

Uranium

Robert Vance¹

*The author is with the Energy Sector,
Natural Resources Canada.
Telephone: (613) 996-2599
E-mail: rvance@nrcan.gc.ca*

OVERVIEW

The commercial fate of the uranium derived from dismantled Russian nuclear weapons remained unresolved throughout 1998, but by year's end there were encouraging signs suggesting that the long-sought-after transaction between the Russian Ministry of Atomic Energy (Minatom) and a consortium of Western companies might finally be concluded in 1999. Concerns about the effects of the uncontrolled release of surplus military inventories into world uranium markets will ease considerably if such an agreement is concluded.

World uranium spot prices declined almost continuously during 1998, and ultimately led to announcements that a number of mines would cut back production or cease operations, and other new mine developments would be deferred. In addition to the continued uncertainty regarding competition from military uranium, primary producers faced growing competition during the year from uranium made available to the market by the operation of enrichment plants in Russia and the United States.

Canadian uranium production in 1998 amounted to 10 925 tU, down 9% from the 1997 total. As Figure 1 shows, the world's two largest uranium-producing companies have operations in Canada. As of January 1, 1998, Canada's total "known" recoverable uranium resources were 419 000 tU, compared with 430 000 tU as of January 1, 1997. The downward adjustment of some 2.5% is roughly equivalent to the resources extracted over the year.

Despite poor market conditions, uranium production capability continues to increase in Canada. In April 1998, the Cigar Lake and Midwest mining projects

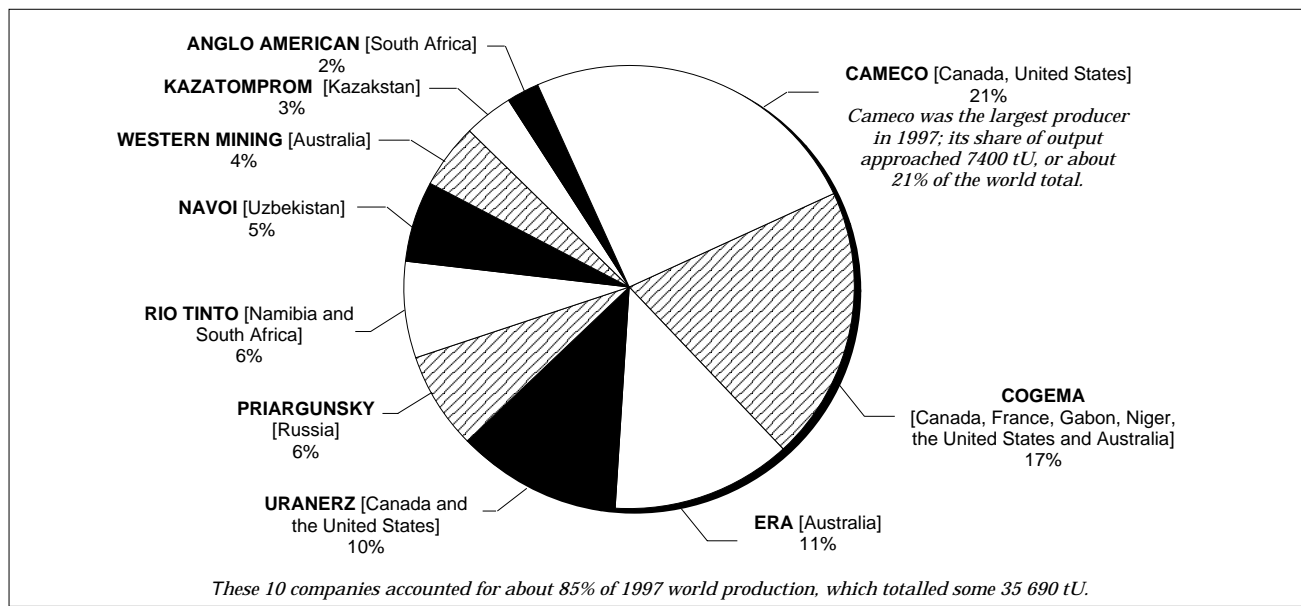
cleared the environmental review process when government approvals to proceed were received. Construction at McClean Lake neared completion, and the mill is expected to begin production in June 1999, subject to regulatory approval. Modifications at Key Lake moved the mill closer to the configuration required to process McArthur River ore, which is scheduled to arrive late in 1999. Test mining and development work continued on schedule at Cigar Lake with the mine currently on track to open in 2001 or 2002.

DOMESTIC PRODUCTION AND DEVELOPMENTS

Primary output from Canada's three uranium-producing operations in 1998 amounted to 10 925 tU, down some 9% from 1997 production (Table 1). In 1997, overall employment at Canada's producing operations remained at just above 1100, with the losses incurred from the Stanleigh mine closure at Elliot Lake compensated for by pre-production activities at the McClean Lake and McArthur River projects in Saskatchewan. As indicated in Table 2, preliminary estimates of 1998 mine shipments, under all domestic and export contracts, decreased in tonnage and in value compared to 1997. Despite this decline, uranium continues to rank among Canada's top 10 metal commodities in terms of output value. Table 3 highlights the main operational characteristics of the existing uranium production centres in 1997, the most recent year for which complete data are available. Table 4 updates the status of new projects that represent Canada's future production capability, while Figure 2 locates Canada's producing uranium mines and major deposits and Figure 3 shows domestic production by project and owner for 1997.

In April 1998, the corporate structure of uranium mining in Canada was significantly altered when Cameco Corporation announced that it had entered into an agreement in principle to purchase Uranerz Exploration and Mining Limited and Uranerz USA Inc. from their parent company, Uranerzbergbau GmbH (UEB) of Germany. The deal was subsequently approved by anti-competition regulatory agencies in Canada, Germany and the United States

Figure 1
World's Top Ten Uranium Mining Companies in 1997



Source: Uranium Institute Pocket Guide, June 1998.

Note: Ranking reflects equity interest in production facilities, not market share.

and, on August 11, 1998, the acquisition was completed at a total cost of \$489 million (\$483 million plus accrued interest of \$6 million). This acquisition strengthened Cameco's position as the world's largest uranium producer, increasing the company's uranium reserves, resources and uranium production levels by about 30%. The principal Canadian assets purchased by Cameco include a 33.33% interest in the Key Lake and Rabbit Lake uranium mines, a 27.92% interest in the McArthur River mine, and a 20% share in the Midwest mine. These projects are all situated in northern Saskatchewan.

The transaction also included acquisition of the 57.69% interest held by Uranerz USA Inc. in the Crow Butte uranium mine in Nebraska, as well as uranium and gold exploration properties in northern Saskatchewan and in the United States. In addition, subject to third-party consent, Cameco acquired the rights to an additional one-third interest in the Inkai uranium joint venture in Kazakhstan.

In the latter half of 1998, the declining uranium market price had an impact on Canadian operations. In August, 1998, COGEMA Resources Inc. (CRI) announced that production at Cluff Lake would be suspended indefinitely as of December 31, 2000. In January 1999, CRI moved the suspension date ahead to the summer of 2000. In November 1998, Cameco announced that in 1999 it will reduce uranium production at its Canadian operations by some 35% of

