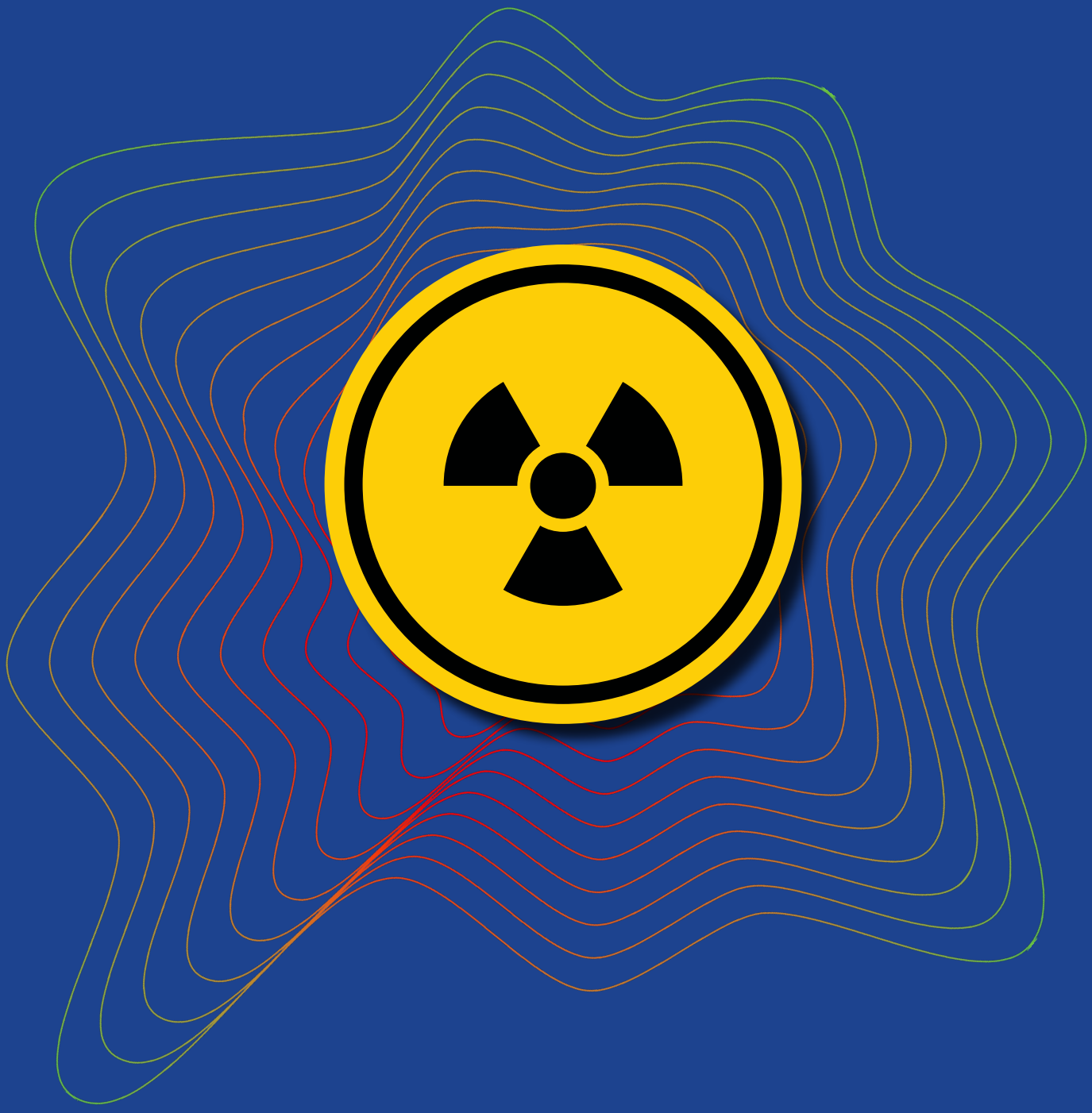

An Introductory Guide to the CDC Radiation Hazard Scale

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Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Conflicts of Interest: None

Contents

Introduction

Following a radiation emergency, people need to know which areas are affected or contaminated and understand the potential hazards and risks of the radioactive contamination and elevated radiation levels. To facilitate prompt and accurate risk communication after a radiation emergency, the Centers for Disease Control and Prevention (CDC) developed the Radiation Hazard Scale in 2014. The Radiation Hazard Scale is a communication tool that can help people assess their own risk and understand how following recommended protective actions can lower their risk of health effects.

The purpose of this guide is to help public health professionals effectively use the Radiation Hazard Scale in an emergency. The following sections provide information and guidance related to

- Development of the scale
- Description of the scale
- Suggested guidance on assigning radiation hazard categories
- Potential uses of the scale

Development, Testing, and Modifications to the Scale

Between 2014 and 2016, CDC conducted audience testing of the Radiation Hazard Scale with the public and public health officials. The goal of testing the scale was to capture feedback and to explore the effectiveness of the scale for communicating risk and prompting appropriate actions during a radiation emergency. The objectives of this effort were to refine the layout and presentation of the scale and to ensure that the descriptions for each category are easy to understand and effectively communicate risk. Researchers analyzed and presented the results to CDC for consideration for modifying the Radiation Hazard Scale. Participants found the Radiation Hazard Scale useful in assessing health risk. Participants liked the colors of the categories, and they liked the numbers increasing with the severity of each category. They were also partial to the simplicity of the scale. Researchers suggested minor wording revisions for multiple categories in the scale.

After refining the Radiation Hazard Scale based on the initial feedback, CDC conducted another round of testing with public information officers (PIOs) in eight states. The goal of this testing was to assess the effectiveness of the supporting text for each category. The PIOs overwhelmingly responded favorably to the Radiation Hazard Scale, with eight of the nine PIOs rating it seven or higher on a scale of one to ten. Because the goal of this effort was to gather feedback on the supplemental language, the focus group moderator specifically solicited recommendations on word choice and phrasing from the PIOs to help CDC refine the final product. As a result, the supplemental language for every category was edited from the original language based on participants' feedback. CDC also continued to obtain feedback about the scale from a variety of radiation professionals and public health professionals during workshops in 2017, 2019, and 2021.

While simple in principle, the Radiation Hazard Scale fills a vital risk communication role in radiation emergencies. The scale bridges the gap between technical data products, such as models and maps, and the clear, actionable messaging that will be needed to save lives. Through extensive audience and user testing, CDC created a product that meets the needs of end users and audiences alike.

