Emergency Management and Fire Protection, Volume II: Framework for Recovery After a Nuclear Emergency

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Preface

This regulatory document is part of the CNSC's emergency management and fire protection series of regulatory documents. The full list of regulatory document series is included at the end of this document and can also be found on the CNSC's website.

Regulatory document REGDOC-2.10.1, *Emergency Management and Fire Protection, Volume II: Framework for Recovery After a Nuclear Emergency*, outlines guidance that decision makers may need to consider prior to, or following, the response to a nuclear emergency. The guidance in this document is consistent with international best practices.

Since recovery after a nuclear emergency is a broad and complex matter, it will impact many government bodies and levels of government, along with emergency management organizations. This regulatory document was produced through a partnership and ongoing collaboration among three such organizations – the CNSC, Health Canada and Natural Resources Canada.

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Framework for Recovery After a Nuclear Emergency

1. Introduction

This document provides guidance that decision makers may need to consider prior to, or following, the response to a nuclear emergency in Canada. The guidance in this document is consistent with international best practices and the recommendations of the International Atomic Energy Agency and International Commission on Radiological Protection.

1.1 Definition of recovery

For the purposes of this document, "recovery" is defined as the actions taken following a nuclear emergency to restore quality of life, social systems, economies, community infrastructure and the environment. The extent of the measures taken during recovery would typically be determined by the authorized jurisdiction, in consultation with the stakeholders affected by the nuclear emergency and its aftermath. The scope of recovery efforts should be commensurate with the impact of the nuclear emergency on the surrounding population and environment.

The recovery management organization(s) for the authorized jurisdiction will take over from the nuclear emergency management organizations as the emergency transitions from the response phase to the recovery phase. In its planning, the responsible organization should consider the recovery elements described in this document – which is intended, in part, to inform the composition of the recovery management organization so that federal, provincial, and municipal plans for recovery may be further developed.

1.2 Purpose

This document provides guidance for authorities and decision makers who are responsible for preparing and implementing plans for offsite recovery following a nuclear emergency.

1.3 Scope

The guidance provided in this document is for planning and executing offsite recovery operations following a nuclear emergency. A nuclear emergency is a non-routine situation that necessitates prompt action to mitigate a radiological hazard that could result in adverse consequences for human health and safety, quality of life, property or the environment [1].

With respect to the application of recovery elements following a nuclear emergency, it is assumed in this document that a radioactive release has occurred and has resulted in levels of radioactive contamination above prescribed limits in the public domain (i.e., an area accessible to the public that is not under the direct control of a CNSC licensee). Further, the term "nuclear emergency" is used broadly to refer to both nuclear and radiological emergencies where the consequences would require the implementation of a recovery plan.

The following topics are outside of the scope of this document:

- Requirements and guidance for licensees for preparedness and nuclear emergency response; these are provided in REGDOC-2.10.1, *Nuclear Emergency Preparedness and Response* [2]
- Licensee guidance for onsite recovery actions
- Security considerations associated with nuclear emergencies, given that these will have been managed before the initiation of the recovery phase

1.4 Leveraging of international standards, requirements, and recommendations

Canada's framework for recovery after a nuclear emergency reflects international standards, requirements and recommendations, including those provided by the International Commission on Radiological Protection (ICRP) and International Atomic Energy Agency (IAEA). Applying these best practices will contribute to worldwide harmonization of arrangements for preparedness, response and recovery from a nuclear emergency.

The IAEA has set requirements for developing recovery arrangements:

- Requirement 18 in IAEA General Safety Requirements (GSR) Part 7 [3], states: "The government shall ensure that arrangements are in place and are implemented for the termination of a nuclear or radiological emergency, with account taken of the need for the resumption of social and economic activity." Additional specifications for how to ensure that appropriate arrangements are in place for the termination of the emergency are also provided in sections 5.95 to 5.101 of IAEA GSR Part 7.
- Requirement 46 in IAEA GSR Part 3 [4] states: "The government shall ensure that arrangements are in place and are implemented as appropriate for the transition from an emergency exposure situation to an existing exposure situation."

By providing guidance for Canadian recovery actions after a nuclear emergency, this regulatory document aims to promote alignment with these two IAEA requirements.

REGDOC-2.10.1, *Nuclear Emergency Preparedness and Response* [2] establishes and documents CNSC's expectations for nuclear emergency preparedness and response for regulated activities under the *Nuclear Safety and Control Act* (NSCA) [5]. These expectations are also in line with IAEA requirements as described above.

Experience gained from past nuclear and radiological emergencies (e.g., Chernobyl, Fukushima, and Goiânia[1]) highlights the need for greater attention to the recovery phase for nuclear or radiological emergencies.

2. Background

2.1 Introduction to nuclear emergency management

In recognition that this is an area of increasing international focus, the IAEA developed a safety guide, *Arrangements for the Termination of a Nuclear or Radiological Emergency* [6]. Canada participated in the development of this internationally aimed guide, and has furthered its work in this realm through the creation of this regulatory document, which provides practical Canadian-specific guidance. Similarly, other countries have developed national guidance on this topic and the best practices from those documents [7, 8, 9, 10] have been incorporated into this regulatory document.

Nuclear emergency management includes the following actions:

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[1] For a full description of this occurrence, which involved a teletherapy source head that was dismantled and was without control over an 18-day period, see the IAEA publication *The Radiological Accident in Goiânia*.

- **Prevention and mitigation actions** are taken to ensure that a nuclear emergency does not occur, or to reduce the likelihood of a nuclear emergency.
- **Preparedness actions** are taken in order to be ready to respond and manage the consequences of a nuclear emergency (e.g., response procedures and plans, training and awareness, maintaining emergency facilities, exercises).
- **Response** includes onsite and offsite protective actions taken during a nuclear emergency to reduce the magnitude of the hazard and manage its consequences to health, safety and the environment. These protective actions may include worker protection, support for accident management activities, emergency public communication, emergency medical assistance, and shelter-in-place or evacuation.

Nuclear emergency response has the following goals:

- Regain control of the situation
- Prevent or mitigate consequences at the scene
- Prevent the occurrence of deterministic health effects in workers and the public
- Prevent, to the extent practicable, the occurrence of stochastic health effects in the population
- Prevent, to the extent practicable, the occurrence of non-radiological effects in individuals and among the population
- Render first aid and manage the treatment of radiation injuries
- Protect, to the extent practicable, property and the environment
- Prepare, to the extent practicable, for the resumption of normal social and economic activity

Recovery includes the short-term and long-term actions taken both onsite and offsite in order to restore the communities affected by the nuclear emergency to an acceptable level. The level of restoration would typically be determined by the responsible authorities, in consultation with the affected stakeholders.

Some critical activities and infrastructure (such as hospitals) will require actions to be taken to restore their operation in a timely manner following a nuclear emergency, despite the fact that many authorities may still be in emergency-response mode. These early recovery actions should be implemented through the nuclear emergency management organization, and may be guided by the concepts in this document.

2.2 Exposure situations

The recommendations of the ICRP on radiation protection are based in part on the definition of exposure situations. Exposure situations are based on the concept that the system of protection can be applied, in principle, to any situation of radiation exposure. Similar procedures are used to decide on the extent and level of protective actions, regardless of the exposure situation. Notably, the concepts of justification and optimization apply universally to all exposure situations:

- Justification requires that the net benefit of the actions taken to reduce radiation exposure be positive, beyond simply the impact on the radiation exposure to individuals.
- Optimization requires that radiation exposure be as low as reasonably achievable (ALARA), taking economic and societal factors into account. This approach allows the system of radiation protection to be applied to regulated activities such as the use of radioactive

materials in industry or medicine as well as to activities that would not normally be regulated, such as the use of lands where there is naturally elevated background radiation.

ICRP Publication 103, *The 2007 Recommendations of the International Commission on Radiological Protection* [1], outlines three exposure situations:

- **Planned exposure situations** involve the planned use of radioactive materials and/or the operation of nuclear reactors.
- **Emergency exposure situations** are unexpected situations that may occur during the operation of a nuclear reactor or during the use of radioactive materials in a planned situation, which require urgent actions to avoid or reduce undesirable consequences.
- **Existing exposure situations** already exist when a decision on control has to be taken, including prolonged exposure situations after emergencies. These situations include exposure to natural background, exposure due to residual radioactive material that derive from past practices that were never subject to regulatory control, and exposure due to the residual radioactive material deriving from a nuclear emergency.

This document considers each of these three exposure situations, as follows:

- During the conduct of licensed activities, the exposure situation for a member of the public from these activities is considered a planned exposure situation.
- If a nuclear emergency occurs, then a member of the public may be exposed to radiation as a result, and this is considered an emergency exposure situation.
- Finally, as the nuclear emergency terminates, any additional exposure to radiation that comes about due to residual environmental contamination is considered an existing exposure situation.

