Canada's Nuclear Regulator

Regulatory Oversight Report for Uranium Mines and Mills in Canada: 2016

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Cover images
From left to right:

Cigar Lake Mine
McArthur River Mine
Rabbit Lake Mine and Mill
Key Lake Mill
McClean Lake Mill

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Executive Summary

This report, titled *Regulatory Oversight Report for Uranium Mines and Mills in Canada: 2016*, presents Canadian Nuclear Safety Commission (CNSC) staff's assessment of the performance of operating uranium mines and mills regulated by the CNSC. It also provides an update on public information, community engagement programs and relevant aspects of the CNSC's Independent Environmental Monitoring Program.

Due to the static nature of historic and decommissioned uranium mine and mill sites, this 2016 report also includes decommissioned and historic sites with significant events and major developments that occurred during the 2016 calendar year, as well as a status update on the Rio Algom Elliot Lake site. CNSC staff will be presenting a complete review on the performance of all decommissioned and historic uranium mines and mills in Canada every two years, with the next full update scheduled for the 2017 report.

CNSC staff use the Safety and Control Area Framework to evaluate the performance of each licensee. This report provides performance ratings for all 14 safety and control areas (SCAs) for operating uranium mines and mills. Per past practice, this report focuses on the three SCAs that contain the majority of the key performance indicators for these facilities: "radiation protection", "environmental protection" and "conventional health and safety". The information provided covers the 2016 calendar year and, where possible, presents comparisons to previous years and discusses trends.

The SCA ratings in this report were derived from results of compliance activities conducted by CNSC staff. These activities included onsite inspections, technical assessments, review of reports submitted by licensees, event and incident reviews, and ongoing exchanges of information with licensees. For this reporting year, CNSC staff rated all SCAs as "satisfactory" for all uranium mines and mills. CNSC staff confirmed that all operating uranium mine and mill sites in Canada operated safely during 2016.

CNSC staff concluded that each of the regulated sites covered in this report have made adequate provision for the health and safety of workers, the protection of the public and the environment, and Canada's international obligations. Documents referenced in this report are available to the public upon request.

1 Introduction

1.1 Background

The Canadian Nuclear Safety Commission (CNSC) regulates Canada's operating uranium mines and mills to protect health, safety, security and the environment; to implement Canada's international commitments on the peaceful use of nuclear energy; and to disseminate objective scientific, technical and regulatory information to the public.

The CNSC acts in accordance with the requirements of the *Nuclear Safety and Control Act* (NSCA) and its associated regulations. Each year, the CNSC produces a regulatory oversight report on the performance of Canada's uranium mine and mill operations. The information presented in this report covers the 2016 calendar year and, where possible, presents comparisons to previous years and discusses trends. It describes:

- the CNSC's regulatory efforts, public information and community engagement, and the Independent Environmental Monitoring Program (IEMP)
- the safety and control area (SCA) performance ratings for uranium mine and mill operations
- licensee information on operation, licence changes, major developments and significant events
- performance data on the SCAs of radiation protection, environmental protection, and conventional health and safety for each licensed facility

This report summarizes CNSC staff's assessment for the 2016 calendar year of the following uranium mine and mill operations:

- Cigar Lake
- McArthur River
- Rabbit Lake (transitioned to care and maintenance in 2016)
- Key Lake
- McClean Lake

In addition to the operating facilities, the 2015 regulatory oversight report presented the performance of historic and decommissioned uranium mine and mill sites. Due to the static nature of these sites, CNSC staff will be presenting a complete review on the performance of decommissioned and historic uranium mines and mills in Canada every two years, with the next update provided in 2018 for the reporting year of 2017. Information within this report is limited to decommissioned and historic sites with significant events and developments that occurred during the 2016 calendar year and a status update on the Rio Algom Elliot Lake site (appendix K).

Section 8 presents significant events and developments for the following historic and decommissioned sites:

- Beaverlodge
- Cluff Lake
- Deloro
- Gunnar
- Port Radium
- Denison Mines

The following decommissioned and historic sites are not included in this 2016 report:

- Lorado
- Rayrock
- Agnew Lake
- Madawaska
- Bicroft
- Dyno

Throughout 2016, CNSC compliance activities, including inspections and review of licensee submissions and events, continued for all historic and decommissioned sites.

1.2 CNSC regulatory efforts

1.2.1 Licensing and compliance

An approved licence under the NSCA will contain the terms of the licence, the activities licensed and licence conditions. A table summarizing the operating uranium mine and mill licences can be found in appendix A. A licence conditions handbook (LCH) accompanies each licence and contains criteria used by staff to ensure compliance with the conditions making up the licence. Any changes made to the LCHs during 2016 appear in appendix A.

The CNSC ensures licensee compliance through verification, enforcement and reporting activities. CNSC staff develop compliance plans for each operation commensurate with the risk associated with the facility. CNSC staff implement compliance plans by conducting regulatory activities including onsite inspections and technical assessments of licensee programs, processes and reports. Changes to compliance plans are made on an ongoing basis in response to events, facility modifications and changes in licensee performance.

A breakdown of the number of CNSC staff inspections at uranium mine and mill operations is discussed in section 1.2.3. Enforcement actions from these inspections were provided to the licensees in detailed inspection reports and recorded in the CNSC regulatory information bank to ensure these actions were tracked to completion. CNSC staff verified that licensees have complied with the conditions of enforcement actions and that all actions have been closed.

1.2.2 Safety and Control Area Framework

CNSC staff use the SCA Framework in evaluating each licensee's safety performance. SCAs are technical topics CNSC staff use across all regulated facilities and activities to assess, evaluate, review, verify and report on regulatory requirements and performance. The SCA Framework includes 14 SCAs, which are further subdivided into specific areas that define its key components. Appendix B provides definitions of these SCAs and their specific areas.

CNSC staff assess licensee performance in each applicable SCA according to the following four ratings:

- fully satisfactory (FS)
- satisfactory (SA)
- below expectations (BE)
- unacceptable (UA)

A discussion of rating definitions appears in appendix C.

While this report provides CNSC staff's performance ratings for all 14 SCAs, particular focus is given to the three SCAs that cover many of the key performance indicators for these operations: "radiation protection", "environmental protection" and "conventional health and safety".

Through 2016, all SCA performance ratings for the uranium mine and mill operations were rated "satisfactory".

Results from regulatory oversight activities conducted by CNSC staff concluded that uranium mine and mill facilities met the following requirements:

- Radiation protection measures were effective and radiation doses received by workers remained as low as reasonably achievable (ALARA). No worker exceeded regulatory effective dose limits and four action level exceedances were reported.
- Environmental protection programs were effective and resulted in emissions and effluents remaining ALARA. Emissions and effluent management across all uranium mines and mills resulted in:
  - no exceedances of the *Metal Mining Effluent Regulation* discharge limits
  - no exceedances of provincial limits
  - appropriate reporting of two action level exceedances

- Conventional health and safety programs continued to protect workers.

Appendix D contains the SCA performance ratings for the operating mines and mills from 2012 to 2016.

1.2.3 Compliance activities

The CNSC regulates the five uranium mine and mill operations under separate licences. Appendix A provides an outline of these licences and licensing information. CNSC staff verified compliance with regulatory requirements through inspections, review and assessment of reports and licensee programs, which are supplemented with meetings, presentations and facility visits.

CNSC staff performed six inspections at each uranium mine and mill operation for a total of 30 onsite inspections in 2016 (outlined in appendix J). These inspections resulted in 43 non-compliances, all of low safety significance. CNSC staff assessed and verified that licensee's corrective actions taken in response to non-compliances were appropriate and acceptable. All enforcement actions were implemented appropriately by licensees and are considered closed by CNSC staff.

Other regulatory bodies that conduct inspections at the operating facilities include the Saskatchewan Ministry of Environment, the Saskatchewan Ministry of Labour Relations and Workplace Safety, and Environment and Climate Change Canada. These regulatory bodies focus primarily on areas of conventional health and safety and environmental protection. CNSC staff take into account the findings from these regulatory bodies when assessing licensees' performance. When value-added and logistically reasonable, joint inspections are conducted with other federal, provincial or territorial regulatory agencies.

1.2.4 CNSC Independent Environmental Monitoring Program

Under the NSCA, each licensee is required to develop, implement and maintain an environmental monitoring program to demonstrate that the public and environment are protected from releases to the environment related to the facility's nuclear activities. The results of these monitoring programs are submitted to the CNSC for compliance verification with applicable guidelines and limits, as set out in regulations that oversee Canada's nuclear industry.

The CNSC has implemented its IEMP to confirm that the public and environment around regulated nuclear facilities are safe. The IEMP is a tool that complements and informs the CNSC's ongoing compliance verification program. It involves taking samples from public areas around the sites, and measuring and analyzing the amount of radiological and hazardous substances in those samples.

In 2016, samples were collected in a number of publicly accessible areas around the McClean Lake Operation under the CNSC's IEMP. A five-year plan for the IEMP at operating uranium mines and mills was established in 2015. As part of this plan, samples will be collected at the other uranium mines and mills in future campaigns.

IEMP results, found on the CNSC's IEMP Web page, indicate that the public and the environment around the McClean Lake Operation are protected and safe and that there are no health impacts as a result of site operations. These results are consistent with the results submitted by AREVA Resources Canada Inc.(AREVA), demonstrating that the licensee's environmental protection program protects the health and safety of people and the environment. The results from previous IEMP sampling campaigns are also available on the CNSC's IEMP Web page.

1.3 Public information and community engagement

The CNSC is committed to keeping the public informed of regulatory activities occurring at operating mine and mill facilities. Ongoing CNSC public engagement efforts include publishing newsletters, updating website information and maintaining a social media presence. During public engagement activities, the CNSC often staffs an information booth to provide important information on its regulatory role and mandate, as well as to answer any questions community members may have.

To ensure licensees provide open and transparent information to the public, in 2013 the CNSC published new regulatory requirements in RD/GD-99.3, *Public Information and Disclosure*, which were incorporated into the LCH for each licence. According to RD/GD-99.3, licensees are to implement and maintain public information and disclosure programs. These programs are supported by disclosure protocols, which outline the type of information on the operation or site and its activities to be shared with the public (e.g., incidents, major changes to operations, periodic environmental performance reports) and how that information will be shared. This ensures timely information is effectively communicated about the health, safety and security of persons and the environment and other issues associated with the lifecycle of nuclear facilities. In 2016, CNSC staff confirmed through regulatory oversight activities that licensees' implemented programs are in compliance with RD/GD-99.3.

In 2016, licensees and CNSC staff continued regular communication with interested communities. As part of the public information program and outreach activities, licensees and CNSC staff regularly participate in Northern Saskatchewan Environmental Quality Committee meetings and facility tours. The committee represents more than 30 communities throughout the greater northern Saskatchewan region, many of which are Indigenous. No Environmental Quality Committee meetings were hosted by the province of Saskatchewan during the 2016 calendar year. Regularly scheduled meetings resumed in mid-2017; CNSC staff participated in scheduled meetings and facility tours.

1.3.1 Indigenous and public engagement

The CNSC is committed to ongoing engagement and relationship building with interested Indigenous communities. In this regard, First Nation and Métis communities with interest in Canada's uranium mines and mills were provided a copy of this regulatory oversight report. Through its Participant Funding Program (PFP), the CNSC also made available financial support for participation in the review of this report. In addition, during 2016, CNSC staff provided interested Indigenous communities with updates on sampling campaigns for IEMPs at uranium mine and mill operations.

To ensure licensees engage Indigenous communities, in February 2016 the CNSC published REGDOC-3.2.2, *Aboriginal Engagement*, which sets out requirements and guidance for licensees that propose projects that may raise the Crown's duty to consult. Throughout 2016, licensees continued to host meetings and to discuss their operations with Indigenous communities. CNSC staff attended many of these meetings.

Activities attended and carried out by CNSC staff in 2016 included:

- September 19–20, 2016 – Presentation at the University of Saskatchewan to the Expert Panel on the Review of Environmental Assessment Processes (with AREVA, Cameco, Saskatchewan Mining Association, Committee for Future Generations, the Government of Saskatchewan, Saskatchewan Power and the Saskatchewan Environment Society)
- September 20, 2016 – Presentation at the Cameco public meeting in Uranium City to provide an update on the Beaverlodge decommissioned properties
- October 11, 2016 – CNSC 101 presentation with Hatchet Lake First Nation, Black Lake First Nation, Prince Albert Grand Council, Métis Nation – Saskatchewan and the Federation of Sovereign Indigenous Nations
- October 12, 2016 – CNSC 101 presentation with Prince Albert Grand Council and the Federation of Sovereign Indigenous Nations
- November 3, 2016 – Cameco northern tour (Pinehouse community)
- November 4, 2016 – Notification of the McClean Lake Operation licence renewal to the Ya'thi Néné Lands and Resource Office, Black Lake First Nation, English River First Nation, Hatchet Lake First Nation, Fond du Lac First Nation, Prince Albert Grand Council, Federation of Sovereign Indigenous Nations, Métis Nation – Saskatchewan (Northern Region 1) and Kineepik Métis Local Inc. (#9)
- December 2, 2016 – Email to Lac La Ronge Indian Band regarding the McClean Lake licence renewal meeting scheduled in La Ronge, Saskatchewan
- December 8, 2016 – Meeting with Ya'thi Néné Lands and Resource Office to understand its role and provide a presentation on the CNSC's mandate, Aboriginal consultation, PFP, licensing process and approach to environmental assessment

- December 9, 2016 – Email to Ya'thi Néné Lands and Resource Office to follow up on the introductory meeting
- December 12, 2016 – Email to Ya'thi Néné Lands and Resource Office to provide a copy of the McClean Lake Operation licence and licence conditions handbook

On October 11, 2016 CNSC staff provided a CNSC 101 information session to more than 100 participants in the Wollaston Post/Hatchet Lake First Nation community, including representatives from other northern Saskatchewan First Nation and Métis communities and organizations. This session provided an introduction to the CNSC and the work it does to ensure that nuclear facilities in northern Saskatchewan and across Canada are safe and how the public can participate in CNSC processes. In addition, on October 12, 2016 the CNSC hosted a CNSC 101 session in Saskatoon, Saskatchewan, for leadership and staff of the Prince Albert Grand Council and the Federation of Sovereign Indigenous Nations.

A licence renewal hearing was held for the McClean Lake Operation in June 2017 in La Ronge, Saskatchewan. As part of this licence renewal, focused engagement activities and actions were undertaken by CNSC staff. Per the CNSC's public notification process for Commission proceedings, CNSC staff informed the public of the Commission hearing and availability of the PFP via the CNSC's website, email subscription list, social media channels, and radio and print advertisements in local communities in northern Saskatchewan.

The local communities are heavily engaged in the activities associated with mine and mill operations as employees, suppliers, and participants in numerous agreements. A summary report produced by the province of Saskatchewan, titled *2016 Summary of Benefits from Northern Mining*, provides an overview of the benefits associated with mining in northern Saskatchewan. The report highlights that thousands of workers are employed at the northern mines in various capacities. The mines maintain a high northern participation rate, with 48 percent of mine employees classified as northerners. Northern mines are the largest employers of Indigenous peoples in Canada.

CNSC staff continue to develop a structured, formalized approach to ensure engagement updates are regular and include all interested Indigenous communities and organizations. CNSC staff will provide an update on the structured process in the 2017 regulatory oversight report.

2 Overview

This report focuses on the five uranium mines and mills currently operating in Canada. The facilities listed are located within the Athabasca Basin of northern Saskatchewan and are shown in figure 2.1:

- Cigar Lake mine
- McArthur River mine
- Rabbit Lake mine and mill (transitioned to care and maintenance in 2016)
- Key Lake mill
- McClean Lake mine and mill

Figure 2.1: Location of uranium mines and mills in Saskatchewan

The 2016 uranium production data for these operating mine and mill facilities are shown in table 2.1. The CNSC confirmed all facilities operated within their authorized annual production limits in 2016.

Table 2.1: Uranium mines and mills production data, 2016

Production data	Cigar Lake	McArthur River	Rabbit Lake[1]	Key Lake[2]	McClean Lake[3]
Mining – ore tonnage (Mkg/year)	37.27	89.28	79.87	N/A	0.00
Mining – average ore grade mined (% U expressed as U_3O_8)	21.55%	9.30%	0.69%	N/A	0.00%
Mining – U mined (Mkg U/year)	6.81	7.04	0.468	N/A	0.00
Milling – mill ore feed (Mkg/year)	N/A	N/A	61.67	155.30	37.20
Milling – average mill feed grade (% U expressed as U_3O_8)	N/A	N/A	0.76%	5.33%	18.08%
Milling – mill recovery (% of U)	N/A	N/A	97.03%	99.04%	99.10%
Milling – U concentrate produced (Mkg U/year)	N/A	N/A	0.428	6.95	6.67
Authorized annual production (Mkg U/year)	9.25	9.6	4.25	9.6	9.23

1 At Rabbit Lake, the difference in the mine ore grade and the mill feed grade reflects the practice of blending stockpiled material with newly mined ore.
2 At Key Lake, McArthur River ore is blended with stockpiled lower grade material to produce a lower grade mill feed.
3 The McClean Lake mill has been designed to mill high-grade ore from Cigar Lake without any blending or dilution.
Mkg = 1,000,000 kg

Licensees are required to develop preliminary decommissioning plans and associated financial guarantees to ensure work activities and installations are financially covered and work is guaranteed for completion with no liability to the Government. Financial guarantee values for the operating mine and mill facilities range from approximately $48 million at the McArthur River Operation to $218 million at the Key Lake Operation. The values of the financial guarantees are listed in appendix E. Financial guarantees cover all costs necessary to fully decommission and remediate a uranium mine and/or mill to ensure the protection of people and the environment.

2.1 Performance

Safety and control area (SCA) performance ratings for operations were developed using professional judgment and expertise and confirmed during a CNSC annual meeting held on May 26, 2016. Ratings are based on the review of key performance indicators (e.g., accident/event occurrences, responses to accidents/events, desktop review of reports, dose information, environmental (radiological and non-radiological) results) and the results of compliance activities such as inspections and technical assessments.

Once established, ratings are compared across all five operating mines and mills and to the rating methodology defined in appendix C to ensure that consistent and defendable ratings are assigned. The SCA performance ratings of the operating mine and mill facilities are presented in table 2.2. For 2016, CNSC staff concluded that performance of the operating uranium mines and mills was "satisfactory". Appendix D contains the SCA ratings for each facility from 2012 to 2016.

CNSC staff are currently developing a standardized SCA rating methodology for all fuel cycle facilities. A detailed presentation of this methodology will be provided in early 2018.

Table 2.2: Uranium mines and mills SCA performance ratings, 2016

Safety and control area	Cigar Lake	McArthur River	Rabbit Lake	Key Lake	McClean Lake
Management system	SA	SA	SA	SA	SA
Human performance management	SA	SA	SA	SA	SA
Operating performance	SA	SA	SA	SA	SA
Safety analysis	SA	SA	SA	SA	SA
Physical design	SA	SA	SA	SA	SA
Fitness for service	SA	SA	SA	SA	SA
Radiation protection	SA	SA	SA	SA	SA
Conventional health and safety	SA	SA	SA	SA	SA
Environmental protection	SA	SA	SA	SA	SA
Emergency management and fire protection	SA	SA	SA	SA	SA
Waste management	SA	SA	SA	SA	SA
Security	SA	SA	SA	SA	SA
Safeguards and non-proliferation	SA	SA	SA	SA	SA
Packaging and transport	SA	SA	SA	SA	SA

SA = satisfactory

This report focuses on the three SCAs that cover many of the key performance indicators for these facilities: “radiation protection”, “environmental protection” and “conventional health and safety”.

Licensees develop and maintain management systems that include integrated links to all 14 SCAs. Management systems are the framework that establishes the processes and programs required to ensure an organization achieves its safety objectives, continuously monitors performance, identifies inadequacies, and continually improves and fosters a healthy safety culture. CNSC staff reviewed and assessed program performance and key performance indicators across radiation protection, environmental protection, and conventional health and safety of management systems implementation through regular compliance verification activities throughout 2016.

CNSC staff and the licensees have discussed the implementation of recently issued CNSC regulatory documents and CSA Group publications that apply to the uranium mines and mills. With the McClean Lake Operation receiving its licence renewal in July 2017, a commitment was made for these regulatory documents to be implemented by December 2017. The regulatory documents will be included within the licence conditions handbooks (LCHs) of the remaining operating mines and mills facilities in early 2018.

2.2 Radiation protection

Uranium mine and mill licensees in Canada are required to implement and maintain radiation protection programs. Each program must ensure that contamination levels and radiation doses received by individuals are monitored, controlled and maintained below regulatory limits and as low as reasonably achievable (ALARA).

For 2016, CNSC staff rated the radiation protection SCA at all five operating facilities as "satisfactory" based on regulatory oversight activities.

Radiation protection ratings

Cigar Lake	McArthur River	Rabbit Lake	Key Lake	McClean Lake
SA	SA	SA	SA	SA

SA = satisfactory

Radiological hazard control

Sources of radiation exposure at uranium mines and mills include:

- gamma radiation
- long-lived radioactive dust
- radon progeny
- radon gas

CNSC staff's compliance activities confirm these hazards were controlled by licensees' radiation protection programs, including practices relating to the effective use of time, distance and shielding, source control, ventilation, contamination control and personal protective equipment (PPE).

Radiation protection program performance

CNSC staff conducted regulatory oversight activities in the SCA of radiation protection at all five operating facilities during 2016, to verify compliance of the licensees' implementation with regulatory requirements.

Radiation protection programs include codes of practice that outline licensee administrative levels and action levels for exposures and doses of radiation. Administration levels outline exposure conditions that require specific actions such as work normally, continuing to work while monitoring a parameter, or leave the area and initiate an investigation. Administration levels represent normal operating conditions and are used to ensure optimal conditions for workers. If an action level is reached, it may indicate a loss of control of part of a licensee's radiation protection program and, when compared to administration levels, triggers a requirement for significant actions to be taken. Licensees are responsible for identifying the parameters of their programs that represent timely indicators of potential losses of control. For this reason, action and administration levels are licensee-specific and may change over time depending on operational and radiological conditions. If an action level is reached, it triggers the licensee to establish the cause and notify the CNSC, and, if applicable, to restore the effectiveness of the radiation protection program.

The five operations listed have the same maximum action level of 1 millisievert (mSv) per week and 5 mSv per quarter of a given year. A brief description of action level exceedances that occurred in 2016 and the corrective actions implemented are provided in appendix I.

Figure 2.2 shows a prism system used at the Key Lake Operation. Prisms are installed in active mine areas and display current radon progeny levels through a red, yellow and green lighting system. Each light or combination of lights represents an administration level that has specific actions associated with it that workers must follow.

Figure 2.2: Prism system at the Key Lake Operation

CNSC staff confirmed the radiation protection programs and practices at operating mines and mills remained effective in controlling radiological exposure to workers. CNSC staff are satisfied with the actions taken by licensees to address action level exceedances.

Application of ALARA

The radiation protection programs established by uranium mine and mill facilities include responsibilities and processes used to ensure exposures to workers are maintained ALARA.

Through scheduled compliance oversight activities, CNSC staff verified that key elements of these ALARA programs (e.g., management control over work practices, personnel qualification and training, control of occupational and public exposure to radiation, planning for unusual situations) were effectively implemented by uranium mine and mill facilities in 2016.

This report introduces the reporting of annual nuclear energy worker (NEW) collective dose values for each operating mine and mill (see sections 3.2, 4.2, 5.2, 6.2 and 7.2). The collective dose value is the sum of the effective doses received by all NEWs at a uranium mine and mill in a year. Unlike average dose, the collective dose value at a particular facility is not typically influenced by factors such as short-term exposures or a significant increase in the number of workers in lower-dose categories. Collective dose shows the effect of increasing or reducing site activities; for example, the transition of the Rabbit Lake Operation from actively mining and milling ore to care and maintenance status (figure 5.3) or ramping-up production at the McClean Lake Operation (figure 7.2).

