MANAGING WASTES FROM THE ATOMIC AGE AND INTO THE FUTURE: PROGRAMS, PLANS AND CHALLENGES

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ABSTRACT

Various types of waste are generated at Atomic Energy of Canada Limited (AECL) nuclear sites from diversified operations, including research reactor operations, radioisotope production, hot cell operations, nuclear fuel fabrication, research and development activities, facility decommissioning, environmental restoration, etc. AECL is responsible for the safe storage and long-term management of waste generated by Chalk River Laboratories (CRL), Whiteshell Laboratories (WL) and the three partially decommissioned prototype reactors, as well as for the radioactive waste received from off-site waste generators on a fee-for-service basis.

As the home for the first nuclear reactor in Canada and nuclear research facilities, CRL has been a pioneer in the management of nuclear waste. Since the dawn of the nuclear era in the 1940s, CRL's waste management facilities have evolved from storage in simple sand trenches to below-ground concrete storage, to above-ground facilities offering multiple barriers of containment. To continuously improve the waste management at AECL, a formal Waste Management Program has been introduced. An important component of this Program is a focus on waste reduction and appropriate waste characterization to ensure wastes are being handled, stored and/or disposed in the most cost-effective manner.

In 2006, AECL began implementing the Government of Canada-funded Nuclear Legacy Liabilities Program (NLLP) to deal with nuclear legacy liabilities at AECL sites. Approximately 200,000 to 300,000 cubic metres of waste from earlier operations at AECL requires management through the NLLP, with a yearly increase of several thousand cubic metres. Several of the NLLP projects currently underway are focused on improving the robustness of earlier management practices, as older facilities reach the end of their design life. An important element of the NLLP is the development of an Integrated Waste Plan to ensure optimal selection of enabling facilities and their implementation schedules to address the current waste inventory and future wastes from both AECL's operational and decommissioning activities.

This paper provides an overview of AECL's waste management practices, AECL's low- and intermediate-level waste inventory, current activities for the management of those wastes, and the plans for moving forward.

Subject Keywords: waste management, Integrated Waste Plan, radioactive waste storage facilities, nuclear legacy liabilities.

1. INTRODUCTION

Atomic Energy of Canada Limited (AECL) has generated, both historically and currently, a variety of wastes at its nuclear research sites from diversified operations, including research reactor operations, radioisotope production, hot cell operations, nuclear fuel fabrication, research and development activities, facility decommissioning, environmental restoration, etc. The federal government's *Radioactive Waste Policy Framework* [1], issued in 1996, states that the responsibility for the management of radioactive

wastes resides with the generator. Thus, AECL is responsible for the safe storage and long-term management of waste generated by Chalk River Laboratories (CRL), Whiteshell Laboratories (WL) and the three partially decommissioned prototype reactors in Canada. AECL also supports the policy framework through the receipt of radioactive waste from off-site waste generators on a fee-for-service basis.

As the original site of the first nuclear reactor in Canada and nuclear research facilities, CRL has been a pioneer in the management of nuclear waste. Operational activities in the early years encompassed startup and operation of three research reactors, fuel reprocessing activities and various fuel development campaigns. These activities have led to today's nuclear legacy liabilities, which must be managed for the long term consistent with society's current expectations for the safe handling and storage of radioactive materials. In 2006, the Government of Canada approved the first phase of funding for the Nuclear Legacy Liabilities Program (NLLP) [2] to deal with nuclear legacy liabilities at AECL sites, including the CRL. These liabilities consist of radiochemical laboratories, infrastructure, including the prototype and research reactors, buried and stored wastes, and contaminated lands.

AECL has been implementing its strategy for managing its low-level radioactive waste (LLW) and intermediate-level radioactive waste (ILW) through various programs and projects, including the ongoing performance monitoring of the storage facilities to ensure the continued safe storage of the waste that is currently in storage. A formal Waste Management Program, as described further in Section 4, has been introduced which defines requirements for all aspects of waste management from generation to final disposition. A number of improvement initiatives addressing both operational waste and waste produced from the NLLP activities are underway or have been recently completed. The Program requirements and the projects are now being linked through an Integrated Waste Plan – a plan which integrates the interactions between waste types, facilities needed, and timelines. This plan will go through several iterations as the required, more detailed information for decision-making is obtained; however, it will provide the basis for moving forward with due consideration of all requirements and challenges that are identified in the subsequent sections of this paper.

2. WASTE STORAGE PRACTICES: PAST AND FUTURE

The waste storage practices utilized at the CRL site are summarized here to provide an overview of historic and current waste management storage practices. Historically, low- and intermediate-level wastes have been stored in sand or asphalt-lined below-ground trenches, or below-ground concrete structures. Over the past decade, the move to above-ground, special-purpose buildings has been made for the continued safe storage of historic and current operational wastes or wastes produced from facility decommissioning and environmental restoration activities.

