Canada's Nuclear Regulator

Canadian National Report for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

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Canadian National Report for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

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Preface

Information in this report covers the period up to March 31, 2017. However, in some instances the reporting period extends to August 31, 2017, the time of writing the report. Examples include the current status of the Canadian Nuclear Safety Commission’s regulatory documents, the Nuclear Waste Management Organization’s (NWMO) Adaptive Phased Management (APM) approach, and Ontario Power Generation’s (OPG) Deep Geologic Repository (DGR).

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Executive Summary

1.0 Introduction

This sixth Canadian report demonstrates how Canada continues to meet its obligations under the terms of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* during the reporting period from April 2014 to March 2017. This report is a collaboration between the Canadian Nuclear Safety Commission (CNSC), federal government departments and industry. It focuses specifically on the progress of long-term management initiatives for spent fuel and radioactive waste in Canada, revisions and updates to Canada's fifth national report, as well as comments and issues raised at the fifth review meeting, which took place in May 2015. Specifically, this report includes information on:

- Canada's progress in developing and implementing solutions for the long-term management and disposal of different types of radioactive waste and/or spent fuel
- the restructuring of Atomic Energy of Canada Limited (AECL) and the progress AECL has made in advancing accelerated decommissioning and waste management plans and activities under a new government-owned, contractor-operated (GoCo) model
- the status of the Nuclear Waste Management Organization's (NWMO) site-selection process for a deep geological repository for the long-term management of Canada's spent fuel
- the status of Ontario Power Generation's (OPG) application for a licence to prepare site and construct its Deep Geologic Repository for low- and intermediate-level radioactive waste (L&ILW)

2.0 Canada's key highlights and current priorities

The following emerged out of the fifth review meeting as key highlights and current priorities for Canada:

- planning for Canada's long-term management of spent fuel
- reviewing OPG's application for its Deep Geologic Repository project
- completing the restructuring of AECL
- implementing the CNSC's integrated action plan in response to the Fukushima Daiichi accident

2.1 Canada's long-term management of spent fuel

In June 2007, the Government of Canada selected the NWMO-recommended Adaptive Phased Management (APM) approach for the long-term management of Canada's spent fuel. The NWMO is responsible for implementing this plan. As of July 2017, seven of the original 22 interested communities were participating in the site-selection process. A number of First Nation and Métis communities are also involved, which is facilitated through learning agreements. See section K.5 for more information.

2.2 Review of OPG's Deep Geologic Repository project

The Canadian Environmental Assessment Agency (CEA Agency) and the CNSC established a joint review panel (JRP) in January 2012 to review OPG's environmental impact statement in support of its application for a licence to prepare site for and construct a deep geological repository for its L&ILW.

The JRP held public hearings in 2013 and 2014. On May 6, 2015, the JRP issued its environmental assessment report, which included 97 recommendations, to the Minister of Environment and Climate Change for review and decision under the *Canadian Environmental Assessment Act, 2012*. In this report, the JRP concluded that OPG's Deep Geologic Repository project is not likely to cause significant adverse environmental effects, provided the mitigation measures proposed, the commitments made by OPG during the review and the mitigation measures recommended by the JRP are implemented.

The Minister of Environment and Climate Change requested additional information from OPG in 2016 and 2017. The CEA Agency will review the additional information, which considers input from the federal review team, indigenous groups and the public. The phase after the review process includes the CEA Agency preparing a draft report for the minister followed by a 30-day public comment period on that draft report. Subject to the minister's decision, the JRP under the *Nuclear Safety and Control Act*, would decide whether to issue a licence to OPG to prepare a site and construct the Deep Geologic Repository facility.

2.3 AECL restructuring

The restructuring of AECL, the federal Crown corporation responsible for enabling nuclear science and technology and managing federal radioactive waste liabilities, was completed in 2015. This included the creation of Canadian Nuclear Laboratories (CNL). All federal responsibilities related to decommissioning and waste management were transferred to AECL and included as part of the scope of work to be performed under the GoCo contractual agreements. As such, the Nuclear Legacy Liabilities Program (NLLP), which was discussed in previous reports, ended in 2015. Decommissioning and waste management work at AECL sites is now being implemented by CNL under the GoCo model. For further information, see section Annex 7.1.

Canada's historic waste liabilities, including the Port Hope Area Initiative (PHAI), were also transferred to AECL and are being implemented by CNL under a contractual arrangement with AECL. Construction of the containment mound for the Port Hope Project commenced in the summer of 2016. The first cell will be completed in late 2017, with placement of waste from within the community expected to begin in 2018. On November 1, 2016, the first truckloads of low-level radioactive waste were transported away from the Lake Ontario shoreline to the newly built Port Granby Project long-term waste management facility, signalling the start of this significant environmental cleanup. The cleanup is scheduled to take place over three years, after which the mound's cover system will be constructed (expected to be completed in 2021). For more information on the PHAI, see section K.7.3.1 as well as annexes 8.2.1.1 and 8.2.1.2.

2.4 CNSC post-Fukushima integrated action plan

Canada reported in the seventh *Canadian National Report for the Convention on Nuclear Safety* that the CNSC has completed implementation of its integrated action plan in response to the Fukushima accident. The CNSC action plan also included enhancements to the CNSC's nuclear regulatory framework. Updates to regulatory documents were completed during the reporting period. Work is ongoing to amend the *Class I Nuclear Facilities Regulations* and the *Radiation Protection Regulations*.

3.0 Progress since the fifth review meeting

During the peer review of Canada's fifth national report in 2015, contracting parties to the fifth review meeting identified long-term waste management challenges, suggestions and planned measures to improve safety. Subsection 3.1 provides an update and summarizes the progress made toward the long-term management of spent fuel and radioactive waste. For more detailed information on Canada's progress, see section K.2.2.

3.1 Canada's progress on long-term management strategies

Canada continues to make progress on long-term management strategies in the areas of:

a) industry access to suitable skills and resources

b) resources to ensure regulatory oversight

c) finding an acceptable site in a willing host community for spent fuel repository

d) implementing GoCo management model and completing procurement process

e) develop an integrated strategy for non-OPG L&ILW disposal

f) CNL sites - accelerated decommissioning and remediation

g) development of radioactive waste management industry forum

h) consolidated waste and decommissioning regulations

i) federal environment minister decision for OPG's DGR project for its L&ILW

j) continue progress in engineered design and site selection process for the long-term management of spent fuel (APM)

(a) Industry access to suitable skills and resources

OPG, Bruce Power and New Brunswick Power Corporation (NB Power) use a number of strategies that focus on extensive workforce planning, succession management, staff development, advance hiring and knowledge management.

Hydro-Québec faced transitional challenges following the decision to permanently shut down the Gentilly-2 Nuclear Generating Station in 2012. Once defuelling the reactor and draining contaminated systems were completed, a permanent organization was put in place to ensure decommissioning activities are performed during the safe storage state with spent fuel in the wet storage bays (2015–20). This organization is composed of about 70 employees; 95 percent of whom worked at Gentilly-2 while it was in operation.

As part of the implementation of the GoCo model, the majority of AECL’s employees were transferred to CNL, allowing CNL to become a private-sector company, operator of the nuclear laboratories and the employer of approximately 3,000 people. Today, AECL is an expert-based Crown corporation that employs around 40 and has a new role of overseeing the GoCo agreements with CNL and the Canadian National Energy Alliance (CNEA). CNL is currently undertaking a skills assessment of all personnel in the organization, including in research and development (R&D).

For more information on industry access to suitable skills and resources, see section K.2.2.1.

(b) Resources to ensure regulatory oversight

The CNSC is now beginning to reap the benefits of the investment in strategic and operational workforce planning over the last two years. Attrition remains the most critical risk to manage and, as such, the CNSC has adopted a “build” strategy to protect core organizational capabilities and competencies that are essential to carrying out its mandate over the long term. Human resources management effort is focused on four areas: organization design, recruitment and workforce renewal, learning and leadership development, and employee engagement and retention.

(c) Finding an acceptable site in a willing host community for spent fuel repository

Momentum has been sustained for implementing the long-term management approach for spent fuel since the NWMO received its 2007 mandate to implement the APM approach approved by the Government of Canada. Between 2014 and 2017, significant progress was made on the site-selection process (initiated in 2010) as the NWMO worked with interested communities. In 2014, the year began with 17 communities participating in the site-selection process.

As of July 2017, seven of the original 22 interested communities were participating in the site-selection process. A number of First Nation and Métis communities are also involved, which is facilitated through learning agreements. For more information, see section K.5.

(d) Implementing GoCo management model and completing procurement process

In 2009, the federal government embarked on a restructuring of AECL. The restructuring was undertaken in two phases, the first of which was completed in 2011 with the sale of AECL's CANDU Division to Candu Energy Inc., a wholly-owned subsidiary of SNC-Lavalin Inc. The second phase focused on the remainder of the organization, the nuclear laboratories and associated waste management responsibilities, with the objective of implementing a GoCo model.

The implementation of the GoCo model was also completed in two phases. The first phase, completed in November 2014, consisted of creating and operationalizing CNL as a wholly-owned subsidiary of AECL. Through an internal reorganization, virtually all of AECL's employees were transferred to CNL along with all of the necessary licences, permits and other authorizations, allowing CNL to become the operator of the nuclear laboratories and employer of the workforce. Following a procurement process led by Natural Resources Canada with support from Public Works and Government Services Canada, CNEA was selected as the preferred bidder to manage and operate CNL. Once AECL transferred the shares of CNL to CNEA, CNL became a private-sector organization.

As a result, today CNL is a private-sector company responsible for the day-to-day management and operation of all of AECL's sites, facilities and assets. CNL employs approximately 3,000 people, most being previous employees of AECL.

(e) Develop an integrated strategy for non-OPG low and intermediate-level waste disposal

Canada's radioactive waste owners – AECL, OPG, Hydro-Québec and NB Power – and other selected stakeholders have been meeting since 2014 under the sponsorship of the Canadian Nuclear Association's Nuclear Leadership Forum to discuss opportunities for coordination and collaboration on long-term management matters, including relevant technologies and communication strategies.

Since the May 2015 Joint Convention review meeting, significant progress has been made in developing and implementing long-term solutions for L&ILW at AECL sites, which will address more than half of Canada's inventory of these waste types. In addition to the long-term management facilities being constructed for the approximately 1.2 million cubic metres of historic low-level radioactive waste associated with the PHAI (see section K.7.3 for more details), CNL has proposed a project for a near-surface disposal facility at CRL with a total capacity up to one million cubic metres for low-level radioactive wastes and other suitable streams (see section K.7.2.2 for more details).

(f) AECL sites – accelerated decommissioning and remediation

With the implementation of the GoCo model at AECL sites, CNL has plans to significantly accelerate decommissioning and remediation activities. Following the appropriate regulatory approval, CNL anticipates that the following activities will be accomplished over the next eight to 10 years (i.e., by 2026):

- The decommissioning of CRL will be accelerated, including the decommissioning and demolition of more than 120 redundant structures.
- The National Research Universal reactor (which ends operation in March 2018) will be placed in a storage with surveillance state.
- The National Research Experimental reactor will be decommissioned to an agreed end state.
- The proposed near-surface disposal facility for low-level radioactive waste and other suitable waste streams will be constructed, with a total planned disposal capacity of one million cubic metres, pending regulatory approval.

- Stored liquid wastes from several buildings at the CRL site will have been removed, immobilized and the structures decommissioned.
- Interim soil action levels for radioactive and non-radioactive contaminants will have been developed based on proposed land-use scenarios.
- Site remediation activities will progress and be coordinated with the propose near-surface disposal facility availability and need for cover material during that facility’s operations.
- Decommissioning activities at the Whiteshell Laboratories and nuclear power demonstration prototype reactor sites will be completed, including the in-situ decommissioning of the reactor below grade at both sites, pending regulatory approval.
- The PHAI will be completed, with only monitoring activities remaining
- Both the Port Hope and Port Granby long-term management containment mounds for low-level radioactive waste will be closed and capped.
- Other non-Port Hope historic waste liabilities will have been remediated or substantially discharged.

(g) Development of radioactive waste management industry forum

Canada’s largest radioactive waste owners – AECL, OPG, Hydro-Québec and NB Power – and other selected stakeholders have been meeting since 2014 under the sponsorship of the Canadian Nuclear Association’s Nuclear Leadership Forum to discuss opportunities for coordination and collaboration on long-term management matters, including relevant technologies and communication strategies.

The current focus of the group is on the development of a coordinated and integrated communications program that supports major projects underway to establish L&ILW disposal facilities. The objective of collaborating and leveraging lessons learned across the industry is to ensure cost-effective, publicly acceptable and readily accessible long-term radioactive waste management facilities will be available in the future to support a sustainable Canadian nuclear industry.

(h) Consolidated waste and decommissioning regulations

The CNSC is conducting an analysis to determine if there is a need to develop radioactive waste and decommissioning regulations. To address this potential need, CNSC staff continue to work toward a consolidated regulatory framework for waste and decommissioning. A discussion paper on the proposed approach was published on May 13, 2016 to seek stakeholder feedback, which is now being considered.

(i) Federal environment minister decision for OPG’s DGR project for its L&ILW

OPG’s plan for the long-term management of its L&ILW is the Deep Geologic Repository, which would be located 680 metres below the ground surface in argillaceous limestone at the Bruce Nuclear Generating Station site in the municipality of Kincardine, Ontario. OPG’s Deep Geologic Repository would be adjacent to its Western Waste Management Facility, where OPG centrally stores all its L&ILW from OPG-owned nuclear reactors.

On May 6, 2015, the JRP issued its environmental assessment report to the federal government concluding that the project is not likely to cause significant adverse environmental effects, taking into account the implementation of the mitigation measures committed to by OPG together with the mitigation measures recommended by the panel.

The Minister of Environment and Climate Change has requested additional information from OPG. After the technical review process has been completed, the next phase includes the preparation of a draft report by the CEA Agency followed by a 30-day public comment period on that draft report. The CEA Agency will then finalize its report and submit a decision package to the minister.

(j) Continue progress in engineered design and site selection process for the long-term management of spent fuel (Adaptive Phased Management)

In 2014, NWMO's engineering and design program completed a new engineered-barrier system design that received the Canadian Nuclear Society's 2015 Innovative Achievement Award. Since that time, NWMO has further optimized that design, in part to take advantage of current manufacturing capabilities. A proof testing program was initiated to demonstrate that the engineered-barrier system can meet the project's rigorous technical requirements.

The NWMO also updated the conceptual repository designs to reflect the new reference engineered-barrier system. Working collaboratively with communities, NWMO completed the first phase of preliminary assessments, initiated geoscientific and environmental fieldwork in several potential siting areas, and broadened engagement with First Nation, Métis and other communities to collaboratively explore the project and the extent to which it could fit in each of the areas. For more information, see section K.5.

4.0 Conclusion

In Canada, spent fuel and radioactive waste are currently managed in interim storage facilities that are safe, secure and environmentally sound. Interim storage facilities are continually monitored by the licensees and regulator to ensure fitness for service. Canada recognizes that enhanced, long-term management approaches will be required for all its spent fuel and radioactive waste and is progressing towards solutions.

This sixth *National Report for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste* identifies several key initiatives that demonstrate Canada's commitment to identifying and implementing long-term management approaches that do not place an undue burden on future generations.

Section A – Introduction

A.1 Scope of the section

This section is a general introduction to the main themes of the report.

A.2 Introduction

The Government of Canada has jurisdiction over nuclear energy and Natural Resources Canada is the department responsible for federal nuclear energy policy. The Government of Canada has long funded nuclear research as well as supported the development and use of nuclear energy and related applications. As a result of this investment:

- nuclear energy now supplies over 16 percent of Canada's electricity
- the nuclear industry is a significant contributor to the Canadian economy, currently generating $6 billion in economic activity and accounting for more than 30,000 highly skilled direct jobs
- Canada is one of the world's largest suppliers of uranium, which continues to rank among the top 10 metal commodities in Canada for value of production

In 2009, the Government of Canada undertook a restructuring of Atomic Energy of Canada Limited (AECL) with a view of reducing risks and costs to Canadian taxpayers while leveraging AECL's capabilities for the benefit of Canadians and industry.

The restructuring was undertaken in two phases, the first of which was completed in 2011 with the sale of AECL's CANDU Division. The second phase focused on the remainder of the organization, the nuclear laboratories and associated waste management responsibilities with the objective of implementing a government-owned, contractor-operated (GoCo) management model. AECL moved from a government-owned, government-operated model to a GoCo model in September 2015 following the selection of the private-sector consortium Canadian National Energy Alliance (CNEA).

Under this GoCo model, AECL continues to own the sites, facilities, assets and liabilities while the management and operation of the sites is the responsibility of Canadian Nuclear Laboratories (CNL), which is owned by CNEA. CNL is a private-sector company responsible for the day-to-day management and operation of all of AECL's sites, facilities and assets. CNL employs over 3,500 people, most of whom are former AECL employees.

AECL's mandate continues to be to:

- manage the federal government's radioactive waste and decommissioning responsibilities
- facilitate science and technology activities in support of core federal responsibilities
- support Canada's nuclear industry through access to science and technology facilities and expertise on a commercial basis

AECL achieves this mandate through a long-term contract with CNL and CNEA for the management and operation of its sites. These include Chalk River Laboratories (CRL) in Chalk River, Ontario, and Whiteshell Laboratories in Pinawa, Manitoba. Work undertaken at CRL includes nuclear science and technology in the areas of safety, security, health, the environment, energy, non-proliferation and emergency management, as well as important work in decommissioning and waste management. Similarly, the federal government's historic waste liabilities were also transferred to AECL and are being addressed under the GoCo model, including the implementation of the Port Hope Area Initiative (PHAI), a remediation initiative in Port Hope, Ontario.

Radioactive waste has been produced in Canada since the early 1930s when the first radium and uranium mine opened in Port Radium, Northwest Territories. Pitchblende ore was transported from the Port Radium mine to Port Hope, Ontario, where it was refined to produce radium for medical purposes and, later, uranium for nuclear fuel and military applications. Research and development on the application of nuclear energy to produce electricity began in the 1940s at CRL. At present, radioactive waste is generated in Canada from the various stages and uses associated with the nuclear fuel cycle:

- uranium mining and milling
- refining and conversion
- nuclear fuel fabrication
- nuclear reactor operations
- nuclear research
- radioisotope manufacture and use

The Government of Canada gives high priority to the safety of persons and the protection of the environment from the various operations of the nuclear industry and has put in place modern legislation that provides the basis for Canada's comprehensive and robust regulatory regime. Canada's nuclear regulatory body is the Canadian Nuclear Safety Commission (CNSC). In addition to Natural Resources Canada and the CNSC, the major Government of Canada organizations involved in the Canadian nuclear industry include:

- **Health Canada** – Health Canada recommends radiological protection standards and monitors occupational radiological exposures.
- **Transport Canada** – Transport Canada develops and administers policies, regulations and services for the Canadian transportation system, including the transportation of dangerous goods.
- **Environment and Climate Change Canada (ECCC) –** ECCC contributes to sustainable development through pollution prevention to protect the environment and human health from the risks associated with toxic substances. ECCC is responsible for the administration of the *Canadian Environmental Protection Act*.
- **Canadian Environmental Assessment Agency (CEA Agency) –** The CEA Agency is responsible for the administration of the *Canadian Environmental Assessment Act, 2012* (CEAA 2012), the primary federal legislation defining requirements for assessing the environmental effects of planned projects (see annex 2.5 for a further description of CEAA 2012). The CEA Agency works to provide Canadians with high-quality environmental assessments that contribute to informed decision making in support of sustainable development, as does the CNSC for nuclear projects.
- **Major Projects Management Office (MPMO)**: The MPMO works collaboratively with federal departments and agencies to provide overarching project management and accountability for major resource projects in the federal regulatory review process as well as to facilitate improvements to the regulatory system for major resource projects.
- **Northern Projects Management Office (NPMO):** The NPMO was established to improve the environmental review process for proposed major resource development and infrastructure projects in northern Canada. Its mandate is to improve the timeliness, predictability and transparency of northern regulatory processes to foster a more stable and attractive investment climate in the territories.

Annex 1 provides information on Canada's federal structure and detailed descriptions of federal institutions involved in nuclear energy.

The *Nuclear Safety and Control Act* (NSCA), the *Nuclear Fuel Waste Act*, the *Nuclear Liability and Compensation Act* (which came into force on January 1, 2017 and replaced the *Nuclear Liability Act*), and the *Nuclear Energy Act* are the centrepieces of Canada's legislative and regulatory framework for nuclear matters. The NSCA is the key piece of legislation that ensures the safety of the nuclear industry and radioactive waste management in Canada. A detailed description of this legislative and regulatory framework is provided in annex 2.

Provincial governments are responsible for deciding their energy mix, including the role of nuclear energy. Provincial ministries may play roles in nuclear activities and radioactive waste management, with the details of those roles determined by each province.

A.3 Nuclear substances

Under the NSCA, the CNSC regulates nuclear substances to protect human health and the environment. The nuclear substances defined in the NSCA include any radioactive substance, plus deuterium or any related compounds, as well as any substance that regulations define as being required for the production or use of nuclear energy.

Both radioactive waste and spent fuel contain nuclear substances and therefore are regulated in the same manner as any other nuclear substance. Section B.5 describes the policy on managing spent fuel and radioactive waste.

A.4 Canadian philosophy and approach to safety

Canada actively promotes and regulates safety within the nuclear sector. Canada's approach is based on several factors, including the review of international standards (e.g., International Atomic Energy Agency standards and guides) and improvements to CNSC regulatory policies and standards. Canada considers the adoption of international recommendations, such as those regarding radiological dose limits to the public and workers as outlined in the International Commission on Radiological Protection's (ICRP) *Recommendations of the International Commission on Radiological Protection* (ICRP-103, 2007), as well as protection of the environment. For example, limits for controlled release of gaseous or liquid effluents or solid materials are adopted from complementary regulatory regimes (such as Ontario's *Provincial Water Quality Objectives* or *Metal Mining Effluent Regulations*) or derived from specific licence conditions (such as the derived release limits). The CNSC may also adopt other standards established by organizations such as the CSA Group or the American Society of Mechanical Engineers.

The Commission sets the standards and conditions; it is then the responsibility of the licensee or person in possession of the associated nuclear substance or the operator of the associated facility to ensure safety. For example, it is the licensee's responsibility to demonstrate to the satisfaction of the regulatory body that a spent fuel facility or radioactive waste management facility can and will be operated safely throughout the lifetime of the facility. The regulatory regime is flexible about how licensees comply with regulatory requirements. The licensee must demonstrate how the design meets all applicable performance standards and will continue to do so throughout its design life.

A.5 Fundamental principles

The Canadian regulatory approach to the safety of spent fuel and radioactive waste management is based on three principles:

- lifecycle responsibility and licensing
- in-depth defence
- multiple barriers

A.6 Main safety issues

The main safety issue that this report begins to address is the long-term management of spent fuel and radioactive waste.

Currently, interim storage of all waste forms is being conducted in a safe manner. The Canadian nuclear industry and the Government of Canada are developing long-term waste management solutions that will protect health, safety, security and the environment. Key initiatives underway are described in section K of this report. Some of the most important challenges will be to bring these initiatives to fruition and develop and implement appropriate long-term solutions that instill and uphold the public's confidence.

In Canada, the development and implementation of the long-term management of radioactive waste is the responsibility of the waste owner. Ontario Power Generation, Canada's largest nuclear utility, has initiated this process for the long-term management of its low- and intermediate-level radioactive waste, with the submission of a licence application to the CNSC for its Deep Geologic Repository project, which is further described in section K.7.1.

The long-term management of radioactive waste from past practices has presented the federal and provincial governments with challenges in developing and implementing appropriate remedial strategies and long-term waste management solutions. Several initiatives have been completed or are underway to address these sites, as described in sections H.6.1 and K.7.3.

A.7 Survey of the main themes

The main themes in this report are as follows:

- Canadian government departments and agencies and the nuclear industry have roles and responsibilities – confirmed in the 1996 *Radioactive Waste Policy Framework* – to ensure the safe management of spent fuel and radioactive waste.

- The primary responsibility for safety rests with the licensees. All licensees take their responsibilities for safety seriously and are able to raise adequate revenue to support safe operations.

- The Canadian safety philosophy and requirements, applied through the regulatory process, ensure that the risk to the workers, the public and the environment associated with spent fuel management and radioactive waste management is kept as low as reasonably achievable, with social and economic factors taken into consideration.

- The Canadian regulatory body has sufficient independence, authority and resources to ensure compliance with and enforcement of regulatory safety requirements that pertain to the management of spent fuel and radioactive waste.

- Industry and various levels of government are engaged in a number of initiatives to develop and implement long-term solutions for spent fuel and radioactive waste, as well as cleanup of wastes from past practices such as uranium mining and processing.

Section B – Policies and Practices

B.1 Scope of the section

This section addresses article 32(1) ("Reporting") of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* and provides information on Canada's policies and practices for spent fuel and radioactive waste management.

Under the current legislative and regulatory framework, spent fuel is considered to be another form of radioactive waste. As a result, legislation and policies on managing radioactive waste apply equally to spent fuel and other forms of radioactive waste.

B.2 Legislative instruments

Federal legislation used to regulate and oversee the nuclear industry, including the management of radioactive waste and spent fuel, comprises the *Nuclear Safety and Control Act* (NSCA), the *Nuclear Fuel Waste Act*, the *Nuclear Liability and Compensation Act*, and the *Nuclear Energy Act* – all of which are described in annex 2. The nuclear industry is also subject to the *Canadian Environmental Assessment Act, 2012,* the *Canadian Environmental Protection Act* and the *Fisheries Act*.

A number of Government of Canada departments are involved in administering these legislative instruments. Where multiple regulators are involved, the Canadian Nuclear Safety Commission (CNSC) establishes joint regulatory groups to coordinate and optimize the regulatory effort.

In addition, the nuclear industry is subject to the provincial acts and regulations in force within the individual provinces and territories where nuclear-related activities are carried out. Where there is an overlap of jurisdictions and responsibilities, the CNSC takes the lead in efforts to harmonize the regulatory activities, including joint regulatory groups, which involve provincial and territorial regulators.

B.3 National framework for radioactive waste management

The 1996 Government of Canada *Policy Framework for Radioactive Waste* sets the stage for institutional and financial arrangements to manage radioactive waste in a safe, comprehensive, environmentally sound, integrated and cost-effective manner. The framework specifies that:

- the Government of Canada is responsible for developing policy and regulating and overseeing radioactive waste producers and owners to ensure that they comply with legal requirements and meet their funding and operational responsibilities in accordance with approved long-term waste management plans

- waste owners are responsible, in accordance with the "polluter pays" principle, for the funding, organization, management and operation of the facilities required to safely manage their wastes over the short and long terms

The framework recognizes that arrangements may be different for the four broad categories of radioactive waste found in Canada: spent fuel, low-level radioactive waste, intermediate-level radioactive waste, and uranium-mine waste rock and mill tailings.

Government departments and agencies responsible for the management of radioactive waste in Canada are shown in figure B.1.

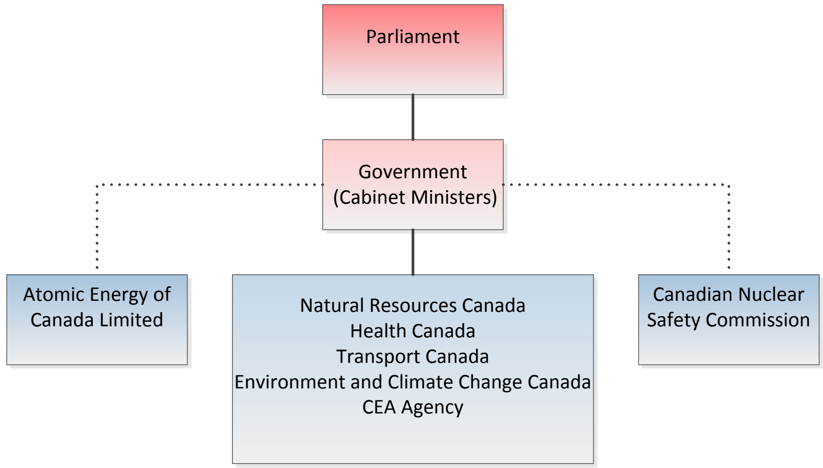

Figure B.1: Government departments and agencies responsible for the management of radioactive waste in Canada

Natural Resources Canada is the lead government department responsible for developing and implementing federal nuclear energy policy across the nuclear supply chain – from uranium mining to the final disposition of waste. This includes uranium and radioactive waste policy, legislation development and implementation, and the establishment and management of a nuclear civil liability and compensation regime. Natural Resources Canada administers the *Nuclear Fuel Waste Act*, the *Nuclear Liability and Compensation Act*, and the *Policy Framework for Radioactive Waste* on behalf of the Minister of Natural Resources.

Historic low-level radioactive waste (LLW) is waste that was managed in the past in a manner no longer considered acceptable, for which the current owner cannot be reasonably held responsible and for which the Government of Canada has accepted responsibility for long-term management.

Legacy wastes (in the Canadian context) specifically date back to the Cold War and birth of nuclear technologies in Canada; these wastes are located at Atomic Energy of Canada Limited (AECL) sites. These wastes include existing radioactive wastes and wastes resulting from decommissioning disused buildings and infrastructure, as well as from environmental remediation.

Uranium mill tailings are wastes produced during the processing of uranium ores. These wastes are located at uranium mine sites in Saskatchewan, Ontario and the Northwest Territories. Most of the closed mine sites have been remediated and are now licensed by the CNSC. The closed mine and mill sites that have not yet been remediated are located in northern Saskatchewan. These mines and mills were operated in the late

1950s to early 1960s by companies that no longer exist, and government-funded projects are underway to remediate these sites (see annex 8 for more information).

Several other federal departments have been assigned roles and responsibilities for the safe management of spent fuel and radioactive waste, including Health Canada, Environment and Climate Change Canada, and the Canadian Environmental Assessment Agency (CEA Agency). Additional information on these departments and the CEA Agency is provided in annex 1.

Atomic Energy of Canada Limited (AECL) and the CNSC are connected to the Government of Canada by dashed lines in figure B.1 to illustrate their arms-length relationships. They both report to Parliament through a minister within the government.

AECL is a Crown corporation whose sole shareholder is the Government of Canada. Its mandate is to enable nuclear science and technology and manage the federal government’s decommissioning and radioactive waste liabilities. Following a restructuring process that was completed in September 2015, AECL now delivers its mandate through a long-term contract with the private sector for the management and operation of its sites, under a government-owned, contractor-operated (GoCo) model. Canadian Nuclear Laboratories (CNL) manages AECL’s sites, including the operation of the nuclear laboratories and the delivery of decommissioning and waste management activities. Activities related to decommissioning and waste management are necessary to address liabilities and reduce hazards that are the result of decades of nuclear research at AECL sites. AECL is also responsible for the cleanup and safe, long-term management of historic low-level radioactive waste at other sites across Canada for which the Government of Canada has accepted responsibility. This includes the Port Hope Area Initiative (PHAI) and the activities associated with the Low-Level Radioactive Waste Management Office.

The CNSC is Canada’s independent nuclear regulatory body. Its mandate is to regulate the use of nuclear energy and materials to protect health, safety, security and the environment; implement Canada's international commitments on the peaceful use of nuclear energy; and disseminate objective scientific, technical and regulatory information to the public. The CNSC’s regulatory decision process is fully independent from the Government of Canada.

B.4 Regulatory policy on managing spent fuel and radioactive waste

In July 2004, the CNSC issued regulatory policy P-290, *Managing Radioactive Waste*, following extensive consultation with the public and industry stakeholders. The policy outlines the philosophy and six principles that govern the CNSC’s regulation of radioactive waste. It is fully consistent with the federal *Policy Framework for Radioactive Waste.* P-290 identifies the need for long-term management of radioactive and hazardous waste arising from licensed activities.

The policy statement in P-290 defines radioactive waste as any form of waste material containing a nuclear substance as defined in the NSCA. This definition is sufficiently comprehensive to include spent fuel without any other special consideration. The policy indicates that, when making regulatory decisions about the management of radioactive waste, the CNSC will seek to achieve its objectives by considering certain key principles in the context of the facts and circumstances of each case, as follows:

- The generation of radioactive waste is minimized to the extent practicable by the implementation of design measures, operating procedures and decommissioning practices.
- The management of radioactive waste is commensurate with its radiological, chemical and biological hazard to the health and safety of persons, to the environment and to national security.
- The assessment of future impacts of radioactive waste on the health and safety of persons and the environment encompasses the period of time when the maximum impact is predicted to occur.
- The predicted impacts on the health and safety of persons and the environment from the management of radioactive waste are no greater than the impacts that are permissible in Canada at the time of the regulatory decision.
- The measures needed to prevent unreasonable risk to present and future generations from the hazards of radioactive waste are developed, funded and implemented as soon as reasonably practicable.
- The transborder effects on the health and safety of persons and the environment, which could result from the management of radioactive waste in Canada, are not greater than the effects experienced in Canada.

The differences between spent fuel and other forms of radioactive waste are addressed by the application of the second principle described above, indicating that waste is expected to be managed according to its hazard.

The principles contained in P-290 are consistent with those recommended by the International Atomic Energy Agency (IAEA). P-290 also recognizes the CNSC’s commitment to optimizing regulatory effort, stating that the CNSC should consult and cooperate with provincial, national and international agencies to:

- promote harmonized regulation and consistent national and international standards for the management of radioactive waste
- achieve conformity with the measures of control and international obligations to which Canada has agreed concerning radioactive waste

As part of CNSC’s modernization of its regulatory framework, P-290 is being re-affirmed and combined with regulatory guide G-320 in a single regulatory document, REGDOC-2.11.1. (See section B.6)

B.5 Regulatory guide on assessing the long-term safety of radioactive waste management

Published in December 2006, regulatory guide G-320, *Assessing the Long Term Safety of Radioactive Waste Management*, helps licensees and applicants assess the long-term impacts that radioactive waste storage and disposal methods have on the environment and the health and safety of people. Specifically, the guide addresses:

- assessment approaches, structures and methodologies
- level of detail of assessments
- confidence to be placed in assessment results
- application of radiological and non-radiological criteria
- definition of critical groups for impact assessments
- selection of time frames for impact assessments
- setting of post-decommissioning objectives
- long-term care and maintenance considerations
- use of institutional controls

G-320 does not, however, address the social acceptability or economic feasibility of long-term management methods or the assessment of facility operations. A copy of the guide is available on the CNSC website at nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents.

As discussed in B.5, P-290 is being re-affirmed and combined with regulatory guide G-320 in a single regulatory document, REGDOC-2.11.1.

B.6 Classification of radioactive waste in Canada

Established in 1919, the Canadian Standards Association (now called the CSA Group) is a not-for-profit organization composed of representatives from the government, industry and consumer groups. Its primary product is safety and performance standards, including those for electronic and industrial equipment, boilers and pressure vessels, compressed gas handling appliances, and environmental protection and construction materials. CSA Group provides training materials and information products.

As reported in the fifth national report, the CSA Group – in collaboration with industry, government and the CNSC – developed a standard that includes a radioactive waste classification system (CSA 292.0-14), which takes into account IAEA safety guide GSG-1, *Classification of Radioactive Waste*, along with the needs of the Canadian industry. Published in 2014, CSA 292.0-14 recognizes four main classes of radioactive waste:

- high-level radioactive waste (HLW) (see section B.7.1)
- intermediate-level radioactive waste (ILW) (see section B.7.2)
- low-level radioactive waste (LLW) (see section B.7.3)
- uranium mine and mill waste (see section B.7.4)

Subclasses for LLWs are also identified to provide better guidance on the appropriate waste management needs.

Organization of classification system

The radioactive waste classification system is organized according to the degree of containment and isolation required to ensure safety in the short and long terms. The classification system also takes into consideration the hazard potential of different types of radioactive waste.

A definitive numerical boundary between the various categories of radioactive waste – primarily between LLW and ILW – cannot be provided because activity limitations differ between individual radionuclides and radionuclide groups, and will be dependent on short- and long-term safety-management considerations. For example, a contact dose rate of two millisieverts per hour (mSv/h) has been used in some cases to distinguish between LLW and ILW.

The following sections provide an overview of the four main classes of radioactive waste in Canada.

B.6.1 High-level radioactive waste

HLW is used (irradiated) nuclear fuel that has been declared radioactive waste or waste that generates significant heat (typically more than two kilowatts per cubic metre) via radioactive decay. In Canada, "irradiated nuclear fuel" or "used nuclear fuel" are more accurate terms for spent fuel because discharged fuel is considered a waste material even when it is not fully spent. Despite the name difference, in this report the term "spent fuel" is used to be consistent with the terminology found in the Joint Convention.

Spent fuel is associated with penetrating radiation, which requires shielding. Furthermore, spent fuel contains significant quantities of long-lived radionuclides, meaning that long-term isolation is also required. Waste forms derived from spent fuel (e.g., nuclear fuel reprocessing wastes) can exhibit similar characteristics and may be considered HLW.

Placement in deep, stable geological formations is considered the preferred option for the long-term management of HLW.

B.6.2 Intermediate-level radioactive waste

ILW is waste that typically exhibits sufficient levels of penetrating radiation to warrant shielding during handling and interim storage. This type of radioactive waste generally requires little or no provision for heat dissipation during its handling, transportation and long-term management. However, some ILW may have heat generation implications in the short term (e.g., refurbishment waste) because of its total radioactivity level.

B.6.3 Low-level radioactive waste

LLW contains material with radionuclide content above established clearance levels and exemption quantities, and generally limited amounts of long-lived activity. LLW requires isolation and containment for up to a few hundred years. LLW generally does not require significant shielding during handling and interim storage. LLW has two subcategories described below:

Very-short-lived low-level radioactive waste

Very-short-lived low-level radioactive waste (VSLLW) is waste that can be stored for decay for up to a few years and subsequently cleared for release. This classification includes radioactive waste containing only short half-life radionuclides of the kind typically used for research and biomedical purposes. Examples of VSLLW are iridium-192 and technetium-99m sources, as well as industrial and medical radioactive waste that contains similar short half-life radionuclides.

Generally, the main criterion for VSLLW is the half-life of the predominant radionuclides. In practice, the management of VSLLW should be applied only to radionuclides with a half-life of 100 days or less.

Very-low-level radioactive waste

Very-low-level radioactive waste (VLLW) has a low hazard potential but is nevertheless above the criteria for exemption. Long-term waste management facilities for VLLW do not usually need a high degree of containment or isolation. A near-surface repository with limited regulatory control is generally suitable. Typically, VLLW includes bulk material such as low-activity soil and rubble, decommissioning wastes and some uranium-contaminated wastes.

B.6.4 Uranium mine and mill waste

Uranium mine waste rock and mill tailings are a specific type of radioactive waste generated during the mining and milling of uranium ore and the production of uranium concentrate. In addition to tailings, mining activities typically produce large quantities of mineralized and clean waste rock excavated to access the ore body. The tailings and mineralized waste rock contain significant concentrations of long-lived radioactive elements, namely thorium-230 and radium-226.

B.7 Operational responsibilities for long-term management

Although numerous government departments, agencies, hospitals, universities and industry members are involved in the management of radioactive waste, only a limited number of organizations are involved in its long-term management. Figure B.2 shows the organizations responsible for the long-term management of spent fuel and radioactive waste in Canada.

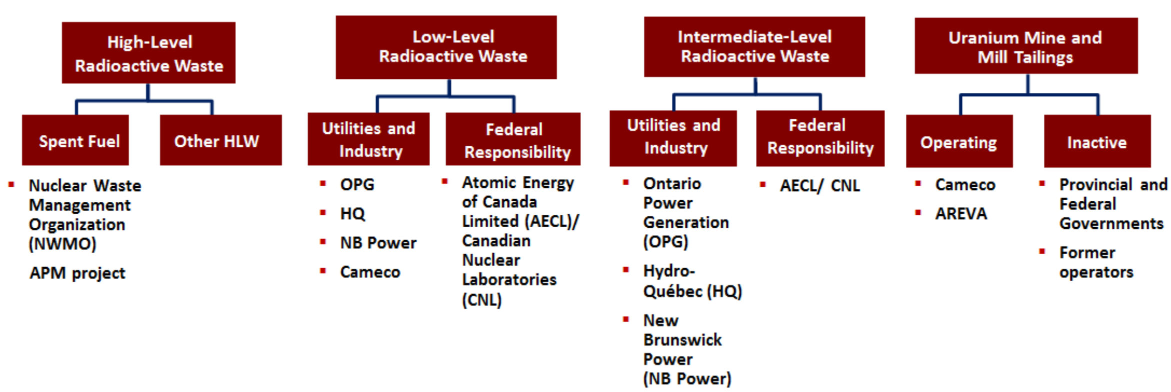

Figure B.2: Organizations responsible for the long-term management of spent fuel and radioactive waste in Canada

The Nuclear Waste Management Organization (NWMO) is responsible for implementing the Adaptive Phased Management (APM) approach that was selected by the Government of Canada for the long-term management of spent fuel. (See sections G.16 and K.5.) Ontario Power Generation (OPG), NB Power and Hydro-Québec are responsible for the management of spent fuel generated at their respective reactor sites until the NWMO is ready to accept the spent fuel for management in a facility constructed under the APM approach. OPG is also responsible for the interim storage of the spent fuel generated at the Bruce A Nuclear Generating Station and Bruce B Nuclear Generating Station. AECL is also responsible for the storage of spent fuel, including spent research reactor fuel, until the NWMO is ready to accept the spent fuel for management in a facility constructed using the APM approach.

Ontario Power Generation (OPG), NB Power and Hydro-Québec are responsible for the long-term management of low- and intermediate-level radioactive waste (L&ILW) generated from nuclear reactor operations. OPG is also responsible for the long-term management of L&ILW generated at the Bruce A Nuclear Generating Station and Bruce B Nuclear Generating Station. See to section K.7.1 for information on OPG’s proposed Deep Geologic Repository for the long-term management of its L&ILW.

AECL is responsible for the long-term management of L&ILW at its sites – Whiteshell Laboratories, Chalk River Laboratories (CRL) and three partially decommissioned prototype reactors (Gentilly-1, Douglas Point and the Nuclear Power Demonstration Reactor) – as well as for the L&ILW it accepts from other Canadian licensees (mostly originating from hospitals and universities) on a fee-for-service basis. Under a GoCo model, CNL delivers this work on behalf of AECL. For information on the AECL/CNL long-term waste management strategy for L&ILW, see subsection K.7.2.

AECL is also responsible for the cleanup and safe management of historic LLW at sites across Canada for which the Government of Canada has accepted responsibility. This includes the PHAI and activities associated with the Low-Level Radioactive Waste Management Office. Again, this work is delivered by CNL on behalf of AECL. For additional information see sections H.6.1, K.7.2 and K.7.3.

Cameco and AREVA Resources Canada Inc. manage the only operating uranium mines and mills in Canada (see annex 6). Inactive uranium mine and mill sites are located in Ontario, the Northwest Territories and Saskatchewan, as described in annexes 7 and 8.

The term “inactive” is used to describe several different types of inventories, including:

- tailings sites that are currently being decommissioned
- tailings sites at operating mill sites where closure activities are in progress (e.g., Rabbit Lake, Key Lake)
- tailings sites at former milling locations, including recently decommissioned sites with engineered tailings containment systems as well as sites that date back to the earliest era of nuclear energy production in Canada when tailings were deposited in lakes or low areas near lakes (e.g., Port Radium)

All of these inactive sites are licensed by the CNSC. The site owners are responsible for monitoring and any future maintenance or remedial work that may be required to protect human health and safety or the environment. Two former uranium mine tailings sites are located in Saskatchewan: the Gunnar and Lorado sites. The Lorado site has been decommissioned and the Gunnar site is in the process of being decommissioned, as described in annexes 8.1.1.2 and 8.1.1.3.

B.8 Management practices for spent fuel

Spent fuel consists of irradiated fuel removed from commercial, prototype and research nuclear reactors. Three provincial nuclear utilities (OPG, Hydro-Québec and NB Power) own about 97 percent of the spent fuel in Canada. AECL owns the remaining three percent. Spent fuel includes nuclear fuel waste as well as research reactor fuel waste that is not in the form of a CANDU fuel bundle.

Canada does not yet have a long-term waste management facility for spent fuel. All spent fuel is currently held in interim wet or dry storage at the nuclear generating stations where it is produced, with the exception of the spent fuel produced at the now-closed Nuclear Power Demonstration facility, which is stored at AECL CRL. Spent fuel discharged from CANDU reactors is placed into special wet storage bays for several years (depending on site-specific needs) and is eventually transferred to an interim dry storage facility. Three designs of dry storage containers are used in Canada:

- AECL silos
- AECL modular air-cooled storage
- OPG dry storage containers

For a complete description of these dry storage containers, see annex 4.3.

To address the long-term management of spent fuel, the three major waste owners – OPG, Hydro-Québec and NB Power – established the NWMO in 2002 under the *Nuclear Fuel Waste Act*. For a full description of the NWMO's long-term management plan for Canada's spent fuel and site selection process, see sections G.16 and K.5.

B.9 Management practices for low- and intermediate-level radioactive waste

As the waste owners, OPG (which owns 20 of Canada's 22 CANDU reactors) and AECL are responsible for approximately 74 percent and 23 percent of the annual accumulated volume of L&ILW, respectively. These accumulation rates represent the waste generated from nuclear power production in Ontario and research and development activities at CRL, respectively. Included in AECL's accumulation rate is L&ILW for long-term management from a number of small producers and users of radioactive materials (e.g., hospitals, universities). The other two CANDU reactors (owned by NB Power and Hydro-Québec) and Cameco's uranium processing and conversion facilities in Ontario generate the majority of the remaining waste. In general, the owners of L&ILW are licensed by the CNSC to manage and operate storage facilities for their radioactive wastes. In addition, the two major waste owners, OPG and AECL/CNL, are pursuing long-term management solutions.

L&ILW from OPG owned CANDU reactors (including Bruce A and B) is safely stored in a central location at the Western Waste Management Facility at the Bruce nuclear site in Kincardine, Ontario. OPG entered into an agreement with the municipality of Kincardine on October 13, 2004 to host a deep geological repository designed to hold current and future L&ILW from OPG's 20 CANDU reactors. More information on this initiative is provided in section K.7.1. NB Power and Hydro-Québec have their own facilities for the interim storage of L&ILW at their reactor sites.

For waste from research and development, AECL/CNL have waste storage facilities at two sites – CRL and Whiteshell Laboratories – as well as at its three prototype reactor sites. Operational storage facilities include the bulk materials landfill for dewatered sewage sludge, modular above-ground storage structures, shielded modular above-ground storage structures, concrete bunkers and tile holes. On behalf of AECL, CNL also accepts L&ILW from small generators – such as those in hospitals, universities and small industries – on a fee-for-service basis.

As described in section K.7.2, activities dealing with legacy radioactive waste and decommissioning liabilities at AECL sites are being advanced by CNL under a GoCo arrangement. In addition to existing interim storage facilities at CRL, a key enabling component is the proposed construction of a near-surface disposal facility with a total planned disposal capacity of 1 million cubic metres, to be available by 2020 for disposal of LLW and other suitable waste streams. The L&ILW generated by decommissioning, environmental remediation, ongoing operations and L&ILW accepted from third-party generators will also be managed in these facilities. Progress and achievements during the last three years are summarized in section K.7.2.1.

Radioactive waste from hospital nuclear medicine departments and from universities and similar facilities contains only small amounts of radioactive materials with short half-lives. The radioactivity of this waste normally decays within hours, days or months. Institutions such as hospital nuclear medicine departments and universities have implemented delay-and-decay programs, after which waste can be treated using conventional means.

Canada has significant volumes of LLW from past practices (referred to as historic waste) that was once managed in a manner no longer considered acceptable but for which the current owner cannot be reasonably held responsible. Canada’s historic waste inventory consists largely of radium- and uranium-contaminated soils in the form of spilled ores on the Northern Transportation Route from the former Port Radium mine site in the Northwest Territories and refinery process residues in the area of Port Hope, Ontario. The Government of Canada has accepted responsibility for the long-term management of these wastes.

The bulk of Canada’s historic LLW is located in the southern Ontario communities of Port Hope and Clarington. These wastes and contaminated soils amount to roughly 1.7 million cubic metres and relate to the historic operations of a radium and uranium refinery in Port Hope dating back to the 1930s. In March 2001, the Government of Canada and the local municipalities agreed to community-developed proposals as potential solutions for the cleanup and long-term management of historic LLW in the Port Hope area, launching the PHAI. The PHAI and other initiatives dealing with historic waste are described in section K.7.3.1 and annexes 8.2.1.1 and 8.2.1.2. These initiatives are under the responsibility of AECL, with the work being delivered by CNL under a GoCo model.

Activities are currently underway to quantify the extent of historic LLW liabilities across Canada (non-Port Hope sites) and develop plans for their discharge. A key objective is that CNL will significantly reduce or eliminate liabilities by 2026 through the safe execution of remediation projects, facilitating the cost-effective long-term management of historic LLW consistent with policy direction provided by AECL.

B.10 Management practices for uranium mine waste rock and mill tailings

Uranium mining and milling processes generate two major sources of radioactive waste: mine waste rock and mill tailings.

More than 200 million tonnes of uranium mill tailings have been generated in Canada since the mid-1950s. There are 25 tailings sites in Ontario, Saskatchewan and the Northwest Territories (figure B.3), 22 of which no longer receive waste material. The three remaining operational tailings management facilities (TMFs) are located in Saskatchewan. The ore mined at McArthur River is transported to Key Lake for milling, resulting in no tailings management areas at the McArthur mine site. Similarly, the ore from Cigar Lake is transported to McClean Lake for milling; tailings reside at the McClean Lake TMF. Both milling and mining have been conducted at Rabbit Lake, resulting in tailings being managed at that site. All operational and inactive uranium tailings sites are the joint regulatory responsibility of the CNSC and the provinces and territories where the sites are located.

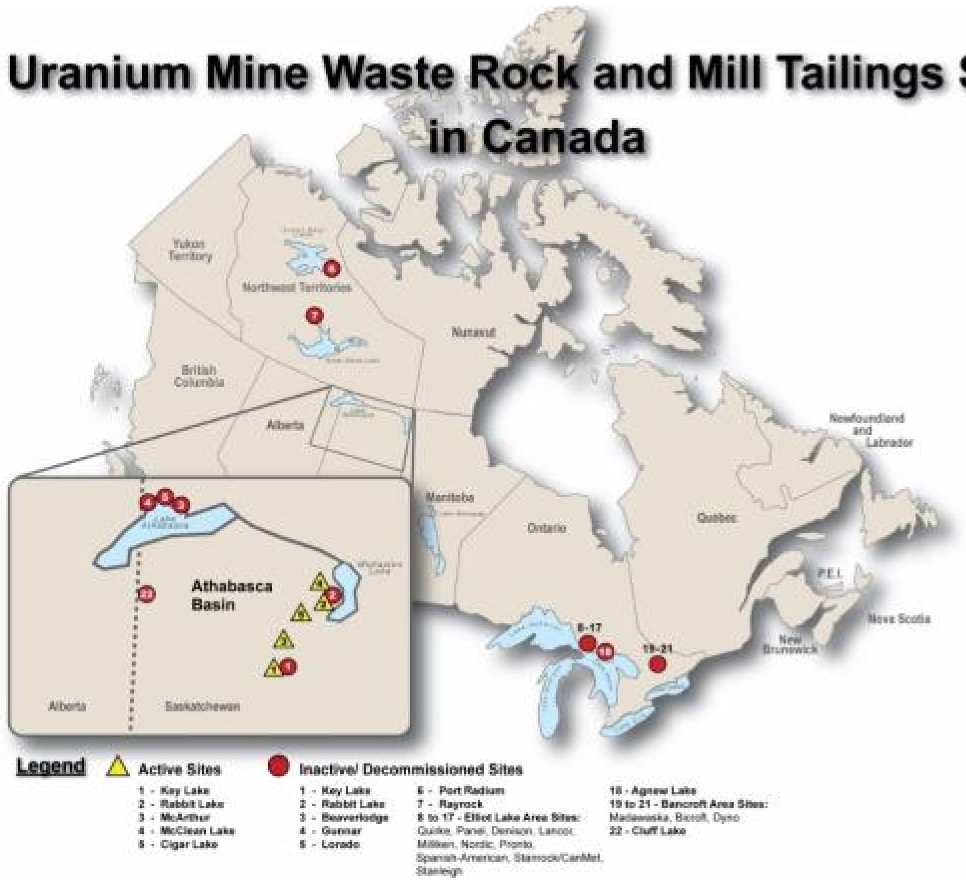

Figure B.3: Locations of operating and inactive/decommissioned sites

Historically, tailings were used as backfill in underground mines, deposited directly into lake basins or placed in low areas on the ground surface and confined by either permeable or water-retaining dams. Surface tailings were left bare, covered with soil or flooded; some bare or covered tailings may have been vegetated. In response to evolving regulatory requirements, the containment structures for surface tailings have become much more rigorously engineered for long-term storage and stability. Tailings management methods at operational facilities include chemically treating tailings to control their mineralogy prior to placing them in hydrostatically contained TMFs converted from mined-out open pits.

Contaminated industrial wastes are typically recycled, deposited in underground mine workings or landfilled at the site-specific TMF. The quantities of contaminated industrial wastes are tracked and recorded; however, in the context of the overall site inventory of radioactive wastes, the actual amount of low specific activity material contained in this volume is negligible and is effectively accounted for in the overall tailings quantity for each site.

In addition to the tailings produced from milling uranium ore, millions of cubic metres of waste rock are excavated to gain access to ore. At the Athabasca Basin open-pit sites, most of this waste rock is sandstone, which is environmentally benign and suitable for surface disposal. Some of the waste rock, however, contains either low-grade, uneconomic ore or significant concentrations of secondary minerals. If left exposed on the surface indefinitely, this special waste rock could generate acid or release contaminants at rates that could impact the local environment. The current method of managing special waste rock is to either blend it with high-grade ore for processing or isolate it from atmospheric conditions (e.g., locate it at the bottom of a flooded pit), keeping it in an environment similar to that from which it was mined and preventing oxidation reactions. In underground mines, waste rock can be used in the mine as backfill material. Waste rock materials used for purposes underground are not classified as waste materials in the waste inventory.

The inventory of nuclear substances in some inactive uranium tailings management areas can result in these areas being licensed as Class I nuclear facilities under the *Class I Nuclear Facilities Regulations*, pursuant to the NSCA. (See section E.3.2.) This has implications for the licensing requirements and long-term management of such facilities. Those responsible for inactive tailings management areas with smaller inventories can be licensed for possession of nuclear substances. These inactive tailings disposal areas and facilities will remain under CNSC licence control in the absence of a suitable alternative (such as provincial institutional controls). The Government of Saskatchewan, however, has developed such an alternative for decommissioned mining sites (not limited to uranium) for institutional control on Crown land. (See section H.10.3.)

Current management practices for CNSC-licensed facilities use a lifecycle planning process. A preliminary decommissioning plan and financial guarantees for decommissioning are integral to the licence approval process and are required in the first stages of CNSC licensing: site preparation and construction. (See section F.8). All phases in the lifecycle of a facility are subject to an environmental assessment process.

Section C – Scope of Application

C.1 Scope of the section

This section addresses article 3 (“Scope of Application”) of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. It provides Canada’s position on reprocessing spent fuel, naturally occurring radioactive waste and military and defence programs**.**

C.2 Introduction

While neither the *Nuclear Safety and Control Act* (NSCA) nor its associated regulations define radioactive waste, the Canadian Nuclear Safety Commission’s regulatory policy P-290, *Managing Radioactive Waste,* asserts that radioactive waste is:

> Any liquid, gaseous or solid material that contains a nuclear substance, as defined in section 2 of the NSCA and for which the owner of the material foresees no further use and the owner had declared as waste. By definition, radioactive waste may contain non-radioactive constituents.

Radioactive waste is therefore regulated in the same manner as all other materials that contain a nuclear substance. All radioactive waste, whether from a large nuclear facility or a small-scale user, is subject to the Joint Convention, with the exception of:

- reprocessed spent fuel
- naturally occurring radioactive materials
- radioactive waste generated by military and defence programs

C.3 Reprocessed spent fuel

Given Canada’s large natural resource of uranium, the nuclear industry has not deemed it necessary to reprocess spent fuel at this time. Therefore, pursuant to article 3(1) of the Joint Convention, Canada declares that reprocessing activities are not part of Canada’s spent fuel management program and so are not included in this report. Note, however, that Chalk River Laboratories did reprocess spent fuel between the 1940s and 1960s to extract plutonium. The wastes from these activities are discussed later in annexes 7.5.

In accordance with article 3(1), medical isotope production fuel is also excluded from the report because it is processed to extract isotopes, meaning it is outside the scope of the Joint Convention and protected from disclosure under article 36.

C.4 Naturally occurring nuclear substances

Naturally occurring nuclear substances – other than those that are or have been associated with the development, production or use of nuclear energy – are exempt from the application of all provisions of the NSCA and its associated regulations, except:

- provisions that pertain to the transport of radioactive materials
- in the case of naturally occurring radioactive material listed in the schedule to the *Nuclear Non-proliferation Import and Export Control Regulations*, provisions that govern the import and export of radioactive materials

In accordance with article 3(2) of the Joint Convention, only non-exempt naturally occurring radioactive substances are discussed in this report: namely, radium-bearing wastes resulting from the former radium industry, and tailings and waste rock from uranium mines and mills.

C.5 Department of National Defence programs

Under section 5 of the NSCA, the Department of National Defence’s programs are not subject to the NSCA or its associated regulations; however, the Royal Military College (RMC) of Canada’s Safe Low-Power Critical Experiment (SLOWPOKE) reactor is subject to the NSCA because it is operated as a research reactor (see section G.4.1). Therefore, in accordance with article 3(3) of the Joint Convention, the RMC SLOWPOKE reactor is the only military or defence program addressed in this report.

C.6 Discharges

Each radioactive waste management facility in Canada must have in place an approved environmental monitoring program. For more information on environmental monitoring programs, see section F.6.6. Radiological effluent discharge levels for radioactive waste management facilities are listed throughout annexes 5, 6, 7 and 8.

Section D – Inventories and Lists

D.1 Scope of the section

This section addresses article 32(2) (Reporting) of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. It provides a list of the various spent fuel and radioactive waste management facilities in Canada and indicates the total inventory of each of the waste categories. Each licensee is required to develop and implement an accountability system, including the appropriate records. This system and associated records are subject to regulatory oversight. A map showing the locations of radioactive waste management sites in Canada (figure D.1) is provided below.

Figure D.1: Location of radioactive waste management sites in Canada

D.2 Inventory of spent fuel in Canada

Nuclear generating stations and research reactor sites store spent fuel onsite in irradiated fuel bays, or reactor pool in the case of McMaster, (wet storage) pending transfer to dedicated spent fuel dry storage facilities. Table D.1 inventories spent fuel in wet storage in Canada and table D.2 summarizes the spent fuel in dry storage.

Table D.1: Inventory of spent fuel in wet storage in Canada as of December 31, 2016

Site	Number of fuel bundles in wet storage	Kilograms of uranium [1]
Bruce Power Nuclear Generating Stations	687,158[2]	13,089,887
Darlington Nuclear Generating Station	333,078[2]	6,402,480
Gentilly-2 Nuclear Generating Station	22,525	430,650
Pickering Nuclear Generating Stations	403,985[2]	7,989,515
Point Lepreau Nuclear Generating Station	36,780	700,666
McMaster Nuclear Research Reactor	37[3]	38
Chalk River Laboratories (CRL) – National Research Universal	1,205[4]	3,559

[1] Inventory includes depleted uranium, enriched uranium, natural uranium, plutonium and thorium in spent fuel.
[2] Inventory is reported as the number of irradiated fuel bundles and rods.
[3] Inventory is reported as the number of irradiated fuel assemblies.
[4] Inventory is reported as the number of irradiated fuel bundles, rods, assemblies and other items.

Table D.2: Inventory of spent fuel in dry storage facilities in Canada as of December 31, 2016

Site	Number of fuel bundles in dry storage	Kilograms of uranium [1]
CRL Waste Management Area (WMA) G	4,886	65,587
CRL WMA B (spent research reactor fuel)	10,106[2]	35,639
Darlington Waste Management Facility	192,314	3,682,635
Douglas Point Waste Management Facility	22,252	300,891
Gentilly-1 Waste Management Facility	3,213	67,692
Gentilly-2 Waste Management Facility	107,400	2,047,937
Pickering Waste Management Facility	326,912	6,517,180
Point Lepreau Waste Management Facility	102,598	1,945,796
Western Waste Management Facility (located at Bruce site)	490,358	9,347,583
Whiteshell Laboratories	2,268	24,270

[1] Inventory includes depleted uranium, enriched uranium, natural uranium, plutonium and thorium in spent fuel.
[2] Inventory is reported as the number of irradiated fuel bundles, rods, assemblies and other items.

D.3 Radioactive waste inventory

Table D.3 summarizes the low- and intermediate-level radioactive waste (L&ILW) generated from normal operations, including waste management methods used and the inventory of L&ILW in storage at each facility in Canada. L&ILW from decommissioning activities is reported separately in table D.5.

Table D.3: Inventory of low-level radioactive waste (LLW) and intermediate-level radioactive waste (ILW) from normal operations in storage in Canada as of December 31, 2016

Radioactive waste management or nuclear fuel cycle facility	Company name or responsible party	Description of stored waste	Storage method	Onsite waste inventory as of December 31, 2016			
				ILW		LLW	
				Volume (m^3)	Activity (TBq)	Volume (m^3)	Activity (TBq)
Western Waste Management Facility (WWMF)	Ontario Power Generation (OPG)	Interim storage of low- and intermediate-level reactor waste generated from Bruce Power, Darlington, and Pickering A and B	ILW: In-ground storage structures (trenches, tile holes, in-ground containers) and above-ground storage structures (retube waste storage building, quadricells) LLW: Above-ground storage structures (low-level storage buildings, steam generator storage buildings)	11,024[1]	56,702[2]	83,466[3]	86[2]
Pickering Waste Management Facility	OPG	Interim storage of intermediate-level reactor refurbishment waste from Pickering A (Units 1 to 4)	ILW: Dry storage modules	1,012[4]	127,155	nil	nil
Radioactive waste operations site 1	OPG	Interim storage of low- and intermediate-level reactor waste generated from Douglas Point and Pickering A (Units 1 to 4)	ILW: In-ground storage structures (trenches, tile holes) LLW: In-ground storage structures (trenches)	5	12[5]	325	<1[3]
Gentilly-2	Hydro-Québec	Operational reactor waste	ILW: Radioactive waste storage area (ASDR) and solid radioactive waste management facility (SRWMF) (concrete cells) LLW: ASDR and SRWMF (concrete cells)	347	53[6]	1,497	5

Radioactive waste management or nuclear fuel cycle facility	Company name or responsible party	Description of stored waste	Storage method	Onsite waste inventory as of December 31, 2016			
				ILW		LLW	
				Volume (m^3)	Activity (TBq)	Volume (m^3)	Activity (TBq)
Point Lepreau	NB Power	Operational waste: Drums, filters and compactable/non-compactible boxed waste	LLW: Concrete vault structures ILW: Concrete vault structures, filter storage structures and refurbishment canisters	158[7]	792	2,586[7]	178
CRL	Atomic Energy of Canada Limited (AECL)	Research reactor and isotope production waste, external waste	ILW: Tile holes and bunkers ILW/LLW: Shielded Modular Above-Ground Storage (SMAGS) LLW: Sand trenches, low-level storage buildings, above-ground stockpiles, modular above-ground storage (MAGS) and bulk materials landfill	19,468[8]	N/A	123,709[8]	N/A
		Contaminated soils	Luggers, 205-litre steel drums, B-25 containers in SMAGS, sand trenches and above-ground stockpiles	nil	nil	382,842	N/A
Whiteshell Laboratories	AECL	Research reactor waste and decommissioned reactor waste	ILW: In-ground concrete bunkers LLW: Above-ground concrete bunkers and trenches	863[8]	2,794	19,700[8,9]	325
Douglas Point Waste Management Facility	AECL	Contaminated soils	LLW: 205-litre drums	nil	nil	66	N/A

Radioactive waste management or nuclear fuel cycle facility	Company name or responsible party	Description of stored waste	Storage method	Onsite waste inventory as of December 31, 2016			
				ILW		LLW	
				Volume (m^3)	Activity (TBq)	Volume (m^3)	Activity (TBq)
Gentilly-1 Waste Management Facility	AECL	Contaminated soils	LLW: 205-litre drums	nil	nil	1	N/A
Port Hope Conversion Facility	Cameco	Non-combustible process waste	LLW: 205-litre drums	nil	nil	10,000	N/A
Blind River Refinery	Cameco	Non-combustible process waste	LLW: 205-litre drums	nil	nil	5,600	N/A
Port Hope Fuel Manufacturing	Cameco	Non-combustible process waste	LLW: 205-litre drums	nil	nil	1,000	N/A
BWXT Fuel Manufacturing Peterborough	BWX Technologies	Non-combustible process waste	LLW: 205-litre drums	nil	nil	5	<1
BWXT Fuel Manufacturing Toronto	BWX Technologies	Non-combustible process waste	LLW: 205-litre drums	nil	nil	36	<1
Best Theratronics Manufacturing Facility Kanata	Best Theratronics	Disused cobalt 60 sealed sources; disused cesium 137 sealed sources	Pool storage or dry containers	<1	7157	nil	nil
Nordion Manufacturing Facility Kanata	Nordion	Disused cobalt 60 sealed sources; disused cesium 137 sealed sources	Pool storage or dry containers	11.9[10]	10,360	nil	nil
Bruce Power	OPG	Disused cobalt 60 sealed sources	Pool storage	2.5	23,384 [11]	nil	nil

Note: N/A means “not available.”

[1] Volume reduced as a result of 2014 trench remediation project.

[2] Approximate activity based on 2013 inventory.

[3] Volume reduced since 2013 as a result of waste minimization initiatives.

[4] Volume reduced since 2013 as a result of reassessment of ILW container count.

[5] Radioactive Waste Operations Site 1 activity estimated based on activity of waste stored at the Western Waste Management Facility.

[6] Excludes activity level of approximately 250 cubic metres of ILW in spent resins.

[7] Volume reduced since 2013 as a result of waste volume minimization initiatives involving incineration/metal melting.

[8] Volumes for ILW/LLW are based on method of storage and do not necessarily represent the actual breakdown of waste into ILW and LLW.

[9] Volume reduced since 2013 as a result of repackaging, during which some materials were deemed to be clean wastes and removed.

[10] Includes volume of flask where applicable.

[11] Calculated based on the maximum average activity of 1000 Curies per returned spent cobalt bundle

Table D.4 describes radioactive waste from past practices, including the volume that is stored at each site and how it is managed.

Table D.4: Management of LLW from past practices

Site name or location	Company name or responsible party	Description of stored waste	Storage method	LLW	
				Volume (m^3)	Activity (TBq)
Port Hope	AECL	Contaminated soils	*In situ* and consolidated storage	720,000	N/A
Welcome Waste Management Facility	AECL	Contaminated soils	Above-ground mound	454,380	N/A
Port Granby	AECL	Waste and contaminated soils	Trench burial	438,200	N/A
Northern Transportation Route	AECL	Contaminated soils	*In situ* and consolidated storage	54,403	N/A
Greater Toronto Area	AECL Regional Municipality of Peel, Ontario	Radium-contaminated soils, radium contamination fixed to structural elements in buildings	*In situ* and consolidated storage Above-ground consolidated mound	15,941	N/A
Deloro Mine site	Ontario Ministry of the Environment	Contaminated soils and historical tailings	*In situ* (fenced-in area)	34,500[1]	2

Note: N/A means "not available."

[1] A revised volume estimate for Young's Creek has reduced the Deloro Mine site total volume by approximately 3,000 cubic metres since 2013.

Table D.5 inventories the L&ILW resulting from decommissioning activities at Canadian facilities as of December 31, 2016.

Table D.5: ILW and LLW in Canada from decommissioning activities as of December 31, 2016

Site name or location	Company name or responsible party	Description of stored waste	Storage method	Onsite waste inventory as of December 31, 2016			
				ILW		LLW	
				Volume (m^3)	Activity (TBq)	Volume (m^3)	Activity (TBq)
Whiteshell Laboratories	AECL	Decommissioning waste (January 1, 2005 to December 31, 2016)	ILW: In-ground concrete bunkers LLW: Above-ground concrete bunkers	22	148	1,598	6
CRL	AECL	Decommissioning waste (January 1, 2005 to December 31, 2016)	ILW: Tile holes and bunkers LLW: MAGS, SMAGS	125	N/A	2,876	N/A
Douglas Point Waste Management Facility	AECL	Decommissioned reactor waste	Reactor building	60[1]	N/A	35[2]	<1
Nuclear Power Demonstration Waste Management Facility	AECL	Decommissioned reactor waste	Reactor building	included in CRL numbers	N/A	12[3]	<1
Gentilly-1 Waste Management Facility	AECL	Decommissioned reactor waste (IX resin)	Reactor building	58[4]	<1	607[2]	N/A
Port Hope Conversion Facility	Cameco	Decommissioning waste	Drums or other appropriate industrial packaging	nil	nil	6000	N/A

Note: N/A means "not available."

[1] Consists of IX resin, fuel transfer tunnel, booster flow tubes, ram extensions, empty flask and pool debris.

[2] Volume has decreased since 2013 as a result of offsite supplier processing services or to CRL.

[3] For the most part, waste has been transferred to CRL; volume is current best estimate and may not reflect material that has been shipped to CRL recently.

[4] Consists of IX resin.

D.4 Uranium mining and milling waste

Uranium mining and milling generates two main forms of waste: tailings and waste rock. Historically, waste rock has been either stockpiled above ground or used as backfill in underground mines. Today, mineralized special waste rock is segregated and managed with due consideration given to the hazards associated with mineralization and particular contaminants. Tailings are managed in engineered tailings management facilities (TMFs). The unit of measure used in this report for uranium mine and mill wastes is tonne of dry mass, as this is the same unit used in the mining industry to track and report materials.

D.4.1 Operational mine and mill sites

Table D.6 details the uranium tailings and waste rock in storage at operational mine and mill sites in Canada.

Table D.6: Uranium tailings and waste rock at operational mine and mill sites as of December 31, 2016

Operating mine and mill sites	Company name or responsible party	Storage method	Onsite waste inventory as of December 31, 2016		
			Tailings	Waste rock	
			Mass (tonnes)	Mineralized (tonnes)	Non-mineralized (tonnes)
Key Lake	Cameco	Deilmann TMF	5,978,820[1]	1,146,585[2]	68,057,937
Rabbit Lake	Cameco	Rabbit Lake in-pit TMF	9,124,938	1,161,802[3]	12,571,572[4]
McClean Lake	AREVA	In-pit TMF	1,953,300[5]	10,200,000	51,700,000
McArthur River	Cameco	No tailings onsite; ore is transported to Key Lake for milling	nil	120,951	426,217[6]
Cigar Lake	Cameco	No tailings onsite; ore is transported to McClean Lake for milling	nil	625,538	62,334[6]

Note: N/A means "not available."

[1] Includes tailings accumulated from the processing of ores from McArthur River.

[2] Volume reduced since 2013 as a result of the processing of mineralized waste rock and a 2013 reporting error.

[3] Volume reduced since 2013 as a result of a 2014 survey update and the processing of mineralized waste rock.

[4] Volume reduced since 2013 as a result of the completion of the reclamation of the B-zone waste rock pile in 2014 and the historic (pre-2013) reclamation of the A-zone, D-zone and North waste rock piles.

[5] Includes tailings accumulated from the processing of ores from Cigar Lake.

[6] Volume reduced since 2013 as a result of the reclassification of potentially acid generating waste rock as mineralized.

D.4.2 Inventory of uranium mine and mill waste at inactive tailings sites

Table D.7 inventories waste rock and mill tailings at sites that are no longer operational. The table also provides the tailings inventory for older, closed TMFs at operational sites – specifically, Key Lake and Rabbit Lake.

Although the waste rock inventory is provided for the Cluff Lake and Beaverlodge sites and included in table D.6 for the Rabbit Lake and Key Lake sites, it is generally not available for the inactive and decommissioned sites. Also, operations at the sites in table D.7 predated current waste segregation practices. As a result, the breakdown between mineralized and non-mineralized waste rock is not available.

