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INVENTORY OF Radioactive Waste in Canada

Low-Level Radioactive Waste Management Office

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A report prepared for the
Low-Level Radioactive Waste Management Office
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EXECUTIVE SUMMARY

This report presents the inventory of radioactive waste in Canada to the end of 1998. It is intended to provide a comprehensive review on the production, accumulation and future projections of radioactive waste in Canada. The data presented in this report have been gathered from a waste management database maintained by the Low-Level Radioactive Waste Management Office (LLRWMO) and from other sources, namely, Atomic Energy Control Board (AECB) documents, published reports and supplemental information provided by waste producers and owners.

Radioactive waste has been produced in Canada since the early 1930s when the first uranium mine began operating at Port Radium in the Northwest Territories. Radium was refined for medical use and uranium was later processed at Port Hope, Ontario. Research and development on the application of nuclear energy to produce electricity began in the 1940s at the Chalk River Laboratories (CRL) of Atomic Energy of Canada Limited (AECL). At present, radioactive waste is generated in Canada from: uranium mining, milling, refining and conversion; nuclear fuel fabrication; nuclear reactor operations; nuclear research; and radioisotope manufacture and use.

Radioactive waste is grouped into three categories: nuclear fuel waste, low-level radioactive waste, and uranium mine and mill tailings.

In accordance with the Radioactive Waste Policy Framework, the producers and owners of radioactive waste are responsible for the funding, organization, management and operation of disposal and other facilities required for their waste. The policy recognizes that arrangements may be different for each of the three waste categories.

Radioactive waste is currently managed in a safe and environmentally responsible manner by storing the waste away from the public and isolating it from the environment, in accordance with the requirements set out by the AECB, Canada's independent nuclear regulator.

The following table presents a summary of the quantity of radioactive waste produced in 1998 and the cumulative inventory to the end of 1998.

Waste Data to 1998

Nuclear Fuel Waste	320 m^3	5,600 m^3
Low-Level Radioactive Waste	4,300 m^3	1.8 million m^3
Uranium Mine and Mill Tailings	1 million tonnes	210 million tonnes

In order to assess the future requirements for the management of radioactive waste, a projection of the inventory to the end of 1999 and 2035 is also provided in the table below. The year 2035 is selected as a future reference because it corresponds approximately to the forecasted end of operation for the last power reactor (Darlington Generating Station).

Waste Inventory Projections to 1999 and 2035

Waste Category	Waste Inventory to End of 1999	Waste Inventory to End of 2035
Nuclear Fuel Waste	5,900 m^3	14,500 m^3
Low-Level Radioactive Waste	1.8 million m^3	2.1 million m^3
Uranium Mine and Mill Tailings	211 million tonnes	248 million tonnes

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1.0 INTRODUCTION

This report provides the annual accumulation rate and inventory of radioactive waste in Canada to the end of 1998.

Radioactive wastes have been produced in Canada since the early 1930s when the first uranium mine in Canada began operating at Port Radium in the Northwest Territories. Radium was refined for medical use and uranium was later processed at Port Hope, Ontario. Research and development on the application of nuclear energy to produce electricity began in the 1940s at the Chalk River Laboratories (CRL) of Atomic Energy of Canada Limited (AECL).

At present, radioactive waste is generated in Canada from: uranium mining, milling, refining and conversion; nuclear fuel fabrication; nuclear reactor operations; nuclear research; and radioisotope manufacture and use.

In accordance with the Radioactive Waste Policy Framework, the producers and owners of radioactive waste are responsible for the funding, organization, management, and operation of disposal and other facilities required for their waste. The policy recognizes that arrangements may be different for each of the waste categories.

Radioactive waste is currently managed in a safe and environmentally responsible manner by storing the waste away from the public and isolating it from the environment. The management of these wastes meets the requirements of the Atomic Energy Control Board (AECB), Canada's independent nuclear regulator.

2.0 REPORT OBJECTIVE

The objective of the report is to:

- provide a comprehensive review on the production, accumulation and future projections of radioactive waste in Canada.

3.0 REPORT SCOPE AND ORGANIZATION

The scope of the report includes radioactive waste of the following three categories generated from the peaceful applications of nuclear energy:

- nuclear fuel waste;
- low-level radioactive waste; and
- uranium mine and mill tailings.

Data on radioactive waste inventory is based on existing information in a waste management database maintained by the Low-Level Radioactive Waste Management Office (LLRWMO), regulatory documents, published reports and supplemental information provided by the regulatory agency, waste generators and waste management facilities. Regulatory documents include: annual or quarterly compliance reports, annual safety reviews and decommissioning reports submitted to the AECB.

Section 4 of this report describes the sources and producers of each of the three categories of radioactive waste. Section 5 summarizes the accumulation rates during 1998 and waste inventory to the end of 1998. Section 6 presents future projections for each of the three categories of waste to 1999 and 2035. Section 7 summarizes current and future inventories.

Appendix A provides the federal policy framework for radioactive waste.

4.0 SOURCES

This section briefly identifies how radioactive waste is produced, where it is located and the producers and owners of the waste. Figure 4.1 provides a map showing where radioactive waste is currently located.

4.1 Nuclear Fuel Waste

Nuclear fuel waste refers to the nuclear fuel bundles discharged from:

- the CANDU power reactors;
- prototype and demonstration power reactors; and
- research and isotope production reactors.

Nuclear fuel wastes are removed from the reactor and stored in water-filled pools at the reactor site. After a number of years in the pools, nuclear fuel waste may be transferred to storage containers for on-site dry storage until a permanent disposal facility becomes available.

There are 22 power reactors in Canada owned by three provincial electric utilities. Ontario Hydro owns 20 reactors while Hydro-Québec and New Brunswick Power each own one reactor. These 22 reactors have a total generation capacity of 15,000 megawatts of electricity.

As of 1998 December 31, 14 nuclear reactors were operating, producing 13% of the electricity in Canada. Nuclear power accounted for 44% of electricity generation in Ontario.

Ontario Hydro has 12 reactors in operation; eight reactors are in extended shutdown mode. The two reactors owned by Hydro-Québec and New Brunswick Power are operational. Depending on economic and market conditions, Ontario Hydro plans to bring all laid up reactors back into service in the 2000-2009 time frame. In late 1998, Ontario Hydro announced plans to provide services under three independent successor companies, effective from 1999 April 01.

There are three prototype or demonstration power reactors located at Douglas Point and Rolphton, Ontario, and Gentilly, Quebec. Each of these facilities have been partially

PULL OUT FIGURE 4.1 HERE

decommissioned and are in Phase 2 decommissioning (storage-with-surveillance). Nuclear fuel waste from the Douglas Point and Gentilly-1 reactors is in dry storage at the on-site waste management facilities. Nuclear fuel waste from the Nuclear Power Demonstration (NPD) reactor at Rolphton was transferred to a waste management facility at AECL's Chalk River Laboratories (AECL-CRL).

There is also a small amount of nuclear fuel waste produced by the research and radioisotope production reactors at AECL and research reactors at universities.

Nuclear fuel wastes from power reactors are currently stored in pools and/or dry storage containers in waste management facilities at each of the operating power reactor sites. Table 4.1 lists power reactors operating under AECB licences and Table 4.2 lists research reactors operating under AECB licences.. Figure 4.2 shows the location of these reactors.

Table 4.1: Summary of AECB Power Reactor Operating Licences

Facility and Location	Licensee	Type and Number of Units/Capacity
Pickering Generating Station A, Pickering, Ontario	Ontario Hydro	CANDU-PHW 4 x 500 MW(e)
Pickering Generating Station B, Pickering, Ontario	Ontario Hydro	CANDU-PHW 4 x 500 MW(e)
Bruce Generating Station A, Tiverton, Ontario	Ontario Hydro	CANDU-PHW 4 x 750 MW(e)
Bruce Generating Station B, Tiverton, Ontario	Ontario Hydro	CANDU-PHW 4 x 840 MW(e)
Darlington Generating Station, Bowmanville, Ontario	Ontario Hydro	CANDU-PHW 4 x 850 MW(e)
Gentilly-2 Nuclear Power Station, Gentilly, Quebec	Hydro-Québec	CANDU-PHW 600 MW(e)
Point Lepreau Generating Station, Point Lepreau, New Brunswick	New Brunswick Power Corporation	CANDU-PHW 600 MW(e)

MW(e) - megawatt (nominal electrical power output)
Source: *AECB Annual Report 1998-99*, Annex V, 1999 March 31.
Notes:
- Nuclear fuel waste from these reactors is stored at the respective sites.
- Nuclear fuel waste from the two partially decommissioned stations, Gentilly-1 and Douglas Point, is stored at those two sites, respectively.

Figure 4.2: Nuclear Reactor Sites

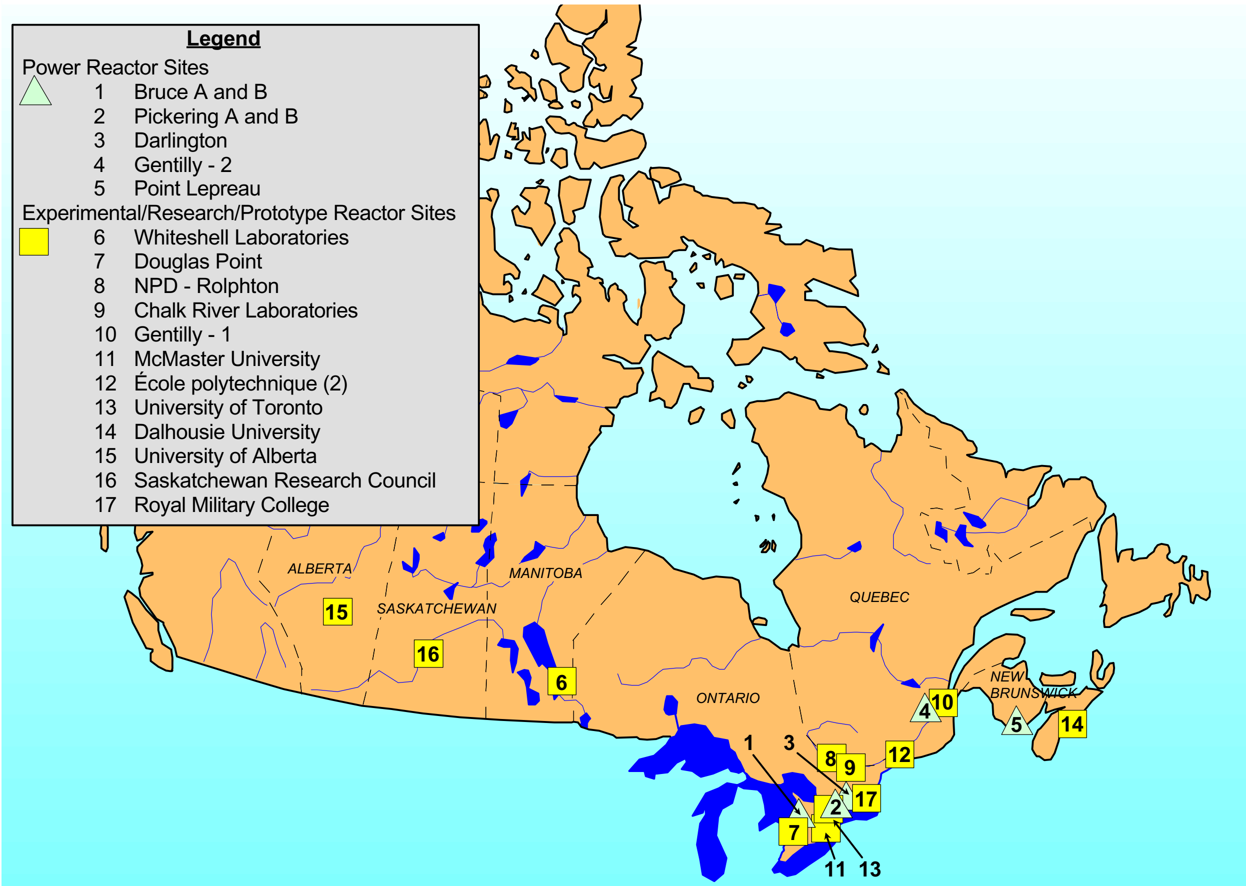


Table 4.2: Summary of AECB Research Reactor Operating Licences

Location	Licensee	Type and Capacity
Hamilton, Ontario	McMaster University	Pool-type 5 MW(t)
Montréal, Quebec	École polytechnique	Subcritical Assembly
Toronto, Ontario	University of Toronto	SLOWPOKE-2 20 kW(t)
Montréal, Quebec	École polytechnique	SLOWPOKE-2 20 kW(t)
Halifax, Nova Scotia	Dalhousie University	SLOWPOKE-2 20 kW(t)
Edmonton, Alberta	University of Alberta	SLOWPOKE-2 20 kW(t)
Saskatoon, Saskatchewan	Saskatchewan Research Council	SLOWPOKE-2 20 kW(t)
Kingston, Ontario	Royal Military College of Canada	SLOWPOKE-2 20 kW(t)

MW(t) - megawatt (thermal power)
kW(t) - kilowatt (thermal power)
Source: *AECB Annual Report 1998-99*, Annex VI, 1999 March 31.
Note: In addition to the above reactors, reactors for research and radioisotope production at AECL-CRL are operating under AECB licences issued for the AECL-CRL site.