Description of the Scale

The Radiation Hazard Scale (Figure 1) features five color-coded categories, each with a brief description of the health hazards associated with the corresponding increases in radiation levels. The scale is intended to be a tool that risk communicators can use to quickly inform people of the magnitude of the radiation hazard in their immediate surroundings, without using highly technical terms and units of measurement.

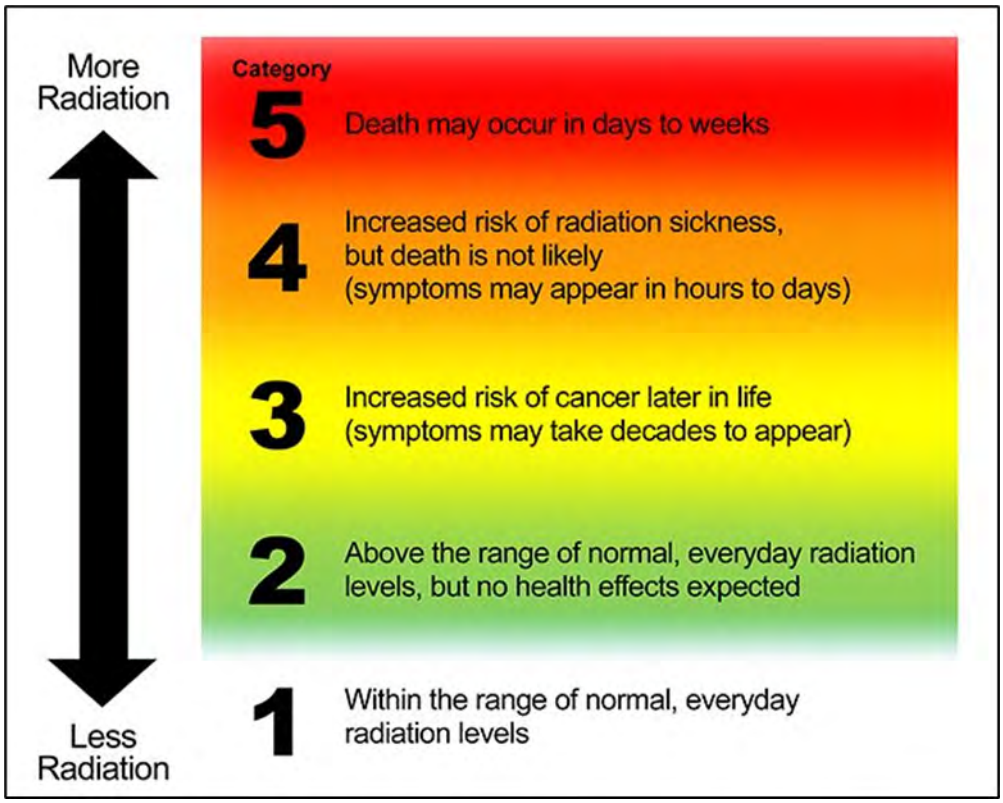

Figure 1. CDC Radiation Hazard Scale.

Category	Supporting Language
5	Category 5 means that radiation doses are dangerously high and potentially lethal. High doses of radiation can cause massive damage to organs of the body and kill the person. The exposed person loses white blood cells and the ability to fight infections. Diarrhea and vomiting are likely. Medical treatment can help, but the condition may still be fatal despite treatment. At extremely high doses of radiation, the person may lose consciousness and die within hours. More information about Acute Radiation Syndrome.
4	Category 4 means that radiation doses are dangerously high and can make people seriously ill. Radiation doses are not high enough to cause death, but one or more symptoms of radiation sickness may appear. Radiation sickness, also known as Acute Radiation Syndrome, is caused by a high dose of radiation. The severity of illness depends on the amount (or dose) of radiation. The earliest symptoms may include nausea, fatigue, vomiting, and diarrhea. Symptoms such as hair loss or skin burns may appear in weeks. More information about the health effects of radiation. More information about the medical treatment of radiation exposure.
3	Category 3 means that radiation doses are becoming high enough where we may expect increased risk of cancer in the years ahead for people who are exposed. Leukemia and thyroid cancers can appear in as few as 5 years after exposure. Other types of cancer can take decades to develop. Studies have shown that radiation exposure can increase the risk of people developing cancer. This increased risk of cancer is typically a fraction of one percent. The lifetime risk of cancer for the population due to natural causes is approximately 40%. The increase in risk of cancer from radiation depends on the amount (or dose) of radiation, and it becomes vanishingly small and near zero at low doses of radiation. Similarly, studies of cancer rates following short term exposures and doses have shown increases in cancer risks. These types of exposures and doses are typically expressed over time, such as dose per hour. More information about the health effects of radiation.
2	Category 2 means that radiation levels in the area are higher than the natural background radiation for that geographic area. However, these radiation levels are still too low to observe any health effects. When radiation levels are higher than what we normally have in our natural environment, it does not necessarily mean that it will cause us harm. More information about the health effects of radiation.
1	Category 1 means that radiation levels in the area are within the range of natural background radiation for that geographic area. The typical natural background radiation dose in the United States is approximately 3.1 mS/year, including the contribution from radon. Low amounts of radioactive materials exist naturally in our environment, food, air, water, and consequently in our bodies. We are also exposed to radiation from space that reaches the surface of the Earth. These conditions are natural, and this radiation is called the natural background radiation[1]. Learn more about radiation in your life and how it can vary by location. *[1]National Council on Radiation Protection and Measurements (2009). Ionizing Radiation Exposure of the Population of the United States. NCRP Report 160. Bethesda: NCRP.*

The combination of the color-coded scale and detailed supporting language provides an effective mechanism for communicating radiation risk. Furthermore, the color gradients of the scale can be replicated on maps and models, showing contamination deposition and areas where people will encounter elevated radiation levels. Figure 2 provides an example of a predictive model that corresponds to the Radiation Hazard Scale categories.

