
Event Location	Crystal River - Unit 3
Source Term	Coolant Release Accidents Reactor shutdown: < date > 00:36 Coolant activity: Increased fuel pin leakage, with coolant contamination spike by factor of 30 Time of coolant release: < date > 00:36
Release Path	Steam Generator Tube Rupture Release height: 30.0 m Release events: < date > 00:36 Leak rate into SG 500 gal/min < date > 00:36 Rupture location – Above water level < date > 00:36 Steaming rate – 7.5e4 lb/h < date > 00:36 Release point – Condenser exhaust
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Containment Holdup (page 106)

Results

Dose type	Holdup (hrs)	Distance from release		
		2 miles	10 miles	25 miles
TEDE (rem)	0	2.1E+00	5.7E-01	1.7E-01
	12	1.1E-01	3.2E-02	9.8E-03
Thyroid CDE (rem)	0	3.9E+01	1.1E+01	3.6E+00
	12	2.1E+00	6.0E-01	1.9E-01

	Holdup (hrs)	
Total Ci	0	1.6E+06
	12	7.0E+05
Ci of Cs-137*	0	7.1E+03
	12	4.4E+02

Inputs

Event Type	Nuclear Power Plant
Event Location	Wolf Creek - Unit 1 Set reactor power to 2852 MWt (this is 80% of the rated 3565 MWt)
Source Term	LOCA (NUREG-1465) Reactor shutdown: < date > 14:15 Core uncovered: < date > 15:25 Core recovered: < date > 15:45
Release Path	Containment Leakage or Failure Release height: 10.0 m Release events: Part 1: No Holdup < date > 15:25 Leak rate (% vol) – 100%/d < date > 15:25 Sprays Off < date > 18:25 Leak rate (% vol) – 0%/d Part 2: 12 hr Holdup < date+1 > 03:25 Leak rate (% vol) – 100%/d < date+1 > 03:25 Sprays Off < date+1 > 06:25 Leak rate (% vol) – 0%/d
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology

Calculation Options   Distance of calculation: Close-in + to 25 miles

End calculations at: Start of release plus 10 hours

Coolant Sample (page 107)

Results

Dose type	Distance from release
	1 mile
TEDE (rem)	4.7E-02
Thyroid CDE (rem)	1.4E+00

Inputs

Event Type	Nuclear Power Plant
Event Location	Crystal River - Unit 3
Source Term	Coolant Sample Sample activity units: μCi/ml Nuclide and activities: I-131 3.11E+02 Sample ID: ABC
Release Path	Steam Generator Tube Rupture Release height: 30.0 m Release events: < date > 00:36 Leak rate into SG 500 gal/min < date > 00:36 Rupture location – Above water level < date > 00:36 Steaming rate – 7.5e4 lb/h < date > 00:36 Release point – Condenser exhaust
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Specified Core Damage Point (page 108)

Results

Dose type	Distance from release
	0.1 mile
TEDE (rem)	1.6E-02
Thyroid CDE (rem)	3.0E-01

Inputs

Event Type	Nuclear Power Plant
Event Location	Comanche Peak - Unit 1
Source Term	LOCA (NUREG-1465) Reactor shutdown: < date > 20:30 Core uncovered: <date> 21:00 Method for core damage estimate: Specified damage amount Cladding failure: 4 percent
Release Path	PWR Dry Containment Leakage/Failure Release height: 10.0 m Start of release to containment: < date > 21:00 Release events: < date > 21:00 Leak rate (% vol) Design < date > 21:00 Sprays Off
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

PAR Evaluation (page 114)

Inputs

Event Type	Nuclear Power Plant
Event Location	Comanche Peak – Unit 1

Source Term	Type: Effluent Releases – by Mixtures
	Shutdown: < date > 08:37
	Sample taken: < date > 10:54
	Release rates:
	  Noble gases = 5.22E+01 Ci/s
	  I-131 equiv = 5.22E-02 Ci/s (initial run; assume 1000x less than noble gas)
	                    2.00E-01 Ci/s (corrected; 3.8x original value)
	  Particulates = 0.00E+00 Ci/s