4.2 Low-Level Radioactive Waste

Low-level radioactive waste (LLRW) includes all LLRW arising from the activities associated with nuclear electricity generation, from nuclear research and development, and from the production and use of radioisotopes in medicine, education, research, agriculture and industry. Examples of LLRW are contaminated materials, rags and protective clothing. LLRW is grouped into two broad categories, as follows:

- *Ongoing Waste:* LLRW that is generated from ongoing activities of companies that are currently in business, for example, nuclear electricity generators. Owners or producers of ongoing waste are responsible for its management.

- *Historic Waste:* LLRW that was managed in the past in a manner no longer considered acceptable but for which the original producer cannot reasonably be held responsible. The federal government has accepted responsibility for this waste.

4.2.1 Ongoing Waste

Ongoing waste results from operation, maintenance and decommissioning of facilities related to:

- the nuclear fuel cycle;
- nuclear research and development; and
- production and use of radioisotopes.

4.2.1.1 Operations

Nuclear Fuel Cycle

The nuclear fuel cycle includes uranium refining and conversion, nuclear fuel fabrication and nuclear power reactor operations. During refining, the ore concentrate from uranium milling operations is upgraded to uranium trioxide. The uranium trioxide is converted to ceramic grade uranium dioxide for fabrication into fuel for CANDU reactors, or processed into uranium hexafluoride for foreign light water reactors. Approximately one quarter of the uranium mined in Canada is used for domestic nuclear electricity production. Cameco Corporation operates Canada's only refinery facility at Blind River, Ontario, and conversion facility at Port Hope, Ontario. Earth Sciences Extraction Company in Calgary, Alberta, has an operating licence to recover high-grade uranium from fertilizer-grade phosphoric acid. The plant was shut down in 1987, partially decommissioned and no longer produces uranium.

During fuel fabrication, uranium dioxide is formed into pellets, sintered and sheathed in zirconium to form fuel bundles for power reactors. General Electric Canada Incorporated and Zircatec Precision Industries Incorporated are the only fuel fabricators in Canada. General Electric Canada produces fuel pellets and fuel bundles at facilities in Toronto and Peterborough, Ontario, respectively. Zircatec Precision Industries produces both pellets and bundles at a facility in Port

Hope, Ontario. Table 4.3 provides a list of AECB licensees involved in uranium refining, conversion and fuel fabrication activities.

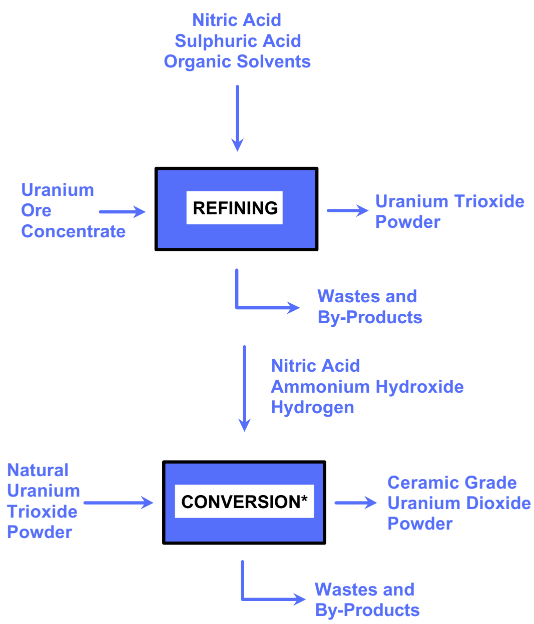
Table 4.3: Uranium Refinery, Conversion Facility and Fuel Fabrication Plant Licences

Licensee and Location	Licensed Activity
General Electric Canada Incorporated, Toronto, Ontario	Fuel Pellets
General Electric Canada Incorporated, Peterborough, Ontario	Fuel Bundles
Earth Sciences Extraction Company, Calgary, Alberta	Uranium Oxide
Cameco Corporation, Blind River, Ontario	Uranium Trioxide
Cameco Corporation, Port Hope, Ontario	Uranium Hexafluoride Natural and Depleted Uranium Metal and Alloys Uranium Dioxide Ammonium Diuranate
Zircatec Precision Industries Incorporated, Port Hope, Ontario	Fuel Pellets and Bundles

Source: *AECB Annual Report 1998-99*, Annex IX, 1999 March 31.

Figure 4.3 summarizes the input and output streams and LLRW resulting from the refining and conversion of uranium. Figure 4.4 shows the process and LLRW associated with nuclear fuel fabrication and fuel bundle production.

Figure 4.3: Process Flowchart for Uranium Refining and Conversion



BY-PRODUCTS
Ammonium Nitrate Fertilizer
Raffinates (recycled)

WASTES

Combustible Wastes
Uncontaminated and contaminated scrap lumber, pallets, rags, paper, cardboard, rubber and plastic

Organic Liquid Wastes

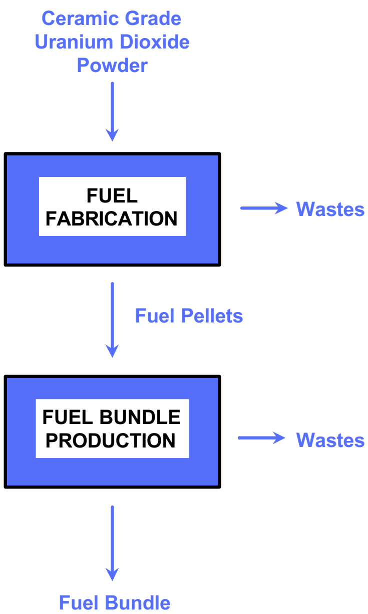
Non-Combustible Wastes
Uncontaminated insulation, pipe-racks, light bulbs, metal turnings, paint cans, cell gaskets, concrete, glass.

Contaminated air filters, fibreglass, PVC ductwork, floor sweepings, sandblast sand, insulation, sample bottles, scrap metal, anodes

Recyclable scrap metal

* In addition to ceramic grade uranium dioxide powder for CANDU reactors, CAMECO also produces uranium hexafluoride for light water reactors.

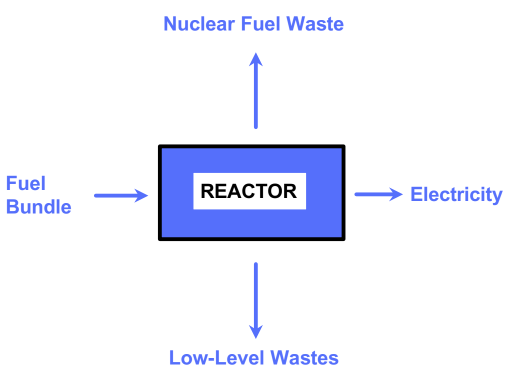
Figure 4.4: Process Flowchart for Nuclear Fuel Fabrication



WASTES
Contaminated soils
Contaminated rags, paper, gloves
Contaminated oils and oil sludges
Contaminated equipment and construction materials
FIlters and dust collectors

Figure 4.5 summarizes the input and output streams and LLRW produced from reactor operations. Wastes include natural uranium, neutron activation or fission products. Both solid and liquid wastes are produced.

Figure 4.5: Process Flowchart for CANDU Reactor Operations



LOW-LEVEL WASTES
Incinerable Wastes
Paper, plastic, rubber, cotton, wood, organic liquids

Compactible Waste
Paper, plastic PVC suits, rubber, fibreglass, metal pieces, empty drums

Non-Processable Waste
Filters, light bulbs cable, used equipment, metals construction debris, absorbents (sand, vermiculite, sweeping compound), ion exchange resins, reactor core components, retube wastes

Processable Liquids
Active drain wastes, chemical cleaning solutions

Table 4.4 provides a list of LLRW management facilities licensed by the AECB.

Table 4.4: Summary of AECB Waste Management Licences

Facility and Location	Licensee
Radioactive Waste Operations Site 1, Bruce Nuclear Power Development, Tiverton, Ontario	Ontario Hydro
Radioactive Waste Operations Site 2, Bruce Nuclear Power Development, Tiverton, Ontario	Ontario Hydro
Central Maintenance Facility, Bruce Nuclear Power Development, Tiverton, Ontario	Ontario Hydro
Pickering Used Fuel Dry Storage Facility, Pickering, Ontario*	Ontario Hydro
Point Lepreau Solid Radioactive Waste Management Facility, Point Lepreau, New Brunswick*	New Brunswick Power
Gentilly-2 Radioactive Waste Management Facility, Gentilly, Quebec*	Hydro-Québec
Douglas Point Radioactive Waste Storage Facility, Douglas Point, Ontario*	AECL
Gentilly 1 Radioactive Waste Storage Facility, Gentilly, Quebec*	AECL
NPD Waste Management Facility, Rolphton, Ontario	AECL
Port Hope, Ontario	AECL
Pine Street Extension, Port Hope, Ontario	AECL
Various Locations	AECL
Port Granby Waste Management Facility, Newcastle, Ontario	Cameco
Welcome Waste Management Facility, Hope Township, Ontario	Cameco
Toronto, Ontario	University of Toronto
Edmonton, Alberta	University of Alberta
Saskatoon, Saskatchewan	University of Saskatchewan
Mississauga, Ontario	Monserco

Source: *AECB Annual Report 1998-99*, Annex X, 1999 March 31.

Notes:
- All of these facilities store or manage LLRW; those marked with an asterisk (*) also have dry storage facilities for nuclear fuel waste.
- In addition to the above facilities, waste produced or owned by AECL is stored at licensed waste management facilities at AECL-CRL and AECL-WL.

Nuclear Research and Development

AECL has research facilities at Chalk River, Ontario, and Pinawa, Manitoba, which are licenced by the AECB. Operational wastes produced at these two sites are stored in waste management facilities at each site. The Chalk River facility (AECL-CRL) has two operating reactors, the NRU reactor and the zero power ZED-2 reactor. Research and development activities at AECL-CRL include the application of nuclear science, reactor development, environmental science and LLRW management.

AECL-CRL also produces radioisotopes for MDS Nordion. At present, development work is continuing on the MDS Nordion Medical Isotope Reactor (MMIR) Project. The MMIR project will consist of two 10 MW MAPLE reactors and a new radioisotope processing facility, which is scheduled to be in service in 1999-2000. The reactors will be built and operated by AECL, on behalf of MDS Nordion.

Research work at Whiteshell Laboratories in Pinawa (AECL-WL) is primarily related to disposal of nuclear fuel waste, environmental sciences and reactor development. Operations at AECL-WL have been significantly reduced in recent years. The nuclear fuel waste disposal program is now fully funded by Ontario Hydro. The WR-1 reactor has been partially decommissioned and the SLOWPOKE Demonstration Reactor has been fully decommissioned.

