1. Executive Summary

1.1 Introduction

In 2008 the U.S. Department of Homeland Security (DHS) published Protective Action Guides (PAGs) for radiological dispersal devices (RDDs) and improvised nuclear devices (INDs). Guidance was offered to protect members of the public in the early, intermediate and late phases of response to terrorist attacks with radiological devices. The optimization (of radiation protection)[1] process was recommended for late-phase recovery in circumstances of widespread contamination with radioactive material. The purpose of this Report is to provide guidance on optimizing decision making for late-phase recovery from a major RDD or IND incident. In light of the March 2011 Fukushima Dai-ichi Nuclear Power Plant (NPP) accident, the scope was expanded to include nuclear accidents.

A nuclear or radiological incident, caused by an act of terrorism or an accident, could have significant societal consequences, depending on the type and magnitude of the incident and circumstances specific to the local communities affected. The long-term impact of widespread contamination with radioactive material is an important concern. Highly populated metropolitan or economically sensitive regions will require an extensive cleanup effort, as evidenced by the 1986 Chernobyl nuclear reactor accident (IAEA, 2006a; 2006b; 2006c; UNSCEAR, 2011) and the 2011 Fukushima Dai-ichi NPP accident (ANS, 2012; GOJ, 2011; 2012; Gonzalez *et al.*, 2013; IAEA/NEFW, 2011; NDJ, 2012). Decisions about cleanup will depend on the scale to which society is adversely affected and the degree of stakeholder acceptance of the remediation goals (Chen and Tenforde, 2010; Eisenbud and Gesell, 1997; Eraker, 2004; Heintz, 2011; IAEA/NEFW, 2011; Porfiriev, 1999). Accomplishing remediation goals will require sound strategies and transparency. This Report examines the challenges faced in late-phase recovery following acts of terrorism (RDDs and INDs) or major NPP accidents with off-site contamination, and offers preparedness guidance to assist decision makers once the immediate crisis has come to an end.

[1]In this Report, optimization refers to the optimization of radiation protection, that is, the balancing of benefits and costs of further reducing doses from radiation exposure.

After the initial response to a nuclear or radiological incident, it remains necessary to consider how best to use resources to reduce radiation exposures to individuals in the population. The broad aim is to ensure that the magnitude of the individual doses, the number of people exposed, and the likelihood of incurring exposures, are all kept as low as reasonably achievable (ALARA), economic and social factors being taken into account (the ALARA principle). If reducing radiation exposures can be achieved only by deploying resources that are not commensurate with the consequent reduction, it may not be in society's interest to take such additional steps, provided that individuals have been adequately protected (ICRP, 2007). The protection can then be said to be optimized and thus to have adhered to the ALARA principle. In such circumstances, the optimization process emerges as a balanced approach to address these very complex and intricate issues facing long-term recovery and the efficient recovery of affected communities.

Radiation protection, however, is not the only concern to be addressed in the management of long-term recovery. Recovery involves restoration of whole communities, including but not limited to infrastructures, public services, business and employment, as well as remediation of the contamination. Key considerations include public health and welfare, socioeconomics, waste management, environmental impacts, and communication.

Late-phase recovery needs to address radioactive contamination of large areas. Depending on the extent and magnitude of the contamination, as well as the possibility of it being caused by a terrorist incident, comparable remediation experiences from past or existing activities associated with cleanup of contaminated lands or facilities may not be readily applicable. For example the experience gained in addressing environmental contamination from nuclear weapons testing in years past is informative but not necessarily applicable to a particular accident or terrorist incident (Eisenbud and Gesell, 1997; IAEA, 1998; Robinson and Hamilton, 2010; Simon *et al*., 2010; UNSCEAR, 1993). Similarly, statutory requirements under defined scopes and specific regulatory provisions may not always be suitable for wide-area contamination following a nuclear incident.