Release Path	Type: Direct to atmosphere Release height: 30 m To atmosphere start: < date > 10:54 Release duration: 12:30 hh:mm
Meteorology	Dataset type: Actual Observations Dataset: PEAK 0900 Obs 202 deg, 10 mph, E stability, no precipitation, 78 °F 1200 Obs 250 deg, 10 mph, E stability, no precipitation, 83 °F
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 15 hours

Answers - Part II

1. Team 2 - 6.8 mrem, Team 3 – 3.3 mrem

2. Team 2 – (1-(1/1.3)) = 23%, Team 3 – (1-(1/1.3)) = 23%

3. Apparently so. Some rounding errors are likely making these results look the same.

4. At 1 mile – 14 mrem, at 2 miles – 6.5 mrem

5. At 1 mile (1-(1/2.7)) = 63%, at 2 miles (1-(1/2.4)) = 58%

6. Since the corrections factors are the same as for Team 2, the Team 2 answers can just be halved (Total 14.3 mrem, Internal 4.1 mrem).

Comparing Field Measurements with RASCAL Results (page 124)

Inputs

Event Type	Nuclear Power Plant
Event Location	Fermi – Unit 2

Source Term	Type: Effluent Releases – by Mixtures
	Shutdown: < date > 10:00
	Sample taken: < date > 11:00
	Release rates:
	  Noble gases = 1.00E+03 Ci/s
	  Total iodines = 5.00E+00 Ci/s
	  Particulates = 5.00E-01 Ci/s

Release Path	Type: Direct to atmosphere Release height: 168 ft To atmosphere start: < date > 11:00 Release duration: 04:00 hh:mm
Meteorology	Dataset type: Actual Observations Dataset: FERM 1100 190 deg, 5 mph, E stability, no precipitation, 47 °F
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Normalizing the Model to Match Field Team Data (page 140)

Inputs

Event Type	Nuclear Power Plant
Event Location	Palisades

Source Term	Type: Effluent Releases – by Mixtures
	Shutdown: < date > 08:31
	Sample taken: < date > 11:45
	Release rates:
	  Noble gases = 1.31E+01 Ci/s
	  I-131 equivalent = 1.31E-02 Ci/s
	  Particulates = 0.00E+00 Ci/s

Release Path	Type: Direct to atmosphere Release height: 10.0 m To atmosphere start: < date > 11:45 Release duration: 02:00 hh:mm
Meteorology	Dataset type: Actual Observations Dataset: user created dataset for Palisades with: < date > 11:00 Obs 230 deg, 2 mph, Stability F, No precip
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

For Case 2 with adjusted values for the release rates:

Release rates:
  Noble gases =   1.048E+02 Ci/s
  I-131 equivalent = 1.048E-01 Ci/s
  Particulates = 0.00E+00 Ci/s

Spent Fuel Assembly Damaged Underwater (page 160)

Results

The following results can be compiled from the source term summary and maximum values tables after the completion of the calculations:

Summary of activity release to atmosphere		
	Ci	% of total
Noble gas	1.4E+05	100.0
Iodines	1.1E-01	0.0
Other	4.8E-02	0.0
Total	1.4E+05	100.0

Dose type	Distance from release	
	0.1 mi	0.2 mi
TEDE (rem)	1.9E-02	9.9E-03
Thyroid CDE (rem)	2.3E-03	< 1E-03

Inputs

Event Type	Spent Fuel
Event Location	Crystal River - Unit 3
Source Term	Pool Storage - Damaged Assembly under Water Number of fuel assemblies damaged: 1 Percentage of fuel rods damaged: 25% Number of days fuel assemblies were exposed: 1620 days (3 cycles x 540 days/cycle) Time since last irradiation: 6 days When did the damage to the fuel occur: < date > 00:49
Release Path	Release height: 20.0 m Start of release to atmosphere: < date > 00:49 End of release to atmosphere: Release duration: 02:00 hh:mm Filtered?: Yes Leak rate to atmosphere: Total failure (100% per hour)
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Summary of activity release to atmosphere 1620 day assembly		
	Ci	% of total
Noble gas	1.7E+03	100
Iodines	0.0	0.0
Other	3.1E-02	0.0
Total (26 nuclides)	1.7E+03	100

Dose type	Distance from release	
	0.1 mi	0.2 mi
TEDE (rem)	<1E-03	<1E-03
Thyroid CDE (rem)	<1E-03	<1E-03

