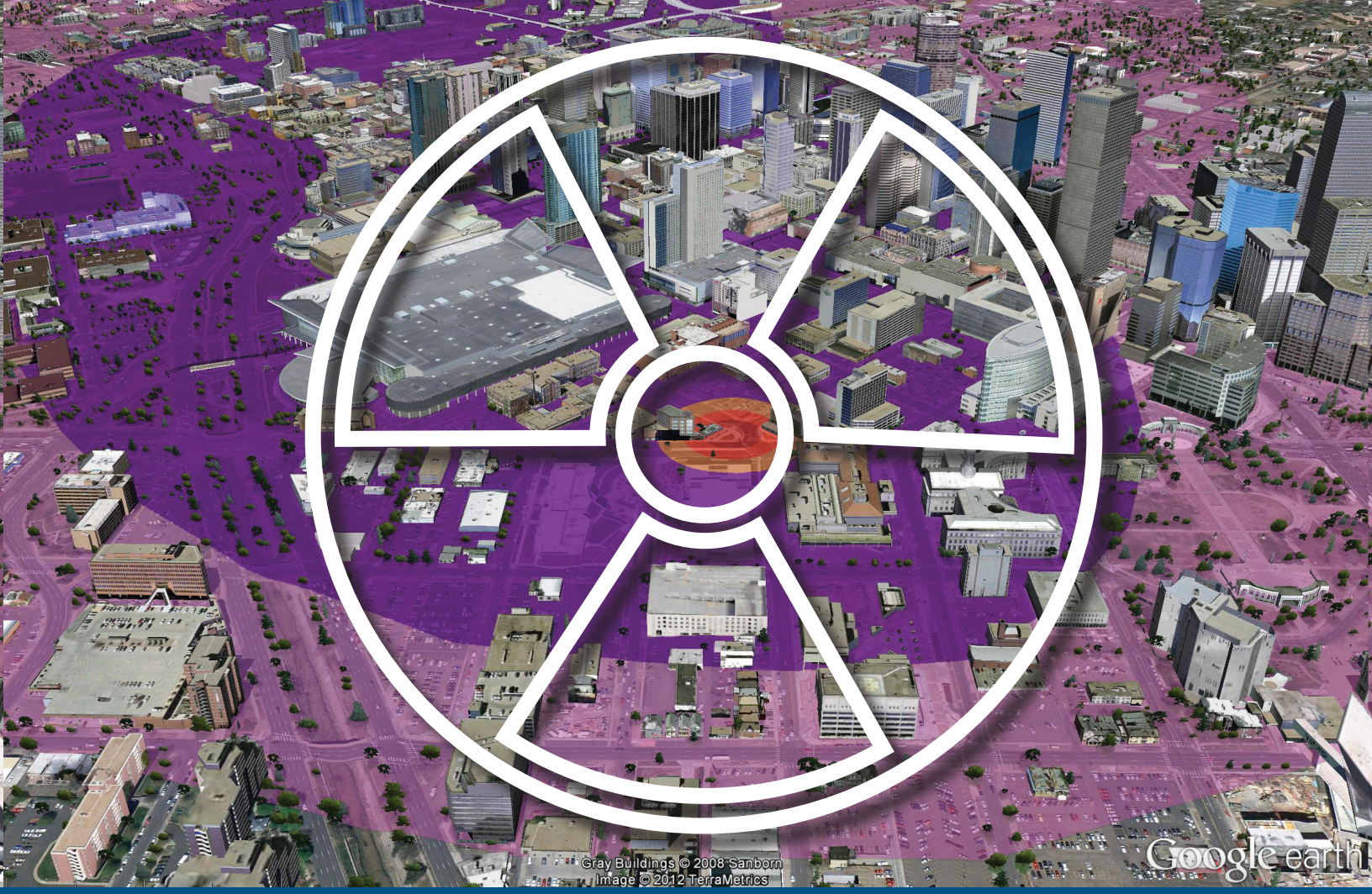

Response and Recovery Knowledge Product:

Key Planning Factors

For Recovery from a Radiological Terrorism Incident

September 2012

Homeland Security

Science and Technology

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 SEP 2012	**Final**	**01 Feb 2010 - 30 Sep 2012**

4. TITLE AND SUBTITLE
Wide Area Recovery and Resiliency Program (WARRP) Key Planning Factors for Recovery from a Radiological Terrorism Incident

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Gorman, Chad

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Chemical, Biological, Radiological, Nuclear, and Explosives (CBRNE) Branch Planning Division Response Directorate U.S. Department of Homeland Security Federal Emergency Management Agency Washington, DC 20472

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Lori Miller Department of Homeland Security Science and Technology Directorate Washington, DC 20538

10. SPONSOR/MONITOR'S ACRONYM(S)
DHS

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
1.11.3

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT
This technical report is scientifically based technical guidance to provide FEMA with a summary of key response planning factors to consider when responding to a radiological incident caused by a radiological dispersal device (RDD). Guided by the National Disaster Recovery Framework and the National Preparedness Goals, this document identifies key technical planning areas that may be used to inform subsequent FEMA response and recovery guidance documents. The document employs a scenario narrative focus to describe an example event and provides analysis and recommendations. The overall objective is to provide input to Federal, state, and local planners and decision makers regarding critical areas where planning can significantly improve disaster recovery.

15. SUBJECT TERMS
WARRP, Radiological Terrorism, Planning, Terrorism, National Disaster Recovery Framework, National Preparedness Goals

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**32**	

Foreword

The *Key Planning Factors for Recovery from a Radiological Terrorism Incident* is a document developed by Lawrence Livermore National Laboratory (LLNL) under contract to DHS S&T as a stand-alone deliverable to the Wide Area Resiliency and Recovery Program (WARRP). The Response and Recovery Knowledge Products (RRKP) data transition agreement established between DHS S&T and FEMA in September 2011. It is designed to identify key planning factors that could substantially aid the recovery process by decreasing the recovery timeline and costs, improving public health and safety, and addressing major resource limitations and critical decisions.

DHS S&T would like to thank the following individuals and groups for their support in development and review of this document. The content represents the best efforts of the participants based on the information available at the time of publication, but is not intended to convey formal guidance or policy of the federal government or other participating agencies. The views and opinions expressed herein do not necessarily state or reflect those of their respective organizations or the US Government.

The modeling and analysis provided by this report could not have been possible without extensive interactions with the State of Colorado and local public safety agencies in an effort lead by Gary Briese. We are grateful for the workshop facilitation provided by Cubic and Pacific Northwest National Laboratory.

Various Federal, state and local agencies participated in workshops and provided subject matter expert technical reviews of this document and their assistance is greatly appreciated.

FEMA HQ, DHS S&T, FEMA Region 8, FEMA Region 10, DOD-SPAWAR, PNNL, EPA OEM, EPA NHSRC, HHS ASPR, DOE/NNSA, CDC, Cubic Applications, Inc., Denver OEM and Homeland Security, Denver Public Health and Environment, Jefferson County OEM, Aurora OEM; Denver EM, Colorado Department of Public Health and Environment, Boulder County OEM, Englewood OEM, Colorado Department of Public Health and Environment, Douglas County OEM, Colorado Division Emergency Management, Denver Dept of Environmental Health.

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This work could not have been accomplished without the extensive modeling and knowledge base built over decades by the Department of Energy's National Nuclear Security Administration (DOE/NNSA) and the national laboratories they operate. In particular, Dr. Daniel Blumenthal and Steven A Morreale of the DOE/NNSA Office of Emergency Response were invaluable for assistance in their technical assessment.

LLNL-TR-574123 / E1036

This work (LLNL-TR-574132) was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Key Planning Factors for Recovery from a Radiological Terrorism Incident

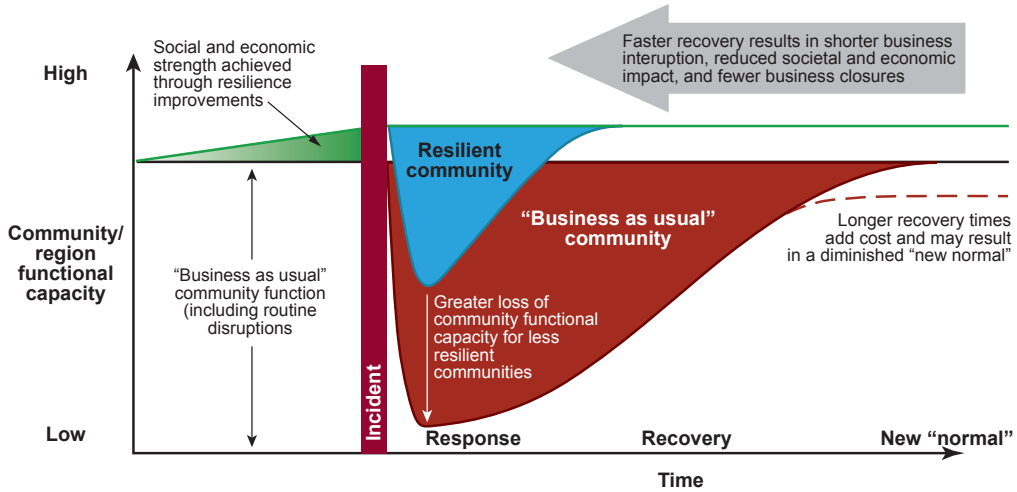
Executive Summary

If a radiological terrorism incident were to occur in a major U.S. city, current response and recovery planning would not support a rapid regional recovery. Identifying issues that may be examined and planned ahead of time will save time, resources, and lives. Key Planning Factors that will lead to community knowledge and/or pre-incident planning efforts with the potential to substantially influence the recovery process have been identified. Their influence extends to increasing the rate of recovery, reducing recovery costs, improving public health and safety, or addressing major resource limitations or critical decisions that may impact overall recovery success.
The Radiological Key Planning Factors are:

1. **Establish Background Radiation Levels Before an Incident.** A simple pre-incident measure that can be taken to dramatically improve determination of contamination levels and public confidence is the characterization of existing background radiation conditions before any release of radioactive material occurs.
2. **Develop Communication Plans.** There are a multitude of references and templates for public communication after a radiological incident; however, an effective public communication effort must begin before the release takes place. Identification of local spokespersons, language or cultural customization, and the identification of appropriate message templates and strategies must be undertaken in advance to ensure a coordinated effort across all Federal, state, and local agencies.
3. **Establish Radiation Protection Operational Guidelines.** Operational guidelines have been developed and published (DOE, 2009) in conjunction with the 2008 RDD/IND Planning Guidance (FEMA, 2008); however, customization is required for many of the guidelines to adjust for regional characteristics and priorities.
4. **Develop Pre-Incident Waste Management Guidelines.** Guidelines will need to be issued during the intermediate phase pertaining to the collection and storage of debris generated during response and recovery operations. Without a debris management strategy, established before the incident, recovery will be delayed and the extent of contamination will likely increase.
5. **Identify/Create Stakeholder Working Groups.** A stakeholder group that is prepared prior to an incident can greatly facilitate a rapid recovery process. An evaluation of existing public stakeholder groups could determine if they might also function as the RDD recovery stakeholder group.
6. **Identify Technical Working Group Participants.** Pre-incident planning and a database of relevant experts or agency contacts developed prior to an incident can greatly facilitate the rapid assembly of a Technical Working Group.
7. **Establish a Process for Developing Clearance Goals.** Clearance goals are imperative for all aspects of recovery; lack of a clear, defined process to establish clearance goals will cause extensive delays in incident recovery.

A radiological dispersal incident has the potential to disrupt life and business in a community through denial of access and service due to real or perceived environmental and facility contamination. Recovery from a major disaster like a radiological agent attack will challenge every level of government and its citizens. Time is the critical element in reducing the potentially enormous societal impact. Pre-incident planning at the state and local level will substantially decrease the recovery time, recovery costs, and improve public health and safety. Key Planning Factors described in these documents will help local, state, and Federal agencies be better prepared to rapidly recover from radiological terrorism.

The figure below, adapted from concepts developed by the Community and Regional Resilience Initiative, illustrates how pre-incident planning can significantly shorten recovery time and improve the overall outcome of the recovery's "new normal."