Concerns over terrorist attacks heightened after September 11, 2001, when four commercial airplanes were hijacked by terrorists and flown into the World Trade Center (WTC) buildings in New York City; the Pentagon in Washington, D.C.; and crashed into a field near Shanksville, Pennsylvania. Although no nuclear device or radiological sources were involved in these particular incidents, there has been a growing concern about the possibility, consequences, and state of readiness to manage such radiological incidents, including the development of countermeasures (DHS, 2008a; 2008b). Unlike examples of historical incidents involving nuclear reactor accidents, the absence of historical instances of radiological terrorist attacks limits the preparedness actions to postulated scenarios, such as those identified under the National Planning Scenarios for radiological and nuclear incidents (DHS, 2008b). National preparedness and resiliency is assessed, enhanced and improved by participation in large-scale exercises (DHS, 2007a; 2007b).

The two types of devices commonly considered in radiological terrorist planning scenarios are the RDD and IND. An RDD is any device that causes the purposeful dissemination of radioactive material with the intent to cause harm, but does not cause a nuclear detonation. An IND is an illicit nuclear weapon that is bought, stolen, or otherwise obtained from a nuclear state, or a weapon fabricated by a terrorist group from illegally obtained fissile nuclear weapons material that produces a nuclear explosion (DHS, 2008a). The RDD uses explosives for dispersal of radioactive materials and is commonly referred to as a "dirty bomb." In general, an RDD is considered to affect only a limited area and produce few casualties, mostly related to the explosion itself. However, under certain circumstances (related to the size, type and number of devices, and atmospheric conditions) an RDD has the potential to contaminate a large area as a result of dispersion. In contrast, a nuclear terrorism incident involving an IND would result in mass casualties, as well as causing widespread dispersion of fission products from fallout. More in-depth information concerning RDDs, INDs, and the emergency response phase of such incidents can be found in *Planning Guidance for Response to a Nuclear Detonation* (DHS, 2010a); National Council on Radiation Protection and Measurements (NCRP) Report No. 138, *Management of Terrorist Events Involving Radioactive Material* (NCRP, 2001); Commentary No. 19, *Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism* (NCRP, 2005); Report No. 165, *Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers* (NCRP, 2010a); and Report No. 166, *Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident* (NCRP, 2010b).

Although a nuclear or radiological incident may lead to some initially high radiation doses to the responders and members of the public, long-term concerns are associated with the widespread contamination that may hinder the recovery effort. Much of the radiological preparedness and response efforts to date have focused on monitoring radiation levels and initial response, including triage and the medical screening of exposed or contaminated persons to determine their relative priority for treatment or decontamination.

The need to address systematically the long-term recovery of affected communities has been discussed (Chen and Tenforde, 2010; ICRP, 2009). The importance of the need for a comprehensive late-phase response to recovery was recently illustrated in the aftermath of the Fukushima Dai-ichi NPP accident of 2011 in Japan, where a sequence of natural disasters resulted in reactor meltdowns, radioactive releases, evacuation of the surrounding populations, and widespread contamination.

The purposes of this Report are to:

- present the general issues associated with late-phase recovery following an RDD or IND incident or a major NPP accident;
- identify and address important challenges facing decision makers and stakeholders; and
- develop a framework for a site-specific optimization process that provides a flexible and iterative approach to decision making that will facilitate recovery under complex societal circumstances.

1.2 Formulating Responses to Nuclear or Radiological Incidents

Emergency management activities related to industrial nuclear or radiological incidents have been underway in the United States for several decades. The PAG was developed by the U.S. Environmental Protection Agency (EPA) in the 1970s to facilitate protection of members of the public from potential radiation exposures during such incidents. Following the Three Mile Island (TMI) NPP accident on March 28, 1979, EPA was assigned the task of establishing exposure guidance that incorporated the lessons learned from TMI. EPA issued a manual of PAGs for radiological emergency response planning for nuclear incidents in 1992 (EPA, 1992), and issued an updated draft version of the PAG manual for public comment and interim use in March 2013 (EPA, 2013a). The final publication date of the new PAG manual was not available at the time this Report went to press.

After the September 11, 2001 terrorist attacks on the WTC and Pentagon, concerns that terrorist attacks could use nuclear or radiological devices led to the 2008 publication entitled *Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents* (DHS, 2008a). This guidance, developed by experts across the federal government, provides PAGs to support decisions on actions to be taken to protect members of the public and emergency responders.