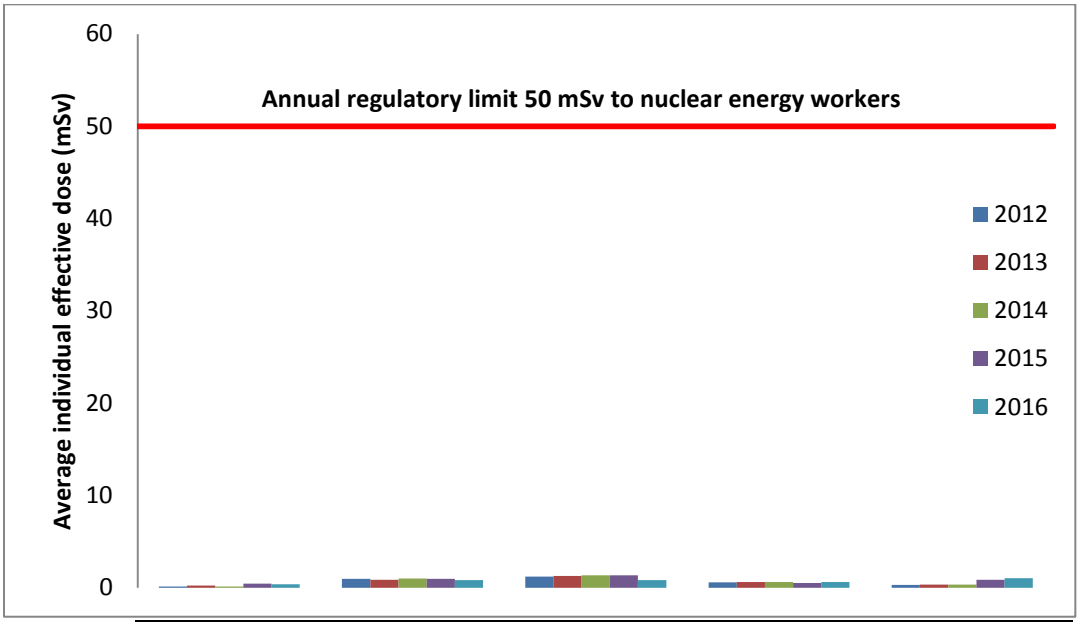
Worker dose control

The radiation protection programs, in accordance with the *Radiation Protection Regulations*, include processes and criteria to provide assurance that all individuals (e.g., permanent employees and contractors) that satisfy the definition of a NEW are appropriately designated, exposures are ascertained and dosimetry services are used.

At all operating mines and mills, NEWs are issued optically stimulated luminescence dosimeters that measure external gamma radiation exposure and resulting doses. Where required, workers also wear personal alpha dosimeters (PAD) to measure alpha radiation exposure from radon progeny and radioactive dust. Optically stimulated luminescence dosimeters and PAD readings are measured by a CNSC-licensed dosimetry service provider. Where direct monitoring through dosimeters is not warranted, approved dose estimation methods (such as area/group monitoring and time cards) are used in accordance with CNSC regulatory guidance. CNSC staff confirmed all licensees met regulatory requirements for the use of licensed dosimetry.

Figures 2.3 and 2.4 show the average individual effective dose and maximum individual effective dose during the 2012 to 2016 reporting period for the five operating facilities. In 2016, no worker at any facility exceeded the regulatory individual effective dose limit of 50 mSv in a one-year dosimetry period.

Figure 2.3: Uranium mines and mills comparison of average individual effective dose to nuclear energy workers, 2012–16 (mSv)

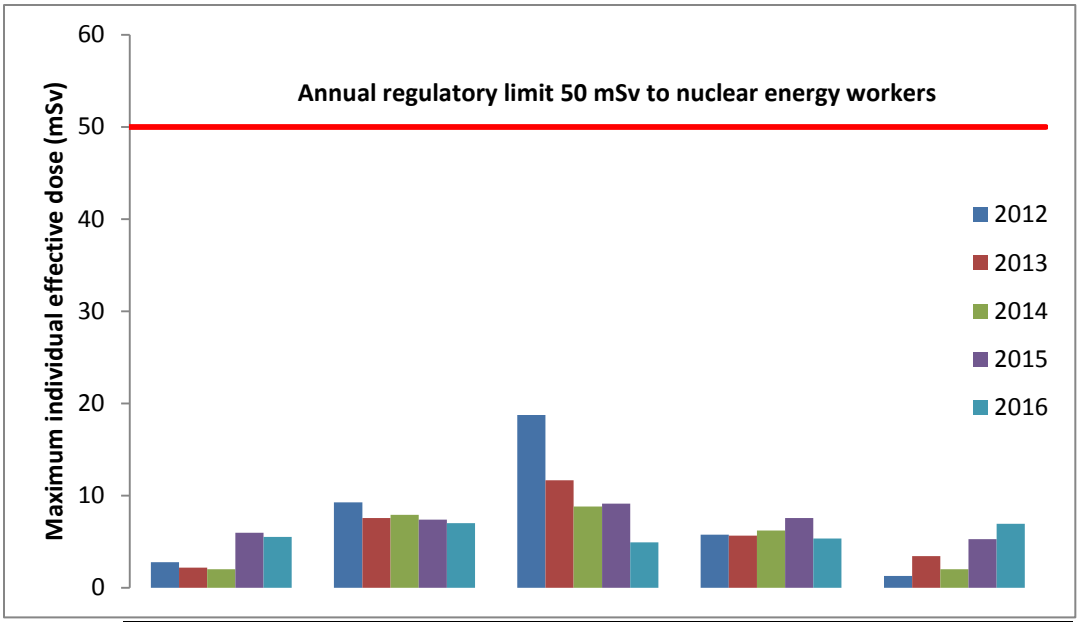


	Cigar Lake (mSv)	McArthur River (mSv)	Rabbit Lake (mSv)	Key Lake (mSv)	McClean Lake (mSv)
2012	0.14	0.97	1.23	0.61	0.32
2013	0.27	0.89	1.30	0.62	0.36
2014	0.16	1.03	1.35	0.63	0.37
2015	0.45	1.00	1.36	0.55	0.89
2016	0.39	0.85	0.85	0.62	1.04

* The annual regulatory limit illustrated applies to individual effective dose and is shown for reference only.

Increases and decreases over time in the effective dose to NEWs is explained in the facility-specific sections under “worker dose control”.

Figure 2.4: Uranium mines and mills comparison of maximum individual effective dose to nuclear energy workers, 2012–16 (mSv)



	Cigar Lake (mSv)	McArthur River (mSv)	Rabbit Lake (mSv)	Key Lake (mSv)	McClean Lake (mSv)
2012	2.78	9.26	18.76	5.76	1.30
2013	2.21	7.58	11.67	5.67	3.44
2014	2.03	7.91	*8.84	6.21	2.03
2015	5.99	7.40	9.14	7.56	5.28
2016	5.53	7.02	4.95	5.37	6.94

* During a dosimetry database upgrade, some errors associated with timecard and database entries were identified that affected some dose assignments at Rabbit Lake, Cigar Lake and McArthur River. The errors were not significant and did not result in any changes to the data reported in the 2015 CNSC Regulatory Oversight Report with the exception of the 8.84 mSv value, which was previously reported as 8.64 mSv.

In 2016, the highest maximum individual effective dose to a uranium mine and mill worker occurred at the McArthur River site. A dose of 7.02 mSv was assigned to an underground process worker that regularly worked in the semi-autogenous grinding mill area.

Appendix F displays the number of NEWs with the corresponding average individual effective dose and maximum individual effective dose for each operating facility during the 2012 to 2016 period.

Estimated dose to the public

Uranium mine and mill operations are remote from local populations. A public radiation dose limit of 1 mSv per year above natural background radiation has been set to ensure the protection of the public's health (including non-NEWs). Radiological exposures measured at the boundaries of these remote licensed facilities are near background radiation levels.

In 2016, based on the outcome of inspections and reviews of the radiation protection programs, radiological hazard control, worker dose control and application of ALARA, CNSC staff were satisfied that uranium mine and mill licensees controlled radiation doses to workers at levels well below the regulatory limits, as well as keeping doses ALARA.

2.3 Environmental protection

The environmental protection SCA covers programs that identify, control and monitor releases of radioactive and hazardous substances and effects on the environment from facilities or as a result of licensed activities.

Based on regulatory oversight activities, CNSC staff rated the 2016 performance of all five uranium mine and mill facilities for the environmental protection SCA as "satisfactory". CNSC staff concluded the licensee's environmental protection program was effectively implemented and met all regulatory requirements.

Environmental protection ratings

Cigar Lake	McArthur River	Rabbit Lake	Key Lake	McClean Lake
SA	SA	SA	SA	SA

SA = satisfactory

Environmental management system

The CNSC requires licensees develop and maintain environmental management systems that provide a framework for integrated activities related to environmental protection at the operation. Environmental management systems are described in approved environmental management programs and include activities such as establishing annual environmental objectives, goals and targets. The licensees conduct internal audits of their programs at least once every year. CNSC staff confirmed the objectives, goals and targets through regular compliance verification activities. Further site-specific details are provided in sections 3.3, 4.3, 5.3, 6.3 and 7.3 of this report.

Environmental risk assessment

The CNSC uses site-specific licensee developed environmental risk assessments (ERAs) as a regulatory tool throughout the lifecycle of uranium mine and mill facilities. Applicants use ERAs during initial environmental assessments for new facilities and for significant changes to existing facilities or activities at licensed operations. The ERA identifies mitigation technologies or practices and predicts:

- physical disturbances
- releases to the atmosphere
- surface water
- groundwater
- changes to the physical environment
- any biological effects

CNSC staff regularly review ERAs, which are typically updated based on revised activities and predictions and resubmitted every five years, to determine the potential risks to human health and the environment and to ensure the implementation of adequate mitigation measures.

Assessment and monitoring

In accordance with the *Uranium Mines and Mills Regulations*, each uranium mine and mill licensee has an environmental monitoring program that monitors releases of nuclear and hazardous substances, and characterizes and monitors any effects to the environment associated with the licensed facility. Nuclear and hazardous substances associated with monitoring programs are selected based on regulated contaminants and constituents of potential concern (COPC) identified through the ERA. COPC identified through the ERA with the potential for adverse environmental effects are managed through increased monitoring, inclusion in the environmental code of practice, further study or implementation of additional controls by licensees. During operations, CNSC staff periodically review environmental monitoring programs as criteria for assessing environmental performance.

Environmental monitoring programs are associated with an environmental code of practice that sets out administrative levels and action levels for select COPC with the potential for adverse environmental effects. An administrative level represents the upper range of design specifications for a specific parameter. Reaching an administrative level triggers an internal review by the licensee. Exceedance of an action level indicates a potential loss of control of the environmental protection program, which is based on the approved facility design envelope, and triggers actions that must be taken by the licensee to correct the problem. An action level provides an early warning system for identifying when there may be potential for significant deviations in operating performance outside normal operation that requires notification to the CNSC, an immediate investigation, subsequent corrective actions and preventive measures, in order to restore the effectiveness of the environmental protection program. It is important to recognize that an exceedance of an action level does not imply a potential risk to the environment, but identifies that the operating parameter may be outside the facility design envelope. Facility administrative and action levels are determined through the identification and proper operation of existing treatment technologies, as well as facility-specific environmental risk studies.

In 2016, there were two action level exceedances for effluent released from the Sue water treatment plant at the McClean Lake site. Further details are presented in section 7.3.

CNSC staff have reviewed risk assessments and environmental monitoring results of uranium mine and mill sites and concluded that the environment is protected.

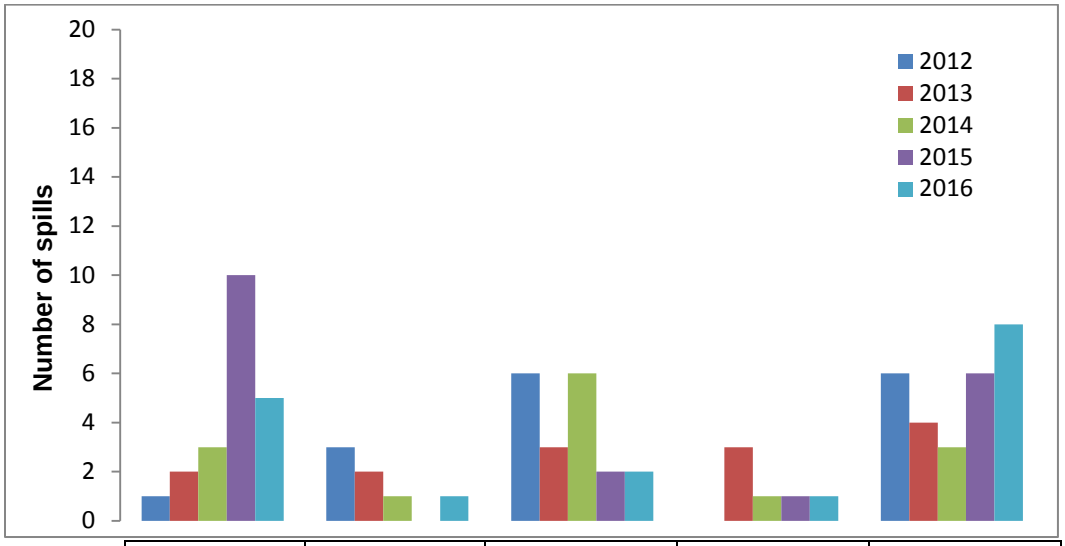
Protection of the public

According to regulatory requirements, each licensee must demonstrate that the public is protected from exposures to radiological and hazardous substances released from an operation. Licensees are required to report to the regulatory authorities, including the CNSC, any unauthorized releases (spills) of hazardous or radioactive substances to the environment.

Figure 2.5 depicts the number of environmental reportable spills for uranium mine and mill facilities during the 2012 to 2016 reporting period. In each case, CNSC staff reviewed the licensee's actions to ensure effective remediation and prevention and were satisfied with actions taken by the licensee. The CNSC rated all 2016 spills as "low significance" resulting in no residual impact to the environment.

The site-specific sections and appendix G further describe each reportable spill and any corrective actions taken by the licensee in response to the spill. The CNSC spill rating definitions are also found in appendix G.

Figure 2.5: Uranium mines and mills environmental reportable spills, 2012–16



	Cigar Lake	McArthur River	Rabbit Lake	Key Lake	McClean Lake
2012	1	3	6	0	6
2013	2	2	3	3	4
2014	3	1	4	1	2
2015	10	0	2	1	6
2016	5	1	2	1	8

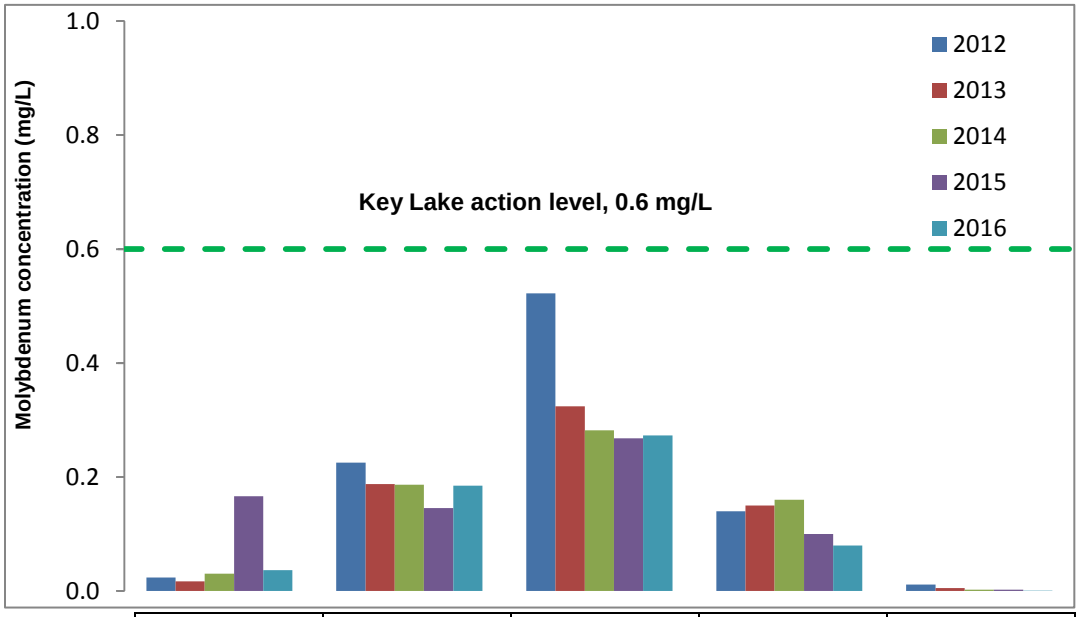
Effluent and emissions control

Treated effluent released to the environment

Licensee-developed ERAs identified releases of molybdenum, selenium and uranium as COPC with potential for adverse environmental effects across multiple operating uranium mines and mills. As a result, improved engineering controls and treatment technologies to reduce effluent releases of these contaminants were implemented where required. In 2016, the treatment technologies implemented continued to keep these contaminant concentrations stable and at acceptable levels. Figures 2.6 to 2.8 display the 2016 average annual effluent concentrations for molybdenum, selenium and uranium at the five operating mine and mill facilities.

In the absence of federal or provincial limits for molybdenum, the CNSC required licensees to develop facility-specific effluent controls within their environmental protection program codes of practice. The 2012 to 2016 molybdenum average effluent concentrations for the five facilities were below the Key Lake code of practice action level. The Key Lake action level for molybdenum is the most stringent of the five operations and is shown for reference only.

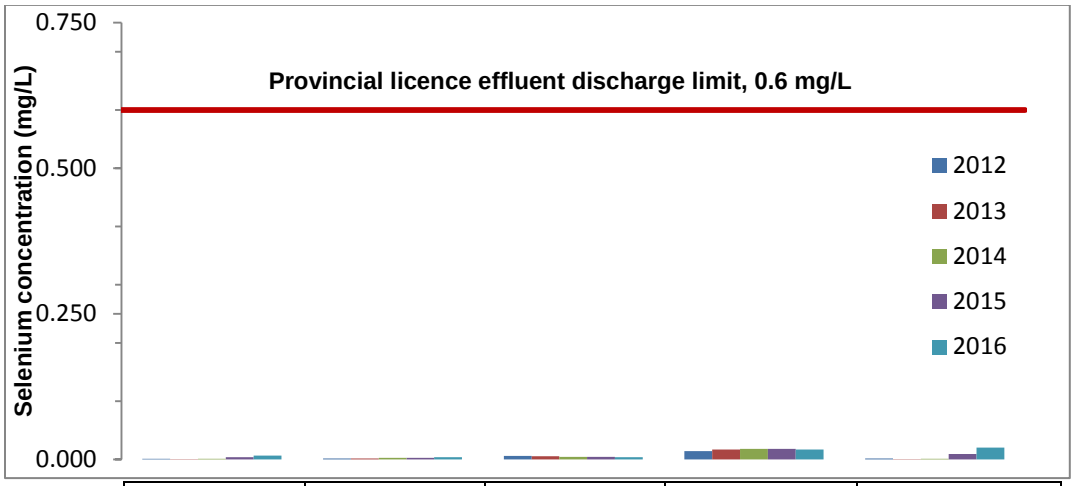
Figure 2.6: Annual average concentration of molybdenum in effluent released to the environment, 2012–16 (mg/L)



	Cigar Lake (mg/L)	McArthur River (mg/L)	Rabbit Lake (mg/L)	Key Lake (mg/L)	McClean Lake (mg/L)
2012	0.0236	0.2251	0.5220	0.1400	0.0114
2013	0.0169	0.1878	0.3240	0.1500	0.0052
2014	0.0303	0.1865	0.2820	0.1600	0.0024
2015	0.1662	0.1458	0.2680	0.1000	0.0024
2016	0.0369	0.1851	0.2730	0.0800	0.0020

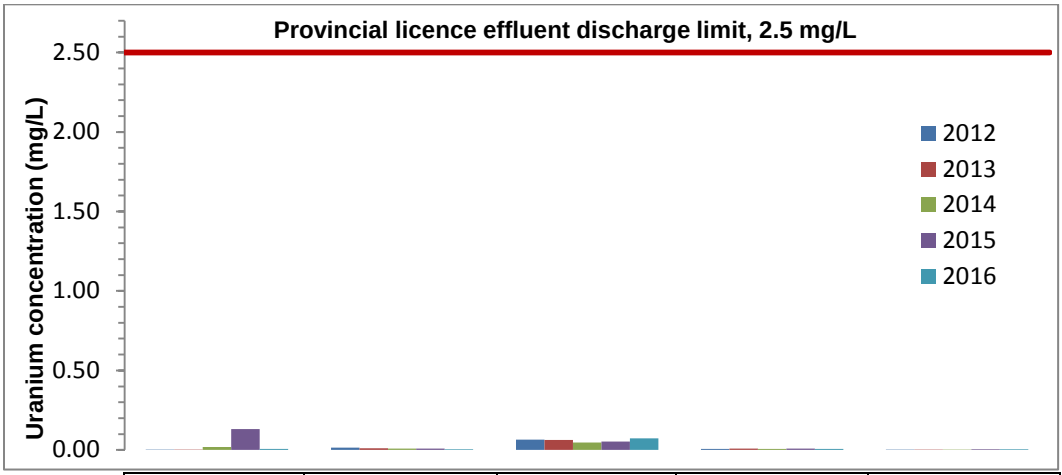
Figures 2.7 and 2.8 demonstrate that both selenium and uranium concentrations in treated effluent released to the environment by operating mine and mill facilities in 2012 to 2016 remained below Saskatchewan's licensed effluent discharge limits of 0.6 mg/L and 2.5 mg/L for selenium and uranium, respectively. There are currently no federal limits for selenium and uranium in effluent discharge. However, the CNSC expects levels to be below provincial limits and requires licensees' effluent contaminant concentrations be ALARA.