Some of AECL's waste management sites, which began operation during the early years of nuclear research and development in Canada, will require remediation or decommissioning in the future. These sites are managed safely by AECL under AECB licences. The wastes include both the original wastes stored at the sites and any soils contaminated by the wastes. These wastes were generated by AECL during research and development work associated with the development of CANDU reactors, the advancement of nuclear science and the production of radioisotopes.

There are also eight research reactor operating licences issued by the AECB (see Table 4.2). Six of these are for SLOWPOKE-2 reactors. These reactors are used for neutron activation analyses and other nuclear research. Operation of these research reactors produces a small amount of LLRW compared with the power reactor sites. Waste from these sites is sent to AECL-CRL for disposal.

Production and Use of Radioisotopes

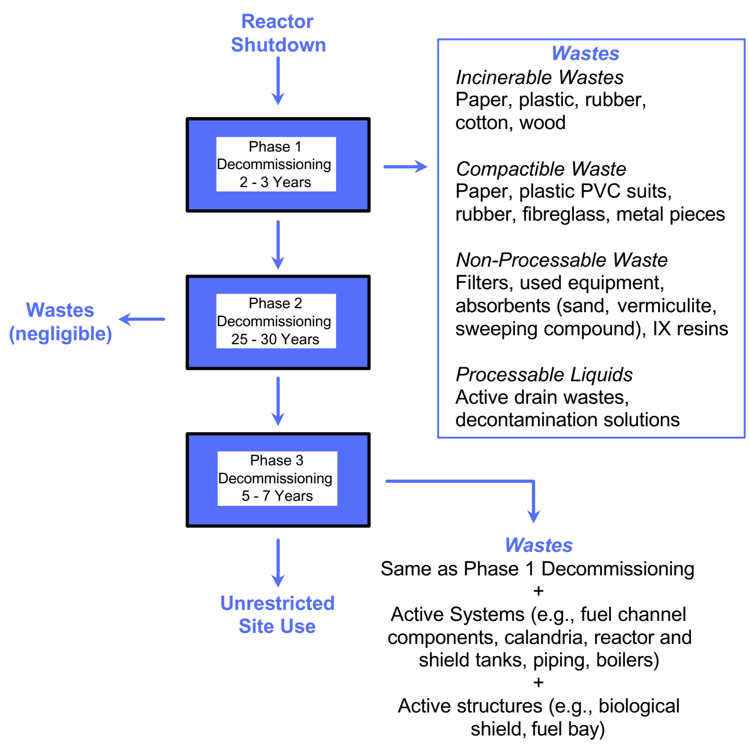
Radioisotopes, as sealed or unsealed sources, have industrial, medical and educational applications. Radioisotopes are marketed in Canada primarily by MDS Nordion, as noted above. Ontario Hydro, Hydro-Québec and AECL produce radioisotopes that are shipped to MDS Nordion for further processing, packaging and distribution to secondary manufacturers, repackagers or clients. Wastes that are generated during production are managed by the respective producers.

When radioisotopes have outlived their useful application, they become radioactive waste. These wastes (or spent sources) are shipped to AECL-CRL for disposal.

4.2.1.2 Decommissioning

Wastes are also generated when nuclear facilities are decommissioned, (i.e. decontaminated and dismantled) at the end of their operational life (see Figure 4.6). Consideration must be given to the health and safety of workers and the public, and to protection of the environment, during decommissioning. Most decommissioning waste will be generated in the future although some inventory already exists from small decommissioning projects completed to date.

Figure 4.6: Process Flowchart for CANDU Reactor Decommissioning



The most significant quantities of wastes will result from the decommissioning of nuclear reactors and their supporting facilities. Wastes will range from highly radioactive materials associated with the reactor core to other building components and materials contaminated during reactor operations.

Based on current plans submitted to the AECB, power reactors will be decommissioned in three phases as summarized in Figure 4.6. Spent fuel will be removed from the reactor core prior to decommissioning. Phase 1 (preparation for storage-with-surveillance) will begin soon after reactor shutdown and last for about three to four years. The purpose of Phase 1 is to isolate and stabilize the remaining reactor components for a long-term storage period to allow sufficient time for most of the radioactivity to decay to a level at which the waste can be released without hazards. Phase

1 decommissioning is expected to produce several hundred cubic metres of LLRW per reactor. Phase 2 (storage-with-surveillance) will last approximately 25 to 30 years. A very small amount of waste is generated during Phase 2. Phase 3 (dismantling) is expected to last about five to ten years. Phase 3 will generate the majority of radioactive waste. At the end of Phase 3, the site should be suitable for unrestricted use.

4.2.2 Historic Waste

The LLRWMO is the federal government's agent for the cleanup and long-term management of historic waste.

There are several large historic waste sites as well as numerous smaller sites throughout Canada. At many of the sites, materials have been placed in interim storage pending disposal. Ongoing site monitoring, inspection and maintenance are conducted at these sites.

Wastes at some of these sites include artifacts or surficially contaminated building materials. Other sites contain large volumes of radium-contaminated soils with low radioactivity. Contaminated soils from cleanups at small sites, and contaminated artifacts and building materials from larger sites only, are removed to the LLRWMO storage buildings at AECL-CRL. Larger volumes of contaminated soils that cannot be accommodated at the LLRWMO storage buildings are managed at or near the source (see the following).

Town of Port Hope, Ontario

Historic waste is present in various areas in the Town of Port Hope, Ontario. The waste dates back to the 1930s when radium was refined for medical applications at a refinery in the town. The waste is primarily soil contaminated with material from the refinery. The LLRWMO is responsible for the monitoring and safe management of the waste at these sites.

Welcome and Port Granby, Ontario

LLRW is located at the Welcome Waste Management Facility (closed in 1955) in Hope Township and the Port Granby Waste Management Facility (closed in 1988) in the Municipality of Clarington. While Cameco Corporation (formerly Eldorado Nuclear Limited, a federal Crown corporation) owns the waste at both sites, Cameco and the federal government share financial responsibility for capital and extraordinary operating costs, including decommissioning costs, associated with the management of the waste at these facilities.

Other Locations

Historic waste is stored at various other locations across Canada. The LLRWMO is responsible for the cleanup and the long-term management of the waste at these sites.

4.3 Uranium Mine and Mill Tailings

Uranium mine and mill tailings are a specific type of LLRW that are generated during the mining and milling of uranium ore and production of uranium concentrate. Uranium ore concentrate is used to make fuel for Canadian and foreign power reactors. Tailings are usually placed in containment areas such as lakes, valleys or pits close to the mine or mill site. Some tailings may be used as backfill in the underground or open pit mine.

Owing to the large volumes, tailings sites are usually decommissioned in place. Decommissioning of surface tailings sites usually includes improvement or construction of dams to provide long-term containment, flooding or covering of tailings to reduce acid generation and the release of gamma radiation and radon gas, and management/monitoring of tailings and effluent.

At some of the newer operations in Saskatchewan, tailings will be managed in an open pit with a coarse pervious surround or perimeter that will be dewatered during operation of the site. When decommissioned, the pit will be covered and allowed to flood. The pervious surround will channel groundwater flow around the emplaced tailings in the pit rather than through them.

Uranium tailings exist at operating uranium mine and mill sites in northern Saskatchewan and at inactive or decommissioned sites in Saskatchewan, Ontario and the Northwest Territories. Table 4.5 provides a list of uranium mine and mill facilities licensed by the AECB. Figure 4.7 shows the locations of uranium mining and milling projects in Canada. Figures 4.8 and 4.9 show the locations of mines and tailings sites in the Elliot Lake and Bancroft areas in Ontario.

4.3.1 Operating Sites

Operating sites with active tailings management areas include Cluff Lake, operated by Cogema Resources Inc., and Key Lake and Rabbit Lake, both operated by Cameco Corporation in Saskatchewan.

The Cluff Lake mine site has been operating since 1980 and includes four mined-out open pits and two ongoing underground mines. Operations are projected to continue until year 2000. Tailings have been managed in a surface facility in the Mill Creek Valley since 1983.

The Key Lake mine site has been operating since 1984 and the last ore was mined from the Deilmann Open Pit in 1997. Tailings at the Key Lake site were deposited in a surface tailings management area until late 1995. In December 1995, deposition of tailings was transferred to the Deilmann Tailings Management Facility (TMF). Initial difficulties with the TMF caused a short-term return (January to early February 1996) of the tailings to the management area. Since February 1996, tailings deposition has been maintained at the TMF.

The Rabbit Lake mine site began operating in 1975. Tailings were deposited at a surface tailings management area until 1985 when deposition of tailings into the Rabbit Lake Pit TMF began. Underground mining at the Eagle Point ore zone continues, while open pits have been mined out.

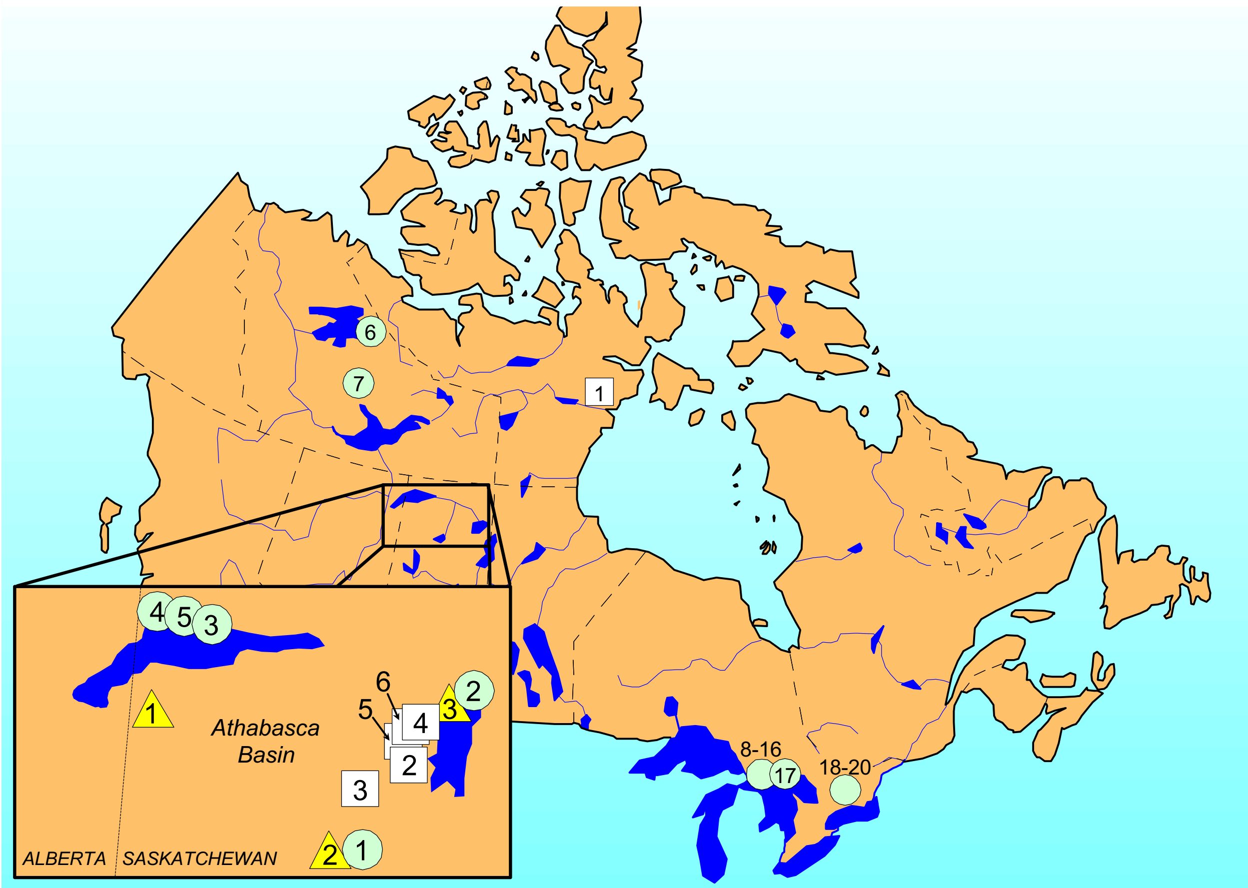
In 1998 November, Cameco announced plans to process a portion of the Cigar Lake ore at the Rabbit Lake site. This plan will extend the operating life of the Rabbit Lake mill and TMF to at least the year 2015.