Note: This document's scope does not include potential exposure to radiation from recovery activities conducted under licences issued under the *Nuclear Safety and Control Act* (NSCA) [5] – for example, contaminated waste disposal at licensed waste facilities. However, such instances would be considered planned exposure situations.

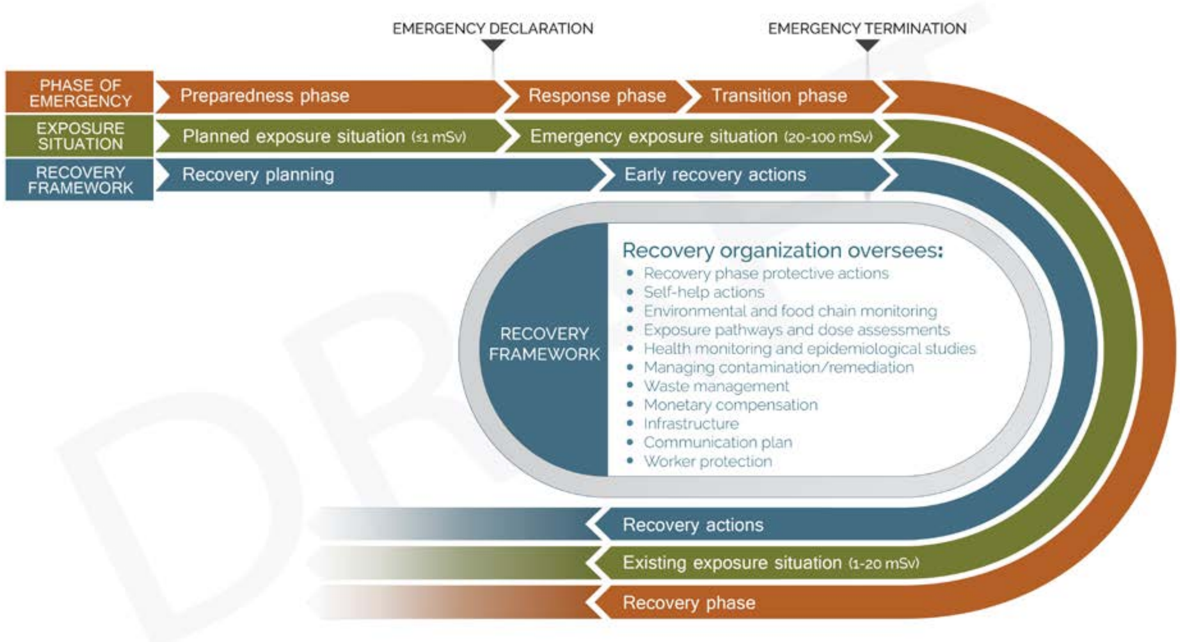
In the Canadian context of nuclear emergency management, there are regulations and licence conditions, established through the NSCA, that apply to CNSC licensees for the management of planned and emergency exposure situations. The *Radiation Protection Regulations* [11] establish dose limits for persons involved in planned exposure situations. In the event of a nuclear emergency, there are dose limits that apply to persons involved in the control of the nuclear emergency under the authority of the licensee. However, the regulations do not specify dose limits for members of the public for emergency or existing exposure situations. In order to manage radiation exposure to members of the public and to responders during emergency and existing exposure situations, this guidance document recommends the application of the ICRP reference levels. These reference levels are provided and explained in section 4.1 and are consistent with recommendations in Health Canada's document *Generic Criteria and Operational Intervention Levels for Nuclear Emergency Planning and Response* [12].

The following tools are used for managing exposure to radiation for the three exposure situations:

- **Planned exposure situations**: Regulatory dose limits in the *Radiation Protection Regulations* (applied to all persons)
- **Emergency exposure situations**: Regulatory dose limits in the *Radiation Protection Regulations* and dose limits specified for workers in Provincial response plans (applied to persons involved in the control of the emergency) and ICRP reference levels (to all other persons)
- **Existing exposure situations**: ICRP reference levels (applied to all persons)

The key elements to ensuring recovery following a nuclear emergency are outlined in figure 1, which incorporates the concepts from recently updated international guidance on exposure situations [1, 4] and arrangements for the termination of a nuclear or radiological emergency [6], along with regulatory dose limits [11] and the dose reference levels recommended by the ICRP for the three exposure situations [1].

Figure 1: Requirements of Canada's recovery framework in the context of international nuclear emergency management guidelines



Notes:

- The green portion illustrates the progression from a planned exposure to an emergency exposure situation, and ultimately to an existing exposure situation. The exposure situations apply to members of the public in relation to the regulated source or activity that is involved in the nuclear emergency.
- The orange portion depicts the progression of emergency phases, from preparedness through to response and transition and finally to a recovery phase – in relation to the exposure situations shown in the green band. Importantly, the nuclear emergency would not be terminated until the elements required for recovery have been arranged for. This concept is expressed in the IAEA document GSG-11, *Arrangements for the Termination of a Nuclear or Radiological Emergency* [6], which describes how these arrangements are to be put into place during the transition phase.
- The blue portion shows the recovery framework, which indicates when recovery elements should be considered in relation to the nuclear emergency phases and the exposure situations. As shown in the figure, recovery should be considered in all phases of nuclear emergency planning and management.

2.3 Nuclear emergency response roles and responsibilities in Canada

Emergency response in Canada is a shared responsibility. The respective roles of the various levels of government in nuclear emergency preparedness and response are derived from legislated responsibilities. CNSC licensees are responsible for developing and implementing programs aimed at preventing, mitigating, and preparing for potential nuclear emergencies related to their operations.

The federal government regulates the peaceful use of nuclear energy in Canada, manages nuclear liability, and supports the responses of provinces to nuclear emergencies within their boundaries. The Government of Canada may provide assistance to provincial and territorial governments at their request and implement protective actions in areas of federal jurisdiction. In addition, the federal government is responsible for liaisons with the international community and diplomatic missions in Canada, assisting Canadians abroad, and coordinating Canada's response to nuclear emergencies that occur in foreign countries, but that have an impact on Canada.

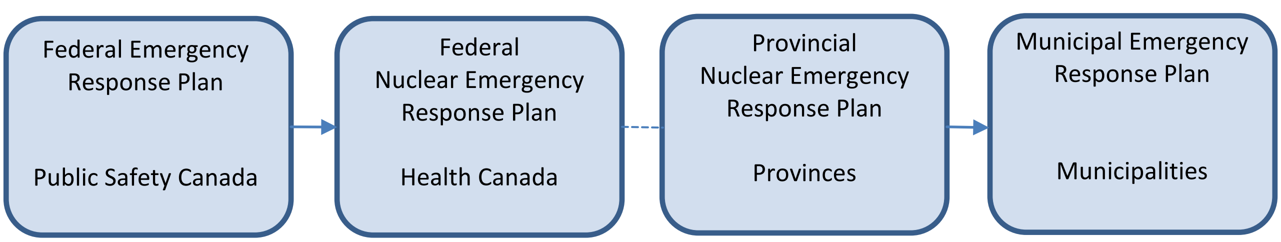
Public Safety Canada is the lead federal agency for emergency management in Canada. Through the *Emergency Management Act* [13], Public Safety Canada administers Canada's *Federal Emergency Response Plan* (FERP) [14], which outlines the processes and mechanisms to facilitate a whole of Government response to any type of emergency, including a nuclear emergency.

Within the structure of the FERP, the *Federal Nuclear Emergency Plan* (FNEP) [15] and its annexes describe Canada's national framework for planning for and responding to a nuclear emergency that impacts Canadians. The FNEP includes an annex outlining the responsibilities of the various federal departments, as well as province-specific annexes that describe the activities required to support each province in its response to a nuclear emergency. Health Canada is responsible for coordinating the FNEP response.

The FERP and FNEP recognize that provinces and territories bear the primary responsibility for protecting public health and safety, property and the environment within their borders. Provincial emergency management authorities are responsible for developing detailed plans for nuclear emergencies with impacts outside the boundaries of CNSC-licensed nuclear facilities, and for leading the implementation of these plans. Municipalities that could be directly impacted by a nuclear emergency are also responsible for planning and implementing measures they may need to undertake.

Figure 2 illustrates federal, provincial and municipal responsibilities for nuclear emergency planning in Canada.

Figure 2. Responsibilities under the Canadian nuclear emergency management framework



The CNSC plays a dual role in nuclear emergency management. In accordance with its mandate established by the NSCA [5], it maintains regulatory oversight of licensees' nuclear emergency activities. As a federal agency, it also participates in Canada's whole-of-government response to a nuclear emergency, in accordance with the requirements of the FERP [14] and the FNEP [15].