Answers and Inputs
Spent Fuel Pool Drained (page 162)

Results – Part A

Summary of activity release to atmosphere		
	Ci	% of total
Noble gas	3.6E+06	31.4
Iodines	2.0E+06	17.2
Other	6.0E+06	51.4
Total	1.2E+07	100.0

Dose type	Distance from release		
	1 mi	5 mi	10 mi
TEDE (rem)	2.9E+02	6.3E+01	2.5E+01
Thyroid CDE (rem)	1.8E+03	3.9E+02	1.7E+02

Inputs

Event Type	Spent Fuel
Event Location	San Onofre - Unit 2

Source Term	Type: Pool Storage - Uncovered Fuel
	Date reactor was last shutdown for refueling: 2 weeks earlier
	Fuel in the pool from this reactor
	   Full core off-load? No (1 batch off loaded at last outage)
	   Number of batches in pool prior to last offload: 9 (previous refueling)
	Fuel uncovered and not cooled: < date > 11:00
	Fuel is recovered or cooled: No

Release Path	Release height: 10.0 m Start of release to atmosphere: < date > 13:00 Filtered?: No
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close in + to 10 miles End calculations at: Start of release plus 8 hours

Results – Part B

Answers will vary. In general, 2nd year PAGs are exceeded beyond 100 mi.

Spent Fuel Dry Cask Rupture (page 166)

Results

The following results are available after the completion of the calculations. The total activity released is from the top of the source term summary.

Summary of activity release to atmosphere		
	Ci	% of total
Noble gas	2.1E+04	87.7
Iodines	0.0	0.0
Other	2.9E+03	12.3
Total	2.3E+04	100.0

Dose type	Distance from release	
	0.1 mi	0.2 mi
TEDE (rem)	5.0E+00	2.4E+00
Thyroid CDE (rem)	3.6E+00	1.8E+00

Inputs

Event Type	Spent Fuel
Event Location	Prairie Island - Unit 1
Source Term	Dry Storage - Cask Release Type of cask: Known: CASTOR V/21 Age of damaged fuel assemblies: How long in storage: 5 years Type of event: Major damage with 75% fuel elements damaged

Release Path	Release height: 10.0 m
	Start of release to atmosphere: < date > 04:15
	End of release to atmosphere:
	  Release duration: 02:00 hh:mm
	Filtered?: No (not an option with dry cask storage releases)
	Leak rate to atmosphere:
	  Total failure (100% per hour)

Meteorology	Dataset type: Predefined data (non site specific) Dataset: Winter - Night - Calm
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Uranium Process Fire (page 169)

Results

TEDE at 0.1 mile	4.6E-02 rem
Predominant dose pathway	Inhalation CEDE

Inputs

Event Type	Fuel Cycle / UF6 / Criticality
Event Location	AREVA Richland
Source Term	Fire Involving Uranium Oxide Type of fire: Production process Uranium enrichment level: 4% Production process: Dry Process Material at risk: 12,000 kg Airborne release fraction: 0.001 (default) Respirable fraction: 1.0 (default)

Release Path	Release height: 10.0 m
	Pathway condition:
	    Inside building
	    Pathway filtered - No
	Release timings
	Start of release to atmosphere: < date > 09:47
	End of release to atmosphere:
	    Duration 0 days 01:00 hh:mm

Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Explosion Involving Uranium Oxide (page 171)

Results

The following results are available after the completion of the calculations:

Total source term (curies)	8.7E-04

Dose type	Distance from release	
	0.54 km	1.1 km
TEDE (rem)	< 1 mrem	< 1 mrem

The doses are so low they do not get displayed in the maximum doses table. To get actual values, go to detailed results and display the TEDE as a numeric table.
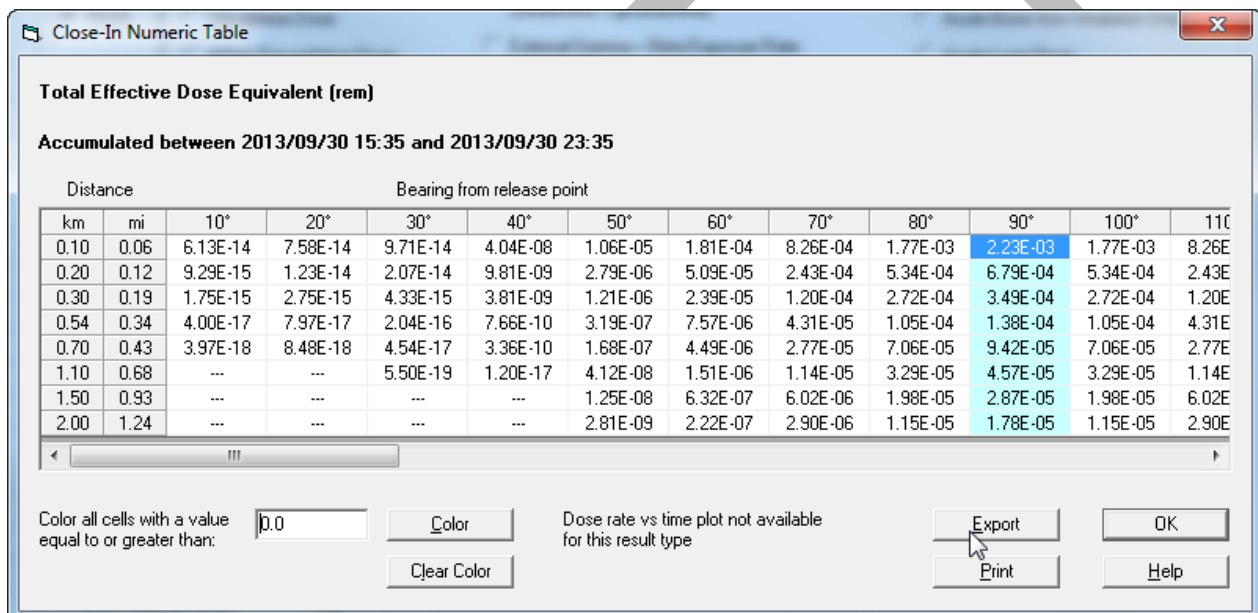
Inputs

Event Type	Fuel Cycle / UF6 / Criticality
Event Location	BWX NOG
Source Term	Explosion Involving Uranium Oxide Characterize the explosion: Deflagration Material form: Powder Material at risk: 3.6 kg ARF and RF: 5.00E-03 and 3.00E-01 Uranium enrichment: 93%

Release Path	Pathway description: Breached roof
	Release height: 12 m
	Pathway condition:
	Inside building, Pathway filtered: No
	Release timings:
	Start of release to atmosphere: < date > 15:35
	End of release to atmosphere: < date > 15:50
Meteorology	Dataset type: Predefined data (non site specific)
	Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in only
	User defined close-in distances.
	Change 0.5 to 0.54, 1.0 to 1.1, and mi to km.
	End calculations at: Start of release plus 8 hours

UF6 Cylinder Rupture (page 174)

Results

The following values are available in the Maximum Dose Values table:

Result type	Result at 0.2 miles	
	Value and units	Impact
HF Lung conc – 1 hr equivalent	3.8 ppm	None. Below level where symptoms are observed
Uranium intake	2.3 mg	None. Below threshold for any observable transient effect
Radiation dose (U TEDE)	0.01 rem	None. Below EPA PAGs and public dose limit

Inputs

Event Type	Fuel Cycle / UF6 / Criticality
Event Location	AREVA NP Richland
Source Term	UF6 Release From Cylinder Amount of UF_6 involved: 　By Type: 1 - 2½ ton cylinder Form of UF_6: Liquid Cylinder damage type: Cylinder rupture Release fraction: 0.65 Release rate: 32 kg/s Start of release: < date > 09:30 Uranium enrichment level : 4%
Release Path	Effective release height: Fixed at ground level. Release pathway to atmosphere: Direct
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in only End calculations at: Start of release plus 8 hours

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## UF6 Cascade Release (page 176)

Results

Result type	Result at 2 miles	
	Numerical value	Impact
Radiation dose (U TEDE)	< 1 mrem (8.86E-04 rem - from detailed results)	None. Below EPA PAGs and public dose limit.
Uranium intake	0.12 mg	None. Below soluble uranium intake limit of 10 mg in 10CFR Part 20
HF Lung conc – 1 hr equi.	0.16 ppm	None. Below ERPG-1