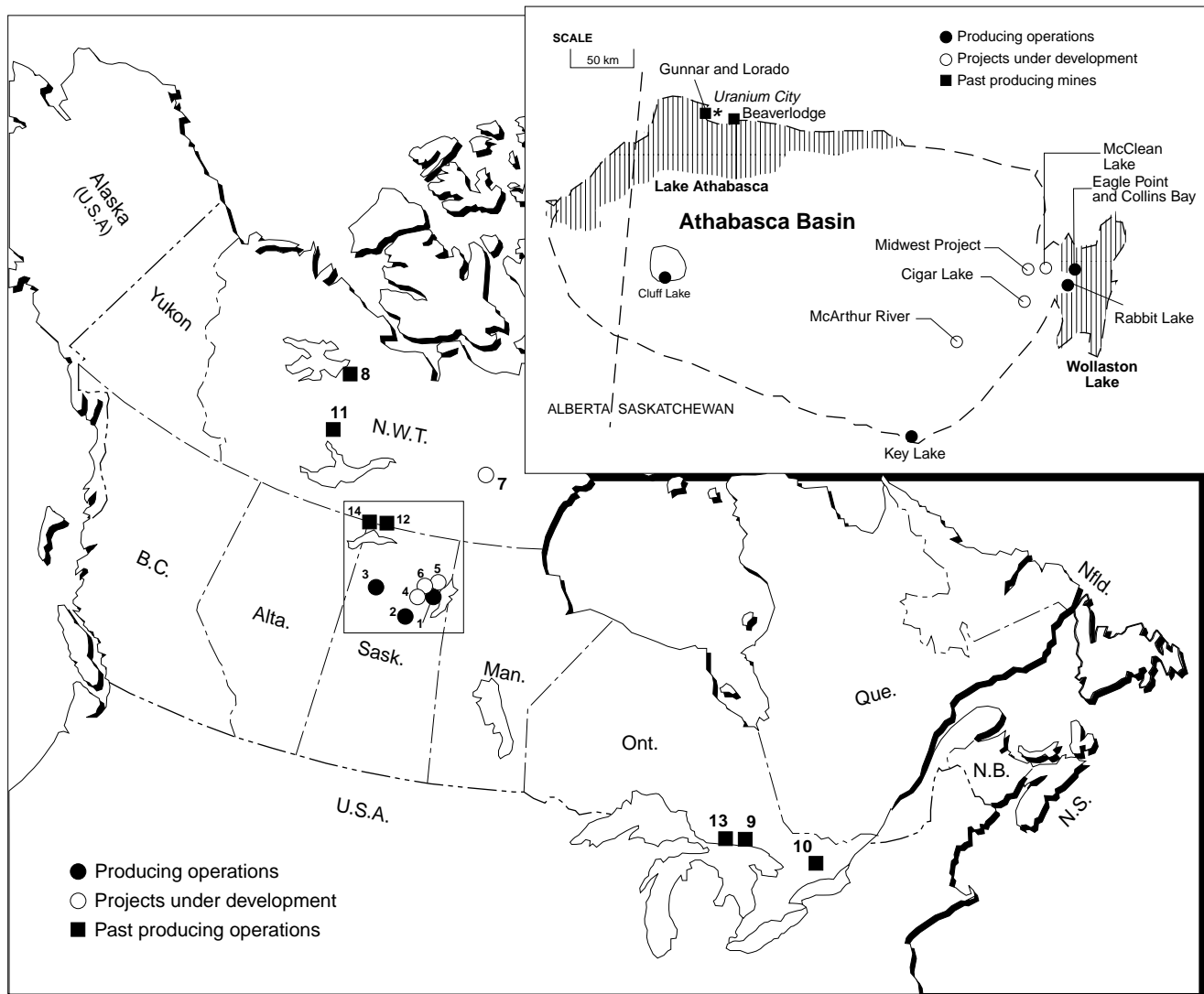
1998 production (or roughly 3800 tU). Cameco also intends to trim uranium conversion services at its Ontario operations by 10%.

Elliot Lake, Ontario

The decommissioning and rehabilitation of Denison Mines Limited's Elliot Lake properties was essentially completed in 1998 with the construction of the final dam and revegetation of the tailings surface at Stanrock. This work was conducted under the mine facility decommissioning licence for Stanrock granted by the Atomic Energy Control Board (AECB) in June 1998. The mine facility decommissioning licence for the Denison mine has not yet been amended to address all of the concerns and recommendations raised by the Federal Environmental Assessment Review Panel and government responses. Denison Mines will be seeking the necessary licence amendments in 1999. Nonetheless, both existing licences incorporate the reclamation programs presented in the Environmental Impact Statement during the environmental review.

Early in 1998, Rio Algom Limited reported that it was in full compliance for its discharges to waterways from its five closed mines at Elliot Lake (Pronto, Nordic, Quirke, Panel and Stanleigh). Significant reductions in contaminant loadings to the Serpent River watershed were documented following closure of the Stanleigh mine. At the Stanleigh waste/

Figure 2
Uranium Mining in Canada, 1998



Numbers refer to locations on map above.

PRODUCING OPERATIONS

- 1. Rabbit Lake (incl. Eagle Point and Collins Bay)
- 2. Key Lake
- 3. Cluff Lake

PROJECTS UNDER DEVELOPMENT

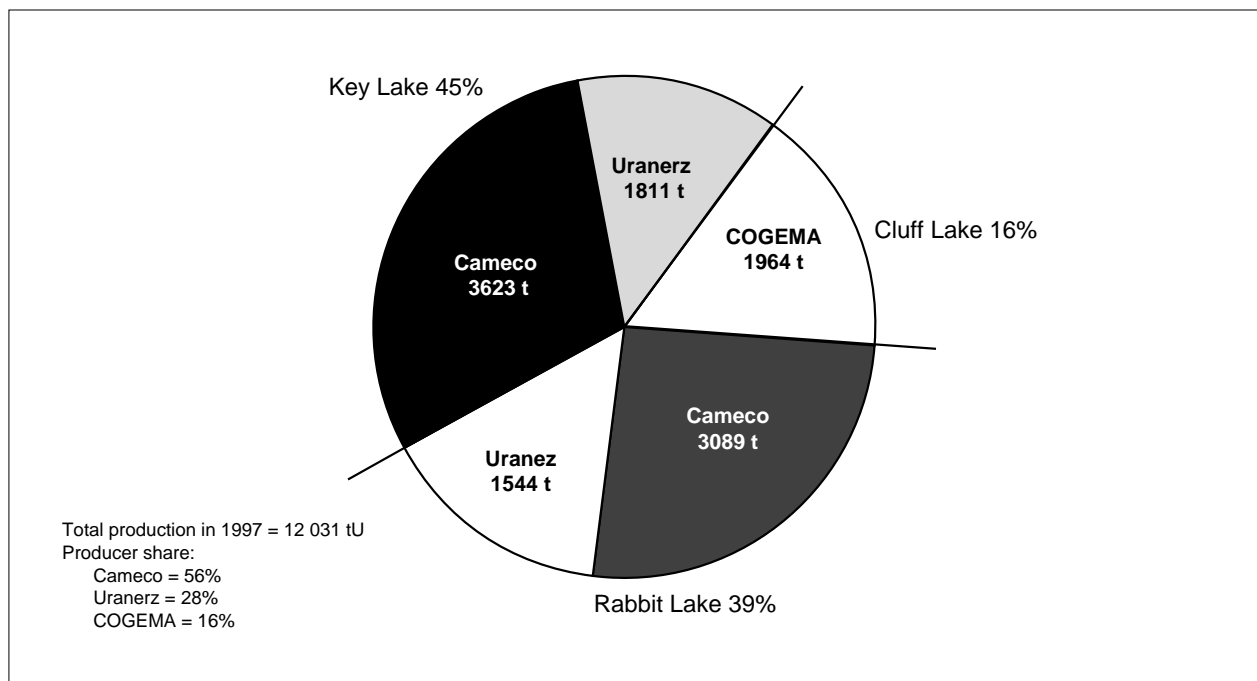
- 4. McArthur River
- 5. Midwest/McClean
- 6. Cigar Lake
- 7. Kiggavik

PAST PRODUCING DEVELOPMENT

- 8. Port Radium
- 9. Agnew Lake
- 10. Madawaska et al (Bancroft)
- 11. Rayrock (Marian River)
- 12. Beaverlodge et al
- 13. Quirke/Panel/Denison and Stanleigh et al (Elliot Lake)
- 14. Gunnar and Lorado et al

Source: Uranium and Radioactive Waste Division, Natural Resources Canada.

Figure 3
Canadian Uranium Production and Ownership, 1997



Source: Uranium and Radioactive Waste Division, Natural Resources Canada.

tailings management area, one existing dam was raised and construction of three new, low-permeability dams and an overflow spillway was completed in 1998. Water levels have been raised to cover the tailings and to create a water barrier to minimize acid formation and prevent airborne release of radiation. Although water levels are currently some 6 m below design levels, flooding to the final elevation is expected to take place over the next two years, depending upon precipitation rates.

Athabasca Basin, Saskatchewan

Rabbit Lake

Following the purchase of Uranerz, Cameco now fully owns and operates the Rabbit Lake uranium production facility. Rabbit Lake mill output in 1998 was about 4500 tU, down slightly from 1997 (4633 tU). Ore sources in 1998 were the Eagle Point underground mine and the Collins Bay A and B zone deposits. In October 1998, the AECB approved a two-year renewal of the Rabbit Lake mine operating licence.