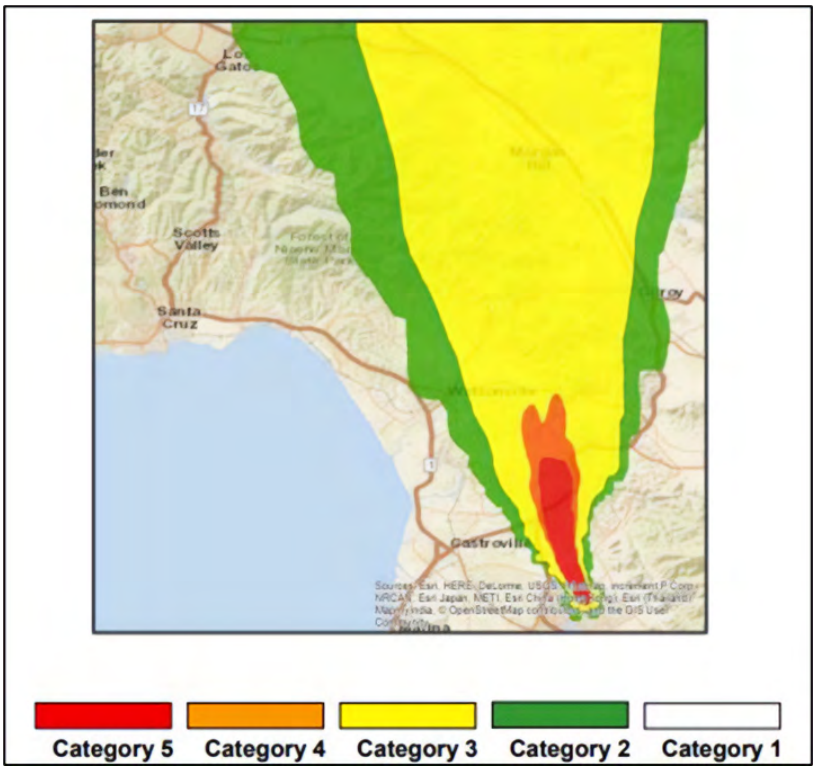

Figure 2. Predictive model showing radiation hazard categories during a fabricated incident.

These maps and models aid risk communication efforts by helping people

1. Visualize which areas have or may be affected.
2. Understand the health risk to people in those areas and how recommended protective actions can help reduce those risks.
3. Gather additional information about the health risks of specific radiation exposures from a trusted source.

In summary, the Radiation Hazard Scale

- Provides a frame of reference for relative hazards of radiation.
- Conveys meaning without using radiation measurements or units that are unfamiliar to people.
- Is designed for use only in radiation emergencies and is applicable for short-term exposure durations over a period of several days or less.
- Is best used when accompanied with protective action recommendations or instructions.
- Has been audience tested with public information officers, emergency management and public health professionals, and members of the public.

Suggested Guidance on Assigning Radiation Hazard Categories

The Radiation Hazard Scale is intended to communicate relative hazards to populations under emergency conditions when exact radiation exposure parameters for specific individuals are not available.

- There are no sharp lines separating radiation hazard categories; that is, there will be some overlap in the hazard categories as the boundaries are estimates.
- Transition from Category 1 to Category 2 depends on the range of natural background radiation for a geographic area.
- The radiation dose values are whole-body doses and are suggested guides for radiation protection purposes. Dose values are meant to be used by radiation protection experts and by emergency response and public health authorities.[2]
- Radiation dose values are not meant to be included in public messaging, especially during the early phase of a radiation emergency. The use of this color-coded scale can assist public communicators in giving qualitative risk messaging to areas impacted by the incident.
- This guide is applicable only for short-term exposures to the whole (entire) body over a short period time, for example, over a period of several days or less and only during an emergency. Although the guidance is qualitative (no specific value for any of the categories), it is a guidance for both PIOs and decision makers when early actions to protect public health are warranted.

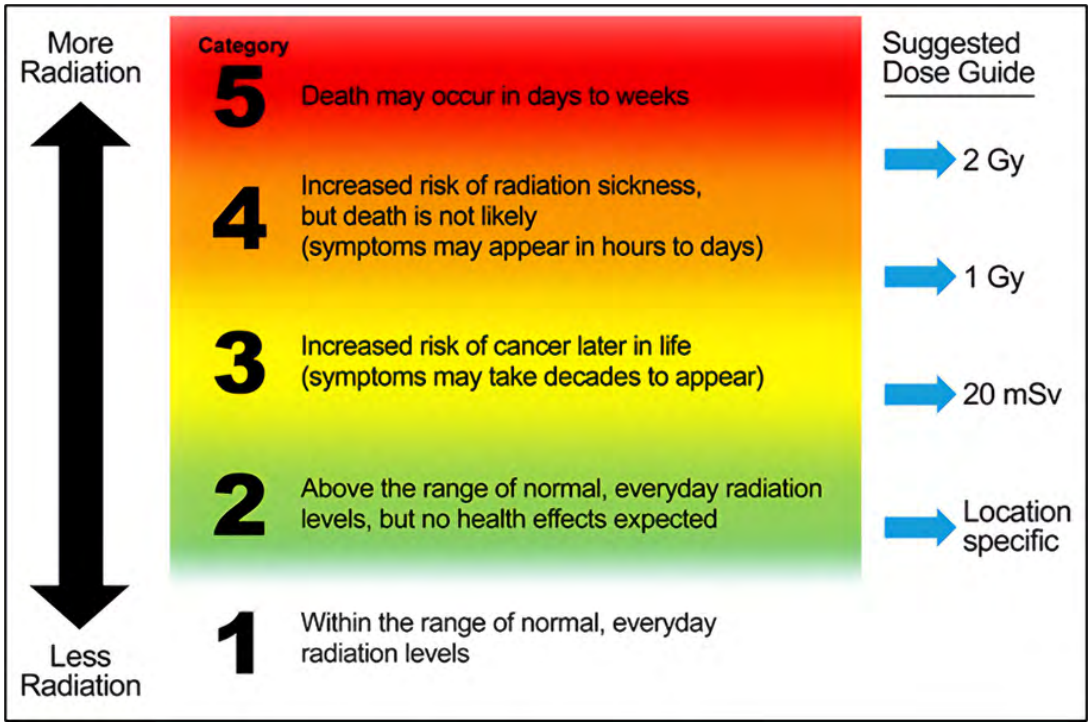

Figure 3. CDC Radiation Hazard Scale with the suggested dose guide

[2] For a description of radiation units listed in the dose guide, see the CDC Primer on Radiation Measurements available at https://www.cdc.gov/radiation-emergencies/php/ph-professionals/measuring-radiation.html.

Potential Uses of the Scale

The following examples demonstrate how the color gradients of the Radiation Hazard Scale can be used on maps in three different types of radiation emergencies. The first example considers the consequences of an improvised nuclear device (IND). The second considers the consequences of a radiological dispersal device (RDD), and the third considers a release from a nuclear power plant.

Responding to an Improvised Nuclear Device

Figures 4 and 5 below use the Radiation Hazard Scale to communicate radiation risk from a hypothetical IND detonation in downtown Atlanta, GA. Note that these graphics show the color gradients of the Radiation Hazard Scale contours overlaid into RadResponder[3].