The first emplacement of radioactive waste at the CRL site took place in 1946, into what is now referred to as Waste Management Area (WMA) A. These emplacements took the form of direct disposal of solids and liquids into excavated unlined sand trenches. The scale of operations was modest and largely unrecorded. Early waste storage practices for LLW at CRL were the same as those used in WMA A; namely, emplacement in unlined sand trenches and capped with sandy fill.

Asphalt-lined and capped trenches were used at CRL for solid ILW from 1955 to 1959, when they were superseded by concrete bunkers constructed below grade but above the water table in WMA B. Concrete bunkers were used to store solid waste packages that did not meet sand trench acceptance criteria, nor required a significant amount of shielding. Early concrete bunkers were rectangular in shape. These were superseded in 1977 by cylindrical structures, which are still being used. Over time, the designs of the

storage facilities evolved to provide better protection of the waste from the elements, but the early practices have resulted in some contaminated lands in the vicinity. Monitoring of the facilities and of the local groundwater are conducted to ensure continued safe storage. The affected lands that may are characterized and remediated if required.

Highly radioactive wastes are stored in below-ground, 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.

Waste Management Area C at CRL, a sand trench facility, was established in 1963 to receive LLW with hazardous lifetimes less than 150 years. 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 the 1990s, it was recognized that this facility was approaching its capacity and the modular above-ground storage (MAGS) and the shielded modular above-ground storage (SMAGS) structures were built to provide improved storage capacity for LLW and selected ILW. The MAGS and SMAGS systems signify a substantial change in the way LLW are handled and stored at CRL. The wastes, previously stored in sand trenches, are now stored in a dry, monitored and easily retrievable state in steel containers in above-ground structures [3]. The MAGS structures are prefabricated metal buildings with reinforced concrete floors containing draining and ventilation systems. The SMAGS structures are constructed of prefabricated concrete wall and roof panels, and provide a greater level of radiation shielding. At CRL, a total of two MAGS structures were built and filled, and two SMAGS structures have been built and are in operation. An additional four SMAGS structures are planned to be built at intervals of three to four years, to provide storage capacity for the next 20 to 30 years.

A number of activities are underway to demonstrate that the existing waste inventory is safely stored at AECL's sites. These include extensive environmental monitoring programs, field characterization studies and condition assessments of waste storage structures. With the NLLP, the focus is on reducing the risk and the liability associated with some of the early waste forms and storage practices. Activities pertaining to risk and liability reduction include immobilization of legacy liquid waste, recovery of special waste emplacements and off-site hazardous waste processing. One of the challenges for the program is to ensure that adequate waste storage facilities designed to today's standards are available, to accept the legacy wastes with their unique characteristics.

3. LOW- AND INTERMEDIATE-LEVEL WASTE INVENTORY

The current low- and intermediate-level waste inventory at AECL sites, and the projected inventory in 2100 are shown in Figure 1. The projection is based on the completion of the decommissioning at the current sites, including the CRL site as identified in the Comprehensive Preliminary Decommissioning Plan [4]. As noted in Figure 1, AECL has a significant amount of LLW requiring long-term management, with LLW accounting for approximately 95% of the inventory.

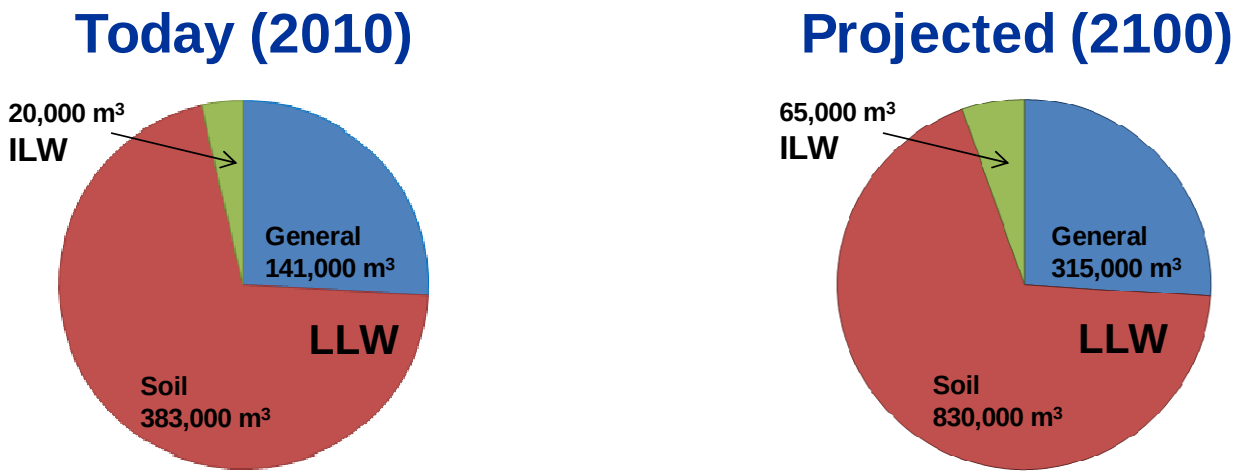

Figure 1: AECL Low-Level and Intermediate-Level Waste Inventory in 2010 and Projected Inventory in 2100