Table D.7: Uranium tailings and waste rock at decommissioned and inactive tailings sites as of December 31, 2016

Site name or location	Company name or responsible party	Storage method	Onsite waste inventory as of December 31, 2016	
			Tailings	Waste rock
			Mass (tonnes)	Mass (tonnes)
Decommissioning tailings sites				
Cluff Lake	AREVA	Tailings management area – surface	3,230,000	18,400,000
Inactive tailings sites				
Key Lake	Cameco	Above-ground TMF	3,579,781[1]	reported in table D.6
Rabbit Lake	Cameco	Above-ground TMF	6,500,000	reported in table D.6
Beaverlodge	Cameco	Above-ground tailings and mine backfill	5,700,000[2]	4,800,000
Gunnar	Saskatchewan Research Council	Above-ground tailings	4,400,000	N/A
Lorado	Saskatchewan Research Council	Above-ground tailings	360,000	N/A
Port Radium	Indigenous and Northern Affairs Canada	Above-ground tailings in four areas	907,000	N/A
Rayrock	Indigenous and Northern Affairs Canada	Above-ground tailings in north and south tailings piles	71,000	N/A
Quirke 1 and 2	Rio Algom Ltd.	Flooded, above-ground tailings	46,000,000	N/A
Panel	Rio Algom Ltd.	Flooded, above-ground tailings	16,000,000	N/A

Site name or location	Company name or responsible party	Storage method	Onsite waste inventory as of December 31, 2016	
			Tailings	Waste rock
			Mass (tonnes)	Mass (tonnes)
Denison	Denison Mines Inc.	Flooded, above-ground tailings in two areas	63,800,000	N/A
Spanish American	Rio Algom Ltd.	Flooded, above-ground tailings	450,000	N/A
Stanrock/Can-Met	Denison Mines Inc.	Above-ground tailings	5,750,000	N/A
Stanleigh	Rio Algom Ltd.	Flooded, above-ground tailings	19,953,000	N/A
Lacnor	Rio Algom Ltd.	Above-ground tailings	2,700,000	N/A
Nordic	Rio Algom Ltd.	Above-ground tailings	12,000,000	N/A
Milliken	Rio Algom Ltd.	Tailings management area	150,000	N/A
Pronto	Rio Algom Ltd.	Above-ground tailings	2,100,000	N/A
Agnew Lake	Ontario Ministry of Northern Development and Mines	Lake-vegetated, above-ground tailings	510,000	N/A
Dyno	EWL Management Ltd.	Above-ground tailings	600,000	N/A
Bicroft	Barrick Gold Corporation	Above-ground tailings in two areas	2,000,000	N/A
Madawaska	EWL Management Ltd.	Above-ground tailings in two areas	4,000,000	N/A

Note: N/A means "not available."

[1] Based on monthly production reports between 1983 and 1996. In 1996, tailings placement switched to the Deilmann TMF.

[2] Tailings volume does not include 4,300,000 tonnes that have been used as backfill.

Section E – Legislative and Regulatory Systems

E.1 Scope of the section

This section addresses articles 18 ("Implementing Measures"), 19 ("Legislative and Regulatory Framework") and 20 ("Regulatory Body") of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. It also addresses the requirements set out in articles 19 and 20 of the International Atomic Energy Agency (IAEA) general safety requirements (GSR) part 1, *Governmental, Legal and Regulation Framework for Safety* (2010). Specifically, this section describes Canada's legislative and regulatory framework, regulatory body and approach to licensing radioactive material.

E.2 Establishment of the Canadian legislative and regulatory framework

In Canada, matters that relate to nuclear activities and substances are under the jurisdiction of the Government of Canada. Natural Resources Canada has been charged with setting Canada's nuclear policies, including those concerning radioactive wastes. The *Policy Framework for Radioactive Waste* establishes the roles and responsibilities of the Government of Canada and waste producers. In particular, the Government of Canada guides, oversees and regulates radioactive waste owners.

Section 9 of the *Nuclear Safety and Control Act* (NSCA) grants regulatory authority over the use of nuclear materials to the Canadian Nuclear Safety Commission (CNSC). The responsibilities of the CNSC include issuing licences, making regulations and enforcing compliance.

A list of the various federal organizations and acts that relate directly to Canada's nuclear industry are provided in annexes 1 and 2. A detailed description of the CNSC – including its structure, operations and regulatory activities – is provided in annex 3.

E.3 National safety requirements

The CNSC operates within a modern and robust legislative and regulatory framework. Figure E.1 depicts the main elements of Canada's nuclear regulatory framework. This framework consists of laws (acts) passed by the Parliament of Canada that govern the regulation of Canada's nuclear industry as well as instruments such as regulations, licences and documents that the CNSC uses to regulate the industry.

The NSCA is the enabling legislation for the regulatory framework. Regulatory instruments fall into two broad categories: those that set out requirements and those that provide guidance on requirements. Requirements are legally binding and mandatory elements and include regulations made under the NSCA, licences (and licence conditions handbooks), certificates and orders. Regulatory documents also become legally binding requirements once they are referenced in licences. The NSCA, regulations, regulatory documents and licences are described in more detail in the sections that follow.

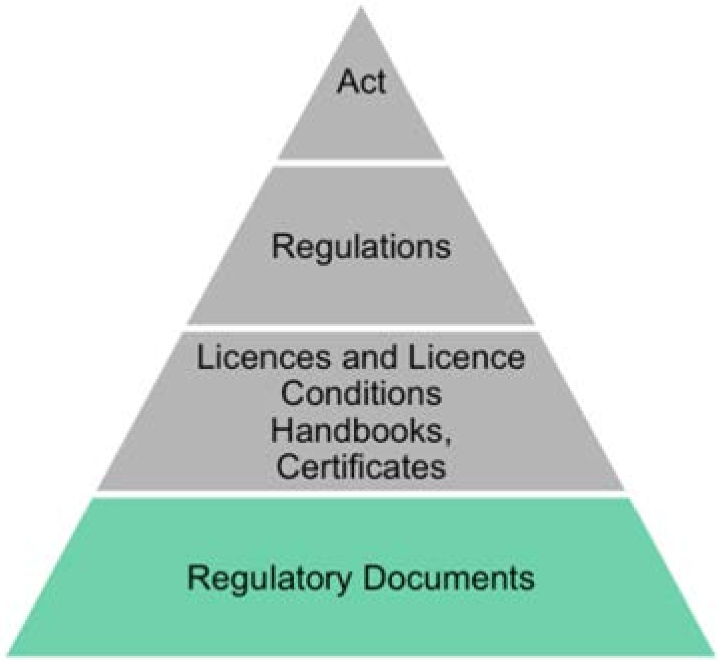

Figure E.1: Elements of the Canadian nuclear regulatory framework

E.3.1 Nuclear Safety and Control Act

In the Canadian parliamentary system, the federal cabinet – on the advice and recommendation of the appropriate minister – makes the decision to introduce government legislation into Parliament. The NSCA was passed by Parliament on March 20, 1997 and became law in May 2000. This was the first major overhaul of Canada’s nuclear regime since the *Atomic Energy Control Act* and the creation of the Atomic Energy Control Board in 1946. The NSCA provides legislative authority for all nuclear industry developments since 1946. These developments include health and safety standards for nuclear energy workers, environmental protection measures, security regarding nuclear facilities and public input into the licensing process. The NSCA can be viewed at laws-lois.justice.gc.ca/eng/acts/N-28.3/index.html.

The NSCA established the CNSC as an independent regulatory body responsible for regulating the use of nuclear material in Canada, including the nuclear fuel cycle. The CNSC comprises the Commission, which makes licensing decisions; and the CNSC’s staff organization, which prepares recommendations to the Commission, exercises delegated licensing and authorization powers, and assesses licensee compliance with the NSCA and its associated regulations and licence conditions. The NSCA gives the CNSC the power to make regulations (see section E.3.2 for more details).

As depicted in figure E.2, the CNSC’s regulatory framework consists of regulations, policies, standards and guides that apply to all nuclear industries, including (but not limited to):

- nuclear power reactors
- non-power nuclear reactors, including research reactors
- nuclear substances and radiation devices used in industry, medicine and research
- the nuclear fuel cycle, from uranium mining through waste management
- the import and export of controlled nuclear and dual-use substances, equipment and technology identified as proliferation risks

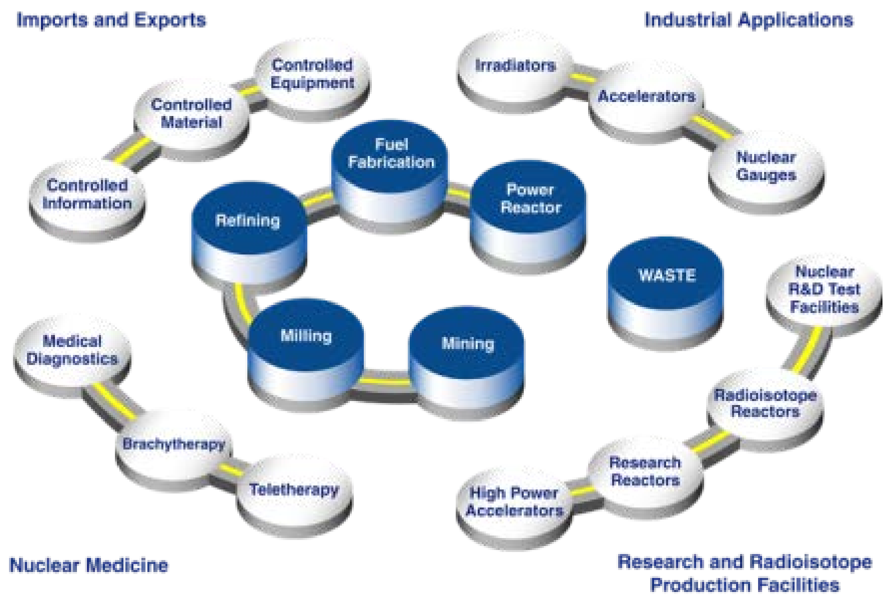

Figure E.2: Nuclear industries regulated by the CNSC

The NSCA defines the CNSC’s mission to regulate the use of nuclear energy and materials to protect the health, safety and security of Canadians and the environment; to implement Canada’s international commitments on the peaceful use of nuclear energy; and to disseminate objective scientific, technical and regulatory information to the public. The CNSC discharges these responsibilities through cooperative arrangements with federal and provincial regulators in other fields, such as those in environmental protection and occupational health and safety.

A Parliamentary directive issued to the CNSC in December 2007, instructs the CNSC take into account the health of Canadians in regulating the production, possession and use of nuclear substances – specifically, by ensuring the necessary protection of the health of Canadians at times when a serious shortage of medical isotopes in Canada or around the world may put the health of Canadians at risk.

The NSCA incorporates stringent regulations to ensure public health and safety are protected. For example, the NSCA includes:

- radiation dose limits consistent with International Commission on Radiological Protection (ICRP) recommendations
- regulations that govern the transport and packaging of nuclear materials
- specifications for enhanced security at nuclear facilities, including spent fuel dry storage and radioactive waste management facilities (WMFs)
- the authority to issue an order for remedial action in hazardous situations
- the requirement for financial guarantees to fund decommissioning of these facilities and managing the resulting radioactive wastes, including spent fuel

E.3.2 Regulations issued under the *Nuclear Safety and Control Act*

Under the NSCA, the CNSC has implemented regulations and by-laws. Regulations prescribe requirements for all types of licence applications and provide for exemptions from licensing. By-laws are in place to govern the management and conduct of the CNSC's affairs. The *Canadian Nuclear Safety Commission Rules of Procedure* set out rules of procedure for public hearings held by the Commission and for certain proceedings conducted by officers designated by the Commission.

As illustrated in figure E.3, the following regulations and by-laws are issued under the NSCA:

- *General Nuclear Safety and Control Regulations*
- *Administrative Monetary Penalties Regulations*
- *Radiation Protection Regulations*
- *Class I Nuclear Facilities Regulations*
- *Class II Nuclear Facilities and Prescribed Equipment Regulations*
- *Nuclear Substances and Radiation Devices Regulations*
- *Packaging and Transport of Nuclear Substances Regulations*
- *Uranium Mines and Mills Regulations*
- *Nuclear Security Regulations*
- *Nuclear Non-proliferation Import and Export Control Regulations*
- *Canadian Nuclear Safety Commission Cost Recovery Fees Regulations*
- *Canadian Nuclear Safety Commission Rules of Procedure*
- *Canadian Nuclear Safety Commission By-laws*

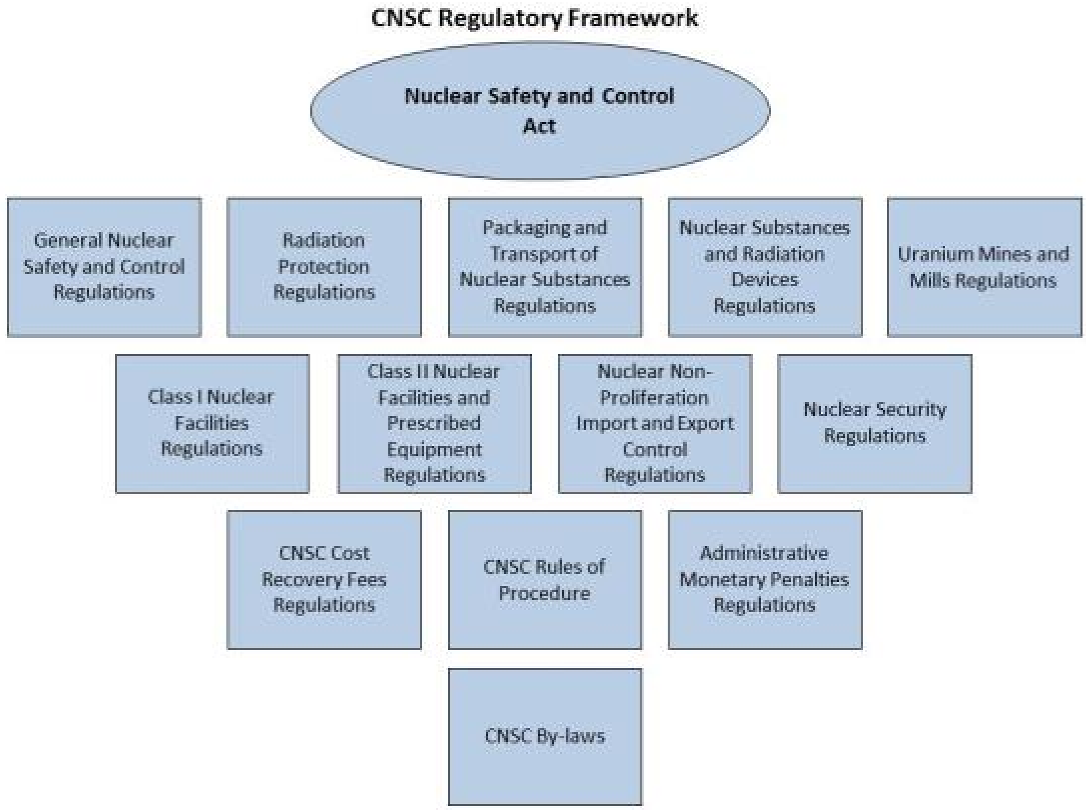

Figure E.3: Regulations and by-laws issued under the NSCA

E.3.3 Regulatory documents

The NSCA and its associated regulations set the requirements while regulatory documents provide the basis for regulatory guidance, expectations and decisions.

The following explanatory text is included in all regulatory documents:

- The CNSC develops regulatory documents under the authority of paragraphs 9(b) and 21(1)(e) of the NSCA.
- Regulatory documents clarify NSCA requirements and associated regulations, and are an integral part of the regulatory framework for nuclear activities in Canada.
- Each regulatory document aims to disseminate objective regulatory information to stakeholders including licensees, applicants, public interest groups and the public, and promote consistency in the interpretation and implementation of regulatory requirements.

Additional information on the CNSC's regulatory documents program is available online at nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents.

As outlined in the CNSC regulatory policy P-299, *Regulatory Fundamentals*, the CNSC bases its regulatory requirements on industry, national and international standards and best practices, including those of the IAEA. Canada has actively helped the IAEA develop nuclear safety standards and create technical documents that outline more specific technical requirements and best practices for radioactive waste management and decommissioning.

Annex 3.6.2 includes a list of the CNSC's regulatory documents. Two of these documents are specific to radioactive waste and spent fuel. For uranium mine and mill waste, the regulatory guidance document *Management of Uranium Mine Waste Rock and Mill Tailings* was published in March 2012. Other, more generic regulatory documents relating to action levels, decommissioning, environmental protection and public information programs may also apply to WMFs. A complete list of regulatory documents is available at nuclearsafety.gc.ca/eng/acts-and-regulations/regulations.

The CNSC's regulatory documents for radioactive waste, decommissioning and public information/disclosure are as follows:

- **Regulatory policy P-290, *Managing Radioactive Waste* –** The CNSC issued this document in July 2004 following extensive consultation with the public, the nuclear industry and other stakeholders. It identifies the need for long-term management of radioactive waste and non-radioactive hazardous waste arising from licensed activities. P-290 is discussed in section B.5.

- **Regulatory guide G-320, *Assessing the Long Term Safety of Radioactive Waste Management* –** The CNSC published this regulatory guide in December 2006 to assist licensees and applicants in assessing the long-term storage and disposal of radioactive waste. It was developed using provincial, federal and international documents following a consultation with the nuclear industry in Canada. G-320 is discussed in more detail in section B.6.

- **Regulatory guide G-219, *Decommissioning Planning for Licensed Activities* –** This document provides guidance on the preparation of plans for the decommissioning of activities licensed by the CNSC. G-219 is described in section F.8.

- **Regulatory document RD/GD-99.3, *Public Information and Disclosure Protocols* –** This document provides guidance on the development and implementation of the requirements for public information programs and disclosure protocols. For more details, see section H.7.1.

- **Regulatory document RD/GD-370, *Management of Uranium Mine Waste Rock and Mill Tailings* –** This document sets out the requirements for the sound management of mine waste rock and mill tailings resulting from site preparation, construction, operation and decommissioning of uranium mine or mill projects in Canada to ensure the protection of the environment and the health and safety of people. It also provides guidance to applicants regarding the CNSC's expectations for new mining projects throughout Canada on the management of waste rock and tailings generated by uranium mining and milling operations.

The CNSC regulation-making process includes extensive consultation with both internal and external stakeholders. In developing its consultation plan, the CNSC recognizes the multiplicity of stakeholders, with their different levels of interest, points of view and expectations concerning the nature and content of a proposed regulatory regime.

Generally, the CNSC's regulations allow the licensees some flexibility to define for their circumstances the means to comply with legislative requirements. Following the March 2011 accident at the Fukushima Daiichi nuclear power station in Japan, the CNSC conducted a thorough review of its regulatory framework and processes. The CNSC Fukushima Task Force was established to review the capability of nuclear power plants – as well as all other nuclear facilities across Canada – to withstand conditions comparable to those that triggered the Fukushima accident.

After reviewing the CNSC's regulatory framework and processes, the Fukushima Task Force confirmed that the Canadian regulatory framework is strong and comprehensive. At the same time, it identified and outlined a series of recommendations aimed at further enhancing the safety of nuclear facilities in Canada. These recommendations included specific proposals to amend certain regulations under the NSCA.

As discussed in Canada's report to the seventh review meeting of the Convention on Nuclear Safety (available at http://nuclearsafety.gc.ca/eng/reactors/power-plants/convention-on-nuclear-safety/index.cfm#sec2), the CNSC has completed the implementation of its integrated action plan in response to the lessons learned from the Fukushima accident. The CNSC action plan also included enhancements to the CNSC's nuclear regulatory framework.

Updates to regulatory documents have been completed. Work is ongoing to amend the *Class I Nuclear Facilities Regulations* and the *Radiation Protection Regulations*.

Brief descriptions of the regulations are provided below, including proposed amendments to the regulations that would be of interest to the Joint Convention. All CNSC regulations may be viewed in full at nuclearsafety.gc.ca/eng/acts-and-regulations/regulations.

General Nuclear Safety and Control Regulations **(GNSCR)**

The GNSCR outline the general information to be included in all licence applications; the obligations of licensees and their workers; definitions of prescribed nuclear facilities, equipment and information; and reporting and record-keeping requirements. They also detail the requirements for an application for a licence to abandon and obligations to provide information on any proposed financial guarantees. Note that these regulations apply to all licensees, including those holding licences for the management of spent fuel and radioactive waste and decommissioning activities. Naturally occurring nuclear substances that are not associated with the development, production or use of nuclear energy are exempt from these regulatory requirements.

As of March 2017, the CNSC is preparing to engage stakeholders on proposed amendments to the GNSCR. Included are requirements to report on nuclear fuel cycle-related research and development activities as well as reporting on the manufacturing of nuclear-related technologies per the agreements the CNSC has in place with the IAEA.

Administrative Monetary Penalties Regulations **(AMPR)**

The CNSC initiated the introduction of the AMPR during the reporting period; the regulations came into force in May 2013. Administrative monetary penalties (AMPs) are monetary penalties imposed by the CNSC, without court involvement, for the violation of a CNSC regulatory requirement. They can be applied to any person or corporation subject to the NSCA. AMPs were proposed to enhance the robustness and effectiveness of the CNSC's enforcement regime and to serve as a credible deterrent, thereby achieving higher levels of compliance. AMPs are not part of the CNSC's cost-recovery mechanism; they are payable to the Government of Canada's Consolidated Revenue Fund.

The AMPR contain three levels of violation for the purposes of AMPs: low, medium and high regulatory significance. Each level has a corresponding monetary penalty range less than or equal to the maximum amount set by the NSCA. The maximum AMPs for individuals and corporations are CAD $25,000 and $100,000, respectively.

Radiation Protection Regulations **(RPR)**

The RPR contain radiation protection requirements that apply to all licensees and others who fall under the mandate of the CNSC. They define the "as low as reasonably achievable" principle, contain limits on radiation doses to workers and members of the public, and require all CNSC licensees to implement radiation protection programs.

The current regulations, introduced in 2000, are based on guidance from the ICRP and IAEA. The CNSC is updating the RPR to align updated international standards, clarify requirements, update and clarify existing requirements for radiation protection during an emergency, and address gaps based on lessons learned since the RPR came into force.

It is anticipated that the amended RPR will come into force in the latter part of 2018.

***Class I Nuclear Facilities Regulations* (CINFR)**

The CINFR detail the information licensees need to supply when applying for different types of Class I nuclear facility licences. Licences are available for each stage in the lifecycle of a Class I nuclear facility, including site preparation, construction, operation, decommissioning and abandonment (i.e., release from CNSC licensing). The CINFR also address record keeping and the certification of reactor operators.

Under the NSCA, one of the definitions of a nuclear facility is “a facility for the disposal of a nuclear substance generated at another nuclear facility.” A nuclear facility also includes, where applicable, the land on which such a facility is located; a building that forms part of the facility; equipment used in conjunction with the facility; and any system for the management, storage or disposal of a nuclear substance. As defined under section 19(a) of the GNSCR, a Class I nuclear facility manages, stores or disposes of radioactive waste and whose resident inventory of radioactive nuclear substances is greater than 10^{15} Bq.

In January 2013, the CINFR were amended to establish 24-month timelines for projects requiring the CNSC’s regulatory review and decision on new applications for a licence to prepare a site for a Class I nuclear facility.

Class II Nuclear Facilities and Prescribed Equipment Regulations

These regulations specify the requirements for the licensing of Class II nuclear facilities and prescribed equipment, including low-energy accelerators, irradiators and radiation-therapy installations.

***Nuclear Substances and Radiation Devices Regulations* (NSRDR)**

The NSRDR provide requirements for the licensing and certification of nuclear substances and radiation devices, use of radiation devices, record keeping and exemption levels. They apply to all licensees of nuclear substances, radioactive sealed sources and radiation devices not covered by other regulations.

***Packaging and Transport of Nuclear Substances Regulations* (PTNSR)**

The PTNSR apply to the packaging and transport of nuclear substances, including the design, production, use, inspection, maintenance and repair of packaging and packages; and the preparation, consigning, handling, loading, carriage, storage during transport, receipt at final destination and unloading of packages. They also cover certification of special-form radioactive material, low-dispersible radioactive material and certain types of packages.

***Nuclear Security Regulations* (NSR)**

The NSR define security-related information requirements and general obligations. They also include information about security requirements for high-security sites and provide security-related requirements for licensing and operation of lower-risk facilities. The NSR are applicable to any CNSC licensee and applicant with respect to Categories I, II and III nuclear material and high-security sites.

***Uranium Mines and Mills Regulations* (UMMR)**

The UMMR detail the information needed for licence applications for uranium mines and mills, along with licensee obligations. Licences are required for each stage of a facility’s lifecycle, including site preparation, construction, operation, decommissioning and abandonment. The UMMR apply to all uranium mines and mills, including management of mill tailings, but not to uranium prospecting or surface-exploration activities.

Nuclear Non-proliferation Import and Export Control Regulations

These regulations govern the import and export of controlled nuclear substances, equipment and information.

Canadian Nuclear Safety Commission Cost Recovery Regulations

These regulations enable the CNSC to recover the actual cost of regulating the nuclear industry equitably through licence fees.

E.4 Comprehensive licensing system for spent fuel and radioactive waste management activities

E.4.1 Licensing procedure

The CNSC maintains the philosophy that a licensee is responsible for the safe operation of its own facilities. Licensees make safety-related decisions routinely; therefore, they must have a robust set of programs and processes in place to ensure adequate protection of the environment and the health and safety of workers and the public. The CNSC performs regulatory oversight and verifies that licensees and operators comply with the NSCA and its regulations.

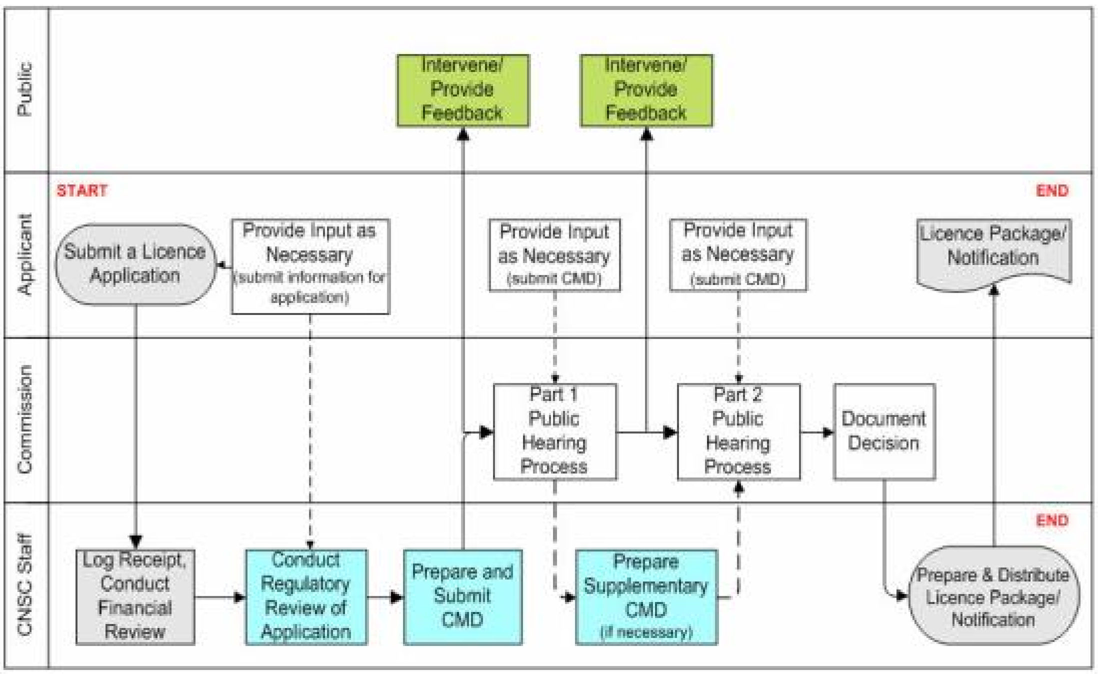

Figure E.4: Process for obtaining a licence for a new Class I facility or uranium mine and mill

Figure E.4 illustrates how an applicant can obtain a licence under the NSCA. First, the applicant must submit to the CNSC an application for a licence. The applicant must provide information and develop programs in accordance with the NSCA and regulations to be considered. The CNSC publishes regulatory documents (including policies, guides, standards and notices) that help licensees meet their regulatory requirements.

Licensees are obligated to adhere to the terms and conditions of a licence, such as references to standards, decommissioning planning and financial guarantee requirements.

An application for a licence may be subject to other legislation and regulations. For example, an environmental assessment under the *Canadian Environmental Assessment Act, 2012* (CEAA 2012) may be required for a designated project regulated under the NSCA and described in the *Regulations Designating Physical Activities* or an environmental assessment may be carried out under the NSCA for projects not listed in the *Regulations Designating Physical Activities* or for projects previously assessed under CEAA 2012 (or its predecessor CEAA 1992). An environmental assessment evaluates potential interactions between projects or activities and the environment. There are opportunities throughout the assessment process for public participation and Aboriginal engagement. Public and Aboriginal engagement opportunities are determined based on the level of interest and the complexity of the facility or activity and its potential interactions with the environment and the public.

Only after a positive decision is made on the environmental assessment (if one is required) may the Commission proceed with a licensing decision. The Commission holds public hearings to consider licence applications for major facilities (see section E.4.3). Under section 37 of the NSCA, the Commission can delegate responsibility for issuing certain types of licences – other than Class I licences and licences for uranium mines and mills – to persons who have been identified as designated officers as defined under the legislation. This can include issuing various types of licences, such as licences for radioactive waste management facilities not defined as Class I nuclear facilities. When a designated officer is delegated this responsibility, no public hearing occurs unless the officer refers the decision back to the Commission using a risk-informed approach. In this case, the Commission will evaluate the need to conduct a public hearing as part of its decision-making process.

The CNSC administers its licensing system in cooperation with other federal and provincial government departments and agencies that work in areas such as health, the environment, transportation and labour.

Once a licence is issued, CNSC staff are responsible for administering the Commission's decision including the development and implementation of a compliance verification program (see section E.6.3) to ensure licensees continue to meet their legislative and licence obligations.

E.4.2 Licence application assessment process

Early communication with the CNSC can help applicants develop a good understanding of the licensing process, regulatory requirements for spent fuel and radioactive waste management facilities, and information to be submitted in support of a licence. Early communication also enables the CNSC to develop a regulatory review plan, which ensures qualified staff are available to carry out the application review.

The management of spent fuel and radioactive waste is regulated through the entire lifecycle – from site preparation, construction and operation to decommissioning and abandonment (see figure E.5). Each phase of the lifecycle requires a separate licence, although a combined licence to prepare site and construct may be requested.

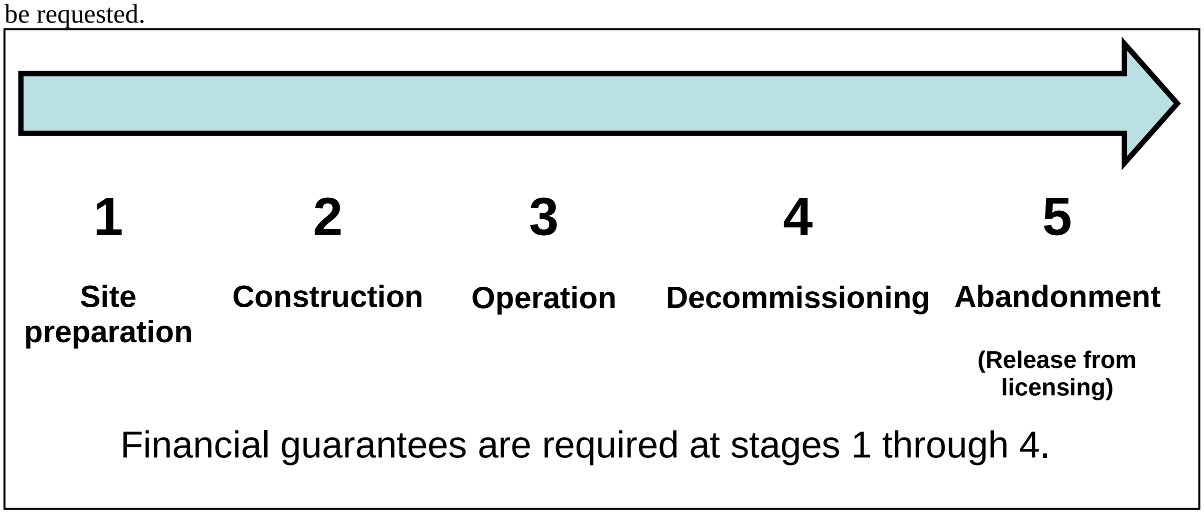

Figure E.5: Lifecycle of the CNSC's licensing approach (step-wise approach/early planning)

E.4.2.1 Licence application

For a new licence, the regulations require applicants to submit comprehensive information on their policies and programs, the design and components of the proposed facility, the manner in which the facility is expected to operate, facility operating manuals and procedures, and any potential impacts on the site or surrounding environment. The design must be such that emissions from the facility meet strict limits under normal operating and upset conditions, as applicants are required to identify the manner by which a facility may fail to operate correctly, predict the potential consequences of such a failure and establish specific engineering measures to mitigate the consequences to tolerable levels. Those engineering measures may include, but are not limited to, multiple barriers to prevent the escape of noxious material. Analyses of potential accidents may be complex, covering a very wide range of possible occurrences.

CNSC staff rigorously review all submissions, using existing legislation and the best codes of practice and experience available in Canada and around the world to ensure regulatory requirements are met. The expertise of the CNSC's staff covers a broad range of engineering and scientific disciplines. Considerable effort is also spent reviewing the analyses to ensure predictions are based on well-established scientific evidence and that defences meet defined standards of performance and reliability.

In addition to reviewing the information described above, section 24(4) of the NSCA places the onus on the CNSC to ensure that the applicant:

- is qualified to carry on the activity that the licence will authorize the licensee to carry on, and

- will, in carrying on that activity, make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed

The comprehensive assessment that takes place during the licensing process may result in defining additional programs and criteria as a condition(s) of the licence. Once satisfied that all of the requirements of the NSCA and its associated regulations are met and that the applicant's documentation is complete and acceptable, CNSC staff prepare a licence recommendation for submission to the Commission – or to a designated officer – for a decision. The recommended licence may include any necessary conditions identified as required during the assessment, including the documentation references submitted in support of the application.

By referring to the applicant's documentation, the licence legally binds the applicant to comply with its own procedures and programs, making them subject to the CNSC's compliance verification and enforcement program.

Licences or licence conditions handbooks may also contain other terms and conditions, such as references to standards, with which licensees must comply. For example, licensees may be required to observe occupational and public radiological exposure limits derived (or adopted) from internationally accepted standards, such as those of the ICRP. Limits for controlled release of gaseous or liquid effluents or solid materials are adopted from complementary regulatory regimes (such as Ontario's *Provincial Water Quality Objectives* or *Metal Mining Limits for Liquid Effluent Releases*) or derived from specific licence conditions, such as the derived release limits. The CNSC may also adopt other standards that have been established by organizations such as the CSA Group or the American Society of Mechanical Engineers.

E.4.2.2 Joint regulatory review process

Although the nuclear sector is subject to federal jurisdiction through the NSCA, the CNSC uses a harmonized or joint review approach with other federal, provincial or territorial departments in such areas as health, environment, transport and labour. The CNSC expects nuclear facilities to comply with all applicable federal and provincial regulations.

In recognition of this dual jurisdiction, the CNSC has established a joint regulatory process. As a lead agency, the CNSC invites other federal and provincial regulatory agencies to participate in the licensing process when their areas of responsibility could impact the proposed nuclear facility. Those that choose to participate become members of a site-specific joint regulatory group.

This process ensures that the legitimate concerns of federal, provincial and territorial agencies are considered in the regulatory process and are reflected, as appropriate, in the licence in the form of site-specific requirements. For example, the CNSC and the Saskatchewan departments of Environment and Labour have an administrative agreement that optimizes the participation of the Ministry of the Environment and Climate Change (MoECC) and the Ministry of Advanced Education and Skills Development (Labour) in the administration of the CNSC's regulatory regime. The involvement of Labour and the MoECC in the regulation of Saskatchewan's uranium mines and mills helps to better

- protect the health, safety and security of Canadians and their environment
- harmonize the CNSC, MoECC and Labour regulatory requirements and regulatory activities

E.4.2.3 Licence periods

Typical licence periods for radioactive waste management facilities vary from five to 10 years.

In 2002, the CNSC introduced flexible licence periods to allow for enhanced risk-informed regulation of spent fuel and radioactive waste management facilities. The CNSC may consider adjusting licence periods based on licensee performance, facility risks, and compliance and verification findings. Short licence periods will continue to be an option in case of unsatisfactory licensee performance or other considerations. Along with the assignment of longer licence periods, CNSC staff report to the Commission in public meetings at predetermined frequencies (annually or biannually) on the facilities' operation and performance in Regulatory Oversight Reports (RORs).

CNSC staff recommend licence periods using a set of consistent factors. These factors include facility-related hazards, the development and implementation of safety programs (see section E.6.3), the implementation of an effective monitoring and maintenance program, licensee experience and performance, the *Canadian Nuclear Safety Commission Cost Recovery Fees Regulations,* and the facility's planning cycle.

Regardless of the specifics of the licence period or the schedule of RORs, CNSC staff have an obligation to inform the Commission of any significant event at a nuclear facility licensed by the CNSC. Should such an event occur, all operational issues must be included in an emergency notification report to be presented to the Commission.

E.4.2.4 Licence renewals

Applications for a licence renewal or amendment require the CNSC to revisit the original documentation and assessment in light of licensee performance and compliance history (see section E.6.1). The CNSC bases its review on performance history, risk and expert judgment. The CNSC also may add, modify or remove licence conditions.

E.4.2.5 Licence amendments

Amendments to spent fuel, radioactive waste management, and uranium mine and mill licences can modify existing licence conditions; add new licensing requirements; or approve revisions to the facility design, operations or licensee programs referenced in the licence. Examples of documents to review before reaching a decision include operating policies and principles, radiation protection requirements and emergency plans. Designated officers, when delegated by the Commission, can typically amend non-Class I licences.

Licence conditions handbook amendments

A licence conditions handbook (LCH) is a separate document linked to the licence that outlines the CNSC's expectations and contains compliance verification details for each specific licence condition. Compliance verification details include activities and reporting requirements. The LCH was developed as a tool that can more easily be updated as the licensees' programs are revised to align with operations. Amendments to the LCH, when delegated by the Commission, can be approved by CNSC staff.

E.4.3 Information and public participation

E.4.3.1 Public hearings

As discussed in the CNSC licensing procedure (see section E.4.1), the NSCA requires that a public hearing be held before a major licensing decision is made or whenever it is in the public interest to do so. Public hearings, such as the one pictured in figure E.6, give organizations and interested members of the public a reasonable opportunity to comment on matters before the Commission. The *Canadian Nuclear Safety Commission Rules of Procedure* apply to these proceedings and set forth the requirements for matters such as the public notification in advance of public hearings and publication of decisions from public hearings.

A public hearing may take place in one or two parts. Most major decisions are made following a two-part public hearing process. The first and second parts may be several months apart (the usual time frame is 60 days) to allow stakeholders enough time to review the application and recommendations. The CNSC's licensing process is described in annex 3.7.

E.4.3.2 Panels

The NSCA authorizes the president of the CNSC to establish, when needed, panels of the Commission consisting of one or more members. The panel, as directed by the president, may exercise any or all of the powers, duties and functions of the Commission, with only a few enumerated exceptions. An act of a panel is deemed to be an act of the Commission.

Figure E.6: Commission members during public hearing

E.4.3.3 Hearings in writing

Some applications pertain to minor changes or updates that are of low safety significance to a facility's operations and reference documentation. The Commission may therefore decide that a full public hearing is not necessary when the amendments are more administrative in nature and there is less public interest in the matter being considered. These matters may be dealt with via a hearing in writing, with public participation.

The process for a hearing in writing differs from that of a public hearing. This could mean shortened notification requirements, reduced time periods or limited participation. A hearing in writing may be held in a closed or public forum. A notice of hearing about upcoming matters to be dealt with through the hearing in writing process is published on the CNSC website. Following the deliberations of the Commission, a record of decision is published on the CNSC's website.

E.4.3.4 Public participation in the hearing and meeting processes

The CNSC's outreach program is described in annex 3.11.

As public hearings and meetings are fundamental to the CNSC's outreach activities, all Commission proceedings are open to the public. The Commission publishes on its website and sends advance notices of hearings or meetings to a list of more than 4,000 subscribers. In addition, on a case-by-case basis, the Commission may offer financial support through its Participant Funding Program (PFP) to help members of the public with the costs associated with participating in a hearing or meeting. In most cases, the notices posted online and sent to subscribers will provide information on the availability of PFP funding.

The Commission publishes a Record of Proceedings, including detailed Reasons for Decision, to explain the basis for its licensing decisions. The Commission also publishes minutes to record the outcome of Commission meetings. Complete written transcripts of all public proceedings are posted online within days of a hearing or meeting – a best practice confirmed through benchmarking analysis. These documents, along with other information about the Commission's proceedings and decisions, are available to the public at nuclearsafety.gc.ca/eng/the-commission/hearings/documents_browse.

In addition to attending a hearing in person, there are other ways for the public to watch and participate in Commission proceedings remotely. For example, even when hearings are held in Ottawa, affected communities may use videoconferencing as a cost-effective way to participate. The Commission offers teleconference and videoconference services to facilitate access to public hearings and meetings. As part of the CNSC's ongoing efforts to enhance its visibility among Canadians and provide easier access to Commission proceedings, the public can view live webcasts of all public hearings and meetings through the Commission's external website. Archived webcasts of past proceedings are also available online for a minimum of three months following the end of the proceedings.

In an effort to encourage public participation, the Commission also holds licensing hearings and Commission meetings in local communities. As an example, in November 2015, the CNSC held a public hearing in the municipality of Courtice, Ontario, for the licence renewal application by Ontario Power Generation (OPG) for the Darlington Nuclear Generating Station. This public hearing, lasting four days, provided an opportunity for interested members of the public to provide oral and written interventions. A total of 285 intervenors participated in this hearing, encompassing 85 oral interventions and 200 written interventions.

An additional example considers the November 2016 public hearing and public meeting that occurred in the municipality of Port Hope, Ontario. A two-day public hearing for the licence renewal request by Cameco for the Port Hope Conversion Facility was followed by a one-day public meeting. This public meeting covered topics such as the status report for nuclear power plants, regulatory oversight reports for Nuclear Processing, Small Research Reactor and Class IB Accelerator Facilities and an update on the Port Hope Area Initiative, a project taking place in the region in and around Port Hope. Interventions were solicited for both the hearing and the meeting, and members of the public provided written and oral interventions at both proceedings. Over the course of the two proceedings, there were 32 oral interventions and 23 written interventions for a total of 55 interventions.

The number of Commission hearing and meeting days is always adjusted to ensure all interested intervenors have an opportunity to contribute. As long as the request to participate relates to the matter before the Commission, an intervenor will not be turned away. In 2014–15, the Commission held five public hearings over the course of five hearing days – with a total of 59 intervenors participating through written and oral submissions – and held 23 hearings in writing, for which one intervenor contributed. In addition, the Commission held eight public meetings that included 15 intervenors. In 2015–16, the Commission conducted five public hearings over a total of 11 days, where it considered submissions from applicants and input from CNSC staff and stakeholders. A total of 362 intervenors participated through written and oral submissions in those hearings. In the same year, the Commission held six hearings in writing, for which three intervenors participated. In addition, the Commission held a total of five public meetings that included seven intervenors. In all, the Commission spent three days in local communities conducting public hearings and meetings in 2015–16.

E.5 System of prohibition for the operation of spent fuel or radioactive waste facilities without a licence

Under section 26 of the NSCA, no person may possess, package, transport, manage, store or dispose of a nuclear substance except in accordance with a licence issued by the CNSC or when exempted by the regulations. As all spent fuel and radioactive waste contains nuclear substances, these are subject to the NSCA and its associated regulations.

E.6 System of institutional control, regulatory inspection, and documenting and reporting

E.6.1 Description of the CNSC Compliance Program

As stated in section E.4.1, only the Commission or a designated officer can issue licences to operate spent fuel and WMFs.

Section 30 of the NSCA authorizes CNSC staff who are designated inspectors to carry out inspections and verify licensee compliance with regulatory requirements, including licence conditions. Licensees must have an approved set of programs and processes in place that adequately protect the environment and human health and safety.

CNSC regulatory policy P-211, *Compliance*, is implemented through a corporate-wide compliance program, the output of which is integral to the licence to operate renewal process and which integrates all three compliance elements:

- promotion to encourage compliance
- verification activities to confirm licensees are complying with safety provisions
- reactive control measures to enforce compliance
- The CNSC rigorously enforces its regulatory requirement through a variety of measures such as inspections, reviews, audits and assessments. CNSC staff:
- apply regulatory requirements in a manner that is fair, predictable and consistent
- use rules, sanctions and processes securely founded in law and graded according to the seriousness of the violation, the compliance history of the licensee and the actions of the licensee once the violation is discovered
- establish and maintain a compliance verification program based on the level of risk the radioactive material or activity presents to human health, its authorized use and the environment
- ensure compliance activities are conducted by trained and qualified staff
- develop and implement a compliance promotion strategy and a compliance enforcement strategy
- implement an AMP system to increase compliance

E.6.2 Compliance promotion

The CNSC Compliance Program aims to inform the regulated community of the rationale behind the regulatory regime, disseminate information to regulated areas about regulatory requirements and standards, and design realistic and achievable requirements and standards. Promotional activities include communication and consultation.

The most common communication and consultation activity used to promote compliance consists of regularly scheduled meetings with the licensee, at which ongoing activities and developments, licensing and compliance issues, safety performance, outstanding commitments and emerging issues are discussed.. The frequency of planned meetings varies by licensee, facility and risk level.

E.6.3 Compliance verification

To verify compliance with regulatory requirements and licence conditions, the CNSC:

- evaluates a licensee's operations and activities
- reviews, verifies and evaluates licensee-supplied information
- ensures administrative controls are in place
- evaluates a licensee's remedial action and any actions taken to avoid future incidents

Programs cited in the licence or previously assessed during the licence application review process are evaluated. The CNSC checks that a licensee's activities meet acceptance criteria derived from:

- legal requirements
- the CNSC policies, standards or guides that clarify how the Commission intends to apply the legal requirements
- licensee-supplied information that expressly states the licensee's intentions to meet the legal requirements in performing the licensed activity
- the expert judgment of CNSC staff, including knowledge of industry best practices

CNSC staff assess licensee programs and their implementations according to the following four ratings:

- FS Fully satisfactory
- SA Satisfactory
- BE Below expectations
- UA Unacceptable

The following categories – commonly referred to by the CNSC as "safety and control areas" – are used to summarize all assessment and inspection results as well as group licensee programs and performance in several safety areas being evaluated for licensing purposes. A standard list of programs or topics has been developed for each type of facility and may include:

- management system
- human performance management
- operating performance
- safety analysis

- physical design
- fitness for service
- radiation protection
- conventional health and safety
- environmental protection
- emergency management and fire protection
- waste management
- security
- safeguards and non-proliferation
- packaging and transport

Compliance verification results are used in licence renewals and RORs.

E.6.3.1 Regulatory inspections

Type II inspections

A type II inspection is a planned and documented activity to verify the results of licensee processes and not the processes themselves. They are typically routine (item-by-item) inspections and rounds, usually of specified equipment, facility material systems or discrete records, products or outputs from licensee processes.

Type I inspections

A type I inspection is a systematic, planned and documented process to determine, through objective evidence, whether a licensee program, process or practice complies with the regulatory requirements as expressed in the compliance criteria associated with the inspection. Type I inspections are also known as audits or evaluations.

E.6.3.2 Regulatory reporting

CNSC staff also assess the contents of submitted operating reports. Licensees are required to submit operating reports to the CNSC according to licence conditions. The frequency of these submissions varies by licensee, facility and risk level but generally ranges from quarterly to annually. The analysis of safety-significant events is another component in the safety performance evaluation of a facility. The objective of these analyses is not for the CNSC staff to duplicate reviews done by licensees but to ensure licensees have adequate processes in place to take corrective actions when needed and integrate lessons learned from past events into day-to-day operations.

Figure E.7: Compliance verification taking place in a nuclear facility

E.6.4 Compliance enforcement

The CNSC uses a gradual approach to enforcement, commensurate with the risk or regulatory significance of the violation. The enforcement tools available to the CNSC are:

- discussion
- verbal or written notice
- warning
- increased regulatory scrutiny
- AMPs
- issuance of an order
- licensing action (e.g., amendment or suspension of part of a licence)
- revocation of personal certification
- prosecution
- revocation or suspension of a licence

Depending on the effectiveness of the initial action, subsequent enforcement measures of increasing severity may be invoked.

The AMP regulations authorize the use of financial penalties for violations of the NSCA. They are designed to address violations and instances of non-compliance with the NSCA early and effectively so that larger issues do not arise. A total of 27 AMPs have been issued to CNSC licensees as of March 31, 2017.

E.7 Considerations taken into account in deciding whether or not to regulate nuclear substances as radioactive waste

Section E.3.1 indicates that the CNSC is authorized under the NSCA to regulate nuclear substances so as to protect human health and the environment. CNSC regulatory policy P-290, *Managing Radioactive Waste,* defines radioactive waste as any waste containing a nuclear substance and promotes the following key principles with respect to radioactive waste:

- The generation of radioactive waste should be minimized to the extent practicable.
- Radioactive waste should be managed in a manner that is commensurate with its radiological, chemical and biological hazards.

For a full description of P-290, see section B.5.

E.8 Establishment of the CNSC

E.8.1 Funding the CNSC

The CNSC is a departmental corporation listed in schedules II and V of the *Financial Administration Act.* The NSCA stipulates that the CNSC report to the Parliament of Canada through a member of the Privy Council for Canada who is designated by the Governor in Council. Currently, this designate is the Minister of Natural Resources Canada. The Commission requires the involvement and support of the minister for special initiatives such as amendments to regulations and requests for funding.

The CNSC's operations are funded primarily from fees collected from industry (licensees), pursuant to the *CNSC Cost Recovery Fees Regulations*, and secondarily through an annual appropriation from Parliament. The CNSC has a revenue-spending authority that allows it to spend the revenues collected to fund the cost of activities that are cost-recoverable per the *CNSC Cost Recovery Fees Regulations*. This authority provides a sustainable and timely funding regime to address rapid changes in the regulatory oversight workload associated with the Canadian nuclear industry.

E.8.2 Maintaining competent personnel

During the March 2014 to March 2017 reporting period, the CNSC's human resource management efforts continued to be focused on maximizing organizational flexibility while maintaining a highly skilled and engaged workforce. Since the last report, the CNSC has invested significant time and effort to increasing its strategic and operational workforce planning capability, which has included using workforce analytics information produced quarterly to help better understand the risks it faces in protecting core organizational capabilities and competencies essential to carrying out its mandate.

Given the changing landscape of the Canadian nuclear industry and its scientific, technical, math and engineering labour market, the retirement of senior experienced regulatory and technical employees remains the greatest workforce risk that the CNSC faces between now and 2025. To mitigate this risk, the CNSC has initiated action centered on the design of the organization, the recruitment and renewal of the workforce, learning and leadership development, and employee engagement and retention.

In 2014, the CNSC consulted with international nuclear regulators and other Canadian science-based organizations to understand their workforce challenges and how they are organized to meet those challenges. This review indicated that the CNSC faced similar human resource challenges as these other regulators and organizations. The findings also concluded that, as an organization, the CNSC was not leveraging the full spectrum of work levels to encourage employee competency development and career progression, thereby leaving it vulnerable to significant retirement risk. In 2015, the CNSC Management Committee approved a CNSC workforce profile to 2025 that would see the organization begin to more effectively use existing working levels to grow talent and transfer knowledge.

With respect to workforce renewal, the CNSC undertook a significant recruitment campaign to attract and hire more than 50 recent science and engineering graduates – approximately five percent of the CNSC's workforce. These new graduates were hired into a variety of CNSC regulatory and technical business lines and were required to carry out a work assignment with another area over the course of a two-year term. Training plans were established and destination positions were identified to ensure these new graduates were then able to participate in a selection process to secure continuous employment. The CNSC is monitoring the retention of these new employees.

Providing employees with an opportunity to diversify their work experience and grow their knowledge, skills and abilities is critical to offsetting the negative impacts of attrition. Individual learning plans continue to be mandatory, ensuring managers and employees work together to build or maintain the skills required to fulfil the responsibilities of an employee's current duties and prepare them for future careers.

In addition to more than 100 in-house courses offered each year, the CNSC encourages employees to take part in informal learning activities such as work assignments, coaching and mentoring, independent study and on-the-job training. During 2014–16, employees in regulatory and technical operations areas, on average, took part in 16 days or more of training annually.

The CNSC recognizes that technical competencies are critical but not sufficient to the effective performance of the organization. As such, the organization has developed its own set of key behavioural competencies that are expected of all CNSC employees in addition to the Government of Canada's key leadership competencies for public service executives, which were formally adopted in 2015. Key leadership competencies have been fully integrated into executive recruitment, development, succession management and performance management practices. Work is underway now to complete the integration of key behavioural competencies into all human resources management practices.

E.8.2.1 Aboriginal consultation

As an agent of the Government of Canada and as Canada's nuclear regulator, the CNSC recognizes and understands the importance of consulting and building relationships with Canada's Aboriginal peoples. The CNSC ensures all of its licensing decisions under the NSCA and environmental assessment decisions under the CEAA 2012 uphold the honour of the Crown and consider Aboriginal peoples' potential or established Aboriginal and/or treaty rights pursuant to section 35 of the Constitution Act, 1982 (together, the "Aboriginal Interests").

The CNSC is also mindful of its role as an independent administrative tribunal, which confers on it the duty to fairly treat all participants in its proceedings. When developing and implementing Aboriginal consultation processes, the CNSC takes into account the guiding principles that have emerged from Canada's case law and best consultation practices as outlined in *Aboriginal Consultation and Accommodation – Updated Guidelines for Federal Officials to Fulfill the Legal Duty to Consult – March 2011*.

In 2016, CNSC published REGDOC 3.2.2, *Aboriginal Engagement*, which sets out requirements and guidance for licensees whose proposed projects may raise the Crown's duty to consult. While the CNSC cannot delegate its obligation, it can delegate procedural aspects of the consultation process to licensees. The information collected and measures proposed by licensees to avoid, mitigate or offset adverse impacts may be used by the CNSC in meeting its consultation obligations. The requirements in this document are meant to ensure potential or established Aboriginal and/or treaty rights are considered and proper implementation will lead to more effective and efficient Aboriginal engagement practices, strengthen relationships with Aboriginal communities, assist the CNSC in meeting its duty to consult obligations, and reduce the risk of delays in the regulatory review processes.

Insofar as its statutory functions allow, the CNSC supports a whole-of-government approach to Aboriginal consultation, with an aim to coordinating consultative efforts, where feasible, with other federal, provincial or territorial regulatory departments and agencies through a one-window approach with respect to environmental assessments and licensing activities.

Further information is available on the CNSC website at nuclearsafety.gc.ca/eng/resources/aboriginal-consultation.

E.8.2.2 Management system

The CNSC aligns its management system in accordance with the requirements and guidance set out in both the IAEA's general safety requirements for integrated management systems, *Leadership and Management for Safety* (GSR Part 2), and the Government of Canada's framework for management excellence, which is known as the Management Accountability Framework.

To help the continual strengthening of the management system, the CNSC's Internal Quality Management Division coordinates the management of all priority improvement initiatives to improve corporate-wide alignment and integration throughout the organization.

A stronger, more robust management system allows the CNSC to deliver on key goals and objectives across all areas (such as safety, health, environment, quality, finance, human resources and security) in a balanced, harmonious and optimal manner. In defining and applying a common set of principles, practices and processes across the entire organization, the management system provides the CNSC with overarching and uniform management structure by:

- coherently and consistently bringing together and managing all of the organization's regulatory and business requirements
- mapping out and managing processes as part of a larger, single integrated system to minimize both gaps in direction/guidance and duplication of effort
- clarifying roles, responsibilities and authorities across all areas and all levels
- providing a consistent, robust platform for enabling continual improvements

As the top-tier document, the CNSC *Management System Manual* summarizes the integrated management system and provides a strong base for aligning management system-related documents such as policies, processes, procedures, work instructions, criteria, forms and guides. These internal documents are developed on a priority basis and are driven by the need for additional guidance and direction for staff, management, licensees and other key stakeholders. This practical approach helps the CNSC to continually strengthen its management system such that it remains comprehensive, well documented and seamlessly implemented.

E.8.2.3 Integrated Regulatory Review Service missions to Canada

In 2009, the CNSC hosted an IAEA Integrated Regulatory Review Service (IRRS) mission to Canada.

The scope of the mission included all activities and facilities licensed by the CNSC (including the regulation of WMFs), with the exception of import and export licences. All activities and facilities within scope were assessed with respect to the eight IRRS modules:

- Module I Legislative and governmental responsibilities
- Module II Responsibilities and functions of the regulatory body
- Module III Organization of the regulatory body
- Module IV Authorization
- Module V Review and assessment
- Module VI Inspection and enforcement
- Module VII Regulations and guides
- Module VIII Management system

Technical areas identified as out of scope for the IRRS mission to Canada included security, emergency preparedness and safeguards.

The 2009 IRRS peer review provided excellent feedback to the CNSC. Recommended improvements were integrated with the CNSC's ongoing improvement initiatives for completion within its Harmonized Plan for Improvement Initiatives.

In response to the IRRS mission recommendations, CNSC staff developed an evergreen action plan for modernizing CNSC's regulatory framework with respect to the regulatory requirements for spent fuel and radioactive waste. Per the regulatory framework plan, CNSC focused on the following related documents:

- an information document on the licensing of geological repositories
- a regulatory guide for the siting of a geological repository
- a regulatory guide for the post-closure of a geological repository
- a regulatory guide for radioactive waste management programs
- a revision of regulatory guide G-320, *Assessing the Long Term Safety of Radioactive Waste Management*

CNSC continues to work toward a consolidated regulatory framework for waste and decommissioning consisting of a suite of updated regulatory documents and analyzing the need for new waste regulations. A discussion paper on the proposed approach was issued for public consultation in 2016.

In 2011, the CNSC hosted a follow-up IRRS mission to review the progress on measures taken to date for addressing the recommendations and suggestions presented in the 2009 IRRS mission report. The CNSC's role in regulating the transport of radioactive material was added at the request of the CNSC. Additionally, a new IRRS core module focusing on the regulatory implications of the Fukushima Daiichi accident was included for review at the request of the CNSC. One policy issue regarding special arrangements for the transport of radioactive material was also discussed during the mission.

The 2011 IRRS review team commended the CNSC for its systematic approach to completing the recommendations and suggestions from the 2009 IRRS mission. The review team also concluded that the regulatory framework for the transport of radioactive material was well established and that the CNSC regulatory response to the Fukushima Daiichi accident was prompt, robust and comprehensive.

In May 2013, the CNSC confirmed the closure of all actions related to both the 2009 IRRS mission and the 2011 follow-up mission.

The 2013 *CNSC Integrated Action Plan on the Lessons Learned from the Fukushima Daiichi Nuclear Accident* called for continued cooperation between the CNSC and its international peers. A specific commitment was expressed for Canada to conduct Operational Safety Review Team (OSART) missions at all Canadian nuclear generating stations. To date, two OSART missions were successfully completed, one at Bruce B Nuclear Generating Station (December 2015) and the second at Pickering Nuclear Generating Station (October 2016). CNSC has recently established a national standard for Potassium Iodide (KI) pill distribution. Nuclear power plant licensees are required to ensure that KI pills are pre-distributed to individuals living or working near a nuclear power plant. During the 2016 mission, OSART identified the KI pill distribution campaign organized by the licensee as a "Good Practice".

Also included was a commitment for continued collaboration with peers to review national experiences in the conduct of lessons learned on nuclear facilities post-Fukushima. As such, in 2015 the CNSC hosted an IAEA International Physical Protection Advisory Service (IPPAS) mission to review national nuclear security practices in Canada.

For more information on CNSC collaboration with international partners, including publicly posting of IRRS reports, visit nuclearsafety.gc.ca/eng/resources/international-cooperation.

E.8.2.4 International Physical Protection Advisory Service mission to Canada

The IPPAS was established by IAEA in 1995. The service is a fundamental part of the IAEA's efforts to help its Member States establish and maintain an effective national nuclear security regime to protect against the unauthorized removal of nuclear and other radioactive material as well as the sabotage of nuclear facilities, other associated facilities and material during transport. IPPAS fulfils this function while recognizing that the ultimate responsibility for physical protection lies with the Member State.

The IPPAS provides peer review of the implementation of relevant international instruments – in particular the *Convention on the Physical Protection of Nuclear Material* together with its 2005 amendment. It also peer reviews the implementation of the IAEA nuclear security series – in particular the fundamentals and recommendations.

The October 2015 IAEA IPPAS mission to Canada was highly successful. IAEA delegates noted in their final report that Canada has a "mature and robust nuclear security regime." The report included three recommendations, 30 suggestions and 21 good practices. CNSC has elected to address the recommendations and suggestions through its Harmonized Plan. A formal IPPAS management action plan was approved and findings were assigned to CNSC subject matter experts for action. Good practices will be shared with various stakeholders but will not be addressed in the management action plan.

IPPAS missions compare the procedures and practices employed by a member state with the obligations specified under INFCIRC/274/Rev.1, *Convention on the Physical Protection of Nuclear Material*, as well as with the existing international consensus guidelines provided in relevant IAEA nuclear security series publications – in particular NSS No. 13, *Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5)*.

The advice rendered must address the physical protection regime and physical protection systems and measures for a wide range of nuclear programs that include a variety of nuclear and other radioactive material, such as radioactive sources, and different types of nuclear and radioactive material facility, such as power reactors, research reactors and nuclear fuel cycle facilities.

The IPPAS missions are based on a modular approach. The current set of five modules is:

- Module I National review of nuclear security regime for nuclear material and facilities
- Module II Nuclear facility review
- Module III Transport review
- Module IV Security of radioactive material and associated facilities and associated activities
- Module V Information and computer security review

Canada elected to have the IPPAS mission review all five modules.

Findings from the 2015 IAEA IPPAS mission to Canada involve not only stakeholders internal to the CNSC but also external stakeholders in the form of licensees, police forces of jurisdictions and a number of Government of Canada departments and agencies whose mandates and capabilities extend beyond the scope of the CNSC.

The licensees that participated in the mission (Bruce Power, OPG, Nordion, McMaster University) and their industry peers from High-Security Nuclear Facilities have been briefed on the findings from the IPPAS mission. CNSC staff provided guidance on how to address each area that impacts the licensed facilities that may be impacted by the findings. CNSC also encouraged those licensee participants from the mission to share with their peers for benchmarking purposes.

Review of the Western Used Fuel Dry Storage Facility

OPG participated in the IPPAS mission to Canada, which included contributing to a workshop in May 2015, responding to interviews and submitting to an international review of its practices during the mission in October 2015.

From the workshop to the preparatory meeting to logistical coordination and finally to the mission and its conclusion, OPG staff assisted with the IPPAS mission by facilitating a visit that demonstrated nuclear security in action. Such extensive visits are crucial in providing a thorough peer review of Canada's nuclear security regime and reflect highly both on OPG and Canada as a whole. The IPPAS team members left their visit to the Western Used Fuel Dry Storage Facility with a greater appreciation for the materials, policies and techniques employed to protect radioactive waste in Canada.

E.9 Supporting the separation of roles

E.9.1 Separation of the CNSC and organizations that promote and use nuclear energy

The NSCA is distinct and comprehensive legislation for the regulation of nuclear activities and the separation of functions of the regulatory body from organizations that promote or use nuclear energy. The CNSC's mission (see section E.3.1) focuses clearly on the health and safety of persons and the protection of the environment and does not extend to economic matters. The CNSC operates at arm's length of, and reports directly to, the Parliament of Canada.

Section 19 of the NSCA authorizes "the Governor in Council [to], by order, issue to the Commission directives of general application on broad policy matters with respect to the objects of the Commission." Any political directives given to agencies (such as the CNSC), however, must be of a general nature and cannot fetter the Commission's decision-making authority in specific cases. In addition, all directives must be published in the *Canada Gazette* and placed before each House of Parliament.

E.9.2 Values and ethics

The CNSC has a firmly entrenched values and ethics regime, which serves to strengthen and support governance and ethical leadership. The CNSC's Office of Audit and Ethics (OAE) administers five ethics-related programs:

- The Values and Ethics Program provides employees with counselling and techniques for strengthening relationships in the workplace and with stakeholders, as well as practical tools for ethical decision-making.
- The Internal Disclosure Program helps employees safely and constructively disclose wrongdoing and protect them from reprisal.
- The Conflict of Interest and Post-employment Program gives the CNSC and employees tools to prevent and avoid situations that could create the appearance of conflicts of interest or result in a potential or actual conflict of interest.
- The Political Activities Program offers guidance to employees who seek to participate in political campaigns and reviews requests to run for office in federal, provincial and municipal elections.
- The External Complaints Program offers members of the public and the industry an opportunity to voice their concerns to a neutral CNSC entity.

The External Complaints Program was established in September 2015. Its purpose is to ensure all external complaints are first reviewed by a neutral CNSC entity, respond consistently to allegations and plaintiffs, provide a single external complaints window, ensure all files are monitored to closure, and provide annual reporting.

Through this program, members of the public, licensee employees and licensee site contractors can make allegations regarding power plant design, construction, operation and maintenance; radiation protection, safeguards and security; wrongdoing or harassment, intimidation, retaliation and discrimination related to raising safety concerns; concerns related to the CNSC's mandate; and misconduct associated with CNSC employees.

The external complaint process starts with a plaintiff contacting the CNSC through phone, email or regular mail to make an allegation. The first staff member to receive the information contacts the OAE and completes the external complaint form.

The OAE conducts a preliminary analysis of the nature of the allegation. The OAE forwards complaints of technical matter to the pertinent director general but keeps the file when allegations are associated with fraud, values and ethics, conflicts of interest, or disclosures that involve CNSC management or staff. The following steps are then taken:

- Either the pertinent director general assesses the issue or the OAE conducts a fact-finding analysis.
- The OAE or pertinent director general determines the next steps (e.g., inspection, regulatory actions).
- The OAE or pertinent director general monitors file progression, responds to plaintiffs and closes file.
- Finally, the OAE aggregates a list of the complaints for annual reporting.

Subject to applicable legislation, regulations and policies, the External Complaints Program adheres to the principles of fairness and equity to alleged wrongdoers and plaintiffs, as well as to the protection of plaintiff identity and the confidentiality of information provided.

Between September 2015 and August 2016, the OAE received 22 complaints. Most complaints were of technical nature and appear to be related to poor work standards and improper individual workplace practices. All files except for one have been closed. The process, timing and, in some cases, how complaints are handled are now monitored by the pertinent director general and the OAE. This provides assurance that files receive appropriate attention, follow-up and closure.

Section F – Other General Safety Provisions

F.1 Scope of the section

This section addresses articles 21 (Responsibility of the Licence Holder) to 26 (Decommissioning) of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. It provides information about the steps Canada takes to meet its obligations for general safety at the national and facility levels. This section also addresses the requirements of several International Atomic Energy Agency (IAEA) standards, including:

- Article 21: Responsibility of the Licence Holder – IAEA Safety Standard GS-R-1
- Article 22: Human and Financial Resources – IAEA Safety Standard GS-R-1
- Article 23: Quality Assurance – IAEA Safety Standards GS-R-1, WS-R-1 and Safety Series 50-C/SG-Q
- Article 24: Operational Radiation Protection – IAEA Safety Standard 115
- Article 25: Emergency Preparedness – IAEA Safety Standard GS-R-2
- Article 26: Decommissioning – IAEA Safety Standard WS-R-2 and Safety Guide WS-G-2.4

F.2 Responsibility of the licence holder

Each licensee in Canada has the prime responsibility for the safety of its spent fuel and radioactive waste management facilities (WMFs). This responsibility includes providing adequate human and financial resources to support the safe management of the spent fuel and radioactive waste management facility over its lifespan.

F.3 Human resources

Adequate human resources are defined as the employment of enough qualified staff to carry out all normal activities without undue stress or delay, including the supervision of work done by external contractors. Paragraph 44(1)(k) of the *Nuclear Safety and Control Act* (NSCA) provides the legislative basis for the qualification, training and examination of staff. Paragraphs 12(1)(a) and 12(1)(b) of the *General Nuclear Safety and Control Regulations* (GNSCR) specify that the licensee must ensure the presence of a sufficient number of trained, qualified workers.

As in the case of many countries with mature nuclear programs, the nuclear sector and the Canadian

Nuclear Safety Commission (CNSC) have both faced challenges in recent years recruiting experienced staff, partly due to an aging Canadian population. The sections that follow outline initiatives the parties have taken to develop sufficient human resources to ensure the long-term sustainability of the workforce.

F.3.1 University Network of Excellence in Nuclear Engineering

Established in 2002, the University Network of Excellence in Nuclear Engineering (UNENE) is an alliance of Canadian universities, nuclear power utilities and research and regulatory agencies working to support and develop nuclear education and research and development capability in Canadian universities. Its purpose is to assure a sustainable supply of qualified nuclear engineers and scientists that can meet the current and future needs of the national nuclear sector. It accomplishes this through university and university-based education, and by encouraging young people to choose a career in the nuclear sector. More information is available at unene.ca.

The alliance consists of a number of Canadian universities, government departments (Natural Resources Canada and the CNSC) and industrial partners including Ontario Power Generation (OPG), the CANDU Owners Group (COG), Bruce Power, Canadian Nuclear Laboratories (CNL), SNC Nuclear, Amec Foster Wheeler and the Nuclear Waste Management Organization (NWMO).

With funding provided by all industry partners, the Natural Sciences and Engineering Research Council and the CNSC are committed to the support of education and research in nuclear science and engineering at the following universities:

- Queen's University
- University of Toronto
- McMaster University
- University of Waterloo
- University of Western Ontario
- Royal Military College of Canada
- University of Ontario Institute of Technology

UNENE funding creates industrial research chairs in specialized areas at these universities, through which students in master's degree and PhD programs are trained. In addition, UNENE sponsors collaborative research of topical interest to industry. It also supports a master of nuclear engineering degree program delivered jointly by participating universities, which is intended for use by the employees of industry partners on a part-time basis.

Examples of current projects undertaken by UNENE include work in best-estimate and uncertainty-based nuclear safety analysis, corrosion and stress-corrosion research related to reactor materials such as Alloy 600, and seismic risk analysis for nuclear power plants.

F.3.2 CANTEACH

The CANTEACH program was established by Atomic Energy of Canada Limited (AECL), OPG, COG, Bruce Power, McMaster University, École Polytechnique de Montréal and the Canadian Nuclear Society to meet succession-planning requirements. The aim of CANTEACH is to develop, maintain and electronically disseminate a comprehensive set of education and training documents. The CNSC and other industry members also contribute information to the program. More information is available at canteach.candu.org.

F.3.3 Ontario Power Generation

OPG's Nuclear Waste Management Division currently comprises approximately 226 full-time employees. Staffing demand fluctuates, depending mostly on attrition from retirements. The Division has recently been reorganized to align with OPG's move to a centre-led model. As such, dedicated support groups such as engineering, health and safety, environment and training have all been moved to central reporting groups rather than being directly managed within the Division. Staff for the skilled and semi-skilled trades are typically recruited from within OPG and, as required, acquired through the external labour marketplace.

OPG's Nuclear Waste Management Division uses the following recruitment and retention strategies, wherever possible:

- **Succession management –** OPG assesses the leadership capabilities and succession/replacement planning for all leadership positions.

- **Advance hiring –** Critical positions within the organization are identified in OPG's succession-management program.

- **Development and co-op student program –** University and college students are recruited in technical and business streams for work terms.

- **Participation in workforce planning within OPG –** To ensure adequate recruitment in advance of hiring needs, staffing demand within the Division is often satisfied through OPG’s internal selection and placement processes. The Division focuses on the skilled operator and maintenance positions with an induction process to provide core skills training.

- **Semi-skilled labour –** When required, labourers are directly hired from community impact areas.

- **Knowledge management –** Managing critical knowledge and the associated knowledge risk when people exit positions (or leave OPG) is a key focus given workforce demographics, impending retirements, role transitions and the training and development required for specialized roles. It is imperative that employees' critical knowledge and expertise are sustained to support ongoing operations.

The Division uses OPG’s knowledge management toolkit and its strategies, tools, and resources to identify and mitigate knowledge risks and sustain critical knowledge within the Division, the result of which culminates in the development of knowledge management plans.