Figure 4 shows a large area in Category 5 (red). The estimated population at risk in this area is approximately 91,000 persons. However, if people in this area obtain adequate shelter (e.g., a protection factor of 10 or greater), the number of people at risk in the Category 5 area falls to approximately 12,000 (see Figure 5). Although this example assumes a high compliance rate for sheltering-in-place, the risk reduction from a Category 5 (red) to a Category 3 (yellow) presents a compelling case for seeking shelter.

Presenting two versions of the Radiation Hazard Scale maps (i.e., hazards categories for unsheltered vs. sheltered populations) facilitates communication of the "Get Inside. Stay Inside. Stay Tuned." message. This presentation graphically illustrates that tens of thousands of lives can be saved by remaining in adequate shelter for 48–72 hours.

The color gradients of the Radiation Hazard Scale on the maps are also useful in communicating to emergency workers the risk of working in particular areas for a specific period of time and how those risks are reduced as a function of time. For example, Figures 6 and 7 illustrate the risks to emergency workers of working an 8-hour shift near the detonation site at 12 hours after the detonation and 1 week after the detonation. These images can help workers understand how response officials can leverage time—and therefore, radioactive decay—to keep responders safe over the duration of the response.

[3] RadResponder is the United States national standard for the management of radiological data. Radresponder is a collaborative effort between the Department of Homeland Security, Department of Energy, Department of Defense, and the Environmental Protection Agency.

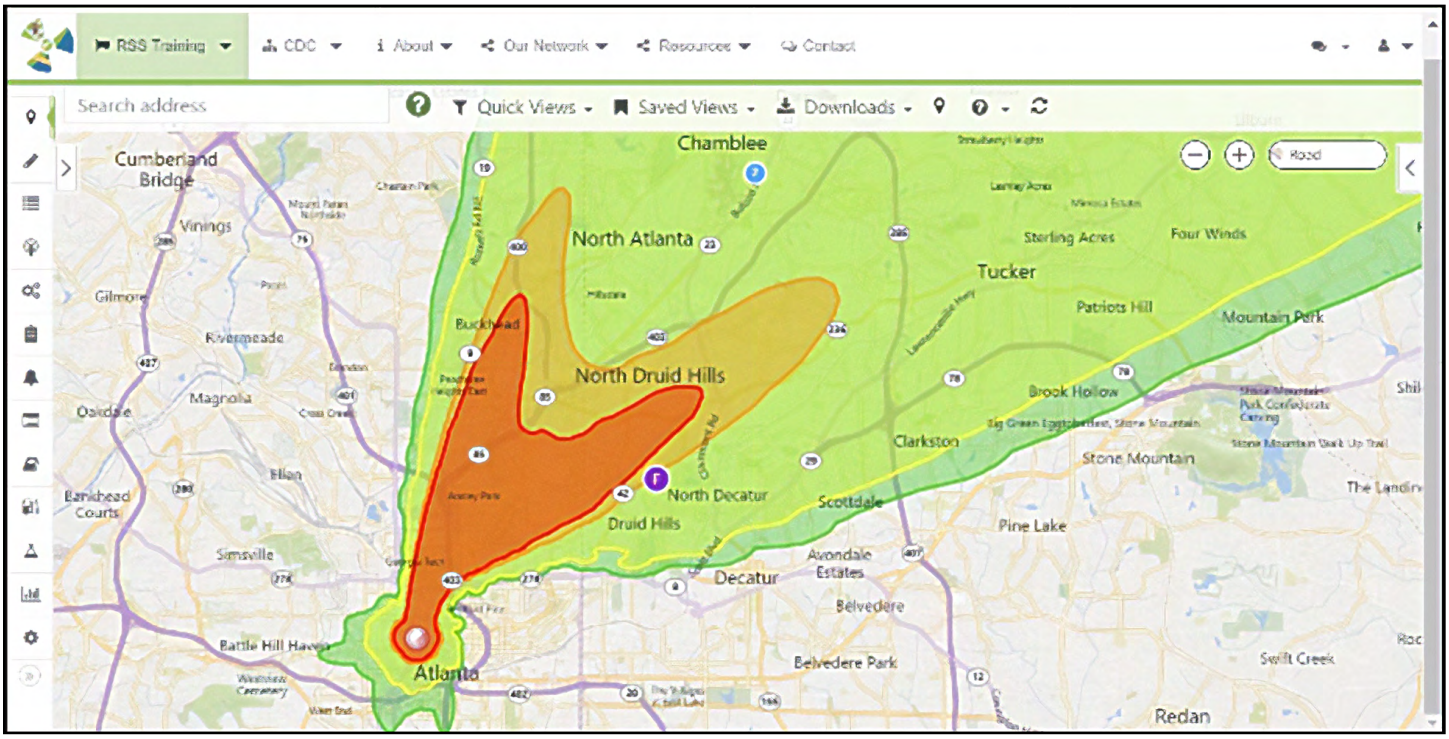

Figure 4. Radiation hazard categories for the unsheltered public following an IND detonation