Both the PAG manual from EPA and the DHS Planning Guidance provide similar approaches and recommendations for protective actions during the early and intermediate phases of an incident. The DHS guidance also established an approach termed "site-specific optimization" that recognized the scope and complexity of late-phase decision making and recovery associated with radioactive contamination. The DHS guidance is consistent with the recommendations of NCRP and the International Commission on Radiological Protection (ICRP), which include optimization as one of the three principles of radiation protection, along with justification of planned activities or remedial actions, and application of dose limits to individuals. While "optimization" is not explicitly mentioned for late-phase recovery in the EPA draft PAG manual, the proposed approach contained flexible provisions for late-phase applications that are generally consistent with those recommended by DHS guidance.

In 2009 ICRP issued Publication 111, *Application of the Commission's Recommendations to the Protection of People Living in Long-Term Contaminated Areas After a Nuclear Accident or a Radiation Emergency* (ICRP, 2009). Drawing on the experiences and lessons learned from past incidents, this publication placed special emphasis on the optimization approach to late-phase recovery issues. When addressing optimization as a process, ICRP Publication 111 states "…while initially the exposures may be rather high and priority may be given to reducing the highest exposures, continuous efforts need to be made to reduce all exposures with time." The ICRP view is that optimization is not a one-time action to address late-phase issues, but rather a continuous, deliberate and iterative effort to manage radiation exposures to responders, remediation workers, and members of the public.

In 2011 the Federal Emergency Management Agency (FEMA) published the *National Disaster Recovery Framework* (NDRF) (FEMA, 2011a) to address recovery issues from major incidents involving all hazards, including natural disasters, accidents, and terrorist acts. Although important guidance and recommendations appear in the NDRF, it does not provide specific guidance for radioactive contamination.

1.3 Late-Phase Recovery: A Challenging Journey to Resume Normal Life

A major nuclear or radiological incident would result in considerable disruption and long-term impact on the affected communities, whether from an NPP accident or a terrorist attack involving an RDD or IND. Hundreds of thousands of citizens could face the possibility of evacuation or relocation during the early and intermediate phases of the response. The disruption of normal life could be prolonged and continue well into the late phase while awaiting appropriate remediation of the contaminated areas and/or specific policy decisions. Such long-term disruption was experienced after the Chernobyl nuclear reactor and Fukushima Dai-ichi NPP accidents where many thousands were evacuated, cities were abandoned, and many thousands will not be able to return to their homes and livelihood.

As learned from experience with past disasters, a robust recovery always depends on the resilience of the affected community. A resilient community is one that has the capacity to bounce back from a catastrophic impact to near-normal conditions in an expedient manner. Resiliency includes a willingness of the community to engage constructively with responsible authorities to achieve their common goals.

In addition to community resilience, a successful recovery requires ample resources in the form of financial, material and organizational support, and a well-structured operational recovery process with timely and transparent decision making. When a community is severely affected by a major incident, many key elements are seriously compromised. The recovery should focus on these elements to restore the functionality of the community and its economic and social health. Key elements include infrastructure (such as utilities, public transportation, communications, and food and water supplies), businesses (such as shopping centers, stores, and banks), employment, public services (such as government, security, medical, financial, public health, and education), and healthy environmental conditions. This multitude of complex and interrelated issues and priorities alone presents a challenging task that requires robust planning and response capabilities to restore the vitality of the affected communities in a timely and orderly manner. At the center of these issues following a radiological or nuclear incident is the urgent need to manage any widespread or potentially high radiation exposures to the population from dispersed radioactive materials. Given the recognized public fear of and anxiety associated with radiation (Bromet, 2014; Slovic, 2012), the effective mitigation of significant radiation exposures may well be one of the most important considerations in community restoration.

Actions important for late-phase recovery include the following, many of which require considerable deliberation and development *before* the occurrence of an incident:

- encourage a community-based recovery effort, and foster a collaborative culture among citizens' groups, business communities, government sectors, and all other stakeholders;
- develop a framework to define options and provide a basis for setting priorities and resolving conflicts that will arise, given the multitude of complex and interconnected issues to be faced;
- develop a transparent decision-making process and rationale to remediate wide-area contamination to facilitate recovery;
- formulate a clear strategy and approach to communicate benefits and risks of late-phase recovery options with stakeholders;
- develop a capability to identify and assemble information to manage available resources effectively;
- develop and maintain community resilience to respond and adapt effectively to the challenges and varying conditions inherent in any long-term recovery process;
- understand the consequences of implementing various remediation approaches and technologies so that options can be compared and selected in such a way to maximize the overall net benefit for the community;
- develop requisite expertise and effective administration of the various technologies that might be employed to remediate contaminated areas; and
- maintain a flexible approach to adapting strategies and decisions to accommodate developing and changing situations with an aim to reduce overall radiation exposures over time.

