The PEAC-WMD Gamma Radiation Dose Calculator

During the last couple of months' newsletters I've discussed some of the new computational tools included in the PEAC-WMD 2007 (v5.5) application. This month I'll discuss the **Gamma Radiation Dose Calculator**. The calculator deals with point radiation sources, i.e., very localized spills vs. dispersed radiological contamination that might be created by a RDD (radiological dispersal device or "dirty bomb"). If the isotope and source strength are known, estimates can be made of either dose received, distance from source or exposure duration based on the other two values. This month I'll discuss the tool, specifically when it may be useful, the type of information provided, and how the tool is used for exercises or a real situation.

Background

Radioactive isotopes are common substances that are used in many different industries, e.g., well logging, weld testing, medical diagnostics, radiation treatment for cancers, university research laboratories, and as the new fuel and spent fuel in nuclear reactors. They are frequently transported through the nation's communities using the interstate highway system and other highways and present no hazard to the public when properly packaged. There can be transportation accidents or other incidents where the radioactive isotopes are released from their normal protective packaging and they then become a potential hazard to those persons exposed to these radioactive materials.

There is also the threat of terrorists and their attempts to acquire radioactive isotopes for the manufacturing of a RDD (radiation dispersal device or "dirty bomb") or a nuclear fission device that could be used as a weapon of mass destruction (WMD). The radioactive material required for a nuclear fission device is very high-grade material and is tightly controlled in most of the world. The likelihood of a terrorist acquiring these high-grade materials within the US is considered remote. Non-fissile radioactive materials are susceptible to terrorists' illegal uses and should be considered as a viable threat that a HAZMAT unit, fire service, or law enforcement First Responder may have to deal with.

The **Gamma Dose Calculator** is **not** intended to be used for incidents like a RRD or when entering a radioactive fallout contaminated area.

The types of radiation fall into four categories: (1) alpha particles, (2) beta particles, (3) gamma radiation and (4) neutron radiation. Alpha particles are the heaviest particles and are highly charge particles that travel only a short distance through the air (4-7 inches) and would not penetrate a sheet of paper or the outer layer of the skin. Alpha particles can cause internal damage to a person if they are inhaled, ingested, or enter through an opening, cuts, or abrasions. Beta particles have the same mass and charge as an electron and can travel further than alpha particles. They can penetrate $^1/_3$ inch of human tissue and can travel several feet through the air. Like the alpha particles, they can cause serious damage inside the body. Gamma radiation is similar to X-rays and depending on the energies (gamma energies vary considerably) they can travel very long distances (up to thousands of feet). Gamma radiation is the most penetrating type of radiation and is stopped by very dense materials such as lead or concrete or earth. Neutron radiation is made up of subatomic particles called neutrons, which have no electrical charge. They are primarily associated with nuclear reactions such as fission but they may also be produced from the decay of radioactive nuclides.

There are three principles to remember when dealing with radiation exposure and how to minimize the exposure to a radiation source: (1) time, (2) distance and (3) shielding. The less

time spent exposed to a radiation source, the less radiation an individual will receive. Increasing the distance from the radiation source will reduce the dose an individual will receive. Shielding involves placing material between the individual and the radiation source. While PPE (personal protective equipment) can provide protection against alpha particles and some beta particles, it will not provide sufficient protection against gamma or neutron sources. Nevertheless, PPE will provide the ability to shed the contamination when the individual sheds the PPE. In addition, the respiratory protection will prevent the inhalation of alpha or beta particles, which can cause internal damage. To prevent inadvertent inhalation or ingestion, there should be no eating, drinking or smoking until an individual has been monitored and designated as decontaminated.

When an event occurs where the responder has to deal with a radioactive material, depending on the type of event, there are various ways to determine what radioactive isotope one is involved. In the case of a transportation accident, the easiest method is by reading the shipping manifest. This should provide not only the radioactive isotope but also the amount of material in the shipment. There are also instruments available that will detect the radioactive isotope and identify what it is by analyzing the energies emitted. If the user knows the radioactive isotope and how much material is present (activity), then other different values can be calculated that relate to distance, exposure time and dose received.

The **Gamma Dose Calculator**

Using the **Gamma Dose Calculator** within the PEAC-WMD software application is easy to start by first selecting **Radioactive Isotopes** from the **Lookup By** field drop-down list of selections and then finding the isotope involved in the incident in the database. Once the isotope is selected (highlighted in the left side of the window) the user can click on the **Gamma Dose Calculator** icon [☢] at the top of the screen, Figure 1.