Pre-incident planning can significantly shorten recovery time. (*Image from LLNL based on work by Community and Regional Resilience Institute and Dr. Mary Ellen Hynes.*)

Contents

Acronyms

ASPR	Assistant Secretary for Preparedness and Response (DHHS)
CBR	Chemical, Biological, or Radiological
CDC	Centers for Disease Control and Prevention (DHHS)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CREATE	National Center for Risk and Economic Analysis of Terrorism Events
CWA	Chemical Warfare Agent
DHHS	Department of Health and Human Services
DHS	Department of Homeland Security
DOD	Department of Defense
DOE	Department of Energy
DOE/ HS-0001	Department of Energy's Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident (DOE, 2009).
EOC	Emergency Operations Center
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FRMAC	Federal Radiological Monitoring and Assessment Center
RDD/ IND-PG	The Federal Register Notice, "Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents" (Vol. 73, No. 149, August 1, 2008).
Gy	Gray, a measure of radiation dose. 100 rads = 1 Gy
ICRP	International Commission on Radiological Protection
IMAAC	Interagency Modeling and Atmospheric Assessment Center
JIC	Joint Information Center
KPF	Key Planning Factor
LLNL	Lawrence Livermore National Laboratory
mrem	1/1000th of a rem. 1000 mrem = 1 rem
NARAC	National Atmospheric Release Advisory Center
NCRP	National Council on Radiation Protection and Measurement
NDRF	National Disaster Recovery Framework, (FEMA, 2011)
NHSRC	National Homeland Security Research Center of the Environmental Protection Agency
NNSA	National Nuclear Security Administration
NPG	National Preparedness Goal (DHS, 2011)
NRF	National Response Framework (DHS, 2008)
OEM	Office of Emergency Management
ORNL	Oak Ridge National Laboratory
PAG	Protective Action Guide
PNNL	Pacific Northwest national Laboratory
PPD-8	Presidential Policy Directive / PPD-8: National Preparedness (EOP, 2011)
PPE	Personal Protective Equipment
R	Roentgen
rad	Radiation Absorbed Dose, a measure of dose
RDD	Radiological Dispersal Device
rem	Roentgen Equivalent Man, a measure of effective radiation dose
RESRAD	RESidual RADiation Family of computer codes
SCBA	Self Contained Breathing Apparatus
Sv	Sievert, a measure of effective dose. 100 rem=1Sv
WARRP	Wide-Area Response and Resiliency Program

1.0 Introduction

While significant progress has been made in building and sustaining US national preparedness (FEMA, 2011), a wide-area chemical, biological, or radiological (CBR) incident continues to pose serious challenges to the recovery of a community. As noted in the *National Preparedness Goal* (DHS, 2011), recovery requires timely restoration, strengthening, and revitalization of infrastructure; implementation of long-term housing solutions; a sustainable economy; and strengthening of the health, social, cultural, historic, and environmental fabric of communities affected by the incident (FEMA, 2011). Fulfilling these requirements during a wide-area CBR incident will be challenging and complex.

Emergency response activities will typically follow well-established principles; however, long-term recovery from acts of terrorism requires additional planning and includes a broad range of interests and stakeholders. Public safety is paramount and economic factors will mandate a quick recovery. In this document, advanced planning considerations are discussed in detail, including determining what is contaminated, developing clearance goals, and establishing radiation protection operational guidelines

Response and recovery from CBR events differ from traditional all-hazards events due to the need for decontamination activities, heightened public anxiety, long term risk management, and substantial disruption to citizen's lives and the economy. Therefore, a major consideration must be to build and maintain public confidence in governmental decisions and direction. Communication to the public must be honest, accurate, timely, and frequent. Coordination of local, regional, state, and Federal public information is critical, particularly in providing a united face to the public. The best solution for achieving these goals lies in pre-disaster planning.

Emergency response activities during the Deepwater Horizon oil spill, hurricane Katrina, and the Japanese earthquake and tsunami highlighted the critical role of planning for the response that leads to recovery following a catastrophic event. The mission of recovery is to maintain and ensure the health and safety of the general public while restarting and recruiting businesses back into the affected region so life transitions to a "new normal."

To support these requirements, this document identifies Key Planning Factors (KPFs) to aid in a successful recovery from a wide-area radiological incident. These KPFs may differ from those of chemical and biological incident recovery as related to exposure pathways and the movement of the agent through the environment, known as fate and transport.

Key Planning Factors for CBR incident recovery will differ across chemical, radiological, and biological areas. For instance, remediation for any agent would depend on the method of agent distribution and the agent persistence (the length of time an agent remains a health or environmental concern). Although radioactive material decays with time, this process can take decades or even centuries for many radionuclides.[1] Radioactive material cannot be "neutralized" or made non-radioactive through any chemical process, it must be removed or allowed to decay to safe levels. Chemical Warfare Agents (CWA)s that are relatively volatile and not persistent would leave less contamination, as would biological agents that degrade rapidly in the environment. On the other hand, persistent CWAs and spore-forming biological agents (e.g., *B. anthracis*) would require more active decontamination methods that may include chemical treatments to neutralize the material of concern. Radioactive material and CWAs can be in liquid or gaseous forms and have different chemical compositions with a wide range of volatilities and viscosities. Because of these properties, some materials will penetrate into some building materials more readily than others.

This document is a companion document to three other Key Planning Factors documents. Two documents focus on key planning factors for biological and chemical incidents and the third describes key planning factors for critical infrastructure and economic recovery. All four documents are built on numerous consequence management, response, and recovery technical and policy guidance documents, including the *National Disaster Recovery Framework* (NDRF), *National Preparedness Goal* (NPG), *Presidential Policy Directive 8: National Preparedness* (PPD-8), the *Interim Consequence Management Guidance for a Wide-Area Biological Attack* (DHS, 2011), and the Federal Register Notice, "Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents" (FEMA, 2008).

1.1 Purpose, Objectives, and Organization

The primary purpose of this document is to motivate and inform regional recovery planning for a wide-area radiological incident. To achieve this goal, this document identifies and describes a selected number of KPFs critical to wide-area radiological incident recovery planning.

The objective is to provide a concise, technical resource that complements existing guidance and helps to prepare for, to the extent possible, a multitude of issues that may significantly limit recovery success. Incorporation of these KPFs into the development of state and local recovery plans will support and enable the achievement of the recovery mission and ultimately increase

[1]For example, Cs-137 has a half life of 30 years. This means that after 30 years, half of the original material will have decayed away. It will take approximately 300 years for 99.9% of the material to decay away.

our national preparedness. It is not the objective of this document to comprehensively identify all the challenges associated with recovery from a radiological incident, but rather to serve as a catalyst for planning that addresses these issues prior to an incident.

The audience for this document is stakeholders within the emergency preparedness community involved in radiological response and recovery planning and operational activities. This community includes local, regional, state, and Federal partners.

This document has been organized to illustrate the response and recovery processes associated with a wide-area radiological incident and identifying the KPFs involved in such processes. Section 1 describes the document's purpose and objectives, defines the term Key Planning Factor, and discusses assumptions and limitations; Section 2 provides a general background on the National Recovery Phases and extends those phases to a wide-area radiological incident; Section 3 provides an illustrative narrative scenario to identify the key factors related to recovery; Section 4 further describes the KPFs for radiological incidents; and Section 5 compares the Cesium-137 scenario to other types of incidents. Finally planning recommendations are provided along with conclusions regarding the KPFs.

1.2 Recovery Support Functions and Key Planning Factors

1.2.1 Recovery Support Functions

The *whole-community* concept described in the NDRF and NPG recognizes that through pre-disaster planning, long-term recovery can be addressed in a more efficacious manner. All stakeholders in a community (e.g., volunteer, faith- and community-based organizations, the private sector, and the public) are needed to work together to effectively recover from a catastrophic event. To facilitate pre-disaster planning and foster coordination among local, state and Federal agencies, nongovernmental partners, and stakeholders, the NDRF identifies functional areas of assistance, known as the recovery support functions.

The following table shows the relationship among the NDRF Recovery Support Functions, the NPG Recovery Core Capabilities, and the WARRP Key Planning Factors.

1.2.2 Key Planning Factors

For a wide-area CBR incident, each recovery support function/ recovery core capability will have unique technical and operational issues that require particular focus or effort. The KPFs identified in this document are **pre-incident planning efforts** that can be **initiated by state and local stakeholders** with the potential to substantially influence the recovery process by increasing the rate of recovery, reducing recovery costs, improving public health and safety, addressing major resource limitations, or informing critical decisions. The KPFs were specifically developed to directly support community planning, but will greatly influence all post-incident NDRF/NPG recovery support functions and core capabilities, either directly or indirectly. The relationships among the NDRF Recovery Support Functions, the NPG Core Recovery Capabilities, and the Key Planning Factors are shown in Table 1.1.

The KPFs are threat-specific. They are derived from the key performance gaps identified by the wide-area response and resiliency program (WARRP) systems study conducted in 2012 (Einfeld, et al., 2012), critical considerations identified during

facilitated discussions in the WARRP Chemical, Biological, and Radiological Workshop,[2] and comprehensive literature review.

The identified performance gaps and critical considerations were shown by the WARRP team to limit recovery effectiveness, increase recovery timelines, and increase recovery costs. In identifying these gaps, the project team adopted a broad perspective that encompassed regional risk management, site-specific recovery, and long-term public health. Furthermore, it incorporated the views of local, state, Federal, and private stakeholders through their participation in the process.

1.3 Assumptions and Limitations

This KPF document does not describe how to prepare a plan for CBR response and recovery or provide a playbook on how to respond during a CBR event. Planning guidance may be found in the *National Urban Area Recovery Plan Guidance* (PNNL, 2012) prepared as a part of WARRP. Instead, this KPF document walks the reader through one possible scenario to provide the context and a foundation for addressing the KPFs. Scenario-specific assumptions are identified. Where appropriate, references are provided for resource documents that enable the reader to further research specific subject matter details.

Table 1-1: Comparison of Recovery functions and Capabilities.

NDRF Recovery Support Functions	NPG Recovery Core Capabilities	Wide Area Recovery and Resiliency Program Radiological Key Planning Factors
Community Planning and Capacity Building	Planning	All KPFs
	Operational coordination	Identify and create Stakeholder Working Group
		Identify Technical Working Group Participants
		Establish Radiation Protection Operational Guidelines
		Develop Pre-Incident Waste Management Guidelines
	Public Information and Warning	Develop Communication Plans
Economic	Economic	See Recovery from CBR Incident: Critical Infrastructure and Economic Impact Considerations (Franco et al., 2012)
Health and Social Services	Health and Social Services	Establish Background Radiation Levels Before an Incident.
		Establish Process for Developing Clearance Goals
Housing	Housing	Not a KPF, addressed by all-hazard planning
Infrastructure Systems	Infrastructure Systems	See Recovery from CBR Incident: Critical Infrastructure and Economic Impact Considerations (Franco et al., 2012)
Natural and Cultural Resources	Natural and Cultural Resources	Establish Process for Developing Clearance Goals

[2]The first workshop conducted under the WARRP Knowledge Enhancement Working Group, was held in Denver, CO on January 30-31, 2012. State, local, and Federal agencies collaborated in the identification of critical CBR considerations to support development of a UASI-level all-hazard response and recovery framework.

2.0 Response and Recovery Phases

A common misconception is that recovery begins after the response phase; however, these efforts actually are performed in parallel and represent similar, overlapping phases. Key Federal doctrine that describes these phases includes:

- *The National Disaster Recovery Framework* (FEMA, 2011), abbreviated hereafter as NDRF.
  - Short-term (days).
  - Intermediate-term (weeks to months).
  - Long-term (months to years).
- *Planning Guidance for Protection and Recovery Following Radiological Dispersal Device* (RDD) and *Improvised Nuclear Device* (IND) *Incidents* (FEMA, 2008), abbreviated hereafter as "RDD/IND Planning Guidance" or just RDD/IND-PG. This guidance largely adopts the early and intermediate phase guidance in the *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents* (EPA, 1992).
  - Early (Hours to days).
  - Intermediate (hours to weeks or months).
  - Late (weeks or months to years).

As noted above, these documents describe similar phases; however, the focus and terminology are slightly different. The RDD/IND Planning Guidance includes Early, Intermediate, and Late Phases. Similarly, as presented in the NDRF, actions following a CBR terrorism incident can be grouped into short-, intermediate-, and long-term phases.

Although phase timing is driven by the size and complexity of the event, there is a slight mismatch between the phases as the RDD/IND Planning Guidance phases start slightly earlier than the NDRF recovery phases with the similar name. This is further complicated by the fact that neither document defines a discrete transition; rather the phases are overlapped so that intermediate phase activities can occur while early and/or late phase activities are also being performed. For the purposes of this document, these phases will be considered to be roughly equivalent. This document will identify some of the major activities and recovery planning factors in the context of these phases.

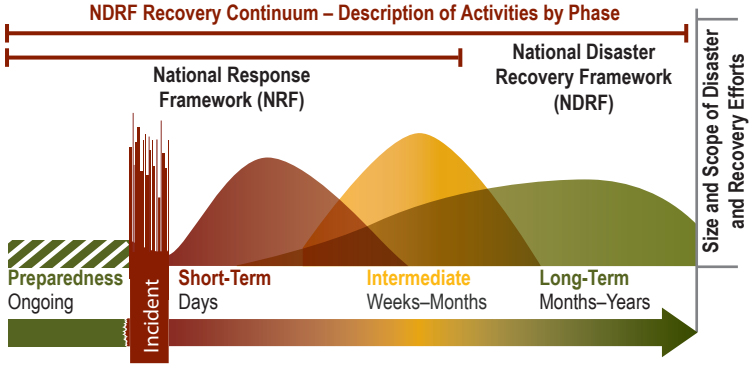


Figure 2-1: The National Disaster Recovery Framework phase continuum.