1.4 Optimizing Decision Making: A Framework and Process

For a nuclear or radiological incident, the primary goal of the entire recovery process will be to develop an agreed strategy for returning areas affected by the emergency to a state as close as possible to that existing before the release of radioactive material and restoring the population to a lifestyle where the accident is no longer a dominant influence. However, the approach to full recovery after an RDD or IND terrorist attack or NPP accident is likely to be multifaceted and highly complex. Consequently, setting priorities for particular decisions will inevitably involve trade-offs among many key factors and also will require comprehensive deliberations with multiple stakeholders to reach decisions.

The principles of radiation protection include justification, optimization and limitation (*i.e.*, the application of dose limits) (ICRP, 2007; NCRP, 1993). Optimization is closely aligned to the ALARA principle. Optimization recognizes the importance of these and other, nonradiation-related issues in framing the decision-making process for populations living in or returning to areas of widespread radioactive contamination (ICRP, 2009).

Remediation of contaminated areas will contribute to the complexity of issues facing a community. The late-phase recovery process begins with understanding and assessing current situations and evolves through characterizing and assessing potential impacts, from which the community goals and remediation options are identified and evaluated. Ultimately, decisions are reached and solutions implemented. Remediation work should be monitored and evaluated for success; adjustments should be made as necessary to respond to unforeseen challenges or opportunities. Through careful deliberation during the interactive process, and upon consulting with the stakeholders, decisions will need to be reached on such subjects as future land use, priority of remediation options, cleanup criteria, socio-political factors, cultural and ethnic issues, human health and public welfare needs, ecological risks, timeliness of cleanup, short- and long-term considerations, effective communication, decontamination technology, costs, and available resources and financing. Furthermore, it should be recognized that one of the inevitable products of widespread remediation efforts will be very large volumes of radioactive waste, the management of which could be a substantial challenge for any government or community.

Remediation of a very large area requires a huge labor pool and a substantial resource commitment, often at a national scale. Decisions must account for all competing factors discussed above to favor the overall well-being of the community in the long term. Although conventional experiences may be useful, their applicability to the specific situations affecting the community must be fully evaluated. For example, current cleanup operations under statutory regulatory provisions, although thorough and generally effective, require a lengthy process and may take up to decades to complete (GAO, 2012). Such a protracted timeframe would not be conducive to the goal of rapidly restoring the community's economic and social viability. Toward this end, DHS (2008a) PAG guidance is as follows:

> "Because of the extremely broad range of potential impacts that may occur from RDDs and INDs (*e.g.*, light contamination of one building to widespread destruction of a major metropolitan area), a pre-established numeric cleanup

> guideline is not recommended as best serving the needs of decision makers in the late phase. Rather, a process should be used to determine the societal objectives for expected land uses and the options and approaches available, in order to select the most acceptable criteria."

For late-phase response (*i.e.*, long-term cleanup), the guidance prescribes a long-term plan that properly balances site-specific circumstances. The primary goal of site-specific optimization is to establish societal objectives that, in addition to health protection, address future land use, cleanup options, technical feasibility, costs, cost-effectiveness, infrastructures, local economy, and public acceptance. Optimization is to be achieved by a flexible, iterative and multifaceted decision-making process that takes incident- and site-specific factors into consideration. For example, a small-scale incident may receive an expedited cleanup effort, while an incident causing extensive contamination (*e.g.*, affecting many city blocks in a major urban area) may require a considerable effort in terms of cost and time, thus influencing the decision on the final cleanup criteria for an acceptable level for remediation. In a wide-area contamination incident, it may not be practical or even possible to return the community and its infrastructures to pre-incident conditions; the resources available and technological capabilities may simply be insufficient to achieve the desired result. The alternative and perhaps only feasible approach is to manage mitigation efforts in an effective yet flexible manner toward a community-developed optimized level of protection (Longstaff *et al.*, 2010).