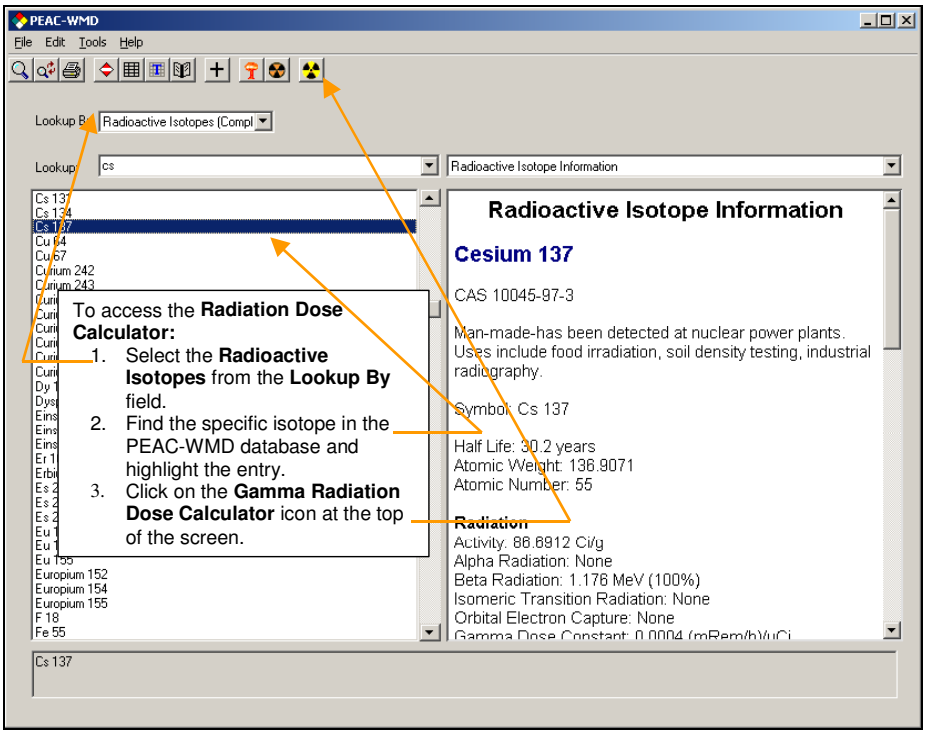

Figure 1 – Starting the Gamma Dose Calculator

The first time the **Gamma Dose Calculator** is executed during a session, a warning window will appear (Figure 2). To continue, the user must acknowledge by clicking on the **[YES]** button. If they click on **[NO]** button, the **Gamma Dose Calculator** will not execute. The warning window will not appear again if the calculator is called again. The warning text is also displayed at the bottom of the report generated when the calculator is exited.

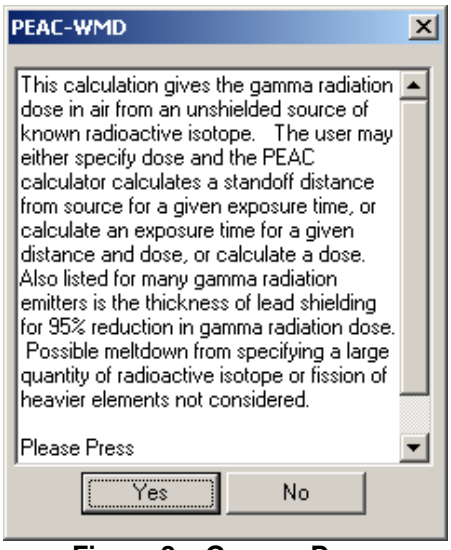

Figure 2 – Gamma Dose Calculator warning

Since the **Gamma Dose Calculator** creates a safe standoff distance, it is possible to generate a Shape file (standard format for polygons) for display on a GIS or mapping application. Therefore, once the disclaimer has been acknowledged, if a GPS is connected or available for entering latitude and longitude a window similar to one of those shown in Figure 3 will be displayed.

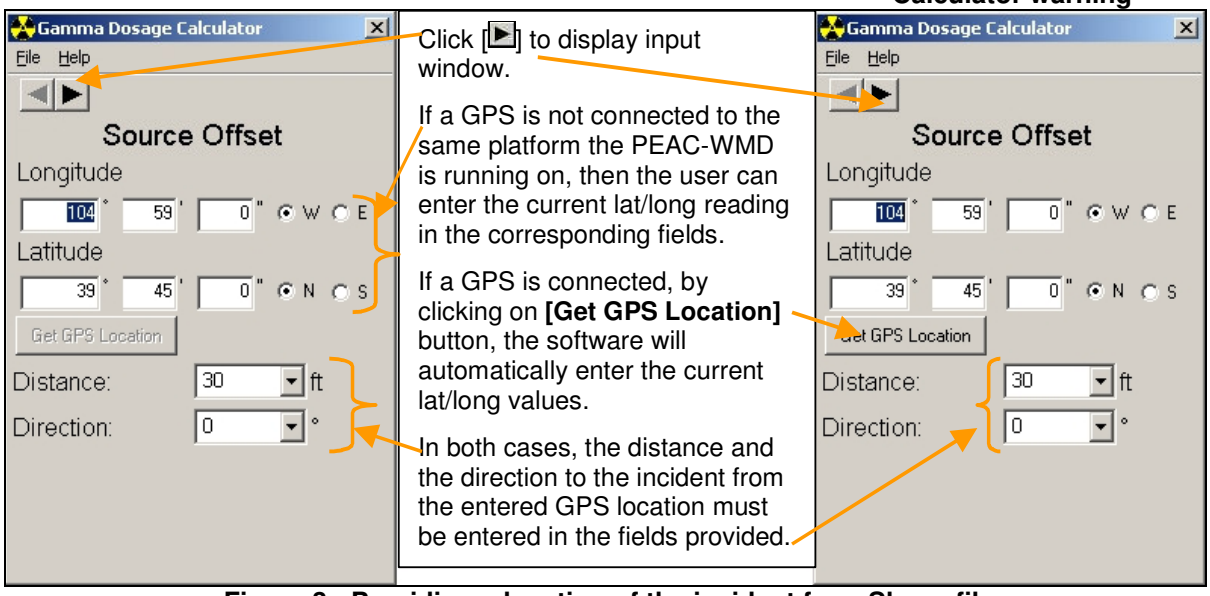

Figure 3 - Providing a location of the incident for a Shape file

If no GPS is connected or available, then the windows demonstrated in Figure 3 will not appear and the **Gamma Dose Calculator** screen will be displayed with either the last values entered and calculated or the default values as shown in Figure 4. The user needs to provide four (4) pieces of information for the **Gamma Dose Calculator** to estimate the radiation dose personnel will be exposed to when approaching an unshielded radioactive isotope.