	Early	Intermediate	Late
Exposure Route			
Direct Plume	☢		
Inhalation Plume Material	☢		
Contamination of Skin and Clothes	☢		
Ground Shine (deposited material)	☢		
Inhalation of Re-suspended material	☢		
Ingestion of Contaminated Water	☢		
Ingestion of Contaminated Food	☢		
Protective Measures			
Evacuation	☢		
Sheltering	☢		
Control of Access to the Public	☢		
Administration of Prophylactic Drugs	☢		
Decontamination of Persons	☢		
Decontanination of Land and Property	☢		
Relocation	☢		
Food Controls	☢		
Water Controls	☢		
Livestock/Animal Protection	☢		
Waste Control	☢		
Refinement of Access Control	☢		
Release of Personal Property	☢		
Release of Real Property	☢		
Re-entry of Non-emergency Workforce	☢		
Re-entry to Homes	☢		

☢ Radiological release incident occurs Exposure or action occurs

[a]For some activities, the figure indicates that protective actions may be taken before a release occurs. This would be the case if authorities have prior warning about a potential RDD/IND incident.

[b]In certain circumstances, food and water interdiction may occur in early phases. In addition, some exposure routes (e.g., ingestion of contaminated food) may occur earlier than depicted in the figure, depending on the unique chracteristics of the incident.

Figure 2-2: Relationship between Exposure Routes, Protective Measures, and Timeframes for Effect, adapted from *FEMA, 2008*.

3.0 Illustrative Scenario

For the purpose of evaluating key recovery planning factors, this document explores what may occur after the detonation of an explosive radiological dispersal device (RDD), sometimes referred to as a "dirty bomb." It is important to note that a RDD is **not** a nuclear device. The radioactive material involved does not, in any way, enhance the kinetics of the explosion; it does not cause atoms to split, nor does it make a brighter flash or a bigger boom.

This scenario considers a large "truck bomb" explosion similar in size to the 1995 Oklahoma City truck bomb. The bomb contains a significant source of the radioactive material Cesium-137. The scenario explosion not only causes significant death and injury, but also lofts fine particles of the radioactive material high into the air.

Cesium-137 (abbreviated Cs-137 or ^{137}Cs) is representative of a large class of commonly used beta/gamma radionuclides that includes Cobalt-60 (Co 60) and Iridium-192 (Ir 192). The strong gamma radiation emitted by this class of material can be of a significant external hazard, especially when the material is concentrated (e.g., before the material is dispersed). When enough of the material is present, it can represent a hazard to an individual several meters away and can be easily detected much further away. Consequentially, heavy shielding must be used to safely handle the thousands of curies (kilocuries) of material used as the initial source in this example.

Although Cs-137 sources are usually encapsulated in stainless steel, the material itself is a powder (cesium chloride), making it both a potential internal hazard if it is dispersed (through inhalation of airborne particulate and ingestion of material deposited on foodstuff) and an external hazard (exposure while in close proximity to the material). With a radioactive half-life of 30 years, relying solely on natural decay is not a practical means of remediation. Cesium chloride is also water soluble, making it very mobile in the environment due to its ability to penetrate relatively deeply into porous materials, such as concrete.

Because it is both an internal and external concern, Cs-137 is the example substance commonly selected in RDD-response scenarios for training first responders and emergency response planners. This radionuclide was used during the federal government's Top Officials-4 Exercise in October 2007, and Cs-137 is the radioactive source material specified in National Planning Scenario #11. Cs-137 has also been involved in several real-world accidents including a significant incident in 1987, where scavengers dismantled a metal canister from a radiotherapy machine at an abandoned cancer clinic in Goiania, Brazil (Figure 3-1). It took over a week to discover the release, and in that time extensive community contamination and exposures occurred, resulting in four deaths and an extensive recovery effort involving over 80 homes and 3500 cubic meters of waste. (IAEA, 1988)

3.1 Scenario Overview and Timeline

On December 1 at 11:15 AM, a large truck bomb is detonated in the downtown business district of Denver, CO The explosion collapses the front of one building and causes severe damage to three others. Windows are broken throughout the downtown area, and they are broken with enough force to cause injury from flying glass for several blocks. This injury area includes the convention center and ~50 other buildings (see yellow area on the image below). The legend below describes the range (extent) of some of the blast effects.

Public safety agencies dispatch responders to the scene, which resembles the Oklahoma City bombing site with partially collapsed structures and almost 100 injured or dead visible in the immediate vicinity. As is protocol for response to a suspicious explosion, approaching units test the scene for chemical and radiological hazards.

11:30 AM: Radiation is detected at the scene. Emergency services dispatchers relay the information to all responding units. Throughout the region, radiation detection equipment is taken out of storage locations and turned on. Even miles away, measurements are being made to determine the spread of contamination.

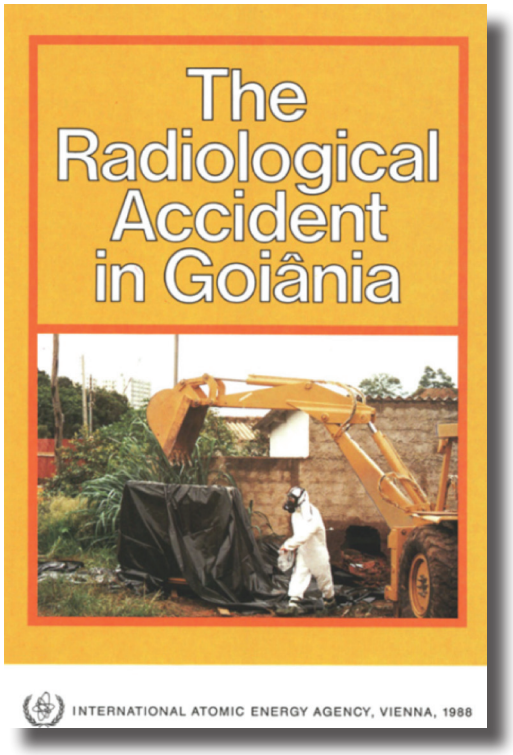


Figure 3-1. 1988 IAEA report describing the Cs-137 accident in Goiania, Brazil.

Blast Effects

Description Level (psi)	Level (psi)	Extent	Area
Fatalities in over 99% of the population	> 100	25.8 m	2,091 m^2
Onset of lethality	> 25	43.4 m	5,930 m^2
Onset of lung damage	> 10	66.1 m	13,715 m^2
Onset of eardrum rupture	> 5	99.6 m	31,146 m^2
Onset of shattered glass from blast effects	> 5	403 m	510,965 m^2

Note: Areas in the table are cumulative.

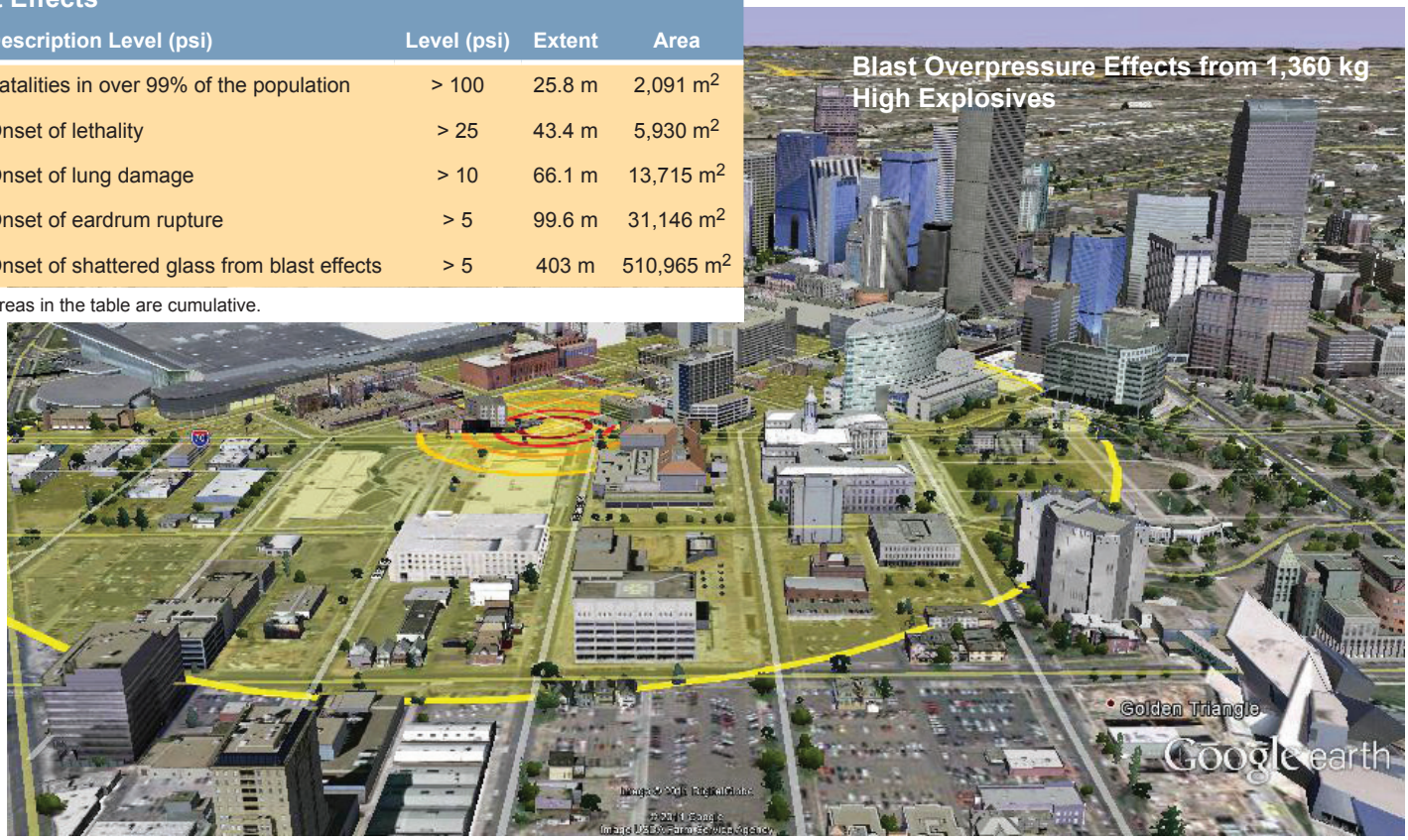


Figure 3-2. Explosive blast effects.

Figure 3-3. A hypothetical RDD incident.

Responders at the scene slow their advance to don protective equipment and monitor their instruments for elevated radiation levels. Alarming dose monitoring tools are used by the responders to alert them if their exposure or exposure rate approaches turn-back levels. As recommended in the National Council on Radiation Protection and Measurements (NCRP) Commentary No. 19 (NCRP, 2005) and NCRP Report No. 165 (NCRP, 2010), lifesaving measures take precedent over radiological monitoring and decontamination. Firefighters and police enter the scene to stabilize and remove victims (Figure 3-3). In addition to monitoring equipment to ensure external exposure safety, firefighters use their normal SCBA and "turnouts," and police officers wear respirators as they help clear the scene. Fire fighting and rescue from collapsed structures is performed.

Contamination levels that exceed the NCRP Report No. 165 Hot Zone criteria (10 milliRoentgen [mR]/hr)[3] are only seen in the immediate vicinity of the blast (within 2-3 blocks). However, contamination levels more than 10 times the background level are being reported several miles to the north (the direction of wind

[3]Roentgen is a measure of exposure. When used as a defined radiation quantity, exposure is a measure of the ionization produced in air by x or gamma radiation. 1 R = 2.58 × 10^{-4} C/kg. Exposure rate is the exposure per unit time [e.g., 1 mR/hr].

Figure 3-4. Initial control area for the Denver scenario based on early measurements following RDD explosion.

travel). As more refined, GPS correlated measurements are made, these are collected electronically[4] and automatically exported to local operation centers and incident command posts where the nature and extent of the event takes shape. The incident commander authorizes the exchange of data with remote Federal assets (e.g. DOE/NNSA Consequence Management Home Team) who integrate the information with atmospheric dispersion modeling to better characterize the extent of contamination.

Noon: A "Shelter in Place" guidance is given to the central business district and broadcast via local news channels. When radiation levels 100 times background are discovered on the freeway three miles to the north of the explosion, the Shelter-in-Place command is expanded to an area that goes from the I-70/I-25 interchange to the north, 13th Ave to the south, Zuni St to the west, and Broadway/Brighton Blvd to the east (Figure 3-4). In an effort to control access and prevent inadvertent exposure and cross-contamination, law enforcement blocks roads and freeways to control access to the area. This is an area of almost 6 square miles with an 11-mile perimeter requiring significant resources to control.

3.2 Short-Term response and Recovery

The initial response and recovery phase of an incident is the period in the first few hours or days of the incident when immediate actions may be required to save and sustain life, including actions to reduce or avoid radiation exposure by the public and responders. Actions in this period are likely to be conducted with minimal or incomplete information on the nature and extent of the incident.

RDD/IND-PG: *"The response during the early phase includes initial emergency response actions to protect public health and welfare in the short term, considering a time period for protective actions of hours to a few days. Priority should be given to lifesaving and first-aid actions. In general, early phase protective actions*

[4]DHS offers a free "RadResponder" smartphone application that performs data collection and mapping.