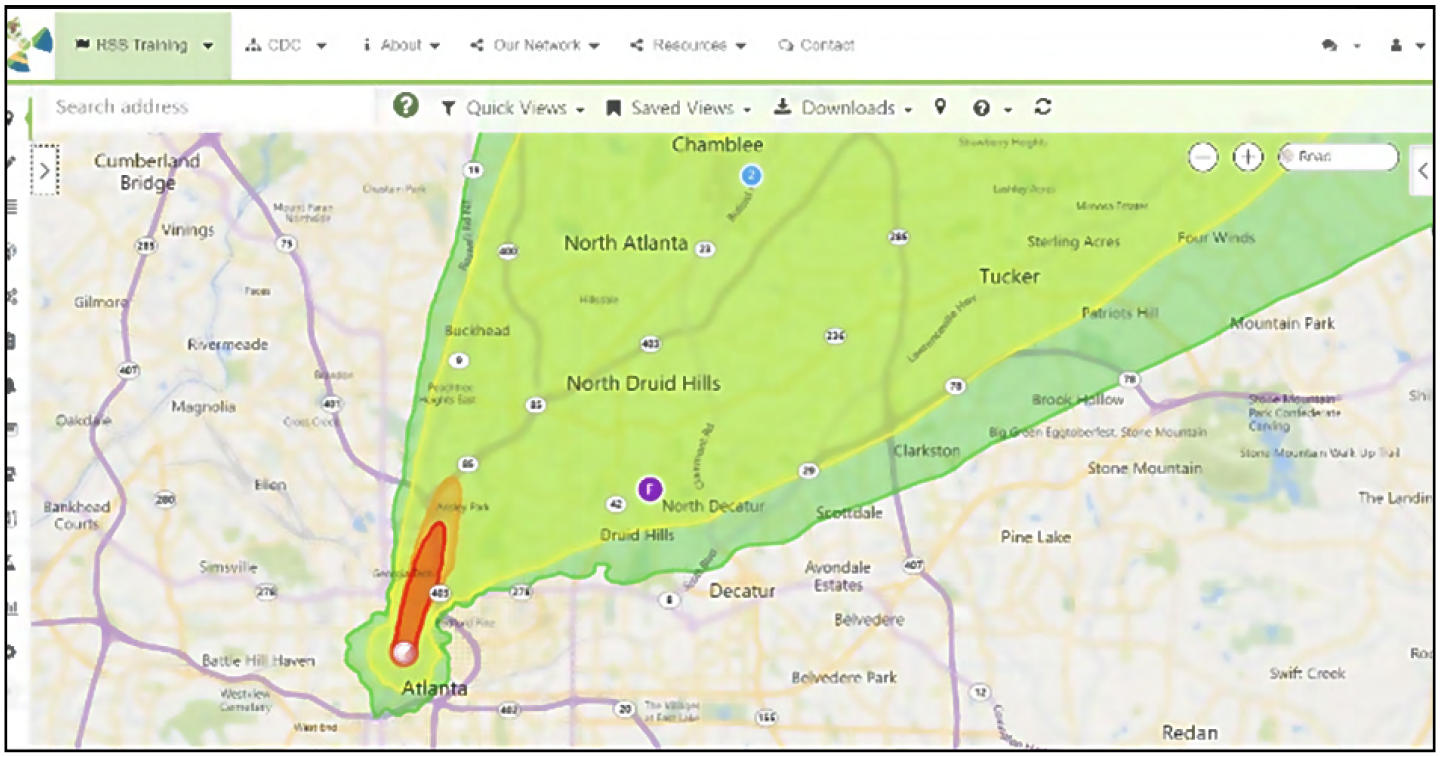

Figure 5. Radiation hazard categories for the sheltered public following an IND detonation