Identifying the radioactive isotope from the list in the PEAC-WMD database has already provided the first piece of information required. The second piece of information is the activity of the isotope involved, Curies for English units or giga-Becquerels for metric units.

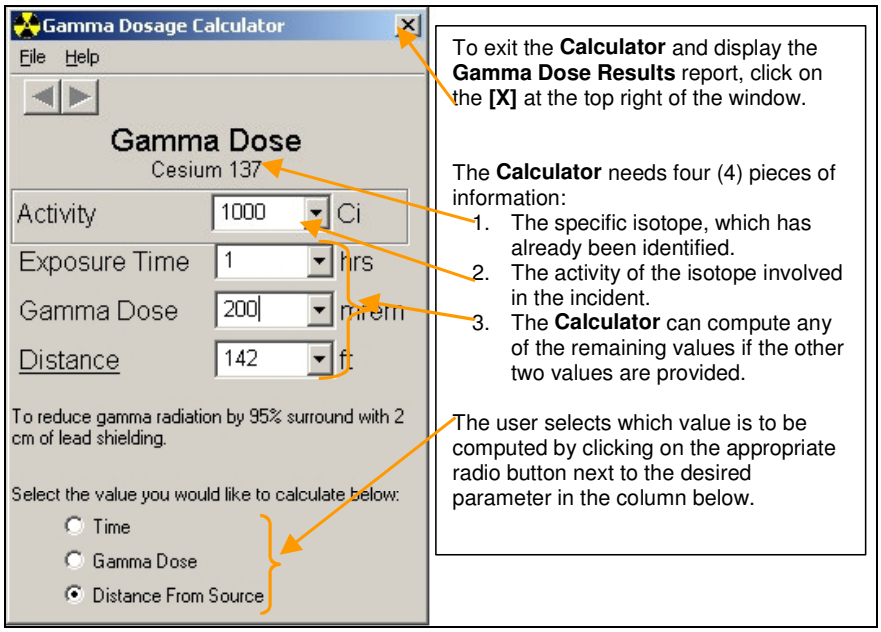

Figure 4 – The Gamma Dose Calculator input & results window

The other two values required are two of the three remaining values: exposure time, gamma radiation dose or distance from the source. The calculator will compute the third value, which is not provided. To clarify what is to be calculated, the tool requires that the desired value to be computed be selected by clicking on the appropriate radio button adjacent to the listed parameters at the bottom of the window. When a parameter's radio button is clicked, its corresponding name adjacent to the entry fields will be underlined. The other two fields will require that values be entered to calculate the desired parameter.

Therefore, assuming one knows how much of a specific isotope is present, if the exposure time is known and the acceptable radiation dose is known, then minimum distance to the source can be calculated. Or, knowing the distance to the source and the exposure time, a total radiation dose can be calculated. The last option is to calculate the exposure time knowing the distance and total radiation dose allowed.

Once the desired parameter has been selected and calculated, the user can generate a **Gamma Dose Results** report by clicking on the [X] at the top right corner of the window to return to the main database window. The **Gamma Dose Results** report will be displayed in the data display side of the window. This report will display a graphic with a circle that shows the distance calculated or entered in the **Gamma Dose Calculator**. This report can be printed, copied or recalled later as needed.

When the **Gamma Dose Results** report is generated, there is also a Shape file created that can be imported into a GIS or mapping application that accepts a standard Shape file. The Shape files are created on the local hard drive of the PC the PEAC-WMD application is running on. The path name is *My Documents\PEAC\Results\Shapes* and the files have a prefix of GD (for Gamma Dose) appended to the first 20 characters of the isotope name then the time stamped using the date and time formatted as yyyy*mmdd_hhmmss.*

An Example of using the Gamma Dose Calculator

Most fire departments and Hazmat response units aren't equipped to deal with cleaning up a radioactive source that has been spilled but they may be called for the initial response to assess the incident and secure the incident location. The following fictional incident will demonstrate how the PEAC-WMD tool could be used to respond to a radioactive spill.

Assume a large pharmaceutical company that provides Iodine 131 (I-131) radioactive materials, used for treatment and diagnostic purposes, is moving a number of Iodine 131 sources in multiple containers from a production facility to a multiple major medical centers in Denver, CO. During transport, there is an accident on E-470 leading from the Denver International Airport to I-70, which leads into downtown Denver. The transport driver reports that one of the containers on the transport is opened and may have released radioactive material from the container. The total activity of the open container is listed at 100 Curies. The transport company says it will be 30-60 minutes before the company's response team can be on site to take over the recover of the radioactive source. The Incident Commander (IC) decides to secure the incident and wait for the response team. A decision needs to be made as to what hazards are presented by the Iodine 131 and how best to maintain a safety zone around the incident.

With the PEAC-WMD tool the user can access quickly the basic information on Iodine 131 and what type of radiation hazards it presents to the Hazmat team. The first task is to assess the type of radiation hazards involved. Figure 5 demonstrates that Iodine 131 poses no alpha particles hazard but does emit beta particles and gamma radiation.