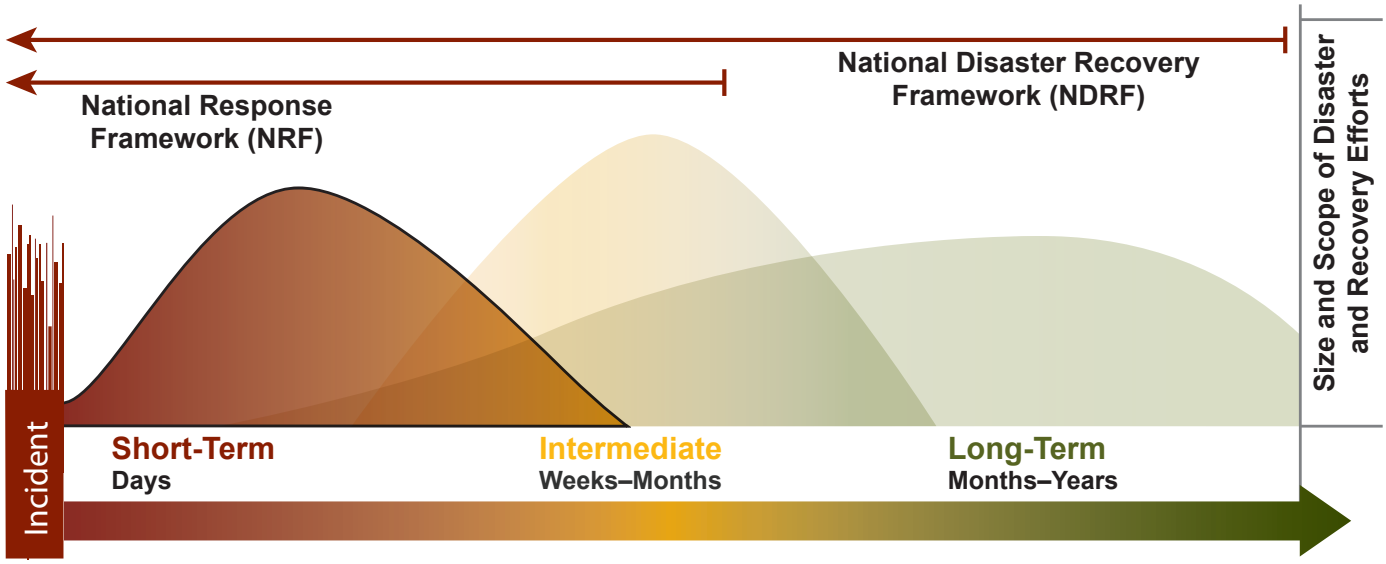


Figure 3-5. Short term response and recovery activities occur in the hours to days immediately following an incident.

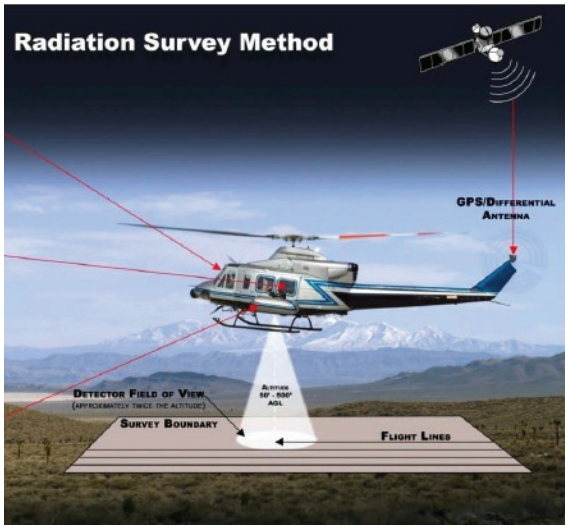


Figure 3-6. DOE/NNSA aerial measurement system and radiological assistance team members.

should be taken very quickly, and the protective action decisions can be modified later as more information becomes available."

NDRF: The Short-Term Phase of recovery *"addresses the health and safety needs beyond rescue, the assessment of the scope of damages and needs, the restoration of basic infrastructure and the mobilization of recovery organizations and resources including restarting and/or restoring essential services for recovery decision-making."*

The Early Phase (RDD/IND-PG) activities and protective action guidance have already been discussed in the scenario introduction above. Short-Term (NDRF) recovery activities must be accomplished in parallel.

The RDD/IND-PG provides initial guidance for potential exposure levels that warrant protective measures. The guidance was developed primarily to help balance the risk of exposure to low levels of radiation (and the associated slight increase in cancer risk) with the hazards of actions, such as shelter or evacuation. This report focuses on recovery issues; however, the Protective Action Guides (PAGs) identified in the RDD/IND-PG can help define areas where initial actions may set important social perceptions of "unsafe" areas.

3.2.1 Denver Scenario (Short-Term)

A Unified Command is established with the FBI as the lead Federal law-enforcement agency for this incident, in coordination with the Colorado Department of Public Safety representing Colorado. Denver Fire Department is the local lead for victim rescue, with support from the Denver Health Paramedic Division on emergency medical actions. Public health actions are co-managed at the local level by Denver Public Health and Denver Environmental Health.

The primary focus in the early phase is on the blast victims and the mass casualty situation. Many of the victims are contaminated

with radioactive material; however, current guidance indicates that medical stabilization takes priority over decontamination.

As additional local, state (including NGB WMD-CST), and regional Federal (DOE/NNSA RAP) radiation detection resources arrive, measurements are made around the site of the blast and for several miles downwind. This information is provided to federal assets, such as the DHS Interagency Modeling and Atmospheric Assessment Center (IMAAC) and DOE/NNSA Consequence Management Home Team, which uses the information to refine estimates of where the contaminated areas are.

By the end of the first day, aircraft operated by the Department of Energy National Nuclear Security Administration (See Figure 3-6) and Environmental Protection Agency arrive to begin over flights of the contaminated area. The aircraft have sensitive detection equipment that can help assess the extent of contamination. Additional federal monitoring capabilities arrive throughout the day and report to the Unified Command (e.g., FRMAC including DOE/NNSA, EPA, and other federal partners).

3.2.2 Early Response Actions: Protective Action Guides and Public Protection Recommendations

Protective Action Guides are based on the ***projected*** dose (to an individual) from an unplanned release of radioactive material at which a specific protective action to reduce or avoid that dose is warranted. For example, the "Early Phase" Protection Action Guides for shelter-in-place begin at a value of 1 rem[5] during the early phase (nominally the first 4 days). This means that if the projected dose is expected to be more than 1 rem during the first 4 days, shelter-in-place or evacuation of the potentially exposed population is warranted.

Measurements and models are used to assess what ***future*** potential population exposures might be in downwind areas and how these potential exposures compare to the Protective Action Guides, which are provided in Table 3-1. The technical community uses this information to develop protective action recommendations, which are presented to the Unified Command for action.

The initial modeling and analysis indicates that the area that might exceed the shelter/evacuation criteria is actually fairly small, only a few blocks in length, as shown in Figure 3-7. However, concern over cross-contamination and in an "abundance of caution" to keep the public exposure as low as possible, the control area outlined in blue above is used as an initial control area and undergoes a phased, deliberate evacuation. Over the next 48 hours, 30,000 people are escorted out of the area via routes that provide the lowest exposure. They are, if desired, surveyed for contamination and assisted in decontamination.

Rescue operations at the site are critical over the first 48 hours while casualties are cleared from the damaged structures. Mass casualty capabilities of the region and the nation are activated to manage the hundreds of injured and dead.

Traditionally, this is where our response preparedness plans and exercises end. Survivors are rescued, the "Hot Zone" is controlled, fires extinguished, and the scene is stabilized. But the real challenges for this city still lay ahead in the extensive public debate and anxiety that radiological incidents inspire. The extended periods that significant portions of the community are considered "contaminated," and the stigma that this causes, has a chilling effect on local business, especially the manufacturing and agricultural industries that rely on exporting their products. The economic impacts, in addition to the cost of trying to "clean up" the contamination, have a crushing effect on the regional economy and community.

Table 3-1. Early-phase Protective Action Guides.

Protective Action	Projected Dose Averted	Comments
Sheltering-in-place or evacuation of the public. Whichever results in lowest exposure	1–5 rem (outdoor, 96-hr exposure)	Should normally begin at 1 rem (0.01 Sv); take whichever action (or combination of actions) that results in the lowest exposure for the majority of the population. Sheltering may begin at lower levels if advantageous

Figure 3-7. Initial PAG area that may exceed shelter-in-place criteria (yellow) is fairly small. Implemented control area (blue) is much larger.

[5]Rem is a quantity used for radiation protection purposes that takes into account the different probabilities of stochastic effects (such as cancer) that occur with the same absorbed dose delivered by radiations with different radiation weighting factors (the factor by which the mean absorbed dose in a tissue or organ is modified to account for the type and energy of radiation in determining the probability of stochastic effects).

As private citizens acquire radiation detection capabilities and radiation measurement capabilities arrive in the region to respond to the crisis, it is quickly reported that "contamination is everywhere." Reporters with radiation detectors demonstrate—on camera—how the meter responds when placed next to the ground or park bench or even just being outside after a rain. What is surprising is that this result occurs everywhere, even hundreds of miles upwind of the event.

Although public health officials indicate that these readings from upwind and other locations are "natural background radiation," a significant fraction of the public are concerned that the government is lying to them and trying to "cover up" the extent of the contamination. Also, there is significant public pressure (often repeated by some elected officials) that the clean up goal is "no radiation." Technical arguments that this goal is impossible because radiation existed in the area before the incident are criticized as excuses and evidence that the "government" does not care about the safety of the citizens of Colorado. This problem is compounded in Colorado, where the radiation levels of natural terrestrial (uranium, thorium) and cosmic (from the high altitude) sources are significantly higher than the rest of the United States. This situation leads to the first KPF for radiological recovery, which is discussed in more detail in Section 4.

Key Planning Factor: Establish Background Radiation Levels Before an Incident

A simple pre-incident measure that can be taken to dramatically improve the determination of contamination levels and public confidence is the characterization of existing background radiation conditions before any release of radioactive material occurs.

Federal, state, and local agencies know the importance of a coordinated public messaging and set up a Joint Information Center. Unfortunately, designated public information officials struggle to communicate confusing technical issues that they are just learning about. This unfamiliarity is complicated by the desire to provide accurate information, which leads to substantial delays as models and measurements have to be validated before being provided to the Joint Information Center (JIC). The result is a significant vacuum of official information. Even several days into the event, public messaging lacks detail and appears pedantic as officials try to simplify complex technical issues.

The media seek experts outside of the Joint Information Center in order to fill this information vacuum, contacting health physicists and environmentalists at national laboratories, universities, and radiation-related special interest groups. Unfortunately, those who are best able to provide expert opinion for this type of event are the radiation safety experts within the government, government contractors, or at the national laboratories who are not allowed to talk to the media. Although a few academic and private radiation safety experts try to fill the gap, the majority of "talking heads" used by the media are from special interest groups whose focus typically is on the negative aspects of radiation and nuclear dangers. This information contradicts official messaging and exaggerates the radiation risk perception.

It is apparent that public trust in their local and Federal governments is waning. Rumors and speculation that the government is trying to cover-up "the real" effects of the incident are amplified in the media to become the dominant view. Just as in the Goiania 1987 incident, over 100,000 citizens in this scenario present themselves to hospitals and reception centers demanding to be monitored and treated for radiation exposure, many of them presenting symptoms of acute radiation illness.[6] Also as in the Goiania case, families deny shelter to relatives made homeless by the incident, and hotels refused to accept evacuees as guests.

A major, preventable public health emergency is unfolding as the seeds of significant psychological and behavioral health problems such as depression, anxiety, and post-traumatic stress disorders are sown. These disorders, and their cost on society, will far outweigh the actual radiogenic health effects or clean-up costs.

Key Planning Factor: Develop Communication Plans

There are a multitude of references and templates for public communication after a radiological incident; however, an effective public communication effort must begin before the release takes place. Identification of local spokespersons, language or cultural customization, and the identification of appropriate message templates and strategies must be undertaken in advance to ensure a coordinated effort across all Federal, state, and local agencies.

3.3 Intermediate-Term Recovery

As the incident is stabilized, it will transition to the next phase, which typically occurs in the days-to-weeks range, but it can follow the early-phase response within as little as a few hours. Although protective actions may still be required in the intermediate phase to reduce or avoid radiation exposure, immediate threats to public safety have been controlled and the general extent and nature of the incident has been largely established. Typical actions during the intermediate-term phase are to conduct more detailed characterization monitoring, agricultural embargos, and a deliberate relocation of residents if warranted.

RDD/IND-PG: *"The intermediate phase of the response is usually assumed to begin after the incident source and releases have been brought under control and protective action decisions can be made based on measurements of exposure and radioactive materials that have been deposited as a result of the incident. Activities in this phase typically overlap with early and late phase activities, and may continue for weeks to many months, until protective actions can be terminated."*

NDRF: The Intermediate Phase of recovery *"involves returning individuals, families, critical infrastructure and essential government or commercial services to a functional, if not pre-disaster, state. Such*

[6] In the Goiania incident, at least 5% of the public presented symptoms of radiation exposure even though they were not exposed or even near the incident site (IAEA, 1988).