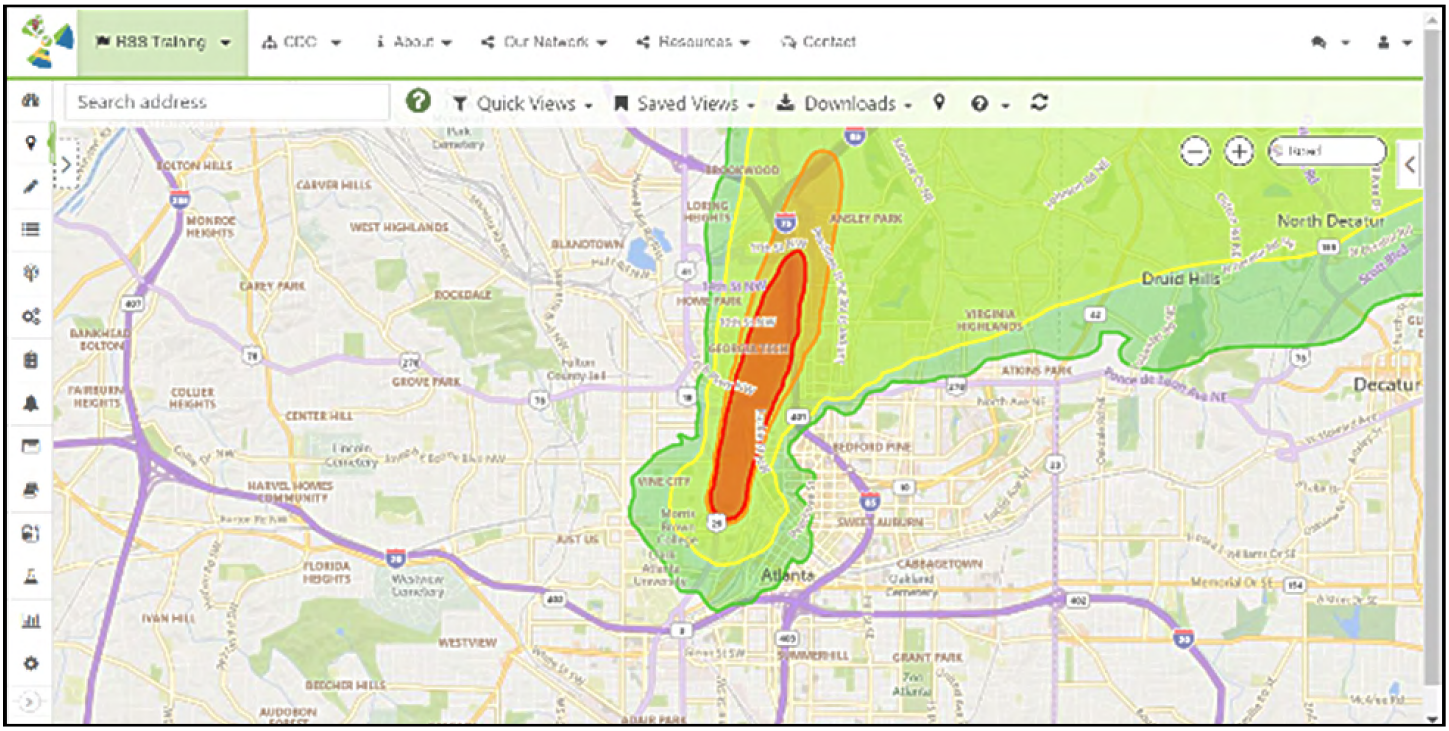

Figure 6. Radiation hazard categories for workers 12 hours after detonation

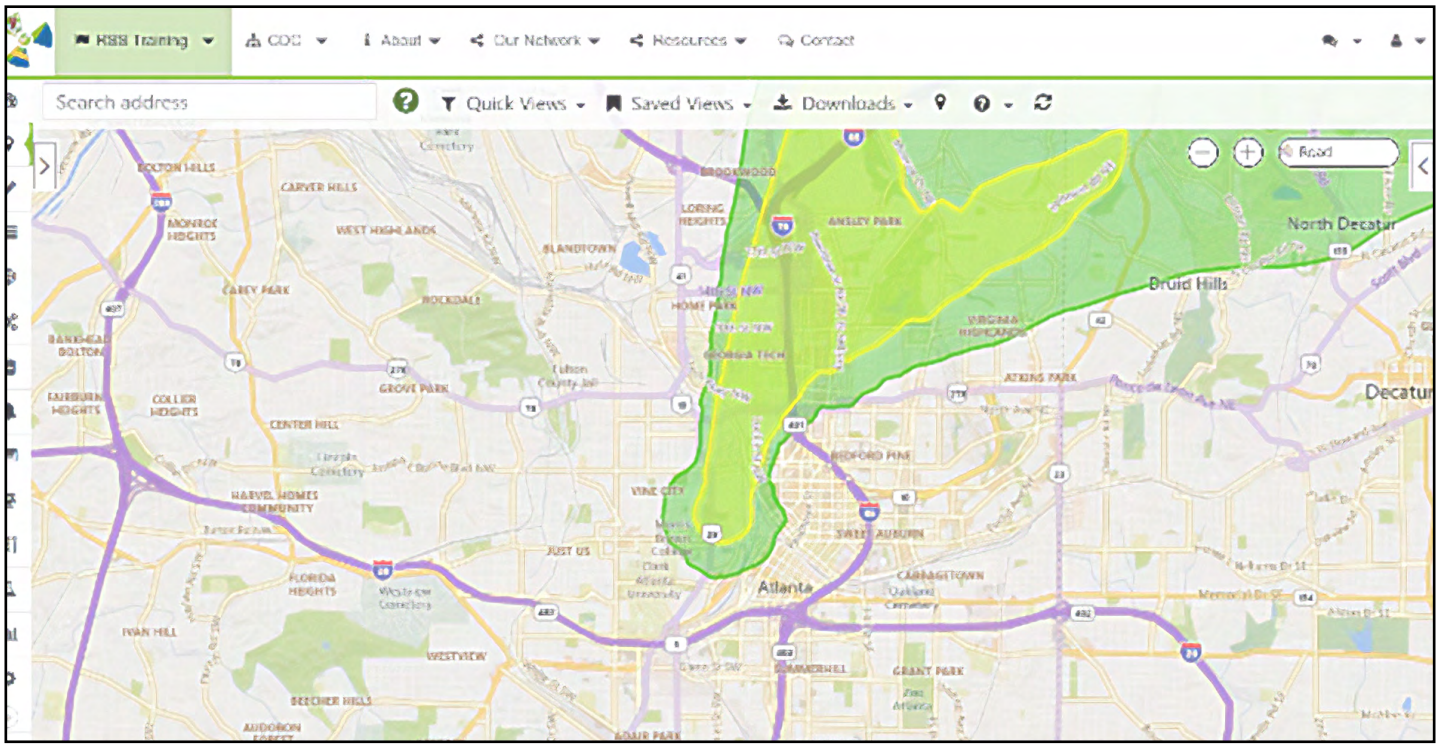

Figure 7. Radiation hazard categories for workers 1 week after detonation

Responding to a Radiological Dispersal Device

Figure 8 illustrates the estimated radiation risk to an unsheltered population from a hypothetical RDD detonation in downtown Atlanta, GA. Although there is little risk of fatality (i.e., Categories 4 and 5) due to radiation from this incident outside the immediate area of the explosion, Figure 9 demonstrates that radiation risk may be reduced by sheltering in place. Note that these graphics show the color gradients of the Radiation Hazard Scale contours overlaid onto Google Earth maps.

The color gradients of the Radiation Hazard Scale on the maps are also useful in communicating to emergency workers the risk of working in particular areas for a specific period of time. Figure 10 below illustrates the radiation risk of working near the detonation site for an 8-hour shift. For planning purposes, it is assumed that the radionuclide(s) used in an RDD will have a long half-life. Therefore, responders will not be able to leverage radioactive decay in the same way they can following a nuclear detonation.

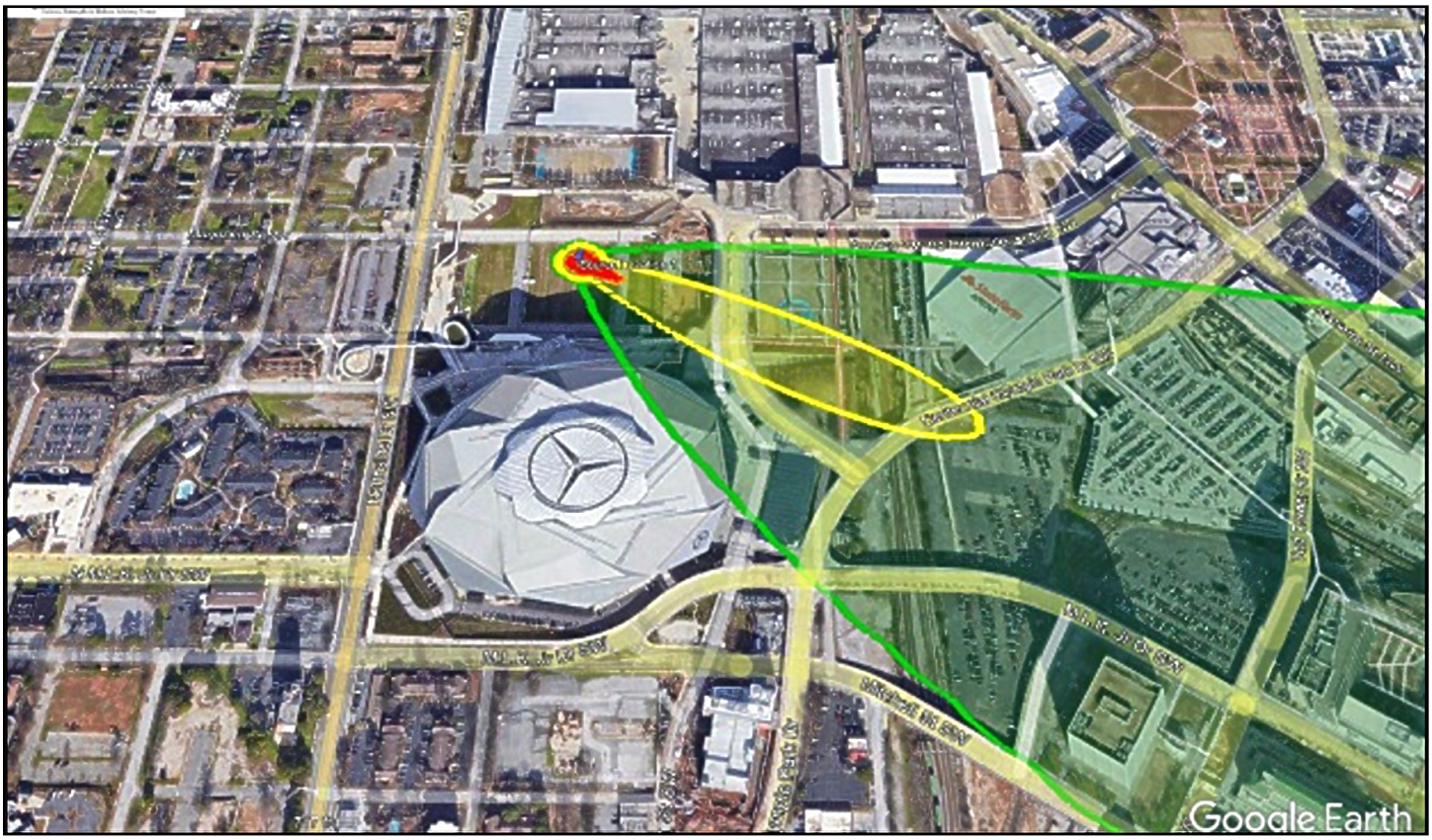

Figure 8. Radiation hazard categories for the unsheltered public following a release from an RDD