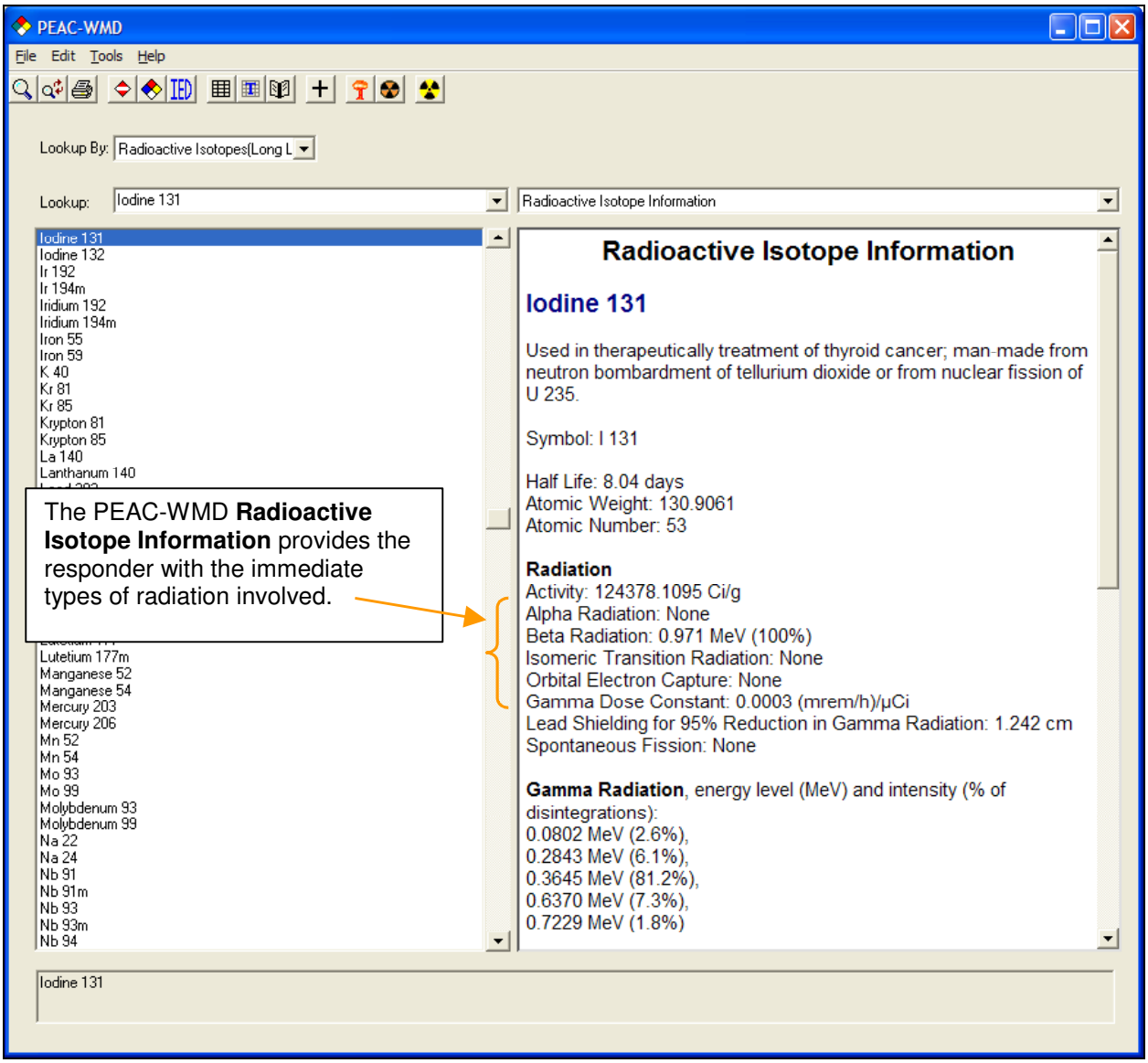

Figure 5 – Basic Radioactive Isotope Information available

Normally beta particles are a limited hazard since they travel a relatively short distance in the air and the responder can be protected with minimal PPE. To evaluate the distance a beta particle from Iodine 131 will travel in free air the user can scroll further down the **Radioactive Isotope Information** screen and view the distances displayed by the PEAC-WMD tool, Figure 6. The distance would be less than 14 feet, which should present no problems.