Table 4.5: Uranium Mine and Mill Facility Licences

Facility and Location	Licensee	Licensed Activity
Cluff Lake, Saskatchewan	Cogema Resources Inc.	Operation
Key Lake Operation, Saskatchewan	Cameco Corporation	Operation
Rabbit Lake Operation, Saskatchewan	Cameco Corporation	Operation
Rayrock, Northwest Territories	Indian and Northern Affairs Canada	Decommissioning
Stanrock Mine, Elliot Lake, Ontario	Denison Mines Limited	Decommissioning
Stanleigh Mine, Elliot Lake, Ontario	Rio Algom Limited	Decommissioning
Beaverlodge Mining Operations, Beaverlodge, Saskatchewan	Cameco Corporation	Decommissioning
Dawn Lake Project, Saskatchewan	Cameco Corporation	Decommissioning
Denison Mine, Elliot Lake, Ontario	Denison Mines Limited	Decommissioning
Dubyna Mine, Uranium City, Saskatchewan	Cameco Corporation	Decommissioning
Panel Mine, Elliot Lake, Ontario	Rio Algom Limited	Decommissioning
Quirke Mine, Elliot Lake, Ontario	Rio Algom Limited	Decommissioning
Madawaska Mine, Bancroft, Ontario	Madawaska Mines Limited	Decommissioning
Kiggavik-Scissons Schultz Baker Lake Area, Northwest Territories	Urangesellschaft Canada Limited	Ore Removal
Cigar Lake Project, Saskatchewan	Cigar Lake Mining Corporation	Underground Exploration
McArthur River Project, Saskatchewan	Cameco Corporation	Construction
Midwest Joint Venture, Saskatchewan	Minatco Limited	Suspended Operation
McClean Lake Project, Saskatchewan	Cogema Resources Inc.	Construction and Operation

Source: *AECB Annual Report 1998-99*, Annex VIII, 1999 March 31.

Figure 4.7: Uranium Mines and Tailings Sites in Canada



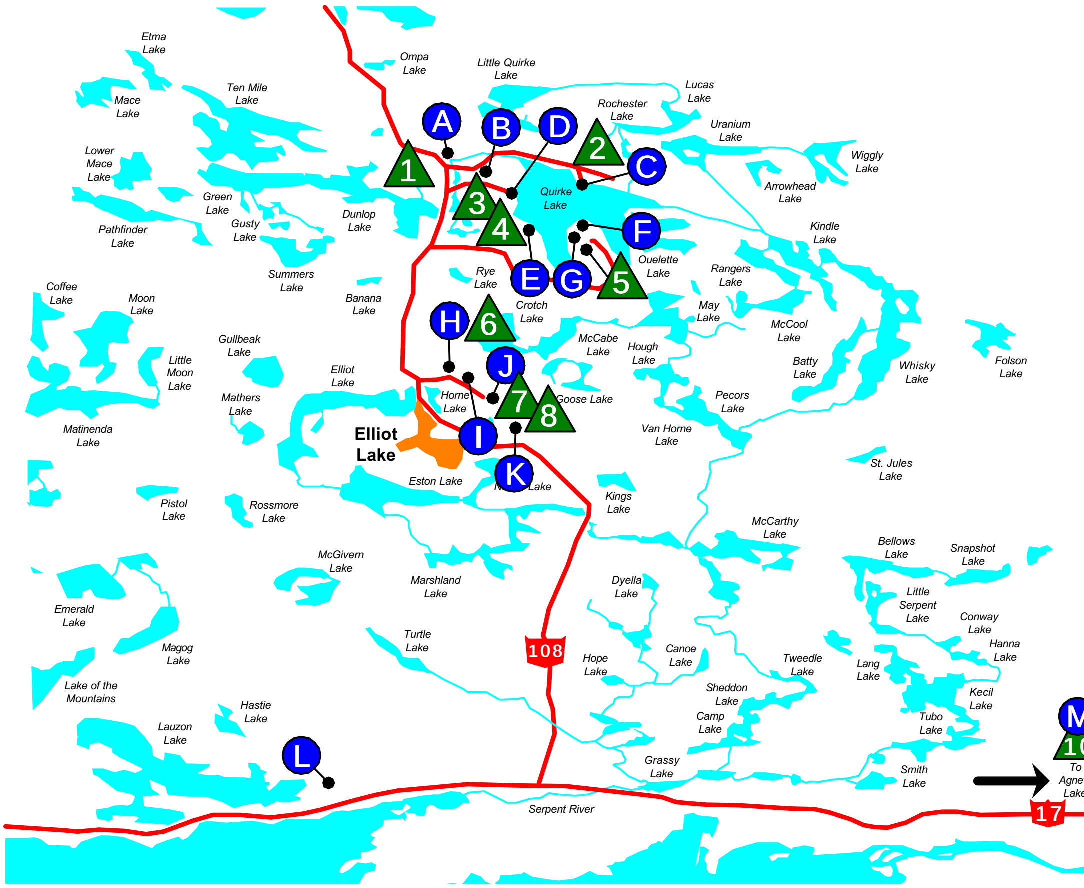
Operating Sites
1 - Cluff Lake
2 - Key Lake
3 - Rabbit Lake

Inactive/Decommissioned Sites
1 - Key Lake   2 - Rabbit Lake
3 - Beaverlodge   4 - Gunnar
5 - Lorado   6 - Port Radium
7 - Rayrock
8 to 16 - Elliot Lake Sites: Quirke, Panel, Denison, Spanish-American, Stanrock, Stanleigh, Lacnor, Nordic, Pronto
17 - Agnew Lake
18 to 20 - Bancroft Sites: Madawaska, Bicroft, Dyno

Development Sites
1 - Kiggavik-Sissons
2 - Cigar Lake
3 - McArthur River
4 - Midwest
5 - McClean Lake
6 - Dawn Lake

Source: *1998 Canadian Minerals Yearbook, Natural Resources Canada*

Figure 4.8: Uranium Mines and Tailings Sites near Elliot Lake, Ontario



MINE/MILL FACILITIES

A - Quirke I	E - Spanish-American	I - Milliken
B - Quirke II	F - CANMET	J - Lacnor
C - Panel	G - Stanrock	K - Nordic
D - Denison	H - Stanleigh	L - Pronto
		M - Agnew Lake

TAILINGS AREAS

1 - Quirke	4 - Spanish-American	7 - Lacnor
2 - Panel	5 - Stanrock	8 - Nordic
3 - Denison	6 - Stanleigh	9 - Pronto
		10 - Agnew Lake

Figure 4.9: Uranium Mines and Tailings Sites near Bancroft, Ontario

4.3.2 Inactive or Decommissioned Sites

In addition to the inactive tailings areas at the operating sites noted in the previous section, there are three inactive uranium sites or areas in Saskatchewan. The Beaverlodge operation was decommissioned in 1985 and is monitored by Cameco. The Lorado and Gunnar sites have been closed since 1960 and 1964, respectively.

There are two inactive uranium sites in the Northwest Territories. The Port Radium site was decommissioned in 1984. The Rayrock site was abandoned in 1959. Indian and Northern Affairs Canada began the decommissioning and rehabilitation of the Rayrock site including capping of the tailings in 1996. Environmental monitoring of long-term performance of the decommissioned Rayrock site began in 1998.

There are nine inactive uranium tailings sites in and around Elliot Lake, Ontario. Rio Algom Ltd. is responsible for seven waste management sites:

i. Quirke 1 and 2, inactive since 1992;
ii. Panel, inactive since 1990;
iii. Spanish-American, inactive since 1959;
iv. Stanleigh, inactive since 1996;
v. Lacnor, inactive since 1960;
vi. Nordic, inactive since 1968; and
vii. Pronto, inactive since 1960.

Denison Mines Limited is responsible for two sites:

i. Denison, inactive since 1992; and
ii. Stanrock, inactive since 1964.

The Agnew Lake Mine north of Espanola, Ontario, was decommissioned by Kerr Addison Mines in the 1980s. The site was turned over to the province in the early 1990s.

Inactive uranium tailings sites in the Bancroft, Ontario, area include Madawaska, Dyno and Bicroft mines. The Madawaska Mine has been inactive since 1983, while operations at the Dyno and Bicroft sites ceased in the early 1960s. AEC West Ltd. has completed decommissioning activities at the Madawaska site. AEC West is also completing rehabilitation activities at the Dyno Mine. Barrick Properties have been carrying out decommissioning activities at the Bicroft Mine.

4.3.3 Development Sites

At the end of 1998, there were six uranium development sites in Saskatchewan and the Northwest Territories, with AECB licences. In 1998, governments agreed with the environmental assessment panel recommendations that the Cigar Lake and the Midwest Lake projects can now advance to the next stage of the regulatory approval process. A similar milestone was reached for the McArthur River project in 1997. At the Kiggavik project, Northwest Territories, and Dawn Lake, Saskatchewan, there was limited exploration activities in 1998.

At the end of 1998, there were no tailings at any of these sites. However, there is some mineralized waste rock or stockpiled ore at the McArthur River and McClean Lake sites.

5.0 CURRENT INVENTORY AND ACCUMULATION RATE

This section summarizes the annual rates of waste accumulation during 1998 and the accumulated waste volumes to the end of 1998.

5.1 Nuclear Fuel Waste

Operation of the CANDU power reactors generates nuclear fuel waste, also known as spent fuel or high-level waste. There is also a small amount of nuclear fuel waste resulting from past operation of nuclear power demonstration reactors, as well as historic and ongoing operation of AECL's research and radioisotope production reactors and research reactors at universities. At present there is no permanent disposal facility for nuclear fuel waste. Nuclear fuel waste is kept in wet or dry storage at the reactor sites and at AECL's waste management facilities at Chalk River, Ontario or Pinawa, Manitoba.

Table 5.1 summarizes the annual accumulation and inventories of nuclear fuel wastes from nuclear power and AECL's prototype/demonstration/research reactors to 1998 December 31. Inventories do not include fuel bundles currently in the reactors.

In 1998, the 14 operating power reactors produced 78,138 bundles of nuclear fuel waste. This represents approximately 313 m^3 of waste based on a volume of 0.004 m^3 for a typical CANDU fuel bundle. The accumulated nuclear fuel waste inventory to the end of 1998 for the power reactors was 1,347,141 bundles or approximately 5,389 m^3 of waste.

Nuclear fuel waste inventory to the end of 1998 for the three shutdown prototype/demonstration reactors (Douglas Point, Gentilly-1 and NPD) remained at 30,322 bundles (121 m^3). The balance of the nuclear fuel waste inventory of 18,236 bundles (73 m^3) comes from the research reactor operations at AECL's Chalk River and Whiteshell facilities.

Figure 5.1 shows the distribution of nuclear fuel waste inventories by major producers. The distribution was approximately Ontario Hydro, 86%; Hydro-Québec, 5%; New Brunswick Power, 6%; and AECL, 3%.