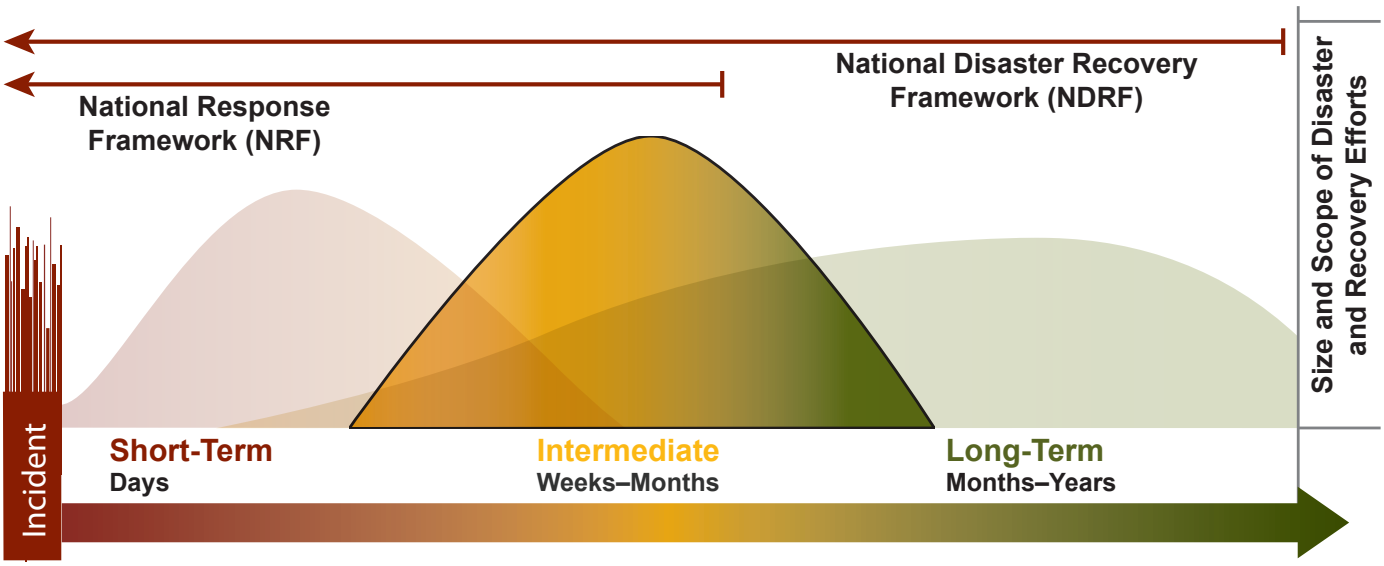


Figure 3-8. The Intermediate Recovery Phase activities may significantly overlap with the Long-term Recovery Phase activities.

activities are often characterized by temporary actions that provide a bridge to permanent measures."

Although the areas that require protective action in the early phase were fairly limited, the predicted areas for intermediate phase activities are much more extensive.

The relocation area, where it is recommended people relocate to avoid an annual exposure of 2 rem (first year) or 0.5 rem (any subsequent year), extends 3 miles downwind and contains 8,000 residents. This area is shown in Figure 3-9. Again, the exposure calculation is done for future, ***preventable*** exposures and does not include exposures already incurred during the first day.

The predicted area where produce ready for harvest may exceed FDA's default food safety guidelines (FDA, 1998) extends over 30 miles to the north (orange in Figure 3-10). The predicted areas where milk from cows pastured in this area may exceed the FDA's default food safety guidelines covers over 500 sq. miles and extends 70 miles to the north (yellow in Figure 3-10).

This is a preliminary assessment based on predicted radioactivity levels in the environment, not concentration of radioactivity in foods. FDA food safety guidance is based on concentration in foods as prepared for consumption. The guidance assumes consumption of 100% contaminated food for an entire year without simple dose reduction methods like eating pre-packaged, consuming non-local food, and feeding livestock stored or imported grain. In an abundance of caution, the State of Colorado embargoes crops and milk products from the area until a sampling protocol is established. Recommendations are made to help reduce the uptake of Cs-137 in livestock.

Intermediate-phase activities will require the movement of people and objects in and out of the contaminated areas, infrastructure restoration, and the return to service of potentially contaminated

Table 3-1. Intermediate-Phase Protective Action Guides.

Protective Action	Protective Action Guidance
Relocation of the Public	2 rem (0.02 Sv) projected dose first year. Subsequent years, 0.5 rem/y (0.005 Sv/y) projected dose[a]
Food Interdiction	0.5 rem (0.005 Sv) projected dose, or 5 rem (0.05 Sv) to any individual organ or tissue in teh first year, whichever is limiting[b]
Drinking Water Interdiction	0.5 rem (0.005 Sv) projected dose in the first year.

[a]Persons previously evacuated from areas outside the relocation zone defined by this PAG may return to occupy their residences. Cases involving relocation of persons at high risk from such action [relocation] (e.g., patients under intensive care) should be evaluated individually. [b](FDA, 1998)

Figure 3-9. Relocation PAG (0.5 rem/yr).

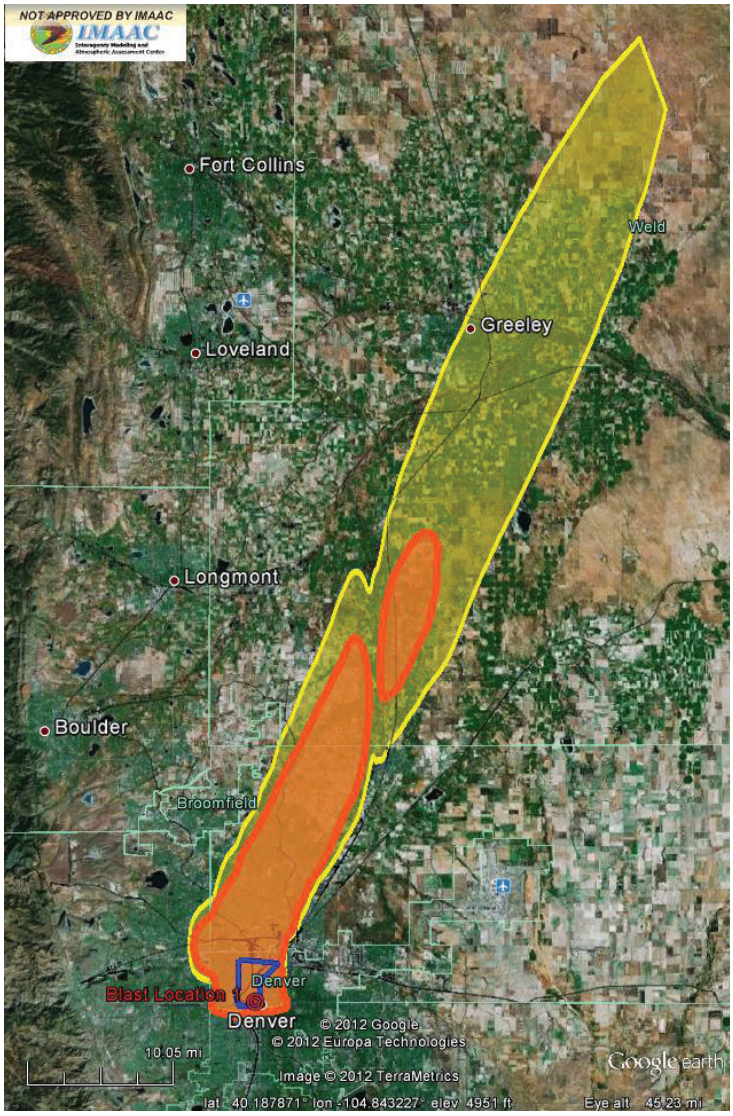


Figure 3-10. Example of agricultural embargo area.

roadways and vital services. Operational guidelines are needed to allow access to key areas and help control contamination on an interim basis, until final clearance levels can be developed and the areas decontaminated. *Operational guidelines* are intended to serve as screening values so that facilities and services critical to public welfare in a relocation area can continue to operate after an RDD incident (DOE, 2009).

Although there is not a specific statutory authority that applies to the aftermath of radiological terrorism, there are several methods and standards that could be used to facilitate the development of operational guidelines. An example methodology for developing operational guidelines can be found in the Department of Energy's *Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident* (referred to hereafter as DOE/HS-0001). However, the operational guidelines developed in DOE/HS-0001 must be adjusted to suit a specific region's demographics, recovery priorities, and geographic character. A relatively small *pre-incident* effort to review community specific parameters and issues would support establishment of appropriate modeling parameters, methods and, in some cases, numerical valuates to trigger protective actions and inform post-incident operational guidelines. The computer code RESidual RADiation(RESRAD)-RDD, as described in the DOE/HS-0001, could be used to make region and incident specific adjustments to published operational guidelines.

Key Planning Factor: Establish Radiation Protection Operational Guidelines

Operational guidelines have been developed in conjunction with the RDD/IND Planning Guidance; however, customization is required for many of the guidelines to adjust for regional characteristics and priorities.

As the incident progresses into the intermediate phase and relocation zones are established questions will begin to arise as what to do with waste being generated from the controlled areas (relocation, embargo etc.) and probably more important what to do with municipal solid waste being generated in areas outside the immediate exclusion areas but with detectable levels of radioactivity. Confusion between disposal site operators, collection service providers and regulatory officials results in the suspension of municipal solid waste collection services over wide areas, recycling operations are also suspended. Meanwhile questions begin to arise concerning storm water runoff from the affected areas as the runoff is concentrated in retention basins, drainage swales and other passive storm water management systems in a round the city. Concerns are also expressed over storm water discharges directly into the North Platt River.

Low but detectable levels of contamination begin to be reported at the city's waste water treatment facility questions from plant operators on the disposal of sludge from plant operations are added to the general discussion of what do we do about the wastes being generated from the impacted areas. Officials consider whether or not to divert sewage plant discharge to holding basins and to suspend the disposal of bio solids. As recovery efforts get under way in the impacted areas large amounts of debris begin to accumulate. Questions arise as to what levels of contamination is acceptable for disposal at the local landfill pressure mounts to find some avenue to remove the large amount s of debris that have accumulated. Temporary staging areas are discussed but since no standards have been developed wastes continue to accumulate at or near the point of generation.

Recovery operations are impacted because there is no approved process to characterize, transport and dispose of the large volume of debris being generated. Liquid waste streams are similarly being

impacted as questions arise as to what are acceptable discharge limits for waste water being generated from the various decontamination and contamination control operations being conducted in support of recovery efforts. Lack of a defined plan results in large volumes of minimally contaminated waste water being contained at various collection points around the city. The lack of disposal/discharge guidelines slows recovery process and increases costs.

Key Planning Factor: Develop Pre-Incident Waste Management Guidelines

Guidelines will need to be issued during the intermediate phase pertaining to the collection, transportation and interim storage of debris generated as a result of response and recovery operations. Without a debris management strategy, established before the incident, recovery will be delayed and the extent of contamination will likely increase.

3.4 Long-Term Recovery

The objective of the long-term phase is to revitalize, rebuild, and repopulate affected areas, including recovery of contaminated areas through the optimization process described in the RDD/IND Planning Guidance. Appropriate cleanup (or clearance) levels and priorities will be established through a process that includes broad community stakeholder input and sound risk management principles.

RDD/IND PG: *"With additional time and increased understanding of the situation, there will be opportunities to involve key stakeholders in providing sound, cost-effective cleanup recommendations that are protective of human health and the environment."*

NDRF: Long-Term phase of recovery *"may continue for months or years and addresses complete redevelopment and revitalization of the impacted area, rebuilding or relocating damaged or destroyed social, economic, natural and built environments and a move to self-sufficiency, sustainability and resilience."*

As can be seen in Figure 3-11, some long-term activities begin early, even within the first few days after the incident. The RDD/IND-PG recommends establishing a Stakeholder Working Group and Technical Working Group to help guide and prioritize the recovery process.

3.4.1 Denver Scenario: Construction of Working Groups

After a week, the Unified Command attempts to assemble a Stakeholder Working Group through outreach to local government, chambers of commerce, civic organizations, and even public notices. Unfortunately, with tens of thousands of people displaced, hundreds of thousands of people living in an agricultural embargo zone, and a large percentage of downtown businesses contaminated, there are an overwhelming number of people who consider themselves key stakeholders. There is also significant activity from special interest groups outside of the region who are influencing local representatives in an effort to promote issues such as concern about nuclear power, government conspiracy, and terrorism. The result is a significant delay in the process of assembling a representative group of stakeholders that is small enough to carry out actions.

The Unified command, in parallel with assembly of the Stakeholder Working Group, attempts to construct a Technical Working Group to help guide the technical decision-making relating to decontamination techniques, operational guidelines, waste management, and clearance. The Unified Command initially contacts the EPA, the Centers for Disease Control and Prevention (CDC), and local and state health and environment department, but, like the Stakeholder Working Group, the Technical Working Group assembly process becomes highly politicized and many organizations promoting views outside of accepted scientific norms demand to be considered. Not only does this delay the formation of the group, but the group becomes ineffective as the members are unable to reach consensus and minority opinions undermine the process by making exaggerated claims to the media.