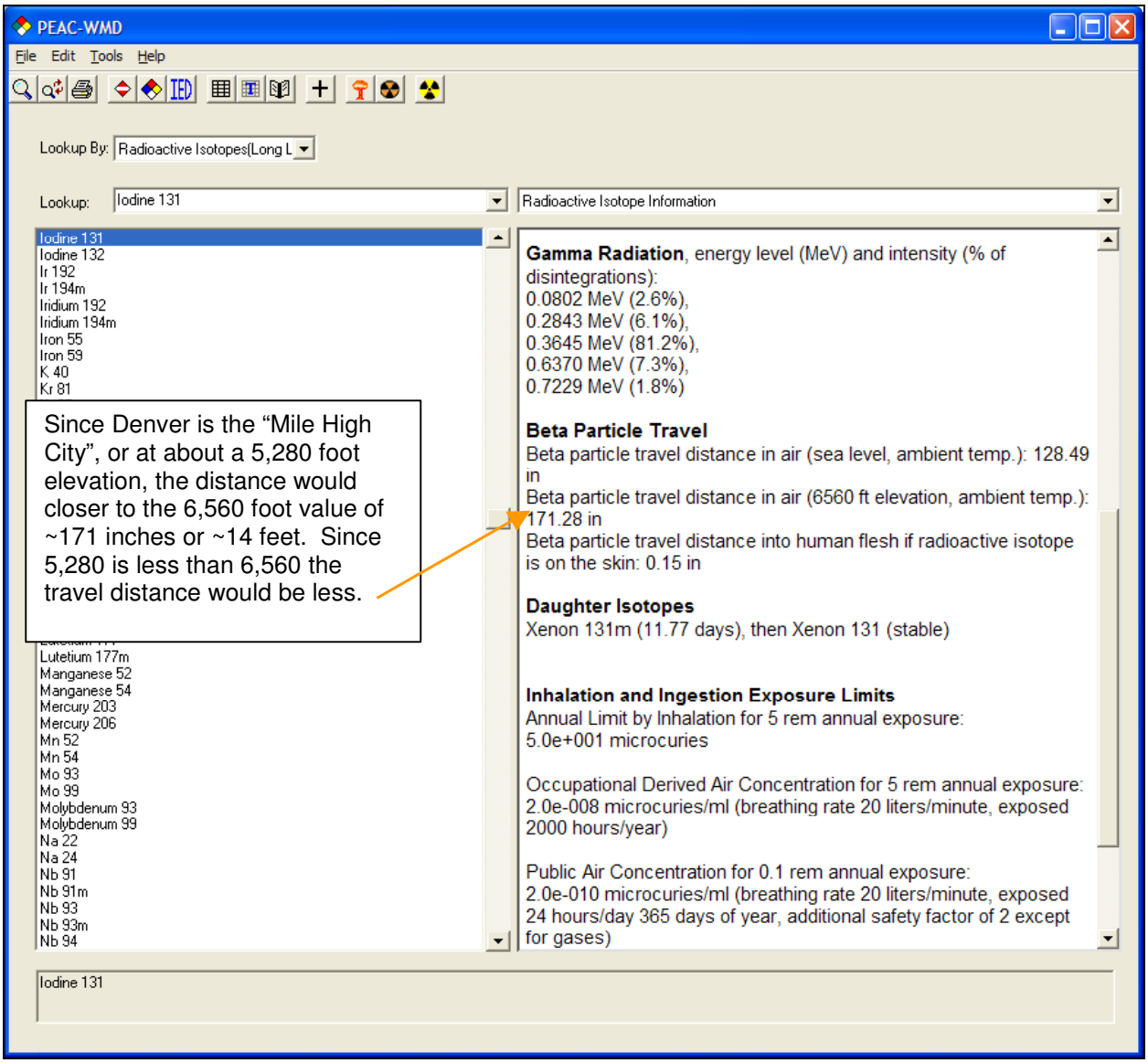

Figure 6 – The beta particle travel distance in free air for Iodine 131

Now the question becomes, how far would be prudent for the gamma radiation hazard for the 100 Curies, assuming all of the Iodine 131 had been released? The Gamma Dose Calculator can provide the responder with an estimated standoff distance. The additional information required is: (1) how long will the evacuation or standoff distance be applied and (2) what is an acceptable radiation dose for persons at the edge of the exclusion zone?

The first question can be estimated based on the 30-60 minute time period before the company’s response team arrives on site. We can use the 60 minutes as an outside guess or give them an extra 30 minutes since “Murphy’s Law” is probably going to be playing a role.

The second question is what radiation dose decision should be made by the IC. A 100 mrem dose is about what a person receives over the course of a year. Specifying a dose of 5 mrem might be reasonable, or at least a starting place to calculate an appropriate standoff distance.

To run the **Gamma Dose Calculator** we have the Iodine 131 already selected in the Lookup field and the user clicks on the **Gamma Dose Calculator** icon [☢] that will be displayed at the top of the main window, Figure 7. The warning window will appear if the first time the calculator has been run during a session. Click **[Yes]** to continue.