Figure 2.7: Annual average concentration of selenium in effluent released to the environment, 2012–16 (mg/L)



	Cigar Lake (mg/L)	McArthur River (mg/L)	Rabbit Lake (mg/L)	Key Lake (mg/L)	McClean Lake (mg/L)
2012	0.0007	0.0016	0.0058	0.0140	0.0014
2013	0.0005	0.0014	0.0052	0.0170	0.0004
2014	0.0009	0.0024	0.0042	0.0180	0.0007
2015	0.0038	0.0025	0.0042	0.0180	0.0092
2016	0.0062	0.0037	0.0035	0.0170	0.0210

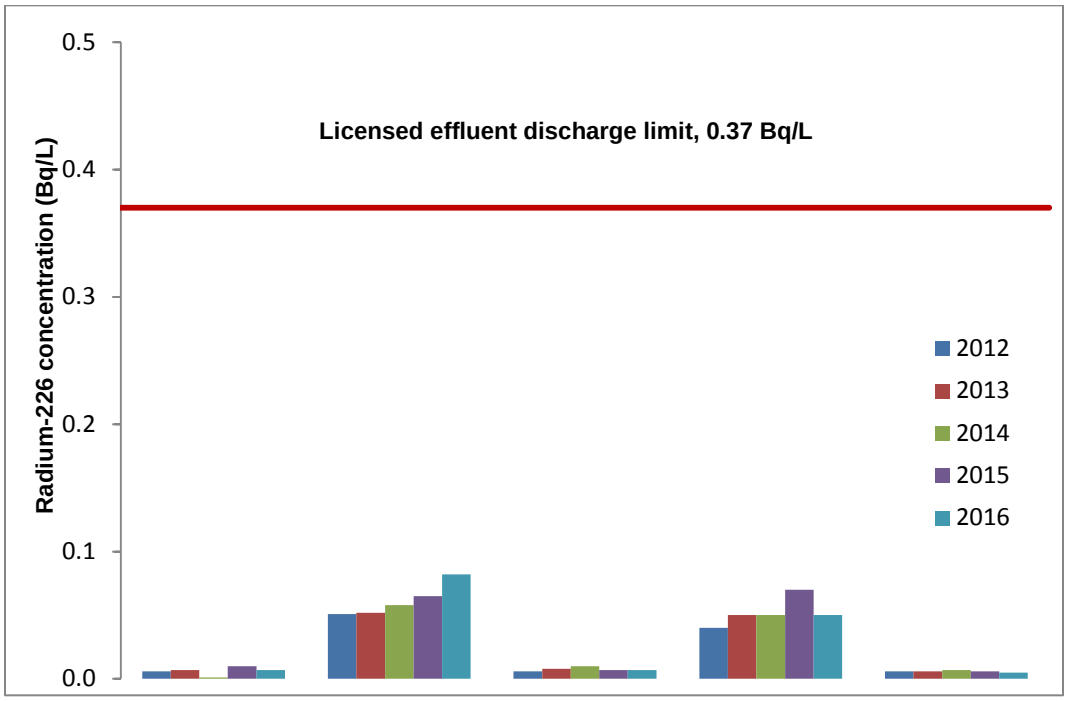
Figure 2.8: Annual average concentration of uranium in effluent released to the environment, 2012–16 (mg/L)



	Cigar Lake (mg/L)	McArthur River (mg/L)	Rabbit Lake (mg/L)	Key Lake (mg/L)	McClean Lake (mg/L)
2012	0.0006	0.0141	0.0650	0.0060	0.0017
2013	0.0011	0.0107	0.0630	0.0080	0.0015
2014	0.0193	0.0095	0.0460	0.0060	0.0018
2015	0.1310	0.0089	0.0520	0.0080	0.0042
2016	0.0063	0.0055	0.0730	0.0060	0.0040

In addition to the above COPC with the potential for adverse environmental effects, a graph showing concentrations of radium is provided in figure 2.9. The 2012 to 2016 radium-226 annual average effluent concentrations for the five facilities was well below the CNSC's licence-authorized effluent discharge limit of 0.37 Bq/L.

Figure 2.9: Annual average concentration of radium-226 in effluent released to the environment, 2012–16 (Bq/L)



	Cigar Lake (Bq/L)	McArthur River (Bq/L)	Rabbit Lake (Bq/L)	Key Lake (Bq/L)	McClean Lake (Bq/L)
2012	0.006	0.051	0.006	0.040	0.006
2013	0.007	0.052	0.008	0.050	0.006
2014	0.008	0.058	0.010	0.050	0.007
2015	0.010	0.065	0.007	0.070	0.006
2016	0.007	0.082	0.007	0.050	0.006

Uranium mine and mill facilities also analyze treated effluent for concentrations of other regulated contaminants and COPC such as arsenic, copper, lead, nickel, zinc, total suspended solids (TSS) and pH. Table 2.3 displays the annual average parameter concentration values in effluent for these substances released in 2016, as well as the discharge limits described in the *Metal Mining Effluent Regulations* (MMER). All metal mines and mills in Canada are subject to MMER of the federal *Fisheries Act*. The CNSC incorporates the effluent limit requirements of MMER in uranium mine and mill licences. In 2016, all treated effluent released to the environment from licensed mining and milling activities for the above substances met the effluent discharge limits.

Table 2.3: Annual average parameter concentration values in effluent released to the environment, 2016

Parameters	MMER discharge limits	Cigar Lake	McArthur River	Rabbit Lake	Key Lake	McClean Lake
Arsenic (mg/L)	**0.5**	0.0919	0.0011	0.0025	0.0070	0.0160
Copper (mg/L)	**0.3**	0.0004	0.0011	0.0013	0.0290	0.0040
Lead (mg/L)	**0.2**	0.0001	0.0009	0.0001	0.0100	0.0010
Nickel (mg/L)	**0.5**	0.0027	0.0033	0.0038	0.1440	0.0240
Zinc (mg/L)	**0.5**	0.0241	0.0016	0.0008	0.0100	0.0050
TSS (mg/L)	**15**	1	1	2	2	2
pH range	**6.0–9.5**	6.8	7.2	7.2	6.4	7.2

In 2016, average treated effluent released to the environment from the licensed mining and milling activities met the effluent discharge limits stipulated in the CNSC operating licence documentation.

CNSC staff will continue to review effluent quality results to ensure effluent treatment performance remains effective.

Air emissions released to the environment

Uranium mines and mills environmental programs include monitoring the effects of operations on the surrounding air and soil. Licensees measure airborne particulate levels and concentrations of regulated contaminants and COPC, as well as the concentration of radon gas. They also monitor contaminant concentrations in soil and terrestrial vegetation to verify that operational impacts are ALARA and below regulatory limits.

Facilities with milling operations monitor atmospheric emissions from acid plants, yellowcake dryers, calciner operations, packaging, grinding and ammonium sulphate operations. Other measured parameters (e.g., ambient radon and stack testing for sulphur dioxide, uranium and heavy metals) verify facility design and evaluate the operation’s performance against predictions made in ERAs.

CNSC staff verified that the operating mines and mills have demonstrated satisfactory performance mitigating and monitoring the effects of their operations on the surrounding air and soil. The air and soil results around the facilities indicate slightly higher than background concentrations for some samples collected in the immediate vicinity of activities; however, the concentrations decrease to background levels within a short distance. The monitoring results indicate negligible impacts from atmospheric releases and confirm all uranium mines and mills are in compliance with their programs and provincial standards.

Treated mining/milling effluent: A comparison of the uranium mining sector to other metal mining sectors across Canada

As noted earlier, metal mines and mills in Canada are subject to MMER of the federal *Fisheries Act*. Compliance with MMER limits provides a good effluent treatment comparison of the mining sector to other metal mining sectors across Canada. The effluent treatment quality of the uranium mine and mill facilities compares favourably to other mining sectors of base metal, precious metal and iron mines.

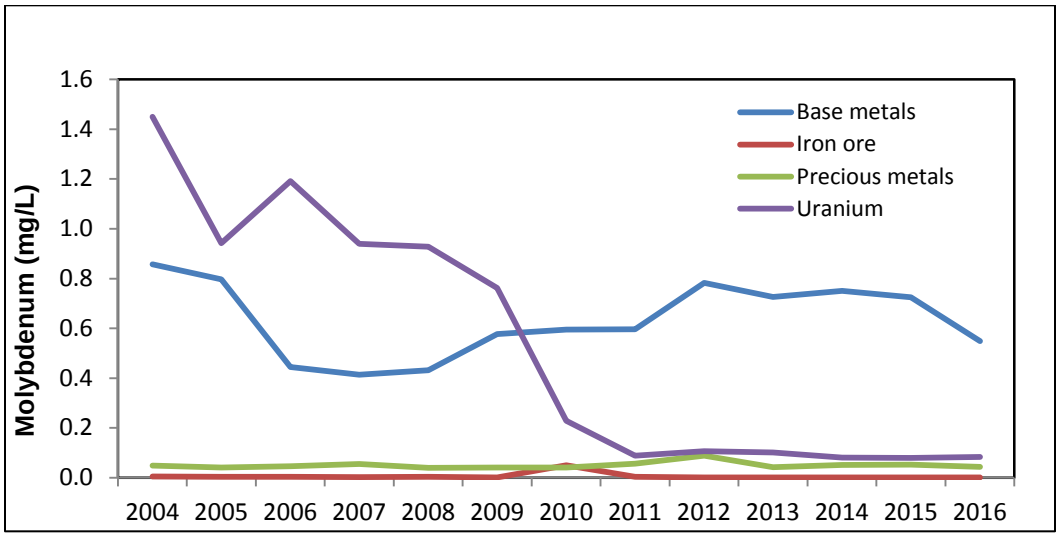
The data used for analysis and comparison are acquired from Environment and Climate Change Canada. MMER data from 2015 are used for comparison within this report since they comprise the most current sector-specific MMER information available with the exception of molybdenum, selenium and uranium, for which 2016 data are available. The mines that released treated effluent reporting under MMER are grouped into four metal mining sectors based on the primary metal produced. The metal mining sectors are:

- uranium – 5 mines
- base metals (such as copper, nickel, molybdenum or zinc) – 51 mines
- precious metals (such as gold or silver) – 51 mines
- iron – 8 mines

Molybdenum is a parameter requiring routine monitoring of treated effluent subject to MMER. Ecological risk assessments completed in the mid-2000s indicated that releases of molybdenum posed a risk to biota that merited adaptive management. As a result of a Commission request, licensees have added administrative and treatment technology upgrades to their effluent management systems. The success of these actions is evident in figure 2.10, which shows molybdenum releases in the uranium mining sector have decreased substantially.

In 2016, molybdenum concentrations in uranium mining sector effluent were similar to those measured in effluent of precious metal and iron mines, and less than those measured in effluent of base metal mines.

Figure 2.10: Average treated effluent concentration of molybdenum by metal mining sector, 2004–16



In mid-2012, MMER added the requirement for monitoring selenium. Table 2.4 summarizes the average selenium concentration in treated effluent from each mining sector using data collected since 2012. Selenium concentration in uranium sector effluent was similar to that of other metal mining sectors in Canada.

Table 2.4: Average selenium concentration in treated effluent by metal mining sector, last half of 2012 and all of 2013–16

Year	Metal mining sector (mg/L)			
	Uranium	Base metals	Precious metals	Iron
2012/2013	0.003	0.005	0.005	0.001
2014	0.004	0.006	0.005	0.001
2015	0.004	0.005	0.004	0.004
2016	0.008	0.006	0.003	0.003

Uranium concentrations have only recently been added to the parameters required to be monitored and reported under the MMER. Table 2.5 presents the average uranium concentrations in metal mining sectors for which there are data. As shown in figure 2.8, the uranium sector had an average concentration of 0.0190 mg/L of uranium in 2016. Uranium mines have significant elevated natural uranium concentrations compared to other conventional mining operations. By way of comparison and to provide context, the action level in the environmental code of practice and the Saskatchewan regulatory limits for uranium are 0.300 mg/L and 2.5 mg/L, respectively. CNSC staff continue to verify that releases of uranium are controlled and reduced to the extent practicable through reviews of effluent quality data, scrutiny of proposed facility changes that could affect effluent quality, and validation of the effectiveness of licensee programs to minimize release of contaminants.

Table 2.5: Average uranium concentration in treated effluent by metal mining sector, 2016

Year	Metal mining sector (mg/L)			
	Uranium	Base metals	Precious metals	Iron
2016	0.0190*	0.0004	0.0023	0.0019

* Data not available from Environment and Climate Change Canada; value calculated from licensee annual reports.

Metal Mining Effluent Regulations performance indicators

MMER specifies the maximum concentration limits in effluent for the following regulated parameters: arsenic, copper, lead, nickel, zinc, radium-226, TSS and an allowable pH range. Effluent must also be non-toxic, which is determined through rainbow trout acute lethality testing. The effluent treatment performance of the four metal mining sectors is compared using the following three performance indicators: compliance with the effluent concentration limits and pH, annual average effluent concentrations in the metal mining sectors, and toxicity test results.

1) Compliance with the effluent concentration limits and pH

Table 2.6 illustrates the number of mines out of compliance with MMER effluent standards for at least one regulated parameter (excluding a toxicity test in 2015). These data are used to assess if compliance with the parameters of MMER is a sector-wide concern.

Two base metal mines had effluent with radium concentrations above the MMER limit for portions of the year. The uranium mines were in full compliance with the provisions of MMER.

Table 2.6: Distribution of MMER effluent non-compliance by mining sector, 2015

Parameter	Mining sector			
	Uranium	Base metals	Precious metals	Iron
Arsenic	0	0	0	0
Copper	0	0	1	0
Lead	0	0	0	0
Nickel	0	1	0	0
Zinc	0	0	0	0
TSS	0	17	6	9
Radium-226	0	2	0	0
pH range	0	3	0	8
Mines out of compliance with at least one parameter*	0	14	6	4
Number of mines	5	51	51	8

* A mine may have more than one parameter out of compliance; thus the number of mines out of compliance with at least one parameter may not equal the sum of the number of mines out of compliance by parameter.

2) Annual average effluent concentrations in the metal mining sectors

Table 2.7 compares the 2015 average effluent parameter concentrations in the metal mining sectors. CNSC staff note that the base metal and iron mine effluent concentrations for radium-226 are comparative to uranium mines.

Table 2.7: A sector comparison of average effluent parameter concentrations, 2015

Parameter*	MMER discharge limits	Uranium	Base metals	Precious metals	Iron
Arsenic (mg/L)	**0.5**	0.011	0.005	0.026	0.0017
Copper (mg/L)	**0.3**	0.004	0.010	0.016	0.004
Lead (mg/L)	**0.2**	0.0002	0.003	0.002	0.002
Nickel (mg/L)	**0.5**	0.018	0.048	0.017	0.007
Zinc (mg/L)	**0.5**	0.006	0.053	0.022	0.015
TSS (mg/L)	**15**	1.1	3.6	4.2	9.0
Radium-226 (Bq/L)	**0.37**	0.025	0.028	0.007	0.006
pH range	**6.0–9.5**	6.90	7.7	7.6	7.3

* Uranium is required to be monitored and reported under the MMER. It is not regulated to a specified concentration.

3) Toxicity test results

Effluent toxicity is measured using the rainbow trout acute lethality test. As the world standard toxicity test for fresh-water, cool-climate conditions, this test has been part of Canadian regulations and guidelines for three decades. In this test, rainbow trout fingerlings or swim-up fry (0.3 g to 2.5 g wet weight) are reared under controlled conditions. They are then placed in undiluted effluent for 96 hours. If less than half of the fish survive, the effluent is deemed acutely lethal. Effluent must be non-acutely lethal to pass the test as a requirement of MMER.

Table 2.8 displays the number of pass and fail results of the rainbow trout acute lethality tests for the metal mining sectors in 2015. The uranium mining metal sector passed all required tests in 2015.

Table 2.8: A sector comparison of pass/fail results of rainbow trout acute lethality tests in 2015

	MMER limit	Uranium	Base metals	Precious metals	Iron
Rainbow trout acute lethality test	**Pass**	32	453	367	165
	Fail	0	8	29	2

A mine is considered compliant if, throughout the year, the effluent passes all trout acute lethality tests. Table 2.9 summarizes the performance of the metal mining sectors. The uranium mine and mill facilities passed all acute lethality tests from 2011 to 2015.

Table 2.9: Percentage of mines in each metal mining sector passing all trout acute lethality tests, 2011–15

Metal mining sector	2011	2012	2013	2014	2015
Uranium	100%	100%	100%	100%	100%
Base metals	85%	98%	93%	98%	92%
Precious metals	96%	94%	86%	96%	98%
Iron	83%	100%	100%	71%	75%

Eastern Athabasca Regional Monitoring Program

The Eastern Athabasca Regional Monitoring Program (EARMP), established by the Province of Saskatchewan in 2011, monitors the safety of traditionally harvested country foods through analysis of water, fish, berries and mammal chemistry from representative northern Saskatchewan communities. The program contractor is a northern Saskatchewan Indigenous-owned business. Community members take part in the monitoring program by collecting samples.

Harvesting and consuming traditional country foods are an important part of the culture in northern Saskatchewan. The intent of EARMP is to provide confidence and transparent communication with community members that traditional country foods remain safe to eat today and for future generations. The complete report and data are available at earmp.ca.

CNSC staff support EARMP and are working to create collaboration opportunities for this valuable program.

Evaluation of country food data from previous years, leading up to five years of data collection, confirm operating uranium mines and mills are not affecting the safety of country foods at nearby communities. The results indicated that radiological and non-radiological exposures to residents consuming country foods were similar to exposures of the general Canadian population and were below values considered to be protective of health effects.

2.4 Conventional health and safety

The conventional health and safety SCA covers the implementation of a program to manage workplace safety hazards and protect personnel and equipment. Uranium mines and mills must develop, implement and maintain effective safety programs to promote safe and healthy workplaces and minimize incidences of occupational injuries and illnesses.

For 2016, CNSC staff rated the conventional health and safety SCA at the uranium mine and mill facilities as “satisfactory” following acceptable performance in health and safety practices, awareness and performance.

Conventional health and safety ratings

Cigar Lake	McArthur River	Rabbit Lake	Key Lake	McClean Lake
SA	SA	SA	SA	SA

SA = satisfactory

Practices

The CNSC expects licensees to identify potential safety hazards, assess associated risks, and introduce the necessary materials, equipment, programs and procedures to effectively manage, control and minimize these risks. CNSC staff work with the Saskatchewan Ministry of Labour Relations and Workplace Safety to provide regulatory oversight of conventional health and safety in uranium mines and mills. CNSC staff's compliance verification activities include inspections, reviews of compliance reports and health and safety events.

CNSC staff confirmed the mine and mill facilities implemented effective management of conventional health and safety in their activities. In addition to CNSC staff's regulatory oversight, the Province of Saskatchewan, through an agreement with the Government of Canada, conducts regular inspections in the areas of occupational health and safety, mine safety and fire protection.

Awareness

CNSC staff observed that the implementation of conventional health and safety programs continued to provide education, training, tools and support to workers (figure 2.11). Each facility promotes the idea that safety is the responsibility of all individuals. This message is reinforced by management, supervisors and workers. Management stresses the importance of conventional health and safety through regular communication, management oversight, and continual improvement of safety systems. CNSC staff concluded that facilities are committed to accident prevention, safety awareness, and a focus on safety culture.

Figure 2.11: Emergency response exercise at the Cigar Lake Operation

Performance

A key performance measure for conventional health and safety is the number of lost-time injuries (LTIs) that occur per facility. An LTI is a workplace injury that results in the worker being unable to return to work for a period of time. In reviewing each LTI, CNSC staff consider the injury's severity and frequency rates. Table 2.10 shows the number of LTIs at the uranium mine and mill facilities along with severity and frequency rates.

Table 2.10: Lost-time injury statistics, 2016 (including contractors)

	Cigar Lake	McArthur River	Rabbit Lake	Key Lake	McClean Lake
Lost-time injuries[1]	1	1	1	2	3
Severity rate[2]	2.4	0	2.7	71.0	10.9
Frequency rate[3]	0.14	0.12	0.27	0.41	0.60

[1] An injury that takes place at work and results in the worker being unable to return to work for a period of time.

[2] The accident severity rate measures the total number of days lost to injury for every 200,000 person-hours worked at the site. Severity = [(# of days lost in last 12 months) / (# of hours worked in last 12 months)] x 200,000.

[3] The accident frequency rate measuring the number of LTIs for every 200,000 person-hours worked at the site. Frequency = [(# of injuries in last 12 months) / (# of hours worked in last 12 months)] x 200,000.

Appendix H describes the 2016 LTIs and corrective actions taken by each licensee. The injuries ranged from minor slips and falls to equipment and PPE malfunction and misuse. CNSC staff and the Saskatchewan Ministry of Labour Relations and Workplace Safety monitor and review each reportable injury to ensure the cause is identified and satisfactory corrective actions are taken. When applicable, injury information is shared among the facilities for lessons learned to improve safety and prevent recurrences.

CNSC staff concluded through their compliance verification activities that the health and safety programs at all uranium mines and mills met regulatory requirements in 2016.

Lost-time injuries: Comparison of the uranium mining sector to other mining sectors

Table 2.11 displays the various safety statistics of mining sectors within Saskatchewan. When contractors are excluded, the uranium mining and milling sector exhibits performance similar to other mining sectors for LTIs and frequency rate. The uranium sector comparison excludes contractors because statistics for the other sectors do not include contractors.

Table 2.11: Safety statistics of mining sectors in Saskatchewan, 2016

Mining sector	Number of LTIs	Frequency rate (200,000 person-hours)	Severity rate (200,000 person-hours)
Potash (underground)*	9	0.2	15.8
Solution (potash)*	0	0.0	0.0
Minerals (sodium sulphate, sodium chloride)*	4	2.2	60.9
Hard rock (gold, diamond)*	8	0.3	14.1
Coal (strip mining)*	9	1.8	59.3
Uranium*	5	0.2	4.5
Uranium (including contractors)**	8	0.3	17.4***

* Source: Saskatchewan Ministry of Labour Relations and Workplace Safety.

** Statistics for all the other mining sectors do not include contractors.

*** The higher severity is due to an event at Key Lake involving a contract truck driver (see appendix H).

3 Cigar Lake Operation

Cameco Corporation is the operator of the Cigar Lake Operation, which is located approximately 660 kilometres north of Saskatoon, Saskatchewan.

The Cigar Lake Operation consists of an underground uranium mine with surface facilities for loading ore slurry into trucks, waste management facilities, water treatment plant, surface freeze plants, administration offices and warehouses. Figure 3.1 provides an aerial view of the Cigar Lake Operation. The Cigar Lake uranium deposit is mined by mass freezing the orebody and surrounding country rock. Hydraulic jets then ground ore into a slurry (a mixture of rock and water). This slurry is pumped to surface, loaded into containers and transported 70 kilometres by truck to AREVA's McClean Lake Operation for milling.

A public Commission hearing was held on April 3, 2013 in Saskatoon for the renewal of the Cigar Lake licence. The Commission issued an eight-year licence valid from July 1, 2013 to June 30, 2021.

Figure 3.1: Aerial view of the Cigar Lake Operation

Table 3.1 shows mining production data for 2012 through 2016. Cigar Lake mine commenced commercial production in the spring of 2014. Ore production increased during 2015 and into 2016.

Table 3.1: Mining production data, Cigar Lake, 2012–16

	2012	2013	2014	2015	2016
Ore tonnage (Mkg/year)	No mining	0.234	3.32	21.6	37.27
Average ore grade mined (% U_3O_8)	No mining	1.4	7.2	22.35	21.55
Uranium mined (Mkg U/year)	No mining	0.04	0.2	4.95	6.81
Authorized annual production (Mkg U/year)	No mining	9.25	9.25	9.25	9.25

Conversion factor of 2.599779167 lb of U_3O_8.

CNSC staff confirmed the Cigar Lake Operation production remains less than the authorized CNSC licence limit for the 2016 calendar year and is carrying forward a cumulative shortfall of 12.5 million kilograms. This shortfall can be recouped in future years by increased production.

Surface construction activities in 2016 included upgrades and additional infrastructure to increase ground-freezing capacity and to store slimes, a clay-like mud waste derived from mining.

3.1 Performance

The Cigar Lake safety and control area (SCA) ratings for the 2012 to 2016 five-year period are shown in appendix D. For 2016, CNSC staff rated all 14 SCAs for the Cigar Lake Operation as “satisfactory”. This report focuses on the three SCAs that cover many of the key performance indicators for these operating mines and mills: “radiation protection”, “environmental protection”, and “conventional health and safety”.

In 2016, CNSC staff carried out compliance inspections covering the SCAs of “management system”, “physical design”, “safeguards”, “operating performance” and “emergency management and fire protection” in addition to those for which a detailed analysis has been provided in the following sections. Non-compliances resulting from CNSC inspections at the Cigar Lake facility for the 2016 calendar year were low risk in nature; corrective actions have been implemented by licensees and reviewed and accepted by CNSC staff. A list of inspections conducted can be found in appendix J.

3.2 Radiation protection

For 2016, CNSC staff continued to rate the radiation protection SCA as “satisfactory” based on regulatory oversight activities.

Cigar Lake radiation protection ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Radiological hazard control

The main source of radiological exposure at the Cigar Lake Operation is from mining and processing of high-grade uranium ore. The effective dose contributors to nuclear energy workers (NEWs) at Cigar Lake were gamma radiation (37 percent), radon progeny (34 percent) and long-lived radioactive dust (LLRD; 29 percent). Gamma radiation hazards are controlled through the effective use of time, distance and shielding. Radon progeny and LLRD are controlled through source control, ventilation, contamination control and personal protective equipment (PPE).