1.5 Stakeholder Engagement in Decision Making

A successful recovery effort is necessarily community-focused and community-based. Active participation by the stakeholders is an absolute necessity throughout the late-phase recovery process. In fact, individual, spontaneous efforts by citizens or community groups often take place before any assistance is provided by authorities or outside groups, as reflected in previous disasters including the recent Fukushima Dai-ichi NPP accident (Gonzalez *et al.*, 2013). The desire to take control and take action exhibited by citizens should be encouraged and supported and is essential to a community-based recovery. Community and stakeholder involvement should always remain central to the decision-making process.

Unlike emergency situations (*i.e.*, in the early phase), where prompt response toward preserving life and critical infrastructures is the overriding consideration, more time is available in the late phase to develop comprehensive and effective schemes for involving stakeholders in decision making. Considerations should include issues that are specific to local/regional needs, cultural/ethnic aspects, and justice/equity that involve the citizens of the affected communities.

Due to the complexity of the multi-faceted issues facing recovery, it is essential that preparations be made to bring stakeholders together for decision making in a way that maintains mutual trust and transparency. Planning for effective engagement with stakeholders should begin in pre-incident preparedness. Stakeholder groups representing the diversity of the community's needs and interests should be identified and engaged prior to the incident. Stakeholders who would be affected by a wide-area incident are generally not a single, monolithic group. They include many groups over a cross-section of the society with diverse backgrounds and differing perspectives. Although they share a common long-term goal for recovery (*i.e.*, a return to normality) individual short- and intermediate-term interests may be so conflicting as to render the decision-making process extremely challenging. For example, decisions regarding the location for storage and/or disposal of radioactive waste as well as cleanup standards and priorities will require exceptional stakeholder engagement. The effective coordination of diverse groups will be necessary to achieve consensus and avoid a protracted decision-making process. The timely implementation of the remediation strategy is essential under certain circumstances, particularly when a population has been displaced into temporary housing in a remote location.

In recognition of the limitations of the government's role and its effectiveness in responding to large-scale incidents, FEMA developed the "whole-community" concept in preparing for responses to a major disaster (FEMA, 2011b). This concept advocates continuous engagement and empowerment of stakeholders responding to disasters throughout all phases of the incident. Clearly, the integration of stakeholders into response actions has now become a central concept to drive an effective community recovery effort following a disaster.

Facilitating a meaningful and substantive integration of stakeholders into the decision-making process requires effective communication methods and the ability to accommodate feedback from stakeholders in a timely fashion. Guiding principles by which such a discourse and engagement can take place are available from the Congressionally-mandated Commission on Risk Assessment and Risk Management (Omenn *et al.*, 1997a; 1997b), the Health Physics Society (HPS, 2010), the International Radiation Protection

Association (IRPA, 2009), National Academies/National Research Council (NA/NRC, 2006; 2009), and NCRP (2004). These approaches emphasize positive and proactive interactions with stakeholders. They seek to develop a process conducive to resolving complex problems by collectively developing common objectives, while adhering to a common code of ethics.

The central principle for stakeholder engagement is a comprehensive communication effort that serves to foster a close partnership at every stage of the site-specific optimization process. This effort must include transparency, inclusiveness, shared accountability, and measures of effectiveness. Stakeholders must be fully informed of the objectives and processes of recovery because they will share in the outcomes. A detailed communication plan should be developed, adapted and improved throughout the entire recovery process. Stakeholders must participate in the iterative process of making decisions on risk management that begins with defining the problem and context, continues with risk analyses for various options, and ends with a decision on actions to be conducted.

As society evolves, so do the technologies for communication. The rapid developments in electronic technology and social media enable an expansion of communication mechanisms that were not previously available. The internet and advanced personal communication technology will continue to both encourage and require the exploration of new means of public communication and will serve an important role in expediting the otherwise complex and protracted decision-making process.