The CNSC does not regulate offsite response or recovery after a nuclear emergency. In this context, this regulatory document provides guidance for authorities with jurisdiction over recovery planning. This guidance may be used along with other federal guidelines, such as the

Generic Criteria and Operational Intervention Levels for Nuclear Emergency Planning and Response [12], which is intended to assist federal and provincial emergency response authorities in choosing appropriate protective actions to protect public health.

3. Current Status of Recovery Planning in Canada

During recovery, the degree of involvement of the various levels of governmental decision makers will depend on the significance of the consequences of the nuclear emergency and the details of the recovery process itself. However, as with nuclear emergency preparedness and response, recovery is primarily the responsibility of the affected province or territory. Due to the need for extensive involvement of the affected individuals and communities in the recovery process, the affected municipalities will also have significant roles to play in the decision-making process. Existing recovery plans of all levels of government are summarized in sections 3.1 to 3.3 (note that the sequence in which these entities are listed is not meant to reflect order of authority or level of involvement). Section 3.4 outlines the *Nuclear Liability and Compensation Act* [16], which establishes a compensation and liability regime in the case of a nuclear accident resulting in civil injury and damages.

3.1 Federal plans for recovery

The details of the management and coordination of the recovery phase of a nuclear emergency are outside the scope of the *Federal Emergency Response Plan* (FERP) [14] and the *Federal Nuclear Emergency Response Plan* (FNEP) [15]. While both the FERP and FNEP indicate that responsibility for recovery is largely within provincial or territorial jurisdiction, these two plans provide some insight into the expected structure of the federal component of recovery operations.

The FERP and FNEP mention the need for a federal management structure for the recovery phase that parallels that of the emergency phase. Whereas the emergency phase has well-documented roles and responsibilities, the specifics of the recovery phase need to be elaborated upon and require further consideration and documentation. This document provides guidance on developing such a plan.

3.1.1 Recovery activities described in the *Federal Emergency Response Plan*

Under the FERP, the Federal Coordination Centre is designated as the regional representative of the federal government, acting as the hub of federal and federal–provincial/territorial coordination during a response. The purpose of the Federal Coordination Centre is to plan the overall strategy of the national response and recovery.

Annex A of the FERP outlines emergency support functions (ESFs), which are assigned to various federal departments and represent specific areas of federal assistance during an emergency. Depending on their respective mandates, the federal institutions that are assigned ESFs are designated as either primary or supporting departments. Along with other duties detailed within each ESF, primary departments are responsible for planning for short and long-term emergency response and recovery operations.

When requested by the designated primary department, supporting departments are responsible for executing their discrete responsibilities. These responsibilities could include participating in planning for short and long-term emergency response and recovery operations, and developing supporting operational plans, standard operating procedures, checklists or other job aids in concert with existing first-responder standards.

3.1.2 Recovery activities described in the *Federal Nuclear Emergency Plan*

The FNEP is intended to deal with the offsite response to a nuclear emergency. Once the situation has stabilized and immediate and other actions for the protection of public health and safety have been completed, emergency management of the nuclear or radiological hazard shifts from the response phase to recovery, at which time the federal partners operating under the FNEP may begin returning to routine operations. These federal partners will continue to play a reduced role in recovery operations.

The FNEP establishes a de-escalation process (return to routine reporting), under which:

- a selected Committee of Deputy Ministers or Committee of Assistant Deputy Ministers, in consultation with the Privy Council Office, will approve the transition from emergency to recovery, and this selected committee will also designate a Primary Federal Minister for Recovery and a National Recovery Coordinator
- the Federal Coordinating Officer (responsible for the overall coordination of the federal emergency response) and the FNEP senior officials from the emergency will transfer the management of the response to the National Recovery Coordinator
- the National Recovery Coordinator will be responsible for assembling, coordinating and identifying federal recovery priorities in a national recovery support organization (NRSO) and to implement the federal recovery activities
- the NRSO will also be involved with the provincially established recovery management organization(s)

Departments and agencies with nuclear emergency functions that may also be relevant to recovery could be called on by primary departments to support recovery.

3.2 Provincial plans for recovery

Ontario and New Brunswick have operating nuclear power plants, and several ports in British Columbia and Nova Scotia are capable of hosting foreign nuclear-powered or nuclear-capable vessels. These provinces therefore have nuclear emergency plans to protect the public in the event of a nuclear emergency.

Some existing provincial nuclear emergency response plans include guidance on recovery actions, particularly with regard to triggering and ensuring the transition from emergency response to recovery. The Ontario Ministry of Community Safety and Correctional Services and the British Columbia Ministry of Health have plans that include descriptions of the mechanisms and responsibilities for the transition to recovery (see sections 3.2.1 and 3.2.2).

3.2.1 Existing provincial plan example: Ontario

Ontario's *Provincial Nuclear Emergency Response Plan* (PNERP) [17] states that when appropriate, the Provincial Emergency Operations Centre (PEOC) will declare the end of the response phase, and ensure a smooth transition to the recovery phase. At a suitable stage, the PEOC will consult with the major organizations involved in the emergency response regarding their transition to the recovery phase, and what lead time they would need to make a smooth transition. Based on these consultations, the PEOC will set a time for ending the response phase and inform all stakeholders involved in advance.

In Ontario, responsibilities are articulated in the PNERP by the Office of the Fire Marshal and Emergency Management. Specific details about the roles of Order in Council ministries are articulated in Annex I of the PNERP. Upon transition to recovery, Ontario's Ministry of Health and Long-Term Care will plan and lead the recovery of the health sector as specified in section 5.13 of the *Radiation Health Response Plan* [18].

3.2.2 Existing provincial plan example: British Columbia

The *British Columbia Nuclear Emergency Plan* [19] states that the de-escalation and transition to recovery are coordinated by the Ministry of Health and will include:

- establishing a recovery management plan with reference levels on residual doses from long-term contamination and strategies for restoration of normal socio-economic activities
- monitoring contaminated areas and assessing potential doses to public and workers
- assessing medium- and long-term health hazards
- environmental decontamination and radioactive waste disposal operations
- maintaining dose registries for emergency workers

The decision regarding the transfer of responsibilities from emergency response to recovery operations is made by provincial ministers and the members of the Deputy Ministers Council.

3.3 Municipal roles and responsibilities for recovery

Municipalities have a significant role to play in the decision-making process due to their direct involvement with affected individuals and communities. Municipal emergency management plans should incorporate planning for recovery. The guidance in this document may help establish municipal plans for recovery.

3.4 Nuclear Liability and Compensation Act regime

The *Nuclear Liability and Compensation Act* (NLCA) [16] came into force on January 1, 2017, superseding the previous *Nuclear Liability Act*. The NLCA establishes a compensation and liability regime in the unlikely event of a nuclear incident resulting in civil injury and damages.

Under the NLCA, operators of nuclear power plants are responsible to pay up to one billion dollars for civil damages resulting from anincident, and must have insurance from an insurer approved by the Minister of Natural Resources Canada.

Damages that can be compensated under the law include bodily injury, property damage, psychological trauma of a person who suffered bodily injury, environmental damage, economic loss as a result of bodily injury or damage to property, lost wages, and costs related to preventive measures (such as evacuation costs). The time period under the NLCA for submitting claims for the compensation of bodily injury is 30 years, while the time period for submitting claims for the compensation of other forms of damage is 10 years.

4. Transition to Recovery

Before making a transition from nuclear emergency response to recovery, the situation should be examined to consider, understand and control the potential progression of the nuclear emergency or any future releases. A transition cannot take place until, at a minimum, the situation at the source has stabilized and there is no longer a need to take additional urgent protective actions. As the situation moves from response to recovery, the decision-making process may become more complex. Roles and responsibilities will need to be shifted, and it is likely that additional organizations will need to be involved. As illustrated in figure 1 (in section 2.2), the nuclear emergency preparedness phase should address the following recovery elements:

- Establishment of a recovery management organization(s)
- Pre-identification of goals of the recovery, such that action plans can be implemented expediently
- Identification of roles and responsibilities for the recovery phase, to the extent practicable
- A mechanism for a formal transfer of responsibilities that will take place during the transition between the emergency phase and the recovery phase

The transition from the emergency response phase (i.e., an emergency exposure situation) to the recovery phase (i.e., an existing exposure situation) is characterized normally by a change in management and strategy. During the response phase, both management and strategy are primarily driven by urgency, with potentially high levels of exposure and central decisions. During the recovery phase, strategies are more decentralized, involve less urgency, and focus on improving living conditions and reducing exposures. In the case of severe accidents affecting large geographical areas, the transition from response to recovery may occur at different times for the contaminated areas [4].

As a nuclear emergency transitions from response to recovery, nuclear emergency management organization(s) that were active during the emergency should be gradually or partially relieved of their duties so that they can return to a state of readiness for any future emergencies. This approach will allow the recovery management organization(s) to take over coordination of the activities to facilitate recovery. As such, at the preparedness stage, arrangements should be made among the relevant response organizations to identify the composition of the recovery management organization(s) to enable this responsibility transfer.