Table 5.1: Nuclear Fuel Waste Accumulation Rate and Inventory, 1998

Site Name	Source Company Name	Nuclear Fuel Waste Generated in 1998		On-Site Waste Inventory to 1998 December 31				Reactor Status as of 1998 December
				Dry Storage	Wet Storage	Total Storage		
		No. of Fuel Bundles/yr	Estimated Volume[c] (m^3/yr)	No. of Fuel Bundles	No. of Fuel Bundles	No. of Fuel Bundles	Estimated Volume[c] (m^3)	
POWER REACTORS								
Bruce A	Ontario Hydro	19,695	79	0	354,567	354,567	1,418	Operational Lay-up
Bruce B	Ontario Hydro	17,602	70	0	275,230	275,230	1,101	Operating
Darlington	Ontario Hydro	21,355	85	0	127,663	127,663	511	Operating
Pickering A and B	Ontario Hydro	11,760	47	32,573	413,422	445,995	1,784	Operational Lay-up of Pickering A only
Gentilly-2	Hydro-Québec	3,898	16	30,000	37,011	67,011	268	Operating
Point Lepreau	NB Power	3,828	15	38,880	37,795	76,675	307	Operating
Subtotal Power Reactors		**78,138**	**313**	**101,453**	**1,245,688**	**1,347,141**	**5,389**	
PROTOTYPE/DEMONSTRATION/RESEARCH REACTORS								
Douglas Point	AECL	0	0	22,256	0	22,256	89	Shutdown and partially Decommissioned
Gentilly-1	AECL	0	0	3,213	0	3,213	13	Shutdown and partially Decommissioned
Chalk River Laboratories[a]	AECL	863	3	20,821	0	20,821	83	Operating
Whiteshell Laboratories[b]	AECL	0	0	2,268	0	2,268	9	Shutdown and being Decommissioned
Subtotal Research Reactors		**863**	**3**	**48,558**	**0**	**48,558**	**194**	
Total		**79,001**	**316**	**150,011**	**1,245,688**	**1,395,699**	**5,583**	

Source: 1998 inventory and generation rates from *AECB Reporter*, 1999 Spring.

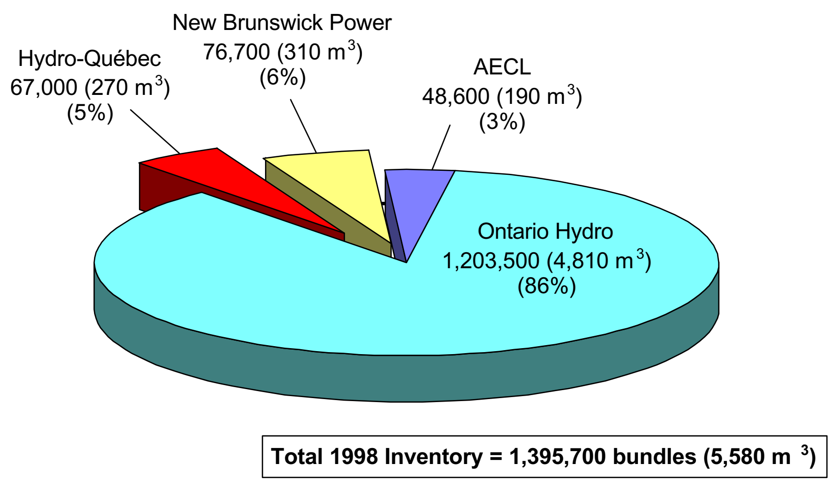
Notes:

[a] Includes all fuel wastes in WMA "G" from NPD reactor (4,853 bundles) and other fuel wastes from Ontario Hydro reactors used in experiments at CRL.
- Spent fuel wastes at Chalk River WMA "B" (Irradiated Fuel Elements and Irradiated Material Disposal) stored in tile holes from NRX and NRU reactors and likely other on-site experimental reactors.
- Total waste storage volume (63 m^3) and annual generation rate (3.5 m^3) for WMA "B" converted to bundles using volume of 0.004 m^3 for typical CANDU fuel bundle for comparison purposes.

[b] Spent fuel wastes at Whiteshell from WR-1 reactor.

[c] Nuclear fuel waste volume calculated assuming a typical volume of 0.004 m^3 for a CANDU fuel bundle based on Ontario Hydro and AECL information.

Figure 5.1: Nuclear Fuel Waste Inventory, 1998
(number of fuel bundles)



5.2 Low-Level Radioactive Waste

At the end of 1998, there were about 1.771 million m^3 of LLRW stored in Canada. At present, wastes are being managed in storage sites throughout the country pending the development and licensing of a permanent waste disposal facility or facilities.

Table 5.2 summarizes the 1998 accumulation rates and accumulated inventory for ongoing and historic LLRW.

Figures 5.2 and 5.3 show the accumulation rates and accumulated inventory for each source. This section provides further breakdowns for each source of LLRW.

5.2.1 Ongoing Waste

About 4,310 m^3 of ongoing waste was generated in 1998. The inventory of this waste to the end of 1998 was 571,250 m^3 (see Table 5.2).

Figures 5.4 and 5.5 provide a further breakdown of the sources, accumulation rate and inventory of ongoing LLRW.

Table 5.2: LLRW Accumulation Rate and Inventory, 1998

WASTE SOURCE		LLRW[a] Accumulation Rate in 1998 (m^3/yr)	LLRW Inventory to 1998 December 31[a] Waste (m^3)	Contaminated Soil (m^3)	Total (m^3)
A. ONGOING WASTE					
Operations	Nuclear Fuel Cycle[c]	2,440	60,000	0	60,000
	Nuclear R&D	1,230	105,930	382,800	488,730
	Radioisotope Production and Use[d]	550	16,610	0	16,610
	Subtotal	**4,220**	**182,540**	**382,800**	**565,340**
Decommissioning	Nuclear Fuel Cycle[e]	0	3,860	0	3,860
	Nuclear R&D	90	2,050	0	2,050
	Radioisotope Production and Use	0	0	0	0
	Subtotal	**90**	**5,910**	**0**	**5,910**
	Total Ongoing Waste	**4,310**	**188,450**	**382,800**	**571,250**
B. HISTORIC WASTE[b]					
	Port Hope	0	0	266,400	266,400
	Welcome and Port Granby	0	0	872,000	872,000
	Other Locations	0	0	61,600	61,600
	Total Historic Waste	**0**	**0**	**1,200,000**	**1,200,000**
TOTAL		4,310			1,771,250

Notes:
[a] Waste volumes have been rounded to nearest 10 m^3. Volume presented is as-stored waste (i.e., after processing); as-generated volume may be about 50% higher.
[b] Historic waste volumes have been rounded to nearest 100 m^3.
[c] Inventory includes approximately 5,000 m^3 of recyclable wastes from uranium refining operations.
[d] Total inventory includes wastes shipped to AECL-CRL since 1983; wastes to CRL from 1946 - 1982 are included under Nuclear R&D.
[e] Inventory includes 2,210 m^3 of wastes in dry storage modules from retubing program at Pickering A.

5.2.1.1 Operations

Waste from operations constitutes the majority of LLRW. This trend will continue until significant decommissioning of nuclear facilities commences. In 1998, about 4,220 m^3 of waste was produced from operational activities. The inventory to the end of 1998 was 565,340 m^3. A detailed breakdown follows.

Figure 5.2: LLRW Accumulation Rate, 1998

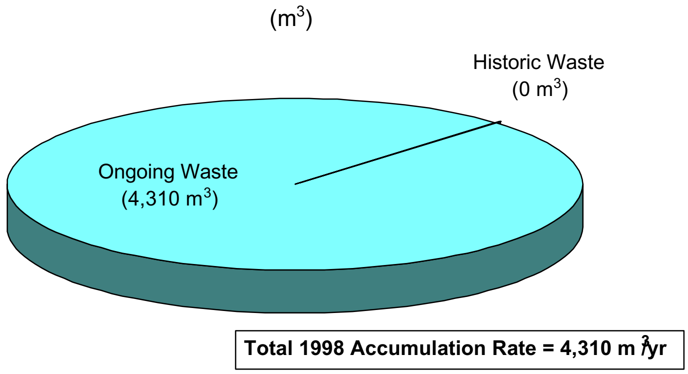


Figure 5.3: LLRW Inventory, 1998

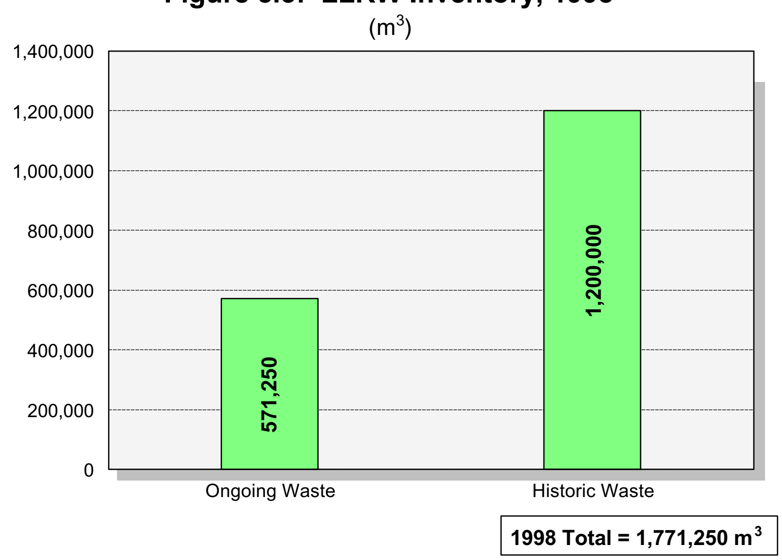


Figure 5.4: Ongoing LLRW Accumulation Rates, 1998

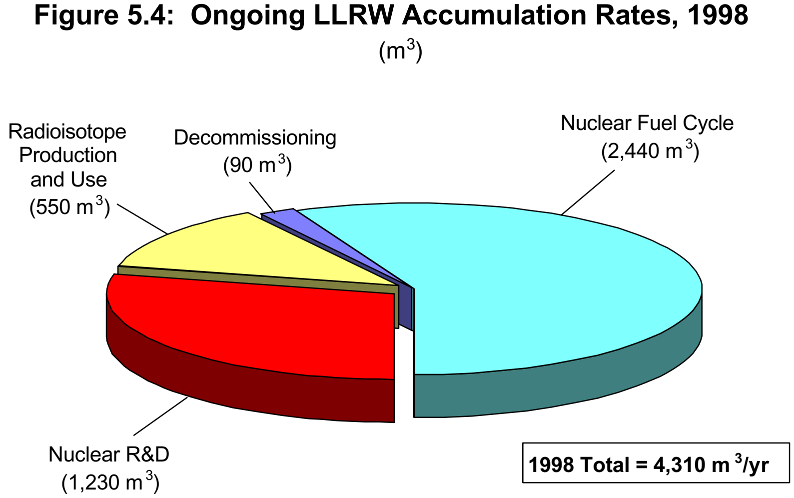
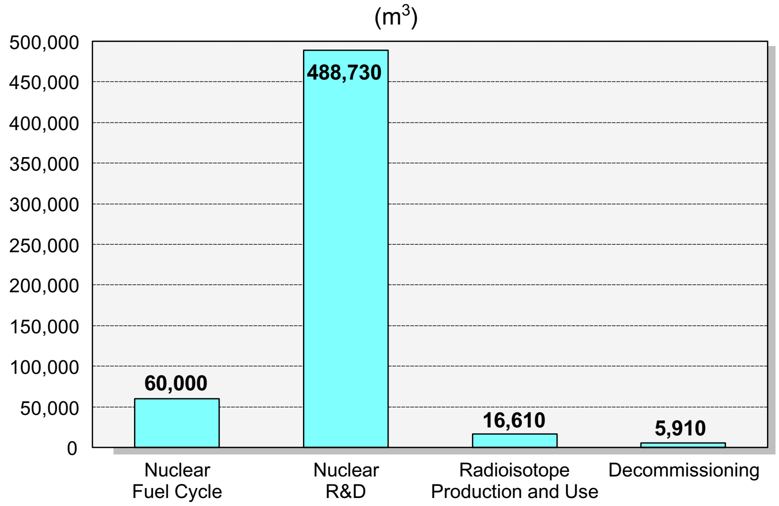


Figure 5.5: Ongoing LLRW Inventory, 1998



Nuclear Fuel Cycle

In 1998, the 14 operating power reactors in Canada produced 2,108 m^3 of the total amount of LLRW. Ontario Hydro, operating 12 reactors, produced the majority of waste (1,928 m^3), while Hydro-Québec and New Brunswick Power produced 180 m^3. The uranium refining, conversion and fuel fabrication companies generated the balance of the total, or 327 m^3 of wastes.