Cameco's production cutbacks include the suspension of mining operations at Eagle Point at the end of March 1999. Originally, the Rabbit Lake mill was slated to close early in the next decade, but Cameco announced in November 1998 that it plans to mill a

portion of the Cigar Lake ore at Rabbit Lake, extending the lifetime of the facility by some 15 years. However, until ore from the Cigar Lake mine arrives sometime in 2001 or 2002, the Rabbit Lake mill will process stockpiled ore and operate at half capacity.

Key Lake

The Key Lake uranium production facility is also fully owned and operated by Cameco following the Uranerz purchase. In 1998, production from stockpiled Deilmann ore reached 5385 tU, down slightly from 1997 (5434 tU). On November 6, 1998, the AECB amended the Key Lake operating licence to permit conversion of the Deilmann in-pit tailings management facility to the subaqueous deposition mode, and to begin construction of receiving and blending facilities to handle ore from the McArthur River mine. An extended shut-down of the Key Lake mill, beginning in July 1999, will be required to finalize construction of these facilities. Most of the remaining stockpiled ore is expected to be depleted by that time. The Key Lake mill is expected to resume production by the last quarter of 1999.

McArthur River

Cameco is also the operator of the McArthur River project, a joint venture between Cameco and CRI. On May 29, 1998, the AECB amended the McArthur

River construction licence to allow the fabrication and installation of an underground ore reclamation and milling system, and surface ore handling facilities. Construction at the McArthur River mine is on budget and on schedule, and ore production at this, the world's largest high-grade uranium deposit, is expected to begin in the last quarter of 1999.

Cigar Lake

The Cigar Lake mine, a joint venture operated by the Cigar Lake Mining Corporation (refer to Table 4), is situated on the world's second largest high-grade uranium deposit. The Cigar Lake mining project cleared the environmental review process early in 1998, and testing of mine equipment and mining techniques continued on schedule throughout the remainder of the year. The mine is scheduled to begin production in 2001 or 2002.

Cluff Lake

The Cluff Lake uranium production facility is wholly owned and operated by CRI. Mining operations were entirely underground (Dominique-Peter and Dominique-Janine West orebodies) in 1998, and overall production amounted to 1040 tU, or almost half of 1997 production. This sharp decline relates in part to the reduced rate of production required to avoid reaching full capacity in the tailings management area.

On March 26, 1998, the AECB approved a nine-month extension to the Cluff Lake operating licence, with conditions. CRI was required to:

- prepare a full report on increased radium levels detected in Snake Lake (situated next to the facility's tailings management area);
- respond to AECB questions about the safety of the operation, which included providing information demonstrating that the current radiation protection program for underground miners complies with the principle of keeping radiation levels as low as reasonably achievable (ALARA);
- submit an updated Code of Practice;
- restrict the placement of tailings in the tailings management area to specific authorized limits; and
- report to the AECB on all these issues by October 1, 1998.

On August 20, 1998, CRI announced that it would be suspending operations indefinitely at Cluff Lake on December 31, 2000. CRI indicated that the low market price of uranium could not sustain the operation in its present form, and that local reserves are insuf-

ficient to support the investment required to create the new tailings management facility (TMF) needed in 2001. However, CRI indicated that it will be conducting a vigorous exploration program in the Cluff Lake area and, if sufficient reserves are located and the market improves, it could re-open the facility.

On August 27, 1998, the AECB approved CRI's construction plan to add interim works to the tailings management facility. Construction of additional berms was required to allow the physical placement of tailings to the maximum approved capacity. CRI had originally requested approval of this plan in February 1998, but the AECB had deferred a decision pending receipt of additional information.

On December 18, 1998, the AECB granted a renewal of the Cluff Lake operating licence through to December 31, 2000, subject to two conditions. The first limited the placement of tailings to maximum elevations in the approved tailings management area (modified to include the 1998 construction areas), and the second required submission of an updated detailed decommissioning plan by June 30, 1999.

On February 2, 1999, CRI announced that it would process the remainder of the low-grade ore stockpile from the Dominique-Janine Extension open pit before suspending operations in order to avoid potential future environmental problems posed by the stockpile. To do so, the Cluff Lake mill will begin running continuously in June 1999. Continuous operation from this date will mean that full capacity in the tailings management area will be reached and operations will be suspended sometime in mid-2000.

McClean Lake

The McClean Lake uranium production facility, currently under development, is majority-owned and operated by CRI. Construction of the mill was completed late in 1997, but production has been held up until CRI obtains the necessary licencing.

On August 14, 1998, the AECB amended the McClean Lake operating licence to allow CRI to conduct specified preparatory work to convert the mined-out JEB pit for use as a TMF. On October 13, 1998, a cease-work order was issued by the AECB when it was discovered that materials used in the filter drain of the JEB TMF did not meet required specifications. This problem was resolved and, on November 19, 1998, construction resumed. However, in early December 1998, CRI stopped construction when it discovered additional problems with the filter material. By year-end, this problem had not been resolved and construction of the TMF had not resumed.

The mining of waste rock at the Sue C pit at McClean Lake was completed late in 1998. Since CRI had not secured the licencing required to begin milling the ore

and the rate of mining was progressively becoming out of step with milling, CRI announced in early January 1999 that it was laying off about 45% of the McClean Lake work force until all licencing issues were resolved. CRI anticipates having the necessary licencing in place by June 1999.

Additional Production Possibilities

Beyond the existing and committed centres of uranium production mentioned above, there are other projects that could be brought on stream in the next few years if environmental and regulatory approvals are received and market conditions are favourable. Table 4 updates, as of March 1, 1999, recent developments at the mining projects that will form the basis of Canada's uranium production capability well into the future, and indicates the current status of the environmental review process for each of them.

Saskatchewan Environmental Assessment and Review Panel

In April 1998, the governments of Canada and Saskatchewan responded to the final report issued by the Joint Federal-Provincial Panel on Uranium Mining Developments in Northern Saskatchewan. This report dealt with the Cigar Lake and Midwest projects, as well as the Joint Panel's summary of cumulative observations on the five new developments in northern Saskatchewan it had reviewed since 1991. After carefully reviewing the report, the federal and provincial governments agreed with the Joint Panel that the Cigar Lake and Midwest projects could advance to the licencing stage, subject to certain specific conditions.

The Joint Panel made 29 recommendations with a number of conditions regarding the Midwest and Cigar Lake mines. These recommendations were directed at mining techniques, disposal of tailings and waste rock, transportation of the ore, long-term environmental monitoring and biophysical impact assessment, worker health and safety, socio-economic benefits, community health and social impacts, and site decommissioning. Governments agreed with all 29 recommendations, but disagreed with two conditions attached to the recommendations.

The Joint Panel suggested that experiments be conducted to determine the long-term acceptability of the JEB TMF *prior* to tailings deposition. The Government of Canada agreed that the JEB TMF can be used, but stated that experimental studies of the aging of tailings should take place *concurrently* with disposal, indicating that laboratory experiments alone could not adequately determine the long-term acceptability of the proposed method for disposing of the tailings.

As in earlier reports, the Joint Panel suggested that a program be developed to direct a share of the ura-

nium royalty revenues to northern municipalities and First Nations. The Government of Saskatchewan did not agree with this suggestion, indicating that this issue should be dealt with separately and apart from the environmental assessment process. Revenue-sharing is one of the topics under discussion between the Chief of the Federation of Saskatchewan Indian Nations, the Minister of Indian and Northern Affairs Canada, and the provincial Minister of Intergovernmental and Aboriginal Affairs as part of the Fiscal Relations Table Memorandum of Understanding.

In its cumulative observations, the Joint Panel made 13 comments that spanned social concerns, such as encouraging the protection of the vitality of northern communities, to technical issues, such as encouraging research on the development of more efficient and environmentally acceptable ways of processing ore and disposing of tailings. The Joint Panel urged governments to continue to support training programs for northern residents, such as the Multi-Party Training Plan, and recommended that the uranium mining companies continue to progress towards achieving targets for northern employment (67%) and northern business involvement (35%). The Joint Panel also recommended that governments and industry continue to support the existing Environmental Quality Committees that train and employ northern residents to monitor aspects of the environment that may be affected by mining and milling activities. Governments supported all of these recommendations.