4.1 Reference levels

The ICRP defines a reference level as “the level of residual dose or risk above which it is generally judged to be inappropriate to allow exposures to occur” and below which protective actions should be planned and optimized [1]. Reference levels are presented as a range or bands of exposures, to provide flexibility for decision makers. They are expressed in millisieverts (mSv) and represent doses received after the implementation of protective actions. Table 1 presents the ICRP’s recommended reference levels.

Table 1. ICRP reference levels

Reference level band (acute or per year)	Type of exposure situation
20–100 mSv	Emergency exposure situations in which events with uncertain consequences require urgent protective actions, such as sheltering and evacuation to minimize the impacts of possible radiation exposures
1–20 mSv	Existing exposure situations in which radioactivity is already present in the

	environment when actions are taken to reduce radiation exposures; **if doses are optimized below the reference level selected from within this band, it is safe to live in the contaminated area**

Doses within these reference levels must be optimized. Optimization in recovery is a forward-looking, iterative process aimed at reducing future exposures; it should be seen as a "frame of mind", in which people always question if the best has been done in the prevailing circumstances. Because the recovery process is focused on the community, all key decisions must be centred on stakeholder involvement and consider technical and socio-economic factors.

4.2 Return to a new normal

It is recognized that following a nuclear emergency, it may not be possible for the affected areas to return to their original condition, and that a "new normal" will need to be established. This new normal may involve living in an existing exposure situation, where protective actions may have been implemented to reduce radiation exposures.

The decision of whether to allow individuals to live in the affected area will depend, in part, on if the desired reference level can be achieved and on the ability to implement a protection strategy if needed. A protection strategy will further optimize the situation to maximize the margin of good over harm.

It is equally important to account for psychosocial aspects when making decisions about returning a population to a new normal. The expected dose under the reference level should not be considered in isolation; the appropriate timing of the return of the population should also be considered. For example, the importance of psychosocial aspects was demonstrated through the results of the Fukushima Health Management Survey[2] where it was determined that the some evacuees did not wish to return to their homes for reasons that included poor access to medical services, the perception that the return of commercial facilities was unlikely, and the severe damage to old homes – as opposed to concern about radiological risks. The decision to return should therefore rest with the responsible recovery management organization(s) in consultation with affected communities.

The new normal may be achieved by:

- establishing new routines, which may include self-help actions and that allow for day-to-day life to resume such that impacts are minimized
- living with some level of exposure that is higher than pre-emergency conditions, but that is still protective of human health.
- establishing communication and engagement with individuals and communities
- periodic re-evaluation of the reference level throughout recovery as the exposure situation evolves

[2]The Fukushima Health Management Survey consisted of a basic survey and four detailed surveys: Thyroid Ultrasound Examination, Comprehensive Health Check, Mental Health and Lifestyle Survey, and Pregnancy and Birth Survey. The basic survey targeted a population of about 2.05 million people who had potentially been impacted by the events.

It may sometimes be decided to abandon contaminated areas altogether and to resettle impacted individuals and communities to areas that were not directly affected by the nuclear emergency in a radiological sense. In this case, many of the activities described in the remainder of section 4.2 would not be applicable. It is important to note that there is a high likelihood of psychological and social impacts associated with the nuclear emergency and resettlement, even in the absence of a radiological impact. Decisions to resettle should only be made following extensive consultation and engagement with stakeholders.

4.2.1 Psychosocial considerations

Psychosocial effects involve psychological and social impacts to persons affected by an emergency; these can include fear, anxiety, feelings of loss of control, depression, and a sense of hopelessness and distress [20]. These effects result from social conditions and can impact mental health leading to behavioral, emotional, and physiological consequences. Psychosocial effects can be observed at the community level, on an individual basis, or both.

Following large nuclear accidents such as Chernobyl and Fukushima, the major health impacts observed were psychosocial in nature [21, 22]. Given the lessons learned, it is imperative to consider psychosocial issues when making decisions about recovery phase protective actions.

The Chernobyl accident was not announced in a timely manner by the government of the former Ukrainian Republic of the Soviet Union, and the subsequent fear and anxiety stemming from the fallout was exacerbated by a loss of trust. The psychological consequences observed following Chernobyl are similar to those observed following atomic bombings and other nuclear accidents. However, findings related to Chernobyl are difficult to interpret and may be unique versus those of any other nuclear disaster, given that dispersion information was unavailable for years following the accident [21].

The combination of the March 2011 earthquake, tsunami and subsequent nuclear accident at TEPCO's Fukushima Daiichi nuclear power plant led to psychological effects in the affected population in Fukushima Prefecture. These effects, which included depression and post-traumatic stress symptoms [23, 24], are common to most disasters and cannot solely be attributed to radiation exposure [25]. The significant impact of the loss of lives and missing loved ones because of the earthquake and tsunami – in conjunction with other conditions such as evacuation, relocation, material and financial loss, along with fear and uncertainty related to radiation exposure and its potential consequences – all contributed to increased mental distress [26]. Of note, there was a documented increase in mortality among the institutionalized elderly in the first year after the evacuation. This has been widely discussed as an example of how decisions based too narrowly on radiological concerns can result in harm due to non-radiological risks [27]. The Japanese government instituted the Fukushima Health Management Survey to monitor the long-term health of the residents of the region, and to determine if long-term low dose radiation exposure from the Fukushima disaster had an impact on health outcomes. The studies performed under this survey have underlined the need for more continuous observational studies, conducted over the long term, to understand the lasting mental health implications of the Fukushima nuclear accident.

The World Health Organization [26] indicated that psychosocial effects following nuclear or radiological accidents may be exacerbated for several reasons, namely:

- a fear of the unknown, since radiation cannot be seen or felt
- use of complex language to explain the magnitude of exposures and their potential effects

- the high degree of uncertainty associated with some accidents
- psychosocial effects being experienced in a geographical area beyond the region actually affected by radiological dispersion
- a combination of some or all of the above factors, which may result in residents of affected areas feeling a sense of social stigma

4.2.2 Mitigation of psychosocial effects

This section proposes best practices for the design and implementation of recovery plans in the event of a nuclear emergency. Suggested best practices are informed with the following key elements for mitigating psychosocial effects:

- **Open communication lines:** The severity and duration of psychosocial effects is likely to be related how the incident is perceived by the community. The provision, timing, and quality of information on the amount of radiation released as a consequence of the nuclear emergency, along with the subsequent emergency and recovery phase protective actions taken by the licensee and regulatory authorities, should alleviate the community's uncertainty and concern. Additionally, open lines of communication within family units affected by the nuclear emergency will minimize conflict and uncertainty in affected communities [28].
- **Access to educational resources:** An extensive thyroid screening survey was initiated in Fukushima to assess the potential for increased thyroid cancer prevalence among children exposed to radioactive iodine. The screening survey was conducted with little education on the purpose of the survey and in some cases, without the participants' consent. This led to alarmist reactions among the participants who eventually had a limited understanding of the meaning of results. Much of the distress experienced in relation to the thyroid examination survey may have been minimized if an education and awareness campaign had been instituted. A study of the psychological issues related to the thyroid examinations in Fukushima and Chernobyl highlighted the impact of how decisions made about community health, communication about health issues and surveillance programs can contribute to a population's concerns about health risks [29]. This information should be taken into account when decisions on emergency and recovery phase protective actions, including mental health care planning, are made.
- **Training:** Experience gained, or lessons learned, from nuclear accidents suggests that public support centres for the affected populations should be established. Local doctors, nurses, pharmacists, psychologists, experts from public universities and associations, and others in positions of trust and who have the respect of the community should hold integral positions at these public support centres. Information that puts health hazards in perspective, along with proper training on effective approaches to risk communication, should be given to support centre workers and volunteers to enable them to appropriate public advice [6].
- **Empowerment of the public:** Decisions on matters such as issuing, lifting or changing the status of protective actions should be community-driven [30, 31, 32, 33, 34] – and most importantly, the outcomes of these decisions must do more good than harm [35]. The public should also be given tools such as dose and contamination monitors, along with training to encourage self-help actions that promote community empowerment (further discussed in section 5.2.1).
- **Minimization of time spent in temporary evacuation:** Experience has shown that psychosocial impacts are reduced when community residents are allowed to return to their homes as soon as possible after a temporary evacuation. Given this, a balanced decision must be made when determining whether to allow residents to return home; projected doses cannot be considered in isolation of potential psychosocial impacts.

5. Best Practices for Key Recovery Elements

This section describes key recovery elements that are informed by international benchmarks, guidance, and lessons learned from experience with affected populations following nuclear (e.g., Chernobyl and Fukushima) and radiological incidents (e.g., Goiânia).