Radiation protection program performance

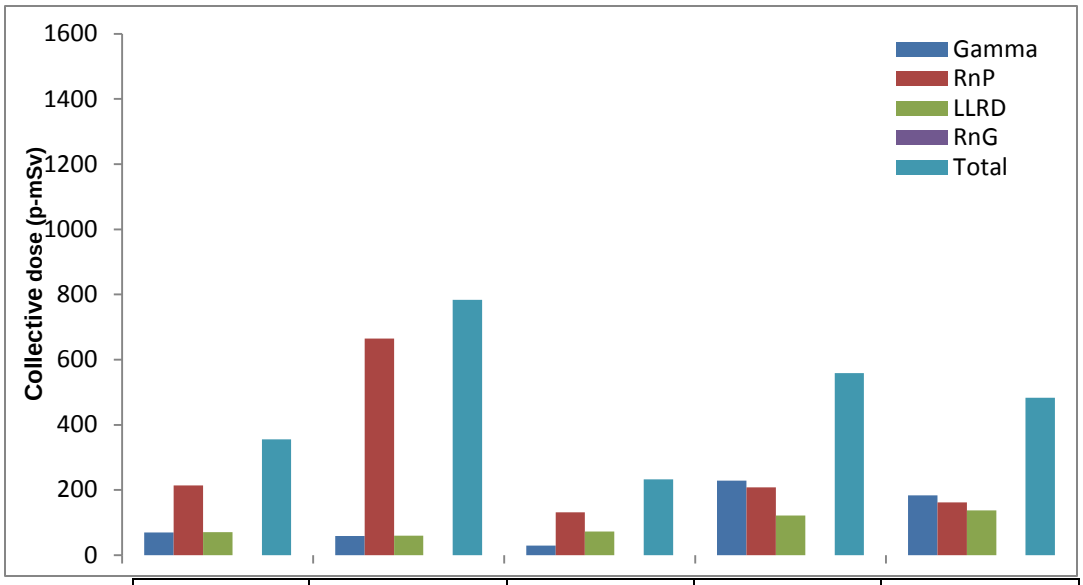
CNSC staff confirmed that the radiation protection program and practices at the Cigar Lake Operation remained effective in controlling radiological exposure to workers. There were no effective dose action levels or regulatory exceedances at the Cigar Lake Operation in 2016.

Application of ALARA

In 2016, the collective radiation exposure to NEWs at the Cigar Lake Operation was 483 person-millisieverts (p-mSv), an approximate 14 percent reduction from the 2015 value of 559 p-mSv (figure 3.2). This decrease is despite an approximate 38 percent production increase in 2016 compared to the previous year (measured by total uranium mined). This decrease is attributed to effective implementation of the Cigar Lake Operation's radiation protection program.

Throughout 2016, Cameco focused on reducing the radiation exposure to underground process operators, a higher dose workgroup at the Cigar Lake Operation. CNSC staff verified that measures to reduce exposures to operators were implemented, such as installation of a screen to reduce exposures resulting from operators cleaning in the ore grinding circuit.

Figure 3.2: Annual collective radiation exposures, Cigar Lake, 2012–16



	2012	2013	2014	2015	2016
Gamma (p-mSv)	70	59	29	229	184
RnP (p-mSv)	214	665	131	208	162
LLRD (p-mSv)	71	60	73	122	137
RnG (p-mSv)	0	0	0	0	0
Total	355	784	233	559	483

RnP = radon progeny; LLRD = long-lived radioactive dust; RnG = radon gas

Other efforts to keep worker exposures as low as reasonably achievable (ALARA) included ongoing assessment of activities and areas with higher levels of risk for radon progeny exposures. While the assessments have demonstrated that the procedural controls in place are effective, some engineering improvements were applied to reduce or eliminate the risk of exposure to elevated levels of radon progeny. For example, improved capture of radon released during backfilling operations directly reduced exposures to miners. CNSC staff concluded that the radiation protection program remains effective in ensuring that worker exposures remain ALARA.

Worker dose control

During 2016, the average individual effective dose for NEWs was 0.39 millisieverts (mSv) and the maximum individual effective dose was 5.53 mSv. This compares to an average effective dose of 0.45 mSv and a maximum individual dose of 5.99 mSv in 2015. As indicated in figures 2.3 and 2.4, all individual effective doses were well below the annual regulatory limit of 50 mSv.

Based on compliance verification activities that include site inspections, reviews of licensees' reports, work practices, monitoring results and individual effective dose results for 2016, CNSC staff were satisfied that the Cigar Lake Operation adequately controlled radiation doses to workers.

3.3 Environmental protection

For 2016, CNSC staff continued to rate the environmental protection SCA as "satisfactory". CNSC staff concluded that the licensee's environmental protection program was effectively implemented and met all regulatory requirements.

Cigar Lake environmental protection ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Environmental management system

The environmental management system at the Cigar Lake Operation is described in its approved environmental management program and includes activities such as establishing annual environmental objectives, goals and targets, all of which are reviewed by CNSC staff.

Environmental risk assessment

The CNSC uses environmental risk assessments (ERAs) to ensure people and the environment are protected. The next update to the Cigar Lake ERA is scheduled for 2017. The 2011 to 2015 Cigar Lake environmental performance report (EPR), which outlines environmental performance over a five-year period, was submitted to the CNSC in 2016. After reviewing the EPR, CNSC staff concluded that adequate measures have been taken at the Cigar Lake Operation to protect the environment and the public. An updated ERA is expected in late 2017 and will be reported on in the next regulatory oversight report.

Assessment and monitoring

CNSC staff confirmed that the licensee, in accordance with the Cigar Lake environmental protection program, successfully carried out required effluent and environmental monitoring, site inspections, environmental awareness training and program implementation.

Through compliance activities conducted during 2016, CNSC staff concluded that the Cigar Lake Operation's environmental monitoring met regulatory requirements and treated effluent discharge complied with licence requirements. There were no exceedances of the environmental code of practice action levels.

The following provides monitoring and assessment results for the Cigar Lake Operation.

Effluent and emissions control

Treated effluent released to the environment

As discussed in section 2.3 and throughout this section, CNSC staff confirmed parameter concentrations in treated effluent were low and remained below treated-effluent discharge limits at the Cigar Lake Operation.

Constituents of potential concern (COPC) with potential to adversely affect the environment in treated effluent at uranium mine and mill operations are molybdenum, selenium and uranium. At the Cigar Lake Operation throughout 2016, concentrations for these constituents (shown in figures 2.6 to 2.8) remained below their respective action levels and well below provincial licence effluent discharge limits.

In addition, the Cigar Lake Operation monitored concentrations of other regulatory contaminants and COPC such as radium-226, arsenic, copper, lead, nickel, zinc, total suspended solids (TSS) and pH. CNSC staff reviewed and confirmed the Cigar Lake Operation continues to meet *Metal Mining Effluent Regulations* (MMER) discharge limits (shown in section 2.3).

The Cigar Lake Operation identified in its 2016 annual report an increasing arsenic trend in effluent. In response, Cameco set up a working group to identify causes of the elevated concentration and develop mitigation strategies. Throughout 2016, Cameco implemented several mitigation techniques to better control arsenic, such as altering the pH profile of the treatment system to create more favourable conditions for arsenic removal. CNSC staff are satisfied that Cameco is taking appropriate actions to lower arsenic concentrations in the effluent and will continue to follow up throughout 2017.

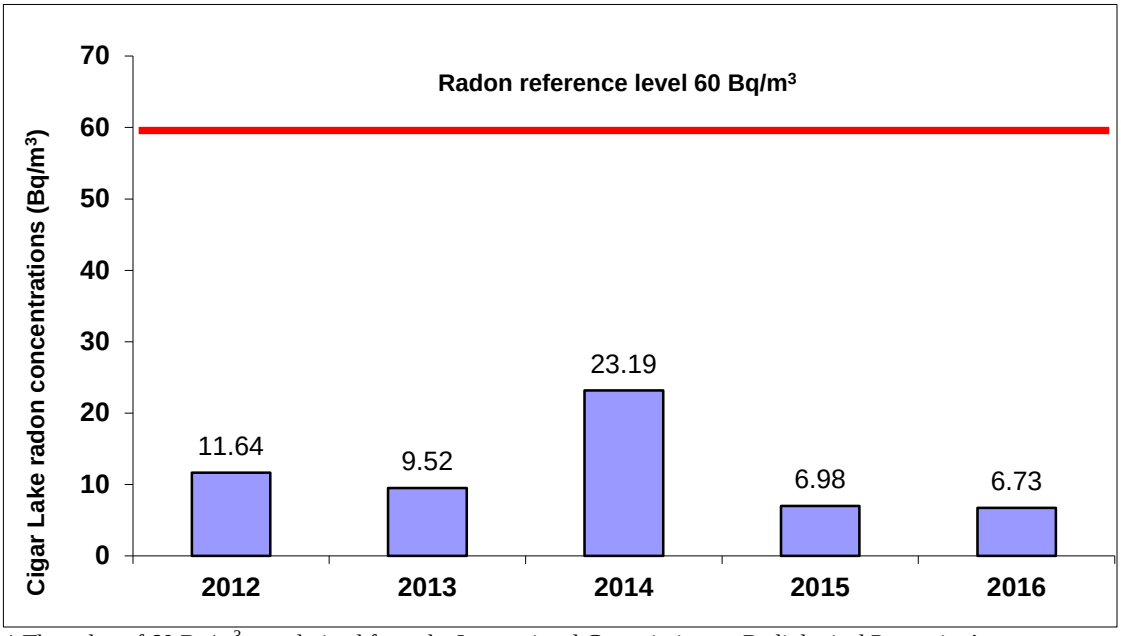
CNSC staff will continue to review effluent quality results to ensure that effluent treatment performance remains effective.

Air emissions released to the environment

As required by the CNSC, the Cigar Lake Operation also maintains an air and terrestrial monitoring program. Air monitoring at the Cigar Lake facility includes ambient radon, total suspended particulate (TSP), soil sampling and lichen sampling to assess the impact of air emissions. Lichen samples are analyzed to determine the level of airborne particulate contaminants deposited on the surface of the lichen as a means of ensuring that a significant level of contamination is not entering lichen consumers, such as caribou.

Figure 3.3 illustrates that the average concentrations of radon in ambient air for 2012 to 2016 were below the reference level for radon. Radon in ambient air is measured using passive track-etch cups at eight monitoring stations around the operation. The radon concentrations were also typical of the northern Saskatchewan regional baseline of less than 7.4 Bq/m^3 to 25 Bq/m^3. As the Cigar Lake facility transitioned into operation through 2015, as expected, an increase was noted in the concentrations of radon in ambient air. CNSC staff confirmed concentrations remained well below the reference level.

Figure 3.3: Average concentrations of radon in ambient air, Cigar Lake, 2012–16



* The value of 60 Bq/m^3 was derived from the International Commission on Radiological Protection's *Protection Against Radon-222 at Home and at Work*, as referenced in the *Radiation Protection Regulations.* The reference level represents an incremental increase above natural dwelling radon levels that could result in a member of the public being exposed to an incremental dose of 1 mSv. Values are calculated as geometric means.

A high-volume air sampler was used to collect and measure TSP in air. The TSP levels were below provincial standards (see table 3.2). The mean concentrations of metal and radionuclides adsorbed to TSP were low and below the reference annual air quality levels identified in table 3.2.

Soil and terrestrial vegetation may be affected by atmospheric deposition of particulate and adsorbed metals and radionuclides associated with onsite activities. Lichen and soil samples were collected in 2016 as required by the triennial sampling program. COPC concentrations measured in the soil samples collected from the study area were comparable to historical results. Concentrations of metals remained below existing Canadian Council of Ministers of the Environment *Canadian Environmental Quality Guidelines* and radionuclide concentrations were low and near, or at background levels and analytical detection limits. CNSC staff concluded that the level of airborne particulate contaminants produced by the Cigar Lake Operation is acceptable and does not pose a risk to the environment.

Table 3.2: Concentrations of metal and radionuclides in air, Cigar Lake, 2012–16

Parameter	Reference annual air quality levels*	2012	2013	2014	2015	2016
TSP (µg/m^3)	**70** [3]	16.5	30.2	24.7	15.8	11.4
As (µg/m^3)	**0.06** [1]	0.00025	0.00025	0.00025	0.00031	0.0003
Mo (µg/m^3)	**23** [1]	0.00028	0.00021	0.0001	0.0001	0.0002
Ni (µg/m^3)	**0.04** [1]	0.00101	0.00104	0.00067	0.00062	0.00105
Pb (µg/m^3)	**0.10** [1]	0.0016	0.0007	0.0013	0.0009	0.0009
Se (µg/m^3)	**1.9** [1]	0.00004	0.00003	0.00003	0.00003	0.00003
Pb^{210} (Bq/m^3)	**0.021** [2]	0.000338	0.000268	0.00025	0.000315	0.000305
Po^{210} (Bq/m^3)	**0.028** [2]	0.000106	0.000074	0.000086	0.000095	0.000099
Ra^{226} (Bq/m^3)	**0.013** [2]	0.000005	0.000004	0.000008	0.000014	0.000020
Th^{230} (Bq/m^3)	**0.0085** [2]	0.000026	0.000011	0.00001	0.000014	0.000012
U (µg/m^3)	**0.06** [1]	0.00009	0.00007	0.00008	0.00055	0.00113

[1] Reference annual air quality levels derived from Ontario's 24-hour ambient air quality criteria (2012).
[2] Reference level from International Commission on Radiological Protection (ICRP) publication 96, *Protecting People Against Radiation Exposure in the Event of a Radiological Attack.*
[3] The Province of Saskatchewan's authorized concentration of contaminants monitored for ambient air quality as listed in the facility's approval to operate pollutant control facilities is shown. Values are calculated as geometric means.
* Province of Ontario and ICRP reference annual air quality levels are shown for reference only. No federal or Province of Saskatchewan limits are currently established.

The lichen chemistry results from exposure stations in 2016 were similar to that of the reference stations and historic data. CNSC staff concluded that the level of airborne particulate contaminants was acceptable and did not pose a risk to lichen consumers.

Protection of the public

In 2016, five events reported to CNSC staff were submitted as releases of hazardous substances to the environment. All five spills listed below were minor and reporting of these events met the requirements of RD/GD-99.3, *Public Information and Disclosure:*

- 7 kg of anhydrous ammonia was released into the atmosphere due to failed condenser coils.
- 273 kg of anhydrous ammonia was released into the atmosphere due to failed condenser coils.
- 204 kg of anhydrous ammonia was released into the atmosphere due to failed condenser coils.
- 4.5 kg of anhydrous ammonia was released into the atmosphere due to failed relief valve fitting.
- 16 m^3 (16,000 L) of calcium chloride brine was released to the ground due to a leak in a return line from a freeze hole.

Three of these five events were attributed to failures of condenser coils. These five failures were due to a combination of extreme temperatures, materials of construction and high load. Cameco has since replaced its aluminum condenser coils with steel. This was confirmed in an August 2016 inspection conducted by CNSC staff. The replaced coils are expected to prevent similar events.

There were no residual impacts to the environment as a result of the 2016 releases of hazardous substance at the Cigar Lake Operation. CNSC staff were satisfied with the Cigar Lake Operation's reporting of spills and the corrective actions taken. CNSC staff rated all 2016 spills as low significance. Figure 2.5 in section 2 displays the number of environmental reportable spills at the Cigar Lake Operation from 2012 to 2016.

Spills in 2016 were primarily associated with anhydrous ammonia releases, which were corrected by replacing aluminum condenser coils with stainless steel. This was discussed during the Commission meeting that addressed the 2015 regulatory oversight report. Appendix G contains a brief description of the spills, corrective actions taken by the licensee, CNSC staff's assessment of those actions and the significance ratings for 2016. CNSC spill rating definitions are also found in table G-2 of appendix G.

3.4 Conventional health and safety

For 2016, CNSC staff continued to rate the conventional health and safety SCA as "satisfactory".

Cigar Lake conventional health and safety ratings

2012	2013	2014	2015	2016
SA	FS	SA	SA	SA

SA = satisfactory

Practices

CNSC staff monitored the implementation of the Cigar Lake Operation's safety and health management program to ensure the protection of workers. The program includes planned internal inspections, a safety permit system, occupational health committees, training and incident investigations. Cameco's incident reporting system includes reporting, trending and investigation of near misses, which helps reduce future incidents that could cause injury.

CNSC staff verified that the conventional health and safety work practices and conditions at the Cigar Lake Operation achieved an adequate degree of personnel safety.

Performance

Table 3.3 summarizes lost-time injuries (LTIs) at the Cigar Lake Operation from 2012 to 2016. There was one LTI at the Cigar Lake Operation in 2016 relating to an incident where an employee slipped. Appendix H contains a brief description of the LTI and the corrective actions which included a redesign of the ramp area. CNSC staff assessed and were satisfied with the follow-up actions taken by the Cigar Lake Operation.

Table 3.3: Lost-time injury statistics, Cigar Lake, 2012–16

	2012	2013	2014	2015	2016
Lost-time injuries[1]	0	4	1*	4	1
Severity rate[2]	0.0	5.57	0.0	17.06	2.4
Frequency rate[3]	0.0	0.25	0.12*	0.56	0.14

[1] An injury that takes place at work and results in the worker being unable to return to work for a period of time.

[2] The accident severity rate measures the total number of days lost to injury for every 200,000 person-hours worked at the site. Severity = [(# of days lost in last 12 months) /(# of hours worked in last 12 months)] x 200,000.

[3] The accident frequency rate measuring the number of LTIs for every 200,000 person-hours worked at the site. Frequency = [(# of injuries in last 12 months) / (# of hours worked in last 12 months)] x 200,000.

* One event that occurred in 2014 was reclassified as a LTI in 2015. In the 2014 report, this number was 0.

Awareness

CNSC staff observed that the conventional health and safety program at the Cigar Lake Operation continued to provide education, training, tools and support to workers. CNSC staff confirmed Cameco has implemented several initiatives in 2016 as part of continuous improvement of its programs. Cigar Lake implemented changes to the safety program, including formation of a safety steering team and safety subcommittees, based on a formal safety assessment. CNSC staff confirmed that dangerous occurrences at the operation were investigated and corrective actions implemented.

CNSC staff compliance verification activities concluded that the Cigar Lake Operation's health and safety program met regulatory requirements in 2016.

4 McArthur River Operation

Cameco Corporation operates the McArthur River mine (figure 4.1), which is located approximately 620 kilometres north of Saskatoon, Saskatchewan.

Facilities at the McArthur River Operation include an underground uranium mine, primary ore processing, ore slurry loading, waste management facilities, a water treatment plant, effluent storage ponds, surface freeze plants, administration offices and warehouse buildings.

Figure 4.1: Aerial view of the McArthur River Operation

High-grade uranium ore is mined, mixed with water and ground in a ball mill to form slurry, which is pumped to the surface. The ore slurry is loaded into containers and transported to the Key Lake Operation for further processing. Low-grade mineralized rock is also transported to the Key Lake facility in covered haul trucks. These materials are then blended with high-grade ore slurry to create the mill ore feed.

In October 2013, the Commission issued a 10-year licence to Cameco for the McArthur River Operation following a public hearing in La Ronge, Saskatchewan. Cameco's licence is set to expire on October 31, 2023.

McArthur River mining production data for 2012 to 2016 shown in table 4.1.

Table 4.1: Mining production data, McArthur River, 2012–16

Mining	2012	2013	2014	2015	2016
Ore tonnage (Mkg/year)	115.11	104.13	108.39	88.24	89.28
Average ore grade mined (% U_3O_8)	7.78	8.83	8.73	10.13	9.30
Uranium mined (Mkg U/year)	7.6	7.8	8.02	7.58	7.04
Authorized annual production (Mkg U/year)	8.1	8.1	8.1	9.6	9.6

Conversion factor of 2.599779167 lb of U_3O_8.

CNSC staff confirmed the McArthur River Operation production for 2016 remained less than the authorized annual production (table 4.1).

4.1 Performance

The McArthur River Operation safety and control area (SCA) ratings for the five-year period of 2012 to 2016 are shown in appendix D. For 2016, CNSC staff rated all SCAs as "satisfactory". This report focuses on the three SCAs that cover many of the key performance indicators for these operations: radiation protection", "environmental protection" and "conventional health and safety".

In 2016, CNSC staff carried out compliance inspections covering the SCAs of "fitness for service", "management system", "operating performance", "emergency management and fire protection" and "packaging and transport" in addition to those for which a detailed analysis has been provided in the following sections.

Non-compliances resulting from CNSC inspections at the McArthur River Operation for the 2016 calendar year were low risk in nature. Corrective actions have been implemented by licensees and reviewed and accepted by CNSC staff. A list of inspections can be found in appendix J.

4.2 Radiation protection

For 2016, CNSC staff continued to rate the radiation protection SCA as "satisfactory" based on regulatory oversight activities.

McArthur River radiation protection ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Radiological hazard control

Mining and processing of high-grade uranium ore are the main sources of radiological exposure at the McArthur River Operation. The effective dose contributors to nuclear energy workers (NEWs) at the McArthur River facility were radon progeny (49 percent), gamma radiation (34 percent), long-lived radioactive dust (LLRD; 16 percent) and radon gas (1 percent). Gamma radiation hazards are controlled through the effective use of time, distance and shielding while radon progeny, radon gas and LLRD are controlled through source control, ventilation, contamination control and personal protective equipment (PPE).

Radiation protection program performance

In 2016, there was one event resulting in two individuals receiving weekly exposures that exceeded the 1 millisievert (mSv) action level:

- January 2016 personal alpha dosimeter results for two Cubex long hole drillers showed a combined radon progeny and LLRD dose that exceeded the 1 mSv/week action level.

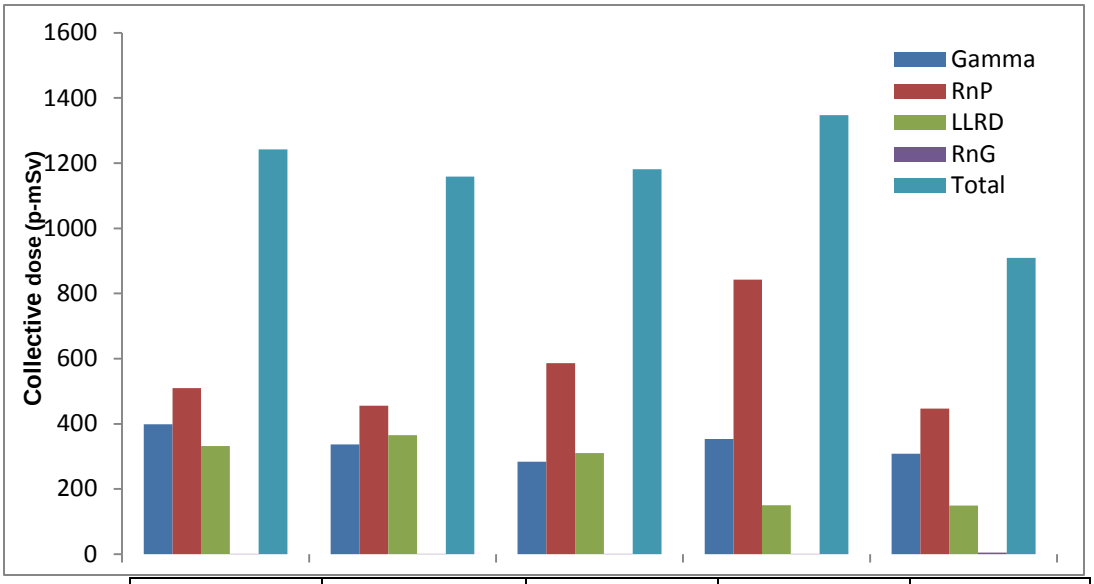
A brief description of the above event and corrective actions implemented is provided in appendix I. CNSC staff assessed and were satisfied with the actions taken by the McArthur River Operation to address these action level exceedances. The doses to workers remained below regulatory limits.