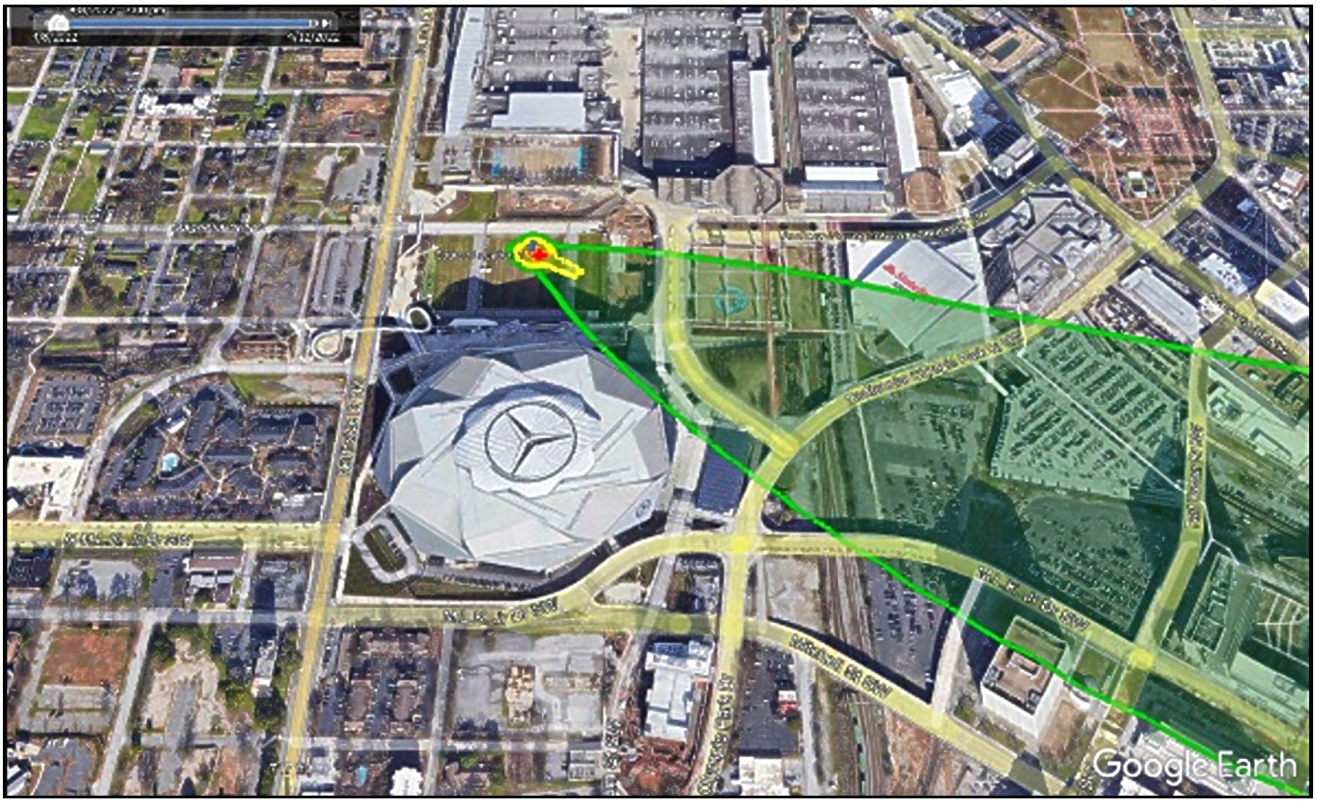

Figure 9. Radiation hazard categories for the sheltered public following a release from an RDD

Figure 10. Radiation hazard categories for workers following a release from an RDD

Responding to a Nuclear Power Plant Accident

The immediate protective measures in response to a severe accident at a nuclear power plant will likely be driven by the condition of the plant. Given that the objective of emergency response officials is to minimize radiation doses to the public—within the bounds of the EPA Protective Action Guides—state and local officials may implement protective measures, such as evacuation or sheltering prior to any release of radioactive materials from the plant.

Assuming that there are indeed releases of radioactive materials as a result of the accident, one of the more difficult tasks will be communicating risks to persons who will either be asked to relocate from areas not evacuated during the initial response or will be advised that they may return to their homes and businesses.

Figure 11 illustrates the use of the Radiation Hazard Scale to communicate these risks. This map portrays the risks related to relocation, re-entry, and return. The map shows a large Category 2 area—an area where elevated radiation risks are present, but in which no adverse health effects would be expected. Figure 12 illustrates the same data at a smaller scale and shows that the area recommended for relocation (Category 3 and higher) is relatively small. Conversely, persons living or working in the areas outside the Category 3 area could be advised to return to their homes and offices. It is worthy of note that even in this severe accident, potentially lethal (Categories 4 and 5) radiation risks are present in the immediate source location area.