Total waste inventory from nuclear fuel cycle facilities at the end of 1998 was 60,000 m^3.

Nuclear Research and Development

Nuclear research and development activities at AECL generated about 1,230 m^3 of LLRW in 1998, most of which (1,173 m^3) was generated at AECL-CRL from nuclear reactor research and radioisotope production. AECL has about 300,000 m^3 of contaminated soils from nuclear activities during the early years of nuclear research and development. At the waste management area “F” of AECL-CRL, there is 82,700 m^3 of waste and contaminated soil from cleanup by the federal government in Port Hope and Ottawa in the late 1970s. AECL is currently assessing these wastes as part of its overall decommissioning plan for the Chalk River site.

Total waste inventory attributed to research and development was 488,730 m^3 at the end of 1998.

Radioisotope Production and Use

Wastes in this category are generated by radioisotope users from across Canada and eventually sent to AECL-CRL for storage. In 1998, 550 m^3 of waste were received and total inventory increased to 16,610 m^3.

5.2.1.2 Decommissioning

There continues to be only limited decommissioning of nuclear facilities in Canada. Most facilities have conceptual decommissioning plans in place. However, many facilities are currently preparing formal, detailed plans that will include waste volume estimates.

Nuclear Fuel Cycle

There were no decommissioning activities at the nuclear fuel cycle facilities in 1998. Waste inventory at the end of 1998 was 3,860 m^3, which included 2,210 m^3 of waste from the Pickering A retubing program. Wastes were from the Phase 1 (preparation for storage-with-surveillance) decommissioning activities at the three prototype/demonstration reactors and from Phase 3 (dismantling) of two fuel fabrication facilities.

Nuclear Research and Development

Decommissioning projects are ongoing at AECL's research facilities in Chalk River and Whiteshell. Phase 1 decommissioning of the WR-1 reactor at Whiteshell was completed in 1994. There is also ongoing limited decommissioning of some buildings and facilities at Chalk River. The University of Toronto completed decommissioning of its sub-critical assembly.

The waste accumulation rate for 1998 was 90 m^3 arising from decommissioning wastes generated at Chalk River. Waste inventory from decommissioning amounted to 2,050 m^3 at the end of 1998.

Radioisotope Production and Use

There were no decommissioning wastes accumulated in 1998 nor was there any inventory at the end of 1998. The MDS Nordion facility in Kanata, which is the main manufacturer of commercial isotopes, is relatively new and is not expected to generate decommissioning wastes in the near future. Commercial isotope users may generate some small volumes of wastes in the future during decommissioning or refurbishment of laboratories or other facilities.

5.2.2 Historic Waste

The inventory of historic waste to the end of 1998 was 1.2 million m^3 (see Table 5.2).

For 1998, the total inventory of historic waste for which the LLRWMO has management responsibility on behalf of the federal government is 328,000 m^3. The waste consists of the following:

Town of Port Hope, Ontario	266,400 m^3
Other locations:	
Scarborough, Ontario	9,100 m^3
AECL-CRL, Ontario	600 m^3
Fort McMurray, Alberta	35,900 m^3
Northwest Territories	11,400 m^3
Surrey, British Columbia	4,600 m^3
	61,600 m^3

Cameco Corporation continues to manage its two waste sites at Welcome and Port Granby. The Welcome Waste Management Facility contains about 492,000 m^3 of wastes and contaminated soils. The Port Granby Waste Management Facility contains about 380,000 m^3 of wastes and contaminated soils. The total volume of these wastes to the end of 1998 remained at 872,000 m^3.

5.3 Uranium Mine and Mill Tailings

Table 5.3 summarizes the waste accumulation rates, accumulated mass and site status for operating uranium tailings sites, inactive/decommissioned sites and development sites in Canada. Figure 5.6 shows the 1998 accumulated inventory.

Uranium mine and mill tailings are presented as mass in tonnes since this is how the mining industry commonly tracks and reports materials. Waste amounts can be converted to volume (m^3) using assumed or measured densities. A typical dry density for tailings would be 1.5 tonnes/m^3. However, tailings densities can vary significantly from site to site and with location or depth at a specific site.

Table 5.3: Uranium Mine and Mill Tailings Accumulation Rate and Inventory, 1998

Mine/Mill Name	Principal Source Company Name/ Responsible Party	Source Company Province	Tailings Site	Accumulation Rate 1998 (tonnes/year)	Accumulated Mass 1998 Dec. 31 (tonnes)	Waste Site Status as of 1998 December
1. Operating Tailings Sites						
Cluff Lake	COGEMA Resources Inc.	Saskatchewan	Tailings management area in Mill Creek Valley	160,000	2,723,000	Operating since 1983
Key Lake	Cameco Corp.	Saskatchewan	Deilmann Tailings Management Facility (DTMF)	354,000	1,015,000	Operating since 1995
Rabbit Lake	Cameco Corp.	Saskatchewan	Rabbit Lake Pit	491,000	4,530,000	Operating since 1985
			Subtotal Operating Sites	**1,005,000**	**8,268,000**	
2. Inactive/Decommissioned Tailings Sites						
Key Lake	Cameco Corp.	Saskatchewan	Old Tailings Pond (surface)	0	3,586,000	Inactive since 1996/ ongoing monitoring
Rabbit Lake	Cameco Corp.	Saskatchewan	Surface Tailings	0	6,500,000	Inactive since 1985/ being decommissioned
Beaverlodge	Cameco Corp.	Saskatchewan	Surface Tailings and Underground/Mine Backfill	0	10,100,000	Decommissioned since 1985/ongoing monitoring
Gunnar	Saskatchewan Government	Saskatchewan	Surface Tailings	0	4,400,000	Inactive since 1964
Lorado	Saskatchewan Government	Saskatchewan	Surface Tailings	0	360,000	Inactive since 1960
Port Radium	Indian and Northern Affairs Canada	Northwest Territories	Surface Tailings - Four Areas	0	907,000	Decommissioned since 1984/ongoing monitoring
Rayrock	Indian and Northern Affairs Canada	Northwest Territories	North and South Tailings Piles	0	71,000	Inactive since 1959/being decommissioned
Quirke 1and 2 - Elliot Lake	Rio Algom Ltd.	Ontario	Quirke Mine Waste Management Area (WMA)	0	46,000,000	Inactive since 1992/ being decommissioned
Panel - Elliot Lake	Rio Algom Ltd.	Ontario	Panel Mine WMA, Main Basin (North) and South Basin	0	16,000,000	Inactive since 1990/being decommissioned
Denison - Elliot Lake	Denison Mines Ltd.	Ontario	Denison Tailings Management Area (TMA)	0	63,800,000	Inactive since 1992/ being decommissioned
Spanish-American - Elliot Lake	Rio Algom Ltd.	Ontario	Spanish American Waste Management Area	0	450,000	Inactive since 1959/being decommissioned
Stanrock/ CANMET Elliot Lake	Denison Mines. Ltd	Ontario	Stanrock Tailings Management Area (TMA)	0	5,750,000	Inactive since 1964/being decommissioned
Stanleigh - Elliot Lake	Rio Algom Ltd.	Ontario	Stanleigh Waste Management Area (WMA), Crotch Lake Basin and Sheriff Creek	0	19,953,000	Inactive since 1996/being decommissioned
Lacnor - Elliot Lake	Rio Algom Ltd.	Ontario	Lacnor Waste Management Area	0	2,700,000	Inactive since 1960/ being decommissioned
Nordic - Elliot Lake	Rio Algom Ltd.	Ontario	Nordic Waste Management Area	0	12,000,000	Inactive since 1968/ being decommissioned

continued . . .

Table 5.3: Uranium Mine and Mill Tailings Accumulation Rate and Inventory, 1998 (cont'd)

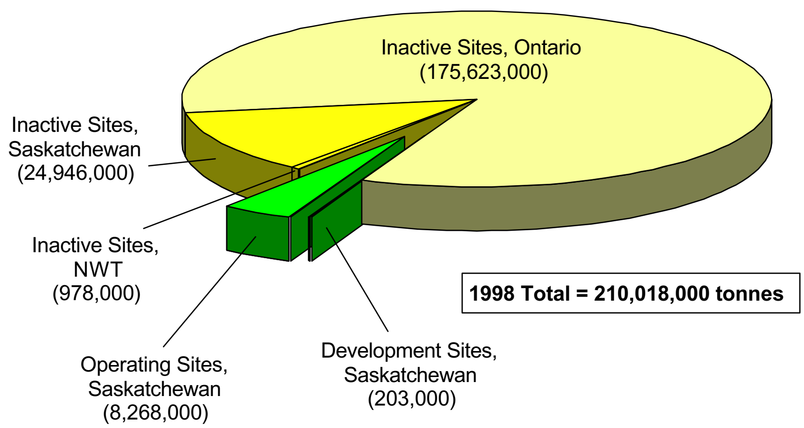
Mine/Mill Name	Principal Source Company Name/ Responsible Party	Source Company Province	Tailings Site	Accumulation Rate 1998 (tonnes/year)	Accumulated Mass 1998 Dec. 31 (tonnes)	Waste Site Status as of 1998 December
Pronto - Blind River	Rio Algom Ltd.	Ontario	Pronto Waste Management Area	0	2,100,000	Inactive since 1960/ being decommissioned
Agnew Lake Mines - Espanola	Kerr Addison	Ontario Mines Ltd.	Tailings Pond	0	510,000	Decommissioned since 1990/ongoing monitoring
Dyno - Bancroft	AEC West	Ontario	Surface Tailings	0	360,000	Inactive since 1960/ being decommissioned
Bicroft - Bancroft	Barrick Properties	Ontario	Surface Tailings - Two Areas	0	2,000,000	Inactive since 1964/ being decommissioned
Faraday/ Madawaska - Bancroft	AEC West	Ontario	Surface Tailings - Two Areas	0	4,000,000	Decommissioned/ ongoing monitoring
		Subtotal Inactive/Decommissioned Sites		**0**	**201,547,000**	
3. Development Sites						
Kiggavik - Sissons Project	COGEMA Resources Inc.	Northwest Territories	No tailings on site	0	0	Care and Maintenance - Project & EIS Under Review
Cigar Lake Project	Cigar Lake Mining Corp.	Saskatchewan	No tailings on site	0	0	Project approved in 1998. Start up expected 2002
McArthur River Project	Cameco Corp.	Saskatchewan	No tailings on site, mineralized waste rock on Waste Pad No. 1	18,000	45,000	Project approved in 1997. Startup expected in 1999
Midwest Project	COGEMA Resources Inc.	Saskatchewan	No tailings on site	0	0	Project approved in 1998. Startup expected in 2003
McClean Lake Project	COGEMA Resources Inc.	Saskatchewan	No tailings on site, stockpiled ore from JEB open pit, ore and special waste from Midwest project	0	158,000	Operating licence - Under development. Startup expected in 1999
Dawn Lake	Cameco Corp.	Saskatchewan	no tailings on site	0	0	Care and maintenance
			Subtotal Development Sites	**18,000**	**203,000**	
Totals				**1,023,000**	**210,018,000**	

At the operating sites, the annual accumulation rate of tailings in 1998 was approximately 1.0 million tonnes with an accumulated inventory to the end of 1998 of 8.3 million tonnes.

Total accumulated inventory of tailings at inactive/decommissioned sites to the end of 1998 was about 202 million tonnes.

At development sites licensed by the AECB, annual accumulation of mineralized waste rock and stockpiled ore in 1998 was approximately 0.02 million tonnes with a total accumulated inventory of 0.2 million tonnes to the end of 1998.