The submission of this Joint Panel report brings to a close the comprehensive environmental assessment process for the five new mine developments in northern Saskatchewan. With Canada's position as the world's leading uranium producer and exporter comes the responsibility to demonstrate that its uranium producers meet a high level of health, safety and environmental standards. The federal-provincial environmental assessment process has contributed significantly to these objectives.

Other Developments Affecting Canada's Uranium Industry

On October 14, 1998, Cameco announced that it had completed an offering in the United States of US\$125 million of preferred securities. Cameco stated that it will use the proceeds to replace a portion of the short-term debt financing used to acquire Uranerz Exploration and Mining Limited and Uranerz USA Inc.

EXPLORATION

Natural Resources Canada (NRCan) completed its 24th annual assessment of Canada's uranium supply capabilities and an associated survey of uranium

exploration activity, and reported² the results in August 1998. Uranium exploration activity remains concentrated in areas favourable for the occurrence of deposits associated with Proterozoic unconformities, notably in the Athabasca Basin of Saskatchewan and the Thelon Basin in the Northwest Territories. In 1997, overall uranium exploration expenditures reached \$58 million, while uranium exploration and surface development drilling approached 104 000 m, up from about 79 000 m reported for 1996.

As in recent years, most of the increase in the overall exploration expenditures can be attributed to advanced underground exploration, deposit-appraisal activities, and care-and-maintenance expenditures associated with those Saskatchewan projects awaiting production approvals. In comparison, the Saskatchewan government estimates that grass-roots uranium exploration in the province reached \$27 million in 1997, up from some \$17 million in 1996. A summary of uranium exploration activity in Canada from 1982 to 1997 is provided in Table 5.

In recent years, the number of companies with major exploration programs in Canada has declined. About 40% of the 80 uranium projects maintained in good standing in 1997 were actively explored. The top five operators,³ accounting for nearly all of the \$58 million expended in 1997, were: Cameco Corporation, Cigar Lake Mining Corporation, CRI, PNC Exploration (Canada) Co. Ltd., and Uranerz Exploration and Mining Limited. Expenditures by CRI include those of Urangesellschaft Canada Limited.

RESOURCES

NRCan's annual assessment of domestic uranium supply capability provides a compilation of Canada's "known" uranium resources, based on the results of an evaluation of company data. Uranium supply from Canada in the next decade will come from known resources, estimates of which are divided into three major categories, *measured*, *indicated* and *inferred*, that reflect different levels of confidence in the reported quantities. Most of these resources are associated with deposits identified in Figure 2.

Recent NRCan assessments of Canada's uranium resources have been restricted to those recoverable from mineable ore at prices of \$150/kgU or less. Table 6 shows the breakdown of the latest resource estimates compared with those of the previous year. As of January 1, 1998, total recoverable known uranium resources were estimated at 419 000 tU, compared with 430 000 tU as of January 1, 1997. The downward adjustment of some 2.5% is roughly equivalent to 1997 Canadian uranium production.

SUPPLY CAPABILITY

In 1998, Canada's uranium supply capability was maintained as producers were able to adjust output levels to compensate for mine closures in Ontario. Timely licensing approvals and higher uranium prices will be required to allow Canada's production capability to expand to its full potential of 20 000 tU or more annually early in the next century.

Developments in the international uranium market, the rate at which projects clear environmental reviews, and uncertainty regarding the costs associated with certain of the planned new projects preclude projecting future production capability levels with much certainty. Table 7 ranks Canada among the world's major producers, showing actual uranium production from 1993 through 1997. Figure 4 illustrates Canada's share of world output in 1997 compared with other major producers.

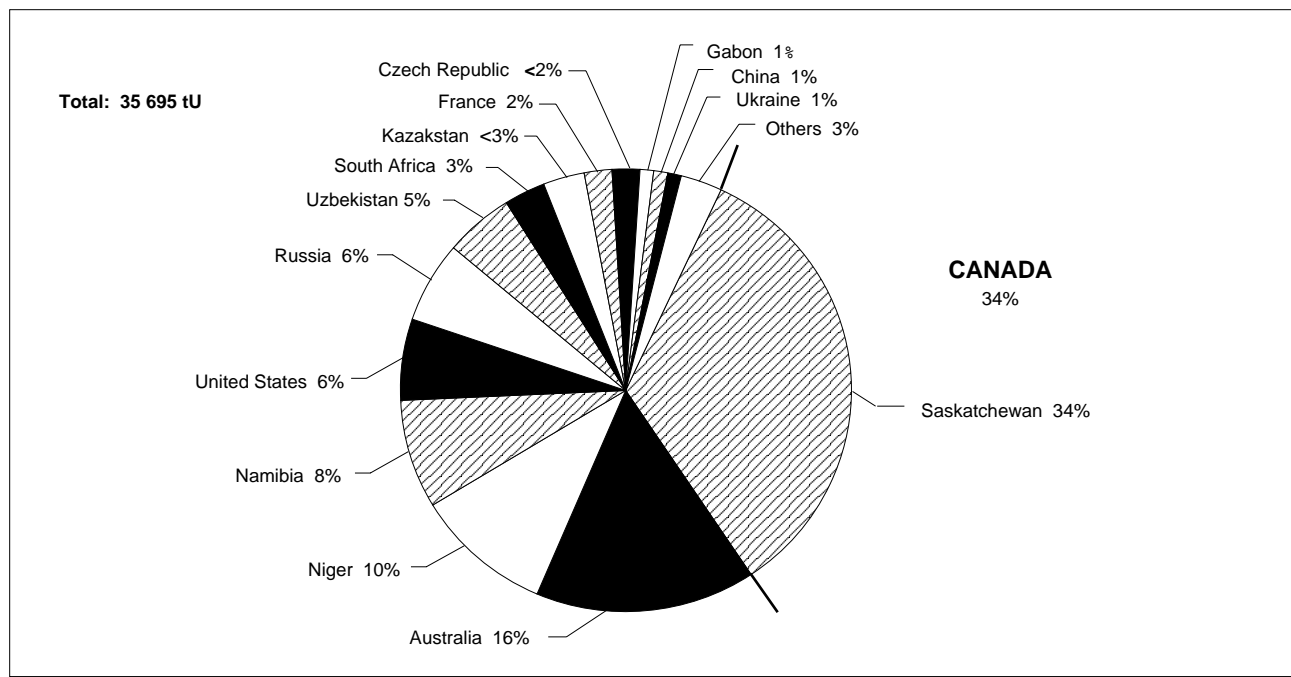
GOVERNMENT INITIATIVES

On March 20, 1997, Bill C-23, *The Nuclear Safety and Control Act* (NSCA), received Royal Assent. Proposed regulations for the NSCA were posted by the AECB for comment in July 1998. In late 1998, the AECB began consultations to address concerns raised by stakeholders regarding the new Act and associated regulations. At the same time, the AECB proceeded with the preparation of Regulatory Guidelines. It is anticipated that the NSCA will come into force in 1999.

On March 13, 1998, after almost 10 years of study and an extensive public review process, the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel (also known as the Seaborn Panel) released its recommendations. The Seaborn Panel concluded that, from a technical perspective, safety of the disposal concept developed by Atomic Energy of Canada Ltd. (AECL) had been, on balance, adequately demonstrated for a conceptual stage of development but that, as it stands, the disposal concept had not been demonstrated to have broad public support. The Panel also found that the concept, in its current form, did not have the required level of acceptability to be adopted as Canada's approach for managing nuclear fuel wastes.

On December 3, 1998, the Government of Canada responded to the Seaborn Panel recommendations and laid out its objectives on the establishment of a Waste Management Organization (to be established as a separate legal entity of waste producers and owners) and federal oversight for the next steps towards the long-term management, including

Figure 4
World Uranium Production, 1997



Source: Uranium and Radioactive Waste Division, Natural Resources Canada.

disposal, of nuclear fuel waste. The Minister of Natural Resources Canada will return to Cabinet within 12 months with recommended options for federal oversight mechanisms.

On December 16, 1998, AECL announced that budgetary constraints had brought it to a decision to terminate its nuclear research activities at Whiteshell Laboratories in Pinawa, Manitoba, by December 2001. Nuclear facilities at the site will be decommissioned, but two key scientific research programs will be continued. The reactor safety research program will be consolidated at AECL's facilities at Chalk River and Sheridan Park, Ontario, and the nuclear waste management program will be privatized, following consultations with key stakeholders.