5.1 Implementation of protection strategies for recovery

The overall objective of implementing a protection strategy for recovery is to ensure that radiological exposures meet the reference levels and selected criteria within the reference bands, while considering the psychological impacts of any protective actions.

Many factors can impact the protection strategy, including timing, resources, waste management options, as well as social and ethical aspects. Stakeholder input should be sought during the development of the protection strategy.

A number of urgent and early protective actions may have been implemented during the emergency response with the goal of reducing potentially harmful radiation exposure. Such actions could include ingestion of potassium iodide, sheltering, evacuation and temporary relocation. Protective actions implemented to control or reduce the ongoing effects of an emergency situation will need to be assessed and transitioned into the recovery period and beyond. As time progresses, any actions taken during the nuclear emergency should be continuously examined to decide if changes are warranted. During the emergency response phase, there will likely be an examination of protective actions taken, but such an examination also requires consideration during the recovery phase, depending on time frames involved. In some cases, protective actions such as access restrictions will likely need to be lifted or modified during the recovery period. Other protective actions, such as restrictions on locally sourced food, milk and drinking water, or the reinforcement of protective works or containment structures, may be modified or adjusted. Various government nuclear emergency response plans provide guidance on lifting the protective actions implemented during the emergency phase [**Error! Reference source not found.**, 17, 36].

Recovery protective actions may need to be taken to maintain or optimize doses below the desired reference level. Even if doses are below the reference level, consideration should be given to continuing these recovery protective actions if doses can be further lowered. The optimization principle [37] must guide this decision, which should be a balanced consideration of potential dose savings, psychosocial impacts, and the economic costs of continuing to implement the actions.

In general, there are two types of actions that could be implemented during the recovery phase:

- **Recovery phase protective actions:** These are actions implemented or overseen by the recovery management organization(s), which generally cannot be implemented by individuals, or actions that are taken by the population as a whole to reduce radiation exposure (further discussed in section 5.1.1).
- **Self-help actions implemented by individuals**: These are voluntary actions undertaken by people to manage their own radiological situation, particularly external and internal radiation exposure (further discussed in section 5.1.2).

Responsibilities implementing the protection strategy for recovery should be established or considered at the preparedness stage. Such decisions should involve relevant response organizations as well as potentially impacted individuals and communities. The detailed plans will need to be based on the specific conditions of the nuclear emergency and therefore should be established only in the event that a nuclear emergency occurs, either prior to or during recovery.

The following is a summary of key tasks that support the recovery strategy for public protection. These tasks include:

- a review of protective actions that have been put in place during the emergency response, to determine if these actions need to be adjusted or terminated
- a review of the doses received by members of the public during the emergency response, and identification of any required follow-up actions
- an assessment of the current exposure situation, through environmental monitoring and exposure pathways modelling (where appropriate), and a prediction of the future development of the exposure situation, based on the results of this assessment
- continuous reassessment of the exposure situation throughout the recovery phase
- identification and implementation of appropriate protective actions, based on the results of the assessment of the exposure situation and a comparison to the selected reference level
- reassessment of the appropriateness and effectiveness of the protective actions, alongside the reassessment of the exposure, and an implementation of activities aimed at physically reducing radioactivity in the environment (e.g., decontamination, characterization and quantification of radioactive waste, and waste management)
- management of doses received by recovery workers who were involved in implementing the recovery phase protective actions and clean-up activities

5.1.1 Recovery phase protective actions implemented by the recovery management organization(s)

Recovery management organizations are primarily responsible for characterizing the exposures of the affected population. This includes identifying the main exposure pathways, estimating doses, and identifying recovery actions that could be applied to the affected population to optimize doses.

Typical recovery actions that could be implemented by recovery management organization(s) [38] include the following:

- Deciding if people can live in contaminated areas
- Cleaning up buildings, parks, and other public areas
- Remediating soil and vegetation
- Issuing controls on food consumption and providing clean food
- Introducing education and outreach programs, including programs for children
- Provision of instruction and equipment to facilitate self-help actions (e.g., for dose measurements)

Recovery phase protective actions implemented by the recovery management organization(s) may be institutional or engineered in nature [7]:

- An example of an **institutional action** is the placement of restrictions on ingesting locally produced food, to avoid ingestion of radionuclides.
- An example of an **engineered action** is the addition of a non-removable layer of pavement or cement, on streets or sidewalks, over gamma-emitting radionuclides

Recovery management organization(s) should identify and delineate the borders of the contaminated area early on, and reassess and adjust these borders throughout the recovery phase. This delineation will enable the implementation of recovery phase protective actions such as restrictions on food, and will also assist when communicating with the local population [8]. The delineation of the contaminated area needs to strike a careful balance between an excessive number of constraints on the area (potentially resulting in unnecessary remediation and inappropriate labelling of the area as unsafe) and inadequate protection or failure to address stakeholder concerns [9].

5.1.2 Self-help actions

Self-help actions are actions undertaken by individuals to manage their own radiological situation, notably their external and internal exposure. These actions involve individuals monitoring their radiological situation, and voluntarily adapting their way of life accordingly, as they see fit.

Experience has shown that direct involvement of individuals, communities and local professionals in the management of a recovery situation improves the process by empowering those impacted. When recovery management organizations facilitate the processes by which inhabitants define and apply their own protection strategies, not only are exposures reduced but adverse psychosocial impacts are also reduced [7, 37]. The ICRP recently recognized the need to empower communities and individuals to make their own decisions on the application of radiation protection and monitoring during recovery. An ICRP initiative called the Fukushima Dialogues put this concept into practice through a series of exchanges with citizens of affected areas, local governments and international experts that allowed all parties to share their perspectives. The structure of these meetings, the topics discussed and the outcomes were documented by the ICRP and provide a model for encouraging community empowerment during any future recovery efforts [38].

Authorities need to provide effective education and information for self-help actions to be successfully implemented. In most cases, individuals will need to be trained on what to do, and the necessary infrastructure to assist them will need to be put in place (e.g., guidance materials and availability of equipment). The population should be given appropriate information to allow them to make informed decisions. Authorities should also facilitate opportunities for affected individuals to share lessons learned among themselves, as well as to enable communication between the affected population and relevant experts (e.g., health, radiation protection, agriculture authorities). Public information centres are an ideal location for providing training and information on self-help actions, facilitating a forum for discussion, and serving as a location for monitoring (e.g., a place to make monitoring equipment available for testing foods).

A challenge of self-help actions to balance the burden placed on the individuals (i.e., constant monitoring of foods eaten and places visited) against the benefits of empowerment to improve people’s own exposure situations. As with all decisions in the recovery phase, a balanced approach – one that considers the optimization principle, economic consequences and psychosocial considerations – should be taken and involve stakeholder input.

Examples of self-help protective actions include:

- monitoring ambient dose rates in living areas and work locations, to identify areas of higher dose rates, and adapting occupancy accordingly, where practical
- measuring the presence of contamination in foods and modifying dietary habits
- monitoring individual doses using personal dosimetry to provide additional information about opportunities to reduce exposures based on people's daily habits

5.2 Environmental and food chain monitoring

The radiological situation will evolve during the recovery phase because of processes such as radiological decay, physical and chemical processes affecting the distribution of radionuclides in the environment, human activities that concentrate or dilute contamination in the environment, and changes to protective actions [37]. An environmental monitoring program that is adequate for the prevailing circumstances and flexible enough to accommodate changes to conditions should be established. Although environmental monitoring systems established for the emergency response phase are also likely to be relied upon for the recovery phase, there may be a need to enhance or modify current monitoring requirements to, for example, include monitoring of public infrastructure such as schools.

An environmental monitoring program in this context refers to the measurements of external dose rates in the environment and radionuclide activity concentrations in different media (e.g., air, water, soil, vegetation, and food) [39]. Any data produced as a result of this monitoring should be made available with enough explanatory context to be easily understood by the general public [8].

Various environmental monitoring programs are already in place across Canada and around nuclear facilities; for example:

- Health Canada has had a national environmental radioactivity monitoring program since 1959 and operates three distinct radiological networks composed of more than 100 detection and monitoring stations across the country. These are located in the vicinity of nuclear power plants, in all major population centres, and in the vicinity of ports visited by foreign nuclear-powered vessels.

- All Canadian nuclear power plants have environmental monitoring programs in place for their surrounding areas, in compliance with the conditions of the operating licences.

- Through independent sampling and analysis, the CNSC's Independent Environmental Monitoring Program complements existing and ongoing activities conducted by the licensees to verify that public health and the environment around nuclear facilities are safe.

- The Department of National Defence has a system to monitor areas around ports visited by foreign nuclear-powered and nuclear capable vessels.