Figure 5.6: Inventory of Uranium Mine and Mill Tailings, 1998
(tonnes)



The total annual accumulation rate of mining and milling wastes in 1998 was 1.0 million tonnes with a total accumulated inventory to the end of 1998 of 210 million tonnes (140 million m^3).

6.0 FUTURE PROJECTIONS

Radioactive waste inventory in Canada has been projected to 1999 and 2035 for the three major waste groups including: nuclear fuel waste, LLRW and uranium mine and mill tailings. The year 2035 was selected as a reference because it corresponds to the forecasted end of operations for the last of the power reactors (Darlington Generating Station).

6.1 Nuclear Fuel Waste

Projection of nuclear fuel waste is provided to 1999 and 2035. This assumes that no new nuclear generating stations will be commissioned before the year 2035 and that all current operating reactors will have ceased operations by this time.

Projected nuclear fuel waste is summarized in Table 6.1. Projected waste quantities were provided by the utilities operating the power reactors and are based on the current operating plans for each reactor. End of operations for the operating power reactors range from year 2010 to 2035. Total lifetime inventory of nuclear fuel waste from these reactors is approximately 3.6 million bundles (14,170 m^3).

Projected nuclear fuel waste inventory to 2035 for the existing prototype/demonstration research reactors owned by AECL is 76,000 bundles (300 m^3).

Figure 6.1 shows the forecasted distribution of the nuclear fuel waste inventory in year 2035 by major producers: Ontario Hydro, 89%; Hydro-Québec, 3%; New Brunswick Power, 6% and AECL, 2%. Figure 6.2 compares nuclear fuel waste inventories to the end of 1998 with inventories projected to 2035.

Nuclear fuel waste inventory at AECL-CRL was estimated to the end of 2035, although AECL-CRL is likely to continue operations beyond this date.

Figure 6.1: Nuclear Fuel Waste Inventories Projection, 2035
(number of fuel bundles)

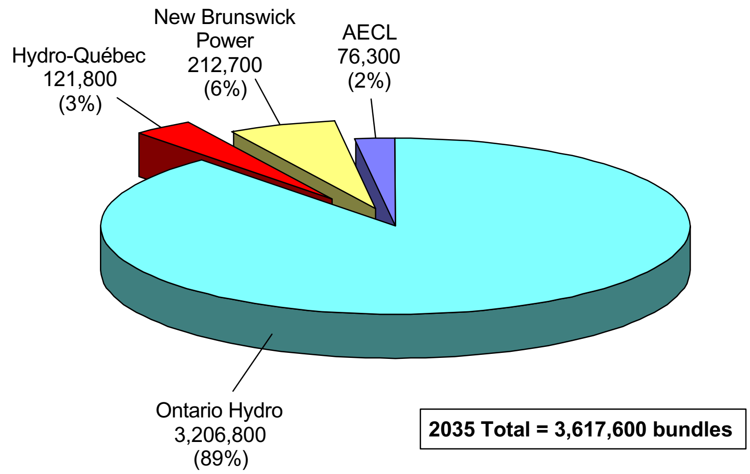


Figure 6.2: Nuclear Fuel Waste Inventory, 1998 and Projection to 2035
(m^3)

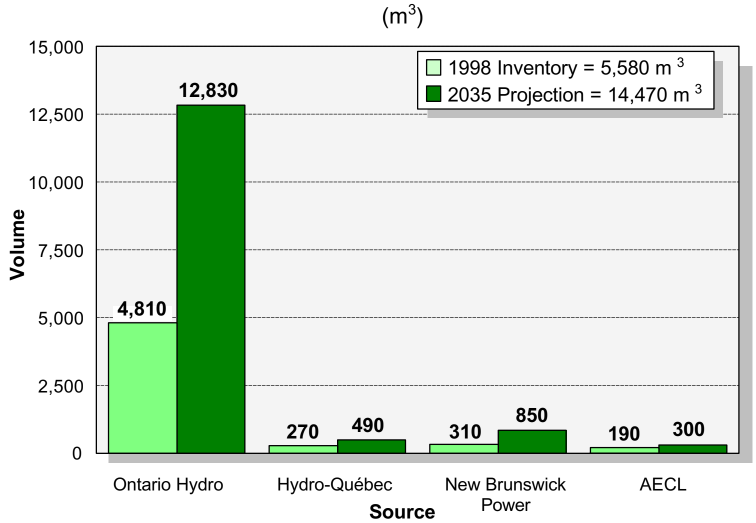


Table 6.1: Projected Nuclear Fuel Waste Inventory to 1999 and 2035

Site Name	Source Company Name	End of Reactor Operations	Nuclear Fuel Waste Inventory: To End of 1998 — Number of Fuel Bundles	To End of 1998 — Estimated Volume[d] (m³)	Projected to End of 1999[b] — Number of Fuel Bundles	Projected to End of 1999[b] — Estimated Volume[d] (m³)	Projected to End of 2035[c] — Number of Fuel Bundles	Projected to End of 2035[c] — Estimated Volume[d] (m³)
POWER REACTORS								
Bruce A	Ontario Hydro	2015-2020	354,567	1,420	374,262	1,500	575,430	2,300
Bruce B	Ontario Hydro	2025-2030	275,230	1,100	292,832	1,170	839,383	3,360
Darlington	Ontario Hydro	2030-2035	127,663	510	149,018	600	846,574	3,390
Pickering A and B	Ontario Hydro	2020-2025	445,995	1,780	457,755	1,830	945,439	3,780
Gentilly-2	Hydro-Québec	2010-2015	67,011	270	70,909	280	121,800	490
Point Lepreau	NB Power	2032	76,675	310	80,503	320	212,675	850
	Subtotal Power Reactors		**1,347,141**	**5,390**	**1,425,279**	**5,700**	**3,541,301**	**14,170**
PROTOTYPE/DEMONSTRATION/RESEARCH REACTORS								
Douglas Point	AECL	1984	22,256	90	22,256	90	22,256	90
Gentilly-1	AECL	1978	3,213	10	3,213	10	3,213	10
Chalk River Laboratories[a]	AECL	N/A	20,821	80	21,684	90	48,571	190
Whiteshell Laboratories	AECL	1997	2,268	10	2,268	10	2,268	10
	Subtotal Research Reactors		**48,558**	**190**	**49,421**	**200**	**76,308**	**300**
Total			**1,395,699**	**5,580**	**1,474,700**	**5,900**	**3,617,609**	**14,470**

Sources: 1998 inventory and generation rates for Power Reactors, Douglas Point and Gentilly-1 from *AECB Reporter*, Spring 1999.
1998 inventory and generation rates for Chalk River and Whiteshell Laboratories from *AECL Annual Safety Review* documents submitted to AECB.

Notes:
[a] Annual generation rate and waste inventory converted to bundles using volume of 0.004 m^3 for typical CANDU fuel bundle for comparison purposes. Forecasted end of operations for Chalk River Laboratories selected as 2035 to compare fuel inventories; for planning purposes, end of operations for CRL is currently projected by AECL as 2100.
[b] Waste forecasts to end of 1999 based on generation rates for 1998.
[c] Waste forecasts to end of 2035 based on information provided by owners as follows: Ontario Hydro waste forecasts provided to the LLRWMO by Ontario Hydro, based on current corporate reference plan (includes operational lay up of Pickering A [4 Units] and Bruce A [4 Units] and return to service of all 8 units between 2000 and 2009; Hydro-Québec waste forecasts provided to LLRWMO by Hydro-Québec, 1998 April; Point Lepreau waste forecasts based on estimated usage of 4,000 bundles per year; waste forecasts to end of 2035 for Chalk River Laboratories based on average generation rates for 1997 and 1998.
[d] Nuclear fuel waste volume calculated assuming a typical volume of 0.004 m^3 for a CANDU fuel bundle based on Ontario Hydro and AECL information.

6.2 Low-Level Radioactive Waste

Projected inventory of LLRW is summarized in Table 6.2. It is estimated that the 1998 inventory of 1.8 million m^3 will increase to approximately 2.1 million m^3 by 2035. Projected inventories and the assumptions used to develop these projections are described in the following sections. Figure 6.3 provides a comparative status of LLRW inventory to 2035.

Table 6.2: Projected LLRW Inventory to 1999 and 2035

WASTE SOURCE		Inventory to End of 1998 (m^3)	Projected Inventory to End of 1999 (m^3)	Projected Inventory to End of 2035 (m^3)
A. Ongoing Waste				
- Operations	Nuclear Fuel Cycle	60,000	62,000	149,800
	Nuclear R&D	488,700	490,000	536,800
	Radioisotope Production and Use	16,600	17,300	44,400
	SUBTOTAL	565,300	569,300	731,000
- Decommissioning	Nuclear Fuel Cycle	3,900	3,900	121,600
	Nuclear R&D	2,100	2,200	5,800
	Radioisotope Production and Use	0	0	0
	SUBTOTAL	**6,000**	**6,100**	**127,400**
	TOTAL ONGOING WASTE	**571,300**	**575,400**	**858,400**
B. Historic Waste				
	Port Hope	266,400	266,400	266,400
	Welcome and Port Granby	872,000	872,000	872,000
	Other Locations	61,600	61,800	71,700
	TOTAL HISTORIC WASTE	**1,200,000**	**1,200,200**	**1,210,100**
TOTAL LLRW		**1,771,300**	**1,775,600**	**2,068,500**

Note: Waste volumes have been rounded to the nearest 100 m^3.

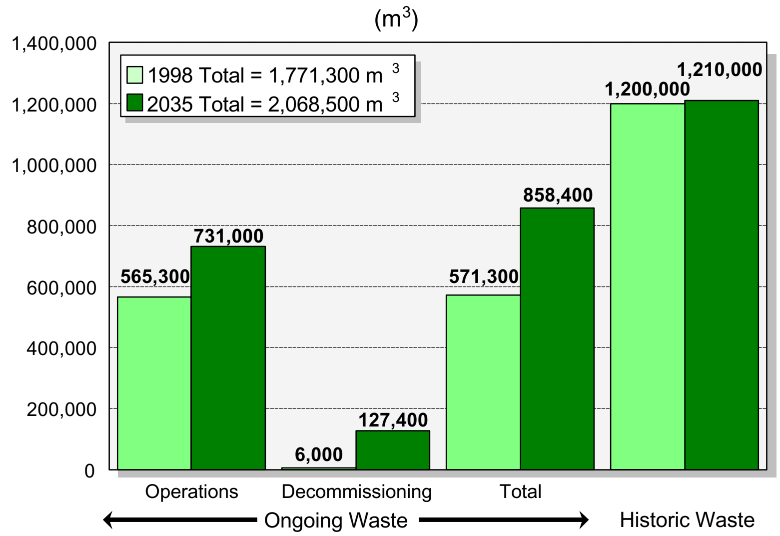
6.2.1 Ongoing Waste

Total inventory projected to 2035 from ongoing operations and decommissioning will be about 0.9 million m^3.

6.2.1.1 Operations

Project of LLRW volumes assumesthat no new major nuclear facilities including new nuclear power reactors,will be commisioned before 2035 and, therefore, there will be no new sources of LLRW. It is also assumed that the 1998 waste accumulation rates will remain constant in the future exceppt where otherwise forecasted by the producers (e.g. electric utilities).

Figure 6.3: LLRW Inventories, 1998 and 2035



The total projected inventory of waste to 2035 from operation and maintenance is 731,000 m^3. Waste from operations will continue to be a major contributor to LLRW inventory until 2014 when Phase 3 decommissioning of the prototype power reactors (Gentilly-1, Douglas Point and NPD) begins.