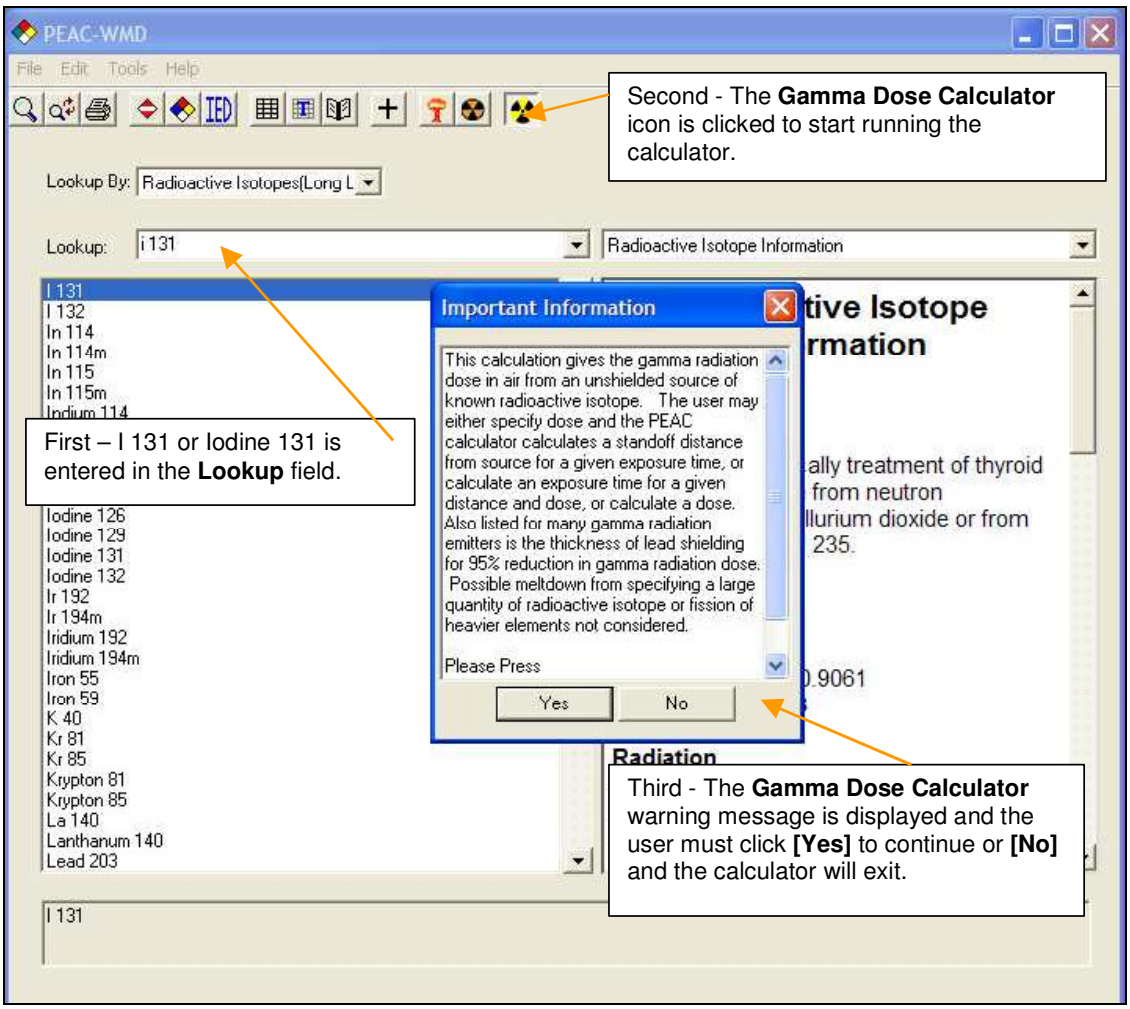

Figure 7 – Starting the Gamma Dose Calculator tool

The first window is the **GPS Location** window since for this example I selected using a GPS not connected to the PC or laptop, e.g., a handheld GPS. The user enters the location from the GPS and then the distance to the incident.

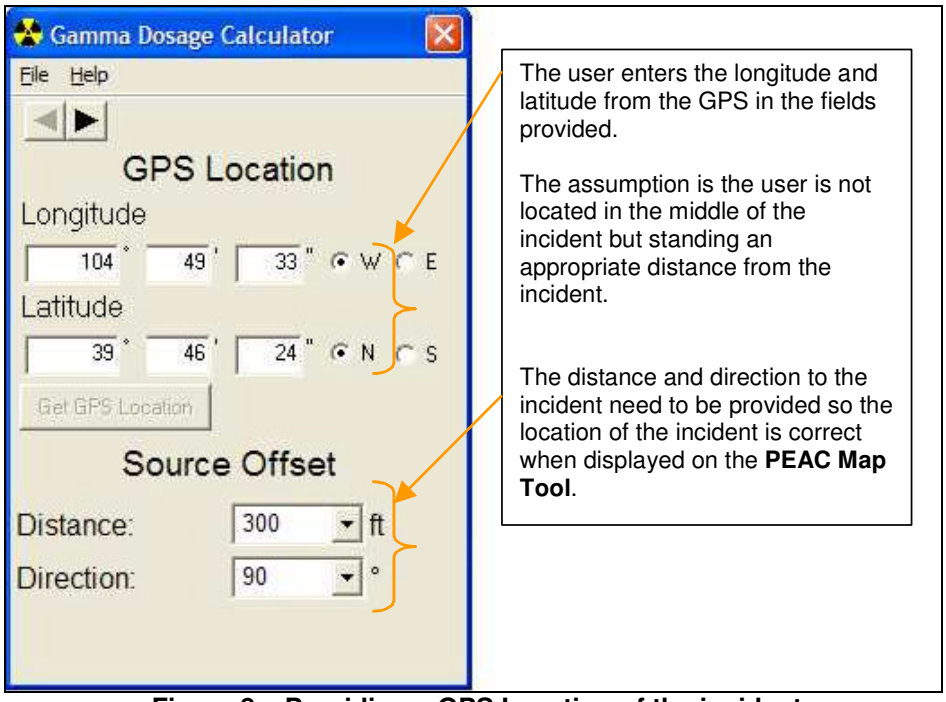

Figure 8 – Providing a GPS Location of the incident

Then the **Gamma Dose Calculator** tool will appear and the user selects the calculation to be performed, in this case **Distance From Source**, since we're trying to calculated a standoff distance (Figure 9). The user enters the Activity of 100 Curies, the Exposure time of 1.5 hours, and the Gamma Dose value of 5 mrem. As shown in Figure 9, the calculated standoff distance is 302 feet.