THE URANIUM MARKET

Overview

Just under half of all global uranium supply is now being met from sources other than new mine production. Yet 1998 brought announcements of several significant production cutbacks and delays of new mine development in the face of plans for further surplus government uranium to be made available to utilities. It also became apparent during the year that uranium producers are facing stiff competition

from enrichers, who are re-enriching depleted uranium tails and "underfeeding" enrichment plants to create additional uranium supply. These developments were accompanied by declining uranium prices throughout the year.

At year's end, it once again appeared that a commercial transaction was imminent that would provide for the purchase by a Western consortium, over a period of several years, of much of the natural uranium being derived from Russian nuclear weapons. This uranium would then be diverted to fulfil the commitments of those companies to their own customers, reducing the quantities overhanging the market and bringing some much needed stability. It will likely be several more years before uranium prices rise sufficiently to justify the development of new production capacity.

Developments Involving Surplus Uranium from Russia and the United States

During the spring of 1998, Minatom became more receptive towards the proposal put forward by Cameco, Compagnie générale des matières nucléaires (COGEMA) of France and Nukem Inc. of Germany to purchase natural uranium derived from the dismantling of Russian nuclear weapons. With the concurrence of a Russian interministerial commission,

Minatom recommenced commercial negotiations and, on June 2, 1998, an agreement-in-principle was reached between the parties.

As the parties moved towards a formal agreement, however, the United States Enrichment Corporation (USEC) filed a registration statement with the U.S. Securities and Exchange Commission in preparation for its privatization. This statement disclosed that USEC had significantly greater inventories of uranium than had been known to the market, and that USEC planned to dispose of most of that inventory over the period 2000-05. Further, USEC planned to "underfeed" its enrichment plants in the future, thereby accumulating significant additional inventories each year that could also be sold. These revelations had an immediate impact on the market outlook, and the Western companies decided that they could not finalize a commercial agreement on the terms outlined in the agreement-in-principle.

This weakened market outlook contributed to decisions announced by a number of uranium companies around the world during the second half of the year to defer the development of new mines, shut down existing mines, or scale back production to coincide with firm sales commitments. As mentioned above, both CRI and Cameco announced adjustments to their Saskatchewan operations during this period.

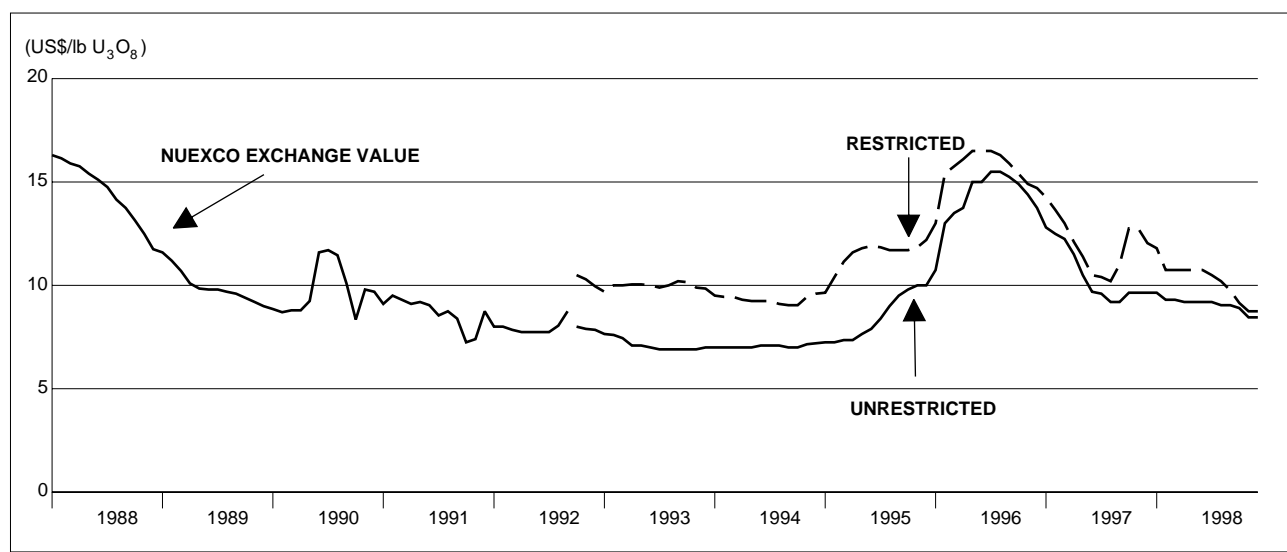
On September 22, 1998, U.S. Secretary of Energy Richardson and Minister Adamov of Minatom issued a joint report on the status of implementation of the highly enriched uranium agreement. This report contained a number of commitments on both sides

designed to encourage the resumption of commercial negotiations. Significant among these was a commitment by the United States to defer further uranium sales by the Department of Energy. On October 21, 1998, the U.S. Congress passed legislation appropriating up to US\$325 million for the purchase of the quantities of uranium associated with the 1997 and 1998 deliveries by Russia of blended down nuclear weapons material. Expenditure of the funds was conditional upon the Russians signing a commercial agreement for the sale of the uranium feed from 1999 forward. Commercial negotiations resumed in December with senior U.S. and Russian officials participating in the talks.

Uranium Prices

The increase in spot market prices during the second half of 1997 proved to be unsustainable, giving way to an almost continuous decline throughout 1998. The "restricted" market price fell from US\$12.05/lb U_3O_8 at the beginning of the year to close at US\$8.75/lb U_3O_8 . The "unrestricted" price, attributable to uranium from the former Soviet Union, declined over the course of the year from US\$9.65/lb U_3O_8 to US\$8.45/lb U_3O_8 . These prices, reported by Trade-Tech,⁴ were influenced mainly by a lack of demand in the spot market and strengthened only briefly during the second quarter. In fact, the total volume transacted on the spot market was less than 3900 tU, the lowest yearly spot volume in over a decade. The marketing plans enclosed in USEC's registration statement altered perceptions of the longer term supply and demand balance, and contributed to the decline in spot prices throughout the second half of the year.

Figure 5
Trend in Uranium Spot Prices, 1988-98



Source: TradeTech.

It took the announcement of several significant mine closures and production cutbacks, including those by Cameco and CRI, to counteract these perceptions. Since the end of the year, spot prices have begun to recover. Figure 5 shows the development of uranium spot prices from 1988, which is the last time prices were above US\$15.00/lb U_3O_8 .

The average price of Canadian export deliveries also decreased from \$51.30/kgU (US\$14.20/lb U_3O_8) in 1997 to US\$51.10/kgU (US\$13.30/lb U_3O_8) in 1998, reflecting mainly the decline in spot prices. Canadian producers were, to a large degree, sheltered from the price decline during 1998 by the weakness of the Canadian dollar against the U.S. currency. Table 8 shows the export price trend from 1975 to 1998, while Table 9 indicates actual exports of Canadian-origin uranium to principal customers from 1992 to 1997. The destination of Canada's exports of uranium in concentrates on a cumulative basis (1993-97 inclusive) is illustrated in Figure 6, which highlights the importance of the United States as a major customer.