- The Ontario Reactor Surveillance Program operates and maintains a radiological surveillance network to assess radiological concentrations around designated major nuclear facilities and selected natural background locations in the province. This program includes continuous surveillance of air and drinking water supply plants near nuclear facilities, and is supplemented by monitoring campaigns of precipitation, milk, recreational surface waters and foods.

- The Ontario Drinking Water Surveillance Program provides water quality information for selected municipal drinking water supply plants for scientific and research purposes through the monitoring of analytes including organic, inorganic and radiological parameters (i.e., tritium, gross alpha radiation and gross beta radiation).

The following are some specific objectives of monitoring the environment during recovery:

- To identify areas in which detailed radiation monitoring is needed
- To identify areas in which remedial actions are justified in radiological terms
- To provide information for estimating actual or prospective doses to members of the public
- To detect changes and evaluate long-term trends in environmental radiation levels as a result of the emergency and recovery efforts
- To disseminate information to the public

The environmental monitoring program should be informed by the radionuclides involved, the physical and chemical composition of the radioactive contamination, the medium containing the radionuclides, and practices relating to land and water use. The locations for measurement and sampling should be selected on a site-specific basis in such a way that the highest radiation doses can be assessed [39].

As part of the development of an environmental monitoring program, the available resources for monitoring should be identified, including the following:

- Organizations, expert bodies, local and national laboratories, private institutions, universities and research centres responsible for implementing the monitoring strategy
- Human resources and technical capabilities (including monitoring equipment and dose assessment tools)
- Organizations responsible for implementing the monitoring strategy
- Mechanisms for ensuring the comparability and consistency of measurements among organizations, as well as mechanisms to interpret these measurements, including training, quality management and inter-comparison exercises
- An organization designated as responsible for the validation, recording and retention of monitoring results and assessments
- A mechanism for incorporating monitoring results and assessments into decision-making processes

In the transition phase, the monitoring strategy may be supported by decision-aiding tools such as models. Models can help adjust monitoring priorities to facilitate the effective and efficient use of available (but usually limited) resources and capabilities. The objective of using such tools and their limitations should be clearly communicated to all concerned parties and documented in the monitoring strategy. Decisions based on models alone should be considered interim until measurements can be collected from potentially affected areas [6].

In the case of emergencies impacting the food supply, it is particularly important to include food in the monitoring program. The monitoring program should be robust enough to ensure compliance with any restrictions put in place, including the existing criteria for restricting contaminated food in the immediate aftermath of a nuclear emergency. For reference, see the operational intervention levels established in the *Generic Criteria and Operational Intervention Levels for Nuclear Emergency Planning and Response* [12] and in the emergency response plans for New Brunswick and Ontario [17, 36]. Additional criteria should be established to manage long-term contamination of the food supply from long-lived radionuclides [9] and for the consumption of country foods that are not part of the managed commercial food supply chains.

Under the *Food and Drugs Act* [40], the Government of Canada has a responsibility for the safety of all domestic and imported food offered for sale within Canada. Health Canada has a mandate to establish standards for the safety and nutritional quality of all food sold in Canada. Once food products have left the affected area, or if food is imported from an affected area abroad, the Canadian Food Inspection Agency is responsible for enforcing the food safety standards and guidelines established by Health Canada; enforcement actions may include taking regulatory actions such as product recalls. The federal government can also provide support to the provinces, territories and municipalities in their food safety-related actions.

The criteria established by the Codex Alimentarius Commission may also need to be considered when monitoring food and food products for suitability for international trade [41].

5.3 Exposure pathways and dose assessments

Exposure pathways are the routes by which radiation or radioactive materials can reach humans and cause radiation exposure. In planning for recovery from a nuclear emergency, exposure pathways are used to assess the potential for the population in the vicinity to be exposed to radiation.

Exposure pathways must be assessed in the conduct of dose assessments that may influence the recovery process. Dose assessments conducted in preparation for transitioning to recovery will inform the recovery phase protective actions imposed for the transition. However, the dose assessments should be updated and refined over time, as the dose pathways are influenced by recovery activities. This iterative dose assessment process will drive the optimization of the recovery strategy.

The following are examples of factors that may impact the dose assessment:

- The imposition or removal of restrictions on food
- Radioactive decay
- Completion of decontamination/remediation activities
- Radioisotope filtration through environmental mechanisms (leaching, migrations, etc.)

The recovery phase of a nuclear emergency will likely have different dose-related considerations than the response phase. For example, significant releases to the air from an incident at a nuclear power plant should no longer occur in the recovery phase; therefore, exposure to radionuclides in a plume released to the atmosphere (i.e., cloudshine) may no longer be a dominant exposure pathway. The remaining exposure pathways that may need to be considered in the recovery phase include, but are not limited to the following:

- External exposure from radionuclides deposited on the ground (i.e., groundshine) and surfaces (i.e., rooftops)
- Internal exposure from inhalation of re-suspended radionuclides
- Internal exposure from ingestion of contaminated food and drinking water

With respect to the consideration of exposure pathways, the pattern of deposition of radioactivity is likely to be complex and the resulting exposure to individuals could vary greatly within a given area. Exposure pathways will depend on circumstances such as the types of land use and the habits of the directly affected people and communities. As such, additional pathways will need to be considered where appropriate. For example, ingestion of soil by children might need to be considered with regard to land use restrictions for parkland.

When moving towards recovery, preliminary dose assessments should be performed focusing on the doses that could be received in the future (i.e., in the existing exposure situation). It is likely there will be a broad range of exposures. Therefore, as information becomes available, the dose assessment should become more specific regarding individual doses.

Results from dose assessments should be used to inform the initial choice of the reference level value, as well as to assess options for implementing recovery strategies and to evaluate these strategies. The process of dose assessment and recovery strategy evaluation should be iterative.

Dosimetric modelling and individual measurement may be required for a long time following a nuclear or radiological emergency; however, participation in survey and monitoring programs should be voluntary so as to recognize the autonomy and dignity of the affected populations [42]. Individuals may prefer to avoid dosimetric monitoring programs because of perceived stigma associated with monitoring programs and lack of self-determination.

5.3.1 Internal dose assessment

Internal dose assessment involves the estimation or measurement of radionuclides that enter the body, and calculation of the resulting radiation dose based on the contributions from the specific radionuclides. In order to estimate the intake of radionuclides from the environmental monitoring results, transfer parameters are used to model how the contaminants enter the body. In Canada, CSA standards N288.1 [43] and N288.2 [44] provide transfer parameters and intake rates useful when completing a dose assessment. Internal doses during the recovery phase due to the ingestion of contaminated food and drinking water should be determined on the basis of environmental monitoring data and consumption rates.

Because of the variability in exposures to different individuals in the recovery phase, doses should be determined on an individual basis or by considering defined portions of the population. For long-lived radionuclides (e.g., tritium and caesium), adults consuming local food will usually be the most exposed population group.

For radionuclides where the dose assessment depends strongly on age because of their specific metabolic properties (e.g., strontium, radium and polonium), infants or children usually form the most exposed population group [39]. The dose assessment should consider realistic habits, the known pattern and extent of deposition of radionuclides in the environment, and the food consumed by the affected population. For instance, the population could be divided into groups based on geographic location or lifestyle habits to assist in tailoring the dose assessments. In some cases, direct individual dosimetry may be warranted or desired, and can be used for the dose assessment.

In regions where the inhabitants normally consume substantial amounts of locally sourced food products (e.g., game, freshwater fish, forest mushrooms and berries), it is important to consider population-specific consumption rates. If environmental monitoring program data for food are unavailable or insufficient, the concentrations of radionuclides in food can be roughly estimated from data on soil deposition or water concentrations by using known coefficients of radionuclide transfer from soil or water to plants and animals. In areas that are significantly contaminated with radionuclides, or in areas with elevated rates of transfer of radionuclides from soil to biota, individual whole-body monitoring may be used to determine the human body burden and to assess doses due to the internal exposure. The results of individual measurements should be used mainly for validation of the models applied for the purposes of internal dose assessment [39].

In Canada, specialized facilities operated by Health Canada and dosimetry services licensed by the CNSC are available to perform internal monitoring using whole-body counting, bioassay and/or thyroid measurements (for exposures to radioiodine) as well as provide advice and assistance (including training) on internal monitoring and internal dose assessments as required.

Special programs of monitoring may be undertaken for the validation of models. The most reliable method of validation of an ingestion model is by comparing its predictions with internal dose assessments made on the basis of data from individual measurements of radionuclide contents in the human body performed by whole-body counting or by analyzing the concentrations of radionuclides in excreta [39].