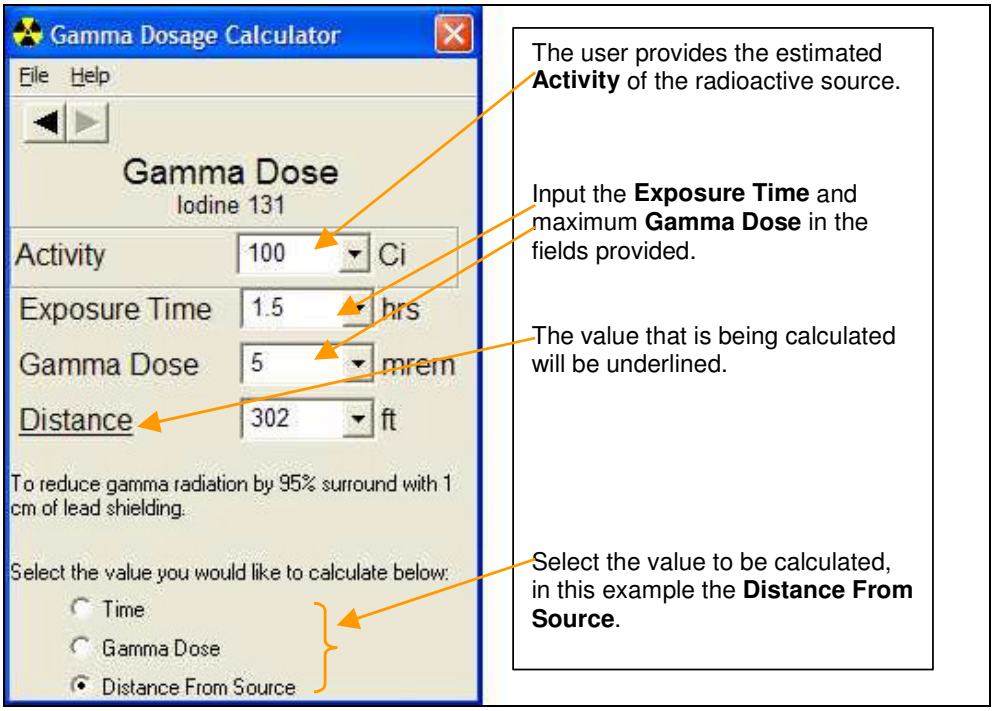

Figure 9 – Providing input and viewing results

When the calculated value is computed and displayed in the **Gamma Dose Calculator** window, the **PEAC Map Tool** will automatically display a street map with the standoff distance displayed as a circle based on the geographical location provided (Figure 10).