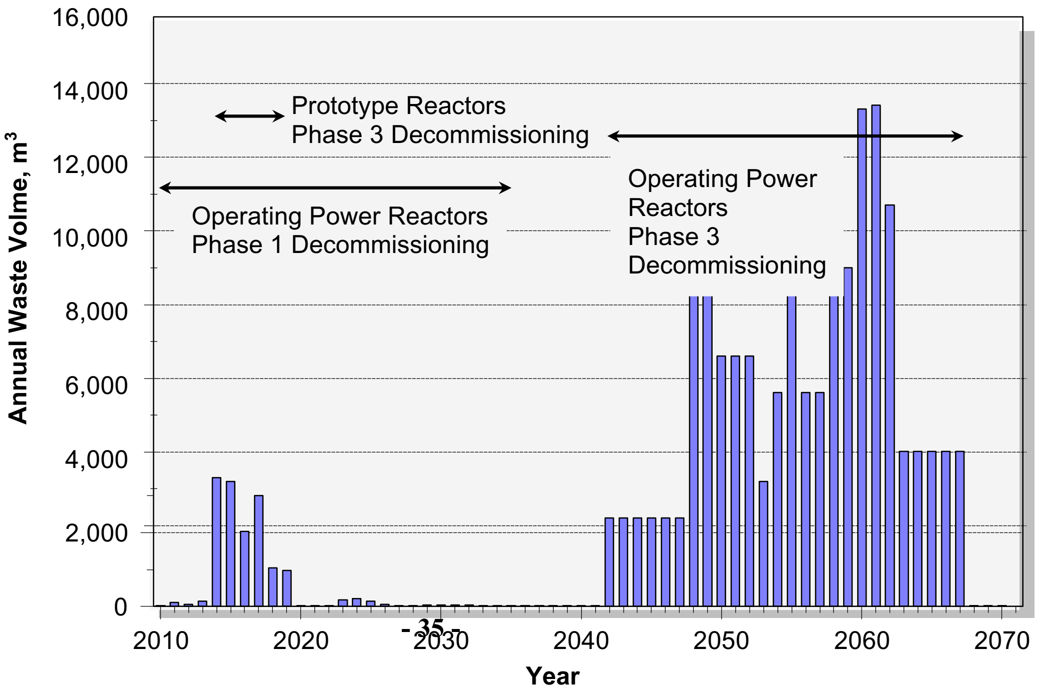
6.2.1.2 Decommissioning

Future projected inventories of decommissioning waste were determined based on decommissioning plans submitted to the AECB. Preliminary decommissioning plans exist for many sites with uncertainties with respect to timing and waste volumes. Decommissioning waste estimates for the nuclear fuel cycle were obtained from a report prepared for the LLRWMO on this topic. Figure 6.4 shows the projected annual decommissioning waste volumes for the power reactors through to 2070 when all the currently known power reactors will have completed Phase 3 decommissioning.

The following assumptions were used in projecting decommissioning waste inventory to year 2035:

- Decommissioning or major site refurbishment may be required at the uranium refining and conversion, and fuel fabrication facilities between year 2020 and 2025, with the exception of the Blind River refinery, which is relatively new. These activities will result in the generation of approximately 102, 000 m^3 of LLRW.

Figure 6.4: Annual Volume of Radioactive Wastes from Decommissioning of Power Reactors to 2070



- The three partially decommissioned prototype power reactors will undergo Phase 3 decommissioning from year 2014 to 2019, which will generate approximately 13,000 m^3 of LLRW.
- Phase 1 decommissioning of the operating power reactors will occur at various dates from 2011 through year 2035. Each of these decommissioning projects will generate approximately 300 m^3 per reactor from Phase 1 decommissioning activities.
- There will be no decommissioning of waste management areas prior to year 2035.

The total projected inventory of decommissioning waste to year 2035 is 127,400 m^3.

6.2.2 Historic Waste

An accumulation rate of 200 m^3/year has been assumed to account for future discovery of historic waste for which the LLRWMO is responsible on behalf of the federal government. The total projected inventory of this waste in year 2035 is 338,100 m^3.

The volume of waste managed by Cameco at its Welcome and Port Granby sites is expected to remain unchanged at the current volume of 872,000 m^3.

The total volume of historic waste in year 2035 will be 1.21 million m^3.

6.3 Uranium Mine and Mill Tailings

Table 6.3 provides a projection of tailings volume to 1999 and 2035 and Figure 6.5 illustrates the comparative tailings volume between 1998 and 2035.

For this projection, the following assumptions have been made:

- Projected inventories to 1999 and 2035 are based on 1998 accumulation rates for operating and development sites.
- Uranium production and tailings generation is assumed to remain constant at 1998 levels until 2035.
- Inventory projections include both current operating sites and development sites that may become operating sites in future years.

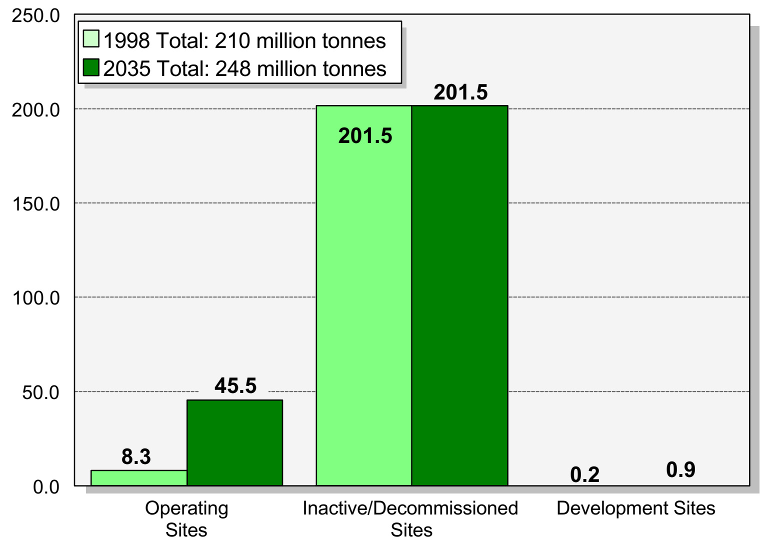
Table 6.3: Projected Uranium Mine and Mill Tailings Inventory to 1999 and 2035

Status of Tailings Site	Accumulation Rate 1998 (tonnes/yr)	Accumulated Mass 1998 Dec. 31 (tonnes)	Projected Inventory to End of 1999 (tonnes)	Projected Inventory to End of 2035 (tonnes)
Operating Tailings Sites	1,005,000	8,268,000	9,273,000	45,453,000
Inactive/Decommissioned Tailings Sites	0	201,547,000	201,547,000	201,547,000
Development Sites	18,000	203,000	221,000	866,000
TOTAL	**1,023,000**	**210,018,000**	**211,041,000**	**247,866,000**

6.3.1 Operating Sites

Future uranium production rates could increase depending on the timing and market conditions. Ore grades from McArthur River, Cigar Lake and McClean Lake will be higher and, as a result, will reduce the uranium tailings production rates. Cameco Corporation plans to blend Key Lake ore or special waste with high grade ore from McArthur River. Blending of low and high grade ores is also planned for Rabbit Lake. Mixing of tailings with waste rock or till prior to deposition is also considered. Due to these possibilities, it is difficult to forecast the final tailings mass from the operating mill sites. For the purpose of the inventory forecast, however, the Canadian uranium production is assumed to remain at the current level. The annual accumulation of tailings is assumed to continue at a rate of 1.0 million tonnes (Mt) per year (accumulation rate 1998). It is also assumed that the development sites will maintain the level of production at the current rate as ore from the three current operating uranium mines becomes exhausted. Total accumulated mass of tailings at the operating sites would increase from the 1998 value of approximately 8.3 Mt to approximately 45.5 Mt by the year 2035, as shown in Table 6.3.

Figure 6.5: Tailings Volume to 1998 and 2035
(million tonnes)



6.3.2 Inactive or Decommissioned Sites

Decommissioning of uranium mine and mill tailings generally involves management in place. The current mass of tailings at all inactive or decommissioned sites is 202 Mt and is assumed to remain unchanged through 2035.

6.3.3 Development Sites

Some of the development sites will likely become operating sites in the future. For the purpose of projections, however, it is assumed that waste/tailings from these sites will accumulate at the current rate of 18,000 tonnes/year, resulting in a total accumulation of 866,000 tonnes by 2035.

7.0 SUMMARY

Radioactive waste has been produced in Canada since the early 1930s when the first uranium mine began operating at Port Radium in the Northwest Territories. At present, radioactive waste is generated from: uranium mining, milling, refining and conversion; nuclear fuel fabrication; nuclear reactor operation for electricity generation; nuclear research; and radioisotope production and use.

Radioactive waste is grouped into three categories: nuclear fuel waste; low-level radioactive waste; and uranium mine and mill tailings. The accumulated inventory of these wastes to the end of 1998 and a projection to 2035 are provided in Table 7.1.

Table 7.1: Summary of Current and Future Inventories

Waste Category	Inventory to 1998 December	Waste Inventory to End of 1999	Waste Inventory to End of 2035
Nuclear Fuel Waste	5,600 m^3	5,900 m^3	14,500 m^3
Low-Level Radioactive Waste	1.8 million m^3	1.8 million m^3	2.1 million m^3
Uranium Mine and Mill Tailings	210 million tonnes	211 million tonnes	248 million tonnes

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Appendix A
Policy Framework for Radioactive Waste

Natural Resources Canada

News Release

96/79
July 10, 1996

McLELLAN ANNOUNCES POLICY FRAMEWORK FOR RADIOACTIVE WASTE

OTTAWA — Anne McLellan, federal Minister of Natural Resources, today announced government approval of a radioactive waste policy framework that will guide Canada's approach for radioactive waste disposal into the next century.

The framework is the result of consultations with waste producers and owners to establish a comprehensive and integrated approach to the long-term management and disposal of radioactive wastes in Canada.

"The Policy Framework lays out the ground rules for radioactive waste disposal in Canada. It defines the role of government and waste producers and owners, and recommends that disposal proceed in a comprehensive and integrated manner," Minister McLellan noted.

"With the Policy Framework in place, the context is set for the further development of the financial and institutional arrangements that will govern waste disposal. Over the coming months, my officials will begin discussions with waste producers to ensure that radioactive waste disposal takes place in a manner that respects the principles in this policy framework," Minister McLellan added.

The Policy Framework recognizes the role of the federal government to develop policy, to ensure that waste producers and owners comply with legal requirements and meet their funding and operational responsibilities in accordance with approved waste disposal plans, as well as the role of the federal Atomic Energy Control Board to regulate waste disposal activities.

Under the framework, waste producers and owners are responsible, in accordance with the principle of "the polluter pays," for the funding, organization, management and operation of disposal and other facilities required for their wastes. This principle recognizes that arrangements may be different for nuclear fuel waste, low-level radioactive waste and uranium mine and mill tailings.

GC 164 (90/06) 7540-21-886-3757

- more -

The federal government has already taken leadership on this issue in announcing, last week, its intention to evaluate the suitability of a low-level radioactive waste facility in Deep River, Ontario.

"The Policy Framework emphasizes the Government of Canada's commitment to the principles of sustainable development. Nuclear energy is an environmentally sound-energy option that does not contribute to climate change or acid rain. Taking action to dispose of radioactive waste is an environmentally responsible initiative that will ensure that the costs related to nuclear activities are not simply passed from one generation to the next," Minister McLellan concluded.

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NRCan's news releases and backgrounders are available on the Internet at http://www.nrcan.gc.ca/

BACKGROUNDER

RADIOACTIVE WASTE POLICY FRAMEWORK

The elements of a comprehensive radioactive waste policy framework consist of a set of principles governing the institutional and financial arrangements for disposal of radioactive waste by waste producers and owners.

- The federal government will ensure that radioactive waste disposal is carried out in a safe, environmentally sound, comprehensive, cost-effective and integrated manner.

- The federal government has the responsibility to develop policy, to regulate, and to oversee producers and owners to ensure that they comply with legal requirements and meet their funding and operational responsibilities in accordance with approved waste disposal plans.

- The waste producers and owners are responsible, in accordance with the principle of "polluter pays", for the funding, organization, management and operation of disposal and other facilities required for their wastes. This recognizes that arrangements may be different for nuclear fuel waste, low-level radioactive waste and uranium mine and mill tailings.

Inventory of Radioactive Waste in Canada

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