Inputs

Event Type	Fuel Cycle / UF6 / Criticality
Event Location	U.S. Enrichment - Paducah
Source Term	Building: C-333 Cascade / Process UF6 Release From Cascade System Release described by: 1 cell with 9,500 pounds per cell Start of release: < date > 12:45 Release rate to building: 130 lb/s Release fraction: 1.0 UF_6 Enrichment level: 5%
Release Path	Cascade building flow configuration: Summer
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Summer - Afternoon - Windy
Calculation Options	Distance of calculation: Close-in only End calculations at: Start of release plus 8 hours

Criticality (page 178)

Results

From the **Criticality shine dose** option on the **Maximum Dose Values** tab, you can see that there were 3.0E+19 fissions during the release period.

Dose (rem)	Distance	
	100 ft	500 ft (~0.1 mi)
TEDE from plume	Not available	0.3
TEDE from criticality shine	3300	130
Total TEDE	3300	130

The total TEDE will be the sum of TEDE from the plume and from the criticality shine. As seen in the results table, the dose is dominated by the direct neutron shine dose. Dose from exposure to the plume is negligible by comparison.

If you consider the total dose delivered, the 1-rem PAG is exceeded beyond 2,000 feet. However, the PAG refers to projected dose that is potentially avoidable if protective actions are taken. Once the first burst has occurred, its shine dose is no longer part of the projected dose. Thus, it could legitimately be subtracted from the projected dose. But doing that would not change the distance significantly.

At a distance of 200 feet, the shine TEDE from all the bursts over 8 hours is 830 rem. However, it is reasonable to assume that after the initial burst, the individual would leave the area. Return to the source term screen to redefine the criticality accident to consist of a single burst instead of the multiple bursts. In that case, the shine dose at 200 feet from the first burst would be 25 rem neutron and 2.5 rem gamma. No early health effects would be expected from that dose.

Inputs

Event Type	Fuel Cycle / UF6 / Criticality
Event Location	AREVA NP Richland
Source Term	Criticality Accident

Start of criticality: < date > 13:45
Criticality consists of: Multiple bursts
Define fission yield by:
    Type of system: Solutions over 100 gal
Airborne release fractions: 1.0, 0.25, and 0.0005 (defaults)
Shielding thickness: 0.0 for steel, concrete, and water

Release Path	Pathway description: Room air vented through exhaust stack Release height**:** 18 m Release timings: Start of release to atmosphere: 13:45 End of release to atmosphere: Duration 0 days 10:00 hh:mm Reduction factors: 1.0 for all 3 groups Leak rate: 100%/h (ordinary ventilation)
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in only. End calculations at: Start of release plus 10 hours

Radioactive Material in a Fire (page 181)

Results

The reported source term is 50 Ci of I-131. That is what would be expected given the release fraction of 0.50.

The following doses are projected:

Dose type	Distance from release (miles)	
	0.1	1.0
TEDE (rem)	5.7E-02	1.5E-03
Thyroid CDE (rem)	1.7E+00	4.2E-02

Inputs

Event Type	Other Radioactive Materials Release
Event Location	E.R. Squibb
Source Term	Sources and Material in a Fire Fire location: Laboratory Activity units for material at risk: Ci U enrichment level: any value is OK List of material at risk in the fire: I-131 and 100.0 Ci
Release Path	Type: Direct to Atmosphere Release height: 10.0 m Start of release to atmosphere: < date > 08:00 End of release to atmosphere: Release duration: 01:00 hh:mm
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Standard Meteorology
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Transportation Accident (page 184)

Results

The source term summary confirms that 15,000 Ci of tritium were released.

The following doses are projected:

Dose type	Distance from release (miles)			
	0.1	0.2	0.5	1.0
TEDE (rem)	3.4E-02	1.1E-02	3.8E-03	2.1E-03

Inputs

Event Type	Other Radioactive Material Release
Event Location	Describe a Material Site not in the Database Name: Truck accident I-80 and I-180 City, State: Milton, PA Lat, Long, Elev: 41.0495, -76.84, 153 m Time zone: Eastern

Source Term	Effluent Release Rates – by Nuclide
	Sample rate units: Ci/min
	Sample Period 1:
	  Start: < date > 02:00
	  Stop: < date > 02:10
	  Nuclide: H-3 1,500 Ci/min