Overall, the radiation protection program and practices at the McArthur River Operation remained effective in controlling radiological exposure to workers.

Application of ALARA

In 2016, the collective radiation exposure to NEWs at the McArthur River Operation was 909 person-millisieverts (p-mSv), an approximate 33 percent reduction from the 2015 value of 1,347 p-mSv (figure 4.2). Production in 2016 was approximately 7 percent lower than in the previous year (measured by total uranium mined). The most significant reduction in 2016 was in radon progeny exposures, which is attributed to improved ventilation rates and administrative controls.

Figure 4.2: Annual collective radiation exposures, McArthur River, 2012–16



	2012	2013	2014	2015	2016
Gamma (p-mSv)	399	337	284	353	308
RnP (p-mSv)	510	456	586	843	447
LLRD (p-mSv)	332	365	310	150	149
RnG (p-mSv)	1	1	1	1	5
Total	1,242	1,159	1,181	1,347	909

RnP = radon progeny; LLRD = long-lived radioactive dust; RnG = radon gas

In 2016, additional radiation protection challenges were encountered with the Zone 4 orebody due to off-gassing of radon bearing water inside mine workings. To address this, Cameco established and implemented a number of engineered and administrative controls to ensure all exposures remained as low as reasonably achievable (ALARA). Specifically:

- Zone 4 was temporarily shut down until radon-bearing water could be fully under control
- access control measures (e.g., signage and barriers) were deployed to prevent any workers from being exposed to a hazard
- mandatory radiation work permits were implemented for work in these areas to control worker entries and exposures
- additional continuous working-level monitors (referred to as prisms) were deployed to provide timely detection of elevated hazard levels
- prism placement drawings were implemented in these areas to ensure continuous working-level monitors were optimally located and their locations were known to workers

CNSC staff verified the implementation of these additional controls as part of regular compliance activities.

CNSC staff concluded that the radiation protection program remains effective in ensuring that worker exposures remain ALARA.

Worker dose control

The average individual effective dose to NEWs was 0.85 mSv. The maximum individual effective dose was 7.02 mSv, assigned to an underground support worker. This compares to an average effective dose of 1.00 mSv and a maximum individual dose of 7.40 mSv in 2015. All individual effective doses were well below the annual regulatory limit of 50 mSv (figures 2.3 and 2.4).

Based on CNSC staff compliance verification activities such as site inspections, reviews of licensees' reports, work practices, monitoring results and individual effective dose results for 2016, CNSC staff were satisfied that the McArthur River Operation adequately controlled radiation doses to workers.

4.3 Environmental protection

For 2016, CNSC staff continued to rate the environmental protection SCA as "satisfactory" based on regulatory oversight activities. CNSC staff verified that the environmental protection program was effectively implemented and met all regulatory requirements.

McArthur River environmental protection ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Environmental management system

The environmental management system at the McArthur River Operation includes activities such as establishing annual environmental objectives, goals and targets. The McArthur River Operation conducts internal audits of its program at least once every year. CNSC staff review and assess the objectives, goals and targets through regular compliance verification activities.

Environmental risk assessment

The CNSC uses environmental risk assessments (ERAs) to ensure people and the environment are protected (section 2.3). The McArthur River environmental performance report (EPR) and updated ERAs for 2010 to 2014 were submitted to the CNSC and the Saskatchewan Ministry of Environment in 2015. CNSC staff reviewed the submissions and determined them to be in compliance with applicable criteria outlined in the McArthur River licence conditions handbook (LCH).

CNSC staff concluded that the environmental protection SCA at the McArthur River Operation met performance objectives and all applicable regulatory requirements.

Assessment and monitoring

In accordance with the McArthur River Operation's environmental protection program, effluent and environmental monitoring, site inspections, environmental awareness training and program implementation audits were performed in 2016.

CNSC staff concluded that the McArthur River Operation's environmental management system and monitoring programs met regulatory requirements and the licensee complied with treated effluent discharge requirements. Figure 4.3 shows a discharge channel for treated effluent. There were no environmental action level exceedances during the 2012 to 2016 review period.

Figure 4.3: Flow path for treated water at the McArthur River Operation

The following provides monitoring and assessment results for the McArthur River Operation.

Effluent and emissions control

Treated effluent released to the environment

CNSC staff verified that treated effluent released to the environment was well below regulatory requirements and has remained stable or improved over the past five years.

As discussed in section 2.3, constituents of potential concern (COPC) with potential to adversely affect the environment in treated effluent at multiple uranium mine and mill operations are molybdenum, selenium and uranium (shown in figures 2.6 to 2.8 of section 2). Of the three COPC, molybdenum posed an elevated risk at the McArthur River Operation. In response, process changes such as adjusting pH and reagent rebalancing were implemented to reduce molybdenum concentrations in treated effluent. Molybdenum removal efficiency in treated effluent has improved. Concentrations decreased from 0.2251 mg/L in 2012 to 0.1851 mg/L in 2016 (see figure 2.6 for results from 2012 to 2016).

In addition to the COPC with a potential to adversely impact the environment, the McArthur River Operation analyzed treated effluent for concentrations of various other COPC such as radium-226, arsenic, copper, lead, nickel, zinc, total suspended solids (TSS) and pH. CNSC staff reviewed the effluent treatment concentrations and confirmed the McArthur River Operation continues to meet *Metal Mining Effluent Regulations* discharge limits (shown in section 2.3).

The CNSC will continue to review effluent quality results to ensure that effluent treatment performance remains effective. Figure 4.4 shows a monitoring pond at the McArthur River Operation.

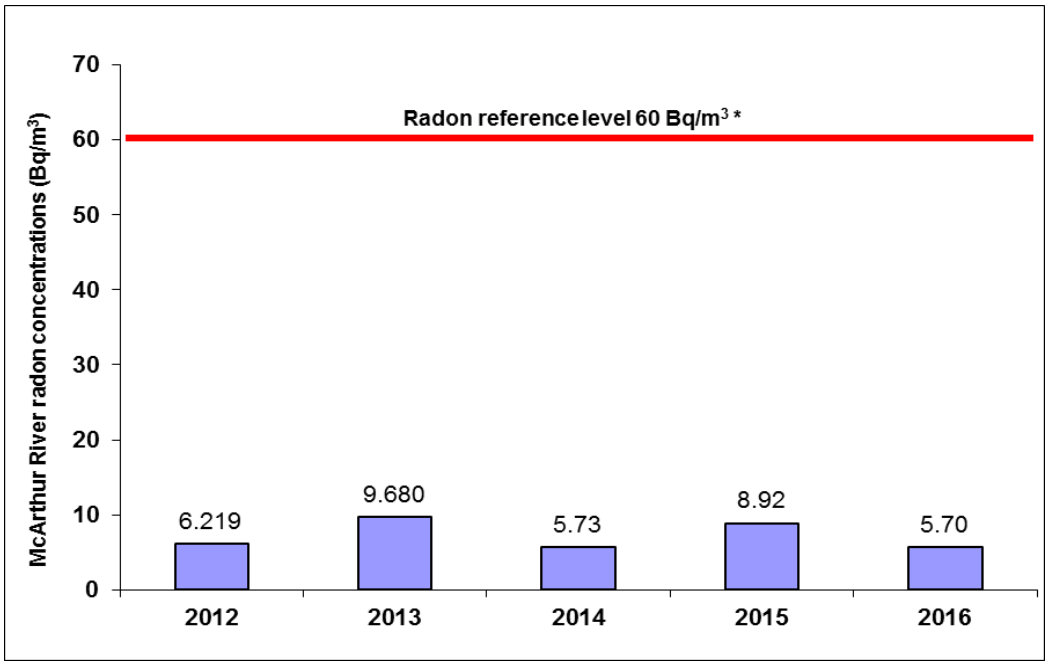
Figure 4.4: Monitoring pond at the McArthur River Operation

Air emissions released to the environment

The CNSC requires that the McArthur River Operation maintain an air and terrestrial monitoring program. Air and terrestrial monitoring at the McArthur River facility includes ambient radon, total suspended particulate (TSP), soil sampling and lichen sampling to assess the impact of air emissions. An analysis of blueberry chemistry was also included to align with country food studies. Blueberry twigs are monitored to determine if soil-borne contaminants (when present) are being absorbed through the roots into the growing plant parts.

Monitoring of radon in ambient air is carried out using passive track-etch cups at 12 monitoring stations around the operation. Figure 4.5 shows the average concentrations of radon in ambient air for 2012 to 2016 were below the reference level. Radon concentrations were similar to past performance with radon concentrations typical of the northern Saskatchewan regional baseline of less than 7.4 Bq/m^3 to 25 Bq/m^3.

Figure 4.5: Concentrations of radon in ambient air, McArthur River, 2012–16



* The value of 60 Bq/m^3 has been derived from the International Commission on Radiological Protection's *Protection Against Radon-222 at Home and at Work,* as referenced in the *Radiation Protection Regulations.* The reference level represents an incremental increase above natural dwelling radon levels that could result in a member of the public being exposed to an incremental dose of 1 mSv. Values are calculated as geometric means.

Two high-volume air samples were used to collect and measure TSP in air. From the average of the two stations, the TSP levels were below provincial standards (see table 4.2). The mean concentrations of metal and radionuclides adsorbed to TSP were low and below the reference annual air quality levels identified in table 4.2.

Soil and terrestrial vegetation may be affected by atmospheric deposition of particulate and adsorbed metals and radionuclides associated with onsite activities. A terrestrial monitoring program is in place and includes triennial measurements of metals and radionuclides in soil and blueberry samples.

Table 4.2: Concentrations of metal and radionuclides in air, McArthur River, 2012–16

Parameter	Reference annual air quality levels*	2012	2013	2014	2015	2016
TSP (µg/m^3)	**70** [3]	21.0	11.5	8.94	6.31	2.24
As (µg/m^3)	**0.06** [1]	0.0003	0.0001	0.0001	0.0001	0.0001
Cu (µg/m^3)	**9.6** [1]	0.0119	0.0067	0.00835	0.00513	0.0065
Ni (µg/m^3)	**0.04** [1]	0.0012	0.0007	0.00085	0.00067	0.0007
Pb (µg/m^3)	**0.10** [1]	0.0018	0.0014	0.0012	0.00118	0.0011
Se (µg/m^3)	**1.9** [1]	0.00005	0.00003	0.0004	0.00004	0.00004
Zn (µg/m^3)	**23** [1]	0.7721	0.01065	0.01225	0.00980	0.0106
Pb^{210} (Bq/m^3)	**0.021** [2]	0.00045	0.00034	0.00032	0.00032	0.0002
Po^{210} (Bq/m^3)	**0.028** [2]	0.00012	0.00010	0.00009	0.00008	0.0001
Ra^{226} (Bq/m^3)	**0.013** [2]	0.00004	0.00001	0.00002	0.00001	0.00004
Th^{230} (Bq/m^3)	**0.0085** [2]	0.00001	0.00001	0.00001	0.00002	0.0001
U (µg/m^3)	**0.06** [1]	0.0012	0.0005	0.0005	0.0003	0.0004

1 Reference annual air quality levels derived from Ontario's 24-hour ambient air quality criteria (2012).
2 Reference level from International Commission on Radiological Protection (ICRP) publication 96.
3 The Province of Saskatchewan's authorized concentration of contaminants monitored for ambient air quality as listed in the facility's approval to operate pollutant control facilities is shown. Values are calculated as geometric means.
* Province of Ontario and ICRP annual air quality levels are shown for reference only. No federal or provincial limits are currently established.

Soil and blueberry twig samples were last collected in 2015 as required by the triennial sampling program. The 2015 results indicated that parameters measured were within historical ranges. Concentrations of metals remained below the *Canadian Environmental Quality Guidelines* set by the Canadian Council of Ministers of the Environment and radionuclide concentrations were low and near, or at, background levels and analytical detection limits. The area surrounding the McArthur River Operation has been subject to forest fires in recent years. As a result, it has been difficult to obtain enough lichen for analysis. Triennial lichen sampling was previously conducted in 2015. Historic data from 1997 to 2003 do not suggest that COPC were accumulating in lichen tissues above background concentrations.

CNSC staff concluded that the level of airborne particulate contaminants produced by the McArthur River Operation is acceptable and does not pose a risk to the environment.

Protection of the public

In 2016, there was one event reported to the CNSC that was classified as a release (spill) of a hazardous substance to the environment. This spill was minor and reporting of this event met the requirements of RD/GD-99.3, *Public Information and Disclosure:*

- An unknown amount (due to low mass released) of anhydrous ammonia was released into the atmosphere due to a leak in a U-bend in the condenser.

There were no impacts to the environment as a result of the spill and CNSC staff were satisfied with the corrective actions taken. CNSC staff rated this spill as low significance.

Appendix G contains a brief description of the spill of anhydrous ammonia and corrective actions taken by the licensee, which included preventive maintenance. CNSC spill rating definitions can be found in appendix G.

Figure 2.5 in section 2 identifies the number of spills at the McArthur River Operation from 2012 to 2016.

4.4 Conventional health and safety

Based on regulatory oversight activities conducted during 2016, CNSC staff rated the conventional health and safety SCA as “satisfactory”.

McArthur River conventional health and safety ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Practices

To promote continued effective safety performance, the McArthur River Operation has implemented a health and safety management program to identify and mitigate risks. The program includes a safety permit system, continued training, planned internal inspections, occupational health committees and incident investigations. The incident reporting system includes reporting on and investigating near misses and provides significant value in reducing future incidents that could cause injury. CNSC staff verified the McArthur River Operation conventional health and safety work practices and conditions met regulatory requirements.

Performance

As shown in table 4.3, there was one lost-time injury (LTI) reported at the McArthur River Operation in 2016.

Table 4.3: McArthur River – Lost-time injury statistics, 2012–16

	2012	2013	2014	2015	2016
Lost-time injuries[1]	1*	1*	1**	0	1
Severity rate[2]	8.0	0	14.6**	7.31**	0
Frequency rate[3]	0.1*	0.11*	0.11**	0	0.12

[1] An injury that takes place at work and results in the worker being unable to return to work for a period of time.

[2] The accident severity rate measures the total number of days lost to injury for every 200,000 person-hours worked at the site. Severity = [(# of days lost in last 12 months) /(# of hours worked in last 12 months)] x 200,000.

[3] The accident frequency rate measuring the number of LTIs for every 200,000 person-hours worked at the site. Frequency = [(# of injuries in last 12 months) / (# of hours worked in last 12 months)] x 200,000.

* One LTI was moved from 2012 to 2013, resulting in the number of LTIs in 2012 decreasing from two to one and the number of LTIs in 2013 increasing from zero to one. These changes resulted in a frequency rate change from 0.2 to 0.1 in 2012 and 0 to 0.11 in 2013.

** A lifting injury in 2014 eventually required surgery in 2015, resulting in lost time. As a result, 2014 LTIs were increased from zero to one, severity rate from zero to 14.6 and frequency rate from zero to 0.11. The 2015 severity rate was also affected due to lost time in 2015.

Compliance verification activities confirmed that the McArthur River Operation focuses on the prevention of accidents, reducing LTIs and the number of injuries requiring medical treatment.

Awareness

CNSC staff observed that the conventional health and safety programs at the McArthur River Operation continued to provide education, training, tools and support to workers. Managers, supervisors and workers share and promote the idea that safety is the responsibility of all individuals. Site operation's management stresses the importance of conventional health and safety through regular communication, management oversight and continual improvement of safety systems.

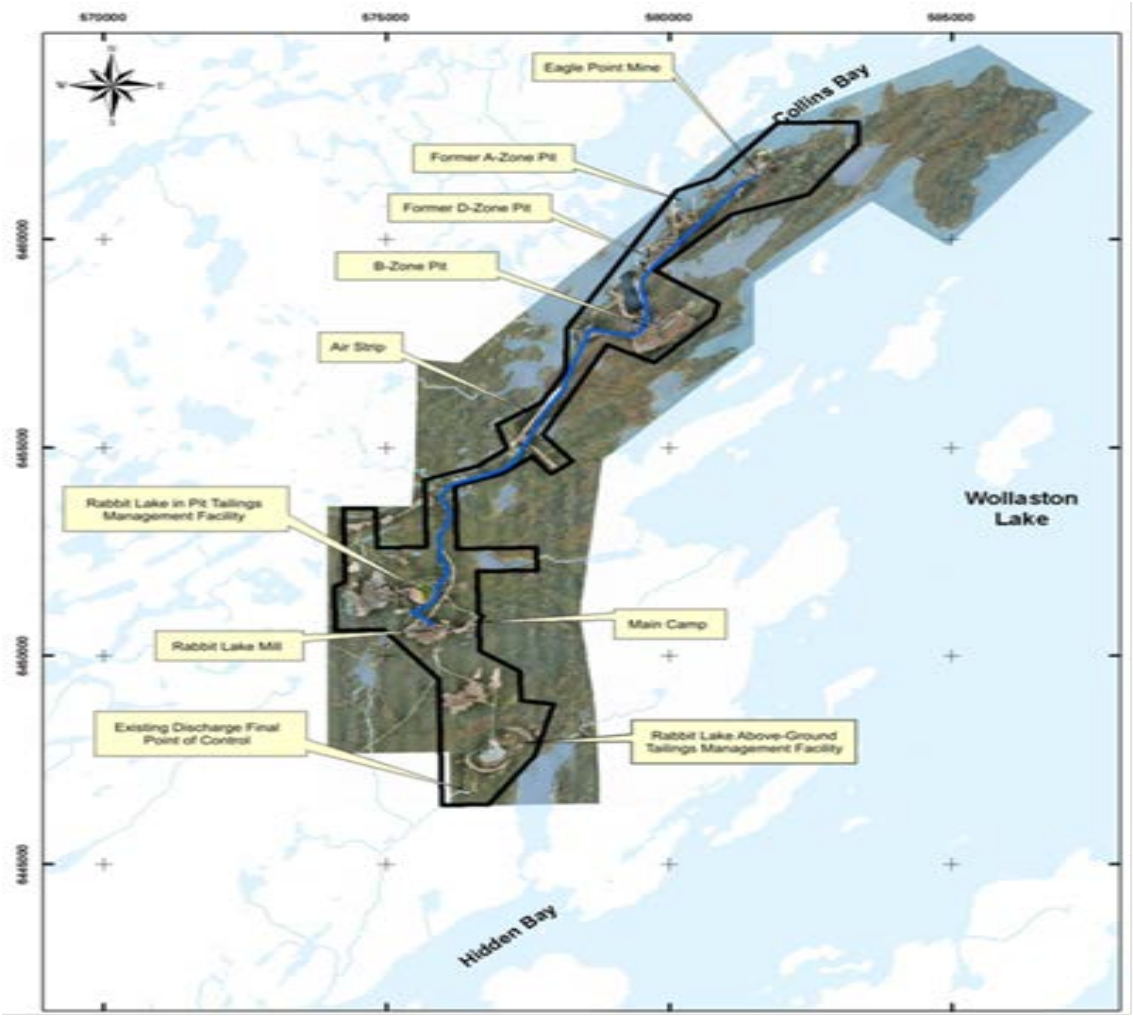
CNSC staff verified that the health and safety program at the McArthur River Operation met regulatory requirements.

5 Rabbit Lake Operation

The Rabbit Lake Operation is located 750 kilometres north of Saskatoon, Saskatchewan (figure 5.1). Owned and operated by Cameco Corporation, the site stretches across approximately 20 kilometres. The Eagle Point underground mine is located at the northern margin of the property. Moving southward, three mined-out and flooded pits – the A, D and B-Zone pits – border Collins Bay of Wollaston Lake. The B-Zone pit remains isolated from the bay by an intact dyke. In the central part of the property, the mined-out Rabbit Lake pit was converted to a tailings management facility (TMF). Adjacent to the in-pit tailings management facility is the mill. South of the mill is the above-ground TMF, which has not received tailings since 1985. At the southern margin, after passage through settling polishing ponds, treated effluent continuously discharges and eventually reaches Hidden Bay of Wollaston Lake.

In October 2013, the Commission issued a 10-year licence following a public hearing in La Ronge, Saskatchewan. Cameco's licence for the Rabbit Lake Operation expires on October 31, 2023.

Figure 5.1: Site map of the Rabbit Lake Operation



Mining production data for the Rabbit Lake Operation are provided in table 5.1.

Table 5.1: Mining production data, Rabbit Lake, 2012–16

Mining	2012	2013*	2014	2015	2016
Ore tonnage (Mkg/year)	225.28	255.15	328.13	309.50	79.87
Average ore grade mined (% U_3O_8)	0.84	0.59*	0.56	0.63	0.69
Uranium mined (Mkg U/year)	1.62	1.28	1.57	1.66	0.47

* 2013 data corrected

Ore from the Eagle Point mine had been blended at the Rabbit Lake mill with previously mined, low-grade material to supplement uranium concentrate production. Table 5.2 presents the 2012 to 2016 milling data for the Rabbit Lake Operation.

Table 5.2: Milling production data, Rabbit Lake, 2012–16

Milling	2012	2013	2014	2015	2016
Mill ore feed (Mkg/year)	260.30	334.98	386.97	313.71	61.67
Average annual mill feed grade (% U_3O_8)	0.71	0.54	0.49	0.64	0.76
Percent uranium recovery	96.8	97.2	97.3	97.1	97.0
Uranium concentrate produced (Mkg U/year)	1.48	1.59	1.60	1.62	0.43
Authorized annual production (Mkg U/year)	4.25	4.25	4.25	4.25	4.25

CNSC staff confirmed the Rabbit Lake Operation production remains less than the authorized annual production (table 5.2).

On April 21, 2016 Cameco Corporation formally announced that, due to market conditions, production at the Rabbit Lake Operation was to be suspended, and the facility was placed into a safe state of care and maintenance. This decision allows Cameco the flexibility to resume production when market conditions improve.

Cameco has planned and implemented the safe transition of the operations into care and maintenance with a focus on three key areas: the preservation of facilities and equipment to ensure future availability; the ongoing collection and treatment of contaminated water from various areas of the operation; and the maintenance of operational compliance to applicable regulations, approvals and licensed programs.

The changes to transition to care and maintenance relate to the suspension of production and the safe shutdown of related infrastructure and systems. The main functional areas to be maintained include mill operations, mine operations and tailings management. A submission updating the plan and process to be followed and the status of the facility was provided to the CNSC and the Saskatchewan Ministry of Environment in October 2016. The submission has been reviewed by both agencies and the measures and activities outlined have been accepted. The following summarizes the transition initiatives.

Mill operations

The mill transition to care and maintenance is similar to a routine maintenance shutdown event:

- The mill production circuits were emptied, flushed, cleaned and preserved.
- The mill ore pad was emptied of remaining ore inventory.
- The water treatment circuit was maintained and restored to normal operating status.
- Sulphuric acid inventories were maximized and the acid plant operation was suspended.
- Mill ventilation was optimized for energy and heating use to reflect the mill circuits status.
- Hazardous materials were transported to other Cameco sites or returned to the supplier.
- Inactive areas were added to a routine inspection schedule with checks conducted and documented on a regular basis.

Fire protection systems will continue to be maintained throughout the main mill complex.

Mine operations

During the care and maintenance period, activities at the Eagle Point mine will be minimized and the focus will be on continued dewatering of the mine. There is no exploration, development or production planned. Underground work will consist only of basic and required inspections and maintenance.

- All development and production work areas have been made safe, and ground conditions have been assessed for stability and verified by a qualified third-party evaluation.