With continued emphasis on succession management, knowledge management, workforce planning and staff development, OPG’s Nuclear Waste Management Division is positively positioned to meet its qualified staffing requirements for both the short and long term.

F.3.4 Nuclear Waste Management Organization

Following the Government of Canada’s selection of the Adaptive Phased Management (APM) approach in 2007, the NWMO began its evolution from a small, study-based group to a sustainable corporation with full responsibility for implementing the plan. Work was undertaken to enhance the organization’s long-term viability and improve its capacity to recruit and retain personnel. Investments were made to ensure resource capacity, expertise, and sound administrative and management policies and practices to provide a foundation for fulfilling the mandate.

On January 1, 2009, the NWMO became its own employer, with the necessary supporting infrastructure including finance, legal services and human resources. Staffing levels increased from 27 at the end of 2007 to 81 one year later, with further increases to 137 by the end of 2016. The initial large staff addition was due to the transfer to the NWMO of OPG personnel who had been working on both NWMO programs and the OPG’s Deep Geologic Repository project for its low- and intermediate-level radioactive waste. A significant benefit of this arrangement was the acquisition of the experience base of an established radioactive waste management and repository team.

Over the past three years, the NWMO has focused on hiring staff and contractors whose specialties match the complex social and technical requirements of the site selection process. The NWMO has reinforced its workforce with the addition of specialists in the fields of repository design and construction, safety assessment, environmental assessment, Aboriginal traditional knowledge, social research, ethics, law, finance, communications, public engagement, transportation and new media. Consistent with the continued community focus of the site selection process, the NWMO has local offices in communities participating in preliminary assessments of site suitability.

NWMO employees are highly skilled professionals who regularly participate in specialized development and training to complement their technical, professional and academic backgrounds. All new staff are required to complete core business needs training. The NWMO continues to recruit staff in all key skill areas. The organization has also developed succession plans to ensure a sustainable senior management team is in place for the future.

Research also helps to shape development of the site preparation process and continues to support its implementation. The NWMO's research capability is supported through contracts with more than a dozen Canadian universities.

The organization works with an extended group of experts from across Canada and internationally to support its design, siting and confidence-building activities. The NWMO also has contacts with many international organizations and has exchange agreements with national radioactive waste management organizations in Sweden, Finland, Switzerland, France, South Korea and the United Kingdom. This ensures best international practices are incorporated.

F.4 Financial resources

F.4.1 General

Canada applies the "polluter pays" principle, by which the Government of Canada has clearly indicated that waste owners are financially responsible for the management of their radioactive waste and has set in place mechanisms to ensure this financial responsibility does not fall on the Canadian public. This position was reaffirmed in the 1996 Government of Canada *Policy Framework for Radioactive Waste* (see section B.4). In 2002, under the *Nuclear Fuel Waste Act*, the owners of spent fuel were specifically required to establish segregated funds to fully finance long-term waste management activities.

F.4.2 Historic waste

In some instances, remedial actions are required on properties not owned by the federal government but where the original owner no longer exists. In these situations, the federal government may make a determination to accept responsibility for management of the wastes on a case-by-case basis. In March 2001, the Government of Canada and the local municipalities in Ontario's Port Hope area entered into an agreement on community-developed proposals to address the cleanup and long-term management of the bulk of Canada's historic wastes, thereby launching the Port Hope Area Initiative (PHAI). In 2012, the Government of Canada announced $1.28 billion in funding to implement PHAI. The management of these wastes, as well as historic wastes located in Canada's North and other locations across Canada, are the responsibility of AECL and being managed by CNL under a government-owned, contractor-operated model.

F.4.3 Financial guarantees

Licensees of nuclear facilities, including spent fuel and radioactive waste management facilities and uranium mines and mills, must provide guarantees that adequate financial resources are available for the decommissioning of these facilities and managing the resulting radioactive wastes, including spent fuel.

Subsection 24(5) of the NSCA provides the legislative basis for this requirement. Paragraph 3(1)(l) of the GNSCR stipulates that, "an application for a licence must contain a description of any proposed financial guarantee related to the activity for which a licence application is submitted." CNSC regulatory guide G-206, *Financial Guarantees for the Decommissioning of Licensed Activities*, covers the provision of financial guarantees for decommissioning activities. Regulatory guide G-219, *Decommissioning Planning for Licensed Activities*, provides guidance on the preparation of plans for the decommissioning of activities licensed by the CNSC. These guides can be viewed at cnsc-ccsn.gc.ca/eng/acts-and-regulations/regulatory-documents.

Financial guarantees must be sufficient to fund all approved decommissioning activities. These activities include not only dismantling, decontamination and closure but also any post-decommissioning monitoring or institutional control measures that may be required, as well as subsequent long-term management or disposal of all wastes, including spent fuel. To ensure that licensees are required to cover the costs of spent fuel only once, the money in the trust funds set up under the *Nuclear Fuel Waste Act* is considered part of the licensee's total financial guarantee to the CNSC.

The CNSC must be assured that it (or its agents) can access adequate funding measures upon demand if a licensee is not available to fulfil its obligations for decommissioning. Measures to fund decommissioning may involve various types of financial guarantees. Acceptable guarantees include cash, letters of credit, surety bonds, insurance and legally binding commitments from a government (either federal or provincial). The acceptability of any of the above measures will be determined ultimately by the CNSC according to the following general criteria:

- **Liquidity** – The proposed funding measures should be such that the financial vehicle can be drawn upon only with the approval of the CNSC and that payout for decommissioning purposes is not prevented, unduly delayed or compromised for any reason.

- **Certainty of value** – Licensees should select funding, security instruments and arrangements that provide full assurance of their value.

- **Adequacy of value** – Funding measures should be sufficient, at all or predetermined points in time, to fund the decommissioning plans for which they are intended.

- **Continuity –** The required funding measures for decommissioning should be maintained on a continuing basis. This may require periodic renewals, revisions and replacements of securities provided or issued for fixed terms. For example, during a licence renewal, the preliminary decommissioning plan may be revised and the financial guarantee updated accordingly. Where necessary, to ensure there is continuity of coverage, funding measures should include provisions for advance notice of termination or intent to not renew.

Since 2000, the CNSC has concentrated on financial guarantees for large complex facilities and has required all major licensees with Class I operating facilities and uranium mines and mills to have financial guarantees in place. Since the last reporting period, CNSC staff broadened the financial guarantee program to users of sealed sources and radiation devices.

F.5 Quality assurance

F.5.1 Quality assurance program requirements

NSCA regulations require licensees to prepare and implement quality assurance (QA) programs for nuclear facilities. The licensees of spent fuel and radioactive waste management facilities submit their overall QA programs to the CNSC before they begin their planned activity. The organization responsible for a facility must establish and implement a QA program for the items and services the facility supplies. The overall QA program may cover the licensed spent fuel and radioactive waste management activities for more than one site. After a licence is granted, the involved organization must demonstrate the effectiveness of the QA programs.

In 2013, the CSA Group issued CSA N286-12, *Management system requirements for nuclear facilities.* The requirement for a management system to meet this standard emphasizes the paramount importance of safety in guiding decisions and actions. CSA N286-12 applies to all nuclear facilities, including spent fuel and WMFs at nuclear power plants. This standard also lists specific requirements for the lifecycle activities of radioactive waste management facilities.

The QA programs for uranium mines and mills facilities must comply with the QA expectations of the NSCA and the *Uranium Mines and Mills Regulations*. The application for a licence must list the QA programs that are being reviewed by CNSC staff. The specific waste management activities are performed under accepted QA programs. Reviews conducted by CNSC staff during a licence application and QA program changes concentrate on an applicable QA program that satisfies CNSC-accepted QA requirements and on the program's ability to:

- consistently define roles and responsibilities for the facility

- implement the QA program in a structured manner

- demonstrate the control of changes and program interactions
- conduct self-assessments and corrective action

F.5.2 Quality assurance program assessment

To assess licensee QA programs or management system effectiveness, CNSC staff review the licensee's program documentation against the criteria established by the referenced requirement documents and standards. CNSC staff also examine the results from the licensee's internal reviews and assessments. After the QA program is accepted, the CNSC plans and carries out compliance verification to ensure the licensee complies with its provisions. When deficiencies are detected, the CNSC produces detailed reports of the findings and forwards them to the licensee for response and corrective actions. Based on the safety significance of the findings, the CNSC may decide an enforcement action is appropriate. Section E.6.4 provides further information on the CNSC's compliance enforcement.

F.6 Operational radiation protection

F.6.1 Keeping radiation exposures and doses as low as reasonably achievable

Operations at Canada's spent fuel and radioactive waste management facilities must be carried out in a manner that ensures radiation exposures and doses to workers, the public and the environment are below the CNSC regulatory dose limits and kept as low as reasonably achievable (ALARA), social and economic factors taken into account. This approach is legislated through the NSCA and the *Radiation Protection Regulations* (RPR). Radiation exposures and doses are kept ALARA through the implementation of a radiation protection program with the following elements:

- management control over work practices
- personnel qualification and training
- control of occupational and public exposure to radiation
- plans for unusual circumstances
- ascertainment of the quantity and concentration of any nuclear substance released as a result of a licensed activity

In addition, the RPR require that every licensee ensure the following effective dose limits are not exceeded:

- 50 millisieverts (mSv) in a year and 100 mSv over five years for a nuclear energy worker
- 4 mSv for a pregnant nuclear energy worker for the balance of pregnancy
- 1 mSv per year for a person who is not a nuclear energy worker (i.e., the public)

Details on proposed amendments to the RPR that will harmonize the RPR with updated international standards (such as those of the International Commission on Radiological Protection) are discussed in section E.3.2.

To ensure consistent application of the ALARA requirement by licensees, the CNSC has issued regulatory guide G-129 rev 1, *Keeping Radiation Exposures and Doses "As Low as Reasonably Achievable" (ALARA)*, to provide further details on regulatory expectations.

F.6.2 Derived release limits

Some nuclear facilities release small quantities of gaseous radioactive material in a controlled manner into the atmosphere (e.g., incineration of radioactive waste) and into adjoining water bodies as liquid effluents (e.g., treated waste water). Radioactive material released from nuclear facilities into the environment through gaseous and liquid effluents can result in radiation doses to members of the public through one or more of the following ways:

- direct irradiation
- inhalation of contaminated air
- ingestion of contaminated food or water

To ensure the regulatory dose limit for members of the public is not exceeded, the RPR limit the amount of radioactive material released in effluents from nuclear facilities. These effluent limits are derived from the public dose limit and are referred to as derived release limits (DRLs). The nuclear sector sets operating targets or administrative limits that are typically a small percentage of the DRLs. These targets are based on the ALARA principle and are unique to each facility, depending on the factors that exist at each site.

When approving DRLs for nuclear facilities, the CNSC considers the environmental pathways through which radioactive material could reach the most exposed members of the public – also known as the "critical group" – after being released from the facility. Members of the critical group are those individuals expected to receive the highest dose of radiation because of their age, diet, lifestyle and location.

Doses received by members of the public through routine releases from Canadian nuclear facilities are very low and constitute a small fraction of the CNSC regulatory dose limits. Figure F.1 shows CNSC staff gathering an environmental sample during a routine inspection at a nuclear facility.

Figure F.1: Effluent monitoring

F.6.3 Action levels

Licensees may propose and establish action levels. An action level is defined in the RPR as a specific level that, if reached, may indicate a loss of control of part of the radiation protection program. When an action level is reached, the following actions must be taken:

- notify the CNSC
- conduct an investigation to establish the cause for reaching the action level
- take action to restore the effectiveness of the radiation protection program

CNSC regulatory guide G-228, *Developing and Using Action Levels,* was published to guide licensees in developing action levels in accordance with the RPR.

F.6.4 Dosimetry

The CNSC requires that every licensee ascertain and record the magnitude of radiation exposure to workers by direct measurement or monitoring or, in cases where this is not possible, by estimation. If a nuclear energy worker has a reasonable probability of receiving an effective dose of greater than 5 mSv in a one-year dosimetry period, the licensee is required to use a CNSC-licensed dosimetry service. Standards for licensed dosimetry services in Canada are found in regulatory document S-106 rev.1, *Technical and Quality Assurance Requirements for Dosimetry Services* (published March 2006). Licensed dosimetry services must file the dose results of each nuclear energy worker to Health Canada's National Dose Registry.

F.6.5 Preventing unplanned releases

The nuclear sector uses several means to reduce the risk of unplanned effluent releases of radioactive material into the environment: multiple barriers, reliable components and systems, competent staff, and the detection and correction of failures.

Due to the robust design of storage facilities housing high-risk materials such as spent fuel, the potential for a significant release is present mainly when materials are handled. Such operations are closely monitored by the licensee, who would be available in the unlikely event of an accidental release. The process of transferring waste from the point of origin to a storage site is subject to stringent control and is only done in the safest possible manner. Some of these controls involve transporting the spent fuel at extremely low speeds and prohibiting the transfer of spent fuel during periods of rain or snow.

In the event of an uncontrolled release into the environment, competent licensee staff are available for an initial mop-up exercise, preventing further spread of radioactive contaminants. If necessary, the stored radioactive waste may be retrieved and held more securely. Depending on the magnitude and severity of the release, emergency procedures and emergency preparedness plans may be activated.

F.6.6 Protection of the environment

Environmental protection is one of the 14 safety and control areas the CNSC considers when evaluating how well its licensees meet regulatory requirements and expectations in preventing unreasonable risk to the environment in a manner consistent with Canadian environmental policies, acts and regulations, and with Canada's international obligations. The environmental protection safety and control area covers programs that identify, control and monitor all releases of radioactive and hazardous substances. It also covers the effects on the environment from facilities or as the result of licensed activities.

CNSC regulatory document REGDOC-2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures* (published December 2016) supersedes P-223, *Protection of the Environment*, and REGDOC-2.9.1, *Environmental Protection: Environmental Protection Policies, Programs and Procedures* (September 2013). It sets out the CNSC's regulatory requirements and expectations for programs related to environmental protection. More precisely, REGDOC-2.9.1 describes:

- the CNSC’s principles for environmental protection for all nuclear facilities or activities that interact with the environment
- the scope of an environmental assessment, including the roles and responsibilities associated with an assessment
- the CNSC’s requirements and guidance to applicants and licensees for developing environmental protection measures, including an environmental risk assessment (ERA) where required, for both new and existing facilities or activities

REGDOC-2.9.1 clarifies the CNSC's expectations of applicants and licensees and provides guidance for the environmental protection measures licensees should have in place to ensure the protection of persons and the environment. The necessary measures for environmental protection are determined on a facility- or activity-specific basis. Not every facility or activity is required to have every environmental protection measure described in this section. The applicant or licensee may address certain requirements by demonstrating that a particular measure is not necessary or does not apply to that facility or activity. A licence application that describes the nature of the proposed licensed activities is considered sufficient for ensuring protection of the environment, provided CNSC staff conclude the facility or activities do not interact with the environment.

Environmental management system

An environmental management system (EMS) refers to the management of an organization’s environmental policies, measures and procedures in a comprehensive, systematic, planned and documented manner. It includes the organizational structure, planning and resources for developing, implementing and maintaining policy for environmental protection and continuous improvement by:

- identifying and managing environmental risks associated with a facility or activity
- identifying, implementing and maintaining pollution control activities and technologies
- monitoring releases
- monitoring contaminants and their potential effects in the environment

The EMS serves as the management tool for integrating all of the applicant’s or licensee’s environmental protection measures in a documented, managed and auditable process by:

- identifying and managing non-compliances and corrective actions within the activities, through internal and external inspections and audits
- summarizing and reporting the performance of these activities, both internally (licensee’s management structure) and externally (to the Commission and the public)
- training of the personnel involved in these activities
- ensuring the availability of resources (such as qualified personnel, organizational infrastructure, technology and financial resources)
- defining and delegating roles, responsibilities and authorities essential to effective environmental management

The EMS may be implemented within the licensee's integrated management system. CAN/CSA ISO 14001, *Environmental management systems – Requirements with guidance for use* (2004 edition or successor editions), specifies the requirements for an EMS that licensees can use to enhance environmental performance.

Within the EMS, the licensee should address reporting requirements for potential or real emergency situations. In addition, the EMS should address environmental emergency preparedness. The licensee should address environmental emergency preparedness and response in terms of:

- the proposed measures to prevent or mitigate the effects of accidental releases of nuclear and hazardous substances on the environment
- the proposed measures to ensure the availability and accessibility of environmental monitoring instrumentation during emergencies
- the inclusion of environmental monitoring instrumentation and equipment layouts in emergency plans

Environmental risk assessment

An ERA is a systematic process that identifies, quantifies and characterizes the risk posed by contaminants (nuclear or hazardous substances) and physical stressors in the environment. It is a practice or methodology that provides science-based information to support decision making and to prioritize the implementation of mitigation measures.

The ERA provides the basis for the scope and complexity of monitoring programs, including effluent and environmental monitoring programs. An ERA can provide input into an effluent monitoring program by identifying and prioritizing the specific radioactive and non-radioactive contaminants and physical stressors and the sources or release points from the nuclear facility or licensed activity.

CSA standard N288.6, *Environmental risk assessments at Class I nuclear facilities and uranium mines and mills* (published in 2012), addresses the design, implementation and management of an ERA program. Similarly, an understanding of the environmental risk posed by the facility can develop the scope and complexity of an environmental monitoring program. The results of the ERA can be used to identify environmental monitoring requirements for normal operating conditions.

Protection of the public

The licensee must demonstrate that the health and safety of the public are protected from exposures to hazardous substances released from the nuclear facility. A human health risk assessment is completed as a sub-element of an ERA for both nuclear and hazardous substances. The human health risk assessment predicts the nature and probability of adverse human health effects as a result of releases from the nuclear facility.

Releases of hazardous substances are controlled and monitored by the effluent and emissions control and monitoring program and the environmental monitoring program. Licensees are required to report to the regulatory authorities, including the CNSC, any unauthorized release of hazardous or radioactive substances to the environment (e.g., spills).

Effluent and emissions control and monitoring

Controls on environmental releases are established to provide protection to the environment and to respect the principles of sustainable development and pollution prevention. Licensees set action levels to provide assurance that facility release limits will not be exceeded by providing early indication of a potential loss of control of part of the environmental protection program. Action levels are also used to ensure licensees demonstrate adequate control of their facility based on their approved facility design, environmental protection programs and radiation protection programs. CSA standard N288.8, *Establishing and implementing action levels for releases to the environment from nuclear facilities* (published in 2017), provides guidance in developing and implementing action levels for releases from nuclear facilities.

Although specific to radiation protection, CNSC regulatory guide G-228, *Developing and Using Action Levels*, provides useful generic guidance on the principles underlying action levels. These principles, along with the ALARA principle – as outlined in regulatory guide G-129, *Keeping Radiation Exposures and Doses "As Low as Reasonably Achievable" (ALARA)* – should be used to develop targets for environmental performance.

In conjunction with specific regulatory monitoring requirements, the ERA provides the technical foundation and structure for identifying the need for, and details of, effluent and emissions monitoring. The site-specific effluent and emissions monitoring program is designed using the characterization of the locations, the anticipated volume, chemistry and flow rate of releases, and the proposed maximum quantities and concentrations of nuclear and hazardous substances (including their physical, chemical and radiological characteristics). CSA standard N288.5, *Effluent monitoring programs at Class I nuclear facilities and uranium mines and mills* (published in 2011), addresses the design, implementation and management of an effluent monitoring program that meets legal and business requirements.

Effluent and emissions monitoring is not required for facilities and activities with no significant measurable releases to the environment. In such cases, the licensee should demonstrate (through engineering or scientific methods) that appropriate barriers and practices are implemented, monitored and maintained to prevent releases to the environment.

Monitoring is also not required for facilities and activities where the releases are of low risk or the quantities are too low or too difficult to measure. The licensee may estimate emissions based on site-specific process chemistry and engineering principles.

Environmental monitoring

Environmental monitoring consists of a risk-informed set of integrated and documented activities to sample, measure, analyze, interpret and report one or all of:

- the concentration of nuclear and hazardous substances in environmental media to assess the exposure of receptors to those substances and/or the potential effects on human health, safety and the environment

- the intensity of physical stressors and/or their potential effect on human health and the environment

- the physical, chemical and biological parameters of the environment normally considered in the design of the environmental monitoring necessary to support the interpretation of the results; some examples are supportive data for transport (such as wind velocity) or toxicity assessment (such as organic carbon or hardness) or measurements at reference stations (where incorporated in the monitoring)

With the promulgation of the NSCA in 2000, protection of the environment (as opposed to the previous human-focused legislation) from both radionuclides and hazardous substances also became the responsibility of the CNSC. As mentioned in the previous reporting period, CSA standard N-288 (issued in 1990) had several identified gaps; therefore, it was recognized that a revised environmental monitoring standard/guide was required.

The revised CSA standard N288.4, *Environmental monitoring programs at Class I nuclear facilities and uranium mines and mills*, involves significant changes and addresses both radiological and hazardous substances and their potential effects on human and non-human biota.

The CNSC has implemented its Independent Environmental Monitoring Program (IEMP) to confirm that the public and environment around CNSC regulated nuclear facilities are safe. The IEMP is a tool that complements the CNSC's ongoing compliance verification program. The IEMP involves taking samples from public areas around the sites and measuring and analyzing the amount of radiological (nuclear) and hazardous substances in those samples. CNSC staff collect the samples and send them to the CNSC's state-of-the-art laboratory for testing and analysis. A summary of the results is made available on the CNSC's IEMP website at nuclearsafety.gc.ca/eng/resources/maps-of-nuclear-facilities/iemp/index-iemp.cfm.

Groundwater protection and monitoring

Groundwater protection is an inter-related system of initiatives, processes and activities with the overall goal of protecting the quality and quantity of groundwater by minimizing interactions with the environment from activities associated with a nuclear facility, allowing for effective management of groundwater resources. Groundwater protection is a specialized element of the overall environmental protection measures. As groundwater flow and associated contaminant transport can be more difficult to detect and delineate than that of surface water, specific requirements and guidance are provided in CSA standard N288.7, *Groundwater protection programs at Class I nuclear facilities and uranium mines and mills*, which was published in 2015.

F.6.7 Canadian Nuclear Safety Commission activities

To verify compliance with the requirements of a licence and regulations, CNSC staff:

- review documentation and operational reports submitted by licensees
- conduct radiation protection evaluations
- conduct evaluations of licensees' environmental protection programs and other programs as required

A detailed description of the compliance verification program is provided in section E.6.3.

F.7 Nuclear emergency management

Nuclear emergency preparedness and response in Canada is a multi-jurisdictional responsibility shared by all levels of government and includes the CNSC and the licensed nuclear facilities. Licensees must respect Canada's international commitments on the peaceful use of nuclear energy and are responsible for protecting health, safety, security and the environment by preventing or mitigating the effects of accidental releases of nuclear or hazardous substances. The provinces and territories have primary responsibility to implement measures for civil protection and for offsite nuclear emergency preparedness and response, including designating municipalities to carry out nuclear emergency planning within their jurisdictions.

In accordance with IAEA guidance and requirements, responsibilities for nuclear emergency response are subdivided into two basic areas: onsite and offsite. Onsite nuclear emergency response pertains to all actions and measures taken within the boundary of the licensee site, whereas offsite nuclear emergency response pertains to actions and measures taken outside and beyond the licensee site boundary. The response activities and strategies in these two areas may involve and require different stakeholders; however, they are not independent of each other and therefore coordination must occur among all levels of government, the CNSC and the licensee to assure an effective and efficient response to a nuclear emergency.

All organizations playing a role in nuclear emergency response, including the CNSC and its licensees, must have nuclear emergency response plans in place, as well as operational facilities equipped and appropriately staffed to coordinate and direct the responses to the nuclear emergency.

Federal

The CNSC has a dual role in nuclear emergency response. Under the mandate established by the NSCA, the CNSC maintains regulatory oversight of the onsite nuclear emergency response activities of its licensees. As a federal agency, the CNSC also participates in the whole-of-government response to a nuclear emergency in accordance with the requirements of both the Federal Emergency Response Plan (FERP) and the Federal Nuclear Emergency Plan (FNEP).

The CNSC requires licence applicants to assess the impacts of their proposed activities on health, safety, security and the environment, and to propose and implement measures to prevent or mitigate the effects of accidental releases of nuclear or hazardous substances. Once the CNSC has reviewed, accepted and issued a licence, these measures become binding upon the licensee. Due to the variety of risk among CNSC licensed facilities in Canada, some facilities require detailed emergency preparedness and response plans that must be coordinated with mutual aid organizations, while others may require only internal emergency procedures. Post-Fukushima, all major radiological and nuclear facilities in Canada were required to review their emergency planning basis, taking into account severe accidents and multi-event scenarios (e.g., loss of power coincident with a release of radioactive material) to determine if their current preparedness measures were still appropriate or if additional measures needed to be incorporated into their plans.

The CNSC maintains its regulatory role and responsibilities during emergencies through direct oversight of the licensees' response actions, providing technical and advisory support to the provincial, territorial and federal authorities through the Government of Canada's FERP and FNEP. These responsibilities encompass a wide range of contingency and response measures to prevent, correct or mitigate accidents, spills, abnormal situations and emergencies.

Ontario

Because many of the major nuclear facilities in Canada are located in Ontario (specifically, the largest radioactive waste management facility and 20 of the 22 Canadian reactors), Emergency Management Ontario has been a key stakeholder in planning and preparedness with relation to Canada's nuclear industry. In 2013, Emergency Management Ontario merged with the Office of the Fire Marshal to form the Office of the Fire Marshal and Emergency Management. This division provides leadership and expertise in the coordination, development and implementation of prevention, mitigation, preparedness, response and recovery strategies to keep Ontario communities safe and secure.

Quebec

Until recently, Quebec had one operating nuclear reactor, located at Gentilly near Trois-Rivières, Quebec, on the St. Lawrence River. In 2012, the Gentilly-2 Nuclear Generating Station reactor was shut down and defuelled. Even though the reactor is no longer fuelled and producing electricity, there is a requirement for emergency preparedness plans until the site has been decommissioned. Consequently, l'Organisation de la sécurité civile du Québec (OSCQ) is still the lead provincial organization for the emergency management effort for all hazards, including offsite nuclear emergencies. The OSCQ nuclear emergency plan, le plan de mesures d'urgence nucléaire externe à Gentilly-2 (PMUNE-G2), is in accordance with Quebec provincial acts of legislation, such as Loi sur la sécurité civile (L.R.Q., c. S-2.3), Loi sur la santé publique (L.R.Q., c. S-2-2) and others, which define the responsibilities of the government agency with specific objectives for minimizing consequences, protecting the public and providing support to the municipality.

New Brunswick

New Brunswick has a single operating CANDU reactor located at Point Lepreau, approximately 40 kilometres southwest of Saint John. The New Brunswick Emergency Measures Organization (NB EMO) coordinates emergency preparedness for the New Brunswick provincial and municipal governments. NB EMO works at the provincial and municipal levels through district coordinators to ensure the province and its communities have appropriate and tested emergency plans. In addition, New Brunswick has invested significantly in provincial communications infrastructure to improve connectivity and harmonization with federal and provincial intervening organizations during a nuclear emergency.

Saskatchewan

Saskatchewan has several uranium mines and mills in the northern part of the province. The Saskatchewan Emergency Management Organization is the provincial government's lead agency for emergency management. It coordinates overall provincial emergency planning, training and response operations for the safety of residents and the protection of property and the environment before, during and after an emergency. Corrections and Public Safety, through the Saskatchewan Emergency Management Organization, is the provincial government's lead agency for emergency management. Corrections and Public Safety is responsible for the *Emergency Planning Act* (November 1, 1989), which contains provisions for emergency planning, emergency powers and disaster relief.

The Saskatchewan Emergency Management Organization supports community preparedness by encouraging the formation of local government emergency measures organizations, assisting in the development of local emergency plans, and providing onsite consultation to municipal officials during government-declared states of emergency. It also supports provincial preparedness by maintaining the provincial government emergency plan and related contingencies; coordinating provincial government resources during a state of emergency; assisting government departments, Crown corporations and agencies with emergency planning; and coordinating with Government of Canada emergency preparedness programs within Saskatchewan.

Nova Scotia

In Nova Scotia, many shipments containing radioactive substances pass through the Port of Halifax. The *Emergency Measures Act* is Nova Scotia's emergency-management and emergency-powers legislation. It establishes the rules for managing emergencies in Nova Scotia and requires municipal governments to have emergency plans in place. The Nova Scotia Emergency Management Office is the lead agency to ensure the safety and security of residents of Nova Scotia, their property and the environment by providing for a prompt and coordinated provincial and municipal response to an emergency. This is accomplished through cooperative and consultative planning before emergencies occur and by coordinating the provision of provincial resources to assist with the response. The organization facilitates and coordinates communication and emergency planning efforts between all levels of government.

F.7.1 CNSC assessment of licensee emergency management programs

Applicants, including those for spent fuel and radioactive waste management facilities, must submit their emergency plans as part of their licence application. CNSC staff review and evaluate those plans according to regulatory criteria and guidance documents. Once a licensee has been issued its licence, CNSC staff regularly review and perform audits of the licensee's emergency plans.

F.7.2 Types of nuclear emergencies

With respect to nuclear accident mitigation, emergency planning includes both onsite and offsite consequences, as described below:

- **Onsite nuclear emergencies –** Events that occur within the physical boundaries of a CNSC-licensed nuclear facility. The operators of those nuclear facilities are responsible for their onsite emergency planning, preparedness and response, but must also have plans and procedures in place to assist with any potential offsite consequences as a result of an onsite emergency occurring at their facility.

- **Offsite nuclear emergencies –** Events that occur outside licensed facilities but may originate from or be associated with a licensed facility or activity, and may even originate outside Canada. Events of this type may require intervention from provincial, territorial or municipal authorities operating outside of the licensed facility or activity, likely requiring support from the licensee and possibly the Government of Canada through the FNEP.

F.7.3 Government of Canada responsibilities

In the event of a nuclear site or facility accident with potential offsite consequences, the offsite response would follow a tiered process involving the following parties:

- the licensee
- municipal government
- provincial/territorial governments
- federal government

The provincial governments are responsible for:

- overseeing public health and safety and protection of property and the environment
- enacting legislation to fulfil the province's lead responsibility for public safety
- preparing emergency plans and procedures and providing direction to municipalities that they designate to do the same
- managing the offsite response by supporting and coordinating the efforts of organizations with responsibility in a nuclear emergency
- coordinating support from the nuclear site or facility licensee and the Government of Canada during preparedness activities and response in a nuclear emergency

Federal government support and response for potential offsite impacts are required for addressing areas of federal responsibility, including an incident's effects that extend beyond provincial or national borders. Likewise, the coordination of federal assistance when requested by an affected province is also required. Some provinces have pre-agreements with the federal government for the provision of specific types of technical support. Federal responsibility also encompasses a wide range of contingency and response measures to prevent, correct or eliminate accidents, spills, abnormal situations and emergencies, and to support provinces and territories in their responses to a nuclear emergency. The Government of Canada is also responsible for:

- liaising with the international community
- liaising with diplomatic missions in Canada
- assisting Canadians abroad
- coordinating the national response to a nuclear emergency occurring in a foreign country

Public Safety Canada was created in 2003 to ensure coordination across all federal departments and agencies responsible for national security and the safety of Canadians. It is responsible for coordinating the overall federal government response to emergencies in support of provinces, including nuclear emergencies. The *Emergency Management Act* (EMA), which entered into force in 2007 and replaced the former *Emergency Preparedness Act*, recognizes the roles that all stakeholders must play in Canada's emergency management system. It sets out the leadership role and responsibilities of the Minister of Public Safety and Emergency Preparedness, including coordinating emergency management activities among government institutions and in cooperation with the provinces and other entities. Responsibilities of other federal ministers are also set out in the EMA.

Canada's federal government is dedicated to working collaboratively with provinces and territories to support communities when disasters strike. To this end, *An Emergency Management Framework for Canada* was revised and approved by federal, provincial and territorial ministers in 2011. The framework establishes a common approach for a range of collaborative emergency management initiatives in support of safe and resilient communities. It can be viewed at publicsafety.gc.ca/cnt/rsrcs/pblctns/mrgnc-mngmnt-frmwrk/index-eng.aspx.

Public Safety Canada is the lead authority for the Federal Emergency Response Plan (FERP). Health Canada is the lead authority for the Federal Nuclear Emergency Plan (FNEP) and also has responsibilities related to radiation protection. Health Canada administers a federal interdepartmental and a federal–provincial nuclear emergency management committee.

Other federal organizations with responsibilities in nuclear emergency preparedness and response include the CNSC, Transport Canada, Environment and Climate Change Canada (ECCC), Natural Resources Canada and the Public Health Agency of Canada (PHAC):

- Natural Resources Canada is responsible for providing emergency radiation mapping and surveying services, providing policy advice and coordinating federal actions in relation to nuclear liability, including administering the *Nuclear Liability and Compensation Act* (NLCA).

- Transport Canada is responsible for the Canadian Transport Emergency Centre (CANUTEC).

- Internationally, Health Canada and the CNSC serve as national competent authorities to the IAEA.

- ECCC operates a regional specialized meteorological centre under the World Meteorological Organization and provides atmospheric modelling services to the IAEA as part of its emergency response functions.

- PHAC is the national authority for reporting to the World Health Organization under the *International Health Regulations*.

Health Canada led a review and update of the FNEP, which was endorsed in October 2012 by federal deputy ministers on the condition that the revised FNEP be tested in a national-level exercise. This exercise was undertaken in May 2014 with the involvement of the full range of implicated federal and provincial organizations, municipal governments and electricity utilities. Exercise UNIFIED RESPONSE successfully demonstrated the federal government's capability to provide an effective response to a nuclear emergency and met the deputy ministers' direction to validate the FNEP. Together with experiences from subsequent exercises, including INTREPID 2015 and HURON RESOLVE, underlying procedures have continued to be refined through lessons learned.

The Government of Canada is also responsible for establishing and managing a nuclear civil liability regime that addresses civil liability and compensation for injury and damage arising from nuclear incidents. This regime is established under the NLCA. Operators of nuclear installations designated under the NLCA are absolutely and exclusively liable for any civil damages caused by an incident at that installation, and are required to carry financial security to cover their liability. In the event of a serious incident, the NLCA provides special compensation measures that may be imposed by government to replace the normal court process. Natural Resources Canada is the lead department for ensuring the process of compensation is well coordinated and administered in Canada.

F.7.4 International arrangements

Canada has signed and ratified the following three international emergency response conventions:

- ***Canada–United States Joint Radiological Emergency Response Plan* (1996)** – This plan focuses on emergency response measures of a radiological nature rather than generic civil emergency measures. It is the basis for cooperative measures to deal with peacetime radiological events involving Canada, the United States or both countries. Cooperative measures contained in the FNEP are consistent with this plan.

- ***Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency* (1986)** – This international assistance agreement, which was developed under the auspices of the IAEA, promotes cooperation between signatories and facilitates prompt assistance in the event of a nuclear accident or radiological emergency. Its purpose is to minimize the consequences of such an accident; practical steps include taking measures to protect life, property and the environment. The agreement sets out how assistance is requested, provided, directed, controlled and terminated.

- ***Convention on Early Notification of a Nuclear Accident* (1987)** – This international convention, which was developed under the auspices of the IAEA, defines when and how the IAEA would notify the signatories associated with an international event that could have an impact on their respective countries.

F.8 Decommissioning

In accordance with CNSC regulatory guide G-219, *Decommissioning Planning for Licensed Activities*, Class I nuclear facilities and uranium mines and mills licensees are required to keep decommissioning plans up to date throughout the lifecycle of a licensed activity. The CNSC also requires licensees to prepare a preliminary decommissioning plan (PDP) and detailed decommissioning plan (DDP) for approval.

The PDP must be filed with the CNSC as early as possible in the lifecycle of the activity or facility, and must be reviewed and updated:

- every five years
- when operational experience is gained or technological advancements are made
- when requested by the Commission or person authorized by the Commission

In the case of nuclear facilities, specific requirements for decommissioning planning are set out in the CNSC regulations for Class I and Class II nuclear facilities and for uranium mines and mills.

The PDP documents the preferred decommissioning strategy – whether it is prompt decommissioning, deferred decommissioning or *in situ* confinement – along with objectives at the end of decommissioning. The plan should be sufficiently detailed to assure the proposed approach is technically and financially feasible. It must also be in the interests of health, safety, security and protection of the environment. The plan defines areas to be decommissioned and the general structure and sequence of the principal decommissioning work packages envisioned.

The DDP is filed with the CNSC prior to decommissioning and is required for appropriate licensing action (i.e. licence to authorize decommissioning). The DDP refines and adds procedural and organizational detail to the PDP.

CSA standard N294-09, *Decommissioning of facilities containing nuclear substances*, was published in July 2009. The CNSC worked with the CSA Group on amendments to this standard, with the updated version released in 2014.

The applicable regulations and regulatory guide can be viewed on the CNSC website at nuclearsafety.gc.ca.

Decommissioning activities are listed in annex 7. Decommissioning waste generated in the last reporting period is listed in section D.

F.8.1 Qualified staff and adequate financial resources

Subsection 24(5) of the NSCA legislates that licensees of nuclear facilities must guarantee that adequate financing and human resources will be available for the decommissioning of facilities and the management of resulting radioactive wastes, including spent fuel. Paragraph 3(1)(l) of the GNSCR states: "An application for a licence shall contain a description of any proposed financial guarantee relating to the activity to be licensed." (Section F.4.3 of this report describes the financial guarantees applicable to the decommissioning process.) Paragraph 44(1)(k) of the NSCA provides the legislative basis for the qualification, training and examination of personnel. Paragraphs 12(1)(a) and 12(1)(b) of the GNSCR specify that the licensee must ensure the presence of a sufficient number of trained, qualified workers.

F.8.2 Operational radiation protection, discharges, unplanned and uncontrolled releases

During the entire lifecycle of a facility, including decommissioning, the licensee is required to implement and maintain a radiation protection program that ensures radiation exposures and doses to persons are below CNSC regulatory dose limits and kept ALARA through the implementation of:

- management control over work practices
- personnel qualification and training
- control of occupational and public exposure to radiation
- planning for unusual situations

Additionally, licensees are required to ascertain the quantity and concentration of any nuclear substance released as a result of a licensed activity and to implement measures to protect the environment and prevent or mitigate the effects of unplanned releases.

F.8.3 Emergency preparedness

For nuclear emergency management during the decommissioning phase, an emergency response plan is still required; however, the plan will be commensurate to the risks associated with the facility at the time of decommissioning.

F.8.4 Records

As part of the planning process for decommissioning, records are reviewed and relevant aspects are incorporated into the documentation required for formal approval of both the preliminary and detailed decommissioning plans. A preliminary plan serves as the basis for the decommissioning financial guarantees provided by the licensee. The CNSC requires that the PDP and financial guarantee be in place prior to the start of construction and operations. A detailed decommissioning plan must be developed while operations approach completion; this serves as the basis for subsequent licensing of the decommissioning activities. The detailed plan must include a description of the records and information that will be permanently retained and of the reports that are to be submitted to the CNSC.

The licensee must retain specified records and information, typically through the corporate office, as the need for onsite staff diminishes. Reports submitted to regulatory agencies will be retained in accordance with the respective agencies' procedures.

For example, the *Class I Nuclear Facility Regulations* require every licensee who operates a nuclear facility to keep a record of the following:

- operating and maintenance procedures
- the results of the commissioning program
- the results of the inspection and maintenance programs

- the nature and amount of radiation, nuclear substances and hazardous substances within the nuclear facility
- the status of each worker’s qualifications, re-qualifications and training

Also, every licensee who decommissions a Class I nuclear facility must keep a record of the following:

- the progress achieved in meeting the schedule
- the implementation and results of the decommissioning
- the manner in which, and the location at which, any nuclear or hazardous waste is managed, stored, disposed of or transferred
- the name and quantity of any radioactive nuclear substances, hazardous substances and radiation that remain at the nuclear facility after completion of the decommissioning
- the status of each worker’s qualifications, re-qualifications and training

The *Class I Nuclear Facility Regulations* can be viewed on the CNSC’s website at nuclearsafety.gc.ca/eng/acts-and-regulations.

Section G – Safety of Spent Fuel Management

G.1 Scope of the section

This section addresses article 4 (General Safety Requirements) to article 10 (Disposal of Spent Fuel) of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.* It provides a comprehensive description of spent fuel management in Canada. Effective defences against potential hazards are in place at every stage of spent fuel management. These defences protect individuals, society and the environment from the harmful effects of ionizing radiation.

In addition to describing facilities and their normal operation, this section discusses the steps and controls in place to prevent accidents with radiological consequences and mitigate the consequences should such accidents occur. The information contained in this section demonstrates that the requirements of the following applicable International Atomic Energy Agency (IAEA) safety standards have been addressed:

- Article 4: General Safety Requirements – IAEA Safety Requirements SSR-2/1, SSR-5 and GSR Part 5
- Article 6: Siting of Proposed Facilities – IAEA Safety Requirement NS-R-3
- Article 7: Design and Construction of Facilities – IAEA Safety Requirements SSR-2/1 and SSR-5
- Article 8: Assessment of Safety of Facilities – IAEA Safety Requirements SSR-2/1, SSR-5 and GSR Part 3
- Article 9: Operation of Facilities – IAEA Safety Standards SSR-2/1, SSR-5, GSR Part 5 and GSR Part 3
- Article 10: Disposal of Spent Fuel – IAEA Safety Standard SSR-5

G.2 Nuclear power plants

In Canada, spent fuel is stored in wet and dry states at the locations where it is produced. When the fuel first exits a power reactor, it is placed in water-filled bays. Water cools the fuel and shields the radiation. After several years in the bays – six to 10 years, depending on site-specific needs and organizational administrative controls – and when the associated heat generation has diminished, the spent fuel can be transferred to an onsite dry storage facility. These dry storage facilities are large, reinforced concrete cylinders or containers. Each nuclear power plant in Canada has enough storage space to store all the spent fuel produced during the operating life of the station. A 600-megawatt CANDU nuclear reactor produces approximately 90 tonnes of heavy metal spent fuel annually.

G.3 CANDU fuel

All CANDU fuel bundles are fabricated from natural uranium oxide pellets contained in a zirconium-alloy (zircaloy-4) tube (cladding). There are normally 30 uranium oxide pellets per element. The maximum nominal bundle diameter is 102 millimetres, with an overall bundle length of 495 millimetres. The weight of a nominal bundle is 23.6 kilograms, of which 21.3 kilograms are uranium oxide. Approximately 19.2 kilograms can be attributed to the uranium (without the oxygen component). These numbers are averages and may vary depending on the type and age of the CANDU bundle. Each year, 4,500 to 6,000 fuel bundles per reactor are added to the wet storage bays, based on 80 to 95 percent full power reactor operation.

G.4 Research reactors

G.4.1 Canada's research reactors

Canada contributed its expertise and perspective to the development of two IAEA documents: the *Code of Conduct on the Safety of Research Reactors* and *Safety Requirements for Research Reactors.* These documents will help strengthen the regulatory framework governing the safe operation of research reactors in Canada.

As of March 2017, there were seven operating research reactors in Canada. Four of these are Safe Low Power Critical Experiment (SLOWPOKE-2) reactors, designed by Atomic Energy of Canada Limited (AECL). These SLOWPOKE-2 reactors are located at:

- Royal Military College of Canada (Kingston, Ontario)
- École Polytechnique de Montréal (Montréal, Quebec)
- University of Alberta (Edmonton, Alberta)
- Saskatchewan Research Council (Saskatoon, Saskatchewan)

Of the three remaining research reactors, one is a five-megawatt pool-type reactor at McMaster University (Hamilton, Ontario). The final two reactors – National Research Universal (NRU) and Zero Energy Deuterium-2 (ZED-2) – are located at AECL's Chalk River Laboratories (CRL).

In the past, research reactors have typically used highly enriched uranium (HEU) for the fuel cores, but within the last decade some of them have been converted to low-enriched uranium (LEU) fuel. The University of Alberta and the Saskatchewan Research Council continue to use HEU fuel in their research reactors; the other two research reactors (Royal Military College of Canada and École Polytechnique de Montréal) use LEU fuel. The University of Alberta's research reactor is scheduled to be decommissioned in 2017. The Saskatchewan Research Council is currently exploring its options for the future, which may include continuing operations as is, implementing a transition plan to use LEU fuel or decommissioning the reactor.

G.4.2 Nuclear fuel waste from research reactors

All SLOWPOKE-2 cores are preassembled and cannot be modified by the licensee. The cores last many years, with the addition of beryllium reflector shims compensating for reactivity decreases in fuel. Once the addition of the shims can no longer compensate for the decreased reactivity of the spent fuel (usually after 20 to 30 years, depending on usage), the complete core is removed and the spent fuel is sent either to CRL for storage or returned to the United States. The fuel may also be removed if the facility is being decommissioned or converted to an LEU core.

The waste and spent fuel from the reactors located at CRL are stored onsite. The spent fuel from the NRU reactor is stored in fuel storage pools until it can be transferred to a waste management area at CRL (see annex 4). The ZED-2 reactor is operated occasionally and is mainly used for testing of prototype fuel to determine fuel characteristics.

G.5 Medical isotope production fuel

This type of fuel is not included in the report because, once spent, it is reprocessed for extraction of medical isotopes. According to article 3(1), this activity falls outside the scope of the Joint Convention.

G.6 Storage of spent fuel

In Canada, all spent fuel is stored at the site where it was produced, with the following exceptions:

- small quantities that are transported to research facilities for experimental or examination purposes, and which are stored at those facilities
- the fuel from the Nuclear Power Demonstration (NPD) reactor, which is stored at the nearby CRL site

All Canadian nuclear power reactors were constructed with onsite spent fuel storage bays or water pools. Spent fuel is stored in either storage bays or in dry storage facilities at the location where it was produced. The spent fuel produced at the now-closed NPD nuclear facility was transferred to CRL, where it was placed in a dry storage facility. (See section D.1 for a map of the locations)

Secondary or auxiliary bays have also been constructed at Pickering A (Units 1 to 4) and Bruce A and Bruce B for additional storage. Since 1990, dry storage technology has been chosen for additional onsite interim storage. In addition, the spent fuel from the Gentilly-1 and Douglas Point shutdown prototype reactors is stored onsite in dry storage facilities (concrete canisters). With regard to fuel from research reactors at the CRL and Whiteshell Laboratory, it is stored in tile holes and in concrete canisters in the waste management areas at the CRL and Whiteshell Laboratory sites. Highly enriched fuel from Slowpoke research reactors is returned to the United States.

The engineered structures, canisters, Modular Air-Cooled Storage (MACSTOR) and Ontario Power Generation (OPG) dry storage containers were originally designed for a 50-year lifetime. The actual life of the structures could be much longer. These structures are vigorously monitored; in the event of a structural failure, the spent fuel can be retrieved and transferred to a new structure.

Dry storage facilities are licensed for a limited period. Licences issued by the Canadian Nuclear Safety Commission (CNSC) are generally valid for a five- to 10-year period. At the time of licence renewal, the CNSC examines the operational performance and future plans of the dry storage facility to determine whether it can continue to operate safely for another licensing term – again, typically for a five- to 10-year period. This situation may continue until a long-term management facility becomes available.

G.7 Spent fuel management methods and requirements for spent fuel storage

The fuel cycle in Canada is a once-through process (currently, there is no reprocessing or intent to reprocess spent fuel for recycling of its uranium and plutonium content). The development and selection of an approach for long-term management of spent fuel is discussed in section G.16.

Spent fuel handling and storage facilities are required to provide the following:

- containment
- shielding
- dissipation of decay heat
- prevention of criticality
- assurance of fuel integrity for the required time of storage
- allowance for loading, handling and retrieval
- mechanical protection during handling and storage
- allowance for safeguards and security provisions
- physical stability and resistance to extreme site conditions

The CSA Group has developed a standard consisting of best practices for the safe site preparation (siting), design, construction, commissioning, operation and decommissioning of facilities and associated equipment for the dry storage of spent fuel, known as CSA standard N292.2-13, *Interim dry storage of irradiated fuel*. The Canadian nuclear sector uses this standard as a guide to facilitate the licensing process.

G.8 Safety of spent fuel and radioactive waste management

In Canada, spent fuel and radioactive waste management and associated facilities are regulated in a similar fashion. Safety and licensing issues are regulated according to *Nuclear Safety and Control Act* (NSCA) requirements and associated regulations.

G.8.1 General safety requirements

Canada ensures that individuals, society and the environment are adequately protected at all stages of spent fuel and radioactive waste management. This is accomplished through the Canadian regulatory regime. Canada’s approach to the safety of spent fuel and radioactive waste management is in line with the guidelines provided by the IAEA *Safety Guides and Practices*.

G.8.2 Canadian licensing process

The Canadian licensing process covers site preparation, construction, operation, decommissioning and abandonment. No phase may proceed without the required applications, documentation, assessments and approvals. A full description of Canada’s comprehensive licensing system is provided in section E.4.

G.8.3 Protection and safety fundamentals

The main objective in the regulation of spent fuel and radioactive waste management is to ensure facilities and activities do not pose unreasonable risks to health, safety, security and the environment. The regulation of spent fuel and radioactive waste can be divided into:

- generic performance requirements
- generic design and operational principles
- performance criteria

G.8.3.1 Generic performance requirements

There are three main generic performance requirements:

- The applicant must make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of security.
- The applicant must comply with all applicable laws, regulations and limits (e.g., dose limits, as low as reasonably achievable (ALARA) principle).
- The applicant must assure or demonstrate compliance with tests, analyses, monitoring programs, records, data and relevant reports.

G.8.3.2 Generic design and operational principles

There are two main principles for generic design and operations:

- Multiple engineered barriers are used to ensure spent fuel and radioactive waste are adequately contained and isolated from humans and the environment during normal and abnormal conditions.

- Administrative controls and procedures are used to augment and monitor the performance of the engineered barriers.

G.8.3.3 Performance criteria

The performance criteria accepted by the CNSC are as follows:

- Structural integrity must be maintained over the design life of the structure.
- Radiation fields at one metre from the storage structure and at the facility perimeter must not exceed regulatory limits for the public and for workers.
- There must be no loss of effective shielding during the design life of the storage container.
- There must be no significant release of radioactive or hazardous contaminants over the design life of the storage container.
- There must be no significant tilt or upset of the storage containers under normal conditions.
- Physical security systems of the contents and facility components must be maintained.

G.8.4 Safety requirements

Spent fuel and radioactive waste management facilities must be operated in a safe manner that protects the environment and the health and safety of workers and the public. System components that may require periodic maintenance must be readily accessible and designed to permit safe and efficient maintenance.

Safety requirements at spent fuel and radioactive waste facilities include the following:

- nuclear criticality safety
- radiation safety
- physical security and safeguards
- industrial safety

G.8.4.1 Nuclear criticality safety

Per CNSC regulatory document RD-327, *Nuclear Criticality Safety*, criticality safety requirements must address both normal and abnormal conditions. This document applies to operations with fissionable materials outside nuclear reactors, except for the assembly of these materials under controlled conditions (such as in critical experiments). Criticality safety analyses must be performed when significant quantities of fissionable materials are stored or handled. Each analysis must clearly demonstrate that the storage and handling of the radioactive waste is safe, which means that an inadvertent criticality cannot occur under normal (or credible abnormal) conditions. The analysis of a facility must consider the offsite consequences of improbable or inadvertent criticality events and demonstrate that these consequences do not violate the public evacuation criteria established by international standards (IAEA safety standards series GS-R-2, *Preparedness and Response for a Nuclear or Radiological Emergency*) and national guidelines (*Health Canada Guidelines for Intervention During a Nuclear Emergency*).

G.8.4.2 Facility design

Spent fuel storage and radioactive waste systems must be designed to ensure radiation exposures to persons and radioactive emissions to the environment are kept ALARA. It is a CNSC regulatory requirement for dose rates at storage area boundaries and at any accessible points within storage areas to be monitored, controlled and maintained at levels that would not result in an exposure to a person that would exceed the corresponding CNSC regulatory dose limit for workers and members of the public.

Spent fuel and radioactive waste management facilities in Canada operate at a small fraction of the CNSC regulatory dose limits for workers and members of the public.

G.8.4.3 Security and safeguards

The CNSC monitors and assesses the effectiveness of the security of nuclear facilities and nuclear materials and provides guidance to licensees on how to apply the *Nuclear Security Regulations* and other applicable regulatory requirements. The CNSC is the designated competent authority for Canada responsible for implementing the requirements of the Canada/IAEA safeguards agreements within the regulatory framework established through the NSCA and its associated regulations. As a result of these agreements, much of the nuclear material and many of the facilities identified in this report are also subject to verification undertaken by the IAEA.

G.8.4.4 Industrial safety

At every stage in the lifecycle of a spent fuel and radioactive waste management facility, the licensee must take into consideration the occupational health and safety of workers. The handling of hazardous materials must meet all federal and provincial legislation.

G.9 Protection of existing facilities

Canadian regulations ensured the safety of the spent fuel management facilities that existed when the Joint Convention entered into force, as all facilities were under a CNSC licence. Consequently, the operation of spent fuel management facilities must be conducted according to NSCA requirements, associated regulations and licence conditions.

Storage facilities for spent fuel and radioactive waste have been designed to ensure there are no effluent discharges to the environment. Effluent discharges from the processing of spent fuel or radioactive waste (e.g., incineration of combustible radioactive waste) are monitored to ensure they do not exceed regulatory guidelines. All discharges from nuclear facilities must conform to the NSCA, its associated regulations and, if applicable, the conditions specified in the licence.

G.10 Protection in the siting of proposed facilities

As discussed in section E.3.2, spent fuel storage facilities are considered to be Class I nuclear facilities in accordance with the definition provided in the *Class I Nuclear Facilities Regulations* (CINFR). The regulations stipulate several licensing steps for these types of facilities:

- licence to prepare site
- licence to construct
- licence to operate
- licence to decommission
- licence to abandon

The requirements for a licence to prepare a site for a Class I nuclear facility are listed in section 4 of these regulations. Other requirements are indicated in section 3 of the *General Nuclear Safety and Control Regulations* (GNSCR) and section 3 of the CINFR.

G.10.1 Public information programs

It is a regulatory requirement for licence applicants and licensed operators of Class I nuclear facilities and uranium mines and mills to have public information programs about their facilities and activities. The CNSC has issued regulatory requirements regarding licensee public information programs. Regulatory document RD/GD-99.3, *Public Information and Disclosure*, is available on the CNSC website at nuclearsafety.gc.ca/eng/acts-and-regulations/regulatory-documents (also see section E.3.3 for more information). A key component of the CNSC requirements is the proactive disclosure of information to the public by the licensed operator.

At the Bruce site, OPG operates the Western Waste Management Facility, which accommodates all the low- and intermediate-level radioactive waste (L&ILW) for the 20 OPG-owned or operated nuclear units. The facility also has a spent fuel dry storage facility for the interim management of spent fuel from the Bruce reactors. OPG has an extensive and integrated public information program for the Bruce site, as described in section H.7.1.1. Similar storage facilities for interim storage of spent fuel are also in operation at OPG's Darlington and Pickering stations. The public information programs for these sites are integrated and include many of the same communication strategies used for the Bruce site, such as brochures, newsletters, tours, media and key stakeholder briefings, and the Internet. In addition, the information centres at the Darlington and Pickering sites feature displays on spent fuel dry storage.

G.10.2 International arrangements with neighbouring countries that could be affected

The Canadian regulatory regime does not obligate the proponents of domestic nuclear facilities that may affect the United States to consult with foreign jurisdictions or with the public about the proposed siting of such facilities.

Canada and the United States, however, are signatories to the *International Convention on Environmental Impact Assessment in a Transboundary Context* (Espoo, Finland, February 25, 1991). The Convention entered into force on September 10, 1997, it obliges signatories to:

- take all appropriate and effective measures to prevent, reduce, and control significant adverse transboundary environmental impacts of proposed activities (including the site preparation, construction and operation of nuclear installations)
- ensure that affected Parties are notified of the proposed installation
- provide an opportunity to the public in the areas likely to be affected to participate in relevant environmental impact assessment procedures regarding proposed activities, and ensure the opportunity provided to the public of the affected Party is equivalent to that provided to the public of the Party of origin
- include in the notification information on the proposed activity, including any available information on its possible transboundary impact

The governments of Canada and the United States, in cooperation with state and provincial governments, are also obligated to have programs in place for the abatement, control and prevention of pollution from industrial sources. This includes measures to control the discharges of radioactive materials into the Great Lakes system. These obligations are contained within the *Great Lakes Water Quality Agreement* (1978), as amended by the protocol signed September 7, 2012.

The CNSC and the United States Nuclear Regulatory Commission have practised cooperation and consultation since the 1950s. On August 15, 1996, the two countries entered into a bilateral administrative arrangement for cooperation and the exchange of information on nuclear regulatory matters. As part of this agreement, both countries committed to the exchange of certain technical information related to the regulation of health, safety, security, safeguards, waste management and environmental protection aspects of the siting, construction, commissioning, operation and decommissioning of any designated nuclear facility in Canada or the United States.

G.11 Design, construction and safety assessment of facilities

After the granting of a licence to prepare a site, the second formal licensing step for nuclear facilities is the licence to construct. Sometimes an application for a licence to prepare site and construct is submitted to the CNSC for approval concurrently.

The requirements for a licence to construct a Class I nuclear facility are listed in section 5 of the CINFR. Information listed in section 3 of the GNSCR and section 3 of the CINFR is also required. This includes items such as the proposed design (including systems and components), the quality assessment program, the possible effects on the environment and the proposed measures to control releases to the environment, a waste management strategy, and a preliminary decommissioning plan.

In some cases, the CNSC may be required to conduct an environmental assessment under the *Canadian Environmental Assessment Act, 2012* before making a licensing decision on site preparation and the construction of a new nuclear facility to manage spent fuel. The CNSC published regulatory guide G-320, *Assessing the Long Term Safety of Radioactive Waste Management* (see section B.6), to assist licensees and applicants as they assess the long-term safety of storage and disposal of spent fuel and radioactive waste.

G.12 Operation of facilities

The third step in the licensing process is obtaining a licence to operate.

Requirements to operate a Class I nuclear facility are listed in section 6 of the CINFR. Information listed in section 3 of the GNSCR and section 3 of the CINFR is also required. This includes such items as a safety analysis report, commissioning program, the measures to prevent or mitigate releases of nuclear substances and hazardous substances to the environment, and a preliminary decommissioning plan.

As a requirement of a licence to operate, the licensee must also keep a record of the results of:

- effluent and environmental monitoring programs
- operating and maintenance procedures
- commissioning programs
- inspection and maintenance programs
- the nature and amount of radiation, nuclear substances and hazardous substances within the nuclear facility
- the status of each worker's qualifications, re-qualifications and training

G.13 Monitoring of spent fuel dry storage facilities

Dry storage facilities are required if a nuclear facility is to have an operational monitoring performance assessment program. The program is the means by which the performance of individual barriers – as well as the entire containment system – is evaluated with respect to:

- established safety criteria
- standards related to potential impacts on human health and safety, as well as to non-human biota and the physical environment

A monitoring program for a dry storage facility must be able to detect any unsafe condition or the degradation of structures, systems and components. A typical monitoring program for a spent fuel dry storage facility may include:

- gamma radiation monitoring
- canister monitoring for leaks as well as tightness verification of the baskets and canister liners
- effluent monitoring (including airborne emissions and liquid emissions)
- an environmental monitoring program

G.13.1 Gamma radiation monitoring experience

Routine gamma radiation surveys are performed by using a handheld monitor at appropriate points inside the dry storage facility fence and on all sides of the dry storage containers, or by using thermoluminescent dosimeter mounted devices to monitor cumulative fields. Experience has demonstrated that gamma radiation at dry storage facilities is significantly less than predicted during the design phase.

G.13.2 Leak tightness verification experience

Leak tightness verification of the AECL-type fuel baskets and concrete canisters consists of connecting a pump to the liner cavity and recirculating the air through filters. Excessive humidity indicates either a liner leak or water holdup in the canister from operations carried out before sealing. The presence of radioactivity indicates a basket leak. For the OPG-type dry storage containers, leak tightness is verified through helium leak testing before containers are placed in storage. Subsequent aging management activities provide assurance that the container condition and weld integrity are not compromised and that helium cannot leak out.

Experience indicates that the various dry storage structures and components currently used in Canada effectively contain the fission products in the fuel bundles.

G.13.3 Environmental monitoring experience

Every nuclear power plant (and the nuclear facilities managed by Canadian Nuclear Laboratories) has an environmental monitoring program. Spent fuel dry storage facilities at these sites are addressed in the site environmental monitoring programs, which:

- provide an early indication of the appearance or accumulation of radioactive material in the environment
- verify the adequacy and proper functioning of effluent controls and monitoring programs
- provide an estimate of actual radiation exposure to the surrounding population
- provide assurance that the environmental impact is known and within anticipated limits

- provide standby monitoring capability for rapid assessment of risk to the general public in the event of accidental releases of radioactive material

Experience shows that spent fuel dry storage facilities in Canada operate safely and within prescribed regulatory limits.

G.13.4 Effluent monitoring experience

G.13.4.1 Atomic Energy of Canada Limited (Canadian Nuclear Laboratories)

The fuel baskets of the NRU research reactor are wet-loaded in the facility rod bay area. The loaded fuel basket is raised into the shielded workstation. While being raised, an annular ring with spray nozzles sprays the chain and loaded fuel basket with demineralized water to clean them. All liquids are returned to the spent fuel storage bay. Once in the shielded workstation, the loaded fuel basket is air-dried and weld-sealed. The air-drying system consists of:

- two air heaters
- blowers with high-efficiency particulate air filters
- associated ductwork
- dampers

Following shutdown of the prototype generating stations (Nuclear Power Demonstration, Douglas Point and Gentilly-1) spent fuel was transferred to concrete canisters for storage during the 1980s (see sections 4.3.1, 4.5.11, 4.5.12, 4.5.13). The Dry Fuel Storage Canister Air Sampling Program at each location continues to show sampling results at or near limit of detection thereby confirming containment of the fuel in storage.

G.13.4.2 Ontario Power Generation

OPG's dry storage containers are wet-loaded in the fuel bay and then decontaminated, drained and dried, and have a transfer clamp installed to secure and seal the lid during onsite transfer. The fuel bay area is equipped with an active ventilation system, and most of the liquids resulting from the draining and vacuum drying are returned to the fuel bay. Other liquids from the draining and vacuum drying are directed to the station's active liquid waste system. At the dry storage facility, a special workshop houses the following dedicated systems for dry storage container processing:

- closure welding and welding-related systems
- non-destructive examination of welds
- vacuum drying system
- helium backfilling system
- helium leak detection system

Airborne contamination hazards may present a danger if any loose surface contamination on the dry storage container becomes airborne or if there is leakage of the dry storage container internal gas (such gas may contain krypton-85 as well as radioactive particulates). The processes that could give rise to these airborne hazards are:

- dry storage container draining and drying
- transfer clamp and seal removal

- dry storage container backfilling with helium

Airborne particulate monitors and gamma radiation monitors are used to detect any abnormally high levels. Re-suspension of loose surface contamination is a low-probability event, and experience from the used fuel dry storage facilities supports this. The workshop also has active ventilation, which consists of exhaust fans, radioactive filter assemblies and a discharge stack. Any airborne radioactive particulate contamination, if present in the ventilation exhaust, is effectively removed by high-efficiency particulate air filters in the active ventilation system. Monitoring results to date from the Pickering Used Fuel Dry Storage Facility, Darlington Waste Management Facility and Western Used Fuel Dry Storage Facility have shown no significant levels of particulates in the active ventilation exhaust.

Because the dry storage containers are fully drained and vacuum dried at the generating station fuel bay area, there are no liquid emissions from the dry storage container during onsite transfer to the dry storage workshop. The exterior surfaces of dry storage containers are decontaminated prior to their transfer from the fuel bay area to the dry storage workshop. Spot decontamination operations do not generate liquids and liquids are not normally used in the storage areas. Because of this – and because loose contamination is not permitted on dry storage containers or facility surfaces – no contaminated liquid effluents are expected from the dry storage operations. However, some liquid effluents may originate in the container processing area as a result of maintenance. Such liquids from the Pickering Waste Management Facility are sampled and placed in appropriate containers for proper disposal or, when acceptable, pumped into the generating station’s active liquid waste management system from the Pickering Used Fuel Dry Storage Facility. Monitoring results at the Pickering Used Fuel Dry Storage Facility have shown no significant levels of radioactivity in the drainage effluent transferred to the generating station system. As a result, the Darlington Waste Management Facility and Western Used Fuel Dry Storage Facility do not have active liquid waste management systems.

G.14 Disposal of spent fuel

Canada does not currently have a disposal facility for spent fuel. Any proposal for the site preparation, construction, operation, decommissioning (closure and post-closure) and abandonment (i.e., release from CNSC licensing) of a disposal facility, such as a deep geological repository, must satisfy the requirements of the NSCA and its associated regulations. The CNSC can make a licensing decision on a deep geological repository only after a positive decision is made on the environmental assessment.

G.15 New facilities

Spent fuel from the operation of research reactors at CRL is currently stored below ground in vertical cylindrical concrete structures called “tile holes.” These are situated in CRL’s Waste Management Area B. The fuel initially loaded into these storage structures from 1963 to 1983 was research reactor prototype fuel and included uranium metal fuel that has less corrosion resistance than modern-day alloy fuels. The fuel consists of about 700 prototype and research reactor fuel rods, with a total mass of approximately 22 tonnes. Although the fuel is safely stored, monitoring and inspection have shown that some of the fuel containers and fuel is corroding.

A new above-ground dry storage facility to repackage, dry and store this inventory of spent legacy research fuel has been constructed and is now receiving fuel. The first fuel was transferred into this facility at the end of 2015. The new dry storage system is located in the fuel packaging and storage building at Waste Management Area B. The fuel packaging and storage building contains a packaging and vacuum drying station and a monitored storage structure. The existing storage container is placed – with the spent fuel remaining inside – in a new stainless-steel container and dried before being placed in the monitored storage structure. The storage structure is engineered to last a minimum of 50 years and provides safe interim storage for the packaged fuel until a long-term management facility is available.

Fuels stored in tile holes at CRL since 1983 are more corrosion resistant and continue to be stored in tile holes that are better designed to prevent water ingress.

G.16 Long-term management of spent fuel

Since the early days of the CANDU program, several concepts for the long-term management of spent fuel have been under consideration. The options for long-term management in Canada were reviewed by a royal commission in 1977. Subsequently, Canada's spent fuel waste management program was formally initiated by the governments of Canada and Ontario. AECL was assigned responsibility to develop a concept for placing spent fuel in a deep underground repository within the plutonic rock of the Canadian Shield. Ontario Hydro (now OPG) was assigned responsibility to study and develop technology to store and transport spent fuel. It was also designated to provide technical assistance to AECL in the area of repository development. In 1981, the governments of Canada and Ontario announced that site selection for a repository would not be undertaken until after the disposal concept had been accepted.

In 1994, AECL submitted its environmental impact statement on the deep geological repository concept for review by a federal environmental assessment panel (the Seaborn Panel). This review included input from government agencies, non-governmental organizations and the general public. Public hearings conducted by the Seaborn Panel associated with the review took place during 1996 and 1997. The Seaborn Panel's report, titled *Report of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel,* was submitted to the Government of Canada in 1998. It concluded that a deep geological repository in crystalline rock was technically feasible but "until broad public acceptance of a nuclear fuel waste management approach has been achieved, the search for a specific site should not proceed."

It also made recommendations to help the Government of Canada reach a decision on the acceptability of the disposal concept and the steps to be taken to ensure the safe long-term management of spent fuel in Canada (per the Canadian Environmental Assessment Agency, 1998).

The Government of Canada responded to the Seaborn Panel report later in 1998 and announced the steps it would require the producers and owners of spent fuel in Canada to take, including the formation of the Nuclear Waste Management Organization (NWMO) by the nuclear utilities. In 2002, the Canadian Parliament passed the *Nuclear Fuel Waste Act* (NFWA), which indicates that the Governor in Council will select one approach for the long-term management of spent fuel from those examined by the NWMO. Under the NFWA, the following actions were to take place:

- The nuclear energy corporations were to establish a waste management organization, the purpose of which would be to study and propose approaches for the management of spent fuel and to implement the approach selected by the Governor in Council. The study was to include a technical description and a comparison of the benefits, risks and costs as well as the ethical, social and economic considerations associated with each approach. It was also to include specification of economic regions for implementation and plans for implementation of each approach in the study. The waste management organization was to consult the general public and, in particular, Aboriginal peoples on each approach.

- The waste management organization was to create an advisory council, which would reflect a broad range of scientific and technical disciplines. Its expertise should include public affairs, other social sciences as needed and traditional Aboriginal knowledge. It was also to include representatives of the local and regional governments and Aboriginal organizations affected by the selected approach because of their geographic locations.

- The waste management organization was to submit, within three years of the NFWA coming into force, a study setting out proposed approaches for the management of spent fuel as well as its final recommendation. The study would need to include approaches based on the following methods:

    - a modified AECL concept for deep geological disposal in the Canadian Shield

    - storage at nuclear reactor sites

    - centralized storage, either above or below ground

Under the NFWA, the Government of Canada was tasked with reviewing the study prepared by the waste management organization, selecting a long-term management option from those proposed and providing oversight during implementation. Natural Resources Canada was tasked with overseeing how the waste management organization implements the management approach and ensuring compliance with the NFWA. The waste management organization was to report annually to the Minister of Natural Resources. Every third year – following the selection of an approach by the Governor in Council – this report would include a summary of activities and a strategic plan for the subsequent five years. Canada's plan has now moved forward in conjunction with this legislative framework.

Pursuant to the NFWA, the waste management organization – the NWMO – was established in 2002 by the nuclear energy corporations of OPG, Hydro-Québec and NB Power. Upon its establishment in 2002, the NWMO's first mandate was to develop collaboratively with Canadians a management approach for the long-term care of Canada's spent fuel that is socially acceptable, technically sound, environmentally responsible and economically feasible. From 2002 to 2005, the NWMO studied various approaches to the long-term management of Canada's spent fuel.

In 2005, the NWMO recommended the Adaptive Phased Management (APM) approach to the Minister of Natural Resources. APM includes a technical method based on an end point of centralized containment and isolation of the spent fuel in a deep geological repository in a suitable rock formation. It provides for continuous monitoring of the spent fuel and the potential to retrieve it for an extended time. There is provision for contingencies, such as the optional step of shallow storage at the selected central site if circumstances favour early centralization of the spent fuel before the repository is ready.

Flexibility in the pace and manner in which the project is implemented allows for phased decision making, with each step supported by continuous learning, research and development, and public engagement. An informed, willing community will be sought to host the centralized facilities. Sustained engagement of people and communities is a key element of the plan, as the NWMO continues to work with citizens, communities, municipalities, all levels of government, Aboriginal organizations, non-governmental organizations, industry and others.

On June 14, 2007, following a review of the NWMO's study *Choosing a Way Forward*, the Government of Canada announced it had selected the APM approach for the long-term management of spent fuel in Canada.

With this government decision, the NWMO assumed responsibility for implementing the APM approach. Governance and organization staffing have evolved to provide the oversight, skills and capabilities required to implement APM. The advisory council continues to provide advice as required by the NFWA and the NWMO issues its reports annually to the Minister of Natural Resources and to the public. In March 2017, the NWMO submitted its third triennial report to the minister, as required by the NFWA.

To support financing of the plan, waste owners continue to make regular deposits into the segregated trust funds established in 2002. In 2008, the NWMO submitted to the Minister of Natural Resources a funding formula and schedule for trust fund deposits; this funding formula was later approved in 2009. The current status of the APM initiative can be found in section K.5.

The NWMO will be required to obtain licences from the CNSC for site preparation, construction, operation, decommissioning and abandonment (release from CNSC licensing) of the repository facilities.

Section H – Safety of Radioactive Waste Management

H.1 Scope of the section

This section addresses article 11 (General Safety Requirements) to article 17 (Institutional Measures After Closure) of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* and provides a comprehensive description of radioactive waste management in Canada.

At every stage of radioactive waste management, there are effective defences that protect individuals, society and the environment against potential hazards and the harmful effects of ionizing radiation, now and into the future. In addition to describing facilities and their normal operations, this section describes the steps or controls that are in place to prevent accidents with radiological consequences and mitigate the consequences should accidents occur.