REFINING AND CONVERSION

Cameco operates Canada's only uranium refining and conversion facilities, located at Blind River and Port Hope, Ontario, respectively. At the Blind River refinery, which is the world's largest, uranium mine concentrates from Canada and abroad are refined to uranium trioxide (UO_3), an intermediate product. The

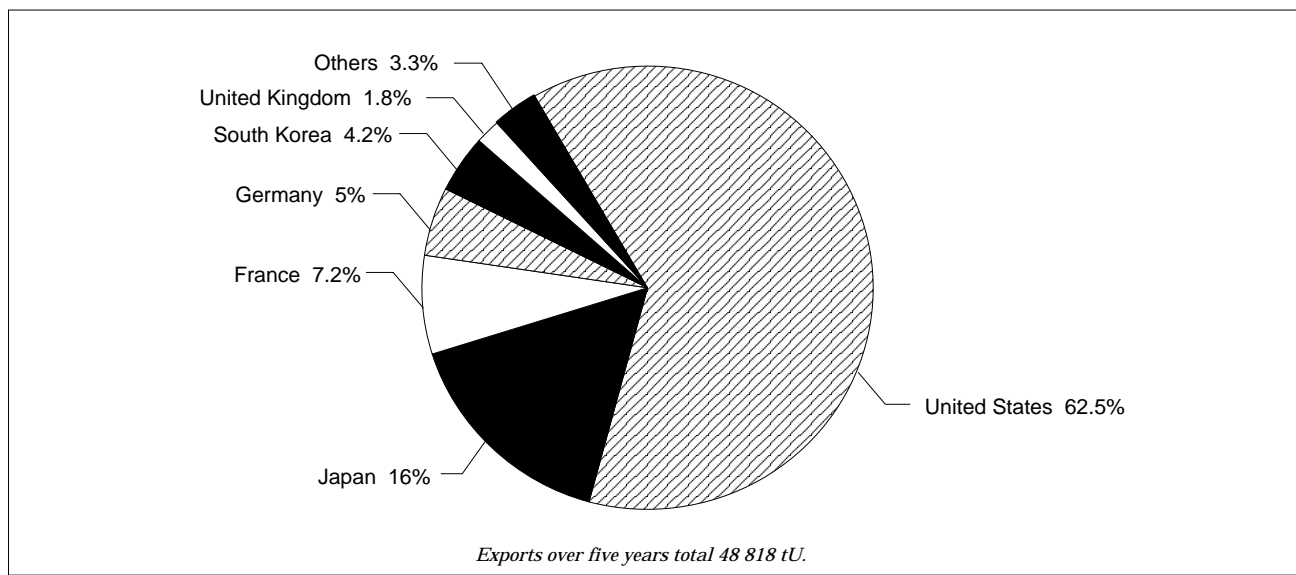
UO_3 is then trucked to the Port Hope facilities, which have about one quarter of the Western World's annual uranium hexafluoride (UF_6) conversion capacity and currently provide the only commercial supply of fuel-grade natural uranium dioxide (UO_2). UF_6 is enriched outside Canada for use in foreign light-water reactors, while natural UO_2 is used to fabricate fuel bundles for CANDU reactors in Canada and abroad. About 80% of the UO_3 from Blind River is converted to UF_6 , while the remaining 20% is converted to UO_2 . Table 10 tabulates Canada's production of refined and converted uranium, and notes the associated work force from 1994 to 1997, inclusive.

Cameco's reduced uranium production will have an impact on these fuel services facilities. In 1999, summer shut-downs will be extended to ten weeks from four at Blind River, and to thirteen weeks from four at Port Hope. About 315 employees will be laid off during these shut-downs. In addition, five positions at each of the two plants will be eliminated.

NUCLEAR POWER DEVELOPMENTS

In 1998, nuclear plants generated about 13% of Canada's electricity, mainly in the province of Ontario. During the year, Ontario Hydro continued its Nuclear Recovery Program, based on recommendations from the *Independent, Integrated Performance Assessment (IIPA)*. Four units at Pickering A and the three operational units at Bruce A were laid up in early 1998 (Bruce A Unit 2 was mothballed in

Figure 6
Canadian Uranium Exports, by Country of Final Destination, 1993-97



Source: Atomic Energy Control Board (AECB), Canada.

1995). The reactor lay-up is not because of safety problems, but was deemed necessary to focus on improving the performance of the newer units still in operation. Progress toward Ontario Hydro's goal of returning to world-class performance was evident in the improved performance of the 12 operating units at the Pickering, Bruce and Darlington stations in 1998. Decisions regarding the re-start of the Pickering A units are expected in the spring of 1999. Decisions relating to Bruce A re-starts will depend on the overall success of the 12-unit recovery plan, system needs, and the results of a business case analysis. The relevant statistics for Canada's nuclear energy program are provided in Tables 11 and 12.

AECL submitted a bid for a CANDU nuclear station at Akkuyu, Turkey, in response to the Turkish invitation to bid that was issued in December 1996. AECL is one of three vendors contending for the project. The winning bid has not yet been announced, but a decision is expected in the spring of 1999 (after national elections). At Wolsong in South Korea, construction of two of the three remaining CANDU reactors to be built proceeded on schedule. Unit 3 was brought into service in June 1998, and Unit 4 construction was nearly complete at year's end. Wolsong Unit 2, brought into service in 1997, continued to perform well throughout 1998. AECL also began construction of the first of two reactors for the China National Nuclear Corporation in June 1998.

OUTLOOK

By early 1999 it appeared that many of the remaining obstacles had been addressed, and the prospects appeared to be good for the eventual conclusion of the commercial transaction that would allow natural uranium derived from the dismantling of Russian nuclear weapons to move smoothly into Western commercial markets. If the agreement is finally concluded during 1999, the uncertainty overhanging the international uranium market will be significantly reduced, providing a more stable environment for long-term investment decisions. That, in turn, should enable Canada to remain a stable and competitive supplier of uranium to world markets for the foreseeable future.

Improved market conditions will be welcomed by Canadian producers as they enter an important period of transition in 1999. As mineable reserves at Key Lake, Rabbit Lake and Cluff Lake near depletion, new high-grade mines are poised to enter into production, beginning with McClean Lake and McArthur River, followed by Cigar Lake. Successfully bringing these operations on stream will ensure that Canada remains the world's premier uranium producer well into the next century.

ENDNOTES

¹ John French, Advisor, Uranium Markets (tel. (613) 995-7474), has contributed to the text in those sections dealing with international uranium market developments and uranium prices.

² *Canada's Uranium Industry - World's Largest High-Grade Uranium Mines Proceeding*, NRCAN Mailing, August 14, 1998.

³ In certain cases, the identified operator has reported the total expenditures of a joint-venture effort. Therefore, contributions by other parties not responding to the NRCAN survey are accounted for in the \$39 million total expenditure for 1996.

⁴ NUEXCO, an international uranium brokerage firm, was originally called the Nuclear Exchange Corporation. Several companies in the NUEXCO organization that were associated with uranium trading declared bankruptcy in early 1995. Certain of these have been reorganized and continue to provide brokerage services. NUEXCO's publication activities are carried on by TradeTech.

Note: (1) For definitions and valuation of mineral production, shipments and trade, please refer to Chapter 65. (2) Information in this review was current as of March 1, 1999. (3) This paper, and other information on developments in Canadian nuclear policy, can be accessed on the Internet at <http://nuclear.nrcan.gc.ca/>.

TABLE 1. URANIUM PRODUCTION AND ASSOCIATED WORK FORCE IN CANADA, 1995-97

Province and Producer	Company Work Force ¹ (Dec. 31)			Annual Output ² (tU)		
	1995	1996	1997	1995	1996	1997
ATHABASCA BASIN, SASKATCHEWAN						
Cluff Mining (COGEMA Resources Inc., 100%)	208	234	222	1 214	1 926	1 964
Key Lake JV (Cameco)	397	395	316	5 464	5 429	5 434
Rabbit Lake JV (Cameco)	249	281	285	3 148	3 973	4 633
McClellan Lake (pre-production)	..	214	225	—	—	—
McArthur River (pre-production)	57	—	—	—
Subtotal	854	1 124	1 105	9 826	11 328	12 031
ELLIOT LAKE, ONTARIO						
Rio Algom Limited Stanleigh	488	31	—	647	378	—
Total	1 342	1 155	1 105	10 473	11 706	12 031

Sources: Company annual reports; Atomic Energy Control Board open files.

— Nil; .. Not available.

¹ Figures are for company-payroll employees only; on-site contractors (mining, construction, services, etc.) are not included. ² Primary output only. With the closure of Rio Algom's Stanleigh operation at Elliot Lake in mid-1996, by-products from Cameco's refinery/conversion facilities are no longer processed in Canada. Prior to 1997, by-product totals were NOT included in the Canadian totals of primary uranium production noted above, but were included in the shipments and value of shipments figures provided in Table 2.

TABLE 2. VALUE¹ OF URANIUM SHIPMENTS² BY PRODUCERS IN CANADA, 1994-98

	Unit	1994	1995	1996	1997	1998
Total producer shipments	tU	11 253	10 293	11 396	11 127	9 984
Total value of shipments ³	C\$ millions	625	534	624	554	500

Source: Natural Resources Canada.

¹ Value of shipments includes the value of uranium recovered from the refinery/conversion facility by-products noted in Table 1, which are not included in primary production. ² Shipments in tonnes of uranium (tU), contained in concentrate, from ore-processing plants. ³ Estimates derived using an average market price.