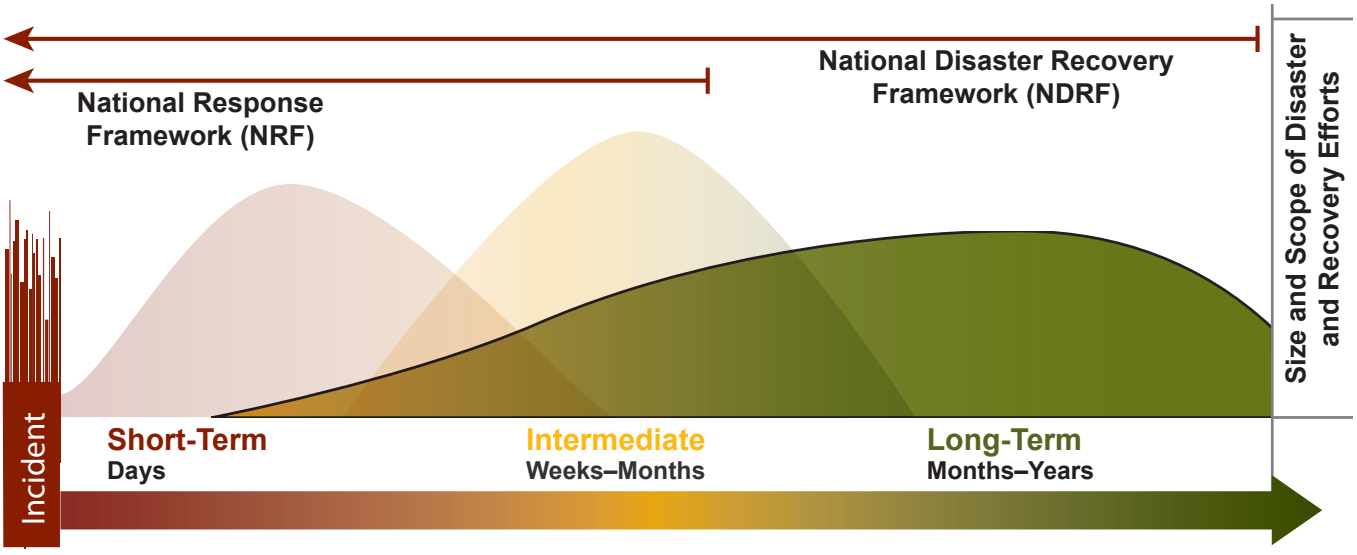


Figure 3-11. Long-Term recovery efforts may initiate as early as the Short-Term phase.

This delay and the ineffectiveness of these critical working groups greatly increase the economic and social impact of the event because it is not possible to quickly restore contaminated areas and restore industrial, commercial, and social infrastructure. Recent analysis supported by the U.S. Department of Homeland Security through the National Center for Risk and Economic Analysis of Terrorism Events (CREATE) concluded that the greatest impact from an RDD was business interruption in the short run and behavioral impact in the long run (Giesecke, et al., 2012). Both of these impacts can be dramatically reduced by rapid recovery. Rapid assembly of the stakeholder and technical working groups will be key in reducing the recovery duration.

Key Planning Factor: Identify/Create Stakeholder Working Groups

A stakeholder group that is prepared prior to an incident can greatly facilitate a rapid recovery process. An evaluation of existing public stakeholder groups could determine if they might also function as part of the RDD recovery stakeholder group.

Key Planning Factor: Identify Technical Working Group Participants

Pre-incident planning and a database of relevant experts or agency contacts developed prior to an incident can greatly facilitate the rapid assembly of a Technical Working Group.

3.4.2 Denver Scenario: Evaluating and Controlling Long-Term Exposure of the Public

At the end of the first few days, the Federal Radiological Monitoring and Assessment Center (FRMAC) is fully operational and coordinating Federal, state, and local monitoring teams, assessment scientists, and laboratory sample analysis (FRMAC, 2010). The Advisory Team for Environment, Food, and Health is working with FRMAC to produce consensus recommendations to the coordinating agency.[7] Additional agencies are executing their supporting role in accordance with the National Response Framework's Nuclear/ Radiological Incident Annex (DHS, 2008b).

These efforts support state and local leadership by defining the types of annual exposures that might occur to the population around the Denver area if no mitigation measures are taken. These exposure estimates are based on assumptions about the length of time spent in the area and the amount of material resuspended into the air and breathed in, as calculated based on default FRMAC methodology.

Figure 3-12: Comparison of 15-100, 100-200, and 500+ mrem annual outdoor exposure areas.

[7]The Advisory Team is a Federal interagency team tasked with providing the Federal consensus protective action recommendations to state and local governments. The permanent membership includes representatives from the EPA, the Food and Drug Administration (FDA), the CDC, and the U.S. Department of Agriculture.

This methodology generally overestimates potential exposure because it presumes people in the area stay outside (day and night) for the entire year. When time spent indoors and other lifestyle exposure reductions are taken into account, the annual exposures would likely be significantly less. FRMAC and Operational Guideline exposure assessments can readily accommodate revised assumptions based on guidance from state and local agencies.

Although there are no predefined clearance goals suggested by the RDD/IND-PG, dose criteria utilized for non-RDD recovery clearance objectives may be used as a starting point for visualizing the extent of remediation necessary for a radiological dispersal incident. Figure 3-12 displays the Denver areas that would be defined by the various annual dose levels: 0.015 rem (15 mrem) per year derived from the risk range found in the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA); 0.1 rem (100 mrem) per year from NRC, DOE, NCRP, and ICRP; and 0.5 rem (500 mrem) per year, which is the threshold for (second-year) exposures that warrant relocation of the population.

The dark purple area has potential annual exposures that exceed 0.5 rem (500 mrem) and would warrant relocation of the population. This 3-mile-long area has a reported population of 12,400 and 9,300 housing units. It also contains much of the downtown area, including two urgent care facilities and a nursing home. This area would likely require extensive decontamination to reuse/reoccupy.

The pink area (inclusive of the dark purple area) has a potential annual exposure that exceeds 0.1 rem (100 mrem). This 7-mile-long area has a reported population of 22,700 and 13,700 housing units. Including the greater-than 0.5-rem (dark purple) area, it has three urgent care facilities and a nursing home. Although the pink area does not require relocation of the public, there is confusion and concern from the residents when they are informed that their area requires decontamination but is still "safe" to live in.

The light purple area (inclusive of the dark purple and pink areas) has outdoor annual exposures that exceed the CERCLA preliminary remediation goal of 0.015 rem (15 mrem) per year. This 16-mile-long area has a reported population of 130,000 and 55,000 housing units. Including the inner areas, it contains to two hospitals, six urgent care facilities, and eight nursing homes. It should be noted that detectable contamination can be found outside of this area.

The key difference between the starting-point values is whether (a) the community believes it is best to identify a large initial remediation area and then reduce the area requiring remediation after further analysis and stakeholder input, OR (b) start with a (relatively) smaller remediation area and then expand the area based on stakeholder input. Both approaches present challenges with public trust and risk perception.

Key Planning Factor: Establish Process for Developing Clearance Goals

Clearance goals are imperative to all aspects of recovery; lack of a clear, defined process to establish clearances goals will cause extensive recovery delays. Evaluate (for a variety of release sizes and clearance levels) what the preferred community approach is for establishing clearance goals.

4.0 Key Planning Factors

4.1 Background Radiation

Key Planning Factor: Establish Background Radiation Levels Before an Incident

A simple pre-incident measure that can be taken to dramatically improve the determination of contamination levels and public confidence is the characterization of existing background radiation conditions before any release of radioactive material occurs.

The presence and natural variation of natural background radiation will greatly complicate the identification and measurement of contamination from the RDD. Understanding the regional background radiation is critical to rapidly determining the extent of contamination. Much of this data already exists in national and local environmental surveys. Table 4-1 presents data from EPA dose calculator (EPA, 1990) which indicates that the average annual background radiation exposure in the Denver area is more than three times that of the Atlantic and Gulf Coast states.

Table 4-1. Annual external radiation exposures from natural background radiation. Term phase.

Location	Atlantic and Gulf, U.S.	East, West, Central U.S.	Colorado Plateau
Annual Exposure	23 mrem/year	46 mrem/year	90 mrem/year

This is graphically presented in Figure 4-1, which shows the gamma-ray absorbed dose rate in air using US Geologic Survey data. Although sophisticated equipment can be used to measure Cs-137 in the presence of natural background radiation, the pre-existing Cs-137 contamination from world-wide fallout from the atmospheric atom bomb tests (shown in Figure 4-2) also confounds this measurement.

Additionally, building materials, such as marble and granite, contain natural radioactive material and can give an elevated radiation reading. This can create confusion as the survey performed can find large variations from one building to the next.

Finally, significant quantities of natural radon gas can be found in the area, although concentrations will vary significantly with

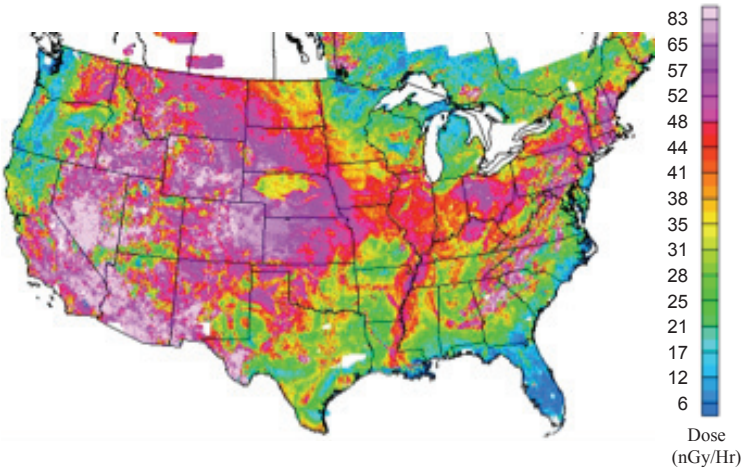


Figure 4-1. Terrestrial background dose rate across North America (*Duval, 2005*).

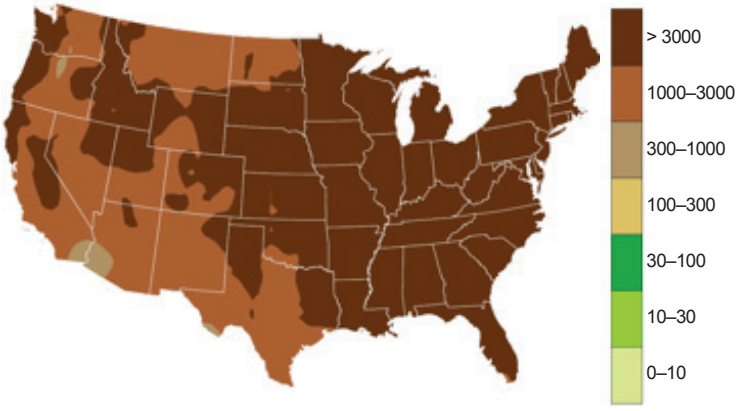


Figure 4-2. Deposition density (Bq/m^{-2}) of Cs 137 from global fallout (*DHHS, 2005*).

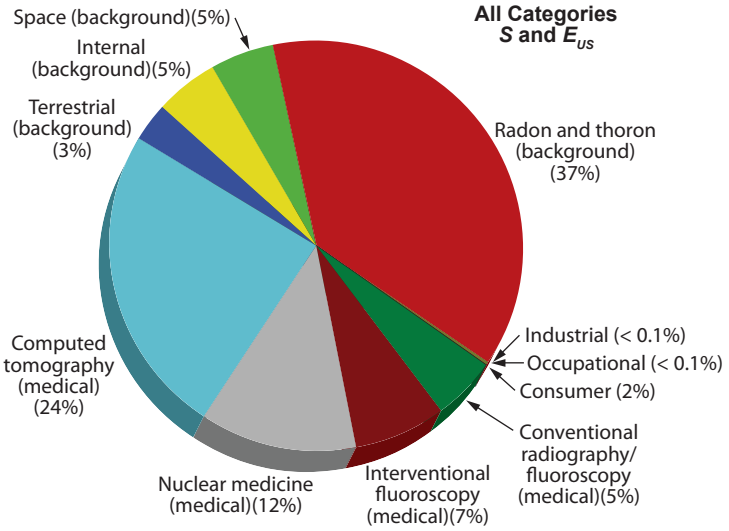


Figure 4-3. Percent contribution of various sources to the U.S. population radiation dose (*Reprinted with permission of the National Council on Radiation Protection and Measurements, http://NCRPpublications.org*).

atmospheric conditions and building interior vs. exterior locations. Figure 4-3 from NCRP Report No, 160 (NCRP, 2009), demonstrates the breakdown of natural and man-made average exposures for the U.S. population. As a national average, the total effective dose per individual in the U.S. population is 620 mrem (6.2 mSv) for 2006. This average annual dose value would be higher for the population on the Colorado Plateau because of the higher natural terrestrial, cosmic, and radon exposures.

Considering that some postulated clean-up criteria are derived to ensure annual exposures are less than 10 mrem (0.1 mSv) per year (or less that 2% the annual average US exposure), actual measurement of this level of contamination can be statistically difficult considering that radiation measurements will be dominated by pre-existing radiation levels.

Paradoxically, despite the higher annual exposure levels received by Colorado citizens, the Colorado 2002-06 cancer incidence rates for all races combined were about 5% lower than U.S. rates, and the Colorado 2002-06 cancer mortality rates were 10-23% lower (Finch, J.L. and J.A. Arend, 2009). Although cancer rates are related to a multitude of factors such as lifestyle and cannot be attributed solely to the presence or absence of radiation, these statistics demonstrate how complex and potentially confusing the relationship of radiation to cancer can be.