Release Path	Type: Direct to atmosphere Release height: 10 m To atmosphere start: < date > 02:00 Release duration: 00:10 hh:mm
Meteorology	Dataset type: Predefined data (non site specific) Dataset: Winter – Night – Calm
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Precipitation (page 188)

Results

A comparison of the 2 shine doses at the selected distances:

Precipitation	Cloudshine dose (rem) at distance of:		
	1 mi	5 mi	10 mi
No rain	2.0E-01	2.4E-02	9.6E-03
Rain	1.7E-01	1.1E-02	3.1E-03

Precipitation	4-day groundshine dose (rem) at distance of:		
	1 mi	5 mi	10 mi
No rain	3.2E+00	1.1E-01	4.3E-02
Rain	1.0E+02	7.3E-01	5.0E-02

Inputs

|	
Event Type	Nuclear Power Plant
Event Location	James A. Fitzpatrick
Source Term	LOCA (NUREG-1465) Reactor shutdown: < date > 03:30 Core uncovered: < date > 06:00 Core recovered: No
Release Path	Pathway from dry well: Through the dry well wall Pathway to atmosphere: Direct from reactor building Release height: 10.0 m Release to containment: < date > 06:00 Release events: < date > 06:00 Leak rate (% vol) 5% / day < date > 06:00 Sprays off
Meteorology	Dataset type: Actual Dataset: use 2 datasets; one with rain and one without
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Calm and Variable Winds (page 190)

Results

Here are the thyroid CDE footprints resulting when the wind speeds were really zero. A different pattern emerges. The bullseye or circular pattern shows the material being distributed in all directions.
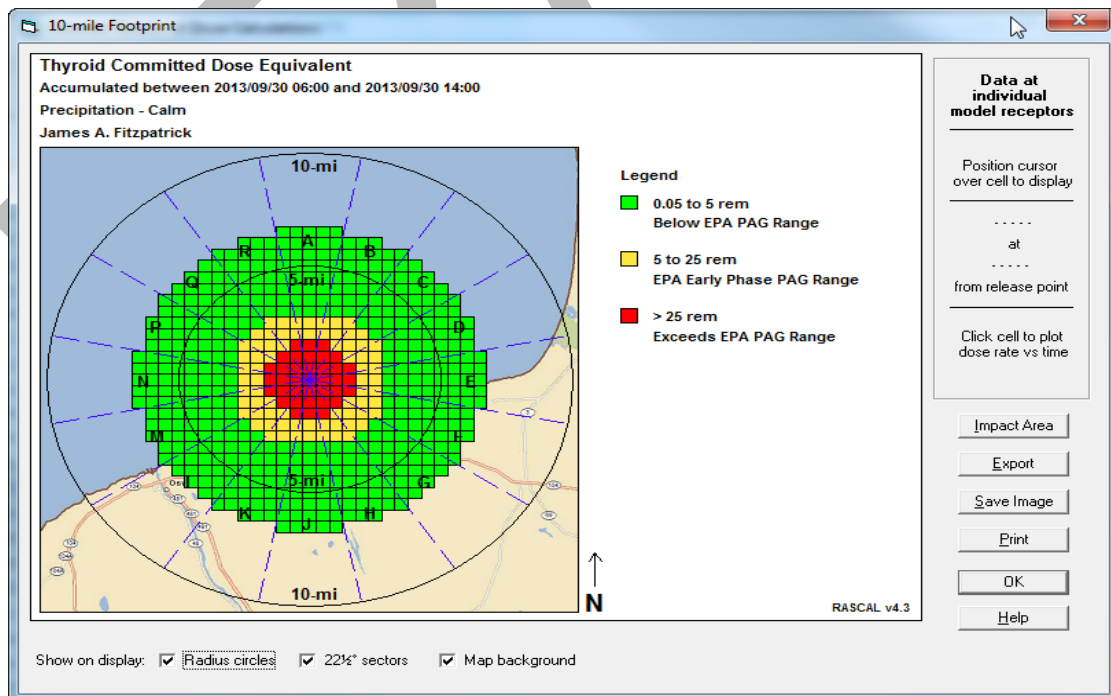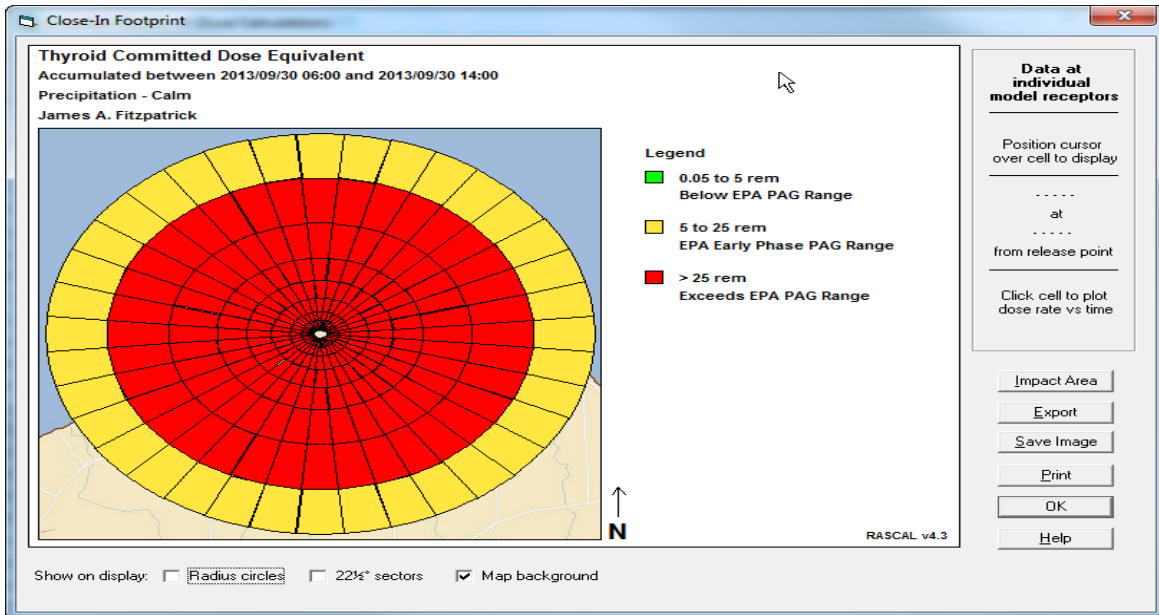
The resulting thyroid CDE values for the case are:

Met dataset	Thyroid CDE (rem) at distance of:		
	0.2 mi	1.0 mi	2.0 mi
Calm	1.4E+03	1.1E+02	1.9E+01

Inputs

Event Type	Nuclear Power Plant
Event Location	James A. Fitzpatrick
Source Term	Time Core is Uncovered Reactor shutdown: < date > 03:30 Core uncovered: < date > 06:00 Core recovered: No
Release Path	Pathway from dry well: Through the dry well wall Pathway to atmosphere: Direct from reactor building Release height: 10.0 m Release to containment: < date > 06:00 Release events: < date > 06:00 Leak rate (% vol) 5% / day < date > 06:00 Sprays off
Meteorology	Dataset type: Actual Dataset: dataset with wind speed = 0
Calculation Options	Distance of calculation: Close-in + to 10 miles End calculations at: Start of release plus 8 hours

Elevated Releases (page 193)

Results

Release height	Thyroid CDE (rem) at distance of:		
	0.2 mi	2 mi	10 mi
10.0 m	3.6E+03	5.3E+02	3.2E+01
385 ft	3.8E+01	1.4E+02	5.1E+01

Release height	Cloudshine (rem) at distance of:		
	0.25 mi	2 mi	10 mi
10.0 m	5.0E+00	6.3E-01	4.7E-02
385 ft	8.0E-01	3.7E-01	1.2E-01

Inputs

Event Type	Nuclear Power Plant
Event Location	James A. Fitzpatrick
Source Term	Time Core is Uncovered Reactor shutdown: < date > 03:30 Core uncovered: < date > 06:00 Core recovered: No
Release Path	Pathway from dry well: Through the dry well wall Pathway to atmosphere: Direct from reactor building Release height: 10.0 m and 385 ft Release to containment: < date > 06:00 Release events: < date > 06:00 Leak rate (% vol) 5% / day < date > 06:00 Sprays off
Meteorology	Dataset type: Actual Dataset: 3 mph F stability
Calculation Options	Distance of calculation: Close-in only + to 10 miles End calculations at: Start of release plus 8 hours