5.3.2 External dose assessment

The external dose to the population during the recovery phase may be estimated via environmental monitoring data as well as personal dosimetry (the CNSC licenses commercial dosimetry services that can provide external dosimeters). Care should be taken when relying on environmental monitoring data (i.e., ambient air monitoring) to estimate doses to the population. Experience from Fukushima has shown that this method can significantly overestimate the dose to a population, and that dose values should be validated through other means such as personal dosimetry, if practical [45, 46]. Persons working primarily outdoors and those living in one-storey houses constructed of light materials such as wood may receive the highest external exposure. Interviews may be used to refine estimations of typical occupancy times for living, working and rest areas [39]. Dose-rate measurement at various occupied locations, both outdoors and indoors, can be used to assess existing external doses.

5.4 Health monitoring

Following a nuclear emergency, the exposed population should receive some information regarding their levels of exposure to radiation (associated with the emergency exposure situation) and the potential related health risks. The population should also be made aware of psychosocial risk factors associated with the nuclear emergency.

During or prior to recovery, a health monitoring program should be established, along with the logistic, scientific and administrative resources needed for implementation [8] to measure and track any health impacts that may arise among the individuals in the impacted population. The purpose of the health monitoring program is to ensure that appropriate support and medical follow-up are provided to the affected population. Determining the level of health monitoring, support and medical follow-up required must be informed by medical professionals, stakeholder input, and community-specific concerns.

Doses received during recovery (i.e., the existing exposure situation) are expected to be low enough so as not to warrant medical follow-up. The doses referred to above are those that may have been incurred from the emergency exposure situation.

This health monitoring program should focus on:

- following up with individuals who may have received doses that resulted in, or could result in, significant deterministic effects (e.g., skin burns, cataracts) to provide appropriate medical attention
- screening affected populations that might have an increased risk of developing cancer, so as to provide for early detection and diagnosis
- screening affected populations that might have an increased risk for psychosocial impacts, so as to mitigate psychological health and social problems
- developing a registry of individuals identified as requiring longer-term health monitoring (this list should be established prior to, or early in the recovery process)
- offering medical, psychological and psychosocial support for affected individuals and populations

Additionally, there is a risk that screening populations for diseases associated with exposure to radiation, without strong justification for performing the monitoring, can have negative impacts on these populations. An example of this from Fukushima is the widespread use of high-technology ultrasound to screen for thyroid diseases, which may have led to increased diagnoses of anomalies identified as potential thyroid cancers. The impact of undergoing further testing may have resulted in negative psychosocial consequences that outweighed the risk associated with the potential for thyroid cancer (a slowly evolving and highly treatable condition).

The Fukushima experience also highlighted the importance of considering ethics during the design and implementation of health monitoring. Radiation protection ethics are further described in the ICRP's *Draft Ethical Foundations of the System of Radiological Protection* [42]. The core ethical values presented in this publication were extracted from the existing system of radiation protection, and include dignity, beneficence/non-maleficence, justice and prudence. The following examples illustrate how these ethical values can be applied to health monitoring:

- Dignity: Respect the dignity of the individuals by obtaining prior consent
- Beneficence/non-maleficence: Do more good than harm
- Justice: Avoid social stigma
- Prudence: Provide adequate information on the purpose of the monitoring, and the results

5.5 Epidemiological studies

Epidemiological studies of the population may also be conducted and require individualized dose data measurements and specific organ dose data. This information is different from the effective dose data that would be generated by the dose assessment models used for protective purposes described in section 5.3. Furthermore, additional data may need to be collected in order to associate health monitoring data with the affected population for the purpose of the epidemiological studies. This data includes the following:

- Date of birth
- Full name and maiden name
- Sex
- Social insurance number
- Place of birth
- Place of residence
- Other radiation doses (medical diagnostics for example)
- Provincial health insurance number (used to link survey data)
- Other health or lifestyle factors that may influence rates of diseases of interest

As described in a SHAMISEN Consortium report [35] published in 2017, there are two main reasons to conduct epidemiological studies:

- They can be used as a surveillance tool to objectively evaluate the frequency of diseases and how this may change following an accident.
- They can increase knowledge of the health effects of a nuclear accident (not limited to radiation-induced effects).

It is important to identify the objectives of any epidemiological studies at the outset. Considerations must also be given to a study’s limitations; for example, the quality of individual dose estimates and associated uncertainties, confounding or modifying factors, selection bias, etc. Participation in the health monitoring program and the use of personal data in the epidemiological study databases should be voluntary so as to recognize the autonomy and dignity of the affected populations [44]. It has been recognized that individuals may prefer to avoid the health monitoring programs due to perceptions of stigmatization due to association with the monitoring programs and lack of self-determination.

5.6 Management of contamination

Management of the contaminated environment can be carried out in many ways, and will depend on the prevailing conditions after the nuclear emergency. In general, effective management of the contamination may include minimization and isolation of the contaminated source material, decontamination to reduce and remove the potentially hazardous materials, and the management of waste.

It must be recognized that decontamination is only part of the overall contamination management strategy – which could also include other types of activities such as imposing different land or commodity uses and restricting their use and export to other areas. Some insight on how to best manage contamination can be gleaned from guidance on remediation of legacy sites, or sites contaminated by past practices [39].

The objectives of decontamination and management of waste are to [7]:

- allow any evacuated or relocated populations to return to their homes as soon as possible
- allow anyone living in the area to resume living as normally as possible
- to allow economic and social activities to be resumed

The management of contaminated areas, including decontamination and the management of waste, should begin as early as possible in the emergency response phase (or the time leading up to recovery). areas being managed for contamination should be clearly identified.

Although it is preferred to remove contaminated materials and ship them to other locations for long-term management, practical considerations may cause emergency response authorities to decide to isolate the contaminated materials locally and to institute a management program to ensure safety. These institutional controls will need to be justified and supported in the recovery period and beyond.

5.7 Remediation

Remediation involves the physical removal of contamination in the environment to an acceptably low level. A decision-making process to determine the methods used to remediate the environment will be required. Some guidance on how to approach this decision making process can be found in publications such as CSA Group or IAEA guidance on radiation monitoring for the protection of the public [47, 48]. If radioactive material cannot be physically removed from the environment, it may be appropriate to choose alternate options such as fixing it in place or covering it. This will, at a minimum, prevent re-suspension, remove the potential for inhalation exposures, and may help limit external exposures [10]. Before remediation activities begin, responsible authorities will need to determine the level of contamination considered acceptable and the amount of remediation required. The acceptable level of contamination will need to consider a number of social and economic factors and will be site-specific, even within a single region. Once the radiological situation is well understood, the areas to be remediated should be prioritized on the basis of which remediation efforts will be most effective in reducing individual exposures. This is done by considering potential exposure pathways, current or future land use and dietary habits [7, 8].

Remediation goals and criteria should be identified and set in terms of measurable quantities, and will need to be established based on an understanding of the following [7, 10]:

- Reference level chosen
- Predicted effectiveness of potential decontamination actions
- Area impacted (i.e., size, characteristics, location relative to the population)
- Predicted use of the area
- Site-specific background levels of radioactivity (if known)
- Impacts of the contamination and potential decontamination actions on human health and the environment
- Stakeholder input

The method employed to remediate the environment will need to be selected in consideration of many of the same factors, including the following [7, 10]:

- Effectiveness of the action to protect human health and the environment over time
- Performance and costs of different technologies
- Effectiveness of the remediation action as the cleanup progresses
- Time to carry out the remediation
- Impacts on the local and regional economy
- Weather conditions and time of year
- Types of surfaces to be cleaned

Setting remediation goals and undertaking remediation strategies should be an iterative process. Remediation goals should be adjusted as experience is gained [7].

5.8 Waste management

Activities carried out in the recovery phase, particularly remediation of the environment, may result in a large amount of waste from varying sources and of different types. Some of the waste may contain high levels of radioactivity, especially if the waste was produced close to the nuclear emergency's origin. Most of the waste is expected to be only slightly contaminated, although potentially in large quantities [7].

Early in the emergency response phase and during the transition to the recovery phase, waste management may simply consist of storing waste in a dedicated area, if appropriate. Criteria will need to be established such that, once the resources become available, the waste can be sorted by the amount of radioactive material and the types of waste (e.g., solid, liquid or organic) based on an appropriate hazard assessment [8, 10].

It may be possible to process the waste to reduce its quantity or to convert it into a more suitable form for disposal. Some processes that could be considered for waste reduction include: sorting, incinerating, filtering, distilling or solidifying liquids; and chemically treating liquids [49].

As part of waste-management efforts, various disposal options may need to be considered. Waste disposal methods are generally based on the principles of isolation and containment [50]:

- **Isolation** involves placing the waste in a remote location away from people's homes and communities, and is typically appropriate for waste contaminated with long-lived radionuclides that cannot be removed.
- **Containment** includes those activities or structures designed to prevent the release of radioactive waste to the environment. Containment also protects the physical environment from the waste. Dilution is generally not considered acceptable since it increases the volume of radioactive waste without reducing the inventory.