To reduce at least some of the uncertainty, regional background data will need to be compiled and assessed in the context of facilitating a clean-up process and determining "acceptable risk." Although existing survey data from USGS can be an excellent starting point, additional pre-incident measurements may be required to determine the nominal levels and variation within high value areas and critical infrastructure. These data should be publicly available before the incident to reduce concerns of data "tampering" post event.

4.2 Public Health and Medical Priorities

Key Planning Factor: Develop Communication Plans

There are a multitude of references and templates for public communication after a radiological incident; however an effective public communication effort must begin before the release takes place. Identification of local spokespersons, language or cultural customization, and the identification of appropriate message templates and strategies must be undertaken in advance to ensure a coordinated effort across all federal, state, and local agencies.

Surprisingly, the most significant public health impact from a radiological incident is not the radiogenic effects, but rather the depression, anxiety, post-traumatic stress disorder, psycho-somatic symptoms, and stigma that are inspired by the perceived risk of radiation exposure. Communicating effectively with the public can dramatically reduce the additional morbidity caused by this issue and can facilitate recovery efforts while maintaining public trust and confidence in the recovery leadership.

There are numerous references available for developing public messages after a radiological incident. The following are some example radiological incident communication guides and strategies, with additional references provided in the reference section of this document.

- Communication Strategies for Addressing Radiation Emergencies and Other Public Health Crises (CDC, 2009)
- Radiation Emergencies; Factsheets, Toolkits, Communication Research, and Information for Professionals website (CDC, 2012)
- Communicating Radiation Risks; Crisis Communication for Emergency Responders. (EPA, 2007).
- Radiological Attack: Dirty Bombs and Other Devices. (National Academies-DHS, 2004).
- Radiation Emergency Medical Management; Risk Communication Resources and Guidance for Public Information Officers website (DHHS, 2012)

4.3 Operational Guidelines

Key Planning Factor: Establish Radiation Protection Operational Guidelines

Operational guidelines have been developed in conjunction with the RDD/IND Planning Guidance; however, customization is required for many of the guidelines to adjust for regional characteristics and priorities.

Although not final clearance remediation levels, activity specific operational guidelines can be used to help control the spread of contamination and access to key areas and resources. For example, for the clearance of materials and equipment from controlled areas during operations, a community can use operational guideline provided in American National Standard *Surface and Volume Radioactivity Standards for Clearance* (ANSI/HPS, 1999). A methodology for developing operational guidelines can be found in the Department of Energy's *Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident* and its companion software tool RESRAD-RDD (DOE, 2009). The series of RESRAD codes were developed to address radiation dose, risk, as well as cleanup criteria for buildings (RESRAD-Build), personal property (RESRAD-Recycle), and on and off-site receptors (RESRAD-Onsite and RESRAD-Offsite).

Operational guidelines relate to radioactivity or radionuclide concentrations in various media. Such pre-derived operational levels can be measured in the field and compared to numerical guidance to quickly determine if protective actions are warranted. The operational guidelines are generated to serve as interim controls and are not regulatory dose limits or criteria.

Table 4-2. Operational Guideline Topics: Groups and Subgroups (*DOE, 2009*).

Groups	Subgroups
Access control during emergency response operations	Life- and property-saving measures Emergency worker demarcation
Early phase protective action	Evacuation Sheltering
Relocation from different areas and critical infrastructure utilization in relocation areas	Residential areas Commercial and industrial areas Other areas, such as parks and monuments Hospitals and other health care facilities Critical transport facilities Water and sewer facilities Power and fuel facilities
Temporary access to relocation areas for essential activities	Worker access to businesses for essential actions Public access to residences for retrieval of property, pets, records
Transportation and access routes	Bridges Streets and thoroughfares Sidewalks and walkways
Release of property from radiologically controlled areas	Personal property, except wastes Waste Hazardous waste
Food consumption	Early-phase food guidelines Early-phase soil guidelines Intermediate-phase soil guidelines Intermediate- to late-phase soil guidelines

Operational guidelines can be used to addresses a variety of scenarios including temporary or intermittent use of facilities, transportation corridors, and critical infrastructure utilization in evacuated or relocated areas. Critical infrastructure operational guidelines are intended to serve as screening values so that facilities critical to public welfare in a relocation area can continue to operate after an RDD event. Examples of operational guideline categories are provided in Table 4-2 (DOE, 2009).

The RESRAD-RDD software tool is provided by DOE without cost; however it is recommended that communities become familiar with its use and identify appropriate parameters for the scenarios and communities of concern. Although the numerical guidelines provided in the Preliminary Report on Operational Guidelines may not always be utilized directly, the general methodology is transferable, with key parameters and assumptions to support use as a preliminary criteria.

4.4 Waste Management

Key Planning Factor: Develop Pre-Incident Waste Management Guidelines

Guidelines will need to be issued during the intermediate phase pertaining to the collection, transportation and interim storage of debris generated as a result of response and recovery operations. Without a debris management strategy, established before the incident, recovery will be delayed and the extent of contamination will likely increase.

Table 4-3. Anticipated Waste Types.

Large bulk debris from blast area
Large Bulk debris from the demolition of the most severely contaminated buildings
Municipal Solid Waste from relocation area
Decontamination waste
Sewage treatment sludge
Agriculture waste from food interdiction

An RDD act targeting a city like Denver has the potential to create large amounts of waste that will need to be stored and managed in the weeks, months, and years following an event.

The actual types and volumes will depend on the extent of contamination and whether decisions are made to decontaminate buildings and structures in the most contaminated areas or to demolish and rebuild. Waste volumes ranging from thousands to millions of metric tons would be expected. Table 4-3 lists some of the waste types anticipated to be generated as a result of response and recovery operations.

For a moderate amount of effort, some of the key decisions and preliminary strategies can be developed pre-incident. For example, one could model disposal operations at the Denver Arapahoe Disposal Site (commonly referred to as DADS) and determine a safe level of radioactivity that could be accepted in radiological incident municipal solid waste. Restrictions on recycling operations could also be established. The designation of temporary storage locations and/or the requirements for such locations could be developed.

The prompt removal of contaminated debris is a key component of any recovery strategy. Once debris has been removed from affected areas, it must be characterized, stored, and packaged for shipment to an appropriate treatment or disposal facility. The

establishment of at least a preliminary waste management process will allow waste to be disposed of in a more timely and efficient manner. Long delays in the development of approved waste management systems can lead to the need for substantial temporary storage areas creating delays in restoration and recovery efforts.

One waste management challenge that will face decision makers during RDD recovery is the disposal of large volumes of minimally contaminated debris where the amount of contamination present is at or near background levels. The current radioactive waste regulatory structure does not provide limits below which materials no longer need to be disposed of as radioactive waste. During a large-scale contamination event, the need to dispose of waste and debris in local landfills will need to be addressed.

In addition, large volumes of liquid waste may be generated during RDD recovery operations. This inventory of radiologically contaminated liquid waste includes routine liquids, such as normal run-off from the most severely contaminated areas. A large volume of this liquid waste could be generated during the decontamination of facilities and structures. It is generally expected that little or no efforts will be expended to capture and contain waste waters generated by emergency decontamination during the early phase of an incident. However as the incident transitions to the intermediate and late phases, restrictions on liquid waste discharges are expected.

4.5 Identify/Create Working Groups

Key Planning Factor: Identify/Create Stakeholder Working Group

A stakeholder group that is prepared prior to an incident can greatly facilitate a rapid recovery process. An evaluation of existing public stakeholder groups could determine if they might also function as the RDD recovery stakeholder group.

Existing social groups, economic groups, and political groups (Lindell, 2007) can be used for a Stakeholder Working Group (SWG). The group(s) should be engaged and informed of their potential supporting responsibilities in the event of a chemical, biological, or radiological release through an outreach effort involving topical presentations by the state or municipal agency that would establish the SWG during an event. Establishing working relationships, transparency, and trust with stakeholders will be essential for the development of a sound recovery policy.

The SWG will interact with the Technical Working Group (TWG) and/or the Environmental Clearance Committee (ECC) and provide recommendations to the Unified Command. Periodic public meetings will be scheduled and conducted in the community to keep the SWG updated on the status of incident recovery and receive feedback and input. The SWG has no operational responsibilities regarding the incident response and recovery and effective management of these efforts should be planned for to ensure constructive participation. Work products will generally include participation in meetings, verbal commentary, or written correspondence and recommendations.

Because of the controversial nature of radiological issues, stakeholder engagement should include the concepts put forth in the International Radiation Protection Association's *Guiding Principles for Radiation Protection Professionals on Stakeholder Engagement* (IRPA, 2008). These concepts include:

- Identify opportunities for engagement and ensure the level of engagement is proportionate to the nature of the radiation protection issues and their context.
- Initiate the process as early as possible, and develop a sustainable implementation plan.
- Enable an open, inclusive, and transparent process.
- Seek out and involve relevant stakeholders and experts.
- Ensure that the roles and responsibilities of all participants are clearly defined.
- Collectively develop objectives for the process, based on a shared understanding of issues and boundaries.
- Develop a culture which values a shared language and understanding, and favors collective learning.
- Respect and value the expression of different perspectives.
- Ensure a regular feedback mechanism is in place to inform and improve current and future stakeholder engagement.

Key Planning Factor: Identify Technical Working Group Participants

Pre-incident planning and a database of relevant experts or agency contacts developed prior to an incident can greatly facilitate the rapid assembly of a Technical Working Group.

The exact selection and balance of subject matter experts is specific to each incident. The Technical Working Group (TWG) should include selected Federal, state, local, and private sector subject matter experts in such fields as environmental fate and transport modeling, risk analysis, technical remediation options analysis, cost, risk-and-benefit analysis, health physics/radiation protection, industrial hygiene, statistics, construction remediation practices, radioactive and mixed hazardous waste management, environmental sampling, and relevant regulatory requirements. The National Academies of Science and Engineering (NAS) may be an organization that can assist with assembling the necessary scientists.

A key consideration for the TWG is the Advisory Team for Environment, Food, and Health; which is comprised of Federal radiological experts in various fields in radiological environment, health, and safety. TWG participation should also consider National Laboratory experts, EPA On Scene Coordinators, as well as

representatives from the Federal Radiological Monitoring and Assessment Center (FRMAC) and/or the Radiological Assistance Program (RAP).

The initial TWG responsibilities are to convene and initiate:

- interim and final clearance level guidance development,
- radioactive waste management guidance development, and
- temporary waste and emergency discharge management plan.

The TWG responsibilities during the intermediate phase are to provide input to the Unified Command Planning Section as they develop:

- characterization survey plans,
- decontamination strategies,
- recovery priorities,
- interim return to service options,
- contaminated rolling stock management plans, and
- waste-disposal strategies.

During long-term (recovery) phase activities, the recommended TWG responsibilities are to:

- Recommend final clearance goals and cleanup performance criteria, as appropriate to the incident, with input from the ECC and SWG, for approval by local, state and national officials.
- Provide assistance and advise the Planning Section - Environmental Unit and Operations – Sampling Group regarding:
  - Adjustments to the sampling plan to address incident specific circumstances.
  - Evaluation of site characterization results and activities in accordance with the characterization sampling plan and validate analytical results.
  - Maintenance of zone classifications as the remediation and recovery activities progress.
  - Development of the incident specific decontamination strategy, selection of appropriate technologies, and adjustments to the pre-incident remedial action plan as appropriate.
- Develop waste management plan.
- Identify needed permits.
- Identify decontamination, sampling, and analytical technologies related to remediation and recovery.
- Coordinate with ECC and SWG regarding acceptability of the data generated.

Pre-incident planning activities of this group include:

- Developing a decision-making process.
- Convening TWG during exercises and facility trainings.
- Developing a notification protocol.
- Developing initial recommendations for interim and final clearance levels. These levels will likely be updated through the optimization process after an incident has occurred, but it can be used as a starting point for decontamination planning purposes.

4.6 Clearance Process

Key Planning Factor: Establish Process for Developing Clearance Goals

Clearance goals are imperative to all aspects of recovery; lack of a clear, defined process to establish clearances goals will cause extensive recovery delays. Evaluate (for a variety of release sizes and clearance levels) what the preferred community approach is for establishing clearance goals.

Clearance goals—the level of residual surface or volume contamination that drives remediation efforts to achieve—are typically derived from some risk or dose criteria to workers or the public who may be exposed to the material. Specific numerical clearance remediation levels after a radiological terrorist attack in public areas do not exist. Additionally, specific risk or dose levels often used to establish clearance levels, such as statutory authorities from the EPA Superfund program and the Nuclear Regulatory Commission's (NRC's) decommissioning program, do not necessarily apply. The consensus among federal agencies is that a numerical value severely restricts the flexibility of the recovery process.

As of the writing of this document, Federal deliberation continues on how to best establish clearance goals after a radiological terrorism release and what the roles and responsibilities will be of Federal agencies. Specifically, the role of CERCLA is unclear. This can affect the metrics, goals, and constraints of the long-term clean-up process.

Fortunately, the general process of establishing clearance goals is consistent, which is one of Federal, state, and local stakeholder involvement through a technically sound and scientifically supported effort. To quote the RDD/IND-PG:

"With additional time and increased understanding of the situation, there will be opportunities to involve key stakeholders in providing sound, cost-effective cleanup recommendations that are protective of human health and the environment."