- Inactive areas have been sealed with bulkheads and mine service infrastructure removed from these areas.
- Mine water collection and the dewatering system has been simplified and centralized.
- Ventilation systems have been optimized for heat and energy use.
- Mine mobile equipment has been stored and preserved in ventilated locations in the mine.
- All explosives have been removed from underground and the remaining inventory removed from site by the vendor.
- Non-essential surface facilities have been vacated and secured.

Routine inspections of the mine are conducted to ensure proper functioning of dewatering and ventilation systems and to monitor for unusual or changing conditions. Emergency response will be maintained in accordance with Saskatchewan Ministry of Labour Relations and Workplace Safety requirements.

Tailings management

The Rabbit Lake in-pit TMF will continue to operate during the care and maintenance period. The primary operating functions will involve storing solids produced by the mill water treatment system; providing ongoing dewatering of tailings solids and hydraulic containment of pore water, supernatant, surface runoff and groundwater from the existing catchment area; and providing short-term water storage capacity as part of the site's water management system. Figure 5.2 provides an aerial view of the in-pit TMF.

Figure 5.2: In-pit tailings management facility at Rabbit Lake, 2016

Reclamation

No significant changes to the existing preliminary decommissioning plan and cost estimate are anticipated to occur due to the suspension of production. Progressive reclamation activities will continue throughout the care and maintenance period. The scope of activities and timing may be adjusted to reflect the change in operating status.

CNSC staff have verified the care and maintenance status of the mine and mill and the continuation of reclamation activities through desktop reviews of applications, reports and onsite inspections. CNSC staff will continue to monitor and review the Rabbit Lake Operation's water management practices and reclamation activities to ensure the environment is protected during this period of care and maintenance.

5.1 Performance

For 2016, CNSC staff rated all 14 safety and control areas (SCAs) as "satisfactory" based on regulatory oversight activities. Ratings at the Rabbit Lake Operation for these 14 SCAs during the five-year period of 2012 to 2016 are shown in appendix D. This report focuses on the three SCAs that cover many of the key performance indicators for these facilities: "radiation protection", "environmental protection" and "conventional health and safety".

In 2016, CNSC staff carried out compliance inspections covering the SCAs of "operating performance", "fire protection", "waste management" and "fitness for service" in addition to those for which a detailed analysis is provided in the following sections. Non-compliances resulting from CNSC inspections at the Rabbit Lake Operation for the 2016 calendar year were low risk in nature; corrective actions implemented by the licensee have been reviewed and accepted by CNSC staff. A list of inspections has been provided in appendix J.

5.2 Radiation protection

For 2016, CNSC staff continued to rate the radiation protection SCA as "satisfactory" based on regulatory oversight activities.

Rabbit Lake radiation protection ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Radiological hazard control

The sources of radiological exposure at the Rabbit Lake Operation were from mining at the Eagle Point underground mine and from milling uranium ore into yellowcake at the Rabbit Lake mill. The effective dose contributors to nuclear energy workers (NEWs) at Rabbit Lake were radon progeny (56 percent), gamma radiation (28 percent), long-lived radioactive dust (LLRD; 11 percent) and radon gas (5 percent). Effective doses to NEWs from exposures to radon progeny, radon gas and LLRD are controlled through the effective use of source control, ventilation, contamination control and personal protective equipment (PPE). Gamma radiation exposure is controlled through the application of time, distance and shielding.

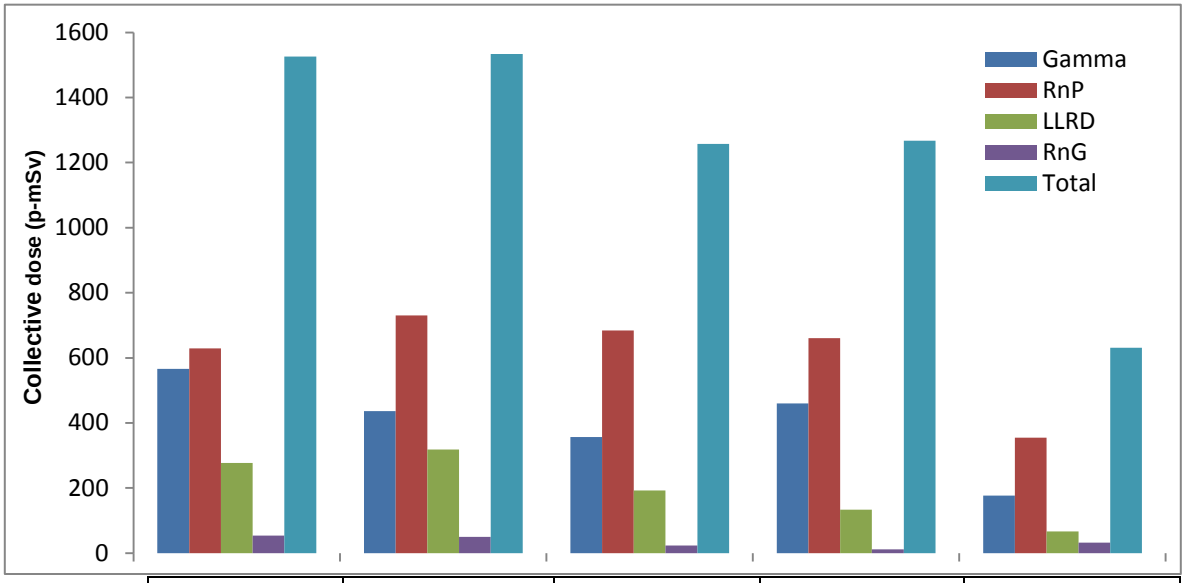
Radiation protection program performance

In 2016, CNSC staff were satisfied that the radiation protection program and practices at the Rabbit Lake Operation remained effective in controlling radiological exposure to workers. The doses to workers remained below regulatory limits and as low as reasonably achievable (ALARA). There were no action level exceedances reported at the Rabbit Lake Operation in 2016.

Application of ALARA

In 2016, collective radiation exposure to NEWs at Rabbit Lake was 631 person-millisieverts (p-mSv), an approximate 50 percent reduction from the 2015 value of 1,267 p-mSv (figure 5.3). The decrease is attributed to the suspension of production and placement of the operation into care and maintenance in 2016.

Figure 5.3: Annual collective radiation exposures, Rabbit Lake, 2012–16



	2012	2013	2014	2015	2016
Gamma (p-mSv)	566	436	357	460	177
RnP (p-mSv)	629	730	684	661	355
LLRD (p-mSv)	277	318	193	134	67
RnG (p-mSv)	54	50	23	12	32
Total	1,526	1,534	1,257	1,267	631

RnP = radon progeny; LLRD = long-lived radioactive dust; RnG = radon gas

In 2016, the Rabbit Lake Operation continued to develop the program initiated in 2015 to identify and minimize areas of elevated radon progeny in the mine. Mapped radon progeny levels were used to inform the ventilation configuration during transition to care and maintenance. Based on these results, Cameco determined that exhaust air raise #2 would remain in service to remove radon progeny from the south side of the mine. Similarly, radon progeny monitoring was conducted throughout the mill to ensure hazard levels continue to meet hazard objectives throughout all ventilation adjustments.

CNSC staff have verified through regulatory oversight activities that Cameco continues to maintain worker exposures ALARA.

Worker dose control

During 2016, the average individual effective dose for NEWs was 0.85 millisieverts (mSv) and the maximum individual effective dose was 4.95 mSv. This compares to an average effective dose of 1.36 mSv and a maximum individual dose of 9.14 mSv in 2015. This decrease is attributed to the suspension of mining and milling as the operation transitioned into care and maintenance. As shown in section 2 and figures 2.3 and 2.4, all individual effective doses for NEWs were below the annual regulatory limit of 50 mSv. Based on CNSC staff compliance verification activities such as site inspections, reviews of licensees' reports, work practices, monitoring results and individual effective dose results for 2016, CNSC staff were satisfied that the Rabbit Lake Operation adequately controlled radiation doses to workers.

5.3 Environmental protection

For 2016, CNSC staff continued to rate the environmental protection SCA as "satisfactory" based on regulatory oversight activities. CNSC staff concluded that the licensee's environmental protection program was effectively implemented and met all regulatory requirements.

Rabbit Lake environmental protection ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Environmental management system

The Rabbit Lake Operation environmental management system is described in its approved environmental protection program and includes activities such as establishing annual environmental objectives, goals and targets. The Rabbit Lake Operation conducts internal audits of its program at least once every year. CNSC staff review and assess the objectives, goals and targets through regular compliance verification activities.

Environmental risk assessment

The Rabbit Lake 2010–14 environmental performance report, which included an environmental and human health risk assessment, was submitted to the Saskatchewan Ministry of Environment and the CNSC in 2015. CNSC staff reviewed the submissions and concluded the monitoring programs and special studies were adequate, provided required information and contained sufficient information to complete a review. This assessment confirms the environment and human health in the vicinity of the Rabbit Lake Operation remains protected. Further information on the environmental risk assessment is provided in section 2.3.

Assessment and monitoring

During 2016, CNSC staff verified the Rabbit Lake environmental protection program was effectively implemented and met regulatory requirements.

CNSC staff concluded that the Rabbit Lake Operation environmental management system and monitoring programs met regulatory requirements and all treated effluent discharged to the environment complied with licence requirements. There were no exceedances of environmental action levels at the Rabbit Lake Operation during 2016.

Effluent and emissions control

Treated effluent released to the environment

For previously identified constituents of potential concern (COPC) with the potential to adversely affect the environment (i.e., uranium, molybdenum and selenium), the effluent treatment system at the Rabbit Lake Operation continues to meet performance expectations in reducing the concentrations of these parameters (see figures 2.6 to 2.8 of section 2). Substantial water treatment modifications have been completed at the Rabbit Lake Operation since 2007 to improve the quality of the treated effluent released to the environment. The licensee installed additional chemical treatment processes to reduce molybdenum. CNSC staff verified molybdenum concentrations displayed a marked reduction from 2012 levels and have remained relatively consistent from 2014 to 2016.

In 2006, a review titled *Uranium Effluent Treatment Process* identified a concentration of uranium in effluent of 0.1 mg/L as a potential treatment design objective that could be achieved and is protective of the environment. The 2007 treatment circuit modifications have also been successful in meeting the uranium target objective of 0.1 mg/L. CNSC staff also confirmed selenium concentrations have remained consistent with previous years (figure 2.7).

The Rabbit Lake Operation also analyzed treated effluent for concentrations of various other contaminants such as radium-226, arsenic, copper, lead, nickel, zinc, total suspended solids (TSS) and pH. As shown in section 2.3, CNSC staff verified the Rabbit Lake Operation continues to meet *Metal Mining Effluent Regulations* discharge limits.

In 2016, the concentrations of regulated parameters in treated effluent released to the environment were well below the regulatory limits. Figure 5.4 shows the B-Zone settling pond at the Rabbit Lake Operation. CNSC staff will continue to review effluent quality results to ensure that effluent treatment performance remains effective.

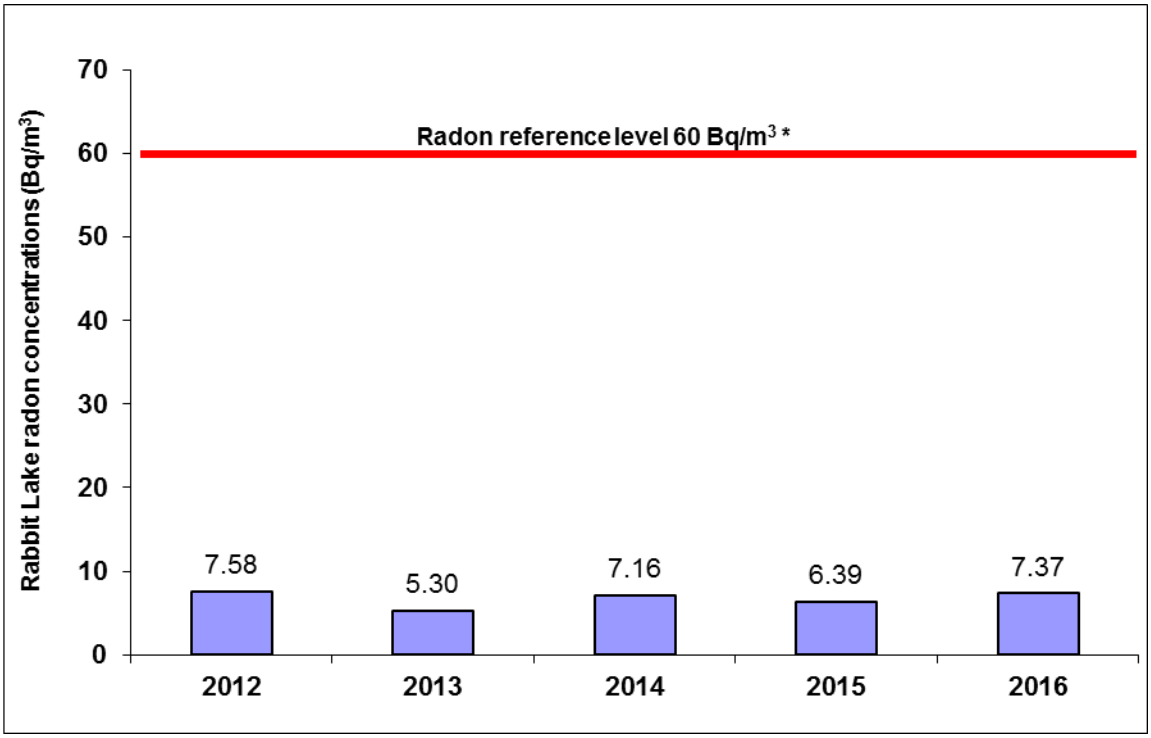
Figure 5.4: B-Zone settling pond at the Rabbit Lake Operation

Air emissions released to the environment

The Rabbit Lake Operation also maintains an air and terrestrial monitoring program. Air and terrestrial monitoring at the Rabbit Lake facility includes ambient radon, total suspended particulate (TSP), sulphur dioxide, soil sampling and lichen sampling to assess the impact of air emissions.

Radon in air around the Rabbit Lake Operation is monitored at 18 stations using passive track-etch cups. Figure 5.5 shows that the average concentrations of radon in ambient air for 2012 to 2016 were below the reference level. The radon concentrations were also typical of the northern Saskatchewan regional baseline of less than 7.4 Bq/m^3 to 25 Bq/m^3.

Figure 5.5: Concentrations of radon in ambient air, Rabbit Lake, 2012–16



* The value of 60 Bq/m^3 has been derived from the International Commission on Radiological Protection's *Protection Against Radon-222 at Home and at Work,* as referenced in the *Radiation Protection Regulations*. The reference level represents an incremental increase above natural dwelling radon levels that could result in a member of the public being exposed to an incremental dose of 1 mSv. Values are calculated as geometric means.

Three high-volume air samplers were used to collect and measure TSP in air. The TSP levels from the average of the three stations are below provincial standards (see table 5.3). TSP samples were also analyzed for concentrations of metals and radionuclides. The mean concentrations of metals and radionuclides adsorbed to TSP are low and remained below the reference annual air quality levels identified in table 5.3.

Table 5.3: Concentrations of metal and radionuclides in air, Rabbit Lake, 2012–16

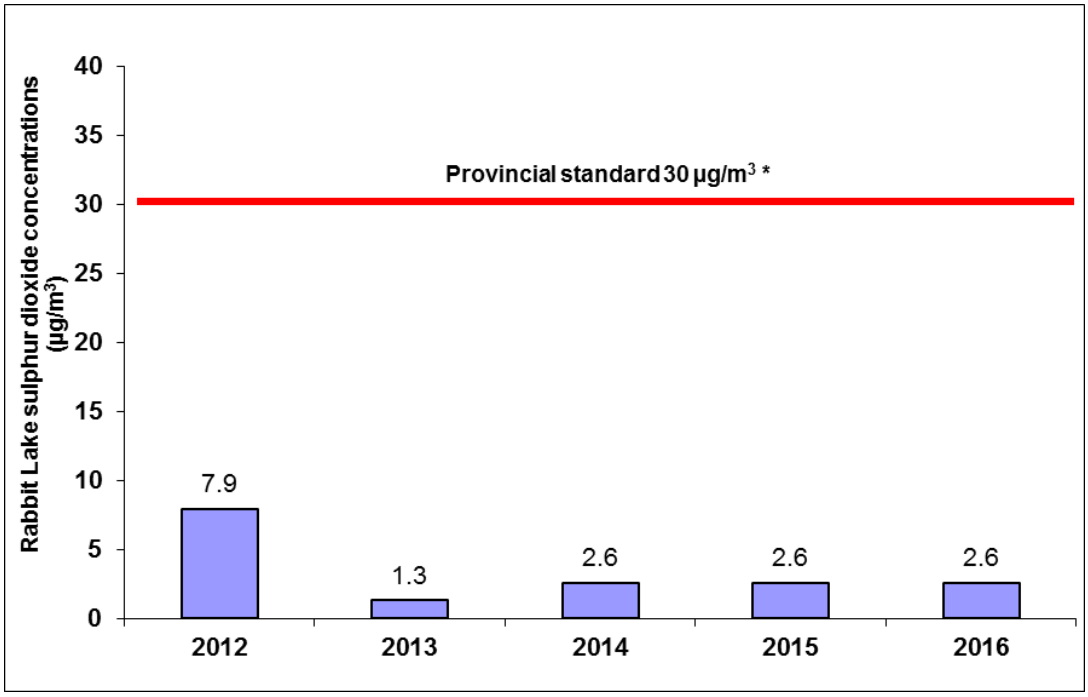
Parameter	Reference annual air quality levels*	2012	2013	2014	2015	2016
TSP (µg/m^3)	**70 (3)**	6.00	7.67	6.21	6.87	4.97
As (µg/m^3)	**0.06 (1)**	0.000233	0.000175	0.000217	0.000207	0.000290
Ni (µg/m^3)	**0.04 (1)**	0.000033	0.000007	0.000138	0.000192	0.000540
Pb^{210} (Bq/m^3)	**0.021 (2)**	0.000012	0.000010	0.000013	0.000015	0.000011
Ra^{226} (Bq/m^3)	**0.013 (2)**	0.000000	0.000002	0.000002	0.000001	0.000002
Th^{230} (Bq/m^3)	**0.0085 (2)**	0.000001	0.000001	0.000003	0.000001	0.000002
U (µg/m^3)	**0.06 (1)**	0.000917	0.001033	0.001960	0.002341	0.000899

1 Reference annual air quality levels derived from Ontario's 24-hour ambient air quality criteria (2012).
2 Reference level from International Commission on Radiological Protection (ICRP) publication 96.
3 The Province of Saskatchewan's authorized concentration of contaminants monitored for ambient air quality as listed in the facility's approval to operate pollutant control facilities is shown. Values are calculated as geometric means.
* Province of Ontario and ICRP annual air quality levels are shown for reference only. No federal or provincial limits are currently established.

Daily in-stack monitoring of sulphur dioxide emissions from the mill acid plant showed a 30 percent reduction in terms of the mass released in 2015 from the previous year. A sulphur dioxide monitoring location approximately 450 metres southwest of the acid plant monitors releases associated with mill operations. Sulphur dioxide monitoring results (figure 5.6) show there were no exceedances of the annual standard of 30 µg/m^3. CNSC staff verified ambient sulphur dioxide levels remain at safe concentrations in the nearby environment.

With the safe-suspension of the acid plant operation and milling activities as a result of the transition from operation into care and maintenance status, sulphur dioxide emissions are expected to be very low for the foreseeable future.

Figure 5.6: Concentrations of ambient sulphur dioxide, Rabbit Lake, 2012–16



*Province of Saskatchewan standard

Soil and terrestrial vegetation may be affected by the atmospheric deposition of particulate and adsorbed metals and radionuclides associated with onsite activities. A terrestrial monitoring program is in place and includes measurements of metals and radionuclides in soil and on lichen.

Lichen sampling has been conducted for three decades at the Rabbit Lake Operation, most recently in 2013. The next sampling is scheduled for 2019. CNSC staff concluded that the level of airborne particulate contaminants produced by the Rabbit Lake Operation does not pose a risk to lichen consumers, such as caribou.

Protection of the public

In 2016, two events reported to CNSC staff were submitted as releases (spills) of hazardous substances to the environment. Both spills were minor and the reporting of these events met the requirements of RD/GD-99.3, *Public Information and Disclosure:*

- 330 m^3 (330,000 L) of snow melt water from the B-Zone ore pad was released from a pipeline culvert.
- 150 kg of propane was released into the atmosphere due to a loose coupling on the top of a propane tank.

Appendix G provides a brief description of each spill and the actions taken by the licensee. The spills were remediated, with no residual impacts on the environment. CNSC staff reviewed the corrective actions taken by the Rabbit Lake Operation and found them to be acceptable. The CNSC rated all the 2016 spills as low significance. Figure 2.5 displays the number of environmental reportable spills from 2012 to 2016 at the Rabbit Lake Operation.

5.4 Conventional health and safety

For 2016, CNSC staff continued to rate the conventional health and safety SCA as "satisfactory" based on regulatory oversight activities.

Rabbit Lake conventional health and safety ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Practices

Cameco's Rabbit Lake Operation has implemented a safety and health management program to identify and mitigate risks. The program includes internal inspections, a safety permit system, occupational health committees, training and incident investigations. CNSC staff monitor this program through compliance activities to ensure the protection of workers.

The incident reporting system at the Rabbit Lake Operation includes reporting on and investigating near misses, which offers significant value in reducing future incidents that could cause injury. CNSC compliance verification activities confirmed the Rabbit Lake Operation continues to focus on the prevention of accidents and injuries through implementation of its health and safety management program.

Performance

The lost-time injury (LTI) performance at the Rabbit Lake Operation for 2012 to 2016 is shown in table 5.4.

Table 5.4: Lost-time injury statistics, Rabbit Lake, 2012–16

	2012	2013	2014	2015	2016
Lost-time injuries[1]	1	0	1	2	1
Severity rate[2]	22.6	25.8	11.4	55.3	2.65
Frequency rate[3]	0.1	0.0	0.15	0.33	0.27

[1] An injury that takes place at work and results in the worker being unable to return to work for a period of time.

[2] The accident severity rate measures the total number of days lost to injury for every 200,000 person-hours worked at the site. Severity = [(# of days lost in last 12 months) / (# of hours worked in last 12 months)] x 200,000.

[3] The accident frequency rate measuring the number of LTIs for every 200,000 person-hours worked at the site. Frequency = [(# of injuries in last 12 months) / (# of hours worked in last 12 months)] x 200,000.

Appendix H contains a brief description of a fall resulting in an LTI that occurred in 2016 and corrective actions, which included the replacement of a step with a ramp. CNSC staff assessed and were satisfied with the follow-up actions taken by the Rabbit Lake Operation.

In 2016, an event initial report (CMD 16-M33) regarding an occurrence at the Rabbit Lake operation was provided to the Commission by CNSC staff. As part of care and maintenance preparations, a contract scaffolder fell from a height of two feet while carrying out routine activities. The worker sustained a head injury and bruised leg as a result of the event. The worker was treated by the site nurse and transferred to a Saskatoon hospital for further assessment and treatment. The severity of the injuries was relatively minor: the worker was able to return to work and the event did not result in a LTI. CNSC staff confirmed that proper reporting of the event occurred and corrective actions to prevent a reoccurrence were completed. These actions included reviewing onsite scaffolding work, conducting a job hazard analysis, and developing a method and specific instructions for preventing the rotation of scaffolding castors. The lessons learned were also shared with other operations.

Awareness

CNSC staff observed that the Rabbit Lake Operation's conventional health and safety program continued to provide education, training, tools and support to workers. Managers, supervisors and workers share and promote the idea that safety is the responsibility of all individuals. Site management emphasizes the importance of conventional health and safety through regular communication, management oversight and continual improvement of safety systems.