The information contained in this section demonstrates that the requirements of the following applicable International Atomic Energy Agency (IAEA) Safety Standards have been addressed:

- Article 11: General Safety Requirements – IAEA Safety Requirements SSR-2/1, SSR-5 and GSR Part 5
- Article 13: Siting of Proposed Facilities – IAEA Safety Requirement NS-R-3
- Article 14: Design and Construction of Facilities – IAEA Safety Requirements SSR-2/1 and SSR-5
- Article 15: Assessment of Safety of Facilities – IAEA Safety Requirements SSR-2/1, SSR-5 and GSR Part 3
- Article 16: Operation of Facilities – IAEA Safety Standards SSR-2/1, SSR-5, GSR Part 5 and GSR Part 3

H.2 Radioactive waste in Canada

Nuclear facilities and users of certain prescribed substances produce radioactive waste. The Government of Canada establishes the policy framework for the management of these wastes. The Canadian Nuclear Safety Commission (CNSC) regulates the management of radioactive waste to ensure it causes no undue radiological hazard to the health and safety of persons or to the environment. The radioactive content of the waste varies with the source; therefore, management techniques depend on the characteristics of the waste (see section H.3).

Certain types of radioactive waste (such as waste from hospitals, universities and industry) contain only small amounts of radioactive materials with short half-lives, meaning the radioactivity decays within hours or days. After holding the waste until the radioactivity has decayed to the acceptable levels authorized by the CNSC, the waste can be disposed of by conventional means (e.g., in local landfill or sewer systems).

With the notable exception of waste from nuclear power plants – which is contaminated with long-lived radioisotopes – radioactive waste from hospitals and universities is generally shipped directly or via a waste broker to the waste management facility (WMF) operated by Canadian Nuclear Laboratories (CNL) at the Chalk River Laboratories (CRL) site. The typical storage facilities at CRL include shielded above-ground storage buildings, concrete bunkers and concrete tile holes. In some cases, radioactive waste is shipped to waste treatment and disposal facilities in the United States. For information on the amount shipped to the United States, see annex 5.1.8.

Canadian methods for the management of radioactive waste are similar to those of other countries. As long-term management facilities are not yet available, primary emphasis is placed on minimization, volume reduction, conditioning, and interim storage of the waste. Radioactive waste is stored onsite or offsite, in above- or below-ground engineered structures. Some of the waste may be reduced in volume by compaction or incineration prior to storage. All radioactive waste currently generated is stored in such a way that it can be retrieved when necessary.

Operators have instituted methods to recover storage space by cascading the waste after sufficient radioactive decay or reclaiming existing storage space through further compaction (super compaction), segregation or both. As is the case for all nuclear activities, the facilities for handling radioactive waste must be licensed by the CNSC and conform to all pertinent regulations and licence conditions. The waste management objective throughout the industry – from mines to reactors – is the same: to control and limit the release of potentially harmful substances into the environment.

H.3 Characteristics of radioactive waste in Canada

H.3.1 Fuel manufacturing waste

In the past, wastes from refineries and conversion facilities were managed by means of direct in-ground burial. This practice was discontinued in 1988 after the closure of the Port Granby WMF. Subsequent to 1988, the volume of low-level radioactive waste (LLW) produced from these operations has been greatly reduced through incineration and the recovery and reuse of uranium bearing materials. The residual volume of LLW is segregated, managed, stored and disposed of at licenced WMFs in Canada and the United States.

Fuel manufacturing waste consists of a variety of potentially uranium-contaminated wastes, including:

- contaminated zirconium
- combustible materials
- rubber and plastic
- oils and solvents
- metal
- sewage sludge
- by-products (ammonium nitrate, fluoride, regeneration products)

H.3.2 Electricity generation waste

Radioactive wastes resulting from nuclear reactor operations are stored in a variety of structures located in radioactive waste management facilities at nuclear reactor sites. Prior to storage, the volume of the radioactive waste may be reduced by incineration, compaction or shredding. In addition, within the nuclear power plant there are facilities for the decontamination of parts and tools, laundering of protective clothing, and the refurbishment and rehabilitation of equipment. Electricity generation waste consists of varying types of low- and intermediate-level activity radioactive waste such as:

- filters
- light bulbs
- cable
- used equipment

- metals
- construction debris
- absorbents (sand, vermiculite, sweeping compound)
- ion exchange resins
- reactor core components
- retube materials
- paper
- plastic
- rubber
- wood
- organic liquids

See figures H.1 and H.2 for examples of how retube waste is being stored at a nuclear power plant's radioactive waste management facility. See figure H.3 for an example of how future Darlington Nuclear Generating Station retube waste will be stored.

Figure H.1: Dry storage modules containing Pickering A (Units 1 to 4) retube waste at the Ontario Power Generation's Pickering Waste Management Facility (PWMF)

Figure H.2: Bruce Units 1 & 2 Retube Waste Containers currently in storage at the Ontario Power Generation's Western Waste Management Facility (WWMF) Retube Component Storage Building

Figure H.3: Darlington Retube Waste Container (RWC) and Darlington Storage Overpack (DSO) cutaway drawing that shows the storage configuration (RWC inside the DSO)

H.3.3 Historic waste

Historic LLW in Canada refers to LLW that was managed in the past in a manner no longer considered acceptable but for which the current owner cannot reasonably be held responsible and the Government of Canada has accepted the long-term responsibility. Atomic Energy Canada Limited (AECL) is responsible for the cleanup and safe management of historic LLW at sites across Canada for which the Government of Canada has accepted responsibility. This includes the Port Hope Area Initiative (PHAI) and activities associated with the Low-Level Radioactive Waste Management Office. This work is delivered by CNL on behalf of AECL under a government-owned, contractor-operated (GoCo) model.

Historic LLW cleanups have been completed across Canada and several sites with historic radium or uranium contamination continue to be monitored. At some sites, materials have been placed in interim storage pending the development of a long-term management approach. Ongoing site monitoring, inspection and maintenance are conducted at these sites. The current plan sees the majority of these liabilities addressed by 2026.

In keeping with the 1996 *Policy Framework for Radioactive Waste,* Canada has taken different approaches for the management of spent fuel, low- and intermediate-level radioactive waste (L&ILW), and uranium mine and mill tailings. These different approaches reflect not only the different scientific and technical characteristics of the wastes but also the economics and the geographic dimensions of Canada and the locations of the waste. Long-term strategies and solutions for historic LLW are being developed and implemented for the various regions of the country.

H.3.4 Radioisotope production and use waste

Radioisotope production and use generate a variety of radionuclides for commercial use, such as cobalt-60 for sterilization and cancer therapy units, and molybdenum-99 or other isotopes for use as tracers for medical research, diagnoses and therapy. A number of WMFs process and manage the wastes that result from the use of radioisotopes for research and medicine. In general, these facilities collect and package waste for shipment to approved storage sites. In some cases, the waste is incinerated or allowed to decay to insignificant radioactivity levels and then discharged into the municipal sewer system or municipal garbage system.

H.3.5 Uranium mining and milling waste

Uranium mining and milling waste comprises three major waste streams: mill tailings, waste rock and waste water.

After ore is removed from the ground, either by underground mining or from an open pit, it is milled. The milling process, in which the ore is crushed and treated with chemicals, extracts the ore's uranium content, leaving a waste product known as mill tailings.

The method used to manage tailings from uranium mine operations varies from mine to mine. Much depends on where the mine is located. The quantity of tailings produced at any uranium mine is determined by the grade of the ore as well as the size of the deposit. Canada's operating mines (all of which are located in northern Saskatchewan) have high-grade ore deposits in comparison to past mining operations in Canada; therefore, smaller volumes of tailings are being produced.

Due to varying mineralogy, different mines use different chemicals, concentrates or mixtures of chemicals in the milling process. As a result, tailings vary in composition from mine to mine.

Tailings management facilities (TMFs) have evolved over the decades from the simple deposition of tailings into natural landforms, lakes or abandoned underground mines to the construction of engineered surface storage facilities (complete with seepage collection systems) to the current practice of placing the tailings in engineered mined-out open pits converted to TMFs. Tailings in modern facilities are covered with water (subaqueous deposition) to enhance radiation protection and avoid oxidization and winter freezing of the tailings.

Waste rock ranges from benign material, devoid of the metal or mineral being sought, to mineralized material that contains sub-economical concentrations of the metal or mineral that was being extracted. Waste rock characteristics are highly variable. Some waste rock contains sufficient concentrations of sulphide to generate moderate levels of acidity. This can mobilize potential contaminants from secondary minerals. In Saskatchewan, some waste rock contains secondary arsenic and nickel minerals, often to the point where the long-term care and control of these non-radioactive contaminants – not the waste rock's radioactivity – drive the level of care needed to manage it.

The waste water (effluent) generated from mining and milling processes is treated as required. Treated water that is discharged to the environment is monitored to ensure it meets regulatory standards prescribed by the provincial and federal governments. These limits ensure the impact on the environment is minimal.

H.3.6 Radioactive waste at research reactors

At all research reactors, radioactive waste materials are segregated by licensees into short-lived and long-lived radioactive waste. Short-lived radioactive wastes are stored onsite to allow for decay until they can be disposed of in a conventional manner. Long-lived radioactive wastes are kept onsite temporarily until a certain amount or volume is accumulated, at which point they are generally transported to CRL for storage. This is also the case for radioactive waste from the Tri-University Meson Facility (TRIUMF), Canada's national laboratory for particle and nuclear physics.

Liquid wastes from research reactors mostly consist of water that contains radioactive contamination. Typically, the water is cleaned up through a water purification system that includes filtration and ion exchange. Once ion exchange resins are used up, they are stored with the long-lived radioactive waste that is eventually sent to CRL. At TRIUMF, the accelerator's vacuum pumps produce a small amount of contaminated oil (approximately two litres per year) that is presently stored onsite. Waste management at CRL is described in detail in annex 5.

H.4 Waste minimization

Canada has adopted IAEA waste minimization practices as described in CNSC policy document P-290, *Managing Radioactive Waste,* which expects that the "generation of radioactive waste is minimized to the extent practicable." (For more information on P-290, see section B.5.) Waste minimization is also a key principle of the CSA Group's industry standard CSA N292.3, *Management of low- and intermediate-level waste*, and CSA N292.0, *General principles for the management of radioactive waste and irradiated fuel*.

In addition, CNSC regulatory guide G-219, *Decommissioning Planning for Licensed Activities*, indicates that waste management plans should include "specific plans for the reuse, recycling, storage or disposal of that waste." Canada has also developed the industry standard CSA N294, *Decommissioning of facilities containing nuclear substances*, which indicates that strategies for waste management must consider and prioritize "the potential for recycling or reuse of equipment and materials."

The Canadian nuclear sector actively promotes and practises waste minimization. For example, the policy of Ontario Power Generation (OPG) is to minimize the production of radioactive waste at the source by preventing materials from unnecessarily becoming radioactive. The Canadian nuclear sector practises waste minimization by:

- implementing material control procedures to prevent materials from unnecessarily entering into radioactive areas
- implementing enhanced waste monitoring capabilities to reduce the inclusion of non-radioactive wastes in radioactive wastes
- implementing improvements to waste handling facilities
- enhancing employee training and awareness

Canadian licensees follow various forms of waste minimization, depending on site and operational specifics. For example, OPG has an overall waste management procedure that derives its authority from OPG's environmental waste management program. This provides the overall framework by which waste is managed. Integrated into this program is the implementation of a number of waste minimization activities. Specific initiatives include the following:

- communication and awareness strategies for maintaining a waste minimization culture
- establishment of a clean zone area for de-packaging materials
- controls to minimize the transfer of unnecessary materials in zoned areas
- use of reusable equipment and materials as much as possible

- segregation of waste into radioactive and “likely clean” at many collection points, allowing for further monitoring and characterization of the likely clean waste
- separation of recyclable materials at collection points
- use of washable protective equipment to replace disposable protective equipment such as gloves and booties
- use of washable bags, cloths and mops
- use of industry best practices related to free release standards and segregation
- development of suitable fleet-wide metrics to drive improvements and monitor performance
- benchmarking of other radioactive waste management facilities, both domestically and internationally, for implementation of best practices
- diversion of waste to external third-party contractors, where possible, to further process specific waste streams (such as diversion of metal waste to metal melting)

CNL is undertaking similar activities on behalf of AECL, operating waste clearance facilities at CRL and Whiteshell Laboratories to enhance its capability to effectively use free-release standards and segregation. CNL recognizes that some of the practices previously adopted to minimize waste volumes when radioactive waste disposal facilities were not available will evolve if the proposed Near Surface Disposal Facility at CRL becomes available and decommissioning progresses at an accelerated pace. The aim will shift from traditional goals of minimizing volume of wastes requiring storage to an overall optimization across integrated decommissioning and waste management activities in terms of dose to workers, conventional safety risk, use of resources and cost.

The CNSC supports the internationally adopted and environmentally friendly principles of good waste management practices in the nuclear industry to reduce the volume of radioactive waste requiring storage.

H.5 General safety requirements

The main objective in the regulation of either a spent fuel dry storage facility or a radioactive waste management facility is to ensure such facilities and their activities do not pose unreasonable risks to health, safety, security and the environment. Canada’s comprehensive licensing system, described in detail in section E.4, does not differentiate between a spent fuel management facility and a radioactive waste management facility. The design, construction and operation of either type of facility must ensure the safety of human health and the environment.

H.5.1 Protection and safety fundamentals

The regulation of spent fuel and radioactive waste can be divided into generic performance requirements, generic design, and operational principles and performance criteria. These criteria are described in section G.8.4.

Uranium mines and mills are governed by the same principles as those for spent fuel or radioactive waste and are also governed by the *Uranium Mines and Mills Regulations*.

H.5.2 Safety requirements

Safety requirements for the management of spent fuel and radioactive waste must provide for the protection of the environment and the health and safety of workers and the public. During normal operations, spent fuel and radioactive waste management facilities must be operated in a safe manner. System components that may require periodic maintenance must be readily accessible and designed to permit safe and efficient maintenance. The safety requirements are described in detail in section G.8.4.

H.6 Protection of existing facilities

The safety of radioactive waste management facilities that existed when the Joint Convention entered into force was ensured through the Canadian regulatory regime. The operation of radioactive waste management facilities must be conducted in accordance with the *Nuclear Safety and Control Act* (NSCA), along with its associated regulations and the licence conditions. The CNSC compliance program activities verify that operators comply with the requirements for safe operation of radioactive waste management facilities. A list of facilities is included in section D.

H.6.1 Past practices

Legacy radioactive wastes at AECL sites (which are managed by CNL) date back to the Cold War and the birth of nuclear technologies in Canada. These include contaminated buildings that have been shut down and contaminated lands that are managed by CNL on behalf of AECL. The liabilities include spent research reactor fuel and intermediate-level liquid waste from the production of medical isotopes and fuel processing experiments conducted in the Cold War era. In 2006, the Government of Canada initiated the Nuclear Legacy Liabilities Program to deal with the liabilities at AECL sites.

In 1982, the Government of Canada established the Low-Level Radioactive Waste Management Office within AECL as the federal agent for the cleanup and management of historic LLW in Canada. Canada's historic LLW inventory consists largely of radium- and uranium-contaminated soils. The Government of Canada has accepted responsibility for the long-term management of this waste. The bulk of Canada's historic LLW is located in the southern Ontario communities of Port Hope and Clarington. In March 2001, the Government of Canada and the local municipalities partnered on community-developed proposals to address the cleanup and long-term management of these wastes. This partnership launched the PHAI.

Upon implementation of the GoCo model in 2015, the federal responsibility for the management and discharge of the Government of Canada's radioactive waste liabilities, including both legacy and historic LLW, was transferred from Natural Resources Canada to AECL. As a result, the Nuclear Legacy Liabilities Program came to an end and the activities associated with the program were included as part of CNL's scope of work under a GoCo arrangement. This is further described in section K.7.2; the PHAI and other initiatives dealing with historic waste are described in section K.7.3.

As already shown in section F.4, when remedial actions are required at uranium mine and mill tailings facilities where the owner no longer exists, the federal and provincial governments ensure the sites are safely decommissioned. In Ontario, home of the former Elliot Lake uranium mining complex, the governments of Canada and Ontario entered into a memorandum of agreement in 1996 that outlined their respective roles in the management of abandoned uranium mine and mill tailings. In keeping with the *Policy Framework for Radioactive Waste*, best efforts are made to identify the uranium producer or property owner of a site. Where such an owner cannot be identified, the governments have agreed to share costs, including an equal sharing of costs associated with any necessary remediation. To date, these arrangements have not been necessary, as all Ontario sites have owners who are complying with their responsibilities.

The governments of Canada and Saskatchewan entered into a similar memorandum of agreement that defines roles and responsibilities for the remediation of certain Cold War era uranium mine sites, principally the Gunnar mine and mill site in northern Saskatchewan. On April 2, 2007, the two governments announced the first phase of the cleanup. The total cost, which was to be shared equally between the governments, was initially estimated to be $24.6 million. Since that time, significant work was completed to better understand the characteristics of the sites and requirements of the remediation. As a result, in 2014 the Government of Saskatchewan established a $222 million liability based on the best estimates to complete all remediation activities. Discussions between the governments are ongoing to share these costs. The remediation of Lorado was completed in 2016 and the site is currently under monitoring. The Gunnar and Lorado mine sites are described in annexes 8.1.1.2 and 8.1.1.3.

H.7 Protection in the siting of proposed facilities

The *Class I Nuclear Facilities Regulations* (CINFR) stipulate a lifecycle licensing approach for radioactive waste management facilities, requiring licensees to hold a licence to:

- prepare site
- construct
- operate
- decommission
- abandon

The *General Nuclear Safety and Control Regulations* (GNSCR), *Nuclear Security Regulations*, *Radiation Protection Regulations*, and *Nuclear Substances and Radiation Devices Regulations* also have requirements that must be met.

The requirements for a licence to prepare site for a Class I radioactive waste management facility are listed in sections 3 and 4 of the CINFR. Note that section 3 of the GNSCR requires additional information.

At the time this report was written, no contracting parties could be affected by the siting of a radioactive waste facility in Canada. The United States and Canada, however, originated a *Nuclear Cooperation Agreement* in 1955. Article 2 of that agreement provides for the exchange of classified and unclassified information "with respect to the application of atomic energy for peaceful uses, including research and development relating thereto, and including problems of health and safety." Article 2 also covers the entire field of health and safety as it relates to the Joint Convention.

H.7.1 Public information programs

CNSC's regulatory document RD/GD-99.3, *Public Information and Disclosure*, defines the CNSC's requirements for public information and disclosure protocols for licensees and applicants. It applies to uranium mines and mills, Class I nuclear facilities and some Class II nuclear facilities, and provides guidance on how to develop and implement the requirements for public information programs and disclosure protocols and is addressed in annex 3.6.2. In addition to the requirements in RD/GD 99.3, CNSC regulatory document REGDOC-3.2.2, *Aboriginal Engagement*, sets out requirements and guidance for licensees whose proposed projects may raise the Crown's duty to consult and are meant to ensure that potential or established Aboriginal and/or treaty rights are considered.

A description of OPG's public information program for spent fuel is addressed in section G.10.1. Information on OPG's existing public information program for its L&ILW storage (section H.7.1.1) and an example of public information for a new uranium mine or mill (section H.7.1.2) are described below.

H.7.1.1 Public information program for L&ILW storage

The following is an example of a public information program in a community where WMFs for spent fuel and radioactive waste are located. This section also includes an example of a program in a community where radioactive waste facilities are proposed to be located.

OPG operates an extensive public information program in the Ontario municipality of Kincardine and its surrounding communities, which are home to OPG facilities that store L&ILW and spent fuel. Information is communicated in a number of ways, based on the interests and concerns people may have about OPG's operations and projects. OPG provides many avenues to learn about its nuclear operations and is committed to sharing information on performance and nuclear operations and projects through open and transparent communication.

In support of its current operations and its proposed Deep Geologic Repository project, OPG operates a broad community engagement program to inform and engage the public in dialogue and discussion on issues related to radioactive waste. Communication strategies include:

- advertisements in local print media
- brochures and one-sheet infographics
- videos posted on the OPG website and YouTube (and shown at local briefings)
- facility tours
- briefings for key community stakeholders with media and elected officials
- printed newsletters in bulk distribution to local households
- direct mailings
- speaking engagements
- exhibits at community events
- sponsorships of local not-for-profit events and groups

To reach beyond the local communities, OPG makes extensive use of the Internet and social media, allowing all Ontarians to access its reports, brochures, videos and newsletters. OPG strives to be open and transparent in all its operations.

H.7.1.2 Public information for a new uranium mine or mill

Subparagraph 3(c)(i) and paragraph 8(a) of the *Uranium Mines and Mills Regulations* state that an application for a new uranium mine or mill shall include a "program to inform persons living in the vicinity of the mine or mill of the general nature and characteristics of the anticipated effects of the activity to be licensed on the environment and the health and safety of persons", as well as "a program to inform persons living in the vicinity of the site of the mine or mill of the general nature and characteristics of the anticipated effects of the abandonment on the environment and the health and safety of persons."

Licensees undertake comprehensive and ongoing engagement activities with the residents of Saskatchewan's north and maintain open communications with the interested local communities and Aboriginal groups. Meetings are also held with the Northern Saskatchewan Environmental Quality Committee, the Athabasca Working Group, community leadership groups and other stakeholders with an interest in the project. A variety of communication tools: videos, a website, factsheets, print media, local radio and ongoing community engagement activities, such as its annual northern tour are used.

H.8 Design, construction and assessment of facilities

The second formal licensing step for nuclear facilities, including radioactive waste management facilities, is the licence to construct. Requirements for a licence to construct a Class I nuclear facility are listed in sections 3 and 5 of the CINFR. Note that section 3 of the GNSCR requires additional information.

Before the CNSC can make a decision about whether to grant a licence to a party that has applied to construct a Class I radioactive waste management facility, the CNSC may have to initiate an environmental assessment in accordance with the *Canadian Environmental Assessment Act, 2012*. Regulatory guide G-320, *Assessing the Long Term Safety of Radioactive Waste Management* (see section B.6), assists licensees and applicants as they assess the long-term safety of storage and disposal of spent fuel and radioactive waste.

H.9 Operation of facilities

The third step in the licensing process is the licence to operate. Requirements to operate a Class I nuclear facility are listed in sections 3 and 6 of the CINFR. Section 3 of the GNSCR and section 3 of the CINFR require additional information. The information includes such items as a safety analysis report, commissioning program, measures to prevent or mitigate releases of nuclear substances and hazardous substances to the environment, and a preliminary decommissioning plan.

H.9.1 Records

As a requirement of a licence to operate, the licensee must keep a record of:

- the results of effluent and environmental monitoring programs
- operating and maintenance procedures
- the results of the commissioning program
- the results of the inspection and maintenance programs
- the nature and amount of radiation, nuclear substances and hazardous substances within the nuclear facility
- the status of each worker's qualifications, re-qualifications and training

H.9.2 Criticality safety

Per CNSC regulatory document RD-327, *Nuclear Criticality Safety*, criticality safety requirements must address both normal and abnormal conditions. A criticality safety analysis must be performed when "large quantities of fissionable materials" are stored or handled. The analysis must clearly demonstrate that the storage and handling of the radioactive waste is safe and, therefore, an inadvertent criticality cannot occur under normal or credible abnormal conditions. The analysis must consider the offsite consequences for low-probability, high-consequence inadvertent criticality events, and must demonstrate that the consequences of such events do not violate the public evacuation criteria established by international standards and national guidelines (specifically, the *Canadian Guidelines for Intervention During a Nuclear Emergency*).

H.10 Institutional measures after closure

H.10.1 About institutional measures after closure

Article 17 of the Joint Convention applies to institutional measures that must be taken after a disposal facility has been closed. Disposal means the radioactive waste is disposed of in a manner where there is no intent to retrieve it and that surveillance and monitoring is not required. Canada does not currently have a disposal facility. Examples of institutional controls for proposed future radioactive waste repositories are discussed in sections H.10.2 (i) and (ii). Decommissioned TMFs require long-term institutional controls. These will vary from minimal – after the closure of the current generation of in-pit TMFs, which were designed for future decommissioning – to ongoing monitoring and maintenance programs at older sites where tailings have been deposited in surface facilities. Section H.10.3 describes the Institutional Control Program developed by the Government of Saskatchewan for decommissioned mine sites, including former uranium mining and milling sites situated on Crown lands in that province.

H.10.1.1 Regulatory body requirements

Any application for a licence for site preparation, construction, operation, decommissioning (closure and post-closure) and abandonment (release from CNSC licensing) of a disposal facility, such as a deep geological repository, must satisfy the requirements of the NSCA and its associated regulations. The CNSC can make a licensing decision on a disposal facility only after a positive decision is made on the environmental assessment.

Several requirements are imposed by the NSCA and its associated regulations, including the following:

- A licence from the CNSC must be held in order for anyone to possess and use nuclear substances.
- Persons and the environment must be protected from unreasonable risk arising from the production, possession and use of nuclear substances and the development, production and use of nuclear energy.
- Licensees must comply with international obligations to which Canada has agreed (such as the commitments in the Joint Convention report).

Release from CNSC regulatory control occurs when the licensee has successfully decommissioned the facility and restored the site to a state that is suitable for future use (e.g., green field or brown field [industrial]). If unrestricted release is yet to be achieved (i.e., due to long-term presence of nuclear substances, contaminated systems, components or structures), perpetual licensing from the CNSC may be required unless the risks are very minimal and oversight by another regulatory or governmental body allows the Commission to exempt the site indefinitely from CNSC licensing (determined on a case-by-case basis).

The CNSC requires, after successful decommissioning, an application for a licence to abandon or exemption from licensing. This submission must be supported by reports on the results of the decommissioning and site restoration activities, as well as the results of the radiological and environmental monitoring, to demonstrate that the site no longer needs to be licensed under the NSCA.

Exemption

In order to be granted an exemption, the licensee must present a safety case that demonstrates long-term safety. The case would have to cite engineering design and barriers and/or the proposed forms of institutional controls, including periodic site verification. The CNSC would examine, on a case-by-case basis, the proposed institutional controls for long-term safety, the costs and consequences of failure of the institutional controls, and the reliability of the institutional controls. Regulatory guide G-320, *Assessing the Long Term Safety of Radioactive Waste Management*, helps licensees and applicants assess the long-term safety of storage and disposal of radioactive waste, including institutional controls (see section B.6).
The guide describes typical ways to assess the impacts that radioactive waste storage and disposal methods have on the environment and the health and safety of people.

Licence to abandon

In reviewing a submission for a licence to abandon, the CNSC must be satisfied that the abandonment of the site, nuclear substance, prescribed equipment or information does not pose an unreasonable risk to the environment, the health and safety of persons, or national security. The abandonment must also not result in a failure to comply with Canada's international obligations. Pursuant to section 8 of the CINFR, an application for a licence to abandon a Class I nuclear facility (which includes spent fuel management facilities) shall contain:

- the name and location of the land, buildings, structures, components and equipment to be abandoned
- the proposed time and location of the abandonment
- the proposed method of and procedure for the abandonment
- the effects on the environment and the health and safety of persons that may result from the abandonment, along with the measures that will be taken to prevent or mitigate those effects
- the results of the decommissioning
- the results of the environmental monitoring

H.10.1.2 Records

According to the GNSCR, the NSCA requires every person to keep records for the period specified in the or, if no such period is specified, until one year after the expiry of the licence that authorizes the activity in respect of which the records are kept. No person may dispose of a record unless the NSCA no longer requires him or her to keep that record or unless he or she has notified the regulatory body of the date of disposal and the nature of the record at least 90 days before disposing of it.

Records relating to a licence to abandon or an exemption from licensing may also need to be archived or stored indefinitely under the oversight of another government or another regulatory body.

H.10.2 Examples of the use of institutional controls for proposed spent fuel and radioactive waste repositories

The following are examples of Canadian initiatives for spent fuel and radioactive waste repositories:

(i) Nuclear Waste Management Organization (NWMO) proposed deep geological repository for the long-term management of spent fuel

In 2005, the NWMO submitted to the Government of Canada a final study, *Choosing a Way Forward*. The recommended approach, Adaptive Phased Management (APM), includes centralized containment and isolation of spent fuel in a deep geological repository in a suitable rock formation. In 2007, the Government of Canada issued its decision, accepting the APM as Canada's plan.

As part of the decision to close the deep geological repository sometime in the future, provisions will be made for site controls and for post-closure monitoring of the site. The precise nature and duration of post-closure monitoring and any requirements to restrict land use in the area will be developed collaboratively during implementation and will take advantage of the most modern technology at the time. This is a decision to be made by a future society.

(ii) Ontario Power Generation Deep Geologic Repository for L&ILW

OPG's licence application to prepare and construct a deep geologic repository for its L&ILW proposed the use of institutional controls for a 300-year period to prevent the inappropriate use of the site by the public following the closure and dismantling of the surface facilities. For OPG's proposed Deep Geologic Repository project, all activities might be permitted during the institutional period except drilling, deep excavation or disruption of the shaft seals, subject to any ongoing use of the site for nuclear activities during the same period. The controls currently proposed are passive in nature and include zoning and land use restrictions. At the current stage of OPG's Deep Geologic Repository project, specific details of these and any additional activities are yet to be defined.

H.10.3 Example of the development of institutional control for decommissioned uranium mines and mills in Saskatchewan

In 2005, Saskatchewan initiated the formal development of an institutional control framework for the long-term management of decommissioned mine and mill sites on provincial Crown land. The purpose of the framework was to ensure the health, safety and well-being of future generations, provide certainty and closure for the mining industry, and recognize obligations by the province as well as national and international obligations for the storage of radioactive materials. The Ministry of Energy and Resources was assigned responsibility for the Institutional Control Registry. An interdepartmental Institutional Control Working Group composed of senior representatives from the provincial ministries of environment, justice, finance, northern affairs, and energy and resources, along with the Government of Saskatchewan's Executive Council, developed the framework following consultations with stakeholders from the federal government, industry, Aboriginal peoples and northern residents, special interest groups and the general public.

In May 2006, the provincial legislature promulgated the *Reclaimed Industrial Sites Act* to implement and enforce a recognized need for institutional control. With the *Reclaimed Industrial Sites Act* in place, the Institutional Control Working Group proceeded with the development of the *Reclaimed Industrial Sites Regulations,* which were subsequently approved in March 2007. Both *Reclaimed Industrial Sites Act* and *Reclaimed Industrial Sites Regulations* legislate the establishment of the Institutional Control Program. In the case of a former uranium mining or milling site, the program recognizes the jurisdictional authority of the NSCA as enforced by the CNSC.

In December of 2009, the Government of Saskatchewan published *Institutional Control Program – Post Closure Management of Decommissioned Mine/Mill Properties on Crown Land in Saskatchewan* under the auspices of the provincial Ministry of Energy and Resources (today the Ministry of the Economy).

The primary components of the Institutional Control Program are:

- Institutional Control Registry
- Institutional Control Funds
- Monitoring and Maintenance Fund
- Unforeseen Events Fund

The Institutional Control Registry will maintain a formal record of closed sites, manage the funding and perform any required monitoring and maintenance work. Registry records will include the location and former operator, site description and historical records of activities, site maintenance, monitoring and inspection documentation, and future allowable land use for the site. In the case of a decommissioned uranium mining or milling site, it will reference the related CNSC documentation and decisions. There is a memorandum of understanding between CNSC and the province regarding the Institutional Control Program and financial guarantees.

The Monitoring and Maintenance Fund will pay for long-term monitoring and maintenance. The Unforeseen Events Fund will pay for unforeseen future events, such as damage resulting from floods, tornadoes or earthquakes. To reduce the province's risk when it accepts custodial responsibility for sites – and to offset the cost of future monitoring, maintenance and unforeseen events – dedicated site-specific funding will be established by the site holder. The funds will be managed by the province but are legislated and stand alone from provincial revenue.

The Institutional Control Program completes the regulatory framework for the province, helping the province respond to industry's requirement for clarity in the investment climate and accepting responsibility for safety and environmental concerns. This helps create a sustainable mining industry and protect future generations. For more information on the Institutional Control Program, visit economy.gov.sk.ca/Institutional_Control-Decommissioned_Mines/Mills.

H.11 Monitoring programs

Each radioactive waste management facility in Canada must have in place an approved monitoring program. The monitoring program for a waste management facility must detect unsafe conditions and degradation of structures, systems and components that could result in an unsafe condition. This is how the performance of the individual storage structures – and the entire waste storage system – is evaluated. It helps ensure standards will create a safe environment for humans, non-human biota and the physical environment. For more information on environmental monitoring programs, refer to section F.6.6. Radiological effluent discharge levels for radioactive waste management facilities are listed throughout annexes 5, 6, 7 and 8.

A typical monitoring program for a radioactive waste management facility, including a uranium mine tailings area, may include the following elements:

- gamma radiation monitoring
- effluent monitoring, including airborne and liquid emissions
- an environmental monitoring program, which may include soil sampling, sediment sampling, fish sampling, and surface water and groundwater monitoring

Section I – Transboundary Movement

I.1 Scope of the section

This section addresses article 27 (Transboundary Movement) of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management* and provides information on Canada’s experience and practices pertaining to the transboundary movement of radioactive material. The information in this section demonstrates that such movements are undertaken in a manner consistent with the provisions of the Joint Convention and relevant binding international instruments.

I.2 Introduction

The following Canadian laws and regulations are used to control the import and export of nuclear substances in accordance with Canada’s bilateral and multilateral agreements:

- *Nuclear Safety and Control Act* (NSCA) and the associated *Nuclear Non-proliferation Import and Export Control Regulations* and *General Nuclear Safety and Control Regulations* (GNSCR)
- *Canadian Environmental Protection Act* and the associated *Export and Import of Hazardous Wastes Regulations*
- *Export and Import Permits Act*
- *United Nations Act*

I.3 Nuclear substances

Under the NSCA, the Canadian Nuclear Safety Commission (CNSC) regulates the import and export of nuclear substances (as well as prescribed equipment and prescribed information). The schedule to the *Nuclear Non-proliferation Import and Export Control Regulations* identifies the “controlled nuclear substances” that require export and import authorization from the CNSC.

The following are considered controlled nuclear substances and require transaction-specific risk assessments and export authorizations from the CNSC:

- plutonium
- uranium
- thorium
- deuterium
- tritium
- radium-226 (greater than 370 megabecquerel)
- alpha-emitting radioisotopes with a half-life of 10 days or greater, but less than 200 years, with a total alpha activity of 37 gigabecquerel/kilogram or greater (with the exception of material with less than 3.7 gigabecquerel of total alpha activity)

Global Affairs Canada regulates the export of certain types of nuclear substances under the *Export and Import Permits Act*.

The export of a radioactive sealed source of the first 16 radionuclides identified by the International Atomic Energy Agency (IAEA) as a Category 1 or Category 2 radioactive sealed source under table 1 of annex 1 of the IAEA *Code of Conduct on the Safety and Security of Radioactive Sources* requires authorization by the CNSC under the NSCA and the GNSCR.

I.4 Exporting state

As stated above, the CNSC and Global Affairs Canada both regulate the export of controlled nuclear substances listed in section I.3. Although the regulations that both organizations use are based on Nuclear Suppliers Group guidelines parts 1 and 2, the regulations administered by the CNSC are slightly broader in scope and coverage, pursuant to its mandate.

In keeping with Canadian nuclear non-proliferation policy, exports of nuclear substances, equipment and information for nuclear use can go forward only to countries with which Canada has established a nuclear cooperation agreement (NCA). Such agreements establish reciprocal obligations to ensure, among other things, that nuclear items will only be used for peaceful, non-explosive purposes. Exports of nuclear substances may still go forward to countries with which Canada does not have an NCA, provided they are of small quantities and/or for non-nuclear use. Canada may also import nuclear substances from countries with which it does not currently have an NCA.

I.5 State of destination

Possession licences issued by the CNSC specify the nuclear substances that the licensee is authorized to hold. These possession licences may also authorize certain types and maximum quantities of nuclear substances to be imported without further authorization. When substances (as defined in section I.3) are imported, transaction-specific authorization must be obtained. This authorization verifies that the applicant holds the necessary possession licences for receiving and properly handling the nuclear substances. If the applicant does not hold the necessary licence, the applicant is notified of the requirements for holding the substance shown in the application.

The Canada Border Services Agency assists the CNSC in administering export and import controls under the NSCA. An importer/exporter must present a valid CNSC licence to a customs officer when importing or exporting a nuclear substance. If a valid licence is not presented upon import or export, the licence holder may be in violation of the conditions of the import/export licence or of the licensing controls under the NSCA.

I.6 Destinations south of latitude 60 degrees

Antarctica is the only land mass south of 60 degrees latitude in the southern hemisphere, as defined under the *Antarctic Treaty* (1959). Seven states currently claim unofficial sovereignty rights to portions of Antarctica. Canada is not one of the seven states. The procedures for ensuring that radioactive material is not transferred to Antarctica are the same as for other destinations. In addition, this international obligation was incorporated under Canadian national law through the *Canadian Environmental Protection Act*.

Section J – Disused Sealed Sources

J.1 Scope of the section

This section addresses article 28 (Disused Sealed Sources) of the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*, which requires the following:

- Each contracting body shall, in the framework of its national law, take appropriate steps to ensure that the possession, re-manufacturing or disposal of disused sealed sources is done safely.
- A contracting party shall allow for the re-entry into its territory of disused sealed sources if, in the framework of its national laws, it has accepted that the sealed sources can be returned to a manufacturer qualified to receive and possess the disused sealed sources.

J.2 Introduction

In Canada, the *Nuclear Safety and Control Act* (NSCA) establishes requirements for the protection of health, safety, security and the environment, as well as the fulfillment of Canada’s international obligations and commitments on the peaceful use of nuclear energy. The Canadian Nuclear Safety Commission (CNSC) is the regulatory authority responsible for controlling the export and import of risk-significant radioactive sealed sources in Canada. It is mandated by the NSCA to:

- regulate the development, production and use of nuclear energy in Canada
- regulate the production, possession, use and transport of nuclear substances, along with the production, possession and use of prescribed equipment and information
- implement measures that respect international control of the development, production, transport and use of nuclear energy and nuclear substances, including the non-proliferation of nuclear weapons and explosive devices
- disseminate objective scientific, technical and regulatory information that concerns the CNSC’s activities (and their effects on the environment and the health and safety of persons) related to the development, production, possession, transport and use of nuclear substances referred to above

Radioactive nuclear substances in sealed or unsealed source form have many industrial, medical, commercial, academic and research applications. A wide variety of organizations make use of nuclear substances, including universities, hospitals, industrial facilities and government departments.

Although most radioactive sealed sources are physically small (see figure J.1), their radioactivity may range from tens to billions of becquerels. When radioactive sealed sources are no longer required or have decayed beyond their useful life and are not intended to be used for the practice for which authorizations have been granted, they become disused radioactive sealed sources. They may then be returned to the manufacturer in Canada or to their country of origin. They may also be sent to a licensed waste management facility (WMF). If a radioactive sealed source has decayed below its exemption quantity or its clearance level – as defined in the *Nuclear Substances and Radiation Devices Regulations* (NSRDR) – it may be released from the CNSC’s regulatory control, pursuant to subsection 5.1 of the NSRDR. Nuclear substances that remain within regulatory control must be managed in consideration of all existing regulations.

Figure J.1: Cesium-137 radioactive sealed source

J.3 Regulatory framework for radioactive sealed sources

In accordance with section 26 of the NSCA and subject to regulatory requirements, no person shall possess, transfer, import, export, use, abandon, produce or service a sealed source, except in accordance with a licence.

As defined in the NSRDR, "sealed source" refers to a radioactive nuclear substance in a sealed capsule or bonded to a cover. The capsule or cover must be strong enough to prevent contact with – or dispersion of – the substance under the conditions for which the capsule or cover is designed.

The export of Category 1 and Category 2 radioactive sources (as identified in table 1 of annex 1 of the International Atomic Energy Agency [IAEA] *Code of Conduct on the Safety and Security of Radioactive Sealed Sources*) requires a transaction-specific authorization issued pursuant to the NSCA. For authorization to export Category 3 and below radioactive sealed sources and authorization to import, use, abandon, produce, manage, store or dispose of a radioactive sealed source, applicants must provide the information required under section 3 of the *General Nuclear and Safety Control Regulations* and section 3 of the NSRDR. For the import and export of controlled nuclear substances, separate licence requirements are prescribed by the *Nuclear Non-proliferation Import and Export Control Regulations*. Additional requirements for persons wishing to apply for a licence to transport nuclear substances are prescribed by the *Packaging and Transport of Nuclear Substances Regulations*.

J.4 Radioactive sealed sources used in Canada

Through Canada's regulatory control program, the CNSC regulates activities involving radioactive sealed sources. Each licence specifies the isotope and the maximum activity (in becquerels) of each radioactive nuclear substance and the maximum activity per sealed source.

J.4.1 Disposal of radioactive sealed sources in Canada

A radioactive sealed source may only be transferred in accordance with the conditions of a licence issued by the CNSC. For long-term management, radioactive sealed sources may be returned to the manufacturer in Canada or to their country of origin. In Canada, certain source manufacturers are recycling radioactive sealed sources at the end of their useful life by either reusing decayed sources for other applications, re-encapsulating them or reprocessing them for other useful applications. The radioactive sealed sources may also be sent to a licensed radioactive waste management facility (such as the facility operated by Canadian Nuclear Laboratories in Chalk River, Ontario) or transferred to a person licensed by the CNSC to possess the radioactive sealed sources. If a radioactive sealed source has decayed below its exemption quantity or its clearance levels (as identified in schedule 1 and schedule 2 of the NSRDR), it may also be released from CNSC regulatory control, pursuant to subsection 5.1 of the NSRDR. Even though the radioactive sealed sources may no longer be under CNSC regulatory control, persons possessing them must still follow applicable federal, provincial and/or municipal regulations.

J.4.2 National Sealed Source Registry and Sealed Source Tracking System

The Sealed Source Tracking System (SSTS) is a secure information management computer program used to populate the National Sealed Source Registry (NSSR). It allows licensees to report the movements of radioactive sealed sources online throughout their complete lifecycle. The NSSR enables the CNSC to build an accurate and secure inventory of radioactive sealed sources in Canada, starting with those that are classified as high risk. The information is as current as the reporting time frames required by the licence (e.g., reporting within two days of receipt and seven days in advance of any transfer). These systems have been efficient and effective since their establishment in 2006.

Licensees may report their transactions via the online interface or by other means (such as fax, email and written submissions by regular mail). Since the initial launch of the online interface, the CNSC has redesigned it twice to keep up-to-date with the Government of Canada's secure system for online services: Access Key in December 2010 and GCKey in December 2012. While doing so, the system was also modified to comply with the Government of Canada's *Standard on Web Accessibility*. For more information on the standard, visit tbs-sct.gc.ca.

By the end of December 2016, the NSSR contained information on 94,018 radioactive sealed sources of all categories in Canada. This was a 42 percent increase over the number of sources in the NSSR at the end of December 2013. This increase was driven primarily by an increase in the number of sealed sources returned to Canadian manufacturers. As of December 2016, the SSTS was tracking 6,491 sources of Category 1 and 46,981 sources of Category 2. The remaining 40,549 sources in the NSSR were of Category 3, 4 and 5, which are subject to mandatory reporting on an annual basis.

Each change in inventory is called a "transaction" for SSTS purposes, and is the result of a radioactive sealed source being imported, exported, created, transferred or received. In 2016, the SSTS registered 79,701 transactions of all types, representing a 10 percent decrease over the number of transactions registered in 2013. In 2013, there was a large number of disused sources transferred to long-term storage, which caused a jump in the number of transactions in that year. Since then, the number of sources transferred to long-term storage has decreased, dropping the number of annual transactions since the peak in 2013.

CNSC staff conducted 434 inspections between January 1, 2014 and December 31, 2016 related to the SSTS requirements. Of the 434 inspections conducted, 95 percent of these confirmed that licensees were compliant with the CNSC requirements, demonstrating a high degree of compliance by the licensed community. The remaining five percent of these inspections (21 in total) were deemed as not meeting all of the requirements. Examples of non-compliances included licensees not providing notifications of a transaction within the required time frame, inconsistencies such as errors in source serial numbers or reference dates, or not registering new locations of use with the CNSC. In all cases, the CNSC ensured all non-compliances were adequately addressed by licensees and corrections were made in the NSSR. The aforementioned information indicates a strong commitment by licensees and the CNSC to the NSSR and SSTS and reflects the system's effectiveness, ensuring the safe and secure management of radioactive sealed sources in Canada.

J.4.3 Import and export of radioactive sealed sources

The enhancement of Canada’s import and export control program for radioactive sealed sources is the result of the government’s commitment to two key IAEA documents: the *Code of Conduct on the Safety and Security of Radioactive Sources* and its supplementary *Guidance on the Import and Export of Radioactive Sources*. Under the leadership of the IAEA, these documents were developed to improve the safety and security of radioactive sealed sources around the world. In support of the IAEA and its efforts to develop a global regime for the control and secure management of Category 1 and 2 radioactive sealed sources, the Government of Canada committed to meet the provisions contained within the Code and to implement an import and export control program as outlined in the Guidance.

As Canada’s nuclear regulatory authority, the CNSC is responsible for controlling the import and export of radioactive sealed sources under the NSCA. Category 1 and 2 radioactive sealed sources reflect IAEA safety standard RS-G-1.9, *Categorization of Radioactive Sources*, which is based on the D-values that define how dangerous a source is. Category 1 and 2 radioactive sealed sources are defined as risk-significant radioactive sealed sources for the purpose of the CNSC import and export control program.

By implementing import and export control measures as outlined in the IAEA Code and Guidance, the CNSC enhances national and international safety and security. These measures ensure that only authorized persons can receive Category 1 and 2 radioactive sealed sources. The CNSC’s import and export control program is consistent with that of the IAEA and aims to:

- achieve a high level of safety and security regarding Category 1 and 2 radioactive sources
- reduce the likelihood of accidental harmful exposure to Category 1 and 2 radioactive sealed sources or the malicious use of such sources intended to harm individuals, society and the environment
- mitigate or minimize the radiological consequences of any accident or malicious act involving Category 1 and 2 radioactive sources

In considering an application to export Category 1 and 2 radioactive sealed sources, the CNSC must satisfy itself that the importing state meets the expectations specified in paragraph 7 of the Guidance regarding Category 1 sources and paragraph 11 with respect to Category 2 sources. Where such assurances cannot be obtained and the CNSC determines that the importing state lacks the appropriate regulatory infrastructure to effectively manage the source in a safe and secure manner, the CNSC may consider denying the authorization of the export.

The CNSC import and export control program for Category 1 and 2 radioactive sealed sources is fully consistent with the provisions of the Code and Guidance. Canadian exporters are required to apply for and obtain an export licence from the CNSC prior to exporting Category 1 and 2 sources. The program encompasses licensing, compliance, prior shipment notifications to importing states, post-shipment verifications, state-to-state requests for import consent to import Category 1 sources, the establishment of bilateral administrative arrangements and the confirmation of receipt of radioactive sources as negotiated in several bilateral administrative arrangements.

To assist licensees and other states, the CNSC published information document INFO-0791, *Control of the Export and Import of Risk-Significant Sealed Sources*, which provides information on the CNSC import and export control program for Category 1 and 2 radioactive sealed sources. An application form and accompanying instructions for obtaining a licence to export Category 1 and 2 radioactive sealed sources are also available at nuclearsafety.gc.ca.

Since implementation of the program on April 1, 2007 the CNSC has received more than 2,185 applications to export Category 1 and 2 sources to 99 countries and has controlled the export of greater than 14.8 million terabecquerels. Canada remains a global leader in the production and export of Category 1 cobalt-60 radioactive sealed sources, supplying approximately 95 percent of the global demand.

International harmonization through bilateral administrative arrangements

To assist the international implementation of the IAEA Code and Guidance in a harmonized manner, the CNSC has developed a model bilateral administrative arrangement with a core set of terms, definitions and procedures. The CNSC has established 12 bilateral administrative arrangements with its international counterparts to ensure imports and exports of Category 1 and 2 radioactive sealed sources between Canada and these countries are conducted in a manner consistent with the Code and Guidance. These arrangements assist in harmonizing regulatory approaches for authorizing imports and exports and facilitate the sharing of regulatory information related to such imports and exports.

The importance of bilateral arrangements for facilitating greater international harmonization of controls was regarded as a good practice by the IAEA's Integrated Regulatory Review Service (IRRS) review of the CNSC regulatory program in June 2009. For more information on the IRRS review, see section E.8.2.3. The practice is also highly regarded internationally, as it assists other states in implementation of the IAEA Code and Guidance. The CNSC encourages the establishment and use of bilateral arrangements to assist in harmonizing regulatory approaches for authorizing imports and exports.

J.4.4 Records

Paragraph 36(1)(c) of the NSRDR requires every licensee to keep a record of any transfer, receipt, disposal or abandonment of a nuclear substance. Records must include:

- the date of the transfer, receipt, disposal or abandonment
- the name and address of the supplier or the recipient
- the number of the licence of the recipient
- the name, quantity and form of the nuclear substance transferred, received, disposed of or abandoned
- when the nuclear substance is a radioactive sealed source, the model and serial number of the source
- when the nuclear substance is contained in a radiation device, the model and serial number of the device

J.4.5 Safety of radioactive sealed sources

In Canada, radioactive sealed sources are referenced in a licence (pursuant to the NSRDR) to ensure that, throughout its lifecycle, a radioactive sealed source is possessed, transferred, imported, exported, used, abandoned, produced or serviced in accordance with regulatory requirements.

Licensees are required to report their inventory of sealed sources and radiation devices to the CNSC on an annual basis for Category 3, 4 and 5 sources, and more frequently for Category 1 and 2 sources. Furthermore, CNSC inspectors physically verify a licensee's inventory of sealed sources during inspections to ensure the licensees are keeping accurate records of the sources in their possession and that they know the whereabouts of all sources in their possession.

Canada's regulatory framework holds licensees responsible for the recovery and safety of lost, stolen and found radioactive sources. Radioactive sources that become disused while within regulatory control must be managed in consideration of all existing regulatory requirements and may be returned to the manufacturer in Canada or to their country of origin. They may also be sent to a licensed WMF. The CNSC has internal procedures to ensure found radioactive sources not under proper regulatory control and not reported lost or stolen by licensees are identified through review of NSSR data, and if a radioactive source is deemed to be orphaned, CNSC staff are aware and familiar with the actions to be taken to bring the source under regulatory control. In extraordinary circumstances, the CNSC will take possession of orphaned sealed sources and radiation devices, and arrange for their proper disposal.

According to regulations, sealed sources that are lost or found must be reported to the CNSC. Licensees that go bankrupt must also report this to the CNSC. All reports are kept in the internal events management database – the Events Information Tracking System – to facilitate the appropriate response by CNSC.

J.4.6 Financial guarantee program for users of sealed sources and radiation devices

In 2015, the CNSC established a financial guarantee program for users of sealed sources and radiation devices. The CNSC has put in place an insurance program through contract with a private institution. Under the program, the CNSC is the sole insured party and licensees pay an annual premium of 0.4437 percent of their total liability (up to a maximum liability of $1 million). Licensees that choose not to participate in the program are required to establish an alternate financial guarantee that is acceptable to the Commission. The establishment of this financial guarantee regime ensures adequate funds will be available for the safe termination of licensed activities in the event of licensee default. The financial guarantee ensures ongoing regulatory control of radioactive sources and does not absolve the licensee of their obligations for safe termination of licensed activities.

J.5 Radioactive sealed sources in the international community

The re-entry of previously exported radioactive sealed sources is permitted either by an import licence (with respect to controlled nuclear substances) or in accordance with a general import authorization licence issued by the CNSC.

Section K – General Efforts to Improve Safety

K.1 Scope of the section

This section provides a summary of key activities and programs mentioned throughout this report, including planned next steps. Where appropriate, these include measures of international cooperation. This section highlights current practices, possible areas for improvement and major challenges, and summarizes measures taken to address suggestions, areas for improvement and challenges identified since the fifth review meeting; international peer reviews and measures taken to make reports public; actions taken to enhance openness and transparency in the implementation of the obligations under the Convention.

K.2 Key highlights, priorities and progress since the fifth review meeting

K.2.1 Canada’s Key highlights and current priorities

The following emerged out of the fifth review meeting as key highlights and current priorities for Canada:

- planning for Canada’s long-term management of spent fuel
- reviewing OPG’s application for its Deep Geologic Repository project
- completing the restructuring of AECL
- implementing the CNSC’s integrated action plan in response to the Fukushima Daiichi accident

Canada’s long-term management of spent fuel

In June 2007, the Government of Canada selected the NWMO-recommended Adaptive Phased Management (APM) approach for the long-term management of Canada’s spent fuel. The NWMO is responsible for implementing this plan. As of July 2017, seven of the original 22 interested communities were participating in the site-selection process. A number of First Nation and Métis communities are also involved, which is facilitated through learning agreements. See section K.5 for more information.

Review of OPG’s Deep Geologic Repository project

The Canadian Environmental Assessment Agency (CEA Agency) and the CNSC established a joint review panel (JRP) in January 2012 to review OPG’s environmental impact statement in support of its application for a licence to prepare site for and construct a deep geological repository for its L&ILW. The JRP held public hearings in 2013 and 2014. On May 6, 2015, the JRP issued its environmental assessment report, which included 97 recommendations, to the Minister of Environment and Climate Change for review and decision under the *Canadian Environmental Assessment Act, 2012*. In this report, the JRP concluded that OPG’s Deep Geologic Repository project is not likely to cause significant adverse environmental effects, provided the mitigation measures proposed, the commitments made by OPG during the review and the mitigation measures recommended by the JRP are implemented.

On February 18, 2016, the Minister of Environment and Climate Change requested additional information from OPG and further studies on the environmental assessment for the Deep Geologic Repository project. The request focused on additional information about alternate locations for the project, cumulative environmental effects and mitigation commitments. On December 28, 2016, OPG submitted information pertaining to the three elements of the minister’s request. The CEA Agency is in the process of reviewing the additional information, which considers input from the federal review team, indigenous groups and the public. The phase after the review process includes the CEA Agency preparing a draft report for the minister followed by a 30-day public comment period on that draft report. Subject to the minister’s decision, the JRP under the *Nuclear Safety and Control Act*, would decide whether to issue a licence to OPG to prepare a site and construct the Deep Geologic Repository facility.

AECL restructuring

The restructuring of AECL, the federal Crown corporation responsible for enabling nuclear science and technology and managing federal radioactive waste liabilities, was completed in 2015. This included the creation of Canadian Nuclear Laboratories (CNL). All federal responsibilities related to decommissioning and waste management were transferred to AECL and included as part of the scope of work to be performed under the GoCo contractual agreements. As such, the Nuclear Legacy Liabilities Program (NLLP), which was discussed in previous reports, ended in 2015. Decommissioning and waste management work at AECL sites is now being implemented by CNL under the GoCo model. For further information, see section Annex 7.1.

Canada's historic waste liabilities, including the Port Hope Area Initiative (PHAI), were also transferred to AECL and are being implemented by CNL under a contractual arrangement with AECL. Construction of the containment mound for the Port Hope Project commenced in the summer of 2016. The first cell will be completed in late 2017, with placement of waste from within the community expected to begin in 2018. On November 1, 2016, the first truckloads of low-level radioactive waste were transported away from the Lake Ontario shoreline to the newly built Port Granby Project long-term waste management facility, signalling the start of this significant environmental cleanup. The cleanup is scheduled to take place over three years, after which the mound's cover system will be constructed (expected to be completed in 2021). For more information on the PHAI, see section K.7.3.1 as well as annexes 8.2.1.1 and 8.2.1.2.

CNSC post-Fukushima integrated action plan

Canada reported in the seventh *Canadian National Report for the Convention on Nuclear Safety* that the CNSC has completed implementation of its integrated action plan in response to the Fukushima accident. The CNSC action plan also included enhancements to the CNSC's nuclear regulatory framework. Updates to regulatory documents were completed during the reporting period. Work is ongoing to amend the *Class I Nuclear Facilities Regulations* and the *Radiation Protection Regulations*.

K.2.2 Progress since the fifth review meeting

During the peer review of Canada's fifth national report in 2015, contracting parties to the fifth review meeting identified long-term waste management challenges, suggestions and planned measures to improve safety. Subsection K.2.2.1 provides an update and summarizes the progress made toward the long-term management of spent fuel and radioactive waste.

K.2.2.1 Canada's progress on long-term management strategies

Canada continues to make progress on long-term management strategies in the areas of:

a) industry access to suitable skills and resources

b) resources to ensure regulatory oversight

c) finding an acceptable site in a willing host community for spent fuel repository

d) implementing GoCo management model and completing procurement process

e) develop an integrated strategy for non-OPG L&ILW disposal

f) CNL sites - accelerated decommissioning and remediation

g) development of radioactive waste management industry forum

h) consolidated waste and decommissioning regulations

i) federal environment minister decision for OPG's DGR project for its L&ILW

j) continue progress in engineered design and site selection process for the long-term management of spent fuel (APM)

(a) Industry access to suitable skills and resources

OPG

OPG uses a number of strategies that focus on extensive workforce planning, succession management, staff development, advance hiring and knowledge management. To address employee retirement by assuring succession planning, OPG uses a succession-management program that assesses leadership capabilities and succession replacement planning for all leadership positions. Critical positions are identified to allow for advance hiring. Specialized knowledge continues to be developed and maintained by having support groups such as engineering, health and safety, environment and training moved to central reporting groups rather than being directly managed within OPG. For more information, see section F.3.3.

Bruce Power

Bruce Power uses a number of strategies that focus on extensive workforce planning, succession management, staff development, advance hiring and knowledge management. To address employee retirement by assuring succession planning, Bruce Power uses a succession-management program that assesses leadership capabilities and succession replacement planning for all leadership positions. Critical positions are identified to allow for advance hiring.

New Brunswick Power Corporation (NB Power)

To ensure access to suitable skills and resources in terms of radioactive waste and spent fuel management, NB Power trains applicable individuals, whose roles are defined via workforce planning, per defined qualification streams. Future competency is ensured via continuing training and refresher training, while succession planning allows for the timely replacement of an individual in the event one needs to vacate his or her position.

Hydro-Québec

Hydro-Québec faced major challenges following the decision to permanently shut down the Gentilly-2 Nuclear Generating Station in 2012. Those challenges included defuelling the reactor and draining contaminated systems. Further, although several employees had to be relocated in other divisions of the company, Hydro-Québec had to maintain adequate expertise at Gentilly-2 to continue early decommissioning activities safely. Once those activities were completed, a permanent organization was put in place to ensure decommissioning activities are performed during the safe storage state with spent fuel in the wet storage bays (2015–20). This organization is composed of about 70 employees; 95 percent of whom worked at Gentilly-2 while it was in operation.

AECL and CNL

The majority of AECL's employees were transferred to CNL as part of the implementation of the GoCo model, allowing CNL to become a private-sector company, operator of the nuclear laboratories and the employer of approximately 3,000 people. Today, AECL is an expert-based Crown corporation that employs around 40 and has a new role of overseeing the GoCo agreements with CNL and the Canadian National Energy Alliance (CNEA). CNL is currently undertaking a skills assessment of all personnel in the organization, including in research and development (R&D). An inventory of the skills has been established and will continue to be updated and used as a basis for future skills initiatives such as succession planning, recruitment and redeployments. A comprehensive set of strategic measures – including degree profile, national and international leadership positions held by R&D staff, publications, awards, etc. – comparable to other nuclear laboratories nationally and internationally will also be developed.

(b) Resources to ensure regulatory oversight

The CNSC is now beginning to reap the benefits of the investment in strategic and operational workforce planning over the last two years. Attrition remains the most critical risk to manage and, as such, the CNSC has adopted a "build" strategy to protect core organizational capabilities and competencies that are essential to carrying out its mandate over the long term. Human resources management effort is focused on four areas: organization design, recruitment and workforce renewal, learning and leadership development, and employee engagement and retention.

(c) Finding an acceptable site in a willing host community for spent fuel repository

Momentum has been sustained for implementing the long-term management approach for spent fuel since the NWMO received its 2007 mandate to implement the APM approach approved by the Government of Canada. Between 2014 and 2017, significant progress was made on the site-selection process (initiated in 2010) as the NWMO worked with interested communities. In 2014, the year began with 17 communities participating in the site-selection process: one community in Step 2 (initial screening); 12 in Step 3, Phase 1 preliminary assessments; and four in Step 3, Phase 2 preliminary assessments.

As of July 2017, seven of the original 22 interested communities were participating in the site-selection process – all in Step 3, Phase 2 preliminary assessments. A number of First Nation and Métis communities are also involved, which is facilitated through learning agreements. For more information, see section K.5.

Finding an acceptable site in a willing host community for spent fuel repository continues to be a challenge.

(d) Implementing GoCo management model and completing procurement process

In 2009, the federal government embarked on a restructuring of AECL. The restructuring was undertaken in two phases, the first of which was completed in 2011 with the sale of AECL's CANDU Division to Candu Energy Inc., a wholly-owned subsidiary of SNC-Lavalin Inc. The second phase focused on the remainder of the organization, the nuclear laboratories and associated waste management responsibilities, with the objective of implementing a GoCo model.

The implementation of the GoCo model was also completed in two phases. The first phase, completed in November 2014, consisted of creating and operationalizing CNL as a wholly-owned subsidiary of AECL. Through an internal reorganization, virtually all of AECL's employees were transferred to CNL along with all of the necessary licences, permits and other authorizations, allowing CNL to become the operator of the nuclear laboratories and employer of the workforce. Following a procurement process led by Natural Resources Canada with support from Public Works and Government Services Canada, CNEA was selected as the preferred bidder to manage and operate CNL. Once AECL transferred the shares of CNL to CNEA, CNL became a private-sector organization.

As a result, today CNL is a private-sector company responsible for the day-to-day management and operation of all of AECL's sites, facilities and assets. CNL employs approximately 3,000 people, most being previous employees of AECL.

For its part, AECL was recreated as a purpose-built small Crown corporation with a view to ensuring it has the necessary expertise and capabilities to oversee the GoCo agreements and an objective to leverage the GoCo model to deliver on its mandate. Its role is to monitor and incentivize the performance of CNL to meet AECL's objectives. As a small Crown corporation with a new role, AECL focuses its efforts on overseeing CNL's activities in two main areas:

- Decommissioning and waste management
- Nuclear laboratories

In terms of science and technology, CNL leverages the capabilities at the CRL, Canada’s largest science and technology complex, in order to provide nuclear science and technology products and services to the Government of Canada and third parties. Key to this is the ongoing revitalization of the CRL which is enabled by $1.2 billion investment in site and science infrastructure over the next ten years. With respect to decommissioning and waste management, AECL contracts out the work necessary to deliver on these responsibilities to CNL, and closely monitors their activities in an effort to deliver value for money for Canadians.

Decommissioning and waste management

The objective is to safely and efficiently reduce the Government of Canada's decommissioning and radioactive waste liabilities, including associated risks to health, safety, security and the environment. The focus is on enabling CNL to significantly advance infrastructure decommissioning, site remediation and waste management for Canada. In previous years, these activities were funded and overseen by Natural Resources Canada through the NLLP, the PHAI and the Low-Level Radioactive Waste Management Office. Under the GoCo model, AECL is now responsible for the federal government’s radioactive waste management responsibilities, including those related to historic low-level radioactive waste for which the government has accepted responsibility. AECL contracts out the work necessary to deliver on these responsibilities to CNL and closely monitors the activities of CNL in an effort to deliver value for money for Canadians.

Nuclear laboratories

The objective is to enable CNL to leverage the capabilities at Chalk River Laboratories (CRL) – Canada’s largest science and technology complex – to provide nuclear science and technology products and services to the Government of Canada and third parties. Key to this is the ongoing revitalization of CRL, which is enabled by an $800-million investment in infrastructure to renew basic site infrastructure and science infrastructure over the next five years.

(e) Develop an integrated strategy for non-OPG low and intermediate-level waste disposal

Canada’s radioactive waste owners – AECL, OPG, Hydro-Québec and NB Power – and other selected stakeholders have been meeting since 2014 under the sponsorship of the Canadian Nuclear Association’s Nuclear Leadership Forum to discuss opportunities for coordination and collaboration on long-term management matters, including relevant technologies and communication strategies.

AECL and CNL

Since the May 2015 Joint Convention review meeting, significant progress has been made in developing and implementing long-term solutions for L&ILW at AECL sites, which will address more than half of Canada’s inventory of these waste types. In addition to the long-term management facilities being constructed for the approximately 1.2 million cubic metres of historic low-level radioactive waste associated with the PHAI (see section K.7.3 for more details), CNL has proposed a project for a near-surface disposal facility at CRL with a total capacity up to one million cubic metres for low-level radioactive wastes and other suitable streams (see section K.7.2.2 for more details). Pending regulatory approvals, this proposed facility is expected to be operational by 2020.

The vast majority of wastes (around 90 percent) destined for the near-surface disposal facility are either already in storage at CRL or will be generated from the decommissioning of redundant facilities or future operations at CRL. The near-surface disposal facility would also receive small amounts of radioactive wastes from Canadian hospitals, universities, research entities and industry clients, consistent with existing commercial arrangements that have been in effect for decades.

CNL has also produced an integrated waste strategy that shows the forecasted waste burdens and reference disposition path for all wastes managed on behalf of AECL by CNL (at all locations) and shows the importance of the long-term management facilities planned and under construction. This effort includes analysis of waste volume projections many decades into the future and identifies significant waste management program issues that need to be addressed. An action plan has been developed and action items are being implemented. The integrated waste strategy will continue to be updated as actions are addressed until all waste streams have a fully implemented disposition pathway. Outputs from this process facilitate easy transfer of information regarding the waste management overview across AECL sites.

As well, CNL shared this information with industry partners during a workshop in October 2016. This information is also useful for identifying potential areas for collaboration with other Canadian waste owners.

Hydro-Québec

Hydro-Québec produced a waste management strategy for decommissioning in 2016. Waste was quantified and possible disposal options were documented. Hydro-Québec is currently working on reducing these volumes to avoid filling the onsite waste storage facility and to minimize the L&ILW to be handled later on. Projects are underway to dispose of very low-level radioactive waste offsite.

In terms of long-term waste management, Hydro-Québec is continuing its discussions with industry partners. Hydro-Québec does not foresee developing its own site, but rather becoming a partner in developing a site for the final disposal of its L&ILW.

NB Power

NB Power has had ongoing engagement with industry to understand options for the disposal of L&ILW and to ensure appropriate funds are available when required, including participation in the current CANDU Owners Group peer group and joint project that were recently established.

(f) AECL sites – accelerated decommissioning and remediation

With the implementation of the GoCo model at AECL sites, CNL has plans to significantly accelerated decommissioning and remediation activities. Following the appropriate regulatory approval, CNL anticipates that the following activities will be accomplished over the next eight to 10 years (i.e., by 2026):

- The decommissioning of CRL will be accelerated, including the decommissioning and demolition of more than 120 redundant structures.
- The National Research Universal reactor (which ends operation in March 2018) will be placed in a storage with surveillance state.
- The National Research Experimental reactor will be decommissioned to an agreed end state.
- The proposed near-surface disposal facility for low-level radioactive waste and other suitable waste streams will be constructed, with a total planned disposal capacity of one million cubic metres, pending regulatory approval.
- Stored liquid wastes from several buildings at the CRL site will have been removed, immobilized and the structures decommissioned.
- Interim soil action levels for radioactive and non-radioactive contaminants will have been developed based on proposed land-use scenarios.
- Site remediation activities will progress and be coordinated with the propose near-surface disposal facility availability and need for cover material during that facility’s operations.
- Decommissioning activities at the Whiteshell Laboratories and nuclear power demonstration prototype reactor sites will be completed, including the in-situ decommissioning of the reactor below grade at both sites, pending regulatory approval.

- The PHAI will be completed, with only monitoring activities remaining
- Both the Port Hope and Port Granby long-term management containment mounds for low-level radioactive waste will be closed and capped.
- Other non-Port Hope historic waste liabilities will have been remediated or substantially discharged.

(g) Development of radioactive waste management industry forum

Canada's largest radioactive waste owners – AECL, OPG, Hydro-Québec and NB Power – and other selected stakeholders have been meeting since 2014 under the sponsorship of the Canadian Nuclear Association's Nuclear Leadership Forum to discuss opportunities for coordination and collaboration on long-term management matters, including relevant technologies and communication strategies.

The current focus of the group is on the development of a coordinated and integrated communications program that supports major projects underway to establish L&ILW disposal facilities. The objective of collaborating and leveraging lessons learned across the industry is to ensure cost-effective, publicly acceptable and readily accessible long-term radioactive waste management facilities will be available in the future to support a sustainable Canadian nuclear industry.

(h) Consolidated waste and decommissioning regulations

The CNSC is conducting an analysis to determine if there is a need to develop radioactive waste and decommissioning regulations. To address this potential need, CNSC staff continue to work toward a consolidated regulatory framework for waste and decommissioning. A discussion paper on the proposed approach was published on May 13, 2016 to seek stakeholder feedback, which is now being considered.

(i) Federal environment minister decision for OPG's DGR project for its L&ILW

OPG's plan for the long-term management of its L&ILW is the Deep Geologic Repository, which would be located 680 metres below the ground surface in argillaceous limestone at the Bruce Nuclear Generating Station site in the municipality of Kincardine, Ontario. OPG's Deep Geologic Repository would be adjacent to its Western Waste Management Facility, where OPG centrally stores all its L&ILW from OPG-owned nuclear reactors.

In April 2011, OPG submitted to the CNSC its environmental impact statement, preliminary safety report and technical support reports for review. Subsequent to OPG's submission and the appointment of a JRP in January 2012, a 15-month public review and a public hearing with 25 hearing days were carried out. Subsequent to the public hearing, OPG received additional questions from the JRP, which OPG answered. The JRP held eight additional hearing days in September 2014 pertaining only to the information received from OPG following the initial hearing days in September and October 2013. The JRP concluded it had sufficient information and issued a notice in September 2014 for submission of closing remarks.

On May 6, 2015, the JRP issued its environmental assessment report to the federal government concluding that the project is not likely to cause significant adverse environmental effects, taking into account the implementation of the mitigation measures committed to by OPG together with the mitigation measures recommended by the panel.

On February 18, 2016, the Minister of Environment and Climate Change requested additional information and undertook studies on three aspects of the environmental assessment: alternate locations, cumulative environmental effects and an updated list of mitigation commitments. OPG submitted responses on December 28, 2016, and subsequently, the CEA Agency held a public comment period on the responses submitted by OPG from January 18 to March 6, 2017. From March 7 to March 28, 2017, the CEA Agency, with the support of the federal review team, reviewed submissions from the public, indigenous groups and non-governmental organizations to determine the potential set of information requests to submit to OPG. The CEA Agency submitted a second set of information requests to OPG on April 5, 2017 and OPG responded to all requests on May 26, 2017.

After the technical review process has been completed, the next phase includes the preparation of a draft report by the CEA Agency followed by a 30-day public comment period on that draft report. The CEA Agency will then finalize its report and submit a decision package to the minister in the fall of 2017.

(j) Continue progress in engineered design and site selection process for the long-term management of spent fuel (Adaptive Phased Management)

In 2014, NWMO's engineering and design program completed a new engineered-barrier system design that received the Canadian Nuclear Society's 2015 Innovative Achievement Award. Since that time, NWMO has further optimized that design, in part to take advantage of current manufacturing capabilities. A proof testing program was initiated to demonstrate that the engineered-barrier system can meet the project's rigorous technical requirements.

The NWMO also updated the conceptual repository designs to reflect the new reference engineered-barrier system. Working collaboratively with communities, NWMO completed the first phase of preliminary assessments that take place in Step 3 of the process, initiated geoscientific and environmental fieldwork in several potential siting areas, and broadened engagement with First Nation, Métis and other communities to collaboratively explore the project and the extent to which it could fit in each of the areas. As the NWMO learned more about the geology of an area and the aspirations of the communities and people for that area, it continued to narrow down siting areas to those showing strong potential to meet the project's rigorous technical requirements and for the project to foster well-being in the area as defined by the people living there. For more information, see section K.5.