There are no numeric cleanup criteria in the RDD/IND-PG. However, dose and risk criteria currently established in regulations and standards are important starting points for choosing remediation levels. Table 4-3 shows a list of such criteria.

The examples below demonstrate the lack of consensus on public dose criteria. Also important is the lack of consistent method for calculating clearance levels based on the exposure criteria. Even with the same risk or dose objectives, differing assumptions regarding statistical input and how the internal and external exposures occur can result in clearance levels that differ by orders of magnitude.

To highlight two key examples,

- On August 22, 1997, EPA issued guidance on radionuclides for cleanup under CERCLA entitled, Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination (EPA 1997). Under this guidance, EPA indicated that annual doses greater than 0.015mSv (15 mrem) should not be used as a preliminary remediation goals for CERCLA cleanups, however the guidance suggested that there could be circumstances where higher limits may be appropriate in establishing final cleanup standards.
- ICRP publication 111 (2008) states: "As the long-term objective for existing exposure situations is 'to reduce exposures to levels that are close or similar to situations considered as normal' (ICRP, 2007, Para. 288), the Commission recommends that the reference level for the optimization of protection of people living in contaminated areas should be selected from the lower part of the 1–20 mSv/year [100-2,000 mrem/year] range and recommended in Publication 103 for the management of this category of exposure situation. Past experience has demonstrated that a typical value used for constraining the optimization process in long term post-accident situations is 1 mSv/year [100 mrem/yr]."

Although these criteria seem mutually exclusive (CERCLA's do not initially exceed 15 mrem and ICRP's do not go below 100 mrem), the resulting remediation guidance from both starting points could easily result in reaching the same contamination clearance levels and clean-up goals after stakeholder engagement and consideration of social, political, and financial factors.

Table 4-3. Anticipated Waste Types.

Reference Point	Criteria
EPA CERCLA	Risk range from $1x10^{-4}$ to $1x10^{-6}$ lifetime risk of excess cancers Preliminary remediation goal not to exceed 0.015 rem
NRC License Termination	0.025 rem
NRC 10CFR20.1301	0.1 rem
DOE 10CFR835.206	0.1 rem
ATSDR	0.1 rem
ICRP 116	From 0.1 to 2 rem (biased toward the lower end)

5.0 Comparison to Other Scenarios

This document focuses on factors for recovery from a radiological incident and utilizes an example scenario that is based on a release of Cesium-137. However, there are important differences in recovery from other types of radioactive material and other all-hazards Incidents.

5.1 CBR Incidents in Comparison to All-Hazards

Response and recovery from CWA, biological, and radiological events may differ from traditional all-hazards events in several important ways. Responders are more familiar with traditional all-hazards events than with the rare CBR event. Further, compared to many large-scale events (such as earthquakes and floods), physical damage may be minimal. Moreover, the hazard may be more insidious or unseen, cross-contamination may be an issue, exposure standards may be uncertain, and the contaminated area may require specialized decontamination. As a result of these factors, public anxiety may be heightened in a CBR event. Therefore, building and maintaining public confidence in governmental decisions and direction is a major consideration, enhancing the importance of honest, accurate, timely, and frequent communication to the public.

Additional challenges posed by CBR incidents must also be factored into the mission of recovery. For example, maintaining and ensuring the health and safety of the responders and the general public while expediting recovery requires balancing risk from recovery processes activities with concerns for rapid economic recovery and revitalization. Restarting and recruiting businesses back into the impacted region so life transitions to a new normal requires levels of trust, transparency, and stakeholder involvement well beyond those needed in traditional disaster events. Meeting these requirements may be especially challenging due to lack of familiarity and the many resources required for recovery (such as decontamination resources and laboratory analysis capacity) may be lacking, which may delay the government's ability to implement recovery actions. The greatest potential for achieving recovery goals lies in pre-event planning.

5.2 Differences among Cs-137 Scenario and Other Radiological Agent Scenarios

The particular threat incident scenario used as an example in this document is only one of many possible scenarios. There are hundreds of different types of radioactive material used in medicine, industry, and science that are potentially available for radiological terrorism. The main factors that influence a radionuclide's response and recovery planning activities are 1) the half life, 2) source strength, 2) the type of radiation emissions, 3) its chemical form, and 4) method of dispersal.

These properties have large impacts on the recovery process because they determine the toxicity level to humans and the environment, the detectability of the radionuclide by field portable instrumentation, the extent of contamination, and the penetration of the agent into impacted surfaces. These issues greatly impact the types of remediation methods selected, level of effort, and overall duration of recovery. However, the KPFs described in this document are applicable to all types of radiological dispersal incidents.

6.0 Conclusions

A radiological dispersal incident has the potential to disrupt life and business in a community through denial of access and service due to real or perceived environmental and facility contamination. Recovery from a major disaster like a radiological agent attack will challenge every level of government and its citizens.

Time is the critical element in reducing the potentially enormous societal impact of the incident. Recent analysis supported by the U.S. Department of Homeland Security through the National Center for Risk and Economic Analysis of Terrorism Events (CREATE) concluded that the greatest impact from an RDD was business interruption in the short run and behavioral impact in the long run (Giesecke, et al., 2012). Many businesses are unable to recover if the interruption is extended beyond a few weeks or months, and large national businesses are likely to relocate, further damaging the local economy and slowing recovery. Figure 6-1, adapted from work done by the Community and Regional Resilience Initiative, illustrates how pre-incident planning can significantly shorten recovery time and improve the overall outcome of the recovery's "new normal."

Advance, pre-incident planning will substantially aid the recovery process by decreasing the recovery timeline and costs, improving public health and safety, and addressing critical decision-making processes. By addressing the KPFs described in this document, local, state, and Federal agencies will be better prepared to successfully recover from a radiological dispersal incident.

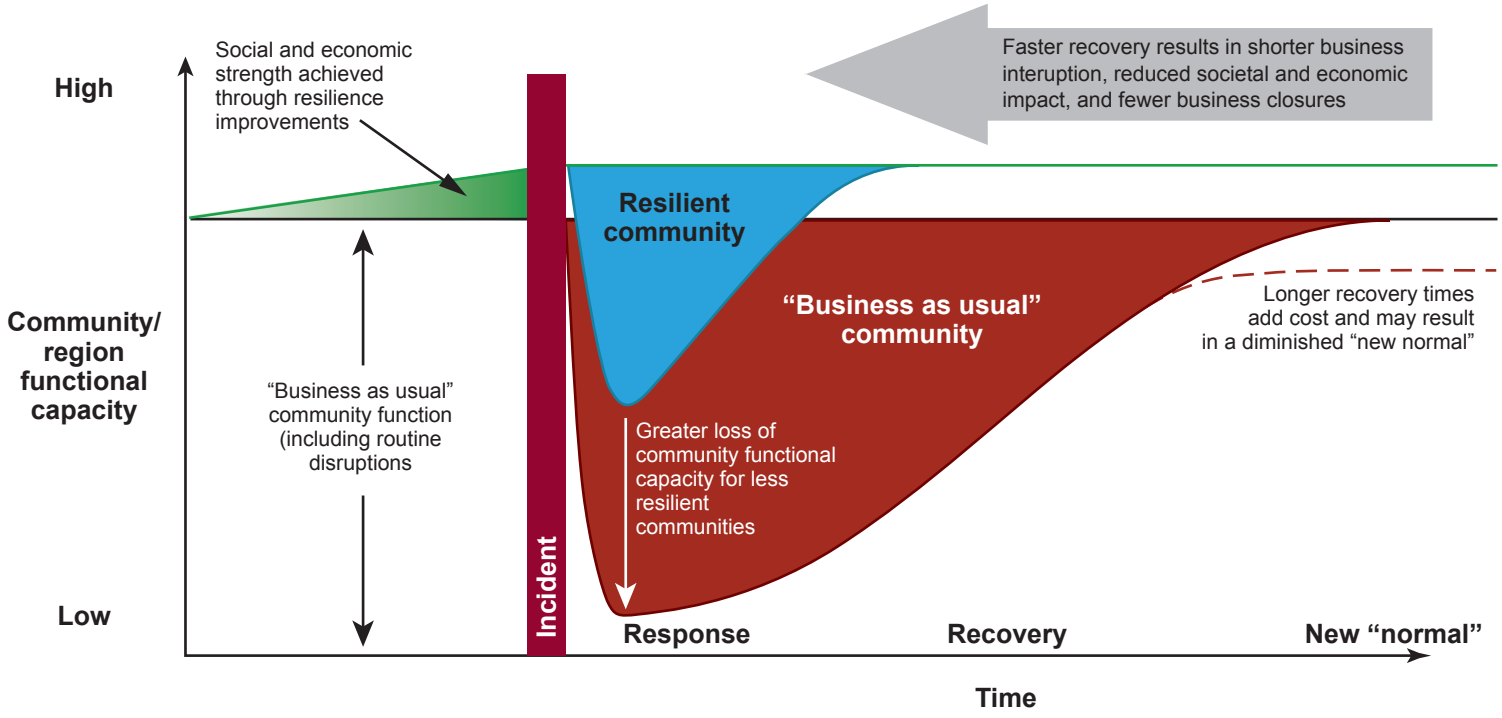


Figure 6-1. Pre-incident planning can significantly shorten recovery time. (*Adapted from image by Community and Regional Resilience Institute and Dr. Mary Ellen Hynes.*)

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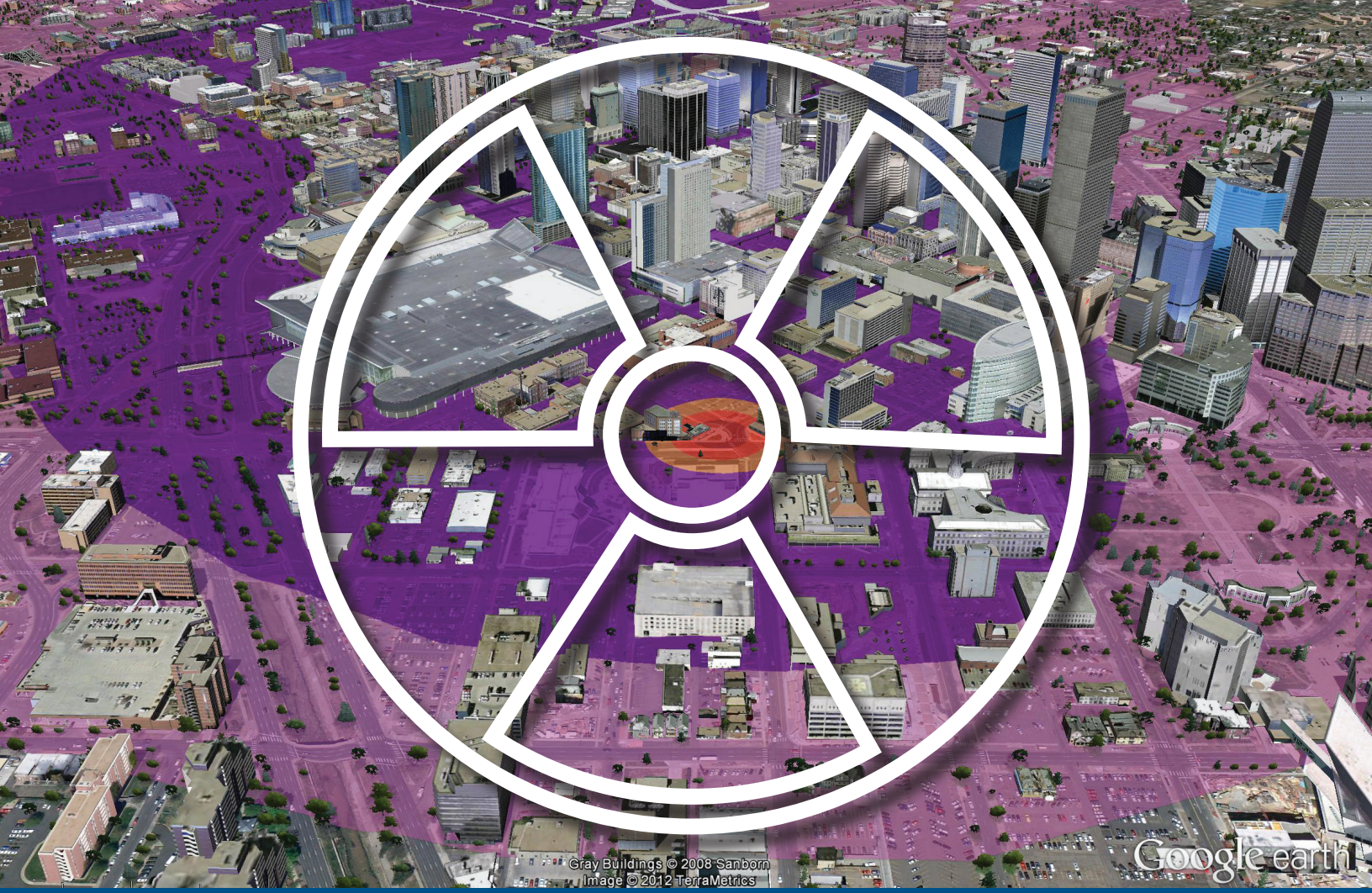
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