1.6 Managing Long-Term Contamination

A resilient community experiencing a major incident must possess several important attributes that include robust resources and adaptive capabilities to bring about a timely recovery. Unlike the nonradiological impacts that might be caused by natural disasters (such as earthquakes, tsunamis and hurricanes), a major nuclear or radiological incident will impose added concerns associated with widespread and long-term radioactive contamination. For radiological incidents, the recovery of the community will depend on developing a strategy and comprehensive plan for reducing residual contamination.

The site-specific optimization approach to reduce residual contamination from an RDD or IND incident or a major NPP accident necessarily involves long-term remediation strategies, through an iterative process. The strategies should comprise all activities undertaken to implement remediation actions and include a means to track the progress of the recovery activities. Further, it is important to evaluate the impacts of residual radioactive material on health and the environment, including food, water, commodities, properties, agriculture, and nonhuman biota.

Planning for long-term management should begin as soon as possible after the radiological incident has occurred. Actions taken during the early and intermediate phases, such as removing debris or storing the generated waste, may affect the available remediation strategies during the late phase. Around the end of the early phase, authorities should have a reasonable assessment of the magnitude of the incident and should be able to estimate the resources required to carry out long-term monitoring activities. During the intermediate phase, resources should be gathered and agreements and commitments for those resources should be completed. Monitoring throughout the process will include public health as well as environmental contamination, and should continue after the remediation effort has been completed and recovery has taken shape. Monitoring will help ensure that both long-term contamination (for residences, commercial properties, commodities, natural resources, and the environment) and public health (including physical and psychological status) issues continue to be addressed, while recognizing and mitigating any anxieties or stigma associated with radioactive contamination.

1.7 Path Forward and Recommendations

Given the potentially large magnitude and consequences of a nuclear or radiological incident, the traditional approaches to long-term recovery (specifically the remediation and cleanup of these contaminated areas), may not be applicable in either scope or approach. In such circumstances, the optimization process emerges as a balanced method to address the very complex and intricate issues facing long-term recovery. Besides protecting human health, the optimization process seeks to balance available resources and societal needs to determine priorities so that a path forward can be implemented for the efficient recovery of affected communities.

Preparation for a nuclear or radiological incident that will require substantial resources and commitments is not easily captured or incorporated into a general preparedness document. Quite often the affected communities may struggle to respond to and recover from an unprecedented situation that is far beyond their understanding. Consequently much more effort and emphasis is needed on community preparedness for late-phase recovery.

Valuable lessons have been learned from past NPP accidents such as Chernobyl in 1986 and Fukushima Dai-ichi in 2011. Both of these radiological incidents resulted in large contaminated areas with unprecedented environmental and economic consequences and numerous challenges and complexities (ANS, 2012; GOJ, 2011; 2012; Gonzalez *et al.*, 2013; IAEA, 2006a; IAEA/NEFW, 2011; ICRP, 2012; NDJ, 2012). A concerted international effort continues to compile and share the experience and information gained from these past incidents for future preparedness. Additionally, conducting exercises using multiple scenarios aimed to address specific societal concerns will produce additional knowledge that can help guide future decision making

After a catastrophic incident, a resilient community is one that is able to bounce back to near-normal conditions in an expedited manner. Recognizing that any response, especially for late-phase recovery, is incident- and site-specific, this Report emphasizes general principles for implementing the late-phase optimization process for circumstances that go well beyond those experienced in conventional cleanups. Important issues are identified that should be addressed more fully in years to come. These issues are enumerated in the following eight recommendations, and are discussed in Section 7:

1. Develop a national strategy to promote community resilience as the most favorable preparedness approach for responding to and recovering from nuclear or radiological incidents involving widespread contamination.
2. Integrate late-phase response into national, state and local government emergency response planning and ensure that it is regularly included in response exercises.
3. Embrace the site-specific optimization process for managing widespread contamination with radioactive material.
4. Ensure that stakeholder engagement and empowerment underpins the optimization process and uses consensus building in the decision-making process.
5. Develop a communication plan as an integral part of the preparedness strategy to ensure that messages are accurate, complete, understandable, and widely distributed
6. Develop adaptive and responsive cleanup and waste management strategies to facilitate the optimization process.
7. Conduct research to develop new technologies, methods and strategies that address remediation of wide-area contamination.
8. Establish a mechanism to integrate new information and lessons learned from past incidents into the strategies for late-phase recovery to promote continuous and adaptive improvements.