K.3 Planned activities

Canada is currently pursuing several initiatives to better manage the spent fuel and radioactive waste produced inside its borders and to ensure the protection of health, safety, security and the environment. These initiatives include:

- improving the regulatory framework
- updating, revising and developing new regulatory documents that provide guidance to licensees
- developing long-term management options for spent fuel and radioactive waste
- addressing historic and legacy issues

K.4 Regulatory framework initiatives

The Canadian Nuclear Safety Commission (CNSC) continually makes improvements to the regulatory framework to make it more robust and more responsive to current and emerging needs. For example:

- international standards (such as those developed by the International Atomic Energy Agency [IAEA] and the International Organization for Standardization) are adapted or adopted as appropriate
- external consultations are aligned with the Treasury Board of Canada's *Guidelines for Effective Regulatory Consultations*
- an online consultation has been launched to encourage people to participate in the development of regulatory documents
- CNSC staff participate in the development of CSA Group standards
- an evergreen five-year regulatory framework plan has been developed and updated

As part of its ongoing modernization of the regulatory framework, the CNSC is currently in the process of developing regulatory document REGDOC-2.11.1, *Waste Programs*, which will consist of two parts:

1. assessing the long-term safety of radioactive waste management

2. management of uranium waste rock and mill tailings

This document will consolidate two existing regulatory documents, G-320, *Assessing the Long term Safety of Radioactive Waste Management* and RD/GD-370, *Management of Uranium Mine Waste Rock and Mill Tailings*.

In addition, the introduction to REGDOC-2.11.1 will include the principles outlined in policy document P-290, *Managing Radioactive Waste*, regarding the management of radioactive waste.

The CNSC also conducted an analysis to identify gaps in its regulatory framework and help develop its long-term regulatory framework plan. The CNSC Regulatory Framework Steering Committee provides strategic direction to coordinate the identification, development and implementation of the framework. This plan can be found on the CNSC website at nuclearsafety.gc.ca/eng/acts-and-regulations.

Coinciding with this, CNSC staff are conducting an analysis to determine if there is a need to develop radioactive waste and decommissioning regulations. To address this potential need, CNSC staff continue to work toward a consolidated regulatory framework for waste and decommissioning consisting of a suite of updated regulatory documents and are analyzing the need for new waste regulations. A discussion paper on the proposed approach was published on May 13, 2016 to seek stakeholder feedback, which is now being considered. For more information, see section E.8.2.3.

CNSC staff have also implemented a financial guarantee program for CNSC licences issued in respect of nuclear substances, prescribed equipment and Class II nuclear facilities. All licences include a condition requiring a financial guarantee based on this proposed program. This condition is also a requirement for Class I nuclear facilities and uranium mines and mills.

During the development and revision of its regulatory documents, the CNSC has been placing a greater emphasis on providing more efficient documents to stakeholders. This includes providing further guidance in relation to regulations, licence conditions and licence application guides for potential licensees of various facility types. For instance, regulatory document REGDOC-1.3.1, *Licence Application Guide: Uranium Mines and Mills*, is currently under development.

As well, CNSC staff are currently drafting a regulatory document REGDOC 1.2.1, *Guidance on Site Characterization Activities* related to siting a deep geological repository for the long-term management of radioactive waste in Canada. Future initiatives include revising regulatory documents G-219, *Decommissioning Planning for Licensed Activities* and G-206, *Financial Guarantees for the Decommissioning of Licensed Activities*, which will be published as REGDOC-2.11.2, *Decommissioning Planning* and REGDOC-3.3.1, *Financial Guarantees* respectively.

K.5 Long-term management of spent fuel

K.5.1 Assessment of options for long-term management of spent fuel

From 2002 to 2005, the Nuclear Waste Management Organization (NWMO) studied approaches for long-term management of Canada's spent fuel.

The NWMO began by analyzing management options that have been considered internationally. Following this review and screening, the NWMO selected as the basis for its initial assessment the three methods specified in the *Nuclear Fuel Waste Act* (NFWA): deep geological disposal in the Canadian Shield, storage at nuclear reactor sites, and centralized above- or below-ground storage. From the insights gained through its analysis and public consultation, the NWMO proposed a fourth option: Adaptive Phased Management (APM).

The management options were subject to multiple assessment processes. The NWMO developed an assessment framework for evaluating the options according to citizen values, ethical principles and eight objectives:

- fairness
- public health and safety
- worker health and safety
- community well-being
- security
- environmental integrity
- economic viability
- adaptability

The analysis included ethical and social considerations. A preliminary assessment of the three options in the NFWA examined the strengths and limitations of each approach through an application of multi-attribute utility analyses. Extensive comparative analysis of the costs, benefits and risks of the three options in the NFWA as well as the NWMO's fourth APM option provided quantitative and qualitative assessments.

The assessment processes were supported by multi-disciplinary research contributions, workshops, submissions from Canadians, guidance on values and ethical principles from citizens, Aboriginal traditional knowledge and the NWMO's Roundtable on Ethics.

The NWMO developed its recommendation, APM, following the input of technical specialists, the public and Aboriginal peoples. It engaged Canadians in a wide-ranging dialogue on the values, principles and objectives they believe are required of a spent fuel waste-management approach for the approach to be socially acceptable, environmentally responsible, technically sound and economically feasible. The NWMO held 120 public consultations and numerous full-day dialogues on values, covering a cross-section of the population in every province and territory. Approximately 18,000 citizens contributed to the study and a further 60,000 people expressed their interest by visiting the NWMO website. The final study report, *Choosing a Way Forward*, contains the detailed recommendation as well as the NWMO's supporting assessment findings and research. It is available on the NWMO website at nwmo.ca.

K.5.2 Adaptive Phased Management

In November 2005, the NWMO submitted its study and recommended the APM approach to the Minister of Natural Resources. On June 14, 2007, following a government-wide review, the Government of Canada announced it had selected the APM approach.

APM comprises:

- a technical method that:
  - is based on centralized containment and isolation of the spent fuel in a deep geological repository of suitable rock formations, such as the crystalline rock of the Canadian Shield or formations such as sedimentary rock
  - is flexible in the pace and manner of implementation through a phased decision-making process supported by a program of continuous learning, research and development

  - provides for an interim step in the implementation process in the form of shallow underground storage of spent fuel at the central site prior to final placement in a deep repository
  - monitors the spent fuel to support data collection and confirmation of the safety and performance of the repository
  - is able to retrieve the spent fuel over a long period until such time as a future society makes a determination on the final closure and the appropriate form and duration of post-closure monitoring

- a management approach with key characteristics that include:
  - responsiveness to advances in technology, natural and social science research, Aboriginal traditional knowledge, and societal values and expectations
  - sustained engagement of people and communities while making and implementing decisions
  - financial stability through funding by Canada's nuclear energy corporations (Ontario Power Generation [OPG], Hydro-Québec and NB Power) and Atomic Energy of Canada Limited (AECL), according to a financial formula required by the NFWA
  - site selection focused on provinces that currently benefit from the nuclear fuel cycle (Saskatchewan, Ontario, Quebec and New Brunswick), although communities in other regions will also be considered
  - selection of a site in an informed, willing community to host the central facilities; the site must meet the scientific and technical criteria to ensure multiple engineered and natural barriers will protect human beings, other life forms and the biosphere

APM was designed to build on the advantages of each of the three NFWA approaches and to provide safety and fairness to current and future generations.

In proposing the APM, the NWMO tried to provide a risk-management approach that comprises deliberate stages and periodic decision points. The APM plan:

  - commits this generation of Canadians to take the first steps to manage the spent fuel it has created
  - includes a design and process that ensure that APM meets rigorous safety and security standards
  - features a step-by-step decision-making process that will provide the flexibility to adapt to experience and societal change
  - provides genuine choice by taking a financially conservative approach and by allowing capacity to be transferred from one generation to the next
  - promotes continuous learning – improvements in operations and design can be made to enhance performance and reduce uncertainties
  - provides a viable, safe and secure long-term storage capability, with the potential for retrieving waste, which can be exercised until future generations have confidence to close the facility
  - is rooted in values and ethics and engages citizens, allowing for societal judgments as to whether there is sufficient certainty to proceed with each step

K.5.3 Implementing the long-term management plan (2014–17)

Following the Government of Canada's decision in 2007, the NWMO developed and confirmed through public review seven strategic objectives that would serve as the foundation of strategic plans for the important first phase of work to implement the approach. Over the past three years, some of the strategic objectives have changed and a new strategic objective has been added to reflect the evolving nature and focus of the NWMO's work. It is against these eight strategic areas that the NWMO presents its progress for 2014–17.

The NWMO has grown into a broader implementing agency and activities are underway in all eight key areas of its five-year plan. The NWMO's current plan, *Implementing Adaptive Phased Management 2017 to 2021*, can be found on the NWMO website at nwmo.ca/implementationplan. These activities are described in the following sections.

K.5.3.1 Building sustainable relationships

Throughout the reporting period, building and nurturing relationships with those potentially affected by the NWMO's work has remained an important focus, with the ongoing invitation to interested organizations and individuals to contribute to shaping implementation plans for the APM project. In 2008–09, important foundations for the APM site-selection process were laid through the collaborative development of a process to identify a safe site in an informed and willing host community. Engagement activities since that time continued to seek input on NWMO plans and policies and strategic objectives for APM. Activities have included:

- working closely with communities involved in the site-selection process to plan field studies and advance learning (for example, through open houses as shown in figure K.1) and reflection on the project in the siting areas
- participating in conferences of municipal associations and groups, in addition to dozens of events each year with interested municipalities and their community groups in each siting area
- participating in a wide range of First Nation and Métis events, including cultural awareness activities, conferences, general assemblies and community events
- continuing to seek guidance from a wide range of expert groups, including the Council of Elders and Youth as well as the Municipal Forum
- finalizing, with the guidance of the Council of Elders and Youth, an *Aboriginal Policy* in 2014 and an *Indigenous Knowledge Policy* in 2016
- signing of a Keepers of the Land Declaration by the NWMO and the Council of Elders and Youth
- acknowledging the contributions of communities and participating neighbours that were screened out of the site-selection process as a result of Phase 2 preliminary assessments
- introducing the NWMO's Acknowledging Early Aboriginal Participation Program to recognize communities that participated in Phase 1 preliminary assessments, complementing a similar program recognizing participating municipalities
- continuing to expand opportunities to learn more about Canada's plan through a wide range of initiatives including the launching of a new website, yearly review of the NWMO strategic objectives and activities as outlined in the implementation plan, publications about new topics and updates to existing publications, and production of information videos
- encouraging youth involvement in science through initiatives of the NWMO's Corporate Social Responsibility Program and through initiatives in the siting areas that enhance community well-being

Figure K.1: Students attending the Nuclear Waste Management Organization open house in Wabigoon Lake Ojibway Nation, October 2015

Figure K.2: Mobile transportation exhibit

K.5.3.2 Collaboratively implementing the site selection process

In 2008 and 2009, the NWMO led the collaborative development of a community-driven process for identifying a safe, secure location in an informed and willing community to host the deep geological repository. The site selection process was initiated in 2010 with an invitation to communities to learn more about the APM project. In 2012, the NWMO suspended the expressions-of-interest phase to focus its support and resources on the 21 communities that had entered the siting process to explore their interest and suitability for hosting the APM project. Working collaboratively with communities, the NWMO continued to make significant progress between 2014 and 2017. Activities during this period included:

- initiating, together with Phase 2 communities, a broadened engagement program designed to begin bringing together interested First Nation, Métis and other communities in the area and surrounding municipalities to explore the potential for working together to implement the project
- concluding Phase 1 preliminary assessments in Arran-Elderslie, Ontario, and Saugeen Shores, Ontario, after early findings showed these two communities have limited potential to contain a site suitable for the project
- conducting in high-resolution airborne surveys in the vicinities of the Phase 2 communities of Creighton, Saskatchewan; Ignace, Ontario; and Schreiber, Ontario
- removing the Township of Nipigon, Ontario, from consideration after the township passed a resolution to withdraw from the site-selection process following a review of the early findings from Step 3, Phase 1 preliminary assessments that identified that the area has only limited potential to meet the requirements of the project
- advancing Central Huron, Ontario, for consideration after the municipality passed a resolution to move into Step 3 of the site-selection process following successful completion of Step 2 initial screening
- completing direct observations of geological features in the Phase 2 Ontario communities of Hornepayne and Ignace
- completing Phase 1 preliminary assessments in the Ontario communities of Brockton, Huron-Kinloss and South Bruce, with Huron-Kinloss and South Bruce identified as focus areas for more detailed Phase 2 assessments
- completing Phase 1 preliminary assessments in the Ontario communities of Blind River, Central Huron, Elliot Lake, Manitouwadge, North Shore, Spanish and White River, with Blind River, Central Huron, Elliot Lake, Manitouwadge and White River identified as focus areas for more detailed Phase 2 assessments
- conducting airborne geophysical surveys of potential siting areas in the vicinities of the Ontario communities of Hornepayne, Manitouwadge and White River
- concluding Phase 2 preliminary assessments in Creighton, Saskatchewan, and Schreiber, Ontario, after studies showed geological complexities that reduce the likelihood of finding a suitable site for a spent nuclear fuel repository
- launching a program to acknowledge First Nation and Métis communities and organizations involved in early stages of engagement and learning about Canada’s plan
- recognizing in communities that participated in preliminary assessments and engagement in the areas of Creighton, Saskatchewan, and Schreiber, Ontario
- initiating detailed geological mapping in the vicinity of Ignace, Ontario, with fieldwork preceded by an indigenous knowledge program and ceremonies

- responding to requests from communities to further explore the potential to foster well-being in an area, with the NWMO sharing economic modelling reports with communities as a starting point for discussing how they and their neighbours might maximize the project’s economic benefits
- conducting direct observations of geological features around Manitouwadge and White River, followed by detailed geological mapping; detailed geological mapping was also conducted around the Ontario communities of Ignace and Hornepayne
- conducting environmental characterization studies around the Ontario communities of Hornepayne, Ignace, Manitouwadge and White River
- initiating discussions about the centre of expertise, early approaches to skills and capacity building in siting areas to prepare for project implementation, and development of a planning framework for the transportation of spent fuel required by the project
- inviting community representatives to participate in the Canadian Nuclear Society Conference on Nuclear Waste Management as well as the International Conference on Geological Repositories

K.5.3.3 Demonstrating safety and feasibility of repository and engineered-barrier design

Between 2014 and 2016, the NWMO’s engineering and design program made significant strides toward its goal of safely containing and isolating Canada’s spent fuel. Specific activities during this period included:

- completing a multi-year design of an engineered-barrier system (which earned the NWMO’s technical program the Canadian Nuclear Society’s 2015 Innovative Achievement Award) specifically designed for the spent CANDU fuel (figure K.3) and beginning implementation of a proof test plan to demonstrate the system’s safety performance
- building the first containers designed specifically for the spent CANDU fuel
- designing specialty handling equipment capable of assisting in the testing of the spent fuel container and buffer box system
- acquiring a preliminary test facility to conduct proof-testing activities (which will be a precursor to the centre of expertise to be located in a community once a repository site has been selected)
- completing a multi-year proof-testing plan and beginning testing on the NWMO’s engineered-barrier system design
- designing a slip-skid pallet and fabricating the mechanism for emplacement of the spent fuel container
- completing updates to the NWMO’s conceptual repository designs
- establishing process tolerances for cold-spray copper production
- fabricating a full-scale buffer box from highly compacted bentonite
- fabricating and pressure-testing a full-scale steel used fuel container prototype
- initiating bentonite backfill (gapfill) emplacement demonstrations
- conducting an independent peer review on the generic corrosion program
- pressure-testing of a full-scale copper-coated spent fuel container prototype (figure K.4)
- fabricating an emplacement room mock-up
- carrying out demonstrations of the slip-skid placement of full-scale buffer boxes

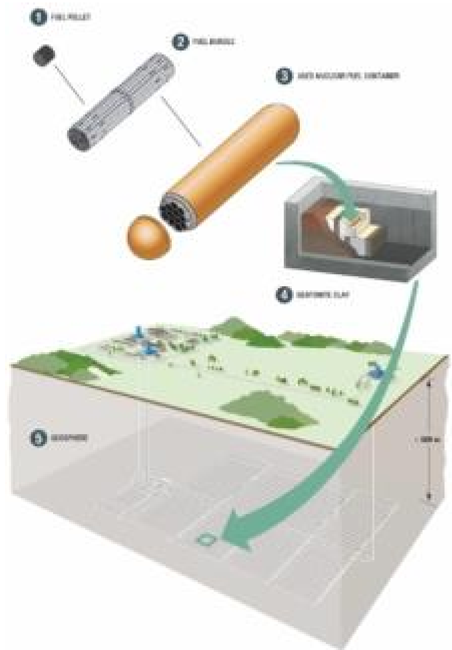

Figure K.3: Deep geological repository concept

Figure K.4: NWMO staff member with prototype spent fuel container at the Applied Research Laboratory's High-Pressure Test Facility at Pennsylvania State University

K.5.3.4 Planning for construction and operation of centre of expertise and deep geological repository

In 2016, the NWMO introduced a new strategic objective to advance planning and capabilities for the construction and operation of the deep geological repository and the associated centre of expertise at the site selected to host the project.

Once a preferred site is selected for the APM project, there will be an escalation of activity on many fronts in the local and regional area. These activities include a range of verification and demonstration activities, as well as initiation of the regulatory processes to support the future construction and operation of the deep geological repository and related surface facilities.

In 2016, activities included:

- providing technical briefings about the centre of expertise within communities engaged in the site-selection process to outline the technical and social activities planned in support of the project
- inviting communities engaged in the site-selection process to discuss social preferences for how the centre of expertise might be designed and developed should their area be selected for the project (figure K.5 provides an example of an artist’s concept for the centre)
- initiating development of a jobs and skills inventory to identify the professions, trades, skills and capabilities required to support the centre of expertise, the regulatory process, and the construction and operation of the deep geological repository
- initiating a hiring plan to build up locally based staff to support community engagement and field studies in potential siting areas
- initiating discussions with communities engaged in the site-selection process about priority steps for developing skills and job opportunities for youth and local community members
- beginning discussions with communities on what investments in training, strategic hiring or business incubation may be important in building the prospects for local employment and businesses

Figure K.5: Artist’s concept of the APM centre of expertise

K.5.3.5 Continuously improving technical knowledge

By collaborating with leading researchers in Canada and other countries, the NWMO helps ensure its work is based on international best practices. At the same time, by sharing its own research advances, the NWMO is making significant contributions to the field of nuclear waste management, both in the geoscience of deep geological repositories and in the optimization of engineered-barrier systems. Highlights and activities during the reporting period included the following:

- The NWMO's technical research program continued to attract significant international interest with visiting delegations from Australia, Belgium, Finland, Japan, South Korea, Sweden, Switzerland, the United Kingdom and the United States.
- The NWMO worked with the Natural Sciences and Engineering Research Council of Canada (NSERC) and the University Network of Excellence in Nuclear Engineering (UNENE) to establish an industrial research chair in radiation-induced corrosion at Western University in London, Ontario.
- NSERC awarded a five-year grant to the NWMO and the University of Ottawa to establish a hydrogeochemistry centre of excellence in the university's new advanced research complex.
- The NWMO worked with NSERC and other partners to establish an industrial research chair in high-temperature aqueous chemistry at the University of Guelph.
- The Korea Radioactive Waste Agency signed a memorandum of understanding with the NWMO, making it the sixth such organization to enter into a research partnership with the NWMO.
- The NWMO initiated a collaborative site analogue study at the Mont Terri Underground Research Laboratory in Switzerland to examine solute migration in geologic time scales.
- NWMO researchers continued to participate in collaborative research projects with their counterparts in other waste management organizations; ongoing joint projects include the fracture parameterization for repository design and post-closure analysis (POST) project with Sweden and Finland, several experiments at the Mont Terri Underground Research Laboratory, and the gas-permeable seal test (GAST) experiment at Grimsel in Switzerland.
- NWMO researchers published more than 50 conference papers, technical reports and peer-reviewed journal articles.
- The NWMO continued to support research projects at 15 Canadian universities.
- The NWMO participated in the Nuclear Energy Agency's working groups, including the Expert Group on Operational Safety and the Expert Group in Inventory Reporting and Methodology.
- The NWMO continued to host the annual NWMO Geoscience Seminar.

K.5.3.6 Providing financial surety

The NFWA requires that Canada's nuclear energy corporations – OPG, Hydro-Québec, NB Power and AECL – ensure there is enough money to pay for the full costs of implementing the plan for the deep geological repository. Since 2002, waste owners have been contributing to individual trust funds that totalled approximately $4 billion at the end of 2016. The NFWA has explicit provisions to ensure the trust funds are maintained securely and used only for their intended purposes. The NWMO cannot access the NFWA trust fund until the NWMO has been issued a licence to construct by the CNSC.

The NFWA trust fund money is in addition to other segregated funds and financial guarantees the companies have set aside for spent fuel and radioactive waste management and decommissioning. These funds and financial guarantees are used to satisfy the financial guarantees requirements that all NWMO members (OPG, Hydro-Québec and NB Power) have provided to the CNSC. The guarantees for the year 2017 total $20 billion and equal the total cost (in terms of present value) of managing the decommissioning of all reactors and permanently managing all radioactive waste (including spent fuel) produced to date. A large portion of these guarantees – approximately $18 billion (at year-end 2016) – exists in segregated funds dedicated to spent fuel and radioactive waste management and decommissioning, with the remainder in the form of provincial guarantees. The guarantees include the NFWA trust fund contributions made by NWMO members.

In addition to making financial provision for work required after the licence to construct is issued, the cost of the NWMO's activities up to receipt of this licence is covered by contributions made by the nuclear energy corporations.

Activities related to the funding of NWMO activities over the last three years have included:

- performing annual assessments of all factors that impact APM cost estimates and funding requirements
- determining annual trust fund contribution requirements in accordance with the funding formula
- completing in 2016 a full update of lifecycle cost estimate for the APM project

K.5.3.7 Developing transportation plans

Though selection of a site is a number of years into the future, work is already well underway to ensure spent fuel will be transported in a way that is safe, secure and socially acceptable. Two complementary programs support this work: a technical program that addresses all aspects of technical safety and security, and an engagement program that helps communities and other interested people learn more about the transportation of spent nuclear fuel and encourages their involvement in planning. Activities during the reporting period included:

- selecting a reference conceptual design for transporting spent fuel stored in AECL-designed baskets (see figure K.6)
- initiating analytical fire and impact modelling of a spent fuel transportation package concept for transporting AECL baskets
- working with researchers at Carleton University to conduct a detailed assessment of Canada's road- and land-development conditions and the potential radiological exposure scenarios resulting from the transportation of spent fuel (with the findings used to prepare a Canadian-specific dose assessment)
- disseminating a discussion document, *Planning Transportation for Adaptive Phased Management*, to encourage and advance discussion with communities
- contracting with third parties to initiate workshops and discussion groups to seek insights into citizen priorities for a safe, secure and socially acceptable approach to transporting Canada's spent fuel
- initiating logistical studies for transporting spent fuel

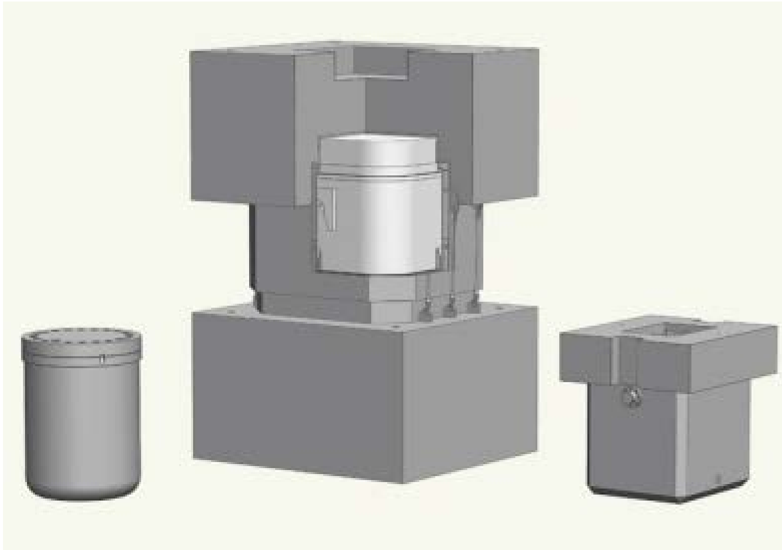

Figure K.6: Three different packages for transportation of spent fuel

From left to right: A basket transportation package (under development), the dry storage container transportation package and the spent fuel transportation package. The dry storage container transportation and used fuel transportation packages are currently licensed for use in Canada.

K.5.3.8 Ensuring accountability and governance

The integrity of the NWMO's work is advanced by multiple layers of oversight and peer review. Internally, the NWMO is governed by its board of directors. Over the reporting period, its accountability and governance was also provided through a broad framework comprising such activities as:

- annual reviews of the NWMO's progress by the Minister of Natural Resources
- participation in the fifth Joint Convention Review Meeting
- ongoing technical reviews of approaches, methods and interpretation of data (e.g., the Geoscientific Review Group continues to help ensure preliminary site geoscientific assessments are conducted according to international best practices)
- annual audits of the NWMO's integrated management system; the NWMO continues to be certified compliant with Canadian (CSA Group) and international (International Organization for Standardization) management system standards

K.6 The CNSC's role and early involvement in the APM project for the long-term management of Canada's spent fuel

As a best practice, the CNSC gets involved early in proposed new nuclear projects to ensure licence applicants and affected communities have a comprehensive understanding of the CNSC's role in regulating Canada's nuclear sector.

Future applicants are provided with CNSC information and guidance on the regulatory requirements and licensing process prior to the submission of a licence application and the initiation of the environmental assessment process. The CNSC engages affected communities to provide factual and unbiased information about how its mandate is fulfilled: to regulate the use of nuclear energy and materials to protect health, safety, security and the environment, and to implement Canada's international commitments on the peaceful use of nuclear energy. More information is available on the CNSC website at nuclearsafety.gc.ca/eng/waste.

K.6.1 Service arrangement between the CNSC and NWMO

In March 2014, the CNSC renewed the service arrangement with the NWMO to provide regulatory guidance and support for implementing the NWMO's APM initiative. The service arrangement identifies the terms under which the CNSC performs work on the APM initiative prior to the submission of a licence application. Work includes providing pre-licensing reviews of the APM deep geological repository concepts, identifying regulatory requirements for a geological repository and participating in public meetings to provide information on the CNSC's involvement. Additionally, the service arrangement is valid for a five-year period unless a licence application is submitted, at which point the agreement would no longer be in effect. For more information about the service arrangement, refer to the CNSC website at nuclearsafety.gc.ca/eng/waste/high-level-waste/index.cfm#Long-term.

As part of this arrangement, since the last reporting period, the CNSC conducted pre-project reviews of reports that the NWMO has submitted on the conceptual design and illustrative post-closure safety assessment for the APM deep geological repository for spent fuel. A summary of the CNSC pre-licensing review is available at nuclearsafety.gc.ca/eng/pdfs/APM-Initiative-Summary-Statement-for-Design-Concepts-eng.pdf.

K.6.2 Relationship building with the public and Aboriginal peoples

Throughout the reporting period, the CNSC continued to meet with the communities that have formally entered the NWMO's siting process and have expanded this outreach to neighbouring communities when requested. Outreach activities have focused on relationship building with the communities and Aboriginal groups, including First Nations and Métis. In this reporting period, CNSC staff have conducted 30 outreach activities (see figures K.8 and K.9 for examples). More information on these activities is available at nuclearsafety.gc.ca/eng/waste/high-level-waste/community-meetings-with-the-CNSC/index.cfm.

At the request of community representatives (typically community liaison committees), additional outreach activities have been undertaken. This includes information sessions, which take place as follows:

1. CNSC staff have an initial conference call with community representatives or the community liaison committee.
2. The CNSC holds a day-long meeting with community representatives (typically the mayor and council, but often a separate meeting is held for the community liaison committee) at the CNSC's Ottawa offices.
3. CNSC staff conduct presentations at community liaison committee meetings within the community. (see figure K.8)
4. An information sessions (e.g., an open house) takes place in the community. (see figure K.9)

The outreach activities are designed to provide information on the CNSC's role as Canada's nuclear regulator and to explain the organization's early role in the APM initiative. Topics addressed during the sessions include:

- the nuclear regulatory process and the factors that go into the review of a licence application
- the environmental assessment process
- Aboriginal engagement and consultation
- technical aspects of a deep geological repository
- the CNSC's early role in the APM initiative

- opportunities for the public to get involved during Commission hearings and environmental assessments
- how the CNSC works with other regulatory bodies to fulfil its mandate when licensing nuclear facilities and activities

Meetings provide an opportunity for participants to ask questions and clarify issues of concern. Feedback from communities has been positive: they see the CNSC as a neutral, independent body with staff who are qualified to evaluate repositories for spent fuel and who are concerned with safety first and foremost. During these meetings, CNSC staff are interested in hearing and learning about the most effective ways to involve communities and Aboriginal groups and how to best provide information to those who want to know more about the CNSC and other relevant matters within the scope of the CNSC’s mandate.

Relationship with Aboriginal communities

Building relationships with First Nation and Métis communities who may have an interest in learning more about projects such as the APM initiative is a priority for the CNSC. As building strong relationships based on trust and mutual respect takes time, the CNSC reaches out to these communities early in the pre-licensing phase.

When an outreach event has been planned in a given area, the CNSC reaches out directly to nearby Aboriginal communities to let those communities know that an independent nuclear regulator exists in Canada and is available to meet and provide information about the CNSC and its regulatory role.

Following the signing of a memorandum of understanding between Natural Resources Canada and the NWMO, the NWMO is responsible for continuing its Aboriginal engagement activities prior to selecting a site, to maintain a consultation log and to keep the Crown informed of these activities. NWMO is also keeping the CNSC informed of its activities– for example, by sharing issues and concerns that are raised related to potential and existing Aboriginal and treaty rights.

Potential sites for a deep geological repository for spent fuel will be narrowed down as the NWMO’s site-selection process evolves. The CNSC will continue its Aboriginal engagement activities during this time; however, greater focus will be given to working with First Nation and Métis communities who may be directly affected by the proposed project. To meet its duty to consult, the CNSC will be seeking information as to whether a future licensing decision may cause an adverse impact on any potential or established Aboriginal or treaty rights.

For information on CNSC’s Aboriginal Consultation, please visit nuclearsafety.gc.ca/eng/resources/aboriginal-consultation/index.cfm. Also see CNSC regulatory document REGDOC-3.2.2, *Aboriginal Engagement*, which sets out requirements and guidance for licensees whose proposed projects may raise the Crown’s duty to consult.

Figure K.7: CNSC staff presenting to community at the request of a Community Liaison Committee

Figure K.8: CNSC staff providing a Radiation Protection Demonstration to Youth at a CNSC Open House

K.6.3 CNSC independent research and assessment on the safe long-term management of radioactive waste and spent fuel in geological repositories

Since 1978, the CNSC has been involved in independent research and assessment, including international collaboration, on the safe long-term management of spent fuel in geological repositories. These activities looked at the Canadian Shield's crystalline rock.

The NWMO is currently looking for a voluntary community to host a spent fuel deep geological repository, with a site that is technically acceptable, in either crystalline rock formations of the Canadian Shield or in sedimentary rock formations in southern Ontario. Concurrently, OPG is proposing a Deep Geologic Repository project for its low- and intermediate-level radioactive waste (L&ILW) at approximately 680 metres deep in a sedimentary formation.

In response to these two initiatives, the CNSC identified the need to expand its technical expertise to include knowledge and understanding of geological disposal in sedimentary rock as well as crystalline rock. Accordingly, the CNSC is conducting a research program to evaluate long-term safety issues related to the deep geological disposal of radioactive waste and spent fuel in both sedimentary rock and crystalline rock. This program consists of independent scientific research conducted by CNSC staff in collaboration with national and international institutions. It also includes monitoring and review of state-of-the-art scientific advancements and participation in international fora to exchange information and knowledge related to deep geological repositories.

K.6.4 Independent advisory group

An independent advisory group composed of Canadian geoscience experts was established in 2013 to help CNSC staff prepare for the review of a future licence application by the NWMO for a deep geological repository for Canada's spent fuel. The purpose of this group is to provide objective, independent advice to CNSC staff on the geoscience aspects of the APM initiative for the long-term management of Canada's spent fuel through review of the NWMO's geoscientific research program and the CNSC's internal research program.

In the future, the advisory group may be asked to focus on particular topics with the goal of evaluating areas that are likely to be included in the safety case and/or supporting safety assessments.

K.7 Long-term management of low- and intermediate-level radioactive waste

All Canadian L&ILW is currently in safe storage. Canada's two major L&ILW owners, OPG and AECL (who are responsible for about 96 percent of the non-historic L&ILW), have initiatives underway to develop and implement long-term solutions. Canadian Nuclear Laboratories (CNL) is leading the management of AECL's waste on its behalf.

The Port Hope Area Initiative (PHAI) involves the cleanup and long-term management of historic low-level radioactive waste (LLW) in Port Hope, Ontario, which accounts for the bulk of Canada's historic LLW. For more information on the PHAI, see section K.7.3.1.

Ongoing initiatives to address the long-term management of L&ILW in Canada are described in the following sections.

K.7.1 Proposed deep geological repository at the Bruce Nuclear Generating Station site

OPG has recognized that while its current approach to radioactive waste storage is safe, secure and environmentally responsible, a permanent solution is required to safely dispose of the waste so it cannot pose a threat to the public or the environment for the long term. A long-term management approach will ensure radioactive waste can be kept safely isolated from the environment without burdening future generations.

The concept for the deep geological repository at the Bruce Nuclear Generation Station site was developed following a request by the Municipality of Kincardine to explore with OPG the options for a long-term management of L&ILW in that region.

The current project proposed by OPG is to prepare the site and construct a deep geological disposal facility on the secure Bruce site within the Municipality of Kincardine (see figure K.9). The purpose of the proposed repository is to ensure the protection of the environment by safely isolating and containing L&ILW deep underground in stable rock formations that are more than 450 million years old.

OPG's Deep Geologic Repository project is designed for 200,000 cubic metres of emplaced L&ILW from operations and refurbishment activities and is planned to be constructed at a depth of 680 metres. The proposed site is adjacent to OPG's existing Western Waste Management Facility, which provides centralized storage for L&ILW from the operation of OPG-owned or operated reactors in Ontario. OPG has safely managed L&ILW for the Pickering Nuclear Generating Station, Darlington Nuclear Generating Station and the reactors at the Bruce site for more than 40 years. For more information on the storage of L&ILW at the Western Waste Management Facility, see section 5.1.2.

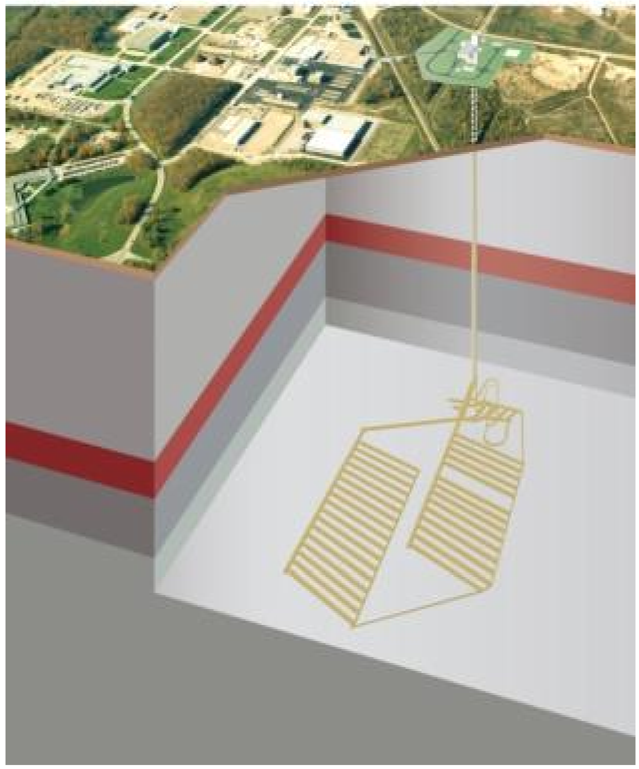

Figure K.9: Artist's concept of the OPG Deep Geologic Repository

A geotechnical feasibility study, a preliminary safety assessment, a social and economic assessment, a community attitude survey, interviews with local residents, businesses and tourists, and an environmental review led to the creation of the independent assessment study. Another component of the study was a public consultation program conducted in Kincardine and surrounding municipalities.

The independent assessment study concluded that a number of options were feasible. The options – which included enhanced processing and storage, a covered above-ground concrete vault and a deep geologic repository – could be constructed to meet international and Canadian safety standards with a high margin of safety and would not have significant residual environmental or socio-economic effects. The geology of the Bruce site was considered ideal for the deep geologic repository option (see figure K.10). The study report can be accessed in the "Background Information" section of OPG's project web site, opg.com/dgr.

In April 2004, the Kincardine Council passed a resolution to endorse the deep rock vault (i.e., deep geological repository) option as the preferred course of study with regard to the management of L&ILW. The deep rock vault has the highest margin of safety and is consistent with international best practices.

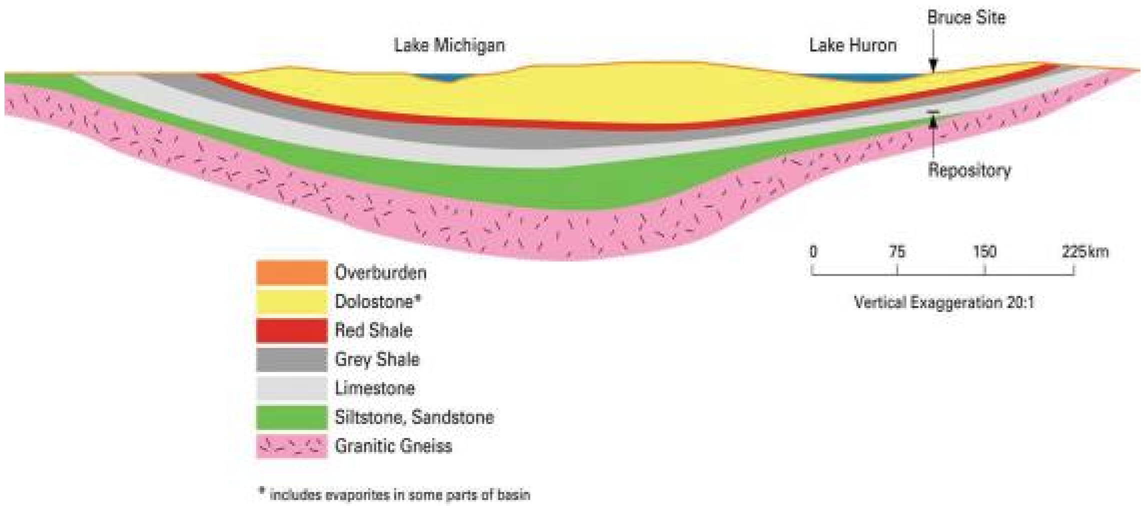

Figure K.10: Michigan basin geology and the Bruce nuclear site

Following the council resolution, Kincardine and OPG began to negotiate terms for a hosting agreement. Hosting agreements have been implemented in other jurisdictions in Canada and internationally by communities that support the location of a long-term waste management facility. The *Kincardine Hosting Agreement* was signed on October 13, 2004. It set out the terms and conditions under which the project would proceed.

From mid-October 2004 to mid-January 2005, OPG helped Kincardine undertake a public dialogue on the Deep Geologic Repository proposal and to determine the level of community support. Each residence in Kincardine was telephoned or followed up with a mail-out, as required. The results of the poll were announced at the Kincardine Council meeting on February 16, 2005:

- 60 percent in favour
- 22 percent against
- 13 percent neutral
- 5 percent didn't know or refused to answer

Of the eligible residents, 72 percent participated in the telephone poll. In December 2005, OPG submitted a letter of intent to prepare the site and construct a Deep Geologic Repository to the CNSC, thus initiating the environmental assessment process that has thus far involved detailed geoscientific investigations, preliminary design work and environmental and safety assessments.

Six deep boreholes were drilled at the site from 2007 to 2010, with two additional boreholes at the main and ventilation shaft sites in 2011. These boreholes have confirmed the expected stratigraphy at the site. More than 200 metres of low-permeability shale form a protective cap over the low-permeability limestone formation where the repository would be constructed. Hydraulic conductivity measurements, in both the limestone and shale formations, have shown values of 10^{-13}m/s and below. These values indicate that any solute movement away from the repository will be diffusion controlled (i.e., there will be little chance of water seeping into the repository).

The Deep Geologic Repository model is composed of horizontally excavated emplacement rooms, which will be arranged in panels with access provided via two vertical, concrete-lined shafts.

K.7.1.1 Joint Review Panel – Regulatory review

The environmental impact statement, preliminary safety report and supporting reports were submitted to the CNSC in April 2011. A Joint Review Panel (JRP) was established in January 2012 by the federal Minister of Environment and the CNSC. The submission package documents can be viewed in the "DGR Submission" section of OPG's project website opg.com/dgr.

Under the JRP agreement, the panel's main role is to conduct an examination of potential environmental effects of the Deep Geologic Repository project to meet the requirements of the *Canadian Environmental Assessment Act, 2012* and to obtain the information necessary for the consideration of OPG's application under the *Nuclear Safety and Control Act* for a licence to prepare site and construct. The agreement, along with more information on the project, is available on the Canadian Environmental Assessment (CEA) Registry at ceaa-acee.gc.ca/050/details-eng.cfm?evaluation=17520.

Following its appointment, the JRP announced a six-month public review period in February 2012 for the Deep Geologic Repository's environmental impact statement, licensing and supporting documents. This important public participation step provided an opportunity for federal and other government agencies, the public, and First Nation and Métis communities to submit comments. The public review period was subsequently extended by the JRP until May 2013, with OPG responding to a total of 575 information requests.

The JRP held a 25-day public hearing (from September 16 to October 11, and from October 28 to 30, 2013) for the Deep Geologic Repository project in the host communities supporting the project (see figure K.11). The public hearing provided an opportunity for participants to hear about the project and the results of the environmental impact statement and to provide their views to the JRP. All documents and hearing transcripts can be found on the CEA Agency's website, ceaa-acee.gc.ca.

The JRP provided OPG two additional information request packages before the public hearing. The OPG responded to the questions in these packages, bringing the total number of information requests from the JRP to 585. The JRP also held eight additional hearing days from September 9–18, 2014, pertaining only to this additional information.

On May 6, 2015, the JRP issued its environmental assessment report to the federal government, which concluded that the project is not likely to cause significant adverse environmental effects. In coming to this conclusion, the JRP took into account the implementation of the mitigation measures committed to by OPG together with the mitigation measures recommended by the panel. The CEA Agency announced a 90-day public comment period on June 3, 2015 for the last phase of the environmental assessment process for OPG's Deep Geologic Repository project for L&ILW.

On November 4, 2015, a new Minister of the Environment and Climate Change was appointed. The federal minister requested additional information from OPG on February 18, 2016, including a study detailing the environmental effects of technically and economically feasible alternate locations, an updated analysis of cumulative environmental effects should a deep geological repository for spent fuel fall within the same territory, and an updated list of mitigation commitments. OPG submitted responses on December 28, 2016, which are available on the CEA Registry at ceaa-acee.gc.ca/050/document-eng.cfm?document=116741.

The CEA Agency led a technical review of the submission from January 18 to March 6, 2017, which included a comment period to collect the viewpoints of the federal departments, indigenous groups and the public. Based on the review process, the CEA Agency submitted information requests to OPG, which issued its responses on May 26, 2017. The next phase includes the CEA Agency preparing a draft report followed by a 30-day public comment period on that report. Following the comment period, the CEA Agency will finalize the report and submit a decision package to the minister.

Figure K.11: OPG's Deep Geologic Repository Joint Review Panel, 2013

K.7.2 Decommissioning and waste management activities at AECL sites (under the management of CNL)

The Government of Canada's legacy radioactive waste and decommissioning liabilities at AECL sites have resulted from more than 60 years of nuclear research and development carried out on behalf of Canada by the National Research Council (1944 to 1952), AECL (1952 to 2014) and CNL (2014 to present).

Nuclear facilities were constructed at sites in Ontario, Manitoba and Quebec. Chalk River Laboratories (CRL) in Chalk River, Ontario, is the only facility that remains operational. Whiteshell Laboratories in Pinawa, Manitoba – which was AECL's other major research centre – is being decommissioned. Further, AECL's three prototype reactors were all shut down between 1979 and 1987 and are being maintained in a safe storage state. Those reactors are the Nuclear Power Demonstration in Rolphton, Ontario; Douglas Point in Kincardine, Ontario; and Gentilly-1 in Bécancour, Quebec. The liabilities also included the site of a former heavy water plant near Glace Bay, Nova Scotia, which did not contain any radioactive waste or contamination. The environmental remediation of this former industrial site was completed in 2014 and the site was subsequently transferred to Enterprise Cape Breton Corporation, a federal Crown corporation, thereby fully addressing this liability.

The nuclear legacy liabilities include outdated and unused research facilities and associated infrastructure, accumulated radioactive waste and contaminated lands. AECL's waste inventory includes spent fuel, low- and intermediate-level solid and liquid radioactive waste, and historic radioactive waste at CRL (largely contaminated soils) from site cleanup work across Canada. Most of the waste is in an unconditioned form and limited characterization information is available for the waste generated in past decades.

In June 2006, the Government of Canada adopted a long-term strategy to deal with the nuclear legacy liabilities at AECL sites, thereby creating the Nuclear Legacy Liabilities Program to safely and cost-effectively reduce risks and liabilities based on sound waste management and environmental principles.

Under this strategy, risks and liabilities were reduced through projects and activities that decommissioned and removed outdated facilities, remediated lands affected by past practices and improved the management of radioactive waste.

The Government of Canada has invested more than $1 billion in the Nuclear Legacy Liabilities Program between June 2006 and September 2015, at which point it furthered its commitment to address the nuclear legacy liabilities at AECL sites by implementing a government-owned, contractor-operated (GoCo) model. Under this model, AECL contracts out the management and operation of its sites – including its decommissioning and waste management responsibilities – to CNL. Through the work of CNL, AECL is now aggressively pursuing work to address its liabilities. This includes:

- the management of AECL's legacy radioactive waste, including:
  - decommissioning and waste management at CRL
  - closure of the Whiteshell Laboratories site
  - closure of the Nuclear Power Demonstration reactor site
  - oversight and management of two prototype reactors – Douglas Point and Gentilly-1 – and planning for their decommissioning
- the cleanup and long-term management of historic LLW, including:
  - the delivery of the PHAI
  - the long-term management of other historic low-level wastes addressed by the Low-Level Radioactive Waste Management Office

As a key enabler to accelerating decommissioning and waste management activities, CNL is currently planning for the construction of a proposed near-surface disposal facility at CRL (see section K.7.2.2). Environmental assessments are also currently underway for the proposed *in situ* decommissioning of the Nuclear Power Demonstration reactor and the research reactor Whiteshell Reactor-1 located at the Whiteshell site.

K.7.2.1 Management of AECL's legacy radioactive waste

At CRL, as buildings are released from operations, they are turned over for decommissioning. Prompt decommissioning is favoured to minimize the costs of ongoing care and maintenance. Buildings are prioritized based on health, safety, security and environmental criteria. Environmental remediation of legacy waste management areas is conducted to remove contaminating sources contributing to plumes or for stabilizing areas that are candidates for *in situ* disposal. Notable progress at CRL since 2014 includes:

- commencing the environmental assessment process for the proposed near-surface disposal facility (see section K.7.2.2), including the release of a draft environmental impact statement for public comment in March 2017
- further removal of active liquids from a high-risk, single-walled buried tank as well as additional risk reduction measures protecting against leakage to environment from other related tanks
- removal of 15 supervised area structures
- construction and commissioning of a third shielded above-ground storage building for L&ILW
- transfer of older experimental fuels from tile holes into the fuel packaging and storage facility, which commenced in 2015
- development of an environmental restoration framework agreement that proposes CNL site end states and interim action levels for radionuclides, metals and volatile organic compounds in soils
- development of an integrated waste strategy for all AECL wastes following a process similar to that developed by the United Kingdom Nuclear Decommissioning Authority

- decommissioning of the former heavy water upgrading plant and turnover of the structure for renovation and reuse for a different operational purpose

Pending regulatory approval, the proposed near-surface disposal facility is planned to be ready for use in 2020. There will be an increased focus on accelerated decommissioning over the next 10 years. By 2026, significant progress will have been made toward decommissioning redundant infrastructure at CRL, with the site featuring:

- more than 120 buildings turned over for decommissioning
- more than 40 buildings decommissioned and demolished in the supervised area
- more than 80 buildings decommissioned and demolished in the controlled area
- the National Research Universal reactor placed in storage with surveillance
- the National Research Experimental reactor decommissioned to an agreed end state
- controlled area footprint reduced in line with decommissioning plan
- stored liquid wastes removed and processed, with the resulting waste product transferred to interim storage (if not suitable for immediate disposal in the proposed near-surface disposal facility) and the stored liquid wastes facilities decommissioned
- all of the transfers of older experimental fuels from the identified tile holes to the fuel packaging and storage facility completed, with the fuel dried and in interim storage until a national repository for spent fuel is available

Since the previous Joint Convention report, AECL is also pursuing accelerated decommissioning of both the Nuclear Power Demonstration and Whiteshell Laboratories sites. The current plan proposed by CNL would see the completion of decommissioning activities at Nuclear Power Demonstration by 2021 and Whiteshell Laboratories by 2024.

K.7.2.2 Waste management and strategic progress for subsequent phases

An environmental assessment process was initiated in 2016 for a proposed Near Surface Disposal Facility (NSDF) at CRL. This ground-level facility would be built to permanently and safely dispose of LLW and other suitable waste.

For many years, AECL (and now CNL) has safely placed waste from its operations and from Canadian hospitals and universities in temporary storage facilities at CRL. These temporary facilities have design lives that range from 25 to 50 years. The intent of the proposed NSDF is to provide a safe and permanent disposal solution for this waste.

If authorized by the CNSC, the NSDF will allow the safe and permanent disposal of:

- waste from 65 years of AECL/CNL nuclear science and technology operations, which is currently stored in temporary storage facilities at CRL
- future CRL operational waste materials as they are generated (i.e., waste resulting from ongoing nuclear science and technology operations)
- materials received through commercial arrangements, including waste from hospitals, universities, research entities, and industry clients – all currently stored in temporary waste storage facilities at CRL
- waste from future decommissioning activities undertaken by CNL to address other liabilities owned by AECL (e.g., closing the Whiteshell Laboratories and prototype reactor sites)

All waste emplaced in the proposed near-surface disposal facility must follow waste acceptance criteria defined for the facility. The waste acceptance criteria set the limits on the physical (size and packaging), radiological and chemical characteristics of the waste that would be accepted for emplacement in the proposed near-surface disposal facility to assure compliance with operational and long-term safety requirements. Only wastes that are deemed suitable for this method of disposal and meet the waste acceptance criteria will be accepted at the NSDF for emplacement.

The CNSC will assess the proposed near-surface disposal facility to ensure that, if approved, it would meet regulatory requirements during all phases of its lifecycle including construction, operation, decommissioning and post-closure periods.

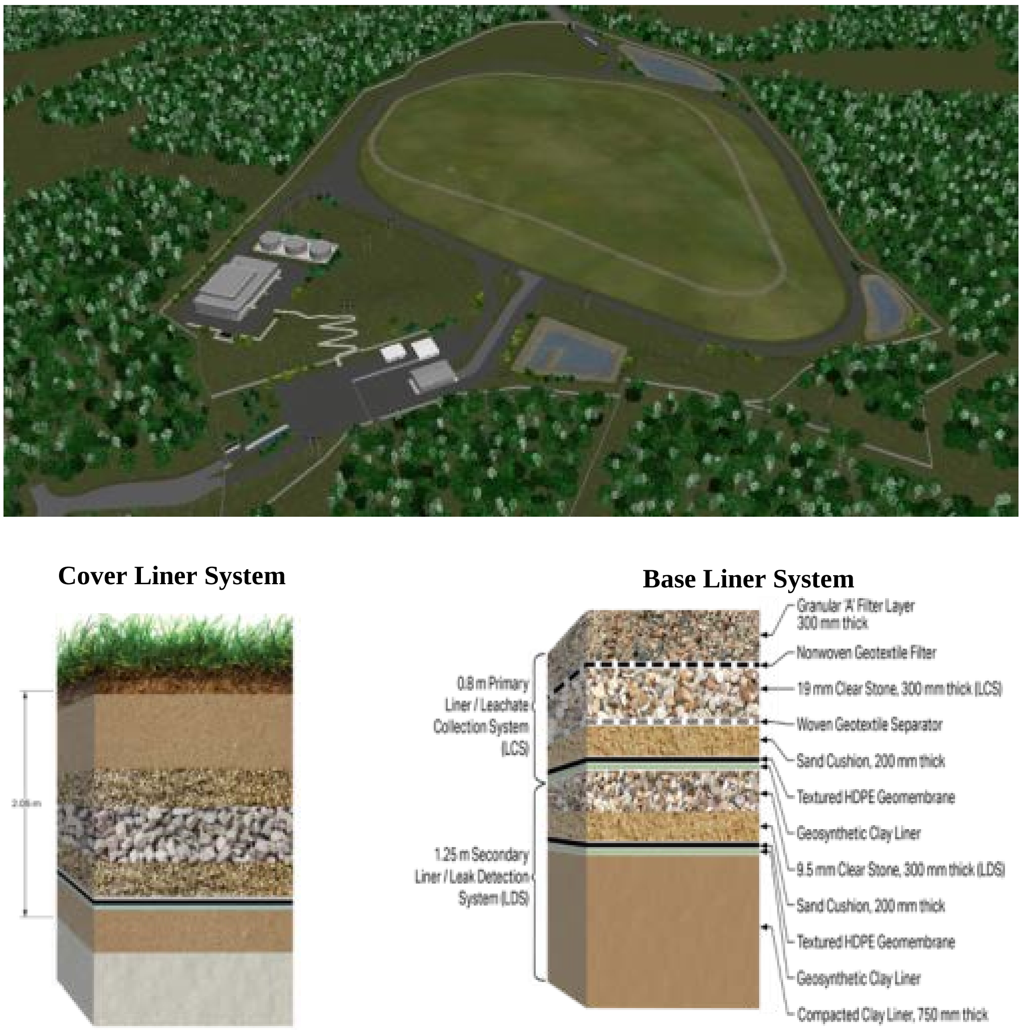

Figure K.12: Artist's rendering of closed and capped near-surface disposal facility along with liner system detail, as proposed to be constructed at Chalk River Laboratories

CNL has been regularly reaching out to the broader community to provide information on the project and seek input. A series of information sessions were held in the summer and fall of 2016 to give the public an opportunity to learn more about the proposed near-surface disposal facility and gather comments on CNL's plans. More of these meetings are planned for 2017. CNL is also engaging Aboriginal groups to discuss the NSDF project.

K.7.3 Management of historic low-level radioactive waste

In 1982, the Government of Canada established the Low-Level Radioactive Waste Management Office (LLRWMO) within AECL to carry out Canada's responsibilities for the management of historic LLW in Canada. The LLRWMO scope involves two major programs: a historic radioactive waste program involving the cleanup and management of historic LLW across Canada, and an information program on radioactive wastes in Canada. Over the course of its existence, the LLRWMO has completed historic radioactive waste cleanups across Canada and continues to monitor several sites with historic radium or uranium contamination.

During the planning stage for the PHAI it was determined that, due to the size and complexity of the two PHAI projects (described below), a dedicated entity should be established for their management. In August 2009, AECL, Natural Resources Canada, and Public Works and Procurement Services Canada formed the PHAI Management Office, a tripartite organization with a mandate to plan, manage and implement the PHAI.

Since the transition to GoCo model in September 2015, AECL is now the government organization responsible for delivering on the federal government's responsibilities with respect to the PHAI and LLRWMO. Under a GoCo contractual arrangement, CNL delivers the PHAI and LLRWMO scopes of work on behalf of AECL. The PHAI focuses on the historic wastes in Port Hope and Clarington, Ontario; the LLRWMO scope focuses on historic wastes elsewhere in Canada, primarily the Greater Toronto Area and along the Northern Transportation Route in the Northwest Territories and northern Alberta.

K.7.3.1 Port Hope Area Initiative

The bulk of Canada's historic LLW is located in the southern Ontario municipalities of Port Hope and Clarington. These wastes and contaminated soils amount to roughly 1.7 million cubic metres. They originate from the operations of a radium and uranium refinery in Port Hope dating back to the 1930s. While recognizing that there are no urgent risks from a health or environmental standpoint, the Government of Canada determined that intervention measures are required to implement more appropriate long-term management measures for these materials.

In March 2001, the Government of Canada and the local municipalities entered into an agreement on community-developed proposals to address the cleanup and long-term management of these wastes, thereby launching the PHAI. The objectives of the PHAI is to safely manage the historic LLW in two above-ground mounds that are being constructed in the local communities. The initiative comprises two projects: the Port Hope Project (see figure K.13) and Port Granby Project.

In January 2012, the Minister of Natural Resources announced a Government of Canada investment of $1.28 billion over 10 years for the implementation phase of the PHAI.

The Port Hope Project entails the cleanup of the urban area and 13 major sites as well as the consolidation of all of the wastes in Port Hope (approximately 1.2 million cubic metres in total, including waste from the current Welcome Waste Management Facility) at one long-term radioactive waste management facility (WMF). This facility is to be located at the site of the existing Welcome Waste Management Facility. The waste water treatment plant for the proposed WMF was completed in 2016 and is currently undergoing active commissioning. Construction of the containment mound commenced in the summer of 2016. The first cell will be completed in late 2017, with placement of waste from within the community expected to begin in 2018.

The Port Granby Project involves the relocation of the existing Port Granby wastes (approximately 500,000 cubic metres) to a new above-ground, long-term WMF. Construction of the Port Granby containment mound commenced spring of 2016. On November 1, 2016, the first truckloads of LLW were transported away from the Lake Ontario shoreline to the newly built Port Granby WMF, signalling the start of this significant environmental cleanup. The cleanup is scheduled to take place over three years, after which the mound's cover system will be constructed. That cover system is expected to be completed in 2021.

Information for the public at large regarding either the Port Hope or Port Granby projects is transmitted through newsletters, open house events, direct contact with communications specialists in the Project Information Exchange, and via the official PHAI website at [phai.ca.](phai.ca)

Figure K.13: Visualization of proposed waste management facility, Port Hope Project

Figure K.14: Radiological investigation at a residential property

The cleanups in Port Hope and Port Granby are anticipated to be completed by 2023. Following the emplacement of wastes and the closure of the new WMFs, the long-term monitoring and maintenance phase will commence and continue for hundreds of years.

K.7.3.2 Other historic radioactive waste sites

On behalf of AECL, CNL delivers on the LLRWMO scope that involves the management of sites along the Northern Transportation Route in the Northwest Territories and northern Alberta that are contaminated with low concentrations of uranium ore, as well as properties in the Greater Toronto Area that are contaminated with radium.

Activities are currently underway to quantify the extent of historic LLW liabilities across Canada (non-Port Hope sites) and develop plans for their discharge. A key objective for CNL is to, by 2026, significantly reduce or eliminate liabilities through safe execution of remediation projects to facilitate cost-effective long-term management of historic LLW facilities and programs, which is consistent with policy direction provided by AECL.

K.7.4 Management of uranium tailings

Since 1995, the CNSC has required that all operating uranium mines have an approved preliminary decommissioning plan as well as a financial assurance to ensure funds will be available for decommissioning. For uranium mines that were closed before these requirements were put into place, the federal and provincial governments have made provisions to ensure those sites are properly decommissioned.

Uranium mines that operated in Ontario between 1955 and 1996 represent more than 80 percent of the uranium tailings in Canada. Before 1977, the regulation of uranium mining was primarily the responsibility of the province. In 1996, the governments of Canada and Ontario entered into a memorandum of agreement that outlined their respective roles in the management of uranium mines and mill tailings in Ontario. If an owner is unable to finance the costs for decommissioning a uranium mine site, the costs will be shared by the two governments equally. To date, these arrangements have not been necessary as all Ontario sites have now been substantively decommissioned and the owners continue to comply with their responsibilities.

During the late 1950s to early 1960s, uranium supplied to Canada’s Cold War allies was produced in the Gunnar and Lorado mines and mills (along with several other smaller mines) in northern Saskatchewan. At the time, these mines operated under provincial regulations that did not require that the sites be decommissioned to the level that would be expected today. As a result, there have been environmental impacts to local soils and lakes that must be addressed. In addition, because the private sector companies that operated these mines no longer exist, these abandoned sites have become the responsibility of the provincial government.

In September 2006, the governments of Canada and Saskatchewan entered into a memorandum of agreement to share the cost of remediating these sites. The environmental assessment for the project to remediate the Gunnar uranium mine and mill site began on June 15, 2007 and an environmental impact statement was submitted for review to the CNSC in January 2011. A revised statement was submitted for review in March 2013 and a CNSC licence for a 10-year period was issued in January 2015. The Lorado tailings management site is being remediated by the Government of Saskatchewan through the Saskatchewan Research Council (SRC) under a 10-year CNSC licence issued in 2013. The majority of remediation activities were completed in 2015; the site is now transitioning into the long-term monitoring phase.

K.8 Shutdown of Gentilly-2 Nuclear Generating Station

The Gentilly-2 Nuclear Generating Station was permanently shut down on December 28, 2012. It was placed in a guaranteed shutdown state and decommissioning activities are being undertaken, following the issuance of a 10-year CNSC licence to decommission in 2016. Hydro-Québec has adopted a deferred decommissioning strategy approach. Activities under this strategy are divided into several phases, the first three being:

- stabilization (2013–14)
- dormancy and transfer of fuel (2015–20)
- dormancy and site monitoring (2021–59)

Further details of each phase and a schedule for the major decommissioning activities are found in annex 7.9.

K.9 International peer review

Canada has hosted international peer reviews which included spent fuel and radioactive waste management facilities and will continue to identify opportunities for future reviews.

Integrated Regulatory Review Service (IRRS)

In 2009, the CNSC hosted an IAEA Integrated Regulatory Review Service (IRRS) mission to Canada. The scope of the mission included all activities and facilities licensed by the CNSC (including the regulation of waste management facilities), with the exception of import and export licences. Furthermore, in 2011, the CNSC hosted a follow-up IRRS mission to review the progress on measures taken to date for addressing the recommendations and suggestions presented in the 2009 IRRS mission report. IRRS reports are publicly available at: http://nuclearsafety.gc.ca/eng/resources/international-cooperation/index.cfm. For more information refer to section E.8.2.3.

Operational Safety Review Team (OSART)

By 2016, two OSART missions were successfully completed. One took place at the Bruce B Nuclear Generating Station (December 2015) and the second at Pickering Nuclear Generating Station (October 2016). During the 2016 mission, OSART identified the KI pill distribution campaign organized by the licensee as a "Good Practice". The OSART report is publicly available at: http://nuclearsafety.gc.ca/eng/resources/educational-resources/feature-articles/OSART-mission.cfm. For more information refer to section E.8.2.3.

International Physical Protection Advisory Service (IPPAS)

In October 2015, Canada hosted an IAEA International Physical Protection Advisory Service (IPPAS) mission. The IAEA IPPAS mission to Canada was highly successful and the IAEA team noted in their final report that Canada has a "mature and robust nuclear security regime". OPG Western Used Fuel Dry Storage Facility was reviewed as part of the IPPAS mission to Canada. From the workshop, preparatory meeting and logistical coordination to the mission and its conclusion, OPG staff assisted with the IPPAS mission by facilitating a visit that demonstrated nuclear security in action. Such extensive visits are crucial in providing a thorough peer review of Canada's nuclear security regime and reflect highly both on OPG and Canada as a whole. The IAEA IPPAS Report is publicly available at http://nuclearsafety.gc.ca/eng/resources/emergency-management-and-safety/index.cfm. For more information refer to section E.8.2.4.

K.10 Openness and transparency in implementing obligations under the Convention

Canada was one of the first countries to ratify the Joint Convention, which came into force on June 18, 2001. The CNSC regulates the safe management of radioactive waste and spent fuel in Canada, and is responsible for coordinating Canada's national report for the Joint Convention. However, Canada's national report is a collective work: it involves the cooperation of various federal departments, as well as input from licensees and industry organizations.

Canada has a dedicated Web page on the Joint Convention which allows the public to access all previous national reports. Canada also publishes responses to questions presented to Canada on the report, as well as presentations from the review meetings. In addition, Canada's Web page offers information on the Joint Convention, including a link to the IAEA Joint Convention review page.
http://nuclearsafety.gc.ca/eng/resources/publications/reports/jointconvention/

Furthermore, in order to enhance openness and transparency, updates to Canada's Joint Convention Web page are proactively shared with the public. When a new national report becomes available, Canada issues a news release and sends out a notification of publication to a distribution list of approximately 2,000 members of the media and public. Social media is also used to disseminate information to the public, with regular announcements of related publications appearing on the CNSC's Facebook and Twitter pages.

Canada also regularly communicates with the public on social media to provide updates on the status of review meetings, and to provide information on upcoming activities related to the Joint Convention.

Finally, every three years, NRCan collects, compiles and analyzes radioactive waste inventory data in Canada. The updated data is published in the triennial *Inventory Summary Report*, which provides an overview of the production, accumulation and future projections of radioactive waste in Canada based on Canada’s four waste categories. In preparing this document, information and some excerpts were used from Canada’s national report. NRCan also provides this data to the IAEA’s radioactive waste management database, which tracks low- and intermediate-level radioactive waste worldwide.

Annex 1 – Federal Structure

1.0 Introduction

Canada is a confederation of 10 provinces and three territories, administered by the Government of Canada. The provinces and territories are self-governing in the areas of legislative power assigned to them by the Canadian constitution, as expressed in the *Constitution Acts, 1867 to 1982*. These areas include local commerce, working conditions, education, direct health care, energy and resources in general.

The constitution gives the Parliament of Canada legislative power over works declared by it to be for the general advantage of the country. The Parliament of Canada used this declaratory power in the *Atomic Energy Control Act* of 1946 and again in the *Nuclear Energy Act* of 2000. It declared certain works and undertakings to be for the general advantage of Canada and therefore subject to federal legislative control. Such works and undertakings are constructed for the following purposes:

- production, use and application of nuclear energy
- research or investigation of nuclear energy
- production, refinement or treatment of nuclear substances

This means that the Government of Canada is responsible for certain aspects of nuclear energy applications that would otherwise have been under provincial jurisdiction, including:

- occupational health and safety
- regulation of boilers and pressure vessels
- coordination of federal response to nuclear emergencies
- environmental protection

Under the Canadian constitution, provincial laws may also apply in these areas when they are not directly related to nuclear energy and do not conflict with federal law. Because both federal and provincial laws may apply in some regulated areas, the approach taken has been to avoid redundant regulations by seeking cooperative arrangements between the federal and provincial departments and agencies that have responsibilities or expertise in these areas.

Although these cooperative arrangements have been successful in achieving industry compliance, they need a firmer legal basis. The *Nuclear Safety and Control Act* (NSCA) binds both the federal and provincial governments as well as the private sector. Like private companies, government departments and agencies must hold licences from the regulatory body – the Canadian Nuclear Safety Commission (CNSC) – to perform any of the nuclear-related activities otherwise prohibited by the NSCA. In addition, the NSCA provides authority for the regulatory body and the Governor in Council to incorporate provincial laws by reference and to delegate powers to the provinces in areas better regulated by them or where licensees would otherwise be subject to overlapping regulatory provisions.

This annex covers the major Government of Canada organizations involved in the Canadian nuclear sector.

1.1 Natural Resources Canada

Natural Resources Canada is responsible for developing Canadian policy concerning energy sources. It provides federal policy leadership concerning uranium, nuclear energy and radioactive waste management. Natural Resources Canada also provides expert technical, policy and economic information and advice to the Minister of Natural Resources and the Government of Canada on issues affecting:

- Canadian uranium exploration and development

- environmental protection
- production and supply capability
- foreign ownership
- domestic and international markets
- exports
- international trade
- end uses

Natural Resources Canada administers, on behalf of the Minister of Natural Resources, the 1996 *Policy Framework on Radioactive Waste*, which provides the basis for ensuring the long-term management of radioactive waste is carried out in a safe, environmentally sound, comprehensive, cost-effective and integrated manner. Canada’s approach to radioactive waste management is that the owners of radioactive waste are responsible for the funding, organization, management and operation of long-term waste management and other facilities required for their wastes.

It is also responsible for administering the *Nuclear Fuel Waste Act* (NFWA). The Nuclear Fuel Waste Bureau is the organizational unit responsible for carrying out this function. The Bureau’s mandate is to support the Minister of Natural Resources in discharging the minister’s responsibilities under the NFWA by overseeing, monitoring, reviewing and commenting on relevant activities of the waste owners and ensuring all NFWA requirements are met. The Bureau’s website address is nfwbureau.gc.ca.

1.2 Canadian Nuclear Safety Commission

The CNSC is Canada’s nuclear regulatory body, created by the Governor in Council under the NSCA. The CNSC reports to the Parliament of Canada through the Minister of Natural Resources. It is not part of Natural Resources Canada; however, the Minister of Natural Resources can seek information from the CNSC on its activities. Under the NSCA, the Governor in Council may issue directives to the Commission of general application on broad policy matters. The Governor in Council cannot give direction to the Commission on specific licensing matters.

The CNSC is a federal regulatory agency and an independent administrative tribunal set up at arm’s length from the government, with no ties to the nuclear industry. To serve Canadians, the ultimate outcome of the CNSC’s work must be the establishment of safe and secure nuclear installations and processes solely for peaceful purposes and of public confidence in the nuclear regulatory regime’s effectiveness. Consistent with the Government of Canada’s SMART (specific, measurable, attainable, realistic and timely) Regulation Initiative to improve regulatory performance and reduce administrative burden on business, the CNSC engages in extensive consultation and sharing of information to ensure the desired results are understood and accepted by stakeholders and licensees.

The CNSC reports to Parliament through the Minister of Natural Resources but is an independent entity. This independence is critical for the CNSC to maintain an arm’s-length relationship with government when making legally binding regulatory decisions. The CNSC is not an advocate of nuclear science or technology. Its mandate and responsibility is to regulate users of nuclear energy or materials to ensure their operations will not pose unreasonable risks to Canadians. The people of Canada are the sole clients of the CNSC.

The CNSC's mandate is to "regulate the use of nuclear energy and materials to protect health, safety, security, and the environment; to implement Canada's international commitments on the peaceful use of nuclear energy; and to disseminate objective scientific, technical and regulatory information to the public." In pursuing its mandate, the CNSC is working to become one of the best nuclear regulators in the world. To achieve that, it encourages its employees to comply with the CNSC's values: respect, integrity, service, excellence, responsibility and safety.

The CNSC is responsible for conducting and making decisions on environmental assessments of nuclear projects under the *Canadian Environmental Assessment Act, 2012* (CEAA 2012), which is the primary environmental assessment legislation in most regions of Canada. The other regions are administered by land claim agreements (e.g., lands north of 60 degrees latitude). Under these land claim agreements, the CNSC has an advisory role during the environmental assessment process.

The CNSC's regulatory policy P-299, *Regulatory Fundamentals Policy*, which was adopted in January 2005, states that persons and organizations subject to the NSCA and its associated regulations are directly responsible for managing regulated activities in a manner that protects health, safety, security and the environment while respecting Canada's international obligations. Through Parliament, the CNSC is responsible to the public for assuring that these responsibilities are properly discharged.

1.3 Atomic Energy of Canada Limited

Atomic Energy of Canada Limited (AECL) is a Crown corporation whose sole shareholder is the Government of Canada. For more than 60 years, AECL has been a world leader in developing peaceful and innovative applications from nuclear technology through its expertise in physics, metallurgy, chemistry, biology and engineering.

Starting in 2009, the federal government undertook a restructuring of AECL in an effort to reduce risks and costs to Canadian taxpayers while leveraging AECL's capabilities for the benefit of Canadians and industry. The restructuring was undertaken in two phases, the first of which was completed in 2011 with the sale of AECL's CANDU Reactor Division to Candu Energy Inc., a wholly-owned subsidiary of SNC-Lavalin. The second phase focused on the remainder of the organization, the nuclear laboratories and associated waste management responsibilities with the objective of implementing a government-owned, contractor-operated (GoCo) model.

The implementation of the GoCo model was also done in two phases. The first phase, completed in November 2014, consisted of creating and operationalizing Canadian Nuclear Laboratories (CNL) as a wholly-owned subsidiary of AECL. Through an internal reorganization, virtually all of AECL's employees were transferred to CNL and all of the necessary licences, permits and other authorizations were transferred to CNL, allowing it to become the operator of the nuclear laboratories and the employer of the workforce. AECL then undertook to rebuild itself as a small, expert-based Crown corporation and put in place policies, processes and procedures to allow it to assume its new role.