TABLE 3. OPERATIONAL CHARACTERISTICS OF EXISTING CANADIAN URANIUM PRODUCTION CENTRES, 1997

Operating Entity (Operator)/Location	Ore-Processing Plant ¹			
	Capacity Nameplate	Recovery Overall	Annual Throughput	
	(t/d)	(%)	Total Ore (t)	Ore Grade (%)
Cluff Mining (COGEMA Resources Inc.)/ Cluff Lake, Saskatchewan	800	98	332 800	0.60
Rabbit Lake JV (Cameco Corporation)/ Rabbit Lake, Saskatchewan	2 000	95	373 860	1.52
Key Lake JV (Cameco Corporation)/ Key Lake, Saskatchewan	710	97	315 280	2.09

Sources: Corporate annual reports; Atomic Energy Control Board open files.

¹ Figures are rounded.

TABLE 4. SUMMARY, CANADIAN URANIUM MINING PROJECTS, AS OF MARCH 1, 1999

Project, Province/Operator	Owners Share	Deposit Type/ Discoverer and Discovery Date	Resources (Company Estimates as of March 1, 1999)	Ore Grade and Notes on Deposits	Mining Method, Milling Rate and Capacity	Project Particulars and Status	Location of Project/ Notes of Interest
(%)							
NEW PROJECTS PLANNED FOR PRODUCTION							
Cigar Lake, Sask./ Cigar Lake Mining Corporation	Cameco (48.75), COGEMA (36.375), Idemitsu (7.875), TEPCO (5), KEPCO (2 non-voting)	Unconformity-related/ COGEMA 1981	Overall property 136 000 tU, <i>mineable</i>	Overall property grade of 12% U; grades vary from 5% to 70% U; orebody at depth of 450 m	"Non-entry" underground; "jet-boring" mining method; milling at McClellan Lake and Rabbit Lake; contributing from 2300 to 6900 tU/y	C\$555 million project; test mining completed in 1992; EIS submitted in October 1995; Joint Panel reports November 1997; government approval April 1998	670 km N of Saskatoon; 500-m-deep shaft sunk; brine freezing of ground is required to mine the ore; production to begin 2001/2
McClellan Lake, Sask./COGEMA Resources Inc.	COGEMA (70), Denison (22.5), OURD (7.5)	Unconformity-related/ original McClellan by CanOxy/Inco 1979-80; JEB & Sue <i>et al</i> - 1982 to 1990 by Minatco Ltd.	Overall property 17 300 tU, <i>mineable</i>	2.7% U average overall; open-pit depths from 20 to 145 m; McClellan under- ground ore to 4% U at depth of 170 m	75% by open pit at JEB, Sue A, B & C; under- ground at McClellan; mill capacity may be expanded to mill Cigar Lake ore	C\$200 million project (alone); public hearings in 1993; approved subject to AECB licensing process; construc- tion completed during 1997	350 km N of La Ronge; JEB open-pit mining started in 1996; milling delayed until 1999; mine life of the co- enterprise >2010
Midwest Project, Sask./COGEMA Resources Inc.	COGEMA (56), Denison (19.5), Cameco (20), OURD (4.5)	Unconformity-related/ Esso Minerals 1977 (interests of Bow Valley, Numac Oil & Gas, <i>et al</i> bought by partners)	Overall property 13 000 tU, <i>mineable</i>	Overall property grade of 4% U; grades vary from 2% to 30% U; orebody at depth of 200 m	"Non-entry" underground; "jet-boring" mining method; milling at McClellan Lake; contribut- ing 2300 tU/y	\$80 million co-venture with McClellan; in 1993, Joint Panel rejects proposal; new EIS in 1995; final hearings August 1997; Joint Panel report November 1997; government approval April 1998	710 km N of Saskatoon; 185-m-deep test-mine shaft; new operator, COGEMA, revised EIS; start-up in 2003 (?)
McArthur River, Sask./Cameco Corporation	Cameco (83.766), COGEMA (16.234)	Unconformity-related/ Cameco 1988	Overall property 186 000 tU; but 98 000 tU <i>mineable</i>	Overall property grade varies from 2% to 70% U, but averages 13% U; <i>mineable</i> grade 16% U; orebody at depth of 550 m	"Non-entry" underground mining method with milling at Key Lake; licensed mill capacity 6150 tU/y but expandable to 6900 tU/y	C\$400 million project; 1993 underground exploration; EIS December 1995; public hearings 1996; Joint Panel report February 1997; government approval May 1997	80 km NE of Key Lake; construction licence August 1997; start-up expected late 1999; will extend operations at Key Lake mill beyond 2015
Kiggavik, N.W.T./ Urangesellschaft Canada Limited	Urangesellschaft (79), COGEMA (20), Daewoo Corp. (1)	Unconformity-related/ Urangesellschaft 1977	Overall property 15 000 tU, <i>mineable</i> ; (more incl. Andrew Lake <i>et al</i>)	0.41% U average overall; depth Centre pit 100 m, Main pit 200 m	Open-pit mining methods; 1200 t/d mill feed; output rate of 1200 tU/y originally expected	EIS submitted but project deemed deficient by Panel; COGEMA expected to review project and submit new EIS	75 km W of Baker Lake; start- up not likely before 2005; >11-year mine life with tributary ore included
RECENTLY APPROVED EXTENSIONS OR EXPANSIONS TO EXISTING OPERATIONS							
Dominique-Janine Extension (DJX) at Cluff Lake, Sask./ COGEMA Resources Inc.	COGEMA Resources Inc. (100)	Unconformity-related/ "D" pit by Mokta 1969 (depleted 1981); Claude <i>et al</i> /Amok 1970-76 (Claude depleted 1989); D-J & Dominique-Peter 1980-86	Overall property 13 000 tU <i>mineable</i> , Dominique-Janine Extension 5000 tU, <i>mineable</i>	Mill-feed grade for 1996 was 0.63% U; DJX to mine >680 000 t of ore grading 0.73% U to yield in excess of 5000 tU	Open pit at DJX before underground; re-licensed mill capacity to 2020 tU/y; milling rate being increased from half- capacity operation	C\$10 million Cluff Lake extension; hearings in 1993; approval to proceed subject to AECB licensing; mining well under way in 1995	720 km N of Saskatoon; revised three-phase mine plan offers mining flexibility; operations to be suspended mid-2000
Eagle Point & Collins Bay at Rabbit Lake, Sask./Cameco Corporation	Cameco (100)	Unconformity-related/Gulf Minerals 1968; Rabbit Lake (depleted 1984); 1971-79 for Collins Bay ("B" pit depleted 1991); 1980 for Eagle Point	Eagle Point <i>et al</i> , 18 000 tU <i>mineable</i> , overall property 27 000 tU (incl. stockpiles)	Mill-feed grade for 1996 was 1.58% U; <i>mineable</i> grade 1.2% U for Eagle Point and 3.45% U for Collins "A&D"; Eagle Pit depth 120-335 m	"Non-entry" underground methods at Eagle Point, open pit for others; milling rate below 5400 tU/y licensed capacity, but increased in 1995	Eagle Point test mining 1992; Joint Panel reviewed and federal government approved in 1993; Eagle Point in production, Collins A & B mined	805 km N of Saskatoon; mining Eagle Point ore since late June 1994; Eagle Point mining to be suspended March 31, 1999

Notes: OURD (Canada) Co., Ltd. is a subsidiary of the Overseas Uranium Resources Development Corporation (OURD) of Japan. Urangesellschaft Canada Limited, operated by Cogema Resources Inc., is a subsidiary of Compagnie générale des matières nucléaires (COGEMA) of France. Idemitsu Uranium Exploration Canada Ltd. is a wholly owned subsidiary of Idemitsu Kosan Co., Ltd. of Japan. Korea Electric Power Corporation (KEPCO) is South Korea's only nuclear-electric utility. In June 1997, COGEMA acquired the 20% interest in the Kiggavik (Northwest Territories) project that Cameco had purchased earlier in the year when it acquired Power Resources Inc. The Tokyo Electric Power Co., Inc. (TEPCO), Japan's largest nuclear power utility, acquired a 5% interest in Cigar Lake from Idemitsu Kosan in mid-1997.