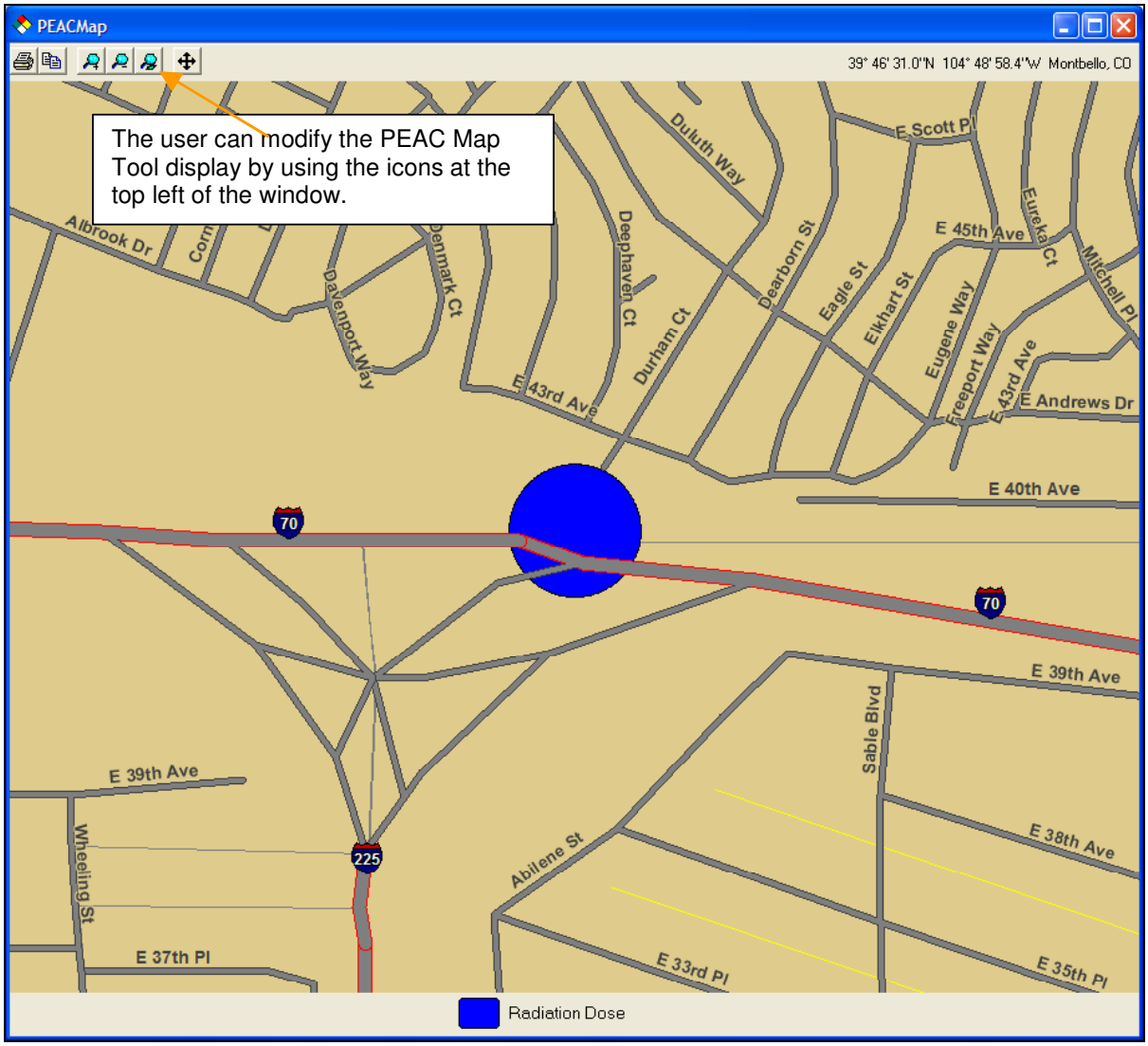

Figure 10 – Results of standoff distance calculation displayed on street map

When the **Gamma Dose Calculator** is exited, a **Gamma Radiation Dose Results Report** (Figure 11) is automatically generated and summarizes the input and results of the completed computation. This report can be copied, printed or recalled later for report development or review purposes.

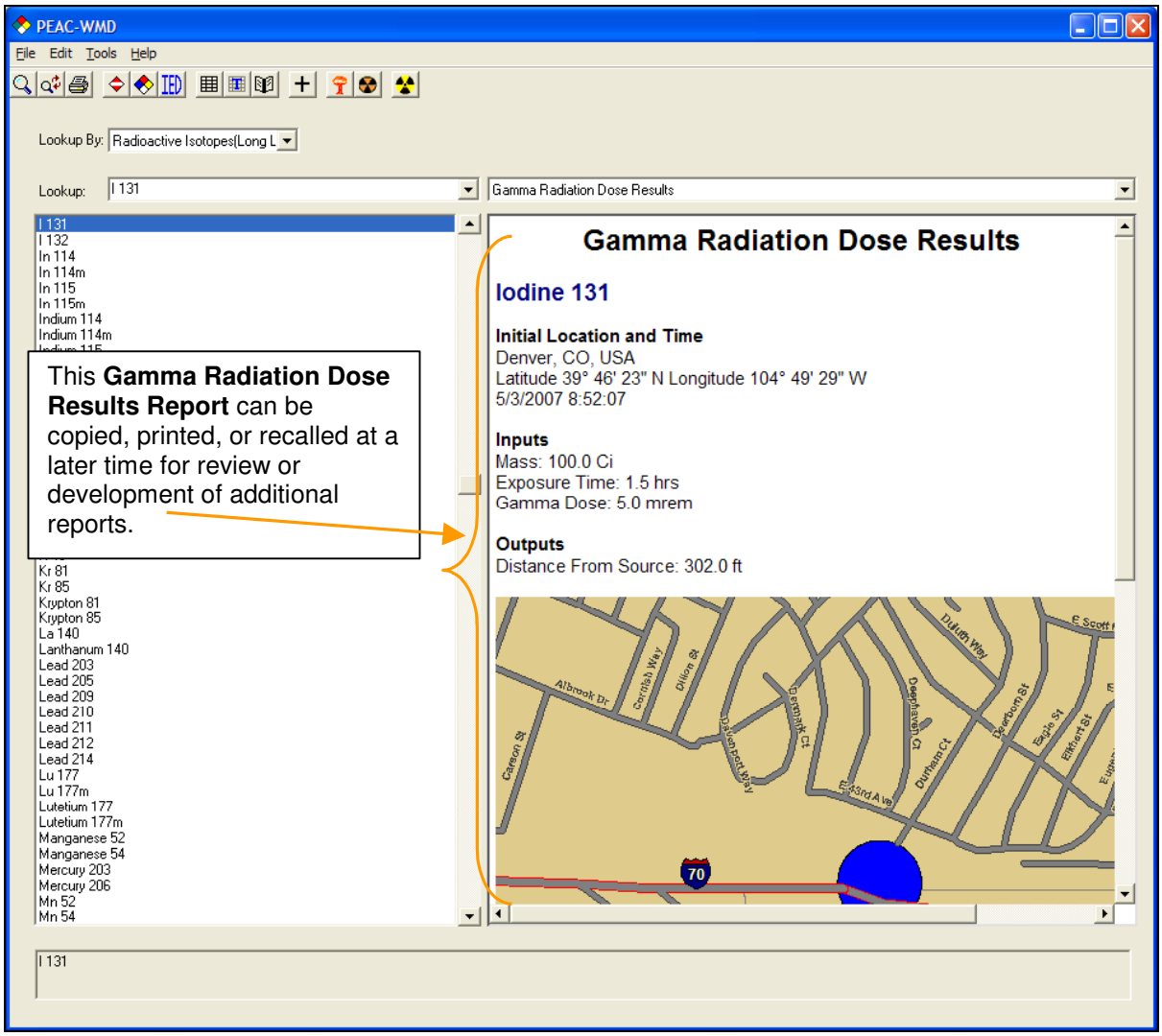

Figure 11 – Gamma Radiation Dose Results Report is automatically generated for printing and stored for recall