Following a procurement process led by Natural Resources Canada with support from Public Works and Government Services Canada (now Public Works and Procurement Canada), the Canadian National Energy Alliance (a consortium made up of CH2M HILL, WS Atkins, Fluor, SNC-Lavalin and Rolls-Royce) was selected as the preferred bidder to manage and operate CNL. Once AECL transferred the shares of CNL to the Canadian National Energy Alliance, CNL became a private-sector organization. AECL then assumed its new oversight role, being responsible to ensure value for money and the achievement of its priorities through the contractual arrangements with the Canadian National Energy Alliance and CNL.

As a result, today CNL is a private-sector company responsible for the day-to-day management and operation of all of AECL's sites, facilities and assets. CNL employs over 3,500 people, most of which were previously employees of AECL.

For its part, AECL was re-created as a purpose-built small Crown corporation with a view to ensuring it has the necessary expertise and capabilities to oversee the GoCo agreements. AECL's objective is to leverage the GoCo model to deliver on its mandate. Its role is to monitor and incentivize the performance of CNL to meet AECL's objectives. To help in its own transition to the GoCo model and in fulfilling its oversight role, AECL has retained the services of international experts who bring significant experience in the management of similar arrangements, both from a government and a contractor perspective.

As a small Crown corporation with a new role, AECL focusses its efforts on overseeing CNL's activities in two main areas: decommissioning and waste management, and nuclear laboratories science and technology. With respect to decommissioning and waste management, the objective is to safely and efficiently reduce the Government of Canada's radioactive waste liabilities including associated risks to health, safety, security and the environment. The focus is on enabling CNL to significantly advance infrastructure decommissioning, site remediation and waste management for Canada. In previous years, these activities were funded and overseen by Natural Resources Canada through the Nuclear Legacy Liabilities Program, the Port Hope Area Initiative (PHAI) and the Low-Level Radioactive Waste Management Office. Under the GoCo model, AECL is now directly responsible for all of the federal government's radioactive waste management responsibilities including those related to historic low-level radioactive waste (LLW) for which the Government has accepted responsibility. AECL contracts out the work necessary to deliver on these responsibilities to CNL and closely monitors the activities of CNL in an effort to deliver value for money for Canadians.

1.4 Canadian Nuclear Laboratories

CNL operates Canada's largest nuclear science and technology complex – Chalk River Laboratories (CRL) – and manages radioactive waste liabilities on behalf of the federal Crown corporation AECL. CNL is under contract with AECL to manage and operate all of its sites under a GoCo model. Under this model, CNL is responsible for the day-to-day operations, and is the employer of the workforce and the nuclear licence holder. CNL focuses its work on three main areas:

- managing AECL's radioactive waste liabilities
- performing nuclear science and technology to respond to the Government of Canada's needs as well as those of the private sector
- revitalizing CRL by implementing an important capital program – $800 million over five years

From a decommissioning and waste management perspective, AECL continues to be the owner of all wastes and associated liabilities. CNL plans to deliver the following on behalf of AECL:

- managing AECL's legacy radioactive waste, including:
    - decommissioning and waste management at CRL (includes CNL's current proposal to build a near-surface disposal facility)
    - closure of the Whiteshell Laboratories site (includes CNL's proposal to decommission the research reactor Whiteshell Reactor-1 *in situ*)
    - closure of the Nuclear Power Demonstration reactor site (includes CNL's proposal to decommission the prototype demonstration reactor *in situ*)
    - Oversight and management of two other prototype reactors – Douglas Point and Gentilly-1 – and planning for their decommissioning
- cleaning-up historic LLW and managing it over the long-term, including:
    - the delivery of the PHAI
    - the long-term management of other historic LLW addressed by the Low-Level Radioactive Waste Management Office

1.5 Canadian Environmental Assessment Agency

The Canadian Environmental Assessment (CEA) Agency is responsible for the administration of the CEAA 2012 (see annex 2.5 for a further description of this legislation). The CEA Agency works to provide Canadians with high-quality environmental assessments that contribute to informed decision making in support of sustainable development, as does the CNSC for nuclear projects.

1.6 Global Affairs Canada

Global Affairs Canada (formerly Foreign Affairs, Trade and Development Canada) is the federal department responsible for promoting nuclear cooperation and safety both bilaterally and multilaterally. It also implements key non-proliferation and disarmament agreements in Canada and abroad.

Implementation of these agreements requires Canadian domestic law to be consistent with Canada's responsibilities under the agreements. It also requires the capacity to ensure effective monitoring to verify that treaty obligations and commitments are being honoured. Global Affairs Canada is responsible for the implementation of the *Chemical Weapons Convention* and the *Comprehensive Nuclear-Test-Ban Treaty*. In addition, it oversees foreign policy, including global security issues, and is a required interlocutor for dealings with other governments.

1.7 Health Canada

Health Canada is the federal department responsible for helping the people of Canada maintain and improve their health. In the area of radiation protection, Health Canada contributes to maintaining and improving the health of Canadians by investigating and managing the risks from natural and artificial sources of radiation. It accomplishes this mission through:

- maintaining the National Radioactivity Monitoring Network
- developing guidelines for exposure to radioactivity in water, food and air following a nuclear emergency
- providing advice and assistance to environmental assessments and reviews, as required by the CEAA 2012
- providing a full range of dosimetry services to workers through the National Dosimetry Services, National Dose Registry, National Calibration Reference Centre and biological dosimetry services
- contributing to the control of the design, construction and function of radiation emitting devices imported, sold or leased in Canada (under the *Radiation Emitting Devices Act*)
- administering the Federal Nuclear Emergency Plan

The Canadian Radiological Monitoring Network is a national network that routinely collects air particulate, precipitation, external gamma dose, drinking water, atmospheric water vapour and milk samples for radioactivity analysis. These surveillance activities of the network serve to establish background radiation levels in Canada.

The National Dosimetry Services, operated through Health Canada, provide occupational monitoring for ionizing radiation to Canadians. Among the services offered are whole body and extremity thermoluminescent dosimetry services, as well as neutron dosimetry services and dosimetry for uranium miners. The National Dosimetry Services are licensed by the CNSC.

The National Dose Registry is a centralized radiation dose record system managed by Health Canada. It contains occupational radiation dose records for all monitored radiation workers in Canada dating back to the 1940s.

1.8 Environment Canada

Environment Canada's mandate is to:

- preserve and enhance the quality of the natural environment, including water, air, soil, flora and fauna
- conserve Canada's renewable resources
- conserve and protect Canada's water resources
- carry out meteorology
- enforce the rules made by the Canada–United States International Joint Commission relating to boundary waters
- coordinate environmental policies and programs for the Government of Canada

Environment Canada administers the *Canadian Environmental Protection Act*.

1.9 Transport Canada

Transport Canada's mission is to develop and administer policies, regulations and services for a national transportation system that is safe and secure, efficient, affordable, integrated and environmentally friendly. Transport Canada sets policies, regulations and standards to protect the safety, security and efficiency of Canada's rail, marine, road and air transportation systems. This oversight includes the transportation of dangerous goods, such as nuclear substances, and ensuring that related developments can be sustained.

Transport Canada administers the *Transportation of Dangerous Goods Act*.

Annex 2 – Canadian Legislative System and Institutional Framework

2.0 Introduction

Five pieces of legislation currently govern the nuclear sector in Canada: the *Nuclear Safety and Control Act* (NSCA), the *Nuclear Energy Act* (NEA), the *Nuclear Fuel Waste Act* (NFWA), the *Nuclear Liability and Compensation Act* (NLCA) and the *Canadian Environmental Assessment Act, 2012* (CEAA 2012). The NSCA is the main legislation dealing with safety considerations.

2.1 *Nuclear Safety and Control Act*

The NSCA was passed by Parliament on March 20, 1997. This was the first major overhaul of Canada's nuclear regulatory regime since the *Atomic Energy Control Act* and the creation of the Atomic Energy Control Board in 1946. The NSCA provides legislative authority that covers the nuclear sector regulatory developments. These developments include health and safety standards for nuclear energy workers, environmental protection measures, security regarding nuclear facilities and public input into the licensing process. The NSCA can be viewed online at laws.justice.gc.ca.

The NSCA established the Canadian Nuclear Safety Commission (CNSC), which comprises the Commission and the CNSC staff. The Commission makes licensing decisions, while CNSC staff make recommendations to the Commission, exercise delegated licensing and authorization powers, and assess licensee compliance with the NSCA, its associated regulations and licence conditions.

Section 26 of the NSCA states that,

"Subject to the regulations, no person shall, except in accordance with a licence,

- possess, transfer, import, export, use or abandon a nuclear substance, prescribed equipment or prescribed information;
- mine, produce, refine, convert, enrich, process, reprocess, package, transport, manage, store or dispose of a nuclear substance;
- produce or service prescribed equipment;
- operate a dosimetry service for the purposes of this act;
- prepare a site for, construct, operate, modify, decommission or abandon a nuclear facility; or
- construct, operate, decommission or abandon a nuclear-powered vehicle or bring a nuclear-powered vehicle into Canada."

The NSCA authorizes the CNSC to make regulations. Several regulations had to be developed before the NSCA could be fully implemented, including:

- *General Nuclear Safety and Control Regulations*
- *Administrative Monetary Penalties Regulations*
- *Radiation Protection Regulations*
- *Class I Nuclear Facilities Regulations*
- *Class II Nuclear Facilities and Prescribed Equipment Regulations*
- *Uranium Mines and Mills Regulations*
- *Nuclear Substances and Radiation Devices Regulations*

- *Packaging and Transport of Nuclear Substances Regulations*
- *Nuclear Security Regulations*
- *Nuclear Non-proliferation Import and Export Control Regulations*

Canada is a signatory of the *Treaty on the Non-Proliferation of Nuclear Weapons*. Pursuant to that treaty, Canada signed the *Agreement Between Canada and the Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*, as well as a protocol additional to that agreement. Pursuant to these legal instruments, Canada must account for and maintain control of all uranium, thorium and plutonium, which is subject to measures implemented by the International Atomic Energy Agency (IAEA) to verify that all declared nuclear material is in peaceful use and that there are no undeclared nuclear materials or activities in Canada.

As a result of these commitments, much of the nuclear material and many of the facilities identified in this report, in accordance with the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*, are also subject to the terms and conditions of the safeguards agreements. The CNSC is the designated governmental authority responsible for implementing the requirements of the safeguards agreements under the regulatory framework established through the NSCA and the associated regulations.

2.2 *Nuclear Energy Act*

Concurrent with the NSCA, the NEA came into force in 2000. It is a revision of the *Atomic Energy Control Act* (1946), intended to address the development and utilization of nuclear energy (with the regulatory aspects of the *Atomic Energy Control Act* having been removed to the NSCA). The NEA can be viewed online at laws.justice.gc.ca.

The NEA gives the designated government minister the authority to:

- undertake or cause to be undertaken research and investigations with respect to nuclear energy
- with the approval of the Governor in Council, utilize, cause to be utilized and prepare for the utilization of nuclear energy
- with the approval of the Governor in Council, acquire or cause to be acquired, by purchase, lease, requisition or expropriation, nuclear substances and any mines, deposits or claims of nuclear substances and patent rights relating to nuclear energy and any works or property for production or preparation for production of, or for research or investigations with respect to, nuclear energy
- with the approval of the Governor in Council, licence or otherwise make available or sell or otherwise dispose of discoveries and inventions relating to, and improvements in processes, apparatus or machines used in connection with nuclear energy and patent rights acquired under this act and collect royalties and fees on and payments for those licences, discoveries, inventions, improvements and patent rights

2.3 *Nuclear Fuel Waste Act*

Three provincial nuclear utilities – Ontario Power Generation (OPG), Hydro-Québec and NB Power – own 97 percent of the spent fuel in Canada. Atomic Energy of Canada Limited (AECL) owns most of the remainder. Following a decade-long environmental assessment for a deep geological repository concept for spent fuel (which ended in 1998), it became clear that the Government of Canada needed to put in place a process to ensure a long-term management approach for Canada's spent fuel would be developed and implemented. Given the relatively small volume of spent fuel in Canada, it was determined that a national solution would be in the best interest of Canadians.

On November 15, 2002, Parliament passed the NFWA, which made the owners of spent fuel clearly responsible for the development of long-term waste management approaches. The legislation required nuclear energy corporations to establish a waste management organization as a separate legal entity to manage the full range of long-term spent fuel management activities. It also required waste owners to establish trust funds with independent financial institutions so as to finance their long-term waste management responsibilities. Through the waste management organization, the owners of spent fuel were required to prepare and submit a study to the Government of Canada on proposed approaches for the long-term management of the waste, along with a recommendation on which one of the proposed approaches should be adopted. The NFWA required this analysis to include feedback from comprehensive public consultations – which included Aboriginal peoples – and be evaluated in terms of social and ethical considerations.

Under the NFWA, the Government of Canada is responsible for reviewing the study prepared by the waste management organization, selecting a long-term management option from those proposed and providing oversight during its implementation. The NFWA can be viewed online at laws.justice.gc.ca.

After coming into force, the NFWA required the nuclear energy corporations to establish the Nuclear Waste Management Organization (NWMO) and the trust funds necessary to finance the implementation of long-term waste management activities. Following extensive studies and public consultation, the NWMO submitted its study of options to the Government of Canada on November 3, 2005. The NWMO presented four options, including those listed in the NFWA:

- long-term storage at the reactor sites
- central shallow or below-ground storage
- deep geological disposal
- a fourth option called the Adaptive Phased Management (APM) approach, which combines the three previous options within a flexible, adaptive management decision-making process.

On June 14, 2007, the Government of Canada announced that it had selected the APM approach for the long-term management of spent fuel. The APM approach recognizes that people benefiting from nuclear energy produced today must take steps to ensure the wastes are dealt with responsibly and without unduly burdening future generations. The approach is also sufficiently flexible to adjust to changing social and technological developments. The NWMO is required to implement the government's decision according to the NFWA, using funds provided by the nuclear energy corporations.

Over the past several years, a number of key government decisions contributed toward the implementation of the APM approach. In April 2009, the Minister of Natural Resources approved the funding formula that ensures there is sufficient money set aside in trust to pay for the full lifecycle cost of this approach. On August 14, 2009, the Minister of Natural Resources entered into a memorandum of understanding with the NWMO regarding Aboriginal engagement. It clarifies the roles and responsibilities of the Crown and the NWMO with respect to their obligation for consultations with Aboriginal peoples regarding this project and in relation to the NFWA.

Since early 2010, the NWMO has been moving forward with its siting process to identify a safe, secure and suitable site for a deep geological repository for managing spent fuel in an informed and willing host community. A number of communities have inquired about the project and are exploring their interest with the NWMO. It is expected to take a number of years before a suitable site within an informed and willing host community is confirmed.

2.4 *Nuclear Liability and Compensation Act*

The NLCA came into force on January 1, 2017 and replaced the *Nuclear Liability Act*. The NLCA establishes the legal regime that would apply in the event of a Canadian nuclear incident resulting in civil damages. The NLCA is administered by Natural Resources Canada, which also has responsibility for policy direction. The NLCA can be viewed online at laws.justice.gc.ca.

The NLCA places total responsibility for civil nuclear damage on the operator of a nuclear installation. As of January 1, 2017, the operator is liable for up to $650 million in damages, with this limit increasing by annual increments to $1 billion at January 1, 2020. The NLCA requires the operator to carry at least half of this liability with insurance that may, subject to approval by the minister, be supplemented by alternate financial arrangements. The NLCA also provides for the establishment of a Nuclear Claims Tribunal in the event of a serious nuclear incident, which would deal with claims for compensation when the Government of Canada deems it to be in the public interest, having regard to the extent and estimated cost of the damage.

Other features of the NLCA are:

- the expanded categories of compensable damage to address environmental damage, economic loss and costs related to preventive measures
- a longer limitation period for submitting compensation claims for bodily injury (30 years versus the current 10 years)
- the elaboration of the process for a quasi-judicial claims tribunal to be established to replace the court system if necessary to accelerate claims payments and provide an efficient and equitable forum

The NLCA also enables Canada to implement the *Convention on Supplementary Compensation for Nuclear Damage*, an international treaty under the auspices of the IAEA, which provides a liability and compensation regime to address damages, including those arising from transboundary and transportation incidents. Canada delivered the ratification documents for that Convention on June 6, 2017.

2.5 *Canadian Environmental Assessment Act*

The CEAA 2012 establishes the legislative basis for the federal practice of environmental assessment in most regions of Canada. The CEAA 2012 can be viewed online at laws.justice.gc.ca.

An environmental assessment offers a systematic approach to documenting the environmental effects of a proposed project and determining the need to eliminate or minimize the adverse effects, if any, to modify the project plan or to recommend further action.

The purpose of the CEAA 2012 is to:

- protect components of the environment that are within federal legislative authority from significant adverse environmental effects caused by a designated project
- ensure designated projects are considered and carried out in a careful and precautionary manner when the exercise of a power or performance of a duty or function by a federal authority is required for the project to proceed
- promote cooperation and coordination between federal and provincial governments
- promote communication and cooperation with Aboriginal peoples
- ensure opportunities are provided for meaningful public participation
- ensure environmental assessments are completed in a timely manner

- ensure projects proposed to be carried out on federal lands and projects outside of Canada that the federal government intends to carry out or fund are considered in a careful and precautionary manner to avoid significant adverse environmental effects

- encourage federal authorities to take action in a manner that promotes sustainable development

- encourage further studies of the cumulative effects of physical activities in a region and the consideration of the study results in environmental assessments

The CEA Agency was historically involved in panel reviews for nuclear projects and remains involved in the ongoing environmental assessment for OPG's Deep Geologic Repository project (see section K.7.1). Under the CEAA 2012, the CNSC is the Responsible Authority for assessing proposed nuclear projects; there are no environmental assessments by review panel for any environmental assessments led by the CNSC. The CNSC is responsible for managing the environmental assessment process, including ensuring an environmental assessment report is prepared. In practice, the project proponent may be delegated to conduct technical studies for the environmental assessment or to ensure mitigation measures and/or a follow-up program are implemented; however, the CNSC's Commission is the federal decision maker when determining if a project is likely to cause significant adverse environmental effects.

Annex 3 – The Canadian Nuclear Safety Commission and the Regulatory Process

3.0 Introduction

The Canadian nuclear sector is diverse. From radioisotopes to electricity generation to radiation devices and non-proliferation of nuclear substances, all are regulated by the Canadian Nuclear Safety Commission (CNSC), which replaced the former Atomic Energy Control Board with the implementation of the *Nuclear Safety and Control Act* (NSCA) on May 31, 2000.

3.1 *Nuclear Safety and Control Act*

A description of the NSCA is provided in annex 2.1.

3.2 Canadian Nuclear Safety Commission

The CNSC's regulatory regime covers the entire nuclear substance lifecycle from production to use through to final disposition of any nuclear substances. Its mandate, derived from the NSCA, is to:

- regulate the development, production and use of nuclear energy and materials to protect health, safety, security and the environment
- regulate production, possession and use of nuclear substances, prescribed equipment and prescribed information
- implement measures respecting international commitments on the peaceful use of nuclear energy and substances
- disseminate scientific, technical and regulatory information concerning the CNSC's activities

3.3 Canadian Nuclear Safety Commission in the government structure

In accordance with the Canadian system of parliamentary government, the decision to introduce government legislation such as the NSCA into Parliament is made by the federal cabinet on the advice and recommendation of the appropriate minister. The NSCA established the CNSC as a departmental corporation, named in schedule II of the Government of Canada's *Financial Administration Act*. The CNSC reports to the Parliament of Canada through a member of the Queen's Privy Council for Canada, designated by the Governor in Council as the minister for purposes of the NSCA. This designate is currently the Minister of Natural Resources. The CNSC is a departmental corporation, an independent agency and not part of any government department.

The NSCA requires the Commission to comply with any directives of general application on broad policy matters, with respect to the objects of the Commission issued by order of the Governor in Council. It is an accepted constitutional convention in Canada that any political directives given to agencies such as the CNSC are general and cannot interfere with Commission decisions in specific cases. An example of such a directive might be the government-wide commitment to the SMART (specific, measurable, attainable, realistic and timely) Regulation Initiative.

CNSC staff routinely interact with the management and staff of Natural Resources Canada in areas of mutual interest. Natural Resources Canada has a general interest in various matters relating to nuclear energy and natural resources. Further information on this is provided in annex 1.1.

In keeping with federal policies on public consultation and regulatory fairness, the CNSC routinely consults with parties and organizations that have an interest in its regulatory activities. These include:

- licensees
- the nuclear sector

- federal, provincial and municipal departments and agencies
- special interest groups
- individual members of the public

As required by federal policies on access to information and in accordance with Canada's SMART regulation principles, formal consultations are conducted in an open and transparent manner.

The CNSC licensees include publicly funded institutions or agents of the federal and provincial governments, including:

- Atomic Energy of Canada Limited (AECL), the federal nuclear research and development company
- nuclear operations of provincially owned electrical utilities (Ontario Power Generation, NB Power and Hydro-Québec)
- Canadian universities
- hospitals and research institutions

The CNSC regulates the health, safety, security and environmental impacts of the nuclear activities of these organizations in the same manner and according to the same standards as required from privately owned companies or operations.

3.4 Organizational structure

The CNSC consists of a president, the federally appointed members of the Commission and approximately 850 staff members (as of the end of March 2016). As defined by the NSCA, the CNSC's organizational structure consists of two components:

- the Commission, which refers to the organization's tribunal component
- the CNSC, which refers to the organization and its staff in general

3.4.1 The Commission

The Commission is an independent administrative tribunal and court of record. It can consist of up to seven permanent members. Commission members are appointed by the Governor in Council of Canada for terms not exceeding five years and may be reappointed. In addition, the Governor in Council may appoint temporary members for a renewable term not exceeding six months. Appointed members are to be independent of all influences, whether political, governmental, special interest or private sector. Commission members commit to the highest standards of ethics and conflict-of-interest guidelines, and carry out their duties impartially. The president of the CNSC is a full-time Commission member. Other members generally serve on a part-time basis.

The Commission's key roles are to:

- establish regulatory policy on matters relating to health, safety, security and the environment
- make legally binding regulations
- make independent decisions on the licensing of nuclear-related activities in Canada

The Commission makes its decisions transparently, guided by clear rules of procedure. The Commission takes into account the views, concerns and opinions of interested parties and intervenors when establishing regulatory policy, making licensing decisions and implementing programs.

The Commission administers the NSCA and its associated regulations. Among these regulations are the CNSC *Rules of Procedure*, which outline the public hearing process, and the CNSC by-laws, which outline the Commission’s meeting process. Decisions on the licensing of major nuclear facilities are made through public hearings.

Public hearings are the public’s primary opportunity to participate in the licensing process. CNSC staff attend these hearings to advise the Commission. Subsection 17(1) of the NSCA stipulates that the Commission can also hire external staff members to advise it independently of the CNSC’s staff, although this is not currently done.

In addition to public hearings, the Commission also holds public meetings. The Commission publishes a notice in advance of each meeting inviting the public to attend. Meetings are webcast live and a written transcript and archived webcast is posted to the CNSC’s external website following the meeting. Minutes are approved by the Commission members and also posted online.

Commission meetings consider a wide range of topics related to the nuclear regulatory process and, in certain cases, serve as the vehicle for making legislative, policy or administrative decisions on matters of particular or general application. Meeting items may include such subjects as annual industry reports, licensee performance reports, technical briefings, event reports and requests for approval of regulatory documents.

The Commission Secretariat supports the Commission by planning its business, publishing notices and decisions, and offering technical and administrative support to the president and other members. The Secretariat is also the official registrar of Commission documentation.

3.4.2 Canadian Nuclear Safety Commission staff

CNSC staff are primarily located at the organization’s headquarters in Ottawa. The Uranium Mines and Mills Division is located in Saskatoon, close to Canada’s major uranium mining operations. CNSC satellite offices are located at each of the four operating nuclear power plants in Canada and at AECL’s Chalk River Laboratories. Regional offices located in Ontario and Alberta conduct compliance activities for nuclear substances, transportation, radiation devices and equipment containing nuclear substances. They also respond to unusual events involving nuclear substances.

CNSC staff support the Commission by:

- developing proposals for regulatory development and recommending regulatory policies
- carrying out licensing, certification, compliance inspections and enforcement actions
- coordinating the CNSC’s international undertakings
- developing the CNSC-wide programs in support of regulatory effectiveness
- maintaining relations with stakeholders
- providing administrative support to the organization

In addition, CNSC staff prepare recommendations on licensing decisions, present them to the Commission for consideration during public hearings and subsequently administer the Commission’s decisions. Where so designated, CNSC staff also render licensing decisions.

In terms of organizational structure, the president’s office provides administrative support services to the president. Other groups in the CNSC organizational structure include the Secretariat, Legal Services, and the Office of Audit and Ethics.

There are four major branches of the CNSC staff: Regulatory Operations, Technical Support, Regulatory Affairs and Corporate Services.

Regulatory Operations Branch

This branch is responsible for the licensing, certification and regulation of nuclear power plants, uranium mines and mills, uranium fuel fabricators and processing facilities, waste management facilities, nuclear substance processing and transport, and industrial and medical applications, in accordance with the requirements of the NSCA and its associated regulations.

The Regulatory Operations Branch comprises the following directorates, which are responsible for licensees in matters of licensing, compliance and enforcement:

- Directorate of Power Reactor Regulation
- Directorate of Nuclear Cycle and Facilities Regulation
- Directorate of Nuclear Substance Regulation
- Directorate of Regulatory Improvement and Major Projects Management

Technical Support Branch

This branch provides specialized expertise in the areas of nuclear science and engineering, safety analysis, safety management, human factors, personnel training and certification, environmental and radiation protection, security, nuclear emergency management, safeguards and nuclear non-proliferation.

The Technical Support Branch comprises the following directorates:

- Directorate of Assessment and Analysis
- Directorate of Safety Management
- Directorate of Security and Safeguards
- Directorate of Environmental and Radiation Protection Assessment

These four directorates also support the CNSC's regulatory mandate.

Regulatory Affairs Branch

This branch of the CNSC is responsible for providing strategic direction and implementation of the CNSC's regulatory policy, communications and stakeholder engagement, strategic planning, international relations and Executive Committee services.

The Regulatory Affairs Branch comprises the following directorates:

- Strategic Planning Directorate
- Regulatory Policy Directorate
- Strategic Communications Directorate

Corporate Services Branch

This branch is responsible for policies and programs related to the management of the CNSC's finances and administration, human resources, information technology and information management.

The Corporate Services Branch comprises the following directorates:

- Human Resources Directorate
- Finance and Administration Directorate
- Information Management Technology Directorate

3.4.3 CNSC Research and Support Program

The CNSC's Research and Support Program supports the CNSC's regulatory mission, which is focused on safety. Although much of the supported research concerns nuclear power plant safety, waste management has become a prominent component. The program supports research associated with uranium processing waste, the handling of spent fuel and management of radioactive waste. The research is carried out by contracted consultants and universities or through various international cooperative efforts. Current research projects sponsored by the CNSC are focused on the underground disposal of waste, in particular the possible siting of a repository in sedimentary rocks. Reports from this research activity will be published to the CNSC's website.

3.4.3.1 Geological repository research

A major effort currently underway includes the development of a mathematical model for the thermal, hydraulic, mechanical and chemical processes applicable to sedimentary rock. The model will be used to assess the stability of shafts and galleries, the formation of excavation damage around them, the response of the rock mass to excavation and, ultimately, the long-term safety of a geological repository.

In support of this theoretical work, the hydro-mechanical properties of the sedimentary rock encountered in southern Ontario have been observed using the tri-axial test facility operated by the University of Toronto. Associated work also includes studying the performance of sealing material (bentonite) under conditions likely to be encountered in a geological repository.

While much work concerning the viability of a geological repository is carried out using mathematical models, their projection for very long periods of time can be questioned. For this reason, the CNSC has carried out a study into the application of natural analogues to support scientific projections on the long-term safety of a geological repository. Similarly, to support confidence in the long-term stability of the rock being considered to host a repository, a study to determine the age of material found in the fractures has been completed. Dating of this material retained in the fractures is indicative of the time when this rock was last disturbed.

Several research projects are examining the possible migration of radioactive material should it breach containment. The physical effects of microbial action are being observed in one series of experiments. In other research the modelling of gas migration through sealing material is being advanced. There is also an experimental program looking at the performance of sealing materials under repository conditions. In the far-field, the CNSC has funded work to improve on the SOAR (scoping of options and analyzing risk) model developed by the United States Nuclear Regulatory Commission. This code calculates the potential dose posed to humans through a leakage of radioactive material from an underground source.

The CNSC participates in several international cooperative programs carrying out research in geological repositories, including:

- **DECOVALEX-2019** (development of coupled models and their validation against experiments) – This project challenges researchers to model the experimental behaviour of events that may occur in a geological repository.

- **SEALEX –** This project aims to assess the long-term performance of bentonite sealing material. It is managed by the Radioprotection and Nuclear Safety Institute (*Institut de Radioprotection et de Sûreté Nucléaire* (IRSN)) in France.

- **SITEX –** This European Union funded program, also coordinated by the IRSN, aims to sustain a network of independent technical expertise on radioactive waste disposal.

More information on the CNSC independent research program for a deep geological repository can be found in section K.6.3.

3.4.3.2 Mine waste

The stability and form of long-lived radionuclides released from uranium tailings ponds is a subject of CNSC research. The CNSC has completed a preliminary program using synchrotron X-ray spectroscopy to better understand how the radionuclides of concern are retained in the tailings and perhaps the conditions that lead to them being mobilized.

3.4.3.3 Spent fuel safety

In the wake of the Fukushima Daiichi accident, it was decided there should be better capability for modelling the behaviour of spent fuel held in a CANDU irradiated fuel bay should the water held in the bay be partially or totally drained. The CNSC assembled a group of experts to study the issue and made recommendations on how this severe accident scenario could be modelled. The report was completed March 31, 2017 which concluded sufficient understanding of the phenomena existed and provided direction for development of a fuel bay accident analysis computer code.

3.5 Regulatory philosophy and activities

The CNSC’s regulatory philosophy is based on two principles, as outlined in regulatory policy P-299, *Regulatory Fundamentals*:

- Persons and organizations subject to the NSCA and its associated regulations are directly responsible for ensuring the regulated activities they engage in are managed so as to protect health, safety, security and the environment, and to respect Canada’s international commitments on the peaceful use of nuclear energy.

- The CNSC is responsible to the public for regulating persons and organizations, subject to the NSCA and its associated regulations, to ensure they are properly discharging their obligations.

The CNSC establishes a strategic framework that encompasses the following:

- a clear and practical regulatory framework

- individuals and organizations that operate safely and conform to safeguards and non-proliferation requirements

- high levels of compliance with the regulatory framework

- cooperation and integration of CNSC activities in national and international nuclear programs

- stakeholders’ understanding of the regulatory program

The following activities are delineated to achieve the above outcomes:

- regulatory framework
- licensing and certification
- compliance
- cooperative undertakings, both domestic and international
- stakeholder relations

The CNSC establishes and requires compliance with regulatory requirements, makes independent and objective decisions based on regulatory action on the level of risk, and seeks public input.

In carrying out its responsibilities, the CNSC issues licences (after assessing whether regulatory requirements and international obligations are met), verifies compliance with the licences that have been issued, sets standards for meeting regulatory requirements, and communicates its work to licensees and other stakeholders.

3.6 Regulatory framework

3.6.1 General framework

The CNSC's mandate, regulatory responsibilities and powers are set forth in:

- the NSCA
- the *Safeguards Agreement and Additional Protocol* between Canada and the International Atomic Energy Agency (IAEA)

The CNSC also conducts environmental assessments under the *Canadian Environmental Assessment Act, 2012* (CEAA 2012) and administered the *Nuclear Liability Act* until December 31, 2016. Since it came into force on January 1, 2017, the *Nuclear Liability and Compensation Act* is administered by Natural Resources Canada.

To carry out these responsibilities, the CNSC uses the following regulatory tools:

- regulations
- licences (along with their licence conditions and licence conditions handbook)
- regulatory documents that provide guidance to CNSC licensees on meeting criteria set out in the NSCA and its regulations

In line with the federal government's *Cabinet Directive on Regulatory Management*, the CNSC has taken steps to enhance stakeholder consultation by holding information sessions on key regulatory documents, posting public comments related to key documents on its website and initiating an online public input process. Also in line with this directive, the CNSC continues to adopt or adapt national and international standards in regulatory documents.

3.6.2 The CNSC's regulatory documents

Regulatory documents support the CNSC's regulatory framework by expanding on expectations set out in the NSCA, its associated regulations, and legal instruments such as licences and orders. These documents provide instruction, assistance and information to the licensees.

The CNSC has developed a five-year regulatory framework plan extending until 2021. This plan notes that regulatory documents will present both requirements and guidance in a single document. CNSC staff are transitioning towards organizing regulatory documents into the following categories:

- regulated facilities and activities
- safety and control areas
- other regulatory areas

A listing of CNSC regulatory documents published since the last review meeting can be found in table 3.1. Additional information on the CNSC's regulatory documents program and full access to all of the CNSC's regulatory documents is available on the CNSC website, nuclearsafety.gc.ca, under the "Acts and Regulations" tab.

Table 3.1: Regulatory documents published by the CNSC since the fifth review meeting

Document number	Document title	Publication date
REGDOC-2.9.1	*Environmental Protection: Environmental Principles, Assessment and Protection Measures, version 1.1*	April 2017
REGDOC-2.2.3	*Personnel Certification: Exposure Device Operators*	March 2017
REGDOC-2.2.4	*Fitness for Duty: Managing Worker Fatigue*	March 2017
REGDOC-3.4.1	*Guide for Applicants and Intervenors Writing CNSC Commission Member Documents*	March 2017
REGDOC-3.6	*Glossary of CNSC Terminology*	January 2017
REGDOC-2.2.2	*Personnel Training, version 2*	December 2016
REGDOC-2.13.2	*Import and Export*	September 2016
REGDOC-3.1.1	*Reporting Requirements for Nuclear Power Plants, version 2*	April 2016
REGDOC-2.10.1	*Nuclear Emergency Preparedness and Response, version 2*	February 2016
REGDOC-2.14.1	*Information Incorporated by Reference in Canada's Packaging and Transport of Nuclear Substances Regulations, 2015*	February 2016
REGDOC-3.2.2	*Aboriginal Engagement*	February 2016
REGDOC-2.3.1	*Conduct of Licensed Activities: Construction and Commissioning Programs*	January 2016
REGDOC-1.6.1	*Licence Application Guide: Nuclear Substances and Radiation Devices*	October 2015
REGDOC-2.3.2	*Accident Management, version 2*	September 2015

Document number	Document title	Publication date
REGDOC-3.5.2	*Compliance and Enforcement: Administrative Monetary Penalties, version 2*	August 2015
REGDOC-2.3.3	*Periodic Safety Reviews*	April 2015
REGDOC-3.5.1	*Licensing Process for Class I Nuclear Facilities and Uranium Mines and Mills*	April 2015

The draft regulatory documents as of March 2017 are listed in table 3.2. Draft documents are either currently in development by CNSC staff, issued for external stakeholder comment or under revision to incorporate comments received during consultation. For a complete list of regulatory documents and the current status of the draft regulatory documents listed in table 3.2, visit the CNSC website, nuclearsafety.gc.ca, and click on the "Acts and Regulations" tab.

Table 3.2: Draft regulatory documents as of March 2017

Document number	Document title	Status
REGDOC-1.1.1	*Licence to Prepare Site and Site Evaluation for New Reactor Facilities*	Currently under development
REGDOC-1.1.3	*Licence Application Guide: Licence to Operate a Nuclear Power Plant*	Currently under development
REGDOC-1.3.1	*Licence Application Guide: Uranium Mines and Mills*	Currently under development
REGDOC-1.4.1	*Licence Application Guide: Class II Nuclear Facilities and Prescribed Equipment*	Public consultation period
REGDOC-1.5.1	*Application Guide: Certification of Radiation Devices or Class II Prescribed Equipment*	Currently under development
REGDOC-2.1.2	*Safety Culture*	Currently under development
REGDOC-2.2.3	*Personnel Certification: Initial Certification Examinations*	Currently under development
REGDOC-2.2.4	*Fitness for Duty*	Currently under development
REGDOC-2.5.5	*Design of Radiography Installations*	Currently under development
REGDOC-2.13.1	*Safeguards and Nuclear Material Accountancy*	Currently under development

Document number	Document title	Status
REGDOC-3.1.2	*Reporting Requirements for Non-Power Reactor Class I Facilities and Uranium Mines and Mills*	Currently under development

3.7 Licensing process

The CNSC licences about 3,500 operations across Canada, including uranium mines, fuel fabrication facilities, radioisotope production, waste management facilities, nuclear power plants and AECL laboratories. Information about the CNSC's licensing process is available at nuclearsafety.gc.ca; a diagram of the licensing process is shown in figure 3.1.

Several types of licences are issued. A facility (Class I or II nuclear facility, uranium mine or mill) is licensed throughout its entire lifecycle, with licences required for site preparation, construction, operations, decommissioning and abandonment. An application for a licence, renewal or amendment may trigger other legislation and regulations. For example, an environmental assessment under the NSCA or CEAA 2012 may be conducted prior to proceeding with a licence application or at the same time as the review of the information in the applicant's licence application. An environmental assessment of a project is conducted to determine potential environmental interactions, proposed mitigation measures and whether the project is likely to result in significant adverse environmental effects. The CNSC ensures that the public has an opportunity to participate in the environmental assessment process. Aboriginal engagement activities are integrated into the environmental assessment process to the extent possible.

In addition, the CNSC also licences the import and export of controlled nuclear substances, equipment, information and nuclear-related dual-use items. Proposed imports and exports are evaluated by CNSC staff to ensure compliance with Canada's nuclear non-proliferation and export policies; its international agreements related to safeguards, health, safety and security; and the NSCA and its associated regulations.

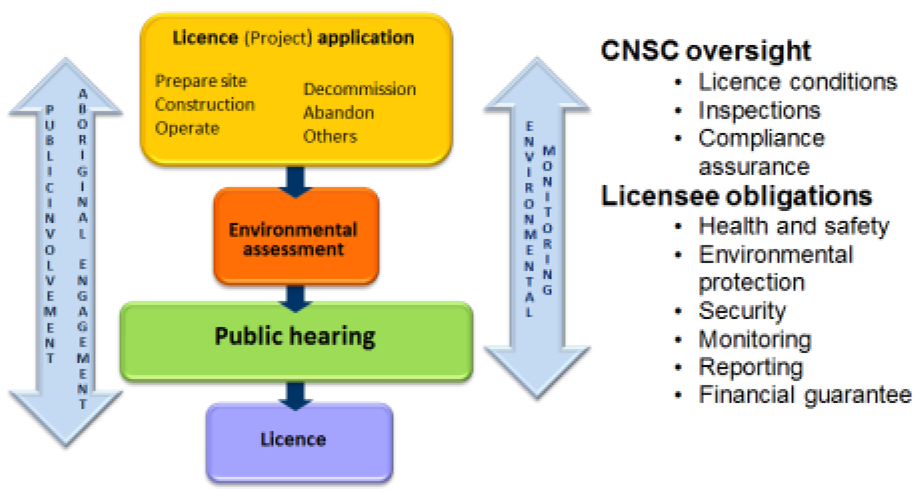

Figure 3.1: CNSC licensing process

3.8 Licensing hearings

The NSCA establishes a legislative requirement for the Commission to hold public hearings, with respect to exercising its power to license. The CNSC *Rules of Procedure* allow the Commission to vary the public hearing requirement to ensure that a matter before it is dealt with as informally and expeditiously as the circumstances and the considerations of fairness permit. The NSCA also requires that applicants, licensees and anyone named in or subject to an order have the opportunity to be heard. The CNSC *Rules of Procedure* sets out the requirements for notification of public hearings and publication of decisions from public hearings.

During a public hearing, simultaneous interpretation in Canada's official languages (English and French) is provided. The CNSC produces and publishes verbatim transcripts on its website and webcasts public hearings. The webcast is archived on the CNSC website for a minimum of three months following the proceeding.

Public hearings usually take place in one or two parts; most decisions involving major nuclear facilities are made through the two-part public hearing process. For a one-part hearing, the Commission hears all of the evidence from the applicant, CNSC staff and intervenors in a single hearing session, generally completed over one or more consecutive days. For a two-part hearing, the first part is reserved to hear the applicant and the CNSC staff recommendations. The second part is reserved to hear interventions and is typically held 60 days after the first part to permit stakeholders time to review the application and recommendations. Commission hearings are normally open to the public, but some are also held *in camera* (i.e., a closed session) in whole or in part. For example, certain protected information may not be discussed in a public forum.

A hearing in writing may also be held for less significant licence amendments. They deal with Commission decisions that are more administrative in nature and when there is less public interest in the matter being considered. Procedural changes made for a hearing in writing could include shortened public notice requirements, reduced time periods or limited participation. A hearing in writing is presided over by one or more Commission member and may be held in a closed or public forum.

3.9 The CNSC Compliance Program

Administering licensing decisions of the Commission entails planned and continuous oversight. Whether based onsite or offsite, CNSC staff work on a daily basis to carry out regular inspections, audits and reviews to provide a comprehensive overall and day-to-day picture of operations. This process ensures the operations are safe and in compliance with the licence and regulatory documentation, as described in section E.6.1.

Confirmation of compliance with licences is managed within the CNSC Compliance Program, which is a formal compliance verification program that includes promotion, verification and enforcement. These elements of the program are described in section E.6.1.

3.10 Cooperative undertakings

The CNSC works cooperatively with a number of other national and international organizations. At the national level, the CNSC's mandate is clearly outlined by the NSCA, which specifies that nuclear regulatory activities are a federal responsibility. Areas such as security, emergency preparedness and mining, however, are examples of areas where provincial departments or other federal departments have legislated parallel or complementary responsibilities.

In addition, to fulfil Canada's international obligations, the CNSC collaborates with various agencies (such as its counterparts in other countries and Global Affairs Canada) to ensure the conducting of nuclear cooperation is consistent with international agreements and the non-proliferation regime.

The CNSC's cooperation and involvement with international nuclear organizations includes the IAEA and the Organisation for Economic Co-operation and Development's Nuclear Energy Agency. The CNSC's role is to promote Canadian interests and evaluate international recommendations, standards and guides for adoption into the CNSC's regulatory framework.

CNSC hosts various international events when the occasion arises. For example, in September 2017, CNSC hosted a 4 week Regional Training Course on the Organization and Implementation of a National Regulatory Programme for the Control of Radiation Sources for representatives from nine Caribbean countries (see figure 3.2). CNSC also hosted over 50 international and Canadian participants at the Nuclear Energy Agency's 18th Meeting of the Working Party on Decommissioning and Dismantling in October 2017 (see figure 3.3).

Figure 3.2: Representatives from nine Caribbean countries participated in classroom and field training hosted by the CNSC from September 11 to October 6, 2017 in Ottawa

Figure 3.3: Participants at the Nuclear Energy Agency's 18th Meeting of the Working Party on Decommissioning and Dismantling from October 3-5, 2017 in Ottawa

3.11 Outreach at the CNSC

The dissemination of technical, scientific and regulatory information related to nuclear activities is part of the CNSC's mandate. These outreach activities are meant to demystify nuclear science, describe CNSC's role as Canada's nuclear regulator and bring a CNSC face into communities across the country (see figure 3.4). The outreach activities also mean to bring openness, transparency and timely communication to the work and management of Canada's nuclear regulatory regime.

Because the CNSC has a reputation as an unbiased scientific expert in the nuclear field, it has been urged, now more than ever, to take part in outreach and engagement activities and events. The organization also strives to involve stakeholders, the public and indigenous groups in the regulatory process through a variety of appropriate consultation opportunities.

3.11.1 Definition of “outreach”

Outreach is the delivery of awareness activities through targeted interactive forums to interested parties. These activities are designed to educate the public, licensees and other stakeholders about a particular issue or topic. Outreach is a way to deliver on the CNSC’s mandate to disseminate objective scientific, technical and regulatory information to the public. It includes:

- meetings with municipal officials and community groups
- interactions with the public
- public hearings of the Commission, particularly when they are held in a local community
- meetings with licensees on non-licence specific issues (e.g., quarterly meetings with the Canadian Nuclear Association or the Cost Recovery Advisory Group)
- presentations by the president, executives and staff at various seminars and stakeholder meetings
- participation in international and national conferences and events
- proactive media relations events
- consultations on environmental assessments
- social media

3.11.2 Definition of “engagement”

Engagement is a means of involving stakeholders in key issues. It includes providing information, understanding concerns and identifying solutions in collaborations between the CNSC and stakeholders. Engagement requires ongoing and sustained two-way dialogue.

3.11.3 Definition of “consultation”

Consultation is a means of involving stakeholders in the regulatory process. Through consultation, the CNSC receives feedback from individuals or groups on specific projects, policies or programs that may affect them directly or in which they have a significant interest. (For information on specific initiatives relating to Aboriginal consultation, see section E.8.2.1.)

Figure 3.4: Examples of CNSC outreach

3.12 CNSC requirement for public information programs

Regulatory document RD/GD-99.3, *Public Information and Disclosure Protocols*, defines the CNSC's requirements for public information and disclosure protocols for licensees and applicants. It applies to uranium mines and mills, Class I nuclear facilities and some Class II nuclear facilities, and provides guidance on how to develop and implement the requirements for public information programs and disclosure protocols.

The primary goal of a public information program, as it relates to the licensed activities, is to ensure information related to the health, safety and security of persons and the environment, along with other issues associated with the lifecycle of nuclear facilities, is effectively communicated to the public. As a component, where the public has indicated an interest in knowing, RD/GD-99.3 requires that a licensee's public information program shall include a commitment to and protocol for ongoing, timely communication of information related to the licensed facility during the course of the licence period.

The CNSC expects a licensee's public information program and disclosure protocol to be commensurate with the public's perception of risk and the level of public interest in the licensed activities – which may be influenced by the complexity of the nuclear facility's lifecycle and activities – along with the risks to public health and safety and the environment perceived to be associated with the facility and activities.

Annex 4 – Spent Fuel Storage Technologies in Canada

4.1 Wet storage technology

Spent fuel discharged from a nuclear reactor is stored initially in wet bays or water pools (see figure 4.1). The wet bays, together with the cooling and purification systems, provide containment of the spent fuel and associated radioactivity and provide good heat transfer to control fuel temperatures. The water also provides shielding and allows access to the fuel, via remotely operated and automated systems, for handling and examination. The bay structure and structural elements (such as fuel containers and stacking frames) provide mechanical protection.

The walls and floors of CANDU reactor water pools are constructed of carbon steel reinforced concrete that is approximately two metres thick. Inner walls and floors are lined with a watertight liner consisting of stainless steel, a fibreglass-reinforced epoxy compound or a combination of the two. The bay structure is seismically qualified so the structures and bay components maintain their structural form and support function both during and following a design-basis event (i.e., an accident such as an earthquake). Other structural design considerations include load factors and load combinations (including thermal loads) for which upper and lower temperature limits have been established.

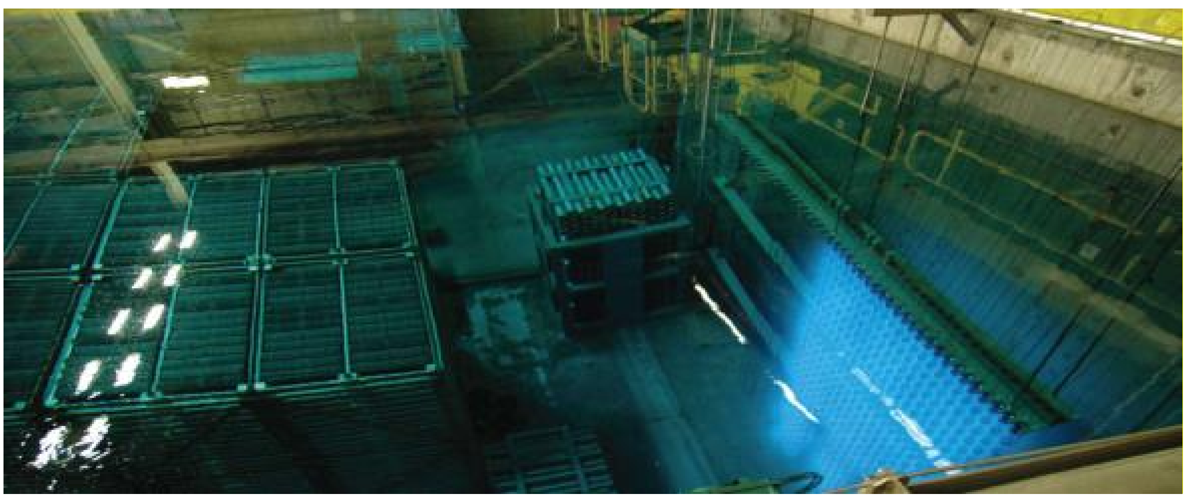

Figure 4.1: Pool storage at Bruce Nuclear Generating Station

4.1.1 Bay liners

The bays are designed to prevent bay water from leaking into the environment through any possible defects in the concrete. The bay's inner liner is the primary barrier against outward leakage. The bays also have a leakage collection system to ensure any leakage that does occur is captured and directed to a controlled drainage system. The design has provisions for leak detection and tracking.

4.1.2 Storage in wet bays

A number of designs are used to hold spent fuel for storage in wet bays. Ontario Power Generation (OPG) has a standardized site-specific, storage-transportation module that stores the fuel compactly. To reduce handling, the storage-transportation module is also suitable for holding the fuel during transportation. Baskets, trays and modules are stacked vertically in the bays within seismically qualified stacking frames.

4.1.3 Water pool chemical control

In all storage bays, water is circulated through cooling and purification circuits. A combination of ion exchange columns, filters and surface skimmers is used to control water purity within design limits. A typical purification system also includes resin traps, sample points and instrumentation to indicate when filters and ion exchange columns are exhausted as well as when resin traps must be cleaned out. Water-pool chemical control aims to:

- minimize corrosion of metal surfaces
- minimize the level of radioisotopes in the water and reduce radiation fields and radioiodine levels in the bay area
- maintain clarity of the bay water for ease of bay operation

Demineralized water is used to ensure purity.

4.2 Experiences with wet storage

Early operating experiences at the Chalk River Laboratories (CRL) research reactor spent fuel bays (which have been in operation since 1947) and at the Nuclear Power Demonstration and Douglas Point reactors have provided a basis for the successful operation of spent fuel bays in the current generation of power reactors. Those experiences – along with the development of high-density storage containers, inter-bay fuel transfers and remote handling mechanisms – have contributed to the establishment of current safe storage techniques.

Good chemical control has been achieved in Canadian spent fuel bays. Radioactivity in the water has been kept to very low or non-detectable levels, resulting in low radiation levels in the bay area. Overall fuel bundle defect rates are low. During early operations, defective fuel was "canned" (i.e., stored in a sealed cylinder). With more operating experience, canning has been found to be generally unnecessary due to minimal release of fission products from most defective bundles. In some cases, known defective fuel is held temporarily in the fuel handling system before being passed to the bay. Known defective fuel is generally stored in a designated part of the fuel bay.

As noted above, an epoxy polymer liner is in place at a number of the stations. With extended operating lifetimes and continual exposure to radiation, some radiation-induced deterioration of the liner occurred at the Pickering Nuclear Generating Station (Units 1 to 4) primary bay (where the first epoxy liner was used). Potential leaks were located and repaired before Pickering was returned to service after an extended shutdown. Techniques have been developed for underwater repairs that use an underwater-curing epoxy. Extensive repairs were completed in 2002–03 at various locations in the Pickering primary bay.

4.3 Dry storage technology

There are currently three basic designs used for the dry storage of spent fuel in Canada:

- Atomic Energy of Canada Limited (AECL) concrete canister
- AECL modular air-cooled storage (MACSTOR) system
- OPG dry storage container (see figure 4.2)

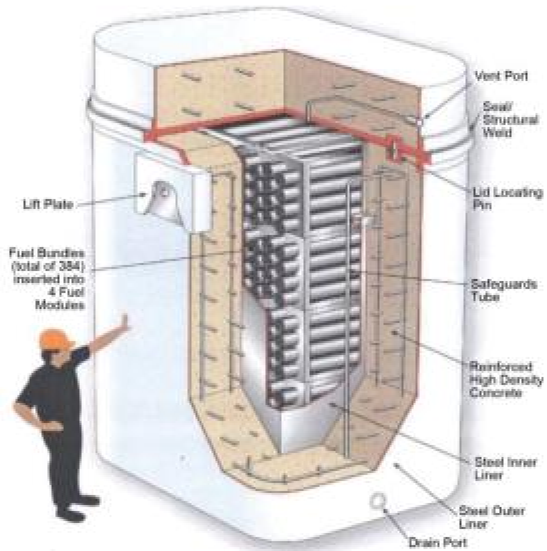

Figure 4.2: OPG dry storage container

4.3.1 Atomic Energy of Canada Limited concrete canisters

The AECL concrete canister fuel storage program was developed at the Whiteshell Laboratories in the early 1970s to demonstrate that dry storage for spent reactor fuel was a feasible alternative to water pool storage. Owing to the success of the demonstration program, concrete canisters were used to store Whiteshell Reactor-1 spent fuel. Thanks to the success of the program, the AECL concrete canister design was used at CRL for fuel bundles from Nuclear Power Demonstration reactor, the Point Lepreau Generating Station, and the partially decommissioned Douglas Point and Gentilly-1 reactors.

The canister system comprises the following main components:

- fuel basket
- shielded workstation
- transfer flask
- concrete canister itself

The fuel basket is constructed of stainless steel and comes in three designs:

- a design to hold 54 bundles (used for fuel from Douglas Point and Nuclear Power Demonstration)
- a design to hold 38 bundles, each of which is placed over a basket pin (used for fuel from Gentilly-1)
- a design to hold 60 bundles (in use at Point Lepreau)

A shielded workstation is equipped to dry a loaded fuel basket and to weld the basket cover to the basket base plate and central post assembly. It is composed of a number of subassemblies used for lifting, washing, drying, seal welding and inspecting the spent fuel baskets. The shielding provided by the workstation is sufficient to reduce the radiation fields and ensure the safety of the workers.

The fuel basket transfer flask is used to shield the basket when it is moved from the shielded workstation at the nuclear generating station to the dry storage canister at the waste management facility.

The concrete canister is a cylindrical, reinforced concrete shell with an internal liner. To provide additional shielding, a two-piece loading plug is used until the canister is filled. Provision is made for International Atomic Energy Agency (IAEA) safeguard seals to be placed on top of the canister plug so it cannot be removed without breaking the seals.

Two small-diameter pipes allow the air between the liner and the fuel baskets to be monitored to confirm the integrity of the confinement barriers. The concrete canisters are supported on reinforced concrete foundations above the water table. Each canister holds six, eight, nine or 10 baskets, depending on the specific needs of the station.

The transfer of spent fuel from the storage bays to dry storage canisters always begins with the oldest fuel. Therefore, the nominal age of the spent fuel in dry storage is usually older than seven years, which adds a measure of conservatism to the assumptions and overall safety of the dry storage of spent fuel.

Three barriers (defence in depth) ensure the containment of the radioactive products:

- fuel sheath
- fuel basket
- internal liner

4.3.2 Atomic Energy of Canada Limited MACSTOR module

The MACSTOR system is a variant of the canister storage technique. MACSTOR modules are currently installed and being operated at the Gentilly-2 Nuclear Generating Station site in Quebec, the Cernavoda site in Romania and the Qinshan site in China.

The original MACSTOR design (MACSTOR-200) is a secure, reinforced concrete structure housing 20 vertical steel cylinders, each of which holds 10 sealed baskets of 60 spent fuel bundles. Each module can store 12,000 bundles of spent fuel. Each cylinder is secured to the top slab of the module and two sampling pipes, which extend to the outside of the MACSTOR module, are provided at its base. These pipes allow confirmation of the integrity of confinement. The MACSTOR-200 is used at the Gentilly-2 site (see figure 4.3) and the Cernavoda site.

The newer design, MACSTOR-400, can store twice as much fuel with a marginal increase in construction costs when compared to MACSTOR-200. The MACSTOR-400 houses 40 vertical steel cylinders, each of which will hold 10 sealed baskets of 60 fuel bundles. In total, the module can store 24,000 bundles of spent fuel. The MACSTOR-400 is used at the Qinshan site and will be used at the Cernavoda site.

The heat of the spent fuel is dissipated primarily by natural convection through ventilation ports that extend through the concrete walls. The ventilation is provided by 10 large air inlets in each longitudinal wall near the base of the module (five on each side) and by 12 large air outlets located slightly below the top of the module (six on each side). The air inlets and outlets are arranged in a series of baffles to avoid direct gamma radiation.

To enhance cooling, the storage cylinders of the MACSTOR module are in direct contact with the air circulating in the module. All the surfaces of the storage cylinders are hot galvanized to protect the storage cylinders from ambient air.

The loading operations for the MACSTOR module are identical to those for the concrete canister. Both use the fuel basket, shielded workstation and transfer flask concept. The only essential difference between the two is the storage structure itself.

Figure 4.3: MACSTOR at Gentilly-2

4.3.3 Ontario Power Generation dry storage containers

OPG currently operates three spent fuel dry storage facilities, located at the Pickering Waste Management Facility (PWMF), the Western Waste Management Facility (WWMF) and the Darlington Waste Management Facility (DWMF).

OPG dry storage facilities employ dry storage containers (see figure 4.4). These are large, transportable containers with an inner cavity for fuel containment. Each one is designed to hold 384 fuel bundles and weighs approximately 60 tonnes when empty and 70 tonnes when loaded.

The containers are rectangular, with walls of reinforced, high-density concrete sandwiched between interior and exterior shells made of carbon steel. The inner liner is an integral part of the containment boundary, while the outer liner is intended to enhance structural integrity and facilitate decontamination of the surface of the dry storage container. Helium is used as the inert cover gas in the dry storage container cavity to protect the fuel bundles from potential oxidation reactions and to facilitate leak testing of the containment boundary. OPG dry storage facilities are located indoors. There are no anticipated radiological releases under normal operating conditions.

Figure 4.4: Dry storage containers at an OPG waste management facility

4.4 Experiences with dry storage

Research programs have assessed the behaviour of spent fuel when stored in dry and moist air conditions and in a helium environment. The programs have concluded that CANDU fuel bundles, whether intact or with defects, can be stored in dry storage conditions for up to 100 years or more without losing integrity. Additional research is ongoing.

The experience gained at licensed dry storage facilities provides a high level of confidence that CANDU dry storage facilities can be operated safely and without undue risk to workers, the general public and the environment. Dry storage containers have been used successfully and safely at the PWMF since 1996. The safety performance of the facility has been excellent over the entire period. Dose rates have remained below regulatory limits. Emissions from the processing area have also remained below regulatory limits.

Thermal and shielding analyses, carried out for design and safety assessment purposes, have been found to be conservative. Analysis and measurements carried out at the PWMF indicate that the maximum fuel cladding temperature does not exceed 175°C in dry storage. In addition, results of neutron dose rate calculations have demonstrated that, as expected, the dose rates produced by neutrons are negligible compared to those generated by gamma radiation. This result is due to the heavy concrete used as shielding in the dry storage containers.

To verify the results of the thermal analysis, an experimental thermal performance verification program was carried out in the summer of 1998. A dry storage container, instrumented with 24 thermocouples at various locations on the inner and outer liners, was loaded with six-year cooled fuel and placed within an array of dry storage containers containing 10-year cooled fuel. Temperatures were also measured at the interspaces between the dry storage containers, in addition to indoor and outdoor ambient temperature measurements. The results demonstrated the conservatism of the temperatures predicted analytically.

4.5 Spent fuel storage facilities

After a cooling period of six to 10 years in the storage bay (the exact cooling period is site-specific), spent fuel is then transferred to an interim dry storage facility. All transfers of spent fuel to dry storage are subject to IAEA surveillance. All loaded dry storage containers in interim storage are also under the surveillance of the IAEA through the application of a dual sealing system.

4.5.1 Pickering Nuclear Generating Station

Pickering hosts two nuclear generating stations, each consisting of four CANDU pressurized heavy-water reactors. The first station (Units 1–4, formerly known as Pickering A) commenced operation in 1971 and continued to operate safely until 1997, when it was placed in voluntary layup as part of what was then Ontario Hydro's nuclear improvement program. In September 2003, Unit 4 was returned to commercial operation. Unit 1 was returned to commercial operation in November 2005. Units 2 and 3 were defuelled, dewatered and placed in safe storage by September 2010.

The second station (Units 5–8, formerly known as Pickering B) commenced commercial operation in 1983 and continues to operate today. OPG plans to continue operating the Pickering Nuclear Generating Station to 2024.

The spent fuel generated at both Pickering stations is stored in the spent fuel bays for a minimum of 10 years before it is transferred to the PWMF.

4.5.2 Pickering Waste Management Facility – spent fuel dry storage

OPG's PWMF is located within the protected area at the Pickering site; the only exception is storage building 3, which is located within its own security protected area on the Pickering site. In operation since 1996, the primary purpose of the facility is to store spent fuel from the Pickering reactors. It is expected that the PWMF will be in operation until at least 10 years after the shutdown of the last Pickering reactor unit.

The spent fuel dry storage area of the PWMF comprises a dry storage container processing building and three storage buildings. The Pickering spent fuel dry storage system is designed to transfer spent fuel from wet storage in the Pickering spent fuel bays into a steel clad concrete dry storage container designed by OPG. Prior to transfer to the PWMF, each loaded dry storage container is drained, its cavity is vacuum dried and the container surface is surveyed for loose contamination. Decontamination is carried out if necessary.

Once the dry storage container loaded with spent fuel is received at the PWMF processing building, the transfer clamp is removed and the lid is seal-welded to the dry storage container body. The lid weld is subsequently inspected for defects. The dry storage container undergoes final vacuum drying and helium backfilling. Subsequently, the drain port is welded and inspected, and helium leak testing is performed.

Finally, touch-up paint is applied to scuffs or scrapes on the container's exterior. Following processing, IAEA seals are applied to each container and placed in storage. The PWMF can process approximately 50 dry storage containers (or 19,200 spent fuel bundles) per year. As of December 2016, there were 855 dry storage containers stored at PWMF.

The nominal design capacity of the PWMF is approximately 650 dry storage containers or 249,600 fuel bundles in the two existing storage buildings in the PWMF phase I area. A PWMF phase II area has been constructed in the Pickering east complex, as shown in figure 4.5. The PWMF phase II complex currently contains one spent fuel dry storage building (storage building 3) with a nominal capacity of 500 dry storage containers, with space for additional storage buildings. The storage buildings in the PWMF phase I and phase II areas will eventually have a combined capacity of up to 3,000 dry storage containers, sufficient to store all of the fuel consumed during the lifetime operation of the Pickering site. The PWMF phase II area operates within its own established protected area.

In 2016, OPG reported releases from the PWMF used fuel dry storage container processing building of 1.75×10^5 becquerels (Bq) particulate to air. Releases to water were 1.98×10^8 Bq tritium and 3.25×10^5 Bq gross beta/gamma. These releases are orders of magnitude below the derived release limits for PWMF which are derived from the public dose limit of 1 mSv per year. It is important to note, however, that activity released from the PWMF is included in the total releases reported for the Pickering site (which includes 6 operating CANDU units).

Figure 4.5: Pickering Waste Management Facility, phase I (processing building, storage buildings 1 and 2, retube components storage building) and phase II (storage building 3, future storage building 4) areas

4.5.3 Bruce Nuclear Generating Stations A and B

The Municipality of Kincardine, Ontario, hosts the Bruce nuclear site, which contains two nuclear generating stations: Bruce A Nuclear Generating Station and Bruce B Nuclear Generating Station. Bruce A consists of four CANDU pressurized heavy-water reactors. Currently, all four units are in operation.

Bruce B consists of four CANDU heavy-water reactors, all of which are currently in operation. This station commenced operation in 1984 and continues to operate today. Bruce Power leases and operates both Bruce A and Bruce B. The spent fuel generated at both Bruce stations is stored in the spent fuel bays for a minimum of 10 years before it is transferred to the WWMF.

4.5.4 Western Waste Management Facility – spent fuel dry storage

OPG's Western Used Fuel Dry Storage Facility, which is part of the WWMF, began operations in February 2003. The facility was designed to provide safe storage for Bruce A and B spent fuel until all of it is transported to an alternative long-term spent fuel storage or disposal facility.

The WWMF can currently provide dry storage for 2,000 dry storage containers or 768,000 fuel bundles produced at Bruce Power. OPG expects the next storage building will be needed by 2019. The spent fuel is stored in dual-purpose concrete dry storage containers, identical to those currently in use at the PWMF and DWMF. The processing of dry storage containers is carried out in a manner similar to that at the PWMF and DWMF.

The WWMF can process approximately 130 dry storage containers (or 49,920 spent fuel bundles) per year.

Section 5.1.2 describes the combined releases to air and water of the WWMF's spent fuel dry storage area and the low- and intermediate-level radioactive waste storage area.

4.5.5 Darlington Nuclear Generating Station

The Darlington Nuclear Generating Station, operated by OPG, consists of four CANDU pressurized heavy-water reactors. The station commenced commercial operation in 1990 and continues to operate today. Following years of detailed planning, OPG has started work to refurbish the four reactors at the Darlington site. The mid-life refurbishment of this facility will ensure continued power for 30 more years. The Darlington refurbishment is scheduled for completion by 2026.

The spent fuel generated at Darlington is stored in the spent fuel bays for a minimum of 10 years before the spent fuel is transferred to the DWMF.

4.5.6 Darlington Waste Management Facility

The DWMF (figure 4.6) is located at the Darlington site. It provides safe storage for the Darlington spent fuel until this fuel is transported to an alternative long-term spent fuel storage or disposal facility.

The DWMF is made up of a processing building and two storage buildings each designed to house up to 500 dry storage containers. The facility, however, is designed to provide a storage capacity for up to 676,000 fuel bundles (approximately 1,760 dry storage containers) once two additional storage buildings are constructed in the future. The spent fuel is stored in dual-purpose (i.e., storage container plus transportation package) concrete dry storage containers that are identical to those currently in use at the PWMF and WWMF. The processing of dry storage containers is also identical to the operations at the PWMF and the WWMF. The DWMF can process approximately 60 dry storage containers (or 23,040 spent fuel bundles) per year.

In 2016, OPG reported releases from the DWMF of 4.00×10^4 Bq particulate into the air and there were no reported releases into water. This release is orders of magnitude below the derived release limits for DWMF which are derived from the public dose limit of 1 mSv per year.

Figure 4.6: Aerial photo of the Darlington Waste Management Facility

4.5.7 Gentilly-2 Nuclear Generating Station

Operated by Hydro-Québec, Gentilly-2 (figure 4.7) houses one CANDU pressurized heavy water reactor. The station went into service in 1982 and began commercial operation in 1983. At the end of 2012, Hydro-Québec ended operations at Gentilly-2 to proceed with decommissioning

Because the station has ended operations, the total number of spent fuel bundles will not increase. There are 129,925 spent fuel bundles in safe storage at the station. The spent fuel is first stored in a pool and then, after an appropriate cooling period of at least seven years, transferred to the dry storage facility. The transfer of spent fuel in baskets is performed directly at the pool. The loaded baskets are then transferred to a shielded workstation wherein the contents are dried and the basket lids welded on. Once the work on the baskets has been completed, the baskets are transported to Hydro-Québec's spent fuel dry storage facility.

Figure 4.7: Gentilly-2 Nuclear Generating Station

4.5.8 Gentilly-2 spent fuel dry storage facility

In operation since 1995, the Gentilly-2 spent fuel dry storage facility (figure 4.8) stores fuel used during the station's operation. Hydro-Québec was authorized to build all of the CANDU Storage (CANSTOR) modules required for the storage of its spent fuel. At the end of 2016, nine CANSTOR modules were in service and two were under construction. The final, permanent shutdown of the nuclear generating station required the construction and commissioning of two additional CANSTOR modules. One CANSTOR module stores 12,000 spent fuel bundles.

The storage baskets are transferred on an as-needed basis in accordance with decommissioning planning requirements, with transfers normally held between April and October each year until 2020. Hydro-Québec must ensure dose rates at the fence line of these facilities stays within the authorized limit of 2.5 microsieverts (μSv) per hour at all times.

Figure 4.8: Gentilly-2 Spent Fuel Dry Storage Facility

4.5.9 Point Lepreau Generating Station

Point Lepreau Generating Station, operated by NB Power, consists of one CANDU pressurized heavy-water reactor. The station commenced operation in 1982. It is currently in full-power operation, having completed a major refurbishment outage in the fall of 2012 that will enable the station to operate for another 25 to 30 years.

4.5.10 Point Lepreau spent fuel dry storage facility

The spent fuel generated at Point Lepreau is initially stored in the spent fuel bay for a minimum of 7 years and then transferred to the spent fuel dry storage facility (figure 4.9), also known as the phase II area of the solid radioactive waste management facility. In operation since 1990, the spent fuel dry storage facility provides storage capacity for Point Lepreau in above-ground concrete canisters. The facility is authorized to construct 300 canisters, which can house a total of 180,000 spent fuel bundles. To handle the spent fuel resulting from the extended operational life of the station on account of the refurbishment outage, land was prepared to permit the construction of up to 300 additional canisters, with the exact amount depending on upcoming needs.

Twenty-eight canisters were filled and sealed during the reporting period (March 31, 2014 to March 31, 2017). By the end of the reporting period, the facility had constructed 220 canisters, 190 of which had been filled and sealed. Approximately 5,000 spent fuel bundles are transferred to dry storage each year the station operates, depending on the power output of the Point Lepreau nuclear reactor.

Samples of surface runoff from the phase II area, collected and analyzed over the reporting period, had an average tritium concentration of 93 Bq/litre. The average dose rate for the reporting period at the spent fuel storage facility perimeter fence, as read from thermoluminescent dosimeters, was 0.10 μSv per hour. The regulatory limit for dose to the public is 1 mSv per year.

Figure 4.9: Point Lepreau spent fuel dry storage facility area

4.5.11 Douglas Point spent fuel dry storage facility

The Douglas Point spent fuel dry storage facility (figure 4.10) is located at the Bruce nuclear site. The prototype CANDU power reactor at Douglas Point became operational in 1968 and was shut down permanently after 17 years of operation. AECL is responsible for the decommissioning of Douglas Point, with that work now being executed by Canadian Nuclear Laboratories (CNL) under a government-owned, contractor-operated (GoCo) arrangement.

Decommissioning began in 1986. Approximately 22,256 spent fuel bundles were transported to concrete canisters in late 1987. The dry fuel storage canister air sampling program demonstrates safe storage-with-surveillance with a continuing trend of close to zero release. Maximum air sampling results for any one canister for 2016 was less than 0.304 Bq/filter gross beta activity and less than 0.0295 Bq/filter gross alpha activity. This ongoing monitoring confirms that the facility continues to remain in a safe storage-with-surveillance state.

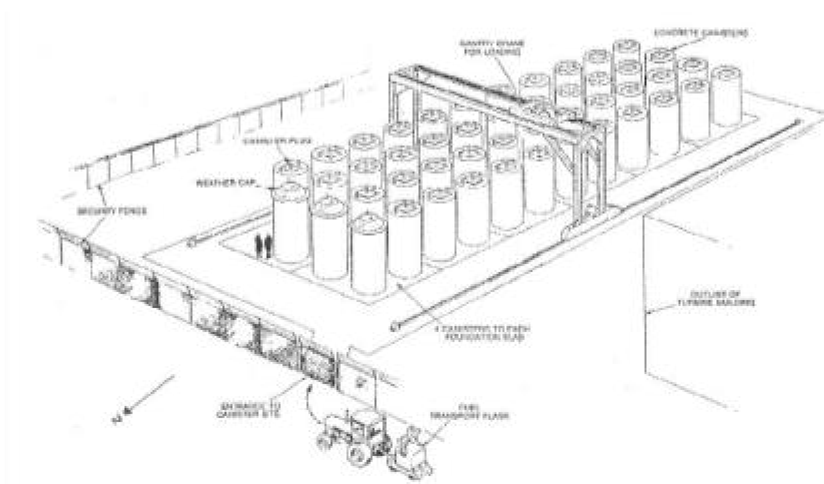

Figure 4.10: Douglas Point spent fuel dry storage facility

4.5.12 Gentilly-1 spent fuel dry storage facility

The Gentilly-1 station became operational in May 1972. It attained full power for two short periods in 1972 and was then operated intermittently for a total of 183 effective full-power days until 1978. The responsibility for decommissioning Gentilly-1 belongs to AECL; this work is now being executed by CNL under a GoCo arrangement.