The LLW consists of waste streams that contain low levels of contamination, ranging from wipes to larger pieces of construction debris, generated from both operational and decommissioning activities. In 2010, there was a total of 524,000 m^3 of LLW, in which approximately 75% was contaminated soil, stored at AECL's sites. The projected LLW volume accumulated in 2100, including all the decommissioning waste, is approximately 1,146,000 m^3. It should be noted that the waste volumes for 2100 are current estimates; refinement of these values are expected when waste sources are better understood and volume reduction techniques are selected and employed.

The makeup of the ILW inventory includes:

- Current and future by-products of isotope production processes generated in the hot cells, excluding fuel pieces and dissolved fuel rod cementation waste;
- Used reactor parts and components associated with reactor operations, excluding fuel rods;
- Spent ion-exchange resins;
- The immobilization of concentrated liquid waste in bitumen from the operations of the Waste Treatment Centre (WTC);
- Stabilization and immobilization of historic liquid wastes;
- Portions of future waste streams generated from the remediation (excavation) of waste management areas and contaminated land; and
- Portions of waste streams from decommissioning of on-site facilities.

There was approximately 20,000 m^3 of ILW stored at AECL's sites as of 2010, and the projected volume in 2100 is approximately 65,000 m^3 after full decommissioning. Some of the ILW streams, such as spent resins and cemented isotope processing waste, will require processing before they can be packaged for long-term management.

4. WASTE MANAGEMENT PROGRAM

In 2007, AECL implemented a formal Waste Management Program. The Waste Management Program establishes requirements for waste management activities with the following objectives [5]:

- Improving waste management practices throughout the waste management life-cycle from waste generation to final waste disposition, through effective implementation of improvement initiatives;
- Assisting waste generators to achieve a reduction of the waste generated and improve reuse and recycle in support of AECL's Environment Policy; and
- Providing waste management oversight to ensure that all regulatory and site licence requirements are complied with.

During program implementation, close collaboration between the Waste Management Program and other departments resulted in improved waste management performance. This included increased segregation of the waste at the source, reduction in waste generation, improved labeling and identification of waste packages, improved recyclables collection, initiating recycling of selected hazardous wastes and ensuring that a waste management plan is prepared to address the materials to be generated by any identified activity.

As a result of Waste Management Program initiatives, including training, employees are more aware of the wastes they generate, and practice waste segregation and minimization in their facilities and activities. As a result, for example, CRL has achieved a significant waste volume reduction in the last three years.

Two key activities that support the Waste Management Program's objectives are waste characterization and waste processing. Both of these activities have been significantly enhanced in the past few years. Waste characterization is a key element in waste management and ensures that the waste is managed in accordance with regulatory requirements and waste acceptance criteria of the waste management facilities. Improvement in the waste characterization capabilities has resulted in improved waste segregation. For example, through appropriate analysis some wastes can now be cleared for recycle or disposed in a conventional landfill [5].

With good waste characterization, appropriate waste processing can be selected and implemented to minimize the volume of waste that requires long-term management or to convert the waste into a stable waste form. The processing of the likely-clean concrete at CRL for clearance monitoring and reuse on-site is a good example that links waste characterization, processing and reuse together [6].

AECL continues to implement various practices to provide a better understanding of the waste, either those already in storage, or those being generated as a result of the facility decommissioning activities, through waste characterization. With this improved knowledge, waste processing or volume reduction technologies can be selected to ensure that the best integrated solution for the wastes being produced is implemented.

An important initiative is to make waste minimization and management of radioactive waste an operational priority. In the past, waste management was not always considered in the design of new facilities or new operating practices, and the opportunities for waste minimization were often missed. Processes are being implemented to help ensure waste management considerations are fully integrated into the design of new facilities or new operating practices. Waste management will also become an integral part of project risk and cost assessments and not dealt with on its own, but rather as one component of the integrated view of protecting workers, the environment and the public.

5. INTEGRATED WASTE PLAN

An important element of the NLLP, described in Section 1, is the development of an Integrated Waste Plan (IWP) to ensure optimal selection of enabling facilities, and their implementation schedules, to address the current waste inventory and future wastes from both AECL's operational and decommissioning activities. Other countries such as the United Kingdom have also developed integrated waste plans for decommissioning sites. Because of the complexity of the CRL site itself and the need to integrate all AECL sites into the plan, an iterative phased approach has been adopted for the development of the IWP. The IWP remains an interim IWP until all gaps identified with respect to the wastes' life cycle have been resolved.