CNSC staff verified that the conventional health and safety program at the Rabbit Lake Operation remained effective in managing health and safety risks.

6 Key Lake Operation

Located approximately 570 kilometres north of Saskatoon, Saskatchewan, the Key Lake Operation is owned and operated by Cameco Corporation. The Operation began with two open-pit mines and a mill complex. The Gaertner open pit was mined from 1983 to 1987, followed by the Deilmann open pit until 1997. An aerial view of the Key Lake Operation is shown in figure 6.1.

Figure 6.1: Aerial view of the Key Lake Operation

Milling of the Deilmann ore continued until 1999, when the McArthur River Operation began supplying ore slurry to the Key Lake mill. The Key Lake Operation continues today as a mill operation processing McArthur River ore slurry.

After open-pit mining in the eastern pit of the Deilmann orebody was completed in 1995, the pit was converted into the engineered Deilmann tailings management facility (TMF) (figure 6.2). Mill tailings continue to be deposited into this facility today.

Figure 6.2: Deilmann tailings management facility at the Key Lake Operation

In October 2013, the Commission issued a 10-year licence following a public hearing in La Ronge, Saskatchewan. The Key Lake Operation licence expires on October 31, 2023.

Milling data for the Key Lake Operation during the five-year reporting period are presented in table 6.1.

Table 6.1: Milling production data, Key Lake, 2012–16

Milling	2012	2013	2014	2015	2016
Mill ore feed (Mkg/year)	193.51	184.10	173.01	165.56	155.30
Average annual mill feed grade (% U_3O_8)	4.61	5.03	5.03	5.26	5.33
Percentage of uranium recovery	98.9	99.3	99.4	99.35	99.04
Uranium concentrate produced (Mkg U/year)	7.52	7.75	7.37	7.35	6.95
Authorized annual production (Mkg U/year)	7.85	7.85	9.60	9.60	9.60

CNSC staff confirmed the Key Lake Operation production remains less than the authorized annual production (table 6.1).

As reported in October 2016 in Commission member document (CMD) 16-M49, Cameco constructed and began commissioning a new calciner. During the commissioning process, it was determined that the new calciner would not operate as designed. Cameco continued to use the existing calciner throughout 2016. To ensure this equipment continues to operate effectively, a number of maintenance activities were planned for the 2017 summer shutdown. Cameco continues to investigate options for modifying or replacing the new calciner. Through regular compliance activities, CNSC staff verified the safe operation of the existing calciner.

6.1 Performance

The Key Lake Operation ratings for the five-year period of 2012 to 2016 for the 14 safety and control areas (SCAs) are shown in appendix D. CNSC staff continue to rate all SCAs for 2016 as "satisfactory" based on regulatory oversight activities. This report focuses on the three SCAs that cover many of the key performance indicators for these uranium mine and mill operations: "radiation protection", "environmental protection" and "conventional health and safety".

In 2016, CNSC staff carried out compliance inspections covering the SCAs of "management system", "operating performance", "human performance management", "waste management" and "physical design" in addition to those for which a detailed analysis has been provided in the following sections. Non-compliances resulting from CNSC inspections at the Key Lake Operation for the 2016 calendar year were low risk in nature; corrective actions have been implemented by licensees and reviewed and accepted by CNSC staff. A list of inspections can be found in appendix J.

6.2 Radiation protection

Based on regulatory oversight activities during the reporting period, CNSC staff rated the radiation protection SCA as "satisfactory".

Key Lake radiation protection ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Radiological hazard control

The effective dose contributors to nuclear energy workers (NEWs) at the Key Lake mill were gamma radiation (46 percent), radon progeny (32 percent) and long-lived radioactive dust (LLRD; 22 percent). Gamma radiation hazards are controlled through the effective use of time, distance and shielding. Radon progeny and LLRD are controlled through source control, ventilation contamination control and personal protective equipment (PPE).

Exposure to radon progeny is primarily determined by a calculation that combines the area's monitoring results with the time spent in that particular area. The radiation department determines specific monitoring for a task and uses the results to calculate exposures for the individuals involved in the task. Normally this monitoring is done by grab sampling prior to and/or during the specific task.

Radiation protection program performance

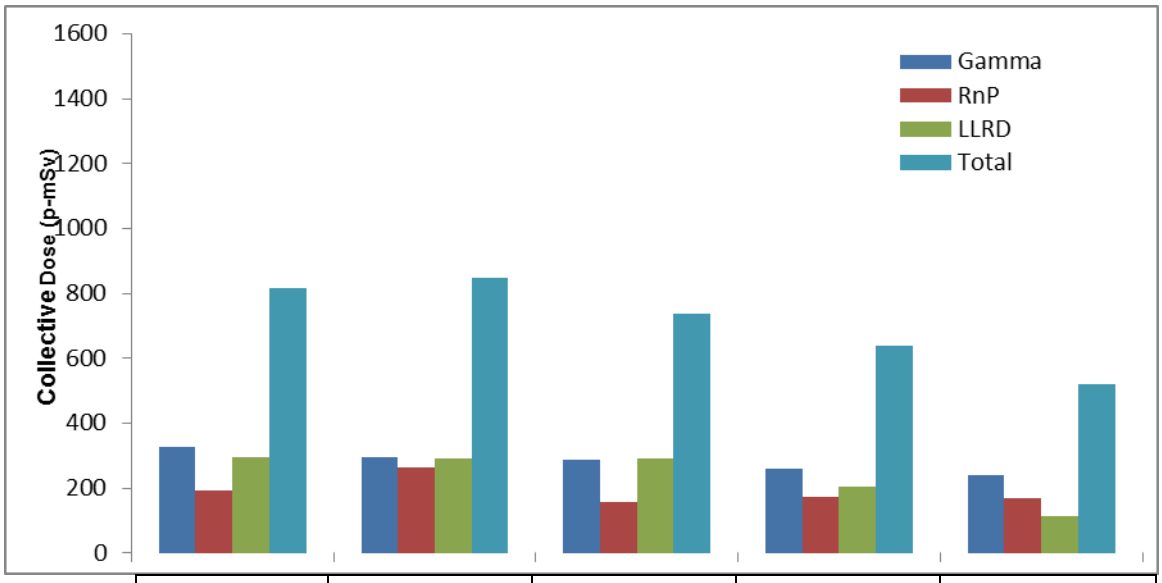
In 2016, one individual received a dose that exceeded the weekly action level (1 millisievert (mSv)). In May 2016, a worker failed to provide a post-entry urine sample following maintenance in the Key Lake calciner room. As a result, no credit was applied for the use of a powered air-purifying respirator, resulting in an uncredited dose.

A brief description of the above event and corrective actions implemented are provided in appendix I. CNSC staff assessed and were satisfied with the actions taken by the Key Lake Operation to address this action level exceedance. The doses to workers remained below regulatory limits.

Application of ALARA

In 2016, the collective radiation exposure to NEWs at the Key Lake Operation was 522 person-millisieverts (p-mSv), an approximate 18 percent reduction from the 2015 value of 638 p-mSv (figure 6.3). Production in 2016 was approximately 6 percent lower than in the previous year (measured by uranium concentrate produced).

Figure 6.3: Annual collective radiation exposures, Key Lake, 2012–16



	2012	2013	2014	2015	2016
Gamma (p-mSv)	327	295	287	259	240
RnP (p-mSv)	193	264	158	172	169
LLRD (p-mSv)	296	291	293	207	113
Total	816	850	738	638	522

RnP = radon progeny; LLRD = long-lived radioactive dust

In 2016, the Key Lake Operation maintained as-low-as-reasonably-achievable (ALARA) objectives, including the High-5 program that was initiated in 2010. In search of opportunities to lower doses, the High-5 program reviews results for the five employees and five contractors who had the highest quarterly effective dose. Site radiation awareness activities were performed throughout 2016. Radiation information related to incidents, events, trends, and changes to work instructions and radiation policy was shared with contractors and Cameco workers. The radiation department shared information through safety meetings, fact sheets, safety inspections and job task observations. CNSC staff concluded that the radiation protection program remains effective in ensuring that worker exposures remain ALARA.

Worker dose control

In 2016, the average individual effective dose to NEWs was 0.62 mSv, while the maximum individual effective dose received was 5.37 mSv. This compares to an average effective dose of 0.55 mSv and a maximum individual dose of 7.56 mSv in 2015.

The maximum individual effective dose at the Key Lake Operation was identified in a mill operations worker who worked a large fraction of the year in the leaching circuit. All individual effective doses remained well below the annual regulatory limit of 50 mSv.

Based on CNSC staff compliance verification activities such as site inspections, reviews of licensees' reports, work practices, monitoring results and individual effective dose results for 2016, CNSC staff were satisfied that the Key Lake Operation adequately controlled radiation doses to workers.

6.3 Environmental protection

For 2016, CNSC staff continued to rate the environmental protection SCA as "satisfactory" based on regulatory oversight activities. CNSC staff concluded the licensee's environmental protection program was effectively implemented and met all regulatory requirements.

Key Lake environmental protection ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Environmental management system

Key Lake Operation's environmental management system includes activities such as establishing annual environmental objectives, goals and targets. The Key Lake Operation conducts internal audits of its program at least once every year. CNSC staff review and assess the objectives, goals and targets through regular compliance verification activities.

Environmental risk assessment

In 2015, the Key Lake environmental performance report (EPR) for the 2010 to 2014 period was submitted to regulators. CNSC staff reviewed and found the EPR contained sufficient information to complete a review of the environmental performance of the Key Lake Operation from 2010 to 2014 relative to predictions contained in the 2013 environmental risk assessment (ERA) for the Key Lake extension project. The monitoring programs and special studies were sufficiently comprehensive and provided the required information. The models used to predict environmental performance continued to be valid. Therefore, CNSC staff confirmed the environment and human health in the vicinity of the Key Lake Operation remains protected. Additional information on the ERA was also provided in section 2.3.

Assessment and monitoring

Effluent and environmental monitoring, site inspections, environmental awareness training and program implementation audits were performed in accordance with the Key Lake operation's environmental protection program.

CNSC staff concluded that the Key Lake Operation's environmental management system and monitoring programs met regulatory requirements and the licensee complied with treated effluent discharge requirements. There were no exceedances of environmental action levels during the 2016 review period.

The following provides monitoring and assessment results for the Key Lake Operation.

Effluent and emissions control

Treated effluent released to the environment

At the Key Lake Operation, two effluent streams are processed in separate treatment facilities before being released to the environment:

- The mill effluent is processed with a treatment system of chemical precipitation and liquid/solid separation, and then released to Wolf Lake in the David Creek system.
- Effluent from dewatering wells of the Gaertner pit and Deilmann pit hydraulic containment systems is treated with a reverse osmosis system before being released to Horsefly Lake in the McDonald Lake system.

The McDonald Lake system receives effluent from the reverse osmosis plant. Monitoring confirms that this effluent is within design specifications and predictions outlined in the ERA. The treated effluent quality further discussed in this report refers only to the mill effluent as released to the David Creek system.

In 2016, CNSC staff verified the concentration of all regulated contaminants in the treated mill effluent met licensed limits. There were no exceedances of environmental action levels at the Key Lake Operation.

As discussed in section 2.3, all regulated parameters and constituents of potential concern (COPC) with potential to adversely affect the environment in treated effluent at the uranium mine and mill facilities are molybdenum, selenium and uranium. Of these, molybdenum and selenium concentrations were the primary concerns at the Key Lake Operation. The licensee has therefore targeted process changes to reduce concentrations in treated effluent.

Significant reductions of molybdenum and selenium occurred from 2008 to 2009 when additional treatment components were installed and optimized. Figures 2.6 and 2.7 show stable concentrations of molybdenum and selenium in treated effluent from 2012 to 2016, indicating these parameters are being effectively controlled. Figure 2.8 indicates that uranium concentrations in treated effluent released from the Key Lake mill remain low and are again effectively controlled.

In addition to the COPC, the Key Lake Operation also analyzed treated effluent for concentrations of other COPC such as radium-226, arsenic, copper, lead, nickel, zinc, total suspended solids (TSS) and pH. As discussed in section 2.3, the Key Lake Operation continued to meet *Metal Mining Effluent Regulations* discharge limits.

CNSC staff will continue to review effluent quality results to ensure effluent treatment performance remains effective.

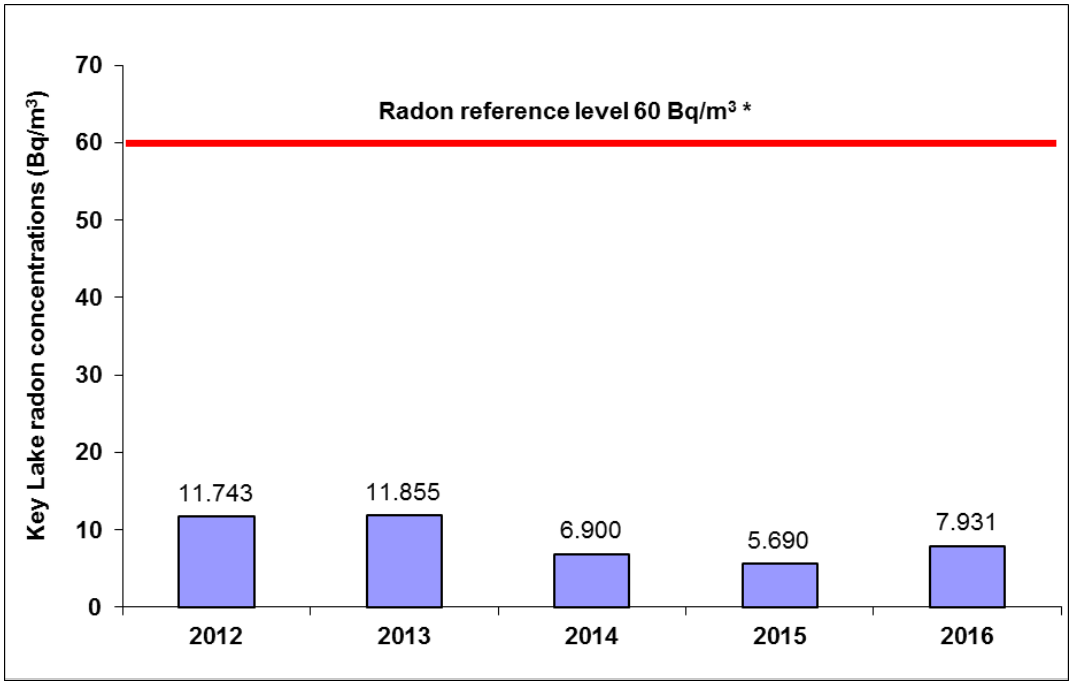
Air emissions released to the environment

The air and terrestrial monitoring program at the Key Lake Operation includes ambient monitoring for sulphur dioxide, radon and total suspended particulate (TSP) as well as soil and lichen sampling to assess air quality. Air emissions monitoring from the mill stacks are also included in the air-quality monitoring program.

The Key Lake calciner stack is monitored annually; the most recent stack test was completed in November 2016. The stack emission results were within historical ranges and verified that operational controls are working as designed. Sulphur dioxide concentrations from the acid plant stack are monitored daily. Concentrations are consistent with those reported since the commissioning of the new acid plant in 2012.

Radon in air around the Key Lake Operation is monitored at five stations using passive track-etch cups. Figure 6.4 shows the average concentrations of radon in ambient air for 2012 to 2016 were below the reference level. The radon concentrations were also typical of the northern Saskatchewan regional baseline of less than 7.4 Bq/m^3 to 25 Bq/m^3.

Figure 6.4: Concentrations of radon in ambient air, Key Lake, 2012–16



* The value of 60 Bq/m^3 has been derived from the International Commission on Radiological Protection's *Protection Against Radon-222 at Home and at Work*, as referenced in the *Radiation Protection Regulations*. The reference level represents an incremental increase above natural dwelling radon levels that could result in a member of the public being exposed to an incremental dose of 1 mSv. Values are calculated as geometric means.

Five high-volume air samplers were used to collect and measure TSP. The TSP levels are below the Province of Saskatchewan's authorized concentration of contaminants monitored for ambient air quality, as listed in the facility's approval to operate pollutant control facilities (see table 6.2). TSP samples are also analyzed for concentrations of metals and radionuclides. The mean concentrations of metal and radionuclides adsorbed to TSP are low and below the reference annual air quality levels identified in table 6.2.

Table 6.2: Concentrations of metal and radionuclides in air, Key Lake, 2012–16

Parameter	Reference annual air quality levels*	2012	2013	2014	2015	2016
TSP (µg/m^3)	**70** [3]	15.63	14.07	15.10	13.77	10.77
As (µg/m^3)	**0.06** [1]	0.00266	0.00166	0.00444	0.0016	0.0010
Ni (µg/m^3)	**0.04** [1]	0.00222	0.00118	0.00340	0.0013	0.0007
Pb^{210} (Bq/m^3)	**0.021** [2]	0.00034	0.00032	0.00044	0.0003	0.0003
Ra^{226} (Bq/m^3)	**0.013** [2]	0.00010	0.00010	0.00022	0.0001	0.0001
Th^{230} (Bq/m^3)	**0.0085** [2]	0.00028	0.00010	0.00022	0.0001	0.0001
U (µg/m^3)	**0.06** [1]	0.0074	0.00646	0.00794	0.0080	0.0076

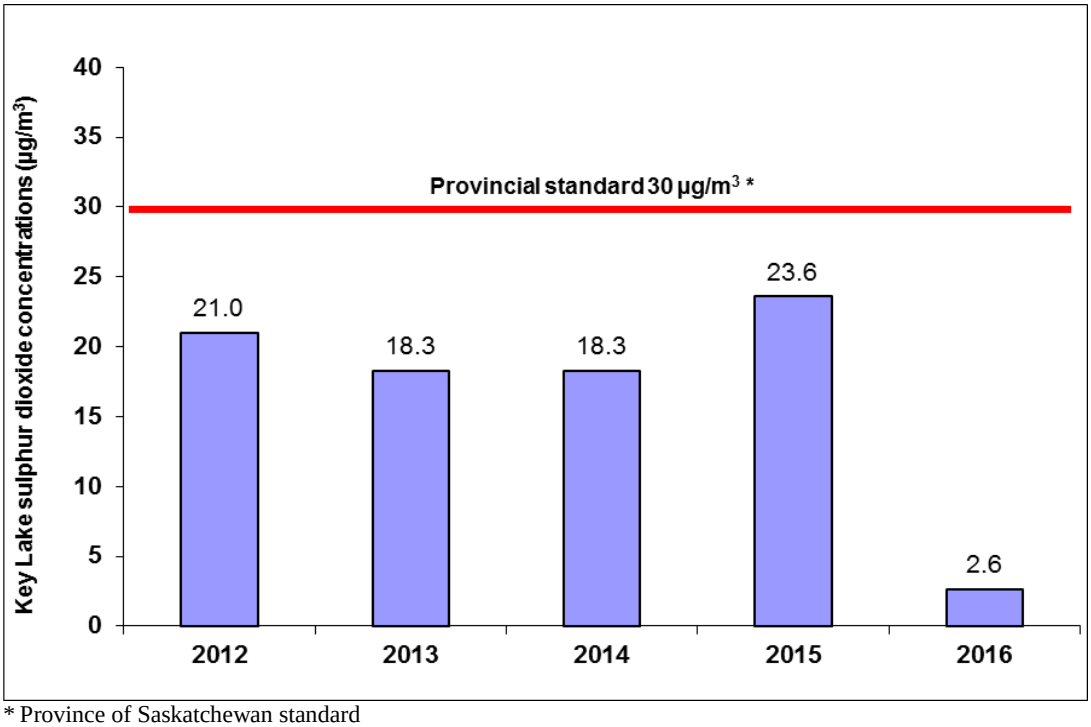
1 Reference annual air quality levels derived from Ontario's 24-hour ambient air quality criteria (2012).
2 Reference level from International Commission on Radiological Protection (ICRP) publication 96, *Protecting People Against Radiation Exposure in the Event of a Radiological Attack.*
3 The Province of Saskatchewan's authorized concentration of contaminants monitored for ambient air quality as listed in the facility's approval to operate pollutant control facilities is shown. Values are calculated as geometric means.
* Province of Ontario and ICRP reference annual air quality levels are shown for reference only. No federal or Province of Saskatchewan limits are currently established.

A sulphur dioxide monitor, located approximately 300 metres downwind of the mill facility, is used to continuously measure the ambient sulphur dioxide associated with mill emissions. The measured sulphur dioxide monitoring data (figure 6.5) show no exceedances of the annual standard of 30 µg/m^3.

There was a substantial decline in sulphur dioxide emissions due to construction of a new acid plant in 2012. These lower emissions have been maintained throughout 2013 to 2016.

In 2016, there was a decline in acid production compared to past years. The concentrations recorded at the ambient monitoring station, which are directly impacted by weather conditions, showed a notable decline.

Figure 6.5: Concentrations of ambient sulphur dioxide, Key Lake, 2012–16



* Province of Saskatchewan standard

In addition to ambient air monitoring for sulphur dioxide, sulphate levels have been monitored in four lakes selected to measure the effects of sulphur dioxide emissions from the operation. The results of the 2016 lake sampling program continued to show that sulphate concentrations remain relatively unchanged from historical concentrations. CNSC staff concluded the operations at Key Lake – and the resulting sulphur dioxide emissions – do not have an adverse effect on the sulphate levels in nearby lakes.

Soil and terrestrial vegetation may be affected by atmospheric deposition of particulate, adsorbed metals and radionuclides associated with onsite activities. The terrestrial monitoring program in place includes measurements of metals and radionuclides in soil and in lichen.

Lichen and soil samples were collected in 2016 as required by the triennial sampling program. Lichen samples were collected and analyzed from five monitoring stations around the operation representing exposure stations and a control station. Radionuclide and metal concentrations at all lichen stations were similar to previous years, with the exception of Wheeler River. Results from one station indicated elevated concentrations of some metals and radionuclides compared to previous years. This station will continue to be monitored to determine if the elevated concentrations are a result of the fire disturbance, relocated sample area or conditions at this station.

Overall, metal and radionuclide concentrations at Douglas Lake were low in comparison to the other stations. With the exception of the Wheeler River sample results, all concentrations were within the regional historical ranges for each parameter.

CNSC staff assessed and concluded that the level of airborne particulate contaminants produced by the Key Lake Operation is acceptable and does not pose a risk to lichen consumers, such as caribou.

Soil samples were taken in the immediate vicinity of the mine. The soil metal parameter concentrations were below the *Canadian Environmental Quality Guidelines* set by the Canadian Council of Ministers of the Environment. Radionuclide concentrations in soils were low and near or at background levels and analytical detection limits. The concentrations of radionuclides and metals in 2016 were consistent with previous sampling results. Based on soil sampling results, CNSC staff concluded that the level of airborne particulate contaminants produced by the Key Lake Operation is acceptable and does not pose a risk to the environment.

Protection of the public

In 2016, one event reported to CNSC staff was submitted as a release of hazardous substances to the environment:

- Approximately 1,000 m^3 (1,000,000 L) of industrial water was released from a cracked sewer line on the mill terrace.

This spill was minor and reporting met the requirements of RD/GD-99.3, *Public Information and Disclosure.*

Appendix G provides a brief description of the spill associated with a cracked sewer line and the actions taken by the licensee. The spill was remediated with no residual impact on the environment. The corrective actions, including the repair of the line, were reviewed and found acceptable by CNSC staff. CNSC staff rated the 2016 spill as low significance. Figure 2.5 in section 2 displays the number of environmental reportable spills as well as the number of releases of hazardous material to the environment from the licensed activities at the Key Lake Operation from 2012 to 2016.

6.4 Conventional health and safety

For 2016, CNSC staff continued to rate the conventional health and safety SCA as "satisfactory" based on regulatory oversight activities.