In 1984, AECL began a two-year decommissioning program during which a total of 3,213 spent fuel bundles were transferred to concrete canisters. The dry fuel storage canister air sampling program demonstrates safe storage-with –surveillance with a continuing trend of close to zero releases. Maximum air sampling results for any one canister for 2016 was less than 0.29 Bq/filter gross beta activity and less than 0.029 Bq/filter gross alpha activity. This ongoing monitoring confirms that the facility continues to remain in a safe storage-with-surveillance state.

4.5.13 Chalk River Laboratories Waste Management Area G – spent fuel dry storage area

CRL’s Waste Management Area G, which is operated by CNL, is a spent fuel dry storage area that contains concrete canisters as described in section 4.3.1. The Nuclear Power Demonstration reactor was operated by Ontario Hydro (now OPG) from 1962 until 1987, when it was decommissioned. As part of its decommissioning program, the spent fuel was transferred to concrete canisters located at CRL spent fuel dry storage area. This site has stored 68 full and partial spent fuel bundles from Bruce, Pickering and Douglas Point, as well as 4,886 fuel bundles from the Nuclear Power Demonstration reactor, in 12 dry storage concrete canisters.

Two concrete canisters were constructed on the existing concrete support pad to store calcined waste from the processing of radioisotopes separated in the new processing facility at CRL. These canisters are in the extended shutdown state, matching the other dedicated isotope facility systems. Construction of the canisters is not completed.

4.5.14 Whiteshell Laboratories spent fuel storage facility

Whiteshell Laboratories was established at Pinawa, Manitoba, in the early 1960s to carry out nuclear research and development activities for higher-temperature versions of the CANDU reactor. The initial focus of research was the Whiteshell Reactor-1 organic cooled reactor, which began operation in 1965. Whiteshell Reactor-1 continued to operate until 1985.

The Concrete Canister Storage Facility Program was developed at Whiteshell in the early 1970s to demonstrate that dry storage was a feasible alternative to water pool storage for spent reactor fuel.

Due to the success of the demonstration program, the Concrete Canister Storage Facility (see figure 4.11) was built to store all remaining Whiteshell Reactor -1 spent fuel. In addition, a number of spent fuel bundles from CANDU stations are stored in the facility after undergoing post-irradiation examinations in Whiteshell’s shielded facilities. The facility provides storage for 2,268 spent fuel bundles originating from both the Whiteshell Reactor-1 operation and CANDU reactors. Some spent fuel from operations prior to 1975 is stored in standpipes in the waste management area. (Further details on the Whiteshell decommissioning program can be found in annex 7.1.)

Figure 4.11: Whiteshell Laboratories Concrete Canister Storage Facility

4.5.15 National Research Universal research reactor

The National Research Universal research reactor is a thermal neutron, heterogeneous, heavy-water moderated and cooled reactor. It was designed for operation with natural uranium metal fuel rods and converted to operation with enriched driver fuel rods in 1964. Gradual conversion to low-enriched uranium fuel began in 1991.

Initial storage of the spent fuel rods takes place in water-filled bays located within the research reactor. After appropriate time to allow for radioactive decay and cooling, the spent fuel is generally transferred to tile holes at Waste Management Area B at CRL. The tile holes are also used to store the spent fuel from the National Research Experimental reactor, which was shut down in 1992.

The National Research Universal research reactor will cease operation on March 31, 2018. Approximately 30 related buildings and structures, along with the main reactor facility, will be turned over to decommissioning and waste management under storage with surveillance by 2021.

4.5.16 McMaster Nuclear Reactor

The McMaster Nuclear Reactor is a pool-type reactor with a core of enriched uranium fuel moderated and cooled by light water. The reactor operates at powers up to 5 megawatts. It was converted from highly enriched uranium fuel to low-enriched uranium fuel during 2006–07. The original highly enriched uranium fuel was returned to the Savannah River nuclear site in the United States. The low-enriched uranium fuel was manufactured in France.

The McMaster Nuclear Reactor is the only Canadian medium-flux reactor in a university environment. The reactor's neutrons are used in nuclear physics, biology, chemistry, earth sciences, medicine and nuclear medicine. Any spent fuel at the McMaster Nuclear Reactor can be stored in a water environment.

Annex 5 – Radioactive Waste Management Facilities

5.1 Radioactive waste management methods

All radioactive waste, with the exception of uranium mine and mill waste, produced in Canada is placed into interim storage, pending the establishment of long-term waste management facilities (WMFs). At existing WMFs, various storage structures are currently in use, such as:

- in-ground burial
- low- and intermediate-level radioactive waste (L&ILW) storage buildings
- intermediate-level radioactive waste (ILW) storage buildings
- shielded above-ground storage buildings
- Quonset huts
- above-ground or in-ground containers or tile holes
- concrete bunkers

5.1.1 Pickering Waste Management Facility – retube components storage

The Pickering Waste Management Facility (see figure 5.1) consists of the spent fuel dry storage area (see annex 4.5.2) and the retube components storage area, which stores reactor core component waste from retube activities at the Pickering Nuclear Generating Station (Units 1–4). The retube components storage area is located within the protected area of Pickering and is operating in storage-with-surveillance mode, meaning it is closed to new waste unless it receives prior written approval from the Canadian Nuclear Safety Commission (CNSC).

The retube components storage area uses dry storage modules – cylindrical casks made from reinforced heavy concrete – to store the retube components. The storage area was designed to accommodate 38 dry storage modules. The design of the modules provides adequate shielding to meet dose rate requirements outside the facility and to keep worker dose rates as low as reasonably achievable. At present, the retube components storage area consists of 34 loaded dry storage modules, two empty modules and space for two additional modules.

The retube components storage area ground surface is covered in an impermeable membrane and provides a low-maintenance surface. A drainage system directs the runoff water from the storage area to the Pickering Units 5–8 outfall. Catch basins permit periodic sampling of the water.

Figure 5.1: Pickering Waste Management Facility with retube components storage area (left) and spent fuel dry storage area (right)

5.1.2 Western Waste Management Facility – low- and intermediate-level waste storage

The Western Waste Management Facility (WWMF) is owned and operated by Ontario Power Generation (OPG) at the Bruce nuclear site near Kincardine, Ontario. The WWMF consists of two distinct areas (see figure 5.2):

- L&ILW storage area
- spent fuel dry storage area (see annex 4.5.4)

The L&ILW storage area provides safe handling, processing and storage of radioactive materials produced at Ontario’s nuclear stations (Pickering, Darlington and Bruce) as well as other facilities currently or previously operated by OPG or its predecessor, Ontario Hydro. The L&ILW storage area consists of various buildings, such as the waste volume reduction building and the transportation package maintenance building. The storage structures used in this facility consist of above-ground low-level radioactive waste (LLW) storage buildings, refurbishment waste storage buildings, quadricells, in-ground containers, in-ground trenches and tile holes.

The waste volume reduction building can receive LLW and sort them into processable and non-processable streams. It can further process some of the waste by using compaction or incineration prior to storage. The building consists of the following main areas:

- The radioactive waste incinerator area contains the radioactive waste incinerator, auxiliary systems and equipment as well as an active drainage sump.
- The compaction area contains a box compactor and a civil maintenance shop. Control and mechanical maintenance shops are located at the transportation package maintenance building to carry out repairs and equipment maintenance.
- The material handling, storage and sorting area provides for material movement, sorting and temporary storage of incoming and processed wastes. Access to the incinerator and compaction areas is included.
- The control room houses the main work control centre. All L&ILW storage area systems and services alarms are monitored in this room.
- Truck bays establish a weather-protected area for the receipt and unloading of LLW.

- Ventilation equipment areas contain air intake filters, intake fans, heating coils, air exhaust filters and exhaust fans. Radioactive airborne effluent monitors for the building ventilation and radioactive incinerator exhaust are also located in this area.

- Electrical and storage rooms provide housing for electrical switchgear and motor control centres, as well as storage for non-waste products.

OPG has developed derived release limits (DRLs) for airborne radioactive releases from the radioactive incinerator and active ventilation in the waste volume reduction and transportation package maintenance buildings, as well as for releases to surface and subsurface drainage at the site. The non-radioactive effluents must conform to the environmental compliance approval for the WWMF site issued by the Ontario Ministry of the Environment and Climate Change. Currently and historically, radioactive and non-radioactive effluents are all below regulatory requirements.

The safe handling, processing and storage of radioactive waste at the WWMF requires a combination of design features, procedures, policies and monitoring programs. Required programs focus on radiation protection, occupational health and safety, environmental protection and monitoring for individual areas as well as the overall facility.

The L&ILW storage area of the WWMF received approximately 2,900 cubic metres of radioactive waste in 2015. The annual amount can vary widely depending on maintenance activities at the various nuclear power plants. The waste is subsequently processed, when possible, and placed into the appropriate storage structure. Currently, an estimated 94,000 cubic metres of L&ILW is stored onsite on an interim basis.

There are two refurbishment waste storage buildings located within the L&ILW storage area. These buildings store the waste that arose from the refurbishment of Bruce A Units 1 and 2. One of these buildings contains the retube components in specially designed concrete and steel boxes, while the other houses the steam generators. The construction schedule for the future refurbishment waste storage structures will be based on need and, therefore, on the refurbishment plans developed for the nuclear power plants by the power reactor licensee.

In 2016, the WWMF (spent fuel dry storage area and the L&ILW storage area combined) released 2.06×10^{13}Bq of tritium, 5.42×10^{3} Bq of particulate, 1.71×10^{5} Bq of iodine-131 and 3.94×10^{9} Bq of carbon-14 to air. Releases to water were 6.12×10^{11} Bq of tritium and 4.62×10^{8} Bq of gross beta. These releases are orders of magnitude below the DRLs and action levels for WWMF.

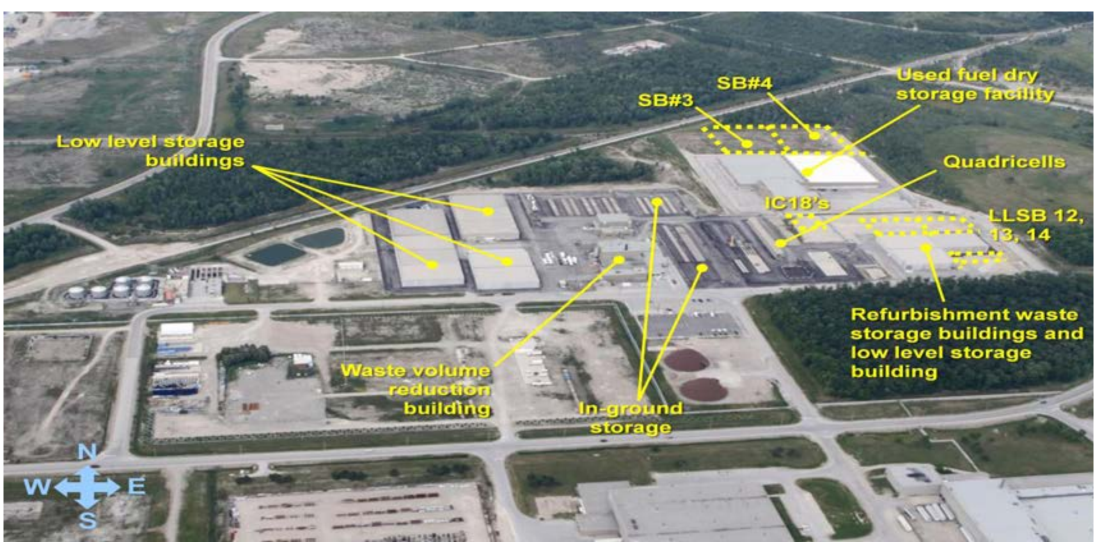

Figure 5.2: Western Waste Management Facility

5.1.3 Bruce Radioactive Waste Operations Site 1

Radioactive Waste Operations Site 1 is owned and maintained by OPG at the Bruce nuclear site. The facility provides for the storage of L&ILW produced at the Douglas Point reactor and from the early operating life at Pickering Units 1–4. The majority of the original wastes from this facility were retrieved and relocated to the WWMF in the late 1990s and early 2000s. Some small volume of wastes remains stored in reinforced concrete trenches with concrete covers and in in-ground monoliths and lined tile holes.

The facility is currently operated in caretaking mode and no longer receives new wastes. OPG monitors and maintains the site and structures, and no new waste can be added without the prior written approval of the CNSC.

5.1.4 Hydro-Québec waste management facilities

Hydro-Québec's solid radioactive waste management facilities (SRWMFs) consist of two separate facilities and provide the safe storage of radioactive materials produced at the Gentilly-2 Nuclear Generating Station (see figure 5.3). Both facilities consist of several types of reinforced concrete bunkers.

ILW with a higher dose-rate, such as filters, is stored in type A bunkers. Type B bunkers are also used to store ILW but with a lower dose-rate than type A bunkers. Type C bunkers are used to store LLW.

Commissioning of phase II of the SRWMF was authorized in 2013. Phase II was originally built for storage of refurbishment waste; however, this installation will be used to store radioactive resins and either ILW or LLW from decommissioning activities.

The volume of LLW is now less than 10 cubic metres per year. Samples of surface water runoff from the SRWMF collected and analyzed in 2016 have shown that tritium concentrations varied between 26 Bq/litre and 1,040 Bq/litre. The average dose rate for 2016 at the SRWMF perimeter fence was 0.05 microsieverts (μSv) per hour. The regulatory limit for dose to the public is 1 mSv per year.

Figure 5.3: Gentilly-2 solid radioactive waste management facility

5.1.5 Point Lepreau solid radioactive waste management facility

The Point Lepreau SRWMF includes a phase I area for the storage of operational solid radioactive waste, a phase II area for the storage of spent fuel (as described in annex 4.5.10) and a phase III area for the storage of solid radioactive waste from the refurbishment outage.

The phase I area contains the following storage structures:

- **Vaults –** The phase I vaults are concrete structures. There are six vaults, each with four equal compartments. They are primarily used to store operational LLW (see figure 5.4). The activity of the majority of the waste stored in the phase I vaults is expected to decay to an insignificant level by the end of the design life of these structures. There was a total of approximately 1,688 cubic metres of solid radioactive waste in the six vault structures at the end of the reporting period.

- **Quadricells** – The phase I quadricells are designed to house high-dose rate ILW, such as spent ion exchange resins, spent purification filters and contaminated system components. There is currently approximately 144 cubic metres of storage space available in a total of nine quadricells. These structures were empty at the end of the reporting period.

- **Filter storage structures –** The filter storage structures in phase I are used for storing spent purification filters from the heat transport purification, moderator purification, active drainage, gland seal supply, spent fuel bay and fuelling machine systems. These structures are contained within one of the vaults mentioned above. A total of approximately 13 cubic metres of spent filter waste was stored within these storage structures at the end of the reporting period.

A total of approximately 247 cubic metres of radioactive waste was transferred to phase I over the reporting period. A volume reduction strategy, whereby processable radioactive waste is sent to EnergySolutions' Bear Creek Processing Facility in Oak Ridge, Tennessee, was implemented in December 2010. An approximate volume reduction of 80:1 is realized via this process in terms of shipped incinerable waste and the returned ash, while melted radioactive metal waste is used for shielding purposes in the nuclear industry in the United States and thus is not returned to NB Power. A total of approximately 604 cubic metres of radioactive waste was transferred from phase I to EnergySolutions over the reporting period.

Samples of surface runoff from phase I, collected and analyzed over the reporting period, had an average tritium concentration of approximately 390 Bq/litre. The average dose rate for the reporting period at the phase I perimeter fence, as read from thermoluminescent dosimeters, was approximately 0.11 µSv per hour. The regulatory limit for dose to the public is 1 mSv per year.

Figure 5.4: Point Lepreau vault storage structure

The phase III area contains the following storage structures:

- **Vaults –** The phase III vaults are concrete structures identical to those in phase I. They are used to store the bulk of the LLW from the refurbishment outage. There is approximately 890 cubic metres of storage space in the two vault structures. As of March 31, 2017, approximately 871 cubic metres of vault storage space was being occupied.

- **Retube canisters** – The phase III retube canisters (see figure 5.5) are concrete structures used to store ILW from the refurbishment of the Point Lepreau reactor, which consists primarily of reactor components. There is approximately 165 cubic metres of storage space in the five structures. There was approximately 140 cubic metres of retube canister storage space being occupied at the end of the reporting period.

A total of 2.27 cubic metres of solid radioactive waste was transferred to this facility over the reporting period, which consisted solely of a coffin box housing 164 closure plugs. The coffin box was originally removed from vault storage in phase III in March 2013 to assess the plugs’ applicability with regard to closure plug challenges at the station.

Samples of surface runoff from the phase III area, collected and analyzed over the reporting period, had an average tritium concentration of approximately 274 Bq/litre. The average dose rate for the reporting period at the phase III perimeter fence, as read from thermoluminescent dosimeters, was approximately 0.11 µSv per hour. The regulatory limit for dose to the public is 1 mSv per year.

Figure 5.5: Point Lepreau retube waste canisters

5.1.6 Radioactive waste management at decommissioned reactor sites

The Douglas Point, Gentilly-1 and Nuclear Power Demonstration reactors are shut down, partially decommissioned and in the storage-with-surveillance phase (see figure 5.6). As these facilities contain radioactive materials – including radioactive wastes from decommissioning activities – they are presently licensed as WMFs. (Annex 7 provides further information on the decommissioning activities at each of these sites.)

5.1.6.1 Douglas Point Waste Management Facility

The Douglas Point Waste Management Facility is located on the Bruce nuclear site in Kincardine, Ontario. The prototype CANDU power reactor was shut down permanently in 1984 after 17 years of operation. Decommissioning began in 1986 and the spent fuel bundles were transferred to concrete canisters in late 1987. The responsibility for decommissioning Douglas Point belongs to Atomic Energy of Canada Limited (AECL), and such work is now being executed by Canadian Nuclear Laboratories under a government-owned, contractor-operated (GoCo) arrangement.

Stored waste consists of activated corrosion products and fission products. The waste is stored in the reactor and service buildings. The sources of each waste type are as follows:

- induced radioactivity in reactor components and the biological shield
- radioactive corrosion products and fission products deposited on the drained heat transport and moderator surfaces
- ion exchange resin from both the heat transport and moderator systems stored in underground tanks
- contaminated soil stored in the service building
- drums of contaminated steel from fuel storage trays
- ILW stored in the fuel transfer tunnel leading from the reactor building to the receiving bay

Routine discharge and environmental monitoring measurements continue to confirm that the facility is operating safely.

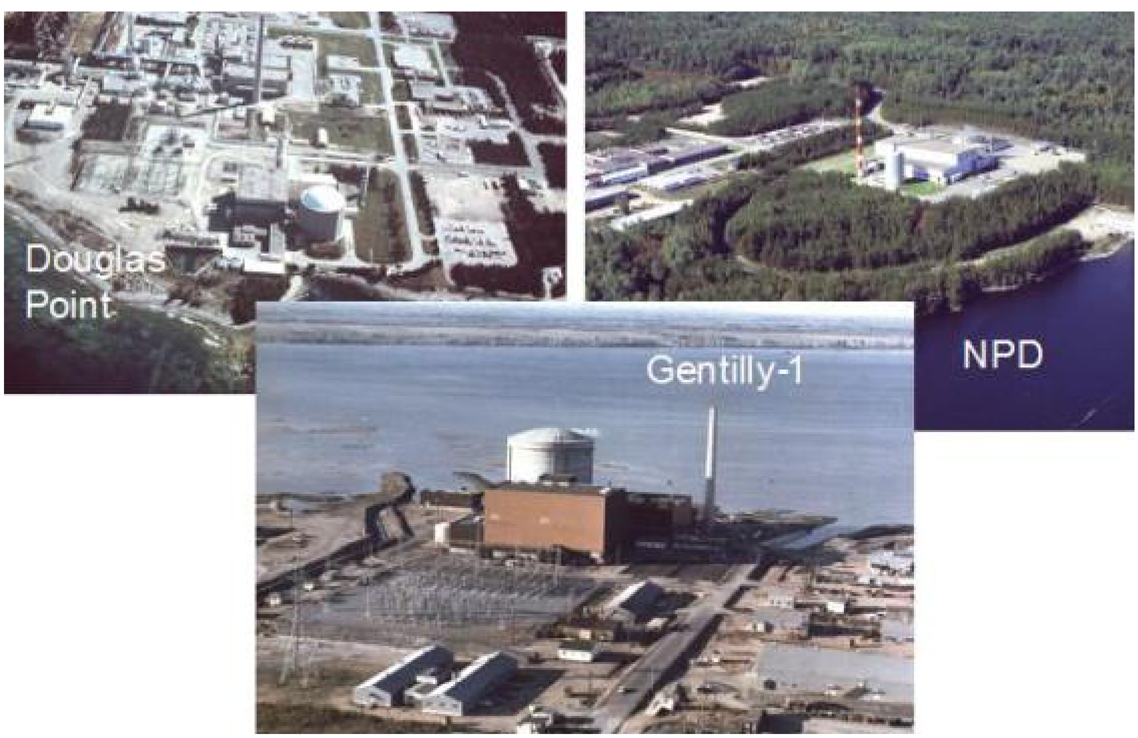

Figure 5.6: Douglas Point, Nuclear Power Demonstration and Gentilly-1 facilities

5.1.6.2 Gentilly-1 Waste Management Facility

The Gentilly-1 Waste Management Facility is situated within Hydro-Québec's Gentilly-2 nuclear power plant boundary. The Gentilly-1 nuclear power station began operation in May 1972 and attained full power for two short periods during that same year. It was operated intermittently for a total of 183 effective full-power days until 1978, when it was determined that some modifications and considerable repairs would be required. Consequently, it was in a layup state from 1980 to 1984, when a decommissioning program was initiated to bring the Gentilly-1 station to a safe sustainable shutdown state that permitted storage with surveillance. The responsibility for decommissioning Gentilly-1 belongs to AECL and such work is now being executed by CNL.

The Gentilly-1 Waste Management Facility consists of specified areas within the turbine and service buildings, the whole reactor building, the resin storage area and the spent fuel storage canister room.

Stored waste consists of activated corrosion products and fission products. The sources of each waste type area are as follows:

- induced radioactivity in reactor components and the biological shield
- radioactive corrosion products and fission products deposited on the drained heat transport and moderator system surfaces
- contaminated soil
- ion exchange resin from the heat transport and moderator systems
- containers of dry low-level contaminated equipment and material that resulted from operation and earlier decommissioning activities

There are no airborne releases from the facility. Routine waste-water discharge and environmental monitoring measurements continue to confirm that the facility is operating safely.

5.1.6.3 Nuclear Power Demonstration Waste Management Facility

Located in Rolphton, Ontario, the Nuclear Power Demonstration Waste Management Facility contains the decommissioned Nuclear Power Demonstration station. The station operated from 1962 until 1987, when Ontario Hydro (now OPG), with assistance from AECL, decommissioned it to a static state interim storage condition. After the static state was achieved, Ontario Hydro turned over control of the Nuclear Power Demonstration Waste Management Facility to AECL in September 1988. Since then, various non-nuclear ancillary facilities – such as the administration wing, training centre, pump house and two large warehouses – were demolished and the refuse was removed from the site for reuse, recycling or waste. The fuel bundles were transferred to the Chalk River Laboratories (CRL) waste management area for storage.

The Nuclear Power Demonstration Waste Management Facility is divided into nuclear and non-nuclear areas. Stored waste consists of induced radioactive products, activated corrosion products and some fission products. The confined residual radioactivity in Nuclear Power Demonstration after removal of the spent fuel and heavy water consists of:

- induced radioactivity in the reactor components and biological shield (i.e., the concrete walls surrounding the reactor)
- radioactive corrosion products in the drained heat transports and moderator systems
- small amounts of radioactivity in auxiliary systems, components and materials stored in the nuclear area of the facility

Routine discharge and environmental monitoring measurements continue to confirm that the facility is operating safety.

Since the transition to a GoCo model in 2015, AECL is now seeking to close the Nuclear Power Demonstration site through the work of CNL. While AECL continues to own the site, CNL is responsible for the facility, which is presently in the storage-with-surveillance phase of decommissioning under a decommissioning waste facility licence issued by the CNSC. The Nuclear Power Demonstration site currently consists of a limited number of structures, including the main reactor building, a diesel generator, a guardhouse and a ventilation stack. Several temporary structures are being added to support the decommissioning project.

5.1.7 Atomic Energy of Canada Limited nuclear research and test establishment facilities

AECL currently has one research facility in Canada: CRL in Chalk River, Ontario. AECL previously had another active research facility, Whiteshell Laboratories in Manitoba, which is currently undergoing decommissioning. (Annex 7 provides further information on decommissioning activities.) Following transition to a GoCo model in 2015, these sites are operated by CNL under agreement with AECL. The radioactive wastes produced at these two sites are stored in WMFs at each site.

5.1.7.1 Chalk River Laboratories

The CRL site is located in Renfrew County, Ontario, on the shore of the Ottawa River 160 kilometres northwest of Ottawa. The site, which comprises a total area of about 4,000 hectares, is situated within the boundaries of the Corporation of the Town of Deep River. The Ottawa River, which flows northwest to southeast, forms the northeastern boundary of the site. The Petawawa Military Reserve abuts the CRL property to the southeast.

The CRL site was established in the mid-1940s and has a history of various nuclear operations and facilities, primarily related to research. Most of the nuclear and associated support facilities and buildings on the site are located within a relatively small industrial plant site area, adjacent to the Ottawa River near the southeast end of the property. Various waste management areas for radioactive and non-radioactive wastes are located within the CRL property, along the southwest to northeast corridor. The CRL waste management areas provide some fee-based waste management for institutions such as universities, hospitals and industrial users that have no other means to manage their wastes.

The CRL waste management areas manage eight types of waste:

- nuclear reactor operation wastes, which include fuel and reactor components, reactor fluid cleanup materials (e.g., resins and filters), trash and other materials contaminated with radioactivity as a result of routine operations
- fuel fabrication facility wastes, which include zirconium dioxide and graphite crucibles used to cast billets, filters and other trash such as gloves, coveralls and wipes
- isotope production wastes, which include general radioactive wastes contaminated primarily with cobalt-60 and molybdenum-99
- isotope usage wastes, which include general radioactive wastes contaminated primarily with cobalt-60 and molybdenum-99
- hot cell operations wastes, which include cleaning materials, contaminated air filters, contaminated equipment and discarded irradiated samples
- decontamination and decommissioning wastes, which include a variety of contaminated wastes with variable physical and chemical properties as well as radiological properties
- remediation wastes, which include solidified waste arising from the treatment of contaminated soil and groundwater
- CRL and offsite miscellaneous wastes, which include radioactive wastes that do not readily fall within the other classes of wastes described above (e.g., wastes from radioisotope laboratories and workshops)

Liquid wastes, such as scintillation cocktails, radiological-contaminated lubricating oils, wastes contaminated by polychlorinated biphenyl and isotope production wastes, are also handled by the CRL waste management operations. Approximately 15 to 20 cubic metres of these types of waste are received into the waste management areas per year – including wastes received from offsite waste generators – and are disposed of using commercial disposal services.

In addition, active aqueous wastes generated at the CRL site are treated at the waste treatment centre. After treatment through a liquid waste evaporator, the treated effluent is monitored and released to the process sewer, which eventually discharges to the Ottawa River.

5.1.7.1.1 Chalk River Laboratories Waste Management Area A

The first emplacement of radioactive waste at the CRL site took place in 1946 into what is now referred to as Waste Management Area A. These emplacements took the form of direct disposal of solids and liquids into excavated sand trenches. The scale of operations was modest and unrecorded until 1952, when the cleanup from the National Research Experimental accident generated large quantities of radioactive waste (which included the reactor's calandria) that had to be managed quickly and safely. At that time, approximately 4,500 cubic metres of aqueous waste, containing 330 terabecquerels (9,000 curies) of mixed fission products, was poured into excavated trenches. This action was followed by smaller dispersals (6.3 terabecquerels and 34 terabecquerels of mixed fission products) in 1954 and 1955, respectively. Waste is no longer accepted for emplacement in Waste Management Area A.

The two active liquid waste tanks in this area received bottled liquids and, based on recorded observations, it is assumed the bottles were intentionally broken at the time of emplacement. The active liquid disposal tank was estimated to have received about 3.7×10^{13} Bq of strontium-90 and about 100 grams of plutonium. The radioactive liquids inside the tanks were recovered in 2013 and sent to an offsite service provider for processing. Retrieval of liquids from these tanks minimizes the potential and consequence of contaminant release from the tanks.

Waste Management Area A is on the western flank of a sand ridge. Three aquifers have been identified in its vicinity: lower sand, middle sand and upper sand (see figure 5.7). Groundwater flow is initially to the south. As the aquifer sands thicken, the flow direction bends to the south-southeast.

The wastes are believed to be above the water table in Waste Management Area A, but infiltration has transported contaminants into the groundwater, which creates a contaminated plume with an area extent of 38,000 square metres. Groundwater monitoring data collected to date have encountered total beta (10 Bq/litre to 7,740 Bq/litre), gross alpha (0.13 Bq/litre to 2.5 Bq/litre) and strontium-90 (5 Bq/litre to 3,800 Bq/litre) in some of the sample wells. The groundwater plume is subject to periodic investigations to monitor migration of the plume and identify any deviations from expected conditions. Routine groundwater monitoring around the perimeter of Waste Management Area A (i.e., near the source of the plume) indicates stable or improving conditions, in that the contamination levels in the groundwater around the perimeter are generally either remaining at similar concentrations or gradually declining with time.

Construction of a permeable reactive barrier, known as the South Swamp Groundwater Treatment System, was completed in 2013. The treatment system is intended to intercept the strontium-90 plume emanating from Waste Management Area A via the upper sand aquifer that flows into South Swamp located in its vicinity.

5.1.7.1.2 Waste Management Area B

Waste Management Area B was established in 1953 to succeed Waste Management Area A as the site for solid waste management at CRL. The site is located on a sand-covered upland, approximately 750 metres west of Waste Management Area A (see figure 5.7). Early waste storage practices for LLW were the same as those used in Waste Management Area A – namely, emplacement in unlined trenches and capped with sandy fill, in what is now the northern portion of the site. Additionally, numerous special burials of components and materials occurred.

Asphalt-lined and capped trenches were used for solid ILW from 1955 to 1959, when they were superseded by concrete bunkers constructed below grade but above the water table in the site's sand. The use of sand trenches in Waste Management Area B for LLW was discontinued in 1963 in favour of concrete bunkers and Waste Management Area C.

Concrete structures were used to store solid waste packages that did not meet sand trench acceptance criteria but did not require a significant amount of shielding, either. Early concrete bunkers were rectangular. These were superseded in 1979 by cylindrical structures, which are still used.

Cylindrical bunkers are formed by using removable metal forms to create corrugated reinforced concrete walls on a concrete pad. The maximum volume of a cylindrical concrete bunker is 110 cubic metres, but typical volumes of stored waste average about 60 cubic metres.

Wastes that present a higher level of hazard are also stored in Waste Management Area B, in engineered facilities known as tile holes. Tile holes are used to store radioactive material that requires more shielding than can be provided in concrete bunkers. Stored materials include irradiated fuel, hot cell waste, experimental fuel bundles, unusable radioisotopes, spent resin columns, active exhaust system filters and fission product waste from the molybdenum-99 production process. A new tile hole array at Waste Management Area B was constructed in 2010 and made available for use in 2011.

There are several groundwater contaminant plumes extending from Waste Management Area B. One plume, on the east side, contains organic compounds (e.g., 1,1,1-trichloroethane, chloroform, trichloroethylene) that emanate from the unlined sand trenches at the north end of the site. This "solvent plume" is subject to periodic investigations to monitor contaminant migration and identify any deviations from expected conditions. Routine groundwater monitoring around the northeast perimeter of Waste Management Area B (i.e., near the source of the plume) indicates stable conditions, in that the contamination levels in the groundwater at the perimeter remain at similar concentrations over time.

The second plume emanates from the northwest corner of the Waste Management Area B and is dominated by strontium-90. The source of this plume is the western section of the unlined sand trenches. Routine groundwater monitoring around the northwest perimeter of Waste Management Area B (i.e., near the source of the plume) indicates improving conditions; the contamination levels in the groundwater at the perimeter decrease over time. The effects of this contaminant migration are mitigated by a plume treatment system known as the Spring B Treatment Plant. This automated treatment facility removes strontium-90 from surface water and groundwater, where the plume flow path discharges to the biosphere in a series of springs. This treatment system removes a significant fraction of the strontium-90 activity in the influent. In 2013, the Spring B Treatment Plant treated 1,308 cubic metres of groundwater, removing 1.60 gigabecquerels (GBq) of strontium-90 and reducing input concentrations from 1,258 Bq/litre (average) to 2.0 Bq/litre (average). Since the Spring B Treatment Plant is close to the end of its design life, a conceptual design of a new treatment system was finalized in 2013. Construction of the new facility is set to commence in 2017, with the completed facility commissioned and turned over to Waste Management Operations by the summer of 2018.

Tritium is another contaminant observed in the groundwater at Waste Management Area B. Routine groundwater monitoring indicates that the tritium contamination levels remain stable over time. A number of different types of waste storage structures within Waste Management Area B are considered the source of this contamination.

Figure 5.7: Waste Management Area B at the Chalk River Laboratories site

5.1.7.1.3 Waste Management Area C

CRL’s Waste Management Area C was established in 1963 to receive LLWs with hazardous half-lives of less than 150 years and wastes that could not be confirmed to be uncontaminated. Early operations consisted of emplacements in parallel trenches separated by intervening wedge-shaped stripes of undisturbed sand. In 1982, this system was changed to a “continuous trench” method to make more efficient use of the available space. In 1983, part of the original parallel trenches was covered with an impermeable membrane of high-density polyethylene.

An extension was constructed adjacent to the south end of Waste Management Area C in 1993 and began accepting wastes in 1995. As the continuous trench and/or its extension was backfilled and landscaped, material from the suspect soil stockpile was used for grading purposes to ensure the surface of Waste Management Area C was suitable for travel by heavy equipment. Material placed in the soil stockpile satisfied specific acceptance criteria.

Besides the sand trench waste, inactive acid, solvent and organic liquid wastes were also placed in specific sections of the trenches or in special pits located along the western edge of the area – although this practice was discontinued. Contaminated sewage sludge was also emplaced in the sand trenches until late 2004.

Since 2006, additional waste inventory, including sewage sludge, has been restricted to interim above-ground storage of sealed containers. The new bulk materials landfill was completed in 2010 and the sewage sludge in containers on the surface of Waste Management Area C was transferred to Waste Management Area J in late 2010. In 2012 and 2013, materials stored on the surface of Waste Management Area C, namely the National Research Experimental stack pieces, were removed in preparation for installation of an engineered cover over Waste Management Area C. The National Research Experimental stack pieces were re-packed in specially designed PacTec bags and transferred to WMA H for surface storage. In 2013, the engineered cover with geotextile and geomembrane layers was installed over Waste Management Area C to minimize the infiltration of atmospheric water into the stored waste.

Groundwater monitoring data at Waste Management Area C indicates that a plume is emanating from this area. The primary contaminant is tritium, although organic compounds are also observed at elevated concentrations in some boreholes. Routine groundwater monitoring indicates that the tritium contamination levels have remained stable over time.

5.1.7.1.4 Waste Management Area D

Waste Management Area D was established in 1976 to store obsolete or surplus equipment and components – such as pipes, vessels and heat exchangers – that are known or suspected to be contaminated but do not require enclosure. Much of this legacy material has been removed, either returned to owners or dispositioned through offsite metal recycling in the last three years.

The mixed waste storage facility is composed of three interconnected, engineered structures designed for the safe short-term storage and handling of mixed liquid waste (i.e., waste that is both chemically and radiologically hazardous). The structures have two storage rooms with proper leak containment and ventilation, as well as a sampling or bulking area with fume hoods, exhaust and leak containment capabilities.

The site consists of a fenced compound that encloses a gravel-surfaced area in which the components are placed. If the components have surface contamination, they must be packaged appropriately for the package to be free of surface contamination.

An aggressive cleanup campaign started in 2014 has resulted in the outside compound becoming cleared of all but neatly stored marine containers. In 2016, material that had been stored in the Butler buildings from prior Low-Level Radioactive Waste Management Office remediation activities has been consolidated in modern standard storage containers to be disposed in the proposed near-surface disposal facility when it is available. All storage in Waste Management Area D is above ground. No burials are authorized in this area. This waste management area will also provide interim storage capacity prior to the proposed near-surface disposal facility becoming operational.

5.1.7.1.5 Waste Management Area E

Waste Management Area E is an area that received suspect and slightly contaminated soils and building materials as well as other bulk soils and building debris from approximately 1977 to 1984. The waste materials were used to construct a roadway in Waste Management Area E, which was intended to become a site for suspect contaminated materials – to be used in place of Waste Management Area C – but was not put into operation.

5.1.7.1.6 Waste Management Area F

Waste Management Area F was established in 1976 to accommodate contaminated soils and slag from Port Hope, Albion Hills and Ottawa – all located in Ontario. The stored materials are known to contain low levels of radium-226, uranium and arsenic. Emplacement was completed in 1979 and the site is now considered closed, although it is subject to monitoring and surveillance to assess possible migration of radioactive and chemical contaminants.

5.1.7.1.7 Waste Management Area G

Waste Management Area G was established in 1988 to store the entire inventory of spent fuel from the Nuclear Power Demonstration prototype reactor in above-ground concrete canisters. It currently consists of 12 Nuclear Power Demonstration fuel canisters and two calcine waste canisters. There are 11 Nuclear Power Demonstration canisters that are full and one empty canister as a spare. The calcine waste canisters were constructed for the anticipated waste that would be created by the processing of radioisotopes separated in the new Dedicated Isotope Facility at CRL. However, both of the calcine waste canisters are empty and in an extended shutdown state, as are other Dedicated Isotope Facility systems. There are currently no plans to construct more canisters.

5.1.7.1.8 Waste Management Area H

Waste Management Area H began operating in 2002. It is the location for the modular above-ground storage (MAGS) structures and the shielded modular above-ground storage (SMAGS) structures. Dry low-level wastes are packaged and, in some instances, compacted in steel containers prior to storage in MAGS (see figure 5.8) and SMAGS. In March 2014, the CNSC granted approval for the construction of six SMAGS structures at CRL. The first three of six SMAGS structures have been completed and are operational. The remaining three are now deferred pending availability of the proposed near-surface disposal facility. Pending regulatory approvals, once the facility is operational, wastes that meet the proposed near-surface disposal facility waste acceptance criteria will be routed directly to it and suitable wastes stored in MAGS and SMAGS will be sent to the facility for disposal. SMAGS will then be focussed on storage of wastes not suitable for disposal in the proposed near-surface disposal facility.

The footprint in Waste Management Area H that SMAGS four through six would have occupied has been prepared as a compacted gravel hard-standing surface to accept containerized wastes for interim storage while the proposed near-surface disposal facility is planned to be constructed.

Figure 5.8: Modular above-ground storage structure in Waste Management Area H

5.1.7.1.9 Waste Management Area J

Construction of the new bulk material landfill located in CRL's Waste Management Area J was completed in 2010. The landfill is designed for the long-term management of the dewatered sewage sludge produced at the sewage treatment plant at CRL. The facility consists of an engineered landfill lined with impermeable layers of geotextile and semi-permeable layers of clay. The leachate from the waste is collected and sent for further processing following analysis. Once all phases (a total of four) are complete, the bulk material landfill will be able to accommodate 100 years of sewage sludge generated at CRL and will ensure proper long-term management of the waste in an environmentally responsible manner. Dewatered sewage sludge had been stored in roll-off containers in WMA C since 2004; the contents of these containers were safely emplaced into the bulk material landfill in late 2010.

5.1.7.1.10 Liquid dispersal area

Development of the liquid dispersal area commenced in 1953 when the first of several infiltration pits was established to receive active liquids via pipeline from the Nuclear Research Experimental rod bays. The pits are located on a small dune in an area bounded on the east and south by wetlands and by Waste Management Area A on the west.

Reactor Pit 1 was a natural closed depression used between 1953 and 1956 for radioactive aqueous solutions. Dispersals included an estimated 74 terabecquerels of strontium-90, along with a wide variety of other fission products and approximately 100 grams of plutonium (or other alpha emitters expressed as plutonium). Between 1956 and 1998, the pit was backfilled with solid materials that included contaminated equipment and vehicles previously stored in Waste Management Area A, plus potentially contaminated soils from excavations in the active area.

Reactor Pit 2 was established in 1956 to succeed Reactor Pit 1. A pipeline was used to transfer Nuclear Research Experimental rod bay water. Samples of water from the holding tank were analyzed for soluble and total alpha, soluble and total beta particles, strontium-90, tritium, cesium-137 and uranium.

A chemical pit was also established in 1956 to receive radioactive aqueous wastes from active laboratories on site (other than the reactors). Its construction is similar to that of Reactor Pit 2 – namely, an excavation backfilled with gravel and supplied by a pipeline.

A laundry pit, installed in 1956, is the last facility in the liquid dispersal area. As its name implies, the laundry pit was used for waste water from the active area laundry and the decontamination centre, but it was only employed for that purpose for a year. The recorded inventory is 100 gigabecquerels of mixed fission products.

The liquid dispersal area has not been used since 2000 and there are no plans for future use of this area. Two groundwater plumes emanate from the liquid dispersal area, as would be expected for dispersal facilities. One plume from the reactor pits contains tritium as the only nuclide released in significant quantities. Routine groundwater monitoring around the reactor pits shows that the tritium contamination levels have significantly decreased since dispersal operations were halted. This groundwater monitoring shows the presence of other radiological contaminants but at low concentrations that are declining over time.

The second plume emanates from the chemical pit, with the contaminant of primary concern being strontium-90. Routine groundwater monitoring around the chemical pit indicates improving conditions – in that the contamination levels in the groundwater are decreasing. The effects of this contaminant migration are mitigated by a plume treatment system known as the chemical pit treatment plant. This facility removes a significant fraction of strontium-90 from groundwater collected from four collection wells that are spaced across the width of the plume near the pit. In 2013, the chemical pit treatment plant treated 2,550 cubic metres of groundwater, removing 2.1 GBq of strontium-90 and reducing input concentrations from 743 Bq/litre (average) to 3.5 Bq/litre (average).

The current groundwater treatment facility has been operating for close to 20 years and is approaching the end of its design life. Given many recent developments, the strategy for this particular area is being revisited. With the proposed near-surface disposal facility planned to be available in 2020 and continued work on proposed land uses and interim soil cleanup levels, the future for this area could involve either early source removal or continued pump and treat. The current treatment methods will continue to be operated and maintained while the options are being further evaluated.

5.1.7.1.11 Acid, chemical and solvent pits

Three small pits are located north of Waste Management Area C and are collectively known as the acid, chemical and solvent pits. Constructed in 1982 and in operation until 1987, the pits were individually used for inactive acid, chemical and solvent wastes. The acid pit received about 11,000 litres of liquid wastes (hydrochloric, sulphuric and nitric acids) and a small amount of solid wastes (potassium carbonate powder, acid batteries and citric acid). The solvent pit received approximately 5,000 litres of mixed solvents, oils, Varsol and acetone, while the chemical pit received smaller volumes of wastes.

5.1.7.1.12 Waste tank farm

The waste tank farm contains seven underground stainless steel tanks that store intermediate-level liquid radioactive waste. The first series of three tanks contains ion exchange regeneration solutions from fuel rod storage bays. One of the three tanks is empty and provides a transfer destination for the contents of either of the other two tanks should they develop a leak.

The second series of four tanks contains acid concentrate, mainly resulting from fuel reprocessing between 1949 and 1956. The last transfer of solutions to any of the storage tanks at the waste tank farm occurred in 1968; no solutions have been added since then. One of the four tanks is empty and serves as a backup in the event that one of the other tanks leaks.

In 2012 the tank 40D leak avoidance project was launched to reduce the environmental risk of a leak in an aging storage structure. Tank 40D is a single-walled direct buried tank. The objective of the project was to protect the environment by removing the tank contents before any leakage occurs. By 2014, more than 80 percent of the liquid contents of this tank was retrieved and processed until all that was left was a fine silty sludge. Further reduction in volume with improved filtration is planned in 2017.

Further hazard reduction activities are underway, with decommissioning plans coordinated with realization of the near-surface disposal facility in 2020. By 2026, stored liquid wastes from this tank farm will have been removed and processed, the resulting waste product transferred to interim storage if not suitable for immediate disposal in the proposed near-surface disposal facility, and the tank farm facilities decommissioned.

5.1.7.1.13 Ammonium nitrate decomposition plant

The ammonium nitrate decomposition plant was built in 1953 and was used to decompose the ammonium nitrate in liquid wastes from the fuel processing plant. The plant was shut down in 1954 following several leak events (releases) and was subsequently dismantled, with much of the equipment being buried *in situ*.

As would be expected for this type of facility, a contaminant plume emanates from the nitrate plant compound, with the contaminant of primary concern being strontium-90. Routine groundwater monitoring at the perimeter of the compound indicates stable conditions in that contamination levels in the groundwater remain stable over time.

The effects of this contaminant migration are mitigated by a plume treatment system – known as the wall and curtain treatment system – that operates passively using a clinoptilolite zone installed in the ground next to an impermeable barrier that extends across the plume flow path. This passive treatment system removes a significant fraction of the strontium-90 activity in the influent. In 2013, the system prevented the discharge of 53.1 GBq of strontium-90 and reduced input concentrations from 2,590 Bq/litre (average) to less than 1 Bq/litre (average). Since 1998, the treatment system has prevented the discharge of 5.64×10^{11} Bq of strontium-90.

5.1.7.1.14 Thorium nitrate pit

In 1955, about 20 cubic metres of liquid waste from a uranium-233 extraction plant on the CRL site was discharged into a pit. The solution contained 200 kilograms of thorium nitrate, 4,600 kilograms of ammonium nitrate, 10 grams of uranium-233 and 1.85×10^{11} Bq each of strontium-90, cesium-137 and cerium-144. The pit was filled with lime to neutralize the acid and precipitate the thorium, and was then covered with soil.

5.1.7.1.15 Glass block experiments

In 1958, a set of 25 hemispheres of glass (weighing two kilograms each) of mixed fission products was buried below the water table as part of a program to investigate methods for converting high-level liquid radioactive solutions into a solid. A second set of 25 blocks of aged fission products was buried in 1960. The burials were designed to test how well the glassified wastes would retain the incorporated fission products if exposed to leaching in a natural groundwater environment. The glass blocks have since been recovered and transferred to secure storage in the waste management areas.

5.1.7.1.16 Bulk storage area

The bulk storage area was used prior to 1973 to store large pieces of equipment from the control area. Significant cleanup of this area was completed, resulting in reduction of future liability. The cleanup of the area was completed in November 2013.

5.1.7.1.17 Emissions

The operation of the CRL waste management areas results in the release of radioactive and non-radioactive contaminants into the environment. Most of the existing releases are historic. They resulted from discontinued practices such as dispersal of intermediate-level liquid waste and sand trench disposal of intermediate solid and liquid wastes. The releases contaminated onsite land, groundwater and surface water, and also resulted in offsite releases of contaminants to the Ottawa River.

The contaminant concentrations in offsite water bodies, however, are well below the standards set for both drinking water and the protection of aquatic life. DRLs have been established for airborne and liquid effluents released from the CRL site. In addition, CRL has developed administrative levels set at a fraction of the DRL and close to the normal operating levels. These levels are used to provide timely warning that a higher than expected release has occurred and that the situation will be investigated promptly.

5.1.7.1.18 Chalk River Laboratories Waste Treatment Centre

The CRL Waste Treatment Centre treats wet solid wastes and liquid wastes from CRL facilities that are contaminated or suspected of being contaminated by radioactivity. It also treats small volumes of liquid radioactive waste received by CRL from offsite waste generators.

The wet solid wastes are baled (after compacting, if possible) and transferred for storage in concrete bunkers in Waste Management Area B. Between 50 and 150 bales measuring 0.4 cubic metres are produced per year. In addition to those quantities, the Waste Treatment Centre generates solid waste internally. This waste includes disposable clothing, paper and cleaning materials, and is compacted (where possible), baled and stored in Waste Management Area B. Liquid waste is treated in variable amounts per year, ranging from 1,500 cubic metres to 4,000 cubic metres per year. These wastes consist primarily of liquid wastes from the decontamination centre, chemical active drain system and reactor active drain system. Smaller amounts of concentrated legacy stored liquid wastes originating from historical operations are pre-treated locally with ion exchange media to reduce radioactive content prior to final treatment in the Waste Treatment Centre. Treatment facilities include a liquid waste evaporator, which concentrates the waste, and a liquid waste immobilization system, which immobilizes the concentrated liquid in a bitumen matrix in drums that are then stored in Waste Management Area B.

Atmospheric releases of radionuclides from the Waste Treatment Centre occur via roof vents. Roof vents are monitored for particulate gross alpha activity, particulate gross beta activity, tritium oxide and iodine-131. Treated liquid effluent from the Waste Treatment Centre is discharged to the process outfall after sampling for gross alpha, gross beta and tritium oxide. The liquid effluent is also regularly monitored for suspended solids, total phosphorus, nitrates, power of hydrogen, conductivity, organic carbon, chemical oxygen demand, solvent extractable, metals, volatile organics and semi-volatiles.

5.1.7.1.19 Whiteshell Laboratories

Whiteshell Laboratories is a nuclear research and test establishment currently undergoing decommissioning in Manitoba, located on the east bank of the Winnipeg River about 100 kilometres northeast of Winnipeg. Comprising a number of nuclear and non-nuclear facilities and activities, the major facilities on site include the Whiteshell Reactor-1, the shielded facilities, research laboratories, and liquid and solid radioactive waste management areas and facilities, which include the concrete canister storage facility complex for the dry storage of spent research reactor fuel. Annex 7.1 provides further information on these decommissioning activities.

The one waste management area is located approximately 1.5 kilometres northeast of the main Whiteshell Laboratories site (2.7 kilometres by road). The area is approximately 148 metres by 312 metres, representing 4.6 hectares. The waste management area, which has been in operation since 1963, provides storage for L&ILW and includes the following facilities:

- incinerator for liquid organic waste
- LLW storage bunkers
- LLW unlined earth trenches
- LLW/ILW storage bunkers
- ILW in-ground concrete bunkers
- high-level radioactive waste (HLW)/ILW in-ground concrete standpipes (similar to the CRL tile holes described in section 5.1.7.1.2)
- liquid waste storage tanks

The concrete canister storage facility, described in annex 4.5.14, is located next to the waste management area.

Hydrologically, the waste management area is located in a groundwater discharge zone, which means that the groundwater flow is predominantly upward from the underground aquifer to the surface. The depth of excavations is limited to ensure the impermeable clay layers are not penetrated.

The incineration facility is used to incinerate waste laboratory solvents and was formerly used to incinerate the organic coolant waste arising from the operation, shutdown and cleanup of Whiteshell Reactor-1.

From 1963 to 1985, LLW was buried in unlined trenches approximately six metres wide by four metres deep, and with lengths up to 60 metres. Trenches were covered with at least 1.5 metres of excavated material after they were filled. There are 25 filled trenches located in the waste management area. Trench storage of LLW was discontinued in 1985 in favour of engineered above-ground LLW storage bunkers. The LLW bunkers are constructed of concrete, with overall dimensions of 26.4 metres long by 6.6 metres wide by 5.2 metres high, with a wall thickness of 0.3 metres, which comes to a total of 805 cubic metres of storage space each. A SMAGS structure has been constructed (discussed in section 5.1.7.1.8) for the storage of future LLW wastes from decommissioning.

In-ground or partially in-ground bunkers are used to store ILW wastes. Possessing a variety of dimensions, these bunkers are constructed of reinforced concrete, with a wall thickness of 0.25 metres. In-ground, concrete standpipes (similar to the CRL tile holes described in section 5.1.7.1.2) were used at Whiteshell Laboratories from 1963 to the mid-1970s (when the use of above-ground concrete canisters commenced) to provide storage for HLW/ILW packages. The standpipes are constructed of reinforced concrete, 0.2 metres thick, with a 0.3-metre integral base lined with galvanized steel pipes. A removable concrete shielding plug, about 0.9 metres thick, provides access.

5.1.8 EnergySolutions Canada Corporation

EnergySolutions Canada Corporation, formerly known as Monserco Limited, has been in operation since 1978 and manages the handling and processing of low-level radioactive material. At a 12,000 square metre (130,000 square feet) WMF located in Brampton, Ontario, EnergySolutions is contracted to collect LLW and slightly contaminated metals from nuclear power plants, hospitals, universities and research institutes. This waste consists mainly of personal protective equipment along with other waste arising from the decommissioning and dismantling of buildings or facilities where radioactive material has been handled or processed. Radioactive material can be sorted and repackaged at the Brampton WMF or directly shipped to other EnergySolutions facilities for processing via incineration or recycling (metal melt). The resultant ash is returned to EnergySolutions and then routed to the appropriate licensed Canadian WMF for long-term storage. Contaminated metal processed via metal melt is recycled within the nuclear industry, thereby eliminating long-term liability.

Activities and operations at the Brampton WMF includes:

- waste processing and transportation
- contaminated tooling/equipment inspection and decontamination
- monitoring and unconditional release
- storage
- radioactive sealed source servicing
- emergency response services

5.1.9 Cameco Blind River and Port Hope waste and by-product management

For both environmental and economic reasons, conserving resources and recycling of waste materials is an important part of operations. At the Canadian Mining and Energy Corporation (Cameco) Blind River Refinery (see figure 5.9), nitrogen oxide air emissions are recovered and converted to nitric acid for reuse. At the Port Hope Conversion Facility, ongoing recycling programs include in-plant recovery of hydrofluoric acid from air emissions for reuse as well as the creation and sale of an ammonium nitrate by-product for use as commercial fertilizer. At the Port Hope Fuel Manufacturing Facility, scrap fuel pellets are recovered and reprocessed.

Figure 5.9: Cameco Blind River Refinery

There are several process streams in the uranium refining, conversion and fuel manufacturing processes that result in materials that contain economically attractive quantities of natural uranium. These products are reprocessed at uranium mills to recover the uranium content.

The Blind River Refinery and Port Hope Conversion Facility waste management programs collect, clean and monitor all contaminated scrap for free release to commercial recycling agencies. Material that cannot be recycled or does not meet strict release criteria can be incinerated to ash or packaged for disposal at a licenced waste facility. The packaged non-recyclable material that cannot be cleaned is primarily insulation, sand, soil and some scrap metal.

The Government of Canada has agreed to accommodate 150,000 cubic metres of wastes from the Port Hope Conversion Facility arising from early operations of that site pre-dating Cameco's formation. These wastes include drummed radioactive wastes, contaminated soils and decommissioning wastes that are part of the Port Hope Area Initiative (see annex 8.2.1.1 for more details).

Annex 6 – Uranium Mine and Mill Facilities

6.1 Background

The first radium mine in Canada, owned by Eldorado Gold Mines (a private company), began operating in 1933 at Port Radium in the Northwest Territories. Uranium ore concentrate was sent to Port Hope, Ontario, where radium was extracted. At that time, uranium had little or no commercial value, so the focus was on the ore's radium-226 content. The Port Radium Mine produced ore for radium until 1940 and reopened in 1942 to supply the demand for uranium from defence programs in the United Kingdom and the United States.

In 1943, Canada, the United Kingdom and the United States instituted a ban on private exploration and development of mines to extract radioactive materials. The Government of Canada also nationalized Eldorado Gold Mines in 1943 and established the federal Crown corporation Eldorado Mining and Refining, which had a monopoly on all uranium prospecting and development. Canada subsequently lifted the ban on private exploration in 1948.

In 1949, Eldorado Mining and Refining began the development of a uranium mine in the Beaverlodge area of northern Saskatchewan and, in 1953, milling the ore onsite commenced. The Gunnar and Lorado uranium mines and mills began operating in the same area in 1955 and 1957, respectively. Several other small satellite mines also opened in the area in the 1950s, sending ore for processing to either Eldorado or the Lorado mills.

In Ontario, 15 uranium mines began production between 1955 and 1960 in the Elliot Lake and Bancroft areas. Ten of the production centres in the Elliot Lake area and three in the Bancroft area produced tailings. The last of these mines ceased operations and was decommissioned in the 1990s. (These former mining and milling sites are discussed in annex 8.)

At present, all active uranium mines are located in Saskatchewan. Uranium mining is ongoing at McArthur River and Cigar Lake; Rabbit Lake entered a prolonged period of care and maintenance, suspending mining and milling operations as of 2016. Uranium mills and operational tailings management facilities (TMFs) exist at McClean Lake, Rabbit Lake and Key Lake. Non-operational tailings management areas in Saskatchewan are located at Rabbit Lake, Key Lake, Cluff Lake, Beaverlodge, Gunnar and Lorado. See figure B.3 for the locations of operating and inactive uranium mining and milling sites in Canada.

6.2 Province of Saskatchewan

Saskatchewan is the only province in Canada with operating uranium mines. In the past, mine and mill operators have requested harmonization in areas such as inspections and reporting requirements, involving the Saskatchewan Ministry of Environment, the Saskatchewan Ministry of Labour Relations and Workplace Safety, and the Canadian Nuclear Safety Commission (CNSC). An agreement currently exists between the CNSC and the Government of Saskatchewan to encourage greater administrative efficiency in regulating the uranium industry. The agreement lays the groundwork for the two groups to coordinate and harmonize their respective regulatory regimes.

6.3 Operational tailings and waste rock management strategy

6.3.1 Overview

About one-quarter of the world's primary uranium production comes from uranium deposits in the Athabasca Basin in northern Saskatchewan. These deposits include:

- the current production sites of Cigar Lake and McClean Lake, as well as Key Lake and McArthur River
- the Rabbit Lake mine and mill, which announced an indefinite suspension of operations in April 2016 and is currently in a state of safe care and maintenance

The newer sites include the highest-grade uranium ore bodies in the world (at McArthur River and Cigar Lake), averaging about 20 percent uranium. Some of these ores in the Athabasca Basin have high nickel and arsenic content (up to five and one percent, respectively), which introduces additional considerations into the management of tailings and waste rock resulting from mining and milling these ores.

Past production centres, which are no longer actively producing uranium, include:

- the Uranium City district mines and mills of Gunnar, Lorado and Beaverlodge
- the decommissioned Cluff Lake site, where production was terminated at the end of 2002

6.3.2 Tailings management strategy

Mills with TMFs are located at Rabbit Lake, Key Lake and McClean Lake. There is no mill at the McArthur River mine because the ore is transported to Key Lake for processing. Similarly, the ore from Cigar Lake is transported to McClean Lake for processing.

All three sites currently use the same basic approach: previously mined open pits have been converted to engineered disposal systems for tailings. Although there are certain differences in detail, two basic principles underlie the containment of the tailings and their potential radionuclide and heavy metal contaminants:

- **Hydraulic containment during the operational phase** – As a result of dewatering during mining, the water level in the pit at the start of tailings placement is well below the natural groundwater level in the area. This dewatering creates a cone of depression in the groundwater system, resulting in the natural flow being directed toward the pit from every direction. This hydraulic containment feature is maintained throughout the operational life of the tailings facility by maintaining the pit in a partially dewatered state. Since water has to be pumped continuously from the pit, current water treatment technology results in high-quality effluent suitable for discharge to surface water.

- **Passive long-term containment using the hydraulic conductivity contrast between the tailings and their surrounding geologic materials** – Long-term environmental protection is achieved through control of the tailings' geochemical and geotechnical characteristics during tailings preparation and placement. This control creates future passive physical controls for groundwater movement in the system, which will exist after the decommissioning of operational facilities.

The tailings contain a significant fraction of fine-grained materials (e.g., chemical precipitates formed during the ore processing reactions). Tailings consolidation occurs during operation and will be completed during the initial decommissioning steps. The outcome is that the consolidated tailings have a very low hydraulic conductivity. When surrounded by a material with a much higher hydraulic conductivity, the natural groundwater path travels around the impermeable plug of tailings.

Potential contaminant transport from the tailings is controlled by diffusion from the outer surface of the tailings mass; this is a slow process, with minimal advective contaminant flux and a consequently high level of groundwater protection. Potential contaminant transport is further minimized by the geochemical properties of the tailings. Reagents are added during tailings preparation to precipitate dissolved elements such as radium, nickel and arsenic to stable insoluble forms, which enables long-term concentrations in the tailings' pore water to remain low.

A constructed permeable zone around the tailings may be installed (in the form of sand and gravel) while the tailings are placed, as is done at Rabbit Lake. Alternatively, the permeable zone may exist naturally, as is the case at McClean Lake and Key Lake. This natural permeable zone allows for subaqueous placement of tailings, which has advantages in terms of radiation protection and prevention of ice formation with the tailings mass. At McClean Lake, the sandstone formation surrounding the tailings has a hydraulic conductivity contrast of more than a factor of 100 relative to the tailings.

Extensive characterizations of the natural geologic formations and groundwater system, as well as the tailings' properties, are used to acquire reliable data for the computer models used to predict long-term environmental performance based on the fundamental principles governing the system. This performance will be confirmed during the life of the operation and through the post-decommissioning monitoring, which will be continued until stable conditions are achieved and for as long as desired thereafter.

Section 6.4 of this annex provides site-specific details for the Athabasca Basin tailings facilities. The development of these facilities began nearly 30 years ago, and their favourable operational experience and design evolutions – based on that experience – provide confidence in their performance both now and in the future.

6.3.3 Waste rock management strategy

In addition to tailings from the milling process, uranium production results in large volumes of waste rock being removed before miners can access and mine the ore. The segregation of these materials according to their future management requirements is now a core management strategy. Material excavated from open pits is classified into three main categories: clean waste (both overburden and waste rock), special waste (containing sub-economic mineralization) and ore.

6.3.3.1 Clean waste

This term refers to waste materials that are benign with respect to future environmental impact and that can be disposed in surface stockpiles or used onsite for construction purposes. These different types of materials are described below:

- **Surficial soils with high organic content** – When practical depths are present, a thin layer of surface soil is stripped and separately stockpiled for replacement as the future surface soil layer during site-reclamation activities.
- **Overburden soils** – A few metres of glacial till (typically around 10 metres) are present before the underlying sandstone rock is encountered. This material is either stockpiled separately for future use as fill during reclamation or used as the base for clean waste rock stockpiles.
- **Waste rock** – The Athabasca Basin is a sandstone basin that overlies the Precambrian Shield basement rock. The sandstone depth is shallow around its perimeter but increases to as much as 1,200 metres toward the centre of the Basin. Depths up to about 200 metres are practical for open-pit mining. The sites at and near the Basin's perimeter primarily feature this mining method.
- **Large volumes (depending on the depth) of unmineralized sandstone –** This material is mined to reach the ore body and is stockpiled on the surface near the pit. The stockpiles, minus whatever amount has been used for construction purposes, are subsequently reclaimed and vegetated.

6.3.3.2 Waste segregation

As mining approaches the ore body, a zone of altered (partially mineralized) rock is present. Both this halo of altered rock and the basement rock below it may contain small amounts of uneconomic uranium or various metals such as nickel or arsenic.

In some instances, because it contains sulphide, there is the potential for acidic leachate when the rock is exposed to moisture and oxygen from the atmosphere. This phenomenon of acid rock drainage is common to many types of mining. Sophisticated methods are now available to segregate those amounts of waste rock that represent a potential environmental risk – due to either acid rock drainage or dissolved contaminants in leachate – if left on the surface for the long term.

This material (referred to as special waste) is managed differently from the environmentally benign waste rock. The segregation methods include borehole logging, collection and analyses of borehole samples prior to mining, and analyses of samples during mining. In addition to a retrospective laboratory analysis, qualified geological interpretation of the mining faces reinforced with real-time analyses made with an ore radiometric scanner are used to segregate each truckload – according to uranium content – as ore, special waste or waste rock and direct it to the appropriate stockpile.

Because uranium ore deposits are in secular equilibrium with their progeny, good correlations can be made between radioactivity of the ore and its uranium content. The latest technical development is the application of a handheld, portable scanner that uses X-ray fluorescence to perform field characterization for arsenic. This method has recently been tested at McClean Lake and has since been incorporated into the mine site's overall waste rock management strategy.

Volumes of waste rock are much smaller for underground mining but the same general considerations apply. Clean waste materials are stockpiled and used for construction or reclamation purposes. Any surplus amounts can be stockpiled, and the stockpiles reclaimed and vegetated. Special waste is either used as aggregate and underground backfill, or is returned underground to other mined areas or transferred to sites with mills or mined-out open pits.

6.3.3.3 Special waste

As noted above, waste rock near ore bodies is potentially problematic. Because it has some halo mineralization around the ore deposit, it potentially generates acid in some instances or becomes a source of contaminated leachates when exposed to an atmosphere containing oxygen. Disposal of this special waste in mined-out pits and flooding to cut off the oxygen supply from the atmosphere and stop oxidation reactions is now a widely recognized solution, provided that the pit is suitable for the long-term management of the risk. If not, engineered covers present an *in situ* solution to impede the interaction of oxygen and moisture with the special waste. As it is mined, the special waste is segregated and temporarily stored on the surface on lined pads, with drainage collection systems for collection and treatment of runoff water. After mining activities have ended, the special waste is backhauled into the mined-out pit (see figure 6.4). At a large pit with two or more zones, the direct transfer of special waste from the mining zone to a mined-out zone is practical. Typically, any waste material with uranium content greater than approximately 300 parts per million triuranium octoxide (U_3O_8) or 0.025 percent (250 parts per million) uranium is classed as special waste.

Similar to tailings facilities, extensive characterizations of natural geologic formations, groundwater system and waste rock properties are used to acquire reliable data for the computer models used to predict long-term performance. This performance is confirmed by post-decommissioning monitoring, which is continued until stable conditions are achieved and for as long as desired thereafter.

6.3.3.4 Ore

The cut-off grade that defines the threshold between ore to be processed through the mill and mineralized waste will vary depending on market conditions for uranium. Typically, cut-off grades are on the order of 0.1 percent for the Saskatchewan mines.

6.3.4 Waste water treatment and effluent discharge

All mine and mill facilities provide water treatment systems to manage contaminated water collected from their tailings disposal facilities as well as water inflows collected during open-pit or underground mining and seepages from waste rock piles. The treatment processes vary from flow-through to batch discharge systems and largely rely on conventional physical settling and chemical precipitation methods found in the general metal mining industry. Typically, these sites have a single point of final discharge into the receiving environment; however, the Key Lake operation has two treated water discharge points. Uranium mines and mills also treat for radionuclides. Specifically, focus is placed on treatment for radium-226, using barium chloride precipitation. In the case of Rabbit Lake, additional treatment has been incorporated to reduce uranium levels in effluent discharge. The quality of effluent is controlled by regulatory approved codes of practice, as well as by effluent quality regulation.

In northern Saskatchewan, effluent quality regulation ensures that the Saskatchewan Environmental Quality Guidelines are maintained in the receiving environment downstream of the operations. If the effluent is found acceptable (i.e., in compliance with regulatory limits), it is released to the environment. Otherwise, the effluent is recycled to the water treatment plants or mill for reprocessing. In 2016, the total volume of treated waste water that met regulatory requirements and was subsequently discharged to the receiving environment was 14.643 million cubic metres from five active uranium mining and/or milling sites in northern Saskatchewan (refer to table 6.1).

Table 6.1: Active uranium mining/milling site waste water volumes

Active uranium mining and/or milling site in northern Saskatchewan	Total volume of waste water that met discharge requirements
AREVA Resources Canada Inc. – McClean Lake	2,023,673 m^3
Canadian Mining and Energy Corporation (Cameco) – Rabbit Lake	4,494,755 m^3
Cameco – Cigar Lake	396,806 m^3
Cameco – McArthur River	2,483,864 m^3
Cameco – Key Lake (Horsefly Lake)	4,473,675 m^3
Cameco – Key Lake (Wolf Lake)	770,189 m^3
Total	**14,642,962 m^3**

To reduce the impact of effluent discharges to the receiving environment, the uranium mining and milling facilities have developed ecological risk models to evaluate the impacts of treated effluent discharges. The prime concerns resulting from this work are chronic, not acute, and relate to control of metals, not radionuclides. The control of nickel and arsenic loading has been a core focus; however, more recently attention has turned to molybdenum and selenium loadings. This broader spectrum of contaminants of concern has led to efforts to develop and install the next generation of treatment technology based on the use of membrane and chemical precipitation technologies.

6.4 Waste management facilities

6.4.1 Key Lake

6.4.1.1 Tailings management

The purpose of tailings management at Key Lake is to isolate and store the waste residue from the milling process so that the public and the environment are protected from any future impact. Conceptually, this effort involves containing the solids and treating the water to quality standards acceptable for release to the environment. The waste metal precipitates removed during water treatment are disposed of as solids in the TMF.

From 1983 to 1996, waste from the Key Lake mill was deposited in an above-ground TMF that covered an area 600 metres by 600 metres (36 hectares) and 15 metres deep. The TMF was constructed five metres above the groundwater table using engineered dikes for perimeter containment and a modified bentonite liner to seal the bottom and isolate the tailings from the surrounding soil infrastructure.

Since 1996, the mined-out Deilmann open pit has been used as the TMF. Commissioned in January 1996, it is used to store tailings produced by milling a blend of McArthur River ore and special waste from McArthur River and Key Lake. The TMF has a bottom drainage layer constructed on top of the basement rock at the bottom of the mined-out pit. Tailings are deposited on top of this drainage layer and water is continually pumped out to promote solids consolidation of overlying tailings.

Tailings were initially deposited into the pit by sub-aerial deposition, with the water being extracted from the tailings mass through the bottom drain layer and the raise well pumping system. The facility was later changed to subaqueous deposition by allowing the pit to partially flood.

Tailings are deposited under the water cover using a tremie pipe system, providing benefits in terms of placement and attenuation of radon emissions. In this system, tailings are placed in the mined-out pit using what is termed "a natural surround" containment strategy. Tailings and residual water on the surface are removed during tailings placement both by the drainage blanket and by surrounding groundwater wells. The residual water extracted from the tailings mass is collected for treatment. The consolidated tailings form a low-permeability mass relative to the higher-permeability area surrounding the tailings.

After decommissioning, groundwater will follow the path of least resistance (i.e., around the tailings rather than through them), which minimizes environmental impacts. At the end of 2016, the Deilmann TMF (see figure 6.1) contained 5.98 million tonnes (dry weight) of tailings.

Figure 6.1: Deilmann tailings management facility at Key Lake

6.4.1.2 Waste rock management

Waste rock management facilities include two special waste storage facilities and three waste rock storage areas. The waste rock disposal areas comprise primarily benign rock and, therefore, do not have containment or seepage collection systems. The special waste contains low (uneconomic) levels of uranium and other potential contaminants, so this material is contained in engineered facilities that consist of underliners and seepage collection systems. Material from the special waste areas is being reclaimed for blending with high-grade McArthur River ore for the Key Lake mill feed. All other waste rock areas are inactive.

To reduce the decommissioning liability associated with the Deilmann North waste rock pile, approximately 1.3 million cubic metres of nickel-rich waste rock were excavated and disposed of in the Gaertner pit.

6.4.1.3 Contaminated industrial wastes

Contaminated industrial wastes are either recycled or landfilled in the above-ground TMF. Leachates from these materials are collected by the above-ground TMF's seepage collection system and returned to the mill for process make-up water or treated and released to the environment. It is estimated that 6,350 cubic metres of uncompacted waste were placed at this site in 2016.

6.4.2 Rabbit Lake

6.4.2.1 Tailings management

The Rabbit Lake above-ground TMF is about 53 hectares in area and contains approximately 6.5 million tonnes of tailings, which were deposited between 1975 and 1985. These tailings were all derived from the processing of the original Rabbit Lake ore deposit. The tailings within the above-ground TMF are confined by earth-filled dams at the north and south ends, and by natural bedrock ridges along the east and west sides. The above-ground TMF is currently undergoing long-term stabilization and progressive reclamation.

The original Rabbit Lake open-pit mine was converted to a TMF in 1986 using pervious surround technology. Since its commissioning, the Rabbit Lake in-pit TMF has been used as a tailings repository for ore from the Rabbit Lake, B-zone, D-zone, A-zone and Eagle Point mines (see figures 6.2(a) and 6.2(b)). At the end of 2016, the Rabbit Lake in-pit TMF contained 9.13 million tonnes (dry weight) of tailings.

The pervious surround, consisting of sand and crushed rock, is placed on the pit floor and walls in advance of the tailings deposition. The pervious material allows drainage of the excess water contained in the tailings to an internal seepage collection system and also allows the water contained in the surrounding host rock to be collected, which maintains a hydraulic gradient toward the facility during operations. The collected water is treated prior to its release into the environment. Upon final decommissioning and return to normal hydrogeologic conditions, groundwater will flow preferentially through the pervious surround rather than through the low permeability tailings. Discharge of contaminants will be limited to diffusion across the tailings/pervious surround interface.