TABLE 5. URANIUM EXPLORATION ACTIVITY IN CANADA, 1982-97

Year	Expenditures ¹	Drilling ²	Million-Dollar Projects ³
	(C\$ millions)	(km)	(number)
1982	71	247	13
1984	35	197	12
1986	33	162	11
1987	37	164	12
1988	59	201	11
1989	58	158	11
1990	45	66	6
1991	44	67	4
1992	46	79	4
1993	40	62	5
1994	36	67	8
1995	44	75	10
1996	39	79	8
1997	58	104	6

Source: Natural Resources Canada.

¹ Direct exploration and drilling expenditures in current dollars; from the late 1980s, includes advanced underground exploration and deposit appraisal expenditures; from the mid-1990s, may also include care-and-maintenance costs associated with deposits awaiting production approvals.

² Exploration and surface development drilling; excludes development drilling on producing properties. ³ Number of projects where direct exploration and drilling expenditures exceeded C\$1 million in current dollars.

TABLE 6. ESTIMATES OF CANADA'S URANIUM RESOURCES RECOVERABLE FROM MINEABLE ORE,¹ JANUARY 1, 1997, AND JANUARY 1, 1998

Price Ranges Within Which Mineable Ore is Assessed ²	Measured		Indicated		Inferred	
	1/1/97	1/1/98	1/1/97	1/1/98	1/1/97	1/1/98
	(000 tU)					
Up to C\$100/kgU	151	140	180	172	99	107
C\$100 to \$150/kgU	—	—	—	—	—	—
Total	151	140	180	172	99	107

Source: Natural Resources Canada.

— Nil.

¹ Actual or expected losses in mining recovery and ore processing have been accounted for; these factors were individually applied to resources tributary to existing or prospective production centres. In underground operations, mineable ore is generally 75% to 85% of the ore-in-place; higher mining recoveries are achievable in open-pit operations. Canada's weighted average ore processing recovery for existing conventional operations exceeded 97% over the 1996/97 period.

² The Canadian dollar figures reflect the price of a quantity of uranium concentrate containing 1 kg of elemental uranium. The prices were used in determining the cut-off grade at each deposit assessed, taking into account the mining method used and the processing losses expected. The price of C\$100/kgU was used by Natural Resources Canada to illustrate those resources that were of economic interest to Canada during the survey period.

Note: \$1/lb U₃O₈ = \$2.6/kgU.

TABLE 7. PRODUCTION OF URANIUM IN CONCENTRATES BY SELECTED MAJOR PRODUCING COUNTRIES, 1993-97

	1993	1994	1995	1996	1997
	(tonnes U)				
Canada ¹	9 190	9 700	10 530	11 750	12 030
Russia	2 700	2 350	2 200	2 600	2 000
Kazakhstan	2 700	2 240	1 580	1 210	1 000
Uzbekistan	2 700	2 120	1 700	1 460	1 760
China	950	480	780	560	500
United States	1 290	1 290	2 324	2 430	2 170
South Africa	1 710	1 670	1 420	1 440	1 100
Namibia	1 670	1 900	2 010	2 450	2 900
Australia	2 270	2 210	3 710	4 970	5 520
Niger	2 910	2 980	2 980	3 320	3 500
France	1 710	1 050	1 020	930	750
Gabon	550	650	630	570	470
Other ²	2 770	2 370	2 730	2 540	1 990
Total ³	33 120	31 010	33 610	36 230	35 690

Sources: *Uranium: Resources, Production and Demand*, a biennial report published jointly by the Nuclear Energy Agency of the OECD and the International Atomic Energy Agency; miscellaneous corporate, national and international reports.

¹ Figures include refinery/conversion facility by-product uranium, and differ from primary production figures shown elsewhere. ² Includes Argentina, Belgium, Brazil, Bulgaria, China, the Czech Republic, Germany, Hungary, India, Israel, Japan, Mongolia, Pakistan, Portugal, Romania, Spain, Ukraine and Yugoslavia. ³ Totals are of the listed figures only and represent global production.

Note: Country figures are rounded to the nearest 10 tU.

TABLE 8. CANADIAN URANIUM EXPORT PRICE,¹ 1975-98

Year	Average Export Prices		Spot Sale Portion of Deliveries
	Current Dollars	Constant 1998 Dollars	
	(C\$/kg/U) ²		(%)
1975	52	143	n.r.
1976	104	261	n.r.
1977	110	259	n.r.
1978	125	276	n.r.
1979	130	262	n.r.
1980	135	245	n.r.
1981	110	180	1
1982	113	170	1.5
1983	98	140	10
1984	90	125	26
1985	91	123	20
1986	89	117	21
1987	79	99	35
1988	79	95	13
1989	74	85	<1
1990	71	79	<1
1991	61	66	<2
1992	59	63	<1
1993	50	53	<1
1994	51	53	<1
1995	47	48	2
1996	53.60	53.78	1
1997	51.30	51.09	<1
1998	51.10	51.10	<2

Source: Natural Resources Canada.

n.r. Not reported.

¹ NRCAN derives the Export Price figure annually based on the average price under all export contracts made by Canadian producers for deliveries in the given year. ² \$/kgU x 0.38465 = \$/lb U₃O₈.

Notes: Prices are rounded. Constant dollar values are derived using the Implicit Price Index for Gross Domestic Product.

TABLE 9. EXPORTS OF URANIUM OF CANADIAN ORIGIN, 1992-97

Country of Final Destination	1992	1993	1994	1995	1996	1997
	(tonnes of contained uranium ¹)					
Argentina	20	29	–	–	–	–
Belgium	–	–	115	3	115	–
France	111	461	766	1 016	679	587
Germany	534	665	465	348	776	184
Japan	2 328	523	3 443	363	1 490	1 968
South Korea	104	715	455	290	261	315
Spain	–	–	274	186	103	160
Sweden	170	–	–	84	142	450
United Kingdom	19	–	50	188	250	374
United States	4 032	6 291	4 938	5 702	7 407	6 187
Total	7 318	8 684	10 506	8 180	11 223	10 225

Source: Atomic Energy Control Board.

– Nil.

¹ Some of this uranium was first exported to an intermediate country for conversion and/or enrichment prior to transfer to the country of final destination.

TABLE 10. URANIUM PROCESSING PRODUCTION AND ASSOCIATED WORK FORCE IN CANADA, 1994-97

Process and Location (Nameplate Capacity)	Production				Site Work Force			
	1994	1995	1996	1997	1994	1995	1996	1997
	(tU)				(number)			
Refining at Blind River (18 000 tU as UO ₃)	9 445	10 729	10 190	12 195	81	86	90	102
Conversion at Port Hope (10 500 tU as UF ₆ and 2500 tU as UO ₂)	9 490	10 552	10 127	12 594	198	231	257	277

Source: Cameco Corporation.

TABLE 11. NUCLEAR POWER PLANTS IN CANADA – INSTALLED CAPACITY AS OF DECEMBER 31, 1998

Reactors	Owner	Net Capacity (MWe)	In-Service Dates
Pickering 1 to 4	Ontario Hydro	2 060	1971-73
Bruce 1 to 4 ^a	Ontario Hydro	3 076	1977-79
Point Lepreau	NB Power ¹	635	1983
Gentilly 2	Hydro-Québec	638	1983
Pickering 5 to 8 ^b	Ontario Hydro	2 064	1983-86
Bruce 5 to 8	Ontario Hydro	3 440	1984-87
Darlington 1 to 4	Ontario Hydro	3 524	1990-93
Total net capacity		15 437	

Source: Natural Resources Canada.

^a Bruce Unit 1 out of service on October 16, 1997; Bruce Unit 2 out of service on October 8, 1995, and being mothballed; Bruce Unit 3 out of service on April 9, 1998; Bruce Unit 4 out of service on March 17, 1998. ^b Pickering Units 1-4 taken out of service indefinitely at the end of 1997.

¹ New Brunswick Power Corporation.

TABLE 12. NUCLEAR POWER DATA IN CANADA AS OF DECEMBER 31, 1998

	Unit	Canada	Ontario	New Brunswick	Quebec
Electricity demand growth	%	0.4	1.1	0.7	-3.8
Nuclear share of electric utility generation	%	13.4	43.8	21.1	2.8
Reactors in service	no.	14	12	1	1
Capacity in service	Net MWe	10 301	9 028	635	638

Source: Natural Resources Canada.