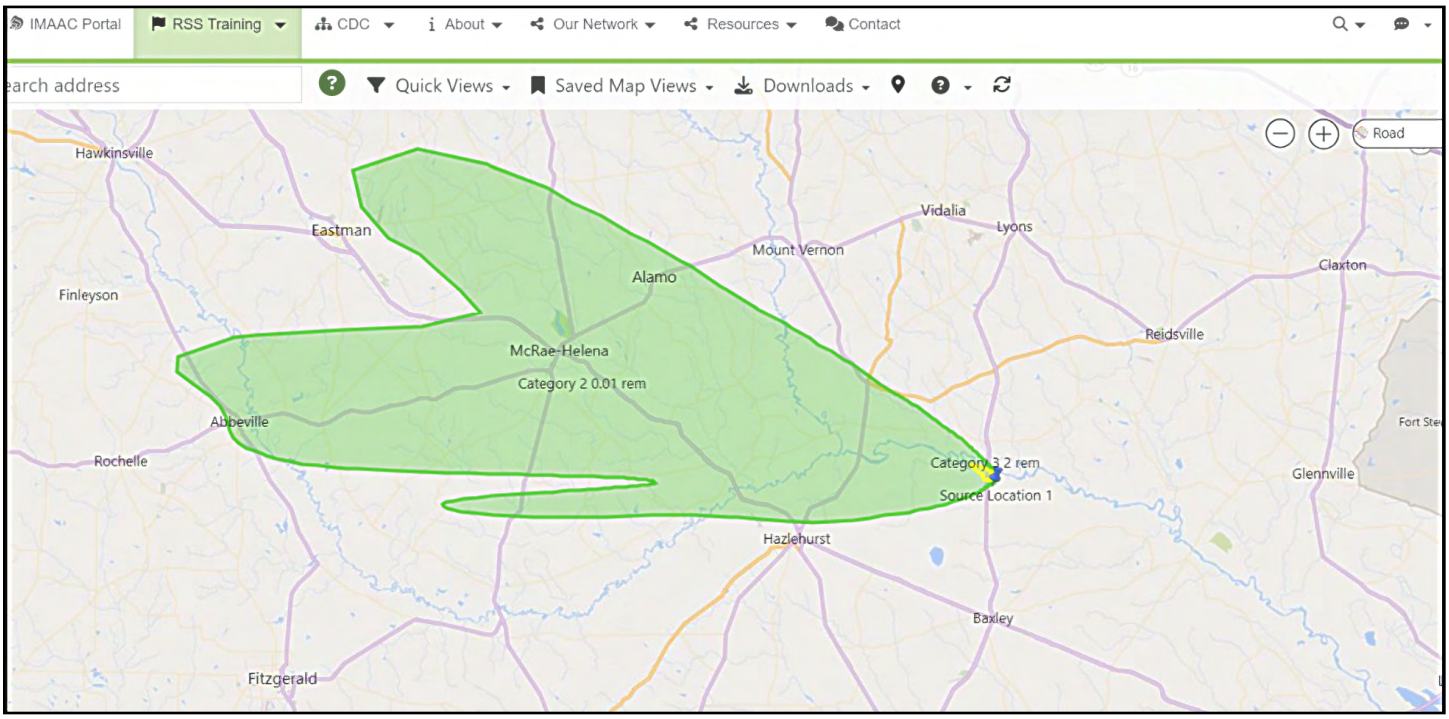

Figure 11. Radiation hazard categories for relocation, re-entry, and return due to a severe nuclear power plant accident

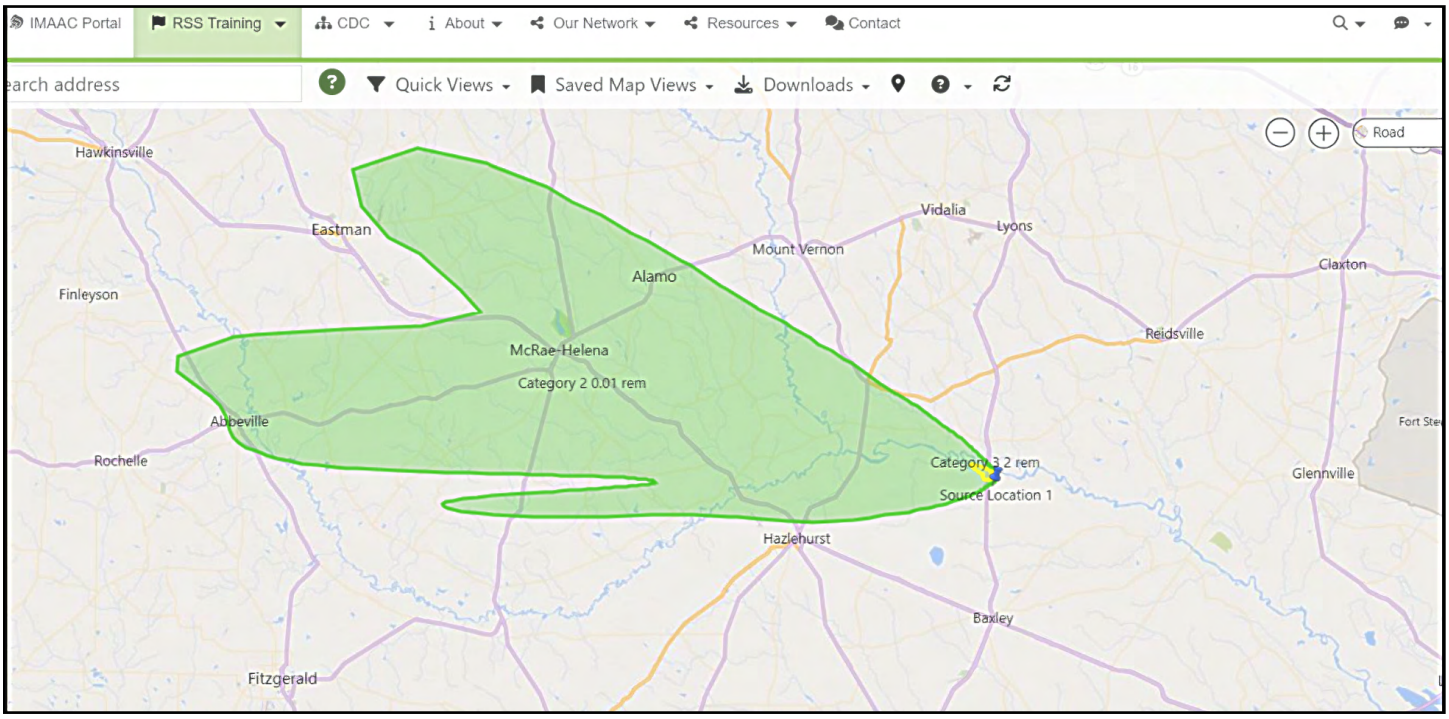

Figure 12. Close-up of radiation hazard categories for relocation, re-entry, and return due to a severe nuclear power plant accident

Conclusion

The Radiation Hazard Scale is a communication tool that public health professionals can use to help the public and emergency workers assess their own risk and understand how following recommended protective actions can lower their risk of health effects during a radiation emergency. The combination of the color-coded scale and detailed supporting language provides an effective mechanism for communicating radiation risk. Furthermore, public health officials can replicate the color gradients of the scale on maps and models to show contamination deposition and areas where people will encounter elevated radiation levels. Presenting the color gradients of the Radiation Hazard Scale using a direct comparison of the maps provides public health professionals another tool to stress the importance of protective action recommendations for the public and emergency workers during a radiation emergency.