Figure 6.2(a): Rabbit Lake in-pit tailings management facility

Figure 6.2(b): Rabbit Lake in-pit tailings management facility

6.4.2.2 Waste rock management

The Rabbit Lake site contains a number of clean and mineralized stockpiles of waste rock produced over the course of mining various local deposits since 1974. Some of the waste rock has been used for construction material. For example, waste rock was used to construct the road and pervious surround for the Rabbit Lake in-pit TMF. Eagle Point special waste is stockpiled on a lined storage pad until it is returned underground as backfill. Some waste rock piles were used as backfill and cover material in their respective pits. One rock pile, consisting primarily of Rabbit Lake sediments, has been contoured and vegetated.

Current projections are that no waste rock will remain on the surface at Eagle Point after the mining and backfilling of mined-out stopes is complete. The A-zone (28,307 cubic metres of clean waste) and D-zone (200,000 cubic metres of primarily lake-bottom sediments) waste rock piles have been flattened, contoured and vegetated. The B-zone waste pile contains an estimated 5.6 million cubic metres of waste material stored on a pile covering an area of 25 hectares. The B-zone pile was contoured and reclaimed through installation of an engineered cover followed by a one-metre till cover complete with vegetation and drainage channels to promote controlled runoff. All the special waste from the A-zone (69,749 cubic metres), B-zone (100,000 cubic metres) and D-zone (131,000 cubic metres) open-pit mines was returned to the pits and covered with layers of waste rock and/or clean till before the mined-out pits were allowed to flood.

There are approximately 6.89 million cubic metres of predominantly sandstone waste rock, with some basement rock and overburden tills, stored on the West 5 waste rock pile adjacent to the Rabbit Lake in-pit TMF. Mineralized waste is stored on four piles (630,000 cubic metres) adjacent to the Rabbit Lake mill. Runoff and seepage from these areas are collected in the Rabbit Lake in-pit TMF.

6.4.2.3 Contaminated industrial wastes

Radioactive and other contaminated materials from the Eagle Point mine and Rabbit Lake mill are disposed of in the contaminated landfill site located on the west side of the Rabbit Lake above-ground TMF. It is estimated that 3,970 cubic metres of uncompacted waste were placed at this site in 2016.

6.4.3 McClean Lake

6.4.3.1 Tailings management

McClean Lake has been the only uranium mill to be constructed in North America over the last 17 years. The mill and TMF are state-of-the-art efforts in worker and environmental protection for processing high-grade uranium ore. Open-pit mining of the initial ore body (the John Everett Bates pit) began in 1995. After the ore was removed and stockpiled, the pit was developed as a TMF (see figures 6.3(a) and 6.3(b)). The design of the TMF has been optimized for performance, both during operation and for the long term, by employing key features such as:

- production of thickened tailings within the mill process (addition of lime, barium chloride and ferric sulphate) to remove potential environmental contaminants from the solution and yield geotechnically and geochemically stable tailings
- transport of the tailings from the mill to the TMF through a continuously monitored pipe-in-pipe containment system
- final subaqueous tailings placement within the mined-out John Everett Bates pit for long-term, secure containment in a below-ground facility
- use of natural surround as the optimum approach for long-term groundwater diversion around the consolidated tailings plug
- subaqueous tremie placement, from a floating barge, of the thickened tailings below a water cover in the pit – a method that minimizes segregation of fine and coarse material, prevents the freezing of the tailings and enhances radiation protection due to the attenuation of radon emissions by the water cover
- use of dewatering wells around the entire pit perimeter to minimize clean groundwater inflow while maintaining hydraulic containment during operations (i.e., the water levels are maintained such that groundwater flow is toward the pit)
- a bottom filter drain feeding a dewatering drift and raise wells to allow collection and treatment of discharged pore water during tailings consolidation
- recycling of pit water by a floating barge and a pipe-in-pipe handling system
- complete backfilling of the pit upon decommissioning with clean waste rock and a till cap

At the end of 2016, the John Everett Bates TMF contained 1.953 million tonnes (dry weight) of tailings.

Figure 6.3(a): McClean Lake operation with John Everett Bates tailings management facility located to the left of the mill

Figure 6.3(b): John Everett Bates tailings management facility at McClean Lake

6.4.3.2 Waste rock management

Open-pit mining at McClean Lake has progressed from one pit to the next, and has included the John Everett Bates, Sue A, Sue B, Sue C and Sue E pits (see figures 6.4(a) and 6.4(b)). Mining was completed at the most recent open pit, Sue B, on November 26, 2008. Open-pit mining has not occurred at McClean Lake since the completion of Sue B.

The majority of the wastes removed from the John Everett Bates and Sue C open pits were overburden material or sandstone. The overburden and clean waste rock stockpiles are located near the pits. The pad for the waste rock stockpile has been constructed using overburden. Special waste from the Sue C and John Everett Bates pits was stockpiled during mining and was subsequently backhauled into the Sue C pit upon completion of mining.

Figure 6.4(a): Sue mining area at McClean Lake

Figure 6.4(b): Sue E pit at McClean Lake

All wastes (exclusive of the overburden) from the Sue A pit were also deposited into the mined-out Sue C pit. This approach was conservative due to the uncertainty regarding segregating special waste based on its arsenic content. Waste rock is segregated into clean and special waste based on acid-generating potential (using a simple laboratory test), radiological content (using the ore scanner) and a key non-radiological contaminant (arsenic, using an X-ray fluorescence scanner that was successfully tested during Sue A mining and subsequently implemented into segregation procedures). Special waste from Sue E was also placed in the mined-out Sue C pit, while clean waste was placed in a separate Sue E waste rock stockpile.

All material removed from the Sue B pit was classified as special waste and placed in the mined-out Sue E pit below an elevation of 400 metres above sea level. The total waste rock inventory at McClean Lake at the end of 2013 was 51.7 million tonnes of clean material (primarily waste rock) and 10.2 million tonnes of mineralized waste rock (special waste).

6.4.3.3 Contaminated industrial wastes

Chemically or radiologically contaminated waste materials originate from the mining, milling and water treatment areas of the McClean Lake operation. All the contaminated material is collected in yellow dumpsters that are distributed around the site and then deposited in the landfill for chemically and radiologically contaminated materials at the perimeter of the TMF. This landfill is within the hydraulic containment area of the John Everett Bates TMF. During final site decommissioning, these materials will be excavated and deposited in the John Everett Bates TMF. The existing contaminated waste temporary landfill was expanded in September 2008. This extension encompassed an area of approximately 2,089 cubic metres. The area averaged three metres in depth, providing an additional 6,267 cubic metres of storage space. From the end of 2013 to the end of 2016, approximately 1,965 cubic metres of waste was placed in the landfill.

6.4.4 Cigar Lake

6.4.4.1 Tailings management

Cigar Lake does not have a mill and does not produce tailings. Cigar Lake ore is processed at the McClean Lake mill.

6.4.4.2 Waste rock management

There are five waste rock storage pads in operation at Cigar Lake. The current inventories result from test mining and mine construction activities conducted at the site. The waste rock is classified as either clean waste rock, potentially acid-generating waste rock or mineralized waste rock. Potentially acid-generating and mineralized waste rock is temporarily stored on engineered lined containment storage pads. Leachate from these pads is contained and collected for treatment in the mine water treatment plant. When possible, clean or benign waste rock is used as fill or construction material onsite. While some potentially acid-reactive waste rock may be used as backfill in the mine, the majority of this material is expected to be eventually transported to the McClean Lake mine site for disposal in a mined-out pit.

6.4.4.3 Contaminated industrial wastes

Contaminated industrial wastes are stored on stockpile B, which is one of the stockpiles used to store potentially acid reactive waste rock (described in section 6.4.4.2) at Cigar Lake and other approved storage areas. These materials will ultimately be disposed of underground during backfilling of exhausted mine chambers and drifts. It is estimated that 207 cubic metres of uncompacted waste was placed at these locations in 2016.

6.4.5 McArthur River

6.4.5.1 Tailings management

McArthur River does not have a mill and does not produce tailings.

6.4.5.2 Waste rock management

The McArthur River operation generates waste rock from production mining, development mining and exploration drilling. The waste rock is classified as either clean waste rock, potentially acid-generating waste rock or mineralized waste rock. The potentially acid-generating and mineralized waste rock is temporarily stored on engineered lined containment storage pads. Leachate from these pads is contained and pumped to effluent treatment facilities. The segregated clean waste rock is disposed of on a pile that does not include the leachate containment and control systems.

The mineralized waste rock is shipped to the Key Lake operation and used as blend material for the ore feed to the Key Lake mill. The potentially acid-generating waste is crushed and screened, and the coarse material is used as aggregate for underground concrete backfilling operations. The clean waste is used for general road maintenance both onsite and on the haul road between McArthur River and Key Lake.

6.4.5.3 Contaminated industrial wastes

A transfer area, located adjacent to the mine headframe, is used to sort and temporarily store contaminated material. The contaminated material is shipped to the Key Lake operation, where it is disposed of in the above-ground TMF.

Annex 7 – Decommissioning Activities

7.1 Atomic Energy of Canada Limited Whiteshell Laboratories

7.1.1 Background

Whiteshell Laboratories is a nuclear research and test establishment that was developed in the early 1960s by Atomic Energy of Canada Limited (AECL) to investigate higher temperature versions of its CANDU reactor design. In the late 1990s, AECL decided to discontinue research programs and operations at the facility, and planning for its closure and decommissioning began. The site is still owned by AECL but is now operated by Canadian Nuclear Laboratories (CNL) under a government-owned, contractor-operated (GoCo) arrangement.

Whiteshell Laboratories is located in Manitoba (see figure 7.1) on the east bank of the Winnipeg River about 100 kilometres northeast of Winnipeg, 10 kilometres west of Pinawa and nine kilometres upstream from Lac du Bonnet. The major structures located on the site include Whiteshell Reactor-1, the main research building (building B300), other research and supporting buildings, and a radioactive waste management area that contains the concrete canister storage facility for the dry storage of irradiated nuclear fuel.

Whiteshell Laboratories is currently licensed under a nuclear research and test establishment licence to decommission that was issued in 2002, renewed in 2008 and amended in 2016. In 2014, the licence was transferred to assign CNL as the licensee. The current licence is valid until December 31, 2018.

During the initial six-year period of the licence to decommission (2002–08), the decommissioning activities focused on the shutdown and decontamination of nuclear and radioisotope laboratory buildings and facilities. Also during this period, two nuclear facilities (the Van de Graaff Accelerator and the Neutron Generator) were completely decommissioned.

Major activities completed since the fifth national report include:

- ongoing asbestos abatement in the above-grade portions of the Whiteshell Reactor-1 reactor building (B100)
- Whiteshell Reactor-1 waste from the first stage of the reactor's decommissioning in the 1990s that was previously packaged in wooden crates and stored in the waste management area has been sorted and repackaged into B25 containers; as part of this process:
    - uncontaminated materials such as wood and asbestos were separated into other wastes streams
    - stages 4 and 7 of the B300 research and development facility were demolished, including remediation of the crawlspace soils
- building B505 (the original central heating plant for the site) was demolished; as part of this process:
    - a legacy fuel spill was discovered following the demolition of the concrete pad, which required extensive remediation of the hydrocarbon contaminated soils
    - operational shutdown and cleanout of the B411 decontamination centre was conducted to allow for upcoming demolition of the structure.
- five other storage buildings were demolished

Since the fifth national report, CNL has been continuing to decommission the Whiteshell Laboratories. Thecurrent licence to decommission expires December 2018.

For the next licence period, CNL is proposing to move up site closure to 2024 and decommission the Whiteshell Reactor-1 using *in situ* decommissioning, which is a different approach to what is currently authorized under the licence. Licence renewal hearings are expected to proceed in the fall of 2018 to consider CNL’s plans.

For the wastes that are currently onsite, CNL is planning to:

- transport certain low-level radioactive waste (LLW) and other suitable wastes from Whiteshell to Chalk River Laboratories (CRL) for disposal in the proposed near-surface disposal facility
- transport intermediate-level radioactive waste to CRL for storage
- transport high-level radioactive waste (spent fuel) to CRL for interim storage until disposal facilities become available
- dispose *in-situ* most of the LLW that resides in unlined soil trenches in the waste management area

In-situ decommissioning is being proposed by CNL for Whiteshell Reactor-1. This entails removing the above-grade structure and grouting the below-grade components using a concrete based grout. The structure would then be capped with concrete and covered with an engineered barrier. *In-situ* decommissioning is intended to isolate the reactor vault and contaminated systems and components inside the below-grade structure. Although not used widely, this approach has been used at other sites internationally. The technique is intended to minimize radiological exposure to workers, reduce the need for handling and transportation and minimize risk to workers and the environment.

Figure 7.1: Aerial view of Whiteshell Laboratories main site (2010)

7.1.2 Underground Research Laboratory

The Underground Research Laboratory, located approximately 15 kilometres northeast of Whiteshell Laboratories in Manitoba, was an underground experimental facility used for research into controlled blasting techniques, rock mechanics and hydrological studies associated with potential deep underground disposal of spent fuel and the behaviour of various materials under the conditions of storage in deep-rock formations. No spent fuel or HLW were ever placed in the Underground Research Laboratory.

Two underground radioisotope laboratories (using low levels of tracer isotopes) were licensed by the Canadian Nuclear Safety Commission (CNSC) under its *Nuclear Substances and Radiation Devices Regulations*. These laboratories were closed and decontaminated several years ago. CNSC staff confirmed this during an inspection conducted prior to the revocation of the site’s licence to operate in 2003. The Underground Research Laboratory site was closed in 2015 after selected boreholes, ventilation raises and the main shaft were sealed, and an environmental and post-closure borehole hydraulic and geochemical monitoring program was conducted over a three-year period.

This also included the removal of the 22 post-closure boreholes, contaminated soil and the Underground Research Laboratory’s surface facilities. AECL returned the leased lands to the Province of Manitoba on March 31, 2016.

7.2 Gentilly-1 Waste Management Facility

The Gentilly-1 Waste Management Facility consists of a permanently shut-down, partially decommissioned prototype reactor and associated structures and ancillaries. This facility is presently in the long-term storage-with-surveillance phase of a deferred decommissioning program. Located on the south bank of the St. Lawrence River about 15 kilometres east of Trois-Rivières, Quebec, the Gentilly complex accommodates both the Gentilly-1 Waste Management Facility and the Gentilly-2 nuclear power plant, a CANDU 600-megawatt unit, which shut down in 2012.

The Gentilly-1 Nuclear Generating Station consists of a CANDU BLW-250 reactor that was put into service in May 1972. It attained full power for two short periods in 1972 and operated intermittently for a total of 183 effective full-power days until 1978, when it was determined that certain modifications and considerable repairs would be required. The station was put into a layup state in 1980 and the decision to not rehabilitate the station was made in 1982.

The main components of Gentilly-1 were the reactor core, heat transport system, turbines and shielding. The reactor was heavy-water moderated, cooled by light water and fuelled with natural uranium in the form of zircaloy-clad uranium dioxide pellets. The reactor vessel was a vertical cylinder that contained a heavy-water moderator and was traversed by 308 pressure tubes and surrounding calandria tubes. The heat produced by the reactor fuel (mostly by boiling) was removed by the light-water coolant and then pumped through inlet and outlet headers and feeder pipes in a closed circuit. The steam generated by the reactor core was separated from the liquid coolant in the steam drum before being delivered to the turbine generator.

The decision to permanently shut down the reactor was made in 1984. A two-year decommissioning program began in April of that year to bring Gentilly-1 to an interim safe and sustainable shutdown state that is equivalent to storage with surveillance. The moderator (heavy water) was drained and shipped to other operating sites. Non-radioactive hazardous materials, such as combustible and flammable materials, laboratory supplies and oils, were identified and removed. The transfer of spent fuel from wet storage in the reactor pool to dry storage in the purpose-built canister storage area was completed in 1986. Major and minor decontamination activities (disassembly, decontamination and consolidation) were completed as required. All major radioactive or radioactively contaminated components not shipped to other licensed facilities were consolidated onsite in either the reactor building or turbine building. Areas that possess significant residual contamination or radioactive materials have been reduced to a few locations. Radiological surveys were performed at the completion of each decommissioning activity.

A three-phase approach has been established for reactor decommissioning. Phase 1 brought the facility to a safe, sustainable shutdown state. Phase 2 is a period greater than 30 years of storage with surveillance. Final decommissioning, approximately 10 years, occurs in phase 3. The Gentilly-1 Waste Management Facility is currently in phase 2.

7.3 Douglas Point Waste Management Facility

The Douglas Point Waste Management Facility is located at the site of the former Douglas Point Nuclear Generating Station situated on the Bruce nuclear site. The station, which consists of a 200-megawatt CANDU reactor, was put into service in 1968. It was owned by AECL and operated by Ontario Hydro (now Ontario Power Generation [OPG]) until 1984. During this operational period, the station generated 17 x 10^9 kilowatt hours of electricity and attained a capacity of 87.3 percent.

The main components of the Douglas Point were the reactor, heat transport system, turbines and power-generating equipment. The reactor was heavy-water moderated, cooled by pressurized heavy water and fuelled with natural uranium. The reactor core contained 306 horizontal fuel-containing pressure tubes and was surrounded by the heavy-water moderator. The heat transport system pumps circulated the pressurized heavy water through the reactor coolant tubes to eight boilers, where the heat was transferred to the boiler steam and water system. The reactor primarily used heavy concrete, steel and water as shielding to protect the surrounding area from radiation during operation. Steam generated in the boilers was transferred to the turbine for power generation.

Douglas Point was permanently shut down on May 5, 1984 and placed in an interim safe and sustainable shutdown state. This interim state is referred to as the storage-with-surveillance state. The Douglas Point Nuclear Generating Station then became the Douglas Point Waste Management Facility.

Following the shutdown of the reactor, the primary heat transport and moderator medium (heavy water) was drained and shipped to other operating sites. The booster rods were removed and shipped to CRL for storage in February 1985. Non-radioactive hazardous materials, such as combustible and flammable materials, laboratory supplies and oils, were identified and removed. The transfer of spent fuel from wet storage in the reactor pool to a dedicated dry storage facility was completed in 1987. Major and minor decontamination activities (disassembly, decontamination and consolidation) were completed as required. All major radioactive or radioactively contaminated components that were not shipped to other facilities licensed to receive them were consolidated onsite. Areas that possessed significant residual contamination or radioactive materials were reduced to a few locations. Radiological surveys were performed at the completion of each decommissioning activity.

A three-phase approach has been established for reactor decommissioning. Phase 1 brought the facility to a safe, sustainable shutdown state. Phase 2 is a period of storage with surveillance lasting between 50 and 60 years. Final decommissioning, approximately 10 years, occurs in phase 3. The Douglas Point Waste Management Facility is currently in phase 2.

The Douglas Point Waste Management Facility is presently in the storage with surveillance phase of a deferred decommissioning program. For decommissioning purposes, the facility is divided into three planning envelopes. Envelope A consists primarily of nominally uncontaminated buildings and structures (which may be decommissioned at any time) with health, safety and environmental concerns taken into account. Envelope B consists primarily of contaminated buildings, which will be decommissioned after allowing for a period of radioactive decay and after long-term waste management facilities become available. Envelope C includes the spent fuel canister area. CNL plans to diminish the non-nuclear footprint over the next five years to reduce care and maintenance costs.

7.4 Nuclear Power Demonstration site

The Nuclear Power Demonstration site is located in Renfrew Country in Ontario, adjacent to the west bank of the Ottawa River approximately three kilometres downstream of the Des Joachims Dam and Generating Station, 25 kilometres upstream from CRL and 15 kilometres from the Town of Deep River. The nuclear generating station was placed in service in October 1962 and operated by Ontario Hydro (now OPG) until May 1987.

In 1988, operating and compliance responsibilities were transferred from Ontario Hydro to AECL. The nuclear generating station was placed into an interim safe and sustainable shutdown phase. This interim storage period is referred to as the storage-with-surveillance phase, under the deferred decommissioning strategy (with an eventful full dismantlement of the facility and unrestricted release of the land). Following the shutdown of the reactor, the heavy water from the primary heat transport and moderator systems were drained and shipped offsite. The reactor was defueled and the fuel bundles were transferred to CRL for storage. Demineralizer system equipment was removed from the various nuclear process systems and transferred to CRL. Major and minor decontamination activities were completed as required. The facility was functionally divided into nuclear and non-nuclear areas, with any equipment or structures either radioactive or radioactively contaminated confined to the nuclear area. All cross-connections between the two areas were blocked off, sealed or permanently locked.

The Nuclear Power Demonstration site consists of a limited number of structures, including:

- the main building (reactor building/powerhouse) storing the partially decommissioned 20-megawatt electrical prototype CANDU reactor and its associated underground services and structures
- the ventilation stack
- the diesel-generator enclosure
- two sea containers
- the pressure relief duct
- foundations from previously removed pumps house, emergency vehicle garage, training centre, construction camps, warehouses, dousing tank, transformer and administration wing
- two onsite landfills, which are currently closed

The site is currently licensed as a waste facility and is still owned by AECL; however, it is operated by CNL. Since the transition to GoCo model in 2015, CNL is pursuing an accelerated decommissioning approach for the Nuclear Power Demonstration site.

CNL is now proposing *in-situ* decommissioning for the Nuclear Power Demonstration site. This approach is also known as "entombment," which designates an immobilization approach where all or part of the nuclear facility is encased in a structurally long-lived material. Although not used widely, this approach has been used at other sites internationally. The technique is intended to minimize radiological exposure to workers, reduce the need for handling and transportation and minimize risk to workers and the environment.

The proposed *in-situ* decommissioning activities include:

- assembling and operating the grout batch mixing plant
- removing the above-ground structure and placing contaminated materials into the below-grade structure
- using grout to seal the below-grade structure, reactor vessel and all of the systems, components and contaminated materials
- installing a concrete cap and engineering barrier over the grouted area
- conducting final restoration of the rest of the site
- preparing for long-term care and maintenance activities

Starting in 2016, as part of an environmental assessment process under the *Canadian Environmental Assessment Act, 2012*, CNL has begun preparing an environmental impact statement for submission to the CNSC for consideration. In conjunction with the required environmental assessment process, CNL will also be requesting a licensing amendment from the CNSC to perform the proposed decommissioning activities.

Should this project be authorized by the CNSC, decommissioning the Nuclear Power Demonstration site will take approximately two years. After site-restoration activities have been completed, the site will enter a period of long-term surveillance under a monitoring program for a period of time established through a safety analysis process.

CNL has not yet submitted its licensing application or safety case in support of *in-situ* decommissioning for regulatory review. A licensing hearing to consider this proposal is expected to occur later in 2018.

7.5 Chalk River Laboratories decommissioning activities

The CRL site is located in Renfrew County, Ontario, on the shore of the Ottawa River 160 kilometres northwest of Ottawa. The site, which has a total area of about 4,000 hectares, is situated within the boundaries of the Corporation of the Town of Deep River. The Ottawa River, which flows northwest to southeast, forms the northeastern boundary of the site. The Petawawa Military Reserve abuts the CRL property to the southeast.

The CRL site was established in the mid-1940s and has a history of various nuclear operations and facilities, primarily related to research. Most of the nuclear and associated support facilities and buildings on the site are located within a relatively small industrial plant site area adjacent to the Ottawa River near the southeast end of the property.

To date, the pace of decommissioning at CRL has been constrained by the availability of waste routes. Priority has been given to hazard reduction and risk mitigation of facilities representing high hazard and risk, as well as to demolition of low-hazard structures for which waste routes are available. Major activities completed since the fifth national report include:

- abatement of asbestos abatement in many facilities, including the National Research Experimental annex and reactor hall
- reduction in fire risk in several facilities following completion of actions from fire hazard analysis, including installation of fire/smoke detection and fire suppression systems where appropriate
- decommissioning of the waste water evaporator building (B228)
- demolishing of the office portion of former thorium reprocessing laboratory (B200B)
- demolishing of the National Research Experimental delay tank (B103/104) upper structures and installed a water-proof cover
- decommissioning of the heavy water upgrade plant (B210/211/212)
- draining and decommissioning of the j-rod bay of the National Research Experimental fuel storage and handling bays (B204)
- demolishing of B456A and B
- demolishing of the B200B superstructure
- demolishing of 15 supervised area buildings: B417, B491, B492, B492A, B492B, B493, B519, B523, B540, B553, B555, B566A, B587A, B587D and B1400

The implementation of a GoCo model at CRL provides an opportunity for AECL to significantly accelerate the decommissioning activities at the site. Over the next 10 years, CNL will focus on early reduction of liabilities in the supervised area footprint to build a skilled workforce, remove redundant buildings, and clear space for science and technology and supporting facilities. In the controlled area, the schedule for reducing risk in high-hazard facilities will rely on construction of the proposed near-surface disposal facility to provide a final waste disposal path. Planned goals and milestones include:

- decommissioning the National Research Experimental reactor to an end state agreed with the CNSC
- placing the National Research Universal reactor in a storage-with-surveillance state

- reducing the footprint of the controlled area in line with decommissioning plan
- decommissioning the buildings in the supervised area
- decommissioning and demolishing more than 120 buildings
- sustaining improved performance in environmental and safety standards

CNL will self-perform the majority of decommissioning activities to gain efficiencies and reduce risks associated with redundant, high-hazard facilities. In the supervised area, integrated teams will develop decommissioning skills on low-hazard buildings, which will ready them for higher hazard work in the controlled area. With this progressive approach, decommissioning teams will continue to learn and build upon relatively low-risk experience, expanding into more difficult areas as they become more efficient in the treatment and management of industrial and radiological hazards. This approach will also support the acceptance and adaptation of site-wide program controls to enable an accelerated decommissioning schedule.

International decommissioning experience gained on multiple sites has demonstrated that the development of a trained and experienced workforce with flexibility to move between buildings as conditions require will be a key step in safely accelerating decommissioning scopes of this magnitude. Additionally, development of a core team and capabilities will reduce incidents and costs, particularly those associated with multiple subcontractors trying to perform multiple scopes of work on a congested site amid other ongoing missions. Decommissioning will be coordinated with capital project timelines to provide the space required for both permanent new facilities and temporary enabling facilities.

Until the proposed near-surface disposal facility is operational in 2020, decommissioning in the controlled area will focus on minimizing radiological waste and removing areas and facilities of high concern. This will be based on health, safety and environmental risk evaluations. Early emphasis will be on removing facilities in the controlled area to support temporary infrastructure and access requirements, which will enable future decommissioning and demolition work. During this period, all non-releasable waste from the controlled area will be placed into interim storage.

Planning is underway to ensure continued interim waste storage needs are met and additional interim waste storage capacity is developed as required to address any gaps. Any adjustment required to the planned sequence of work will be evaluated during the development of CNL’s annual plans, taking into consideration new information available as capital projects progress, mission requirement change and the potential for risk reduction increases or decreases.

CNL plans to commence large-scale demolition work in the controlled area with the availability of the proposed near-surface disposal facility in 2020. Work will be closely coordinated with the start of larger scale environmental restoration efforts, which will need to supply soil to the proposed near-surface disposal facility concurrently with building debris. With the establishment of environmental remediation cleanup criteria, CNL will drive to a seamless transition between completing building demolition and any required soil remediation. CNL will further advance schedules and reduce costs by using the same personnel and equipment already mobilized for demolition.

7.6 Cluff Lake Project

The Cluff Lake Project (see figure 7.4(c)), owned and operated by AREVA Resources Canada Inc., began in 1981 and was completed at the end of 2002, when ore reserves were depleted. More than 62 million pounds of triuranium octoxide (U_3O_8) was produced over the 22-year life of the project. Site facilities included the mill and tailings management area, four open-pit and two underground mines, the camp for workers and site infrastructure.

Cluff Lake is the most recent of the northern Saskatchewan uranium mines to move into decommissioning. The licence to decommission was received from the CNSC in July 2004 after five years of public consultation, environmental assessment and regulatory review. This marked the completion of the planning phase of work to return the site to a natural state. The objective is to return the site as closely as is practical to its original state in a manner that both protects the environment and allows traditional uses such as fishing, trapping and hunting to be carried out safely.

Site staff and contractors carried out the majority of the decommissioning work between 2004 and 2006, with revegetation of restored areas carrying into 2007. Up until mid-2013, a small number of staff remained onsite to carry out the environmental monitoring program and provide minor maintenance to restored areas. In September 2013, the Cluff Lake Project reached a major milestone when the decommissioning of the remaining infrastructure was completed and site occupancy ceased. Environmental monitoring of the site now occurs through quarterly monitoring campaigns. An extensive follow-up monitoring program to assess the performance of the decommissioned site was completed and a report on the follow-up program was submitted to regulatory agencies in September 2015. Ultimately, when all stakeholders judge the performance of the decommissioned site satisfactory, it is expected that the site will be transferred to the Government of Saskatchewan through the institutional control framework established by the *Reclaimed Industrial Sites Act* (see section H.10.3).

The following subsections briefly describe the main decommissioning activities at the site.

7.6.1 Mill area

Decommissioning the mill involved two phases, which were completed in 2004 and 2005 (see figures 7.2(a) and 7.2(b)). The mill demolition work was broadly similar to demolition of other similarly sized industrial facilities, with special measures needed to protect workers from residual contamination and industrial hazards and to prevent the spread of contaminants into the environment. Two warehouses were retained for storage and equipment repair up until 2013, when they were demolished during site cleanup activities. Waste materials were disposed of in one of the open pits at the site, together with much larger volumes of waste rock. Following the mill demolition, till material was placed throughout the former mill area to serve as a growth medium for native wood species planted at the site and to ensure radiological clearance levels were achieved throughout the area.

(a) (b)

Figures 7.2(a) and 7.2(b): Photographs showing (a) the Cluff Lake mill areas during operation and (b) the area following decommissioning but prior to the revegetation becoming established

7.6.2 Tailings management area

The tailings management area at Cluff Lake is a surface impoundment constructed using a series of engineered dams and dikes and extending over about 70 hectares. It formerly consisted of a solids containment area, water-decantation area and water treatment facilities (see figure 7.3(a)). Thickened tailings were pumped to the solids containment area, where consolidation and liquid decantation occurred. The decant water, together with waste water from other sources, was piped to a two-stage water treatment facility for radium-226 precipitation. Currently, the tailings management area is surrounded by two diversion ditches, which divert runoff from the upstream drainage basin around the tailings management area to the downstream water body.

Decommissioning of the tailings management area was initiated by covering the tailings with till in stages to promote consolidation. When consolidation was complete, the tailings management area cover was contoured to provide positive drainage using locally available till with a minimum cover thickness of one metre and then revegetated (see figure 7.3(b)). The surface contour and vegetated cover promote runoff of rainfall and snowmelt as well as evapotranspiration of moisture to the atmosphere, which minimizes net infiltration through the tailings. Extensive characterization of the tailings and the site’s geology and hydrogeology has been performed to acquire reliable data on which to base the assessment of long-term performance.

One of the objectives of the follow-up monitoring program is to verify the key assumptions used in the long-term performance assessment. Seven nested piezometers were installed in the tailings management area in 2010 and six more were installed in 2012 to collect additional hydrogeological data for comparison with the key assumptions. The groundwater and contaminant transport modelling, as well as the ecological and human health risk assessment, were updated for the Cluff Lake Project in 2015. This update incorporated the new monitoring data along with data collected through other components of the follow-up program.

(a) (b)

Figures 7.3(a) and 7.3(b): Photographs of the Cluff Lake Tailings Management Area (a) during operation and (b) after decommissioning but prior to the revegetation becoming established

7.6.3 Mining area

Mining involved four open pits and two underground mines (see figure 7.4(a)). One open pit (“D” pit) and its associated pile of waste rock were reclaimed in the mid-1980s. Water quality data from the flooded pit shows stable, acceptable surface water quality. Native species of vegetation have been re-established on the waste rock pile.

Two open pits have been used for the disposal of waste rock, with one of these two pits also used to accept industrial waste during operations and decommissioning. This waste included the mill demolition waste.

The major decommissioning activities consisted of:

- dismantling and disposing of all above-ground structures
- sealing all access openings (ramps, ventilation shafts) to the two underground mines and allowing them to flood naturally
- relocating waste rock to complete the backfilling of one open pit (Claude pit), then re-contouring and establishing vegetation on these areas
- removing a portion of and then re-contouring the waste rock within another open pit (Dominique-Janine North) and then allowing this pit and the contiguous Dominique-Janine extension pit to flood to the natural level to eventually form a small lake that meets surface water quality criteria (see figure 7.3(b))
- reclaiming the remaining Claude waste rock pile by re-sloping for long-term stability, compacting the waste rock surface, covering with till and establishing a vegetation cover
- re-contouring and establishing native vegetation on all disturbed areas

Extensive characterization of the waste rock, the geologic formations in the area and the site hydrogeology has been performed to acquire reliable data for the assessment of long-term performance. One of the objectives of the post-closure monitoring program is to verify the key assumptions used in the assessment of long-term performance. Eleven nested piezometers were installed in the Claude pit in 2010 and seven more piezometers were installed in 2012 to collect additional hydrogeological data for comparison to the key assumptions. The groundwater and contaminant transport modelling, as well as the ecological and human health risk assessment, were updated for the Cluff Lake Project in 2015. This update incorporated the new monitoring data along with data collected through other components of the follow-up program.

(a) (b) (c)

Figures 7.4(a), 7.4(b) and 7.4(c): Photographs show one of the Cluff Lake mining areas (a) during operations, (b) decommissioned and (c) 6 years post decommissioning

7.7 Gentilly-2 Nuclear Generating Station

Following the decision by the Government of Quebec and upon the recommendation of Hydro-Québec, Gentilly-2’s commercial operation ended on December 28, 2012. The station was placed in a guaranteed shutdown state and decommissioning activities are being undertaken. Hydro-Québec has adopted a deferred decommissioning strategy approach. The activities under this strategy are divided into several phases, the first three of which are:

1. stabilization phase (2013–14)
2. dormancy and transfer of fuel phase (2015–20)
3. dormancy and site-monitoring phase (2021–59)

Figure 7.5 shows the schedule of major decommissioning activities for Gentilly-2 and the following subsections outline these activities.

7.7.1 Stabilization phase

During this phase, which took place in 2013–14, station reconfiguration was planned and the required preparation activities to reach the dormancy and fuel transfer phase were carried out.

The main activities were:

- removal of spent fuel and its storage in a pool
- drainage of heavy water circuits (coolant and moderator) and their storage
- drainage of large volumes (light water, oil)
- shutdown of systems that are no longer required
- introduction of monitoring programs for the next phase (environment, radioprotection, safety)

7.7.2 Dormancy and fuel transfer phase

This current phase, planned from 2015–20, consists of completing the transfer of spent fuel stored in the pool to the dry storage facility at the generating station's secure site. Two additional storage units were built to store all the spent fuel currently in the pool. Other activities planned for this phase are mainly the establishment of program for preventive maintenance; aging management of systems, structures and components; and environmental monitoring.

At the start of 2015, an organization dedicated to the completion of this phase became operational, complete with the human and budgetary resources required to fulfil its mandate.

7.7.3 Dormancy and site-monitoring phase

During this phase, scheduled to occur from 2021–59, the former generating station will be in dormancy for approximately 40 years before preparation and dismantling activities are undertaken. The transfer of spent fuel to the planned national long-term storage site is scheduled to begin in 2050. Final site restoration of the site will be completed in 2066.

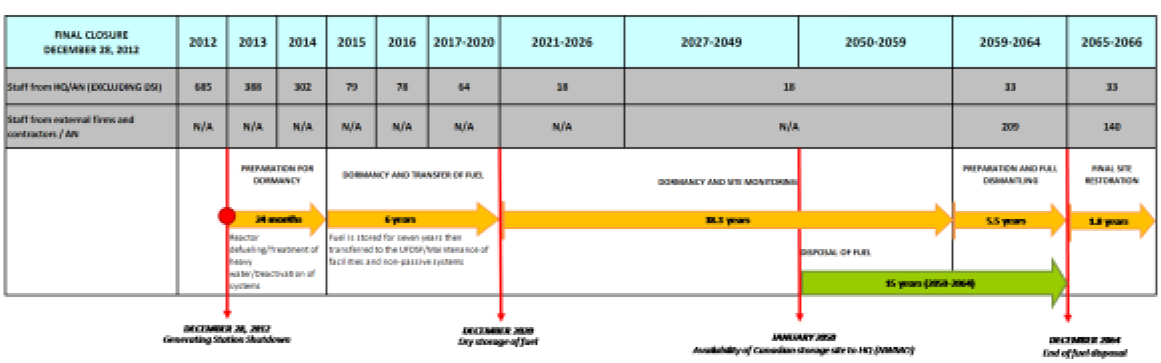

Figure 7.5: Schedule for major decommissioning activities at Gentilly-2 nuclear power reactor

Annex 8 – Inactive Uranium Mines and Mills Tailings Management Areas

8.1 Introduction

There are 20 tailings management sites that have resulted from the operation of uranium mines in Canada: 14 in Ontario, four in Saskatchewan and two in the Northwest Territories. See figure B.3 for a map of their locations.

8.1.1 Saskatchewan

There are four inactive uranium tailings sites in Saskatchewan: Beaverlodge, Lorado, Gunnar and Cluff Lake. In September 2013, AREVA Resources Canada Inc.'s Cluff Lake mining facility completed decommissioning activities and site occupancy ceased (see annex 7.6 for further information).

8.1.1.1 Beaverlodge

Canadian Mining and Energy Corporation (Cameco) holds a waste facility licence to operate for the decommissioned Beaverlodge uranium mine located near Uranium City in the northwest corner of Saskatchewan. Mining of ore at this site began in 1950 and milling in 1953, with both activities continuing until closure in 1982. Decommissioning began in 1982 and was completed in 1985. The site has since been in a monitoring and maintenance phase. All mine structures have been removed from the site, all but one of the open pits has been completely backfilled, and mine shafts have been capped and decommissioned.

All of the control structures associated with this site are passive. Three small, water-level control structures exist but there are no effluent treatment plants. There are roads, waste rock piles and tailings management areas that are subject to inspection programs and local and area-wide environmental monitoring programs.

The Beaverlodge site has three tailings management areas, which contain 5.8 million tonnes of tailings and 4.3 million tonnes of uranium tailings disposed of underground – for a total of 10.1 million tonnes of lower-grade uranium mine tailings. In addition, there are approximately 5.1 million tonnes of waste rock on the site.

At decommissioning in 1982, the site consisted of 73 separate properties that covered approximately 744 hectares. There were 17 different mining areas; 10.161 million tonnes of ore were recovered that averaged 0.25 percent uranium (0.10 percent to 0.43 percent ranges). The Saskatchewan *Reclaimed Industrial Sites Act* later came into effect and created an institutional control framework for the long-term provincial management of post-decommission properties. As a result, five of the 73 Beaverlodge properties were exempted from CNSC licensing and entered into this framework in 2009. These five properties were not part of the overall radiological waste inventory considered in this report.

Figure 8.1: Beaverlodge former mill area

8.1.1.2 Gunnar legacy uranium mine, mill and tailings site

The Gunnar mine site is located on the southern tip of the Crackingstone Peninsula along the north shore of Lake Athabasca, approximately 25 kilometres southwest of Uranium City, Saskatchewan (see figure 8.2). The Gunnar mine site has been abandoned since 1964 and was not adequately decommissioned. The Gunnar site consists of open and underground mine pits, mining infrastructure, three mine tailings deposits and waste rock piles. The total volume of mine tailings at the site is 4.4 million tonnes and the total volume of waste rock is approximately 2.2 to 2.7 million tonnes. The Province of Saskatchewan now has ownership of the site, under the Saskatchewan Ministry of the Economy. The ministry has subsequently appointed the SRC as the project manager to oversee the ongoing management and remediation of the Gunnar mine site.

On April 2, 2007, the governments of Canada and Saskatchewan announced the first phase of the cleanup of the Gunnar legacy uranium mine site in northern Saskatchewan. Private sector companies that no longer exist operated this facility from the 1950s until the early 1960s. When the site was closed, the regulatory framework in place was not sufficient to ensure the appropriate containment and treatment of the waste, which led to environmental impacts on local soils and lakes.

In 2010, the Government of Saskatchewan was ordered by the CNSC to remove hazards associated with engineered structures on the site by dismantling the buildings and safely managing all hazardous materials associated with the demolition work. The conditions of the order were met by September 2011 (see figures 8.3 and 8.4).

In November 2013, the SRC submitted an environmental impact statement that concluded that no significant adverse residual impacts have been identified for any aspect of the project.

In January 2015, the Commission issued a licence to the SRC for the Gunnar Remediation Project following a public hearing. The SRC's licence is valid until November 30, 2024. The remediation work is being carried out in three phases. Phase 1, which is now complete, involved characterizing and monitoring the onsite waste and developing remediation plans. Phase 2 consists of implementing the remediation plans. Phase 3 will be the long-term monitoring and maintenance to ensure the site remains stable and safe.

Figure 8.2: Aerial view of Gunnar mine site

Figure 8.3: Before completion of the CNSC order

Figure 8.4: After completion of the CNSC order

8.1.1.3 Lorado legacy uranium mill and tailings site

The Lorado legacy mill site is located north of Lake Athabasca in the northwest corner of Saskatchewan, approximately eight kilometres southwest of Uranium City. The Lorado mill was closed in 1961 and there was minimal decommissioning work completed. The Lorado mine site is several kilometres away from the Lorado mill and is not included in the Lorado mill site remediation project.

At the end of operations at Lorado, uranium mine tailings covered an area of about 14 hectares, including tailings submerged in the adjacent Nero Lake. EnCana West Limited had been identified as the owner of the land on which a portion of the unconfined tailings from the Lorado milling operation exists. The remainder of the site is provincial Crown land. In 2008, EnCana West Limited negotiated an agreement with the Government of Saskatchewan. The company paid a significant amount of money in exchange for the Saskatchewan government to assume current and future control of and responsibility for the site.

The Province of Saskatchewan now has ownership of the site, under the Saskatchewan Ministry of the Economy. The ministry has subsequently appointed the SRC as the project manager to oversee the ongoing management and remediation of the Lorado site. The SRC’s current CNSC licence for Lorado is valid until April 30, 2023.

The SRC completed remediation of the Lorado site at the end of 2015 (see figure 8.5). The site is in the process of transitioning to the long-term monitoring phase.

Figure 8.5: Remediated Lorado tailings site

8.1.2 Northwest Territories

There are two licensed legacy uranium mine, mill and tailings sites in the Northwest Territories: the Port Radium and Rayrock mines.

8.1.2.1 Port Radium legacy uranium mine, mill and tailings site

The Port Radium site, shown in figure 8.6(a), is located in the Northwest Territories at Echo Bay on the eastern shores of Great Bear Lake, about 265 kilometres east of the Dene community of Deline at the edge of the Arctic Circle. Mining at the Port Radium site occurred from 1932 to 1940, from 1942 to 1960, and from 1964 to 1982 (in the last instance to recover silver). The licensed area covers approximately 12 hectares and is estimated to contain 1.7 million tonnes of uranium and silver tailings (see figure 8.6(b)). The site was partially decommissioned in 1984 according to the standards of the day. In 2006, the Government of Canada reached an agreement with the local community and completed the remediation of the site in 2007 under a CNSC licence. In 2016, the CNSC renewed the licence for the Port Radium closed uranium mine site for 10 years to continue long-term monitoring and maintenance at the site. Under the renewed licence, Department of Indian Affairs and Northern Development Canada (DIAND) will continue performance and environmental monitoring and reporting under the licence.

DIAND sampled surface water in 2016. The results from the surface water samples are as follows:

Location	Ra-226 (Bq/L)	Pb-210 (Bq/L)	Po-210 (Bq/L)	Th-230 (Bq/L)
Labine Bay	<0.005	<0.05	<0.05	<0.01
Silver Point	<0.005	<0.05	<0.05	<0.01
Cobalt Channel	<0.005	<0.05	<0.05	<0.01
Murphy Bay	<0.005	<0.05	<0.05	<0.01

For the 2016 sampling period, the radionuclide concentrations were below detection limits and below Health Canada's drinking water criteria.

Figure 8.6(a): Aerial view of Port Radium mine in the 1950s

Figure 8.6(b): Aerial view of Port Radium mine in 2002

8.1.2.2 Rayrock legacy uranium mine, mill and tailings site

The Rayrock site is located in the Northwest Territories, approximately 145 kilometres northwest of Yellowknife. Uranium mining and milling occurred at the Rayrock site from 1957 until 1959, when it was abandoned (see figure 8.7). The licensed site area is 206 hectares and contains an estimated 80,000 tonnes of tailings. Under a licence issued by the Atomic Energy Control Board (reissued as a CNSC licence in 2001), DIAND decommissioned and rehabilitated the Rayrock site (including the capping of the tailings) in 1996. Performance monitoring and reporting of the results have been ongoing since 1996.

DIAND sampled surface water in 2014 and found the following radiological concentrations at the furthest downstream sampling location:

- 0.1 becquerels per litre (Bq/L) for lead-210
- 0.011 Bq/L for polonium-210

- <0.01 Bq/L for radium-226
- <0.01 Bq/L for thorium-232
- <0.01 Bq/L for uranium-234
- <0.01 Bq/L for uranium-235
- <0.01 Bq/L for uranium-238

For the 2014 sampling period, most of the radionuclide concentrations were below detection limits and in all cases were below Health Canada's drinking water criteria.

Figure 8.7: Rayrock mine

8.1.3 Ontario

8.1.3.1 Elliot Lake area

There are 12 inactive uranium mine sites and 10 uranium tailings management areas in and around Elliot Lake, Ontario. All of the Elliot Lake uranium mines were brought into production between 1955 and 1958. By 1970, five of the mines had been shut down; by 1992, most had ceased operations. Decommissioning of the last of the Elliot Lake uranium mines – the Stanleigh, Quirke, Panel, Stanrock and Denison mine sites – was essentially complete by the end of 1999. All of the sites have been substantively decommissioned, with all mine features capped or blocked, all facility structures demolished, and all sites landscaped and revegetated.

The uranium ore in the Elliot Lake area is classified as low grade (containing less than 0.1 percent triuranium octoxide [U_3O_8]). It also contains pyrite and uranium decay products such as radium-226. When exposed to oxygen and water, the tailings become acid generating and may mobilize contaminants. Most of the Elliot Lake tailings management areas, therefore, have some degree of effluent treatment system associated with each site.

All of the tailings management areas have been closed and all construction activities related to the containment structures have been completed. Currently, the mining companies conduct site-specific and regional environmental monitoring programs, operate the effluent treatment plants, and inspect and maintain the sites.

Rio Algom Ltd. Is responsible for the Quirke, Panel, Spanish American, Stanleigh, Lacnor, Nordic, Buckles, Pronto and Milliken mine sites and their associated tailings management areas. Denison Mines Inc. is responsible for the Denison, Stanrock and Can-Met mine sites and their tailings management areas. Two of the former mine sites – Denison and Stanrock – currently have CNSC licences.

In 2004, Rio Algom Ltd. consolidated all of its Elliot Lake mine sites under one CNSC licence governed by the *Class I Nuclear Facility Regulations* under the NSCA.

8.1.3.1.1 Effluent treatment and environmental monitoring

In Elliot Lake, the tailings management areas use a mixture of both dry and wet covers. Four of the areas (Lacnor, Nordic, Pronto and Stanrock) are engineered with dry covers; vegetation has been established over the tailings at all of these sites. Active water treatment is required at all of the dry tailings management areas to correct for acid generation and radium dissolution in the effluent streams according to the predicted performance for the dry tailings covers. It is expected that water treatment will be required at these sites for many more years as the acid-generating potential of the tailings becomes slowly exhausted due to surface water infiltration and oxidation of the tailings.

The other tailings management areas (Quirke, Panel, Stanleigh, Spanish American and Denison) are all water covered and most require some form of active water treatment. However, the extent of treatment required is greatly reduced over that of the effluents resulting from the dry cover tailings management areas (the water covers minimize exposure to oxygen and the resulting generation of acid). Many of these sites currently require only minimal treatment and it is expected that the effluent treatment plants will not be required for the length of time predicted at the sites with dry covers.

With respect to environmental monitoring, the licensees have implemented two programs at their tailings management areas: the Tailings Management Area Operational Monitoring Program and the Source Area Monitoring Program. The first collects data to track tailings management area performance and supports decisions regarding their management and discharge compliance. The second program was developed to monitor the nature and quantities of contaminant releases to the watershed.

In addition to these measures, both Rio Algom Ltd. and Denison Mines Inc. have jointly implemented two watershed-wide programs: the Serpent River Watershed Monitoring Program and the In-Basin Monitoring Program. The Serpent River Watershed Monitoring Program is designed to evaluate the effects of all mine discharges and water-level changes on the receiving watershed, focusing on water and sediment quality, benthos, fish health, and radiation and metal doses to humans and wildlife. The Serpent River Watershed comprises more than 70 lakes and nine sub-watersheds, which cover an area of 1,376 square kilometres and drain into Lake Huron via the Serpent River. Its companion program, the In-Basin Monitoring Program, focuses on the risks to biota feeding at the tailings management areas by monitoring their physical, chemical and ecological conditions, including ecological changes.

Both programs run in five-year cycles and began in 1999. The fourth cycle of the report was completed in 2016, with CNSC staff completing their review in 2017.

CNSC staff reviewed the results of the various monitoring programs that Rio Algom Ltd. and Denison Mines Inc. implemented and found that, overall, environmental conditions are improving at the Elliot Lake sites. More specifically, water quality is improving and environmental impacts, such as lower taxonomic richness and abundance in the benthic communities, are now only evident immediately downstream of the Quirke, Denison and Stanleigh tailings management areas. Lakes further afield are in good environmental health, sediment contaminant levels continue to be slightly elevated, which is to be expected.

These sites will continue to require monitoring and active management until effluents meet discharge criteria without treatment and then require some form of ongoing (permanent) care and maintenance.

8.1.3.2 Agnew Lake legacy mine, mill and tailings site

The Agnew Lake mine, located about 25 kilometres northwest of Nairn Centre, Ontario, ceased operation in 1983. The former underground uranium mine site was decommissioned and monitored by Kerr-Addison Mines Ltd. from 1983 until 1988. The site was then turned over to the Province of Ontario in the early 1990s. The Ontario Ministry of Northern Development and Mines holds a CNSC licence for the Agnew Lake tailings management area. The tailings management area is estimated to hold 1.35 million cubic metres of material deposited and covers approximately 13 hectares surrounded by the West Dam and East Barrier dyke. The Ministry of Northern Development and Mines reported the following 2016 sampling results for the radiological surface water at the final point of control:

- less than one microgram per litre (µg/L) for uranium
- 0.084 Bq/L for radium-226

These levels are below applicable water quality guidelines.

8.1.3.3 Bancroft area

Uranium tailings management sites also exist at the Madawaska, Dyno and Bicroft mines in the area surrounding Bancroft, Ontario. The Madawaska mine has been inactive since 1983, while operations at the Dyno and Bicroft sites ceased in the early 1960s.

8.1.3.3.1 Dyno idle mine, mill and tailings site

The Dyno idle mine property is located at Farrel Lake about 30 kilometres southwest of Bancroft, Ontario. The mill circuit at Dyno operated between April 1958 and April 1960. The property consists of an abandoned and sealed underground uranium mine, a mill that has been largely demolished, a tailings area, one dam (see figure 8.8) and various roadways. The site is managed and monitored by EWL Management Ltd., which holds a CNSC waste nuclear substance licence for the Dyno idle mine site.

During the sampling period of 2016, EWL Management Ltd. provided the following results for the radiological surface water at the final point of control:

- Uranium concentrations during the spring of 2016, 0.0011 milligrams per litre (mg/L), was within the range reported in previous years (0.1–2.0 µg/L). The observed uranium concentrations during 2002–14 were all below the *Ontario Provincial Water Quality Objectives* of 0.005 mg/L.
- Radium-226 concentrations during the spring of 2016, 0.038 Bq/L, was below the range of the concentrations reported during previous years (less than 0.01–0.36 Bq/L). The measured radium-226 concentrations during 2002–14 were all below the *Ontario Provincial Water Quality Objectives* of 0.6 Bq/L.
- Thorium-230 concentrations during the spring of 2016, less than 0.005 Bq/L, was within the range of concentrations reported for 2002–14 (less than 0.005–0.026 Bq/L).
- Polonium-210 concentrations during the spring of 2016 was below the detection limit of less than 0.005 Bq/L and was within the historical range of less than 0.005–0.21 Bq/L).
- Lead-210 concentrations during the spring 2016 were below the detection limit of less than 0.01 Bq/L and within the range of concentrations reported for 2002–14 (less than 0.01–0.1 Bq/L).

Figure 8.8: Main tailings dam, Dyno mine site

8.1.3.3.2 Madawaska closed mine, mill and tailings site

The Madawaska mine property is located six kilometres southwest of the town of Bancroft, Ontario, on Highway 28. Initial mining and milling operations at Madawaska (Faraday) mine ran from 1957 until 1964 and again from 1976 to 1982. Reclamation activities were carried out from 1983 to 1992. Approximately 4 million tonnes of waste, covering an area of about 13 hectares at a depth ranging from 6 to 15 metres, and containing about 9 x 10^{13} Bq of nuclear material, remain at the location. The tailings management areas have been covered with 0.25 to 1.0 metre of sand fill and have been re-vegetated. The site is currently being safely managed by EnCana West Ltd. CNSC staff inspect the site annually.

During the sampling period of 2016, EnCana West Ltd. provided the following results for the radiological surface water at the final point of control:

- Uranium concentrations during the spring and fall of 2016 were 0.0245 mg/L and 0.0415 mg/L, respectively, and were within the range of the monitoring data from 2006–15 (0.006–0.053 mg/L) as well as the historical range from 1983–2012. Concentrations of uranium during the spring and fall of 2016 were greater than the *Ontario Provincial Water Quality Objectives* (0.005 mg/L), which was consistent with previous years of sampling.

- Radium-226 concentrations during the spring and fall of 2016 were 0.034 Bq/L and 0.068 Bq/L, respectively. The spring 2016 concentration was within the range of 2006–15 monitoring data (0.010–0.240 Bq/L), whereas the fall 2016 concentration was generally higher than the 2006–12 data. Concentrations of radium-226 during the spring and fall of 2016 were below the *Ontario Provincial Water Quality Objectives* (0.6 Bq/L), which was consistent with data collected from 1984 to 2015.

- Thorium-230 concentrations during the spring and fall of 2016 were below the analytical detection limit of 0.005 Bq/L, consistent with concentrations reported in previous years (less than 0.005–0.05 Bq/L).

- Lead-210 concentrations during the spring and fall of 2016 were 0.05 Bq/L and 0.025 Bq/L respectively. The observed concentrations of lead-210 in 2016 were within the range reported in previous years (less than 0.02–0.07 Bq/L).

- Polonium-210 concentrations during the spring and fall of 2016 were 0.008 Bq/L and less than 0.005 Bq/L, respectively. The observed concentrations of polonium-210 in 2016 were within the range reported in previous years (less than 0.005–0.06 Bq/L).

8.1.3.3.3 Bicroft tailings site

The uranium tailings stored in the Bicroft tailings storage site resulted from processing low-grade uranium ore at the Bicroft mine from 1956 to 1962 (see figure 8.9). Remediation work has included vegetation of exposed tailings in 1980 and upgrading of dams in 1990 and 1997. In 2005, the Barrick Gold Corporation was issued a CNSC licence for the Bicroft tailings management site. The effluents discharge results generally meet the Ontario Provincial Water Quality Objectives, with a few exceptions. Therefore, as part of its licence application, Barrick conducted a screening level human health and ecological risk assessment to demonstrate that there is no unreasonable risk to health, safety and the environment, and to support a five-year surface water-sampling program. In 2015, the results for the radiological surface water at the final point of control were 0.96 Bq/L for radium-226 and 23 parts per billion for uranium.

Figure 8.9: South tailings basin spillway at Bicroft tailings storage facility

8.2 Contaminated lands

8.2.1 Historic contaminated lands

Very low-level uranium and radium contaminated sites, resulting from early industrial practices (1930s to 1950s), were identified in the 1970s and have been subject to Government of Canada oversight through the Low-Level Radioactive Waste Management Office (LLRWMO) since 1982. Under a GoCo model, AECL is responsible for the LLRWMO, but CNL delivers this work on behalf of AECL.

Activities are currently underway to quantify the extent of historic low-level radioactive waste (LLW) liabilities across Canada (non-Port Hope sites) and develop plans for their discharge. A key objective is that by 2026, Canadian Nuclear Laboratories will significantly reduce or eliminate liabilities through safe execution of remediation projects, facilitating the cost-effective long-term management of historic LLW consistent with policy direction provided by Atomic Energy of Canada Limited (AECL).

8.2.1.1 Port Hope Area Initiative for the long-term management of historic low-level radioactive wastes

On March 29, 2001, an agreement was signed between the Government of Canada (represented by the Minister of Natural Resources) and the Ontario communities of Port Hope, Hope Township and Clarington for the construction of long-term waste management facilities for historic LLW and for the cleanup of contaminated sites in the Port Hope area. The wastes consist of about 2 million cubic metres of LLW and contaminated soils, containing radium-226, uranium and arsenic as the primary contaminants.

With this agreement, the Government of Canada began the Port Hope Area Initiative (PHAI) to evaluate and implement a long-term solution for the management of the wastes from the Port Hope area sites. This initiative has been divided into two projects that accord with municipal boundaries. The Port Hope Project entails the cleanup and long-term management of wastes from various contaminated sites in the Municipality of Port Hope (formerly the Town of Port Hope and Hope Township). The Port Granby Project involves the implementation of a long-term management approach for radioactive wastes at the existing Port Granby Waste Management Facility in the Municipality of Clarington (see figure 8.10).

Both projects are under the responsibility of AECL but are being delivered by CNL under a government-owned, contractor-operated model.

Single-purpose-built facilities are being constructed to manage the wastes from each cleanup project: the Port Hope Long-Term Waste Management Facility and the Port Granby Long-Term Waste Management Facility. The Port Hope Long-Term Waste Management Facility, with an estimated design capacity of 1.8 million cubic metres, is planned to accept a variety of wastes from the area. These include wastes from the major unlicensed sites in the municipality of Port Hope, including the landfill and the harbour. Other wastes, such as contaminated roadways and soils from private properties, will also be included, along with wastes from Canadian Mining and Energy Corporation (Cameco) Welcome Waste Management Facility and specified historic wastes from the Cameco Port Hope Conversion Facility. Wastes from consolidation sites and temporary storage sites within the community that are being temporarily managed under the LLRWMO scope of work will also be included, along with non-radiologically contaminated industrial wastes, as requested by the municipality and provided for in the agreement.

The Port Hope Long-Term Waste Management Facility is being constructed as an expanded site at the existing Welcome Waste Management Facility located in the Municipality of Port Hope, which currently contains an estimated 500,000 cubic metres of LLW and contaminated soils. An environmental assessment process has been completed for this project and, on November 15, 2012, the Commission issued a 10-year licence to AECL for the Port Hope Project. This project, as well as the Port Granby Long-Term Waste Management Facility, is moving forward in a phased approach.

The Port Hope Project is currently in its implementation phase (phase 2), which includes construction of the new long-term waste management facility and associated water treatment plant, remediation of the existing facility and the contaminated sites in the area of Port Hope followed by a closure of the long-term waste management facility. The construction of the water treatment plant was completed in 2016 and is currently undergoing active commissioning. Construction of the containment mound commenced in the summer of 2016. The first cell will be completed in late 2017, with placement of waste from within the community expected to begin in 2018.

The Port Granby Long-Term Waste Management Facility, with an estimated design capacity of 600,000 cubic metres, will accept wastes only from the existing Port Granby Waste Management Facility located in the Municipality of Clarington. The site selected for these wastes is immediately northwest of the existing facility and away from the Lake Ontario shoreline. An environmental assessment process has been completed for this project and, on November 29, 2011, the CNSC issued a 10-year licence to AECL for the Port Granby Project.

The project is currently in its implementation phase (phase 2), which includes construction of the new long-term waste management facility and associated new state-of-the-art water treatment plant as well as decommissioning and remediation of the existing facility followed by a closure of the long-term waste management facility.

Construction of the containment mound commenced spring of 2016. On November 1, 2016, the first truckloads of LLW were transported away from the Lake Ontario shoreline to the newly built Port Granby Project Long-Term Waste Management Facility, signaling the start of this significant environmental cleanup. The cleanup is scheduled to take place over three years, after which the mound's cover system will be constructed (expected to be complete in 2021).

After completing the Port Hope and the Port Granby projects, both long-term waste management facilities will be capped and the projects will move to a long-term monitoring and surveillance phase (phase 3).

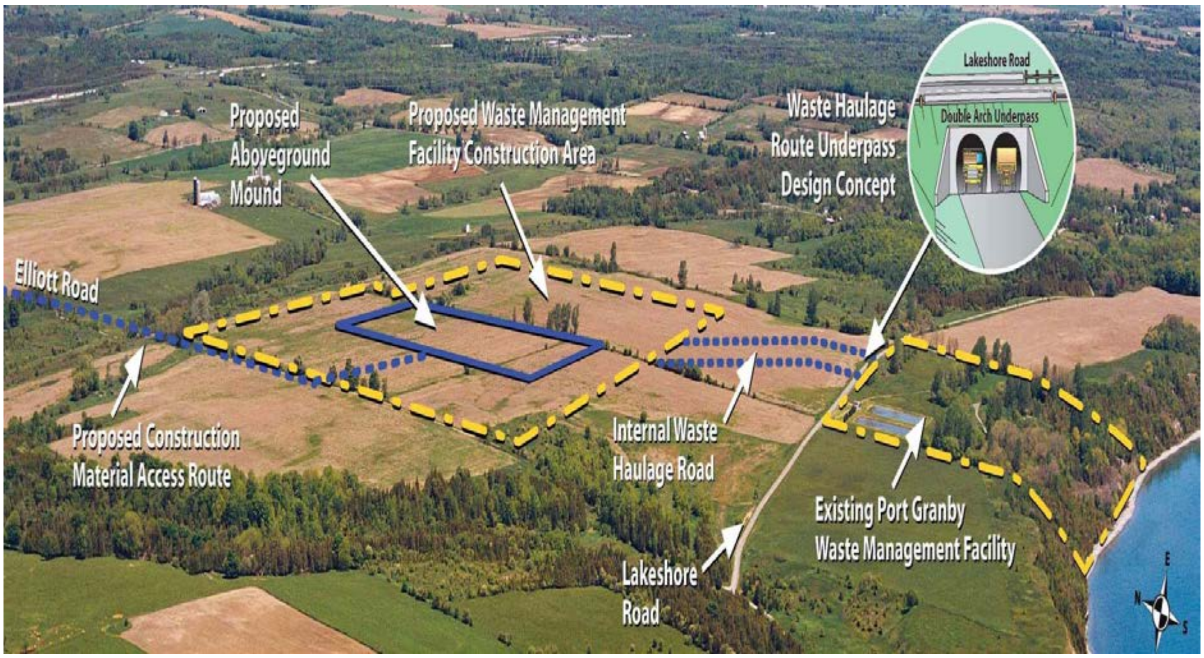

Figure 8.10: Port Granby concept diagram

8.2.1.2 Port Hope contaminated sites

A number of contaminated sites have been identified in Port Hope. Some of these sites are known as major unlicensed sites, others are known as small-scale sites, and there are also some licensed and unlicensed temporary storage and consolidation sites. Although many of these sites are not currently licensed by the CNSC, the CNSC is aware of them and is comfortable with how they are being managed. The sites are safe for casual access, pending implementation of the PHAI, which will remediate them once the Port Hope Long-Term Waste Management Facility is ready for acceptance of this waste.

The major sites are generally well known by the community and municipality and will not be further developed until the historic waste deposits can be removed to an appropriate storage facility. Small pockets of contaminated soils, however, also exist on roadways, municipal road allowances and on municipal, private and commercial properties. These sites are known collectively as small-scale sites.

The development of these sites (which may include common activities such as road repair, infrastructure repair and maintenance, property regrading and landscaping, and private or commercial property development or renovation) is accommodated under the Construction Monitoring Program, an administrative program between the LLRWMO and the Municipality of Port Hope.

Projects that require municipal building permits are forwarded to the LLRWMO for review and action. This action often results in a radiological monitoring of excavated materials in construction areas. If contaminated soils that need to be removed are identified, they are accepted at the Pine Street Extension Temporary Storage Site, a CNSC-licensed storage facility with a receiving capacity of approximately 12,000 cubic metres. In the long term, this material will be placed in the Port Hope Long-Term Waste Management Facility.

Annex 9 – Matrix for Canada's Sixth National Report

Type of Liability	Long-term Management (LTM) Policy	Funding of Liabilities	Current Practice / Facilities	Planned Facilities
Spent Fuel (SF)	National approach for the LTM of SF *Nuclear Waste Fuel Act* (NWFA, 2002) outlines process and implementation	Long-term: • licensees are required to contribute to segregated funds to finance LTM activities under the NFWA Short-term: • licensees are financially responsible and required to provide a Financial Guarantee (FG) for the decommissioning of interim WMFs for SF under the Nuclear Safety and Control Act (NSCA)	SF held in interim storage in wet or dry storage facilities located at the waste producers' site SF from research reactors is either returned to the fuel supplier or transferred to Canadian Nuclear Laboratories (CNL) Chalk River Laboratories (CRL) for storage	Long-term: • Nuclear Waste Management Organization (NWMO) implementing the Adaptive Phased Management (APM) Approach - a deep geological repository (DGR) for the LTM of SF in Canada Short-term: • interim dry storage facilities are constructed as needed
Nuclear Fuel Cycle Waste	Licensees are responsible for the funding, organization, management & operation of their waste management facilities (WMFs) (*Radioactive Waste Policy Framework*, 1996) Government of Canada accepted responsibility for LTM of historic wastes and funds the management of legacy waste	Licensees are financially responsible and required to provide a FG for the decommissioning and LTM of the waste they produce	• managed by licensee (onsite or at a dedicated WMF) • managed in-situ/ above-ground mounds • managed in near-surface facilities adjacent to the mines and mills • waste from small generators transferred to licensed WMFs for management	• OPG planning a DGR for LTM of its low-level waste (LLW) and Intermediate-level waste (ILW) • CNL assessing CRL site for hosting LTM facilities for LLW & ILW • LTM of the bulk of Canada's historic waste implemented under the Port Hope Area Initiative (PHAI) • LTM of Uranium Mines and Mills (UMM) in near-surface facilities adjacent to the mines and mills • CNL assessing options at CRL site for hosting LTM facilities for radioactive wastes
Application Wastes	Licensees are responsible for the funding, organization, management and operation of their WMFs	Licensees are financially responsible and required to provide a FG for the decommissioning and the LTM of the waste that they produce	• delay and decay • returned to manufacturer • transferred to licensed WMFs for management	CNL assessing options at CRL site for hosting LTM facilities for radioactive wastes
Decomm. Liabilities	• licensees are responsible for the funding, organization, management and implementation of decommissioning activities • licensees to give due consideration to the immediate dismantling approach when proposing a decommissioning strategy (G-219)	Licensees are financially responsible and required to provide a FG for the decommissioning & the LTM of the waste that they produce	Major facilities required to keep decommissioning plans and FG up to date throughout the lifecycle of a licensed activity (G-219). These are reviewed on a five-year cycle by the licensee and regulator.	CNL assessing CRL site for hosting LTM facilities for LLW and ILW
Disused Sealed Sources	Licensees are responsible for the funding, organization, management and operation of their WMFs	Licensees are financially responsible and required to provide a FG for the decommissioning and the LTM of the waste that they produce	• delay and decay • returned to manufacturer • transferred to licensed WMF for LTM • recycling by reusing, re-encapsulating, or reprocessing National Sealed Source Registry and Sealed Source Tracking System	CNL assessing options at CRL site for hosting LTM facilities for radioactive wastes

List of Acronyms and Abbreviation

AECA	Atomic Energy Control Act
AECB	Atomic Energy Control Board
AECL	Atomic Energy of Canada Limited
ALARA	as low as reasonably achievable
AMP	administrative monetary penalty
AMPR	Administrative Monetary Penalties Regulations
APM	Adaptive Phased Management
ASDR	l’aire de stockage des déchets radioactifs (radioactive waste storage area)
Bq	becquerel
CANDU	Canada Deuterium-Uranium
CANSTOR	CANDU Storage
CANUTEC	Canadian Transport Emergency Centre
CEAA 2012	Canadian Environmental Assessment Act, 2012
CEA Agency	Canadian Environmental Assessment Agency
CINFR	Class I Nuclear Facility Regulations
CNL	Canadian Nuclear Laboratories
CNEA	Canadian National Energy Alliance
CNSC	Canadian Nuclear Safety Commission
COG	CANDU Owners Group
CRL	Chalk River Laboratories
CSA	Canadian Standards Association
DDP	detailed decommissioning plan
DGR	Deep Geologic Repository (Ontario Power Generation)
DIAND	Department of Indian Affairs and Northern Development
DRL	derived release limit
DSO	Darlington Storage Overpack
DWMF	Darlington Waste Management Facility
ECCC	Environment and Climate Change Canada
EMA	Emergency Management Act

EMS	environmental management system
ERA	environmental risk assessment
EWL	EnCana West Limited
FERP	Federal Emergency Response Plan
FNEP	Federal Nuclear Emergency Plan
GAST	gas-permeable seal test
GBq	gigabecquerel
GNSCR	General Nuclear Safety and Control Regulations
GoCo	government-owned, contractor-operated
GSR	General Safety Requirements (IAEA)
HEU	highly enriched uranium
HLW	high-level radioactive waste
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IEMP	Independent Environmental Monitoring Program
ILW	intermediate-level radioactive waste
IPPAS	International Physical Protection Advisory Service
IRRS	Integrated Regulatory Review Service
IRSN	Institut de Radioprotection et de Sûreté Nucléaire
JRP	Joint Review Panel
KI	Potassium Iodide
LCH	licence conditions handbook
LEU	low-enriched uranium
L&ILW	low- and intermediate-level radioactive waste
LLRWMO	Low-Level Radioactive Waste Management Office
LLW	low-level radioactive waste
MACSTOR	modular air-cooled storage
MAGS	modular above-ground storage
MPMO	Major Projects Management Office
mSv	millisievert

N/A	not available
NB EMO	New Brunswick Emergency Measures Organization
NB Power	New Brunswick Power Corporation
NCA	Nuclear Cooperation Agreement
NEA	Nuclear Energy Act
NFWA	Nuclear Fuel Waste Act
NLCA	Nuclear Liability and Compensation Act
NLLP	Nuclear Legacy Liabilities Program
NPD	Nuclear Power Demonstration
NPMO	Northern Projects Management Office
NRCan	Natural Resources Canada
NRU	National Research Universal
NSCA	Nuclear Safety and Control Act
NSDF	Near Surface Disposal Facility
NSERC	Natural Sciences and Engineering Research Council
NSR	Nuclear Security Regulations
NSRDR	Nuclear Substances and Radiation Devices Regulations
NSSR	National Sealed Source Registry
NWMO	Nuclear Waste Management Organization
OAE	Office of Audit and Ethics
OPG	Ontario Power Generation
OSART	Operational Safety Review Team
OSCQ	Organisation de la sécurité civile du Québec
PDP	preliminary decommissioning plan
PFP	Participant Funding Program
PHAC	Public Health Agency of Canada
PHAI	Port Hope Area Initiative
POST	post-closure analysis
PTNSR	Packaging and Transport of Nuclear Substances Regulations
PWMF	Pickering Waste Management Facility

QA	quality assurance
RMC	Royal Military College
ROR	Regulatory Oversight Report
RPR	Radiation Protection Regulations
RWC	Retube Waste Container
R&D	research and development
SLOWPOKE	Safe Low-Power Critical Experiment
SMAGS	shielded modular above-ground storage
SMART	specific, measurable, attainable, realistic and timely
SRC	Saskatchewan Research Council
SRWMF	Solid Radioactive Waste Management Facility
SSR	Specific Safety Requirements (IAEA)
SSTS	Sealed Source Tracking System
Sv	sievert
TBq	terabecquerel
TLD	thermoluminescent dosimeter
TMA	tailings management area
TMF	tailings management facility
TRIUMF	TriUniversity Meson Facility
UMMR	Uranium Mines and Mills Regulations
UNENE	University Network of Excellence in Nuclear Engineering
VLLW	very-low-level radioactive waste
VSLLW	very-short-lived low-level radioactive waste
WMA	waste management area
WMF	waste management facility
WWMF	Western Waste Management Facility
ZED-2	Zero Energy Deuterium-2