If the waste volumes are relatively small, then existing radioactive waste management facilities may have sufficient capacity to manage the waste. However, if a large amount of material is involved (which is likely in a situation involving a more significant release), the capacity at these facilities may be exceeded. Lessons learned from Fukushima and Goiania are that temporary storage facilities were required in order to allow time to establish more permanent solution. New facilities could be constructed at the site where the radionuclide release originated, elsewhere within the contaminated area, or away from the affected area altogether [6]. If the waste is to be relocated elsewhere, requirements for the acceptance of and transportation of radioactive material should be considered. All waste sites must have appropriate controls, contamination such as waste acceptance criteria, to protect public health and the environment from radioactivity. Highly radioactive materials will need more robust controls than slightly contaminated materials [7]. If waste contains fissile materials, the potential for criticality would have to be managed. Any decision to manage wastes locally or *in situ* should include a strong justification, a long-term management and monitoring plan, and a commitment to maintaining the mitigative structures put in place. If the characteristics of the contaminated materials exceed CNSC licensing limits, the regulatory disposition of the site must be discussed with the CNSC as part of decision making during the recovery phase.

Regardless of the potential requirement for licensing under federal or provincial legislation, all waste management and disposal discussions need to consider the long-term institutional controls necessary to maintain public and environmental safety into the future [51, 52]. There will need to be a commitment to monitoring and maintenance associated with future generations. This is, of course, the case for all industrial activities but may be forgotten or undervalued during an emergency or recovery phase. The long-term (long after the actual nuclear emergency) commitment to the management of the risk associated with the remediation wastes will likely involve both engineered and non-engineered approaches to ensuring safety. Non-engineered instruments, such as administrative controls or maintenance programs, are considered institutional controls.

5.9 Protection of workers

In the recovery phase, there are three distinct situations where workers may be occupationally exposed within the affected area:

- Workers who are at a licensed facility in the affected area during the recovery phase (e.g., nuclear operator at a nuclear power plant)
- Workers who are tasked with conducting recovery actions under the direction of the recovery management organization(s), referred to as “recovery workers” (e.g., workers with the duty of conducting soil remediation activities)
- Workers who are exposed because of their residence, work location and consumption of food within an affected area, but who are not tasked with recovery actions (e.g., workers in a fruit orchard)

For each of these sets of workers, different considerations apply:

- The protection of **workers at the licensed facility** would be governed by the licensee’s protection programs including both conventional and radiation protection. Exposure to these individuals as part of their occupation would be considered a planned exposure situation; this category would include workers at a nuclear power plant performing onsite recovery actions. The dose limits prescribed in sections 13 and 14 of the *Radiation Protection Regulations* (RPR) [11] would apply to these workers during the recovery phase and the application of the principle to keep doses ALARA, taking economic and societal factors into account, would be required.

- Exposure to **recovery workers** would also be considered a planned exposure situation. The protection of workers involved in implementing recovery strategies under the direction of the recovery management organization(s) would be managed through the implementation of similar protection programs with an all-hazards approach commensurate with the risks. It is expected that occupational exposures to radiation for this group of workers would be planned, monitored and optimized in a manner to ensure that radiation exposures remained below limits and ALARA. As part of the safety programs, the recovery management organization(s) would provide information, training, protective equipment and dosimetry to workers. The dose limits prescribed in sections 13 and 14 of the RPR would apply during recovery and the application of the ALARA principle would be expected.
- Doses received by **workers due to their residency, work location and consumption of food** within an affected area, post-emergency would not be considered in the context of the occupational dose limits prescribed by the RPR. Rather, the reference levels for existing exposures situations would apply in these circumstances. Exposure to these workers should still be maintained ALARA. Self-help actions may be used, for example, to limit time spent in areas with higher dose rates during the work day.

It is also important to note that doses received by persons involved in the control of a nuclear emergency would be treated separately from those received via planned occupational exposures (which include recovery efforts, or existing exposure situations).

5.10 Public communication considerations

Throughout the recovery phase, increased levels of communication must be maintained to address the uncertainties, the new normal, and the shift in priorities after the response phase. As with all risk communications, it is important to communicate with the public using terminology that is universally understood. Consistent coordinated messages need to come from credible sources, and they should be communicated in a clear and simple manner, supported by facts, and given with appropriate context.

A variety of tools and media should be used to communicate frequently with the public and other stakeholders. Traditional methods of communication, such as television, print and radio, should be supplemented with other methods such as social media, websites, forums or town halls and instructional videos. Monitoring social media and other modes of communication will give awareness of misinformation, rumours and what the public is interested in. Consistent, ongoing messaging from authorities will help avoid contradiction and confusion among members of the public.

A central communications strategy should be developed in the emergency preparedness phase in order to reach those displaced by the incident and to maintain community engagement. Ongoing communication prior to a nuclear emergency is crucial in building trust with community stakeholders. Engaging the community prior to a nuclear emergency by partnering with community stakeholders and representatives can lead to better buy-in for public health research and eventual community self-sufficiency.

The public and other stakeholders need to be informed and consulted regularly, and involved in decision making. There must be clear communication as to the agencies, or groups of agencies, involved in remediation activities and their respective jurisdictions or responsibilities. This will enable the public to actively contribute to activities influencing their lives and to understand whose directions and procedures are relevant to their situation. Most individuals will be concerned about the potential health consequences, particularly for children, and the effects of the nuclear emergency on the environment. Decisions in the recovery phase will directly affect the daily lives of affected populations for an extended period. Direct engagement with the community will allow people to give feedback on their concerns and priorities, and allow authorities to respond directly – creating trust and transparency.

For affected populations, one effective method of communication is to set up public reception and information centres to collect data and to provide support and information on topics such dose assessments and exposure pathways. Educational programs on the health effects of radiation and the concept of risk presented in cooperation with educational institutions can improve public knowledge and understanding of the actions applied during the transition and recovery phases [28]. These types of centres give the public an opportunity to share their experiences and receive direct responses to their questions [8, 38] and to have access to monitoring equipment to support self-help actions. It is also important to use consistent and frequent communication to raise awareness about radiation protection measures within the community through the involvement of credible leaders, such as teachers, scientific professionals, association members and healthcare professionals. Local leaders can help reach the affected population which will be an important first step in opening dialogue.

Appendix A: Acronyms

ALARA	as low as reasonably achievable
CNSC	Canadian Nuclear Safety Commission
ESF	emergency support function
FERP	*Federal Emergency Response Plan*
FHMS	Fukushima Health Management Survey
FNEP	*Federal Nuclear Emergency Plan*
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
mSv	millisievert
NLCA	*Nuclear Liability and Compensation Act*
NSCA	*Nuclear Safety and Control Act*
PEOC	Provincial Emergency Operations Centre
PNERP	*Provincial Nuclear Emergency Response Plan*
RPR	*Radiation Protection Regulations*

Glossary

For definitions of terms used in this document, see REGDOC-3.6, *Glossary of CNSC Terminology*.

REGDOC-3.6 includes terms and definitions used in the *Nuclear Safety and Control Act* and the regulations made under it, as well as in CNSC regulatory documents and other publications.

The following terms are being defined for the first time in the draft for public consultation. Following public consultation, the final versions of this definition will be submitted for inclusion in the next version of REGDOC-3.6.

emergency exposure situation
An unexpected exposure situation that may occur during the operation of a nuclear reactor or during the use of radioactive materials in a planned situation, which requires urgent actions to avoid or reduce undesirable consequences.

existing exposure situation
An exposure situation that already exists when a decision on control has to be made. Existing exposure situations include the following: prolonged exposure situations after emergencies; exposure to natural background; exposure due to residual radioactive material derived from past practices that were never subject to regulatory control; and exposure caused by residual radioactive material resulting from a nuclear or radiological emergency.

planned exposure situation
An exposure situation involving the planned use of radioactive sources and/or the operation of nuclear reactors

protective action
An *emergency response action* for the purposes of avoiding or reducing *doses* that might otherwise be received in an *emergency exposure situation* or an *existing exposure situation*

recovery
The period during which activities focus on restoration of quality of life, social systems, economies, community infrastructures and the environment. Recovery may begin during the response phase and continue for up to several years after the nuclear emergency.

reference levels
The level of residual dose or risk above which it is generally judged to be inappropriate to allow exposures to occur, and below which protective actions should be planned and optimized.

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Additional Information

The following documents provide additional information that may be relevant and useful for understanding the requirements and guidance provided in this regulatory document:

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CNSC Regulatory Document Series

Facilities and activities within the nuclear sector in Canada are regulated by the Canadian Nuclear Safety Commission (CNSC). In addition to the *Nuclear Safety and Control Act* and associated regulations, these facilities and activities may also be required to comply with other regulatory instruments such as regulatory documents or standards.

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	2.13	Safeguards and non-proliferation
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