The end result of completing this iterative process is a comprehensive document that includes:

- An overall summary of the waste management outlook for AECL;
- Details of all the waste required to be managed, including quantities and generation rates;
- Detailed waste stream pathway maps of the life-cycle for each waste stream from pre-generation planning to final disposition;
- A list of necessary and optimized enabling facilities and schedules for implementation; and
- Cost contingency plans for strategies with high levels of risk.

6. LONG-TERM WASTE MANAGEMENT

AECL's waste management strategy consists of selecting and implementing waste prevention, segregation, processing, storage and disposal options that will ensure the safety of current and future generations, protect the environment, and reduce the life-cycle costs of managing the wastes. The strategy is focused on implementing internationally accepted best practices, establishing a long-term waste management capability, and implementing guidance received from the Government of Canada.

AECL has begun assessing options for the long-term management of low- and intermediate-level wastes. The wide variety and complexity of the waste inventory has resulted in a reference strategy that includes three options: 1) in-situ disposal, 2) a Very Low-Level Waste (VLLW) facility, and 3) a Geologic Waste Management Facility (GWMF). Assessments, feasibility studies and/or pre-project planning for these options are in progress.

In-situ disposal is recognized as one of the options for the disposition of the nuclear liabilities associated with the WMAs. For the WMAs that have only low levels of contamination with relatively short timelines for decay to clearable levels, in-situ disposal with some technical upgrades, such as covers or interventions as necessary, is a viable long-term management method. AECL's approach will assess the extent to which in-situ disposal can be utilized and to develop each case on the basis of protecting health, safety and the environment, as well as a demonstration of regulatory compliance.

Significant cost savings in long-term waste management at CRL could be achieved by constructing a VLLW facility, similar to those operated in France and Spain, to receive large volumes of VLLW wastes. These wastes include soil, concrete, vegetation, asphalt and/or building materials/rubble that are being generated by NLLP infrastructure decommissioning and environmental remediation projects and activities. Project planning and development activities have been initiated.

In 2006, an investigation was initiated to assess the feasibility of the bedrock at the CRL site to host a proposed GWMF as a final enabling facility for the long-term management of low- and intermediate-level solid radioactive waste at the site. The feasibility study involved exploring the geoscience and engineering characteristics of the proposed bedrock and the drilling and testing of characterization boreholes. The

collected information and interpretations were then used to construct three-dimensional deterministic computer models of the geology of the site and the associated groundwater-flow regime. The results of the feasibility study are currently under review by various parties to assist in the decision-making process for moving the long-term management strategy for low- and intermediate-level wastes forward [7].

Based on the As Low As Reasonably Practicable (ALARP) principle, it is a good practice to assess whether or not waste currently being put into storage will need to be processed or re-packaged for long-term management. AECL is developing preliminary Waste Acceptance Criteria (WAC) for the proposed long-term waste management facilities so that the waste characterization and packaging for stored waste will be sufficient for those proposed facilities.

AECL will continue to operate a multi-mission nuclear site for many decades to come, while planning ahead to accommodate the wastes from the decommissioning activities of its various sites. It is important to have an integrated view of the site end-state for refining the long-term waste management strategy. While an end-state is outlined in the preliminary decommissioning plan for the CRL site [4], public input and consideration of technical feasibility, cost effectiveness, environmental and social factors, government policy, etc., can impact the definition of this end-state. The plans for infrastructure decommissioning, environmental restoration and ultimately the long–term management of wastes need to be integrated into the end-state vision. The development of these plans will be iterative. For example, decisions on in-situ disposal and a VLLW facility on the CRL site could define how the environmental restoration would be carried out, and what area of lands could be released for unrestricted reuse. Moreover, public input may lead to other considerations and decisions. The long-term management options and determination of the site end-state vision are included in the planned public participation framework that is under development for the implementation of the NLLP over the coming few years.

7. SUMMARY

AECL has implemented a formal Waste Management Program that is driving continuous improvement in waste management. Various initiatives are underway to improve current and future waste management operations by reducing the volume of waste to be managed, through prevention, reduction, reuse and recycle, and through waste decontamination and segregation practices.

An Integrated Waste Plan has been developed to consolidate all waste management information in one document showing the interactions between waste types, facilities, and program requirements. AECL continues to provide information to the public to promote a good understanding of the waste inventories and their characteristics, and will engage public input for a well-defined end-state of the decommissioned sites.

With the Government of Canada funded NLLP in place over the past few years, AECL has made significant progress addressing some long-standing challenges around waste storage and the decommissioning of AECL's nuclear sites.

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