Key Lake conventional health and safety ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Practices

Throughout 2016, CNSC staff monitored the implementation of the Key Lake Operation's operational health and safety program and concluded that this program continues to be effective.

The Key Lake Operation's incident reporting system records health and safety-related events and uses several layers of review in investigations. Corrective measures are tracked and assessed for effectiveness prior to closure. The Key Lake Operation continued its planned health and safety inspection program in 2016. Any items of concern found during these inspections are included in the licensee's incident reporting system.

Performance

There were three lost-time injuries (LTIs) at the Key Lake Operation between 2012 and 2016 (table 6.3). Two occurred in 2016.

Table 6.3: Lost-time injury statistics, Key Lake, 2012–16

	2012	2013	2014	2015	2016
Lost-time injuries[1]	1	0	0	0	2
Severity rate[2]	21.6	8.5	0	0	71.0
Frequency rate[3]	0.1	0.0	0	0	0.41

[1] An injury that takes place at work and results in the worker being unable to return to work for a period of time.
[2] The accident severity rate measures the total number of days lost to injury for every 200,000 person-hours worked at the site. Severity = [(# of days lost in last 12 months) / (# of hours worked in last 12 months)] x 200,000.
[3] The accident frequency rate measuring the number of LTIs for every 200,000 person-hours worked at the site. Frequency = [(# of injuries in last 12 months) / (# of hours worked in last 12 months)] x 200,000.

Appendix H contains a brief description of the two LTIs that occurred at the Key Lake Operation in 2016. One incident involved an employee sustaining injuries requiring hospitalization after rolling their ankle on a raised curb. The other involved a driver falling from a rear trailer onto a concrete floor while unloading sulphur. Corrective actions included improving the visibility of the raised curb, reminding employees of the curb, implementing a fall-arrest system and revising work instructions to ensure another worker is present during the task.

CNSC staff assessed the corrective actions and were satisfied with the follow-up taken by the Key Lake Operation for both of these incidents.

Awareness

CNSC staff observed that the Key Lake Operation's conventional health and safety programs continued to provide education, training, tools and support to workers. The idea that safety is the responsibility of all individuals is promoted by managers, supervisors and workers. Site management stresses the importance of conventional health and safety through regular communication, management oversight and continual improvement of safety systems.

CNSC staff compliance verification activities concluded that the Key Lake Operation's health and safety program met regulatory requirements in 2016.

7 McClean Lake Operation

The McClean Lake Operation is located approximately 750 kilometres northeast of Saskatoon, Saskatchewan, and is operated by AREVA Resources Canada Inc. An aerial view of the McClean Lake Operation is shown in figure 7.1.

Construction of the McClean Lake Operation began in 1994. The licence was recently renewed by the Commission in July 2017 for a 10-year term and expires June 30, 2027.

Figure 7.1: Aerial view of the McClean Lake Operation

The mining and milling of uranium ore from five open-pit mines was completed in 2008. Conventional mining of ore for the purpose of production and sale has not been carried out at the McClean Lake Operation since that date. The CNSC was informed during the first quarter of 2014 that the surface access borehole resource extraction project had been placed into care and maintenance.

Processing of ore at the McClean Lake Operation was suspended and the mill temporarily shut down in July 2010 due to a shortage of ore. The high-grade ore slurry shipments from Cameco Corporation's Cigar Lake mine began in March 2014, and the McClean Lake Operation restarted in September 2014. After restart and commissioning of the McClean Lake Operation with Cigar Lake ore slurry, CNSC staff focused their oversight activities on the implementation of AREVA's radiation protection program. CNSC staff verified that the McClean Lake Operation continued to keep worker doses as low as reasonably achievable (ALARA) while processing high-grade ore at higher production levels. CNSC staff also confirmed that AREVA's environmental management system continued to protect the environment and meet environment performance objectives for the McClean Lake Operation.

Mill tailings resulting from the processing of ore were deposited within the McClean Lake Operation tailings management facility (TMF), which is constructed in the mined-out John Everett Bates (JEB) open pit.

Milling production data for the McClean Lake Operation during the five-year reporting period are presented in table 7.1.

Table 7.1: Milling production data, McClean Lake, 2012–16

Milling	2012	2013	2014	2015	2016
Mill ore feed (Mkg/year)	No milling*	No milling*	7.83	25.52	37.20
Average annual mill feed grade (% U_3O_8)	No milling*	No milling*	3.00	17.56	18.08
Percentage of uranium recovery (%)	No milling*	No milling*	97.54	98.99	99.10
Uranium concentrate produced (Mkg U)	No milling*	No milling*	0.200	4.30	6.67
Authorized annual production (Mkg U/year)	5.00	5.00	5.00	5.00	9.20

* The McClean Lake mill temporarily stopped producing uranium concentrate in July 2010.

CNSC staff confirmed the McClean Lake Operation production remains less than the authorized annual production (table 7.1).

In June 2016, AREVA submitted an application to reconfigure the JEB TMF. AREVA expects to generate approximately 2.4 million cubic metres of tailings over the next 18 years of operation. The modification would provide additional required tailings storage capacity during continued operation of the McClean Lake mill and was accepted by the Commission as part of the 2017 licence renewal.

CNSC staff conducted a thorough technical assessment of AREVA's TMF expansion proposal. CNSC staff required AREVA to provide clarity and additional information related to the source term, the robustness of the cover, engineering controls and other design features. CNSC staff evaluated AREVA's response and found it acceptable. CNSC staff concluded that the increase of consolidated tailings elevation remains within the licensing basis and will continue to achieve the operational and post-closure objectives developed to ensure safety and protection of the environment.

CNSC staff will continue to monitor progress through ongoing compliance activities.

7.1 Performance

Ratings for all 14 safety and control areas (SCAs) for the five-year period from 2012 to 2016 are shown in appendix D. For 2016, CNSC staff continued to rate all SCAs as "satisfactory" based on regulatory oversight activities. This report focuses on the three SCAs that cover many of the key performance indicators for these facilities: "radiation protection", "environmental protection" and "conventional health and safety".

In 2016, CNSC staff carried out compliance inspections covering the SCAs of "human performance management", "operating performance", "safeguards" and "packaging and transport" in addition to those for which a detailed analysis has been provided in the following sections. Non-compliances resulting from CNSC inspections at the McClean Lake Operation for the 2016 calendar year were low risk in nature; corrective actions have been implemented by licensees and reviewed and accepted by CNSC staff. A list of inspections has been provided in appendix J.

As part of AREVA's July 2017 licence renewal, CNSC staff added the following regulatory documents to the McClean Lake Operation licence conditions handbook (LCH):

- REGDOC-2.2.2, *Human Performance Management, Personnel Training*
- REGDOC-2.10.1, *Nuclear Emergency Preparedness and Response*
- REGDOC 2.12.3, *Security of Nuclear Substances: Sealed Sources*

AREVA committed to the full implementation of the sections of these regulatory documents applicable to uranium mines and mills by December 2017. CNSC staff will monitor implementation of these documents through regulatory oversight activities including onsite inspections and desktop reviews of AREVA's compliance reporting period.

7.2 Radiation protection

For this reporting period, CNSC staff continued to rate the radiation protection SCA at the McClean Lake operation as "satisfactory".

McClean Lake radiation protection ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Radiological hazard control

The source of radiological exposure at the McClean Lake Operation is the milling of high-grade uranium ore received from Cameco's Cigar Lake mine. The three primary dose contributors are gamma radiation (42 percent), radon progeny (35 percent) and long-lived radioactive dust (LLRD; 23 percent). Gamma radiation hazards are controlled through the application of time, distance and shielding. The effective dose to (nuclear energy workers) NEWs from exposures to radon progeny and LLRD are controlled through the effective use of source control, ventilation, contamination control and personal protective equipment (PPE).

The McClean Lake Operation has incorporated specific radiation protection features into its design to process undiluted, high-grade uranium ore. In September 2016, AREVA submitted the results of the radiation performance confirmation plan (RPCP). The RPCP report was developed to validate that the design features would limit radiological hazards for all sources of exposure (i.e., gamma, radon progeny and LLRD) at or below design objectives while processing high-grade ore.

CNSC staff reviewed the RPCP report and concluded that although the McClean Lake Operation is processing high-grade uranium ore slurry at production rates significantly higher than in the past, worker exposures continue to be maintained well below regulatory limits and ALARA.

Radiation protection program performance

In 2016, there were two instances in which workers received weekly exposures that exceeded the 1 millisievert (mSv) action level:

- In December 2016, a mill operator received a dose of 1.94 mSv while performing non-routine duties in the slurry receiving circuit. The majority of this dose was attributed to elevated LLRD as indicated by the worker's personal alpha dosimeter (PAD).
- In December 2016, a mill operator working in the slurry receiving circuit received a dose of 3.23 mSv. The majority of this assigned dose was also attributed to elevated LLRD, as indicated by the worker's PAD.

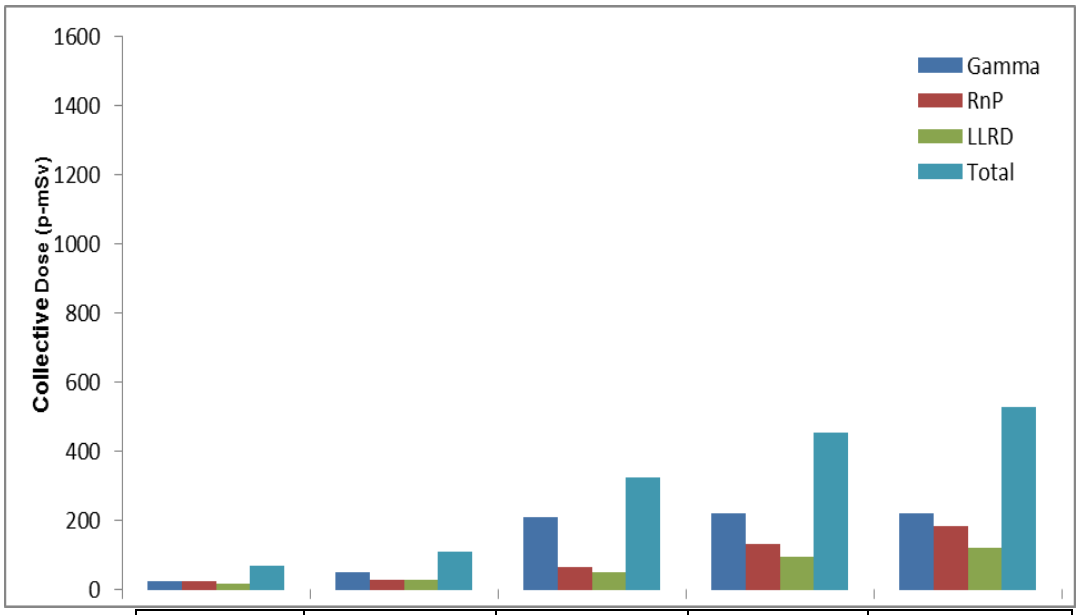
A brief description of these action level exceedances is summarized in appendix I.

Overall, the radiation protection program and practices continued to effectively maintain worker doses ALARA.

Application of ALARA

In 2016, collective radiation exposure to NEWs at the McClean Lake Operation was 529 person-millisieverts (p-mSv), an approximate 17 percent increase from the 2015 value of 454 p-mSv (figure 7.2). This is an increase in collective radiation exposure in consideration of the approximate 55 percent increase in production in 2016 (measured by total uranium concentrate produced) from the previous year. The increasing trend in collective dose from 2014 to 2016 is associated with increased production at the McClean Lake Operation.

Figure 7.2: Annual collective radiation exposures, McClean Lake, 2012–16



	2012	2013	2014	2015	2016
Gamma (p-mSv)	26	50	210	223	221
RnP (p-mSv)	27	31	67	134	185
LLRD (p-mSv)	18	31	50	97	123
Total	71	112	327	454	529

RnP = radon progeny; LLRD = long-lived radioactive dust

CNSC staff verified through regulatory oversight activities that the McClean Lake Operation continues to maintain worker exposures ALARA. In 2016, AREVA continued to implement a number of radiation protection initiatives and projects to minimize worker exposures:

- Radon progeny levels in general work areas were reduced through improvements in the slurry-receiving circuit ventilation to more efficiently exhaust contaminated air by directing it from the general area to the pulp storage enclosure.
- Additional lead shielding was added to some components (e.g., counter current decantation circuit feed tanks, tailings thickener sample box, piping in ore-receiving walkway) to continue to meet design objectives for gamma dose rates.
- To control LLRD levels, a MegaVac system was installed to return yellowcake into the circuit from the packaging enclosure.

Through reviews of the RPCP report and the monthly and quarterly exposure reports, as well as follow-up via inspections, the CNSC confirmed the radiation protection program remains effective in ensuring worker exposures remain ALARA.

Worker dose control

The average individual effective dose for NEWs in 2016 was 1.04 mSv, while the maximum individual effective dose received by a NEW was 6.94 mSv. This compares to an average individual effective dose of 0.89 mSv and a maximum individual dose of 5.28 mSv in 2015. The increase in average worker dose is attributed to production increases, which were 55 percent higher in 2016 than the previous year. All individual effective doses were well below the annual regulatory limit of 50 mSv.

Based on CNSC staff's compliance verification activities, such as site inspections, reviews of licensees' reports, work practices, monitoring results and individual effective dose results for 2016, CNSC staff were satisfied that the McClean Lake Operation adequately controlled radiation doses to workers.

CNSC staff concluded that the effective implementation of the radiation protection program maintained worker doses ALARA.

7.3 Environmental protection

For 2016, CNSC staff continued to rate the environmental protection SCA as "satisfactory" based on regulatory oversight activities. CNSC staff concluded the licensee's environmental protection program was effectively implemented and met all regulatory requirements.

McClean Lake environmental protection ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Environmental management system

AREVA has implemented and maintained an environmental management system. It conducts internal audits to ensure the system is effective and has been properly implemented. Any deficiencies and findings that are identified from the internal audit are documented. A plan is then devised to address any non-conformance items. CNSC staff verified the implementation of McClean Lake Operation's environmental management system through desktop reviews of quarterly environmental reports, annual compliance reports, and onsite inspections.

Environmental risk assessment

AREVA submitted an updated environmental risk assessment (ERA) in 2016. CNSC staff reviewed the document and noted that the predicted ecological and human health risks from the McClean Lake Operation are within predictions of CNSC accepted environmental impact statements and ERAs, with the exception of predicted short-term exposure of aquatic organisms to selenium in McClean Lake's east basin, which is considered an exposure lake. CNSC staff concluded that the McClean Lake Operation is in compliance with regulatory requirements. Further details on ERAs are provided in section 2.3.

An environmental assessment under the *Nuclear Safety and Control Act* (NSCA) was conducted by CNSC staff for AREVA's McClean Lake Operation licence renewal in June 2017. CNSC staff concluded that AREVA has made, and will continue to make, adequate provision for the protection of the environment and the health of persons.

Assessment and monitoring

Environmental monitoring programs serve to demonstrate that the site emissions, wastes, tailings and effluent discharge of nuclear and hazardous substances are properly controlled at the McClean Lake Operation. CNSC staff review the environmental effects monitoring information along with other routine or special investigations to ensure any impacts to the receiving environment and biota are identified. CNSC staff noted that AREVA has continued with routine site inspections, internal audits, environmental training and periodic reviews of environmental monitoring data. These activities were conducted to ensure continual improvement and to confirm that the controls put into place to protect the environment are effective. CNSC staff assessed the environmental protection program and concluded that it met regulatory requirements during 2016.

The following provides monitoring and assessment results for the McClean Lake Operation.

Effluent and emissions control

Treated effluent released to the environment

At the McClean Lake Operation, two effluent streams are processed in separate treatment facilities before being released to the environment:

- The mill effluent is processed at the JEB water treatment plant with a treatment system of chemical precipitation and liquid/solid separation. Treated water is released to the Sink/Vulture Treated Effluent Management System.
- Effluent from the mined-out open pits that is used to control the water level of the mined-out open pits is treated in the Sue water treatment plant using a chemical precipitation and settling pond clarification process before being released to the Sink/Vulture Treated Effluent Management System.

The blended treated effluent is released in a controlled manner. Monitoring has verified ERA predictions supporting that this effluent poses no environmental concern. There were no action level exceedances associated with the JEB water treatment plant in 2016.

The Sue water treatment plant is operational only in summer months. In 2016, there were two action level exceedances for effluent released from the Sue water treatment plant. Twice in August 2016, the pH of treated effluent discharged to the Sink/Vulture Treated Effluent Management System exceeded the action level of greater than 9.0 pH with the highest value of 9.14 pH. Regulatory limits were not exceeded and no impact to the environment occurred. CNSC staff reviewed initial event notifications and follow-up reports outlining corrective actions.

CNSC staff conducted follow-up inspections and are satisfied with the corrective actions taken by AREVA.

After restart and commissioning of the McClean Lake Operation in September 2014, AREVA identified an increasing trend in selenium effluent concentration from the JEB water treatment plant. This increase in concentrations in effluent is attributed to the milling of Cigar Lake ore. Although values remained well below the provincial limit of 0.6 mg/L, AREVA has been proactive and has implemented process improvements to control selenium including:

- an interim administrative level of 0.084 mg/L and action level of 0.112 mg/L
- a selenium adaptive management plan

AREVA submitted a formal selenium adaptive management plan in March 2017 that includes the following strategies:

- pollution prevention plan
- best available technology economically achievable assessment plan
- active commissioning plan

CNSC staff reviewed the plan to verify that AREVA is taking adequate measures to manage and control selenium releases from the McClean Lake Operation, and to verify that the selenium adaptive management plan meets CNSC staff expectations. CNSC staff concluded that the plan meets regulatory requirements and accepted the plan in August 2017.

The McClean Lake Operation also analyzed treated effluent for concentrations of various substances such as radium-226, arsenic, copper, lead, nickel, zinc, total suspended solids and pH. The reduced concentrations of uranium in treated effluent from 2012 to 2016 are well below the provincial limit of 2.5 mg/L (shown in section 2, figure 2.8). As shown in section 2.4, the McClean Lake Operation continues to meet *Metal Mining Effluent Regulations* (MMER) discharge limits.

CNSC staff will continue to review effluent quality results to ensure effluent treatment performance remains effective.

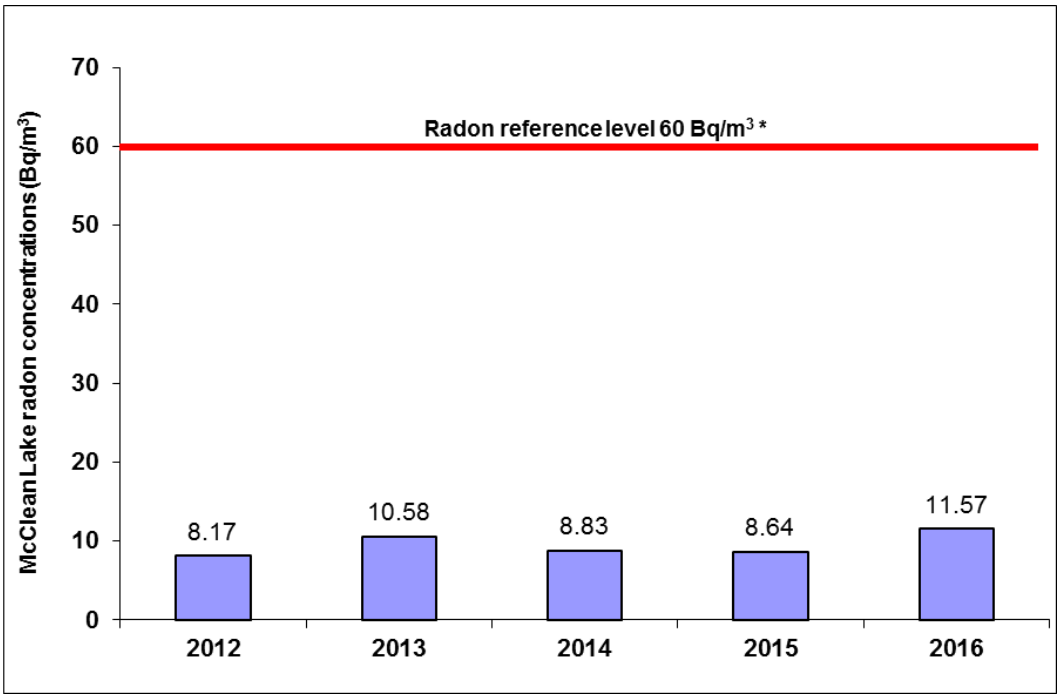
Air emissions released to the environment

Air quality at the McClean Lake Operation is monitored through direct measurement of emissions from the mill, ambient air quality near the operation and indirectly through measurements of metal accumulations in the terrestrial environment.

Air quality monitoring at the McClean Lake Operation includes ambient radon, total suspended particulate (TSP), sulphur dioxide and exhaust stack monitoring. Ambient sulphur dioxide and exhaust stack monitoring was commensurate with the mill commissioning activities and restart in September 2014. Terrestrial monitoring components include soil and lichen sampling.

Environmental monitoring for radon concentrations is conducted using the passive method of track-etched cups. There are 23 monitoring stations in various locations around the site-lease boundary. Figure 7.3 shows the average concentrations of radon in ambient air for 2012 to 2016 were below the reference level for radon. The radon concentrations were also typical of the northern Saskatchewan regional baseline of less than 7.4 Bq/m^3 to 25 Bq/m^3.

Figure 7.3: Concentrations of radon in ambient air, McClean Lake, 2012–16



* The value of 60 Bq/m^3 has been derived from the International Commission on Radiological Protection's *Protection Against Radon-222 at Home and at Work*, as referenced in the *Radiation Protection Regulations*. The reference level represents an incremental increase above natural dwelling radon levels that could result in a member of the public being exposed to an incremental dose of 1 mSv. Values are calculated as geometric means.

Five high-volume air samplers are located at locations around the McClean Lake Operation to monitor TSP. As shown in table 7.2, TSP values remained low in 2016 and well below the provincial standard of 60 µg/m^3.

TSP samples are also analyzed for concentrations of metals and radionuclides. The mean concentrations of metal and radionuclides adsorbed to TSP are low and below reference annual air quality levels identified in table 7.2.

Table 7.2: Concentrations of metal and radionuclides in air, McClean Lake, 2012–16

Parameter	Reference annual air quality levels*	2012	2013	2014	2015	2016
TSP (µg/m^3)	**60** [3]	5.66	6.78	5.66	8.37	5.12
As (µg/m^3)	**0.06** [1]	0.000350	0.000226	0.000420	0.003070	0.000032
Cu (µg/m^3)	**9.6** [1]	0.016789	0.036192	0.013888	0.019630	0.021613
Mo (µg/m^3)	**23** [1]	0.000061	0.000657	0.000721	0.000892	0.000145
Ni (µg/m^3)	**0.04** [1]	0.000259	0.000258	0.000420	0.000247	0.000259
Pb (µg/m^3)	**0.10** [1]	0.000453	0.000422	0.000501	0.000368	0.000762
Zn (µg/m^3)	**23** [1]	0.006790	0.005896	0.005939	0.005452	0.004703
Pb^{210} (Bq/m^3)	**0.021** [2]	0.000388	0.000763	0.000277	0.000271	0.000285
Po^{210} (Bq/m^3)	**0.028** [2]	0.000130	0.000159	0.000088	0.000083	0.000087
Ra^{226} (Bq/m^3)	**0.013** [2]	0.000008	0.000013	0.000010	0.000008	0.000009
Th^{230} (Bq/m^3)	**0.0085** [2]	0.000004	0.000000	0.000005	0.000005	0.000005
U (µg/m^3)	**0.06** [1]	0.000444	0.000328	0.000576	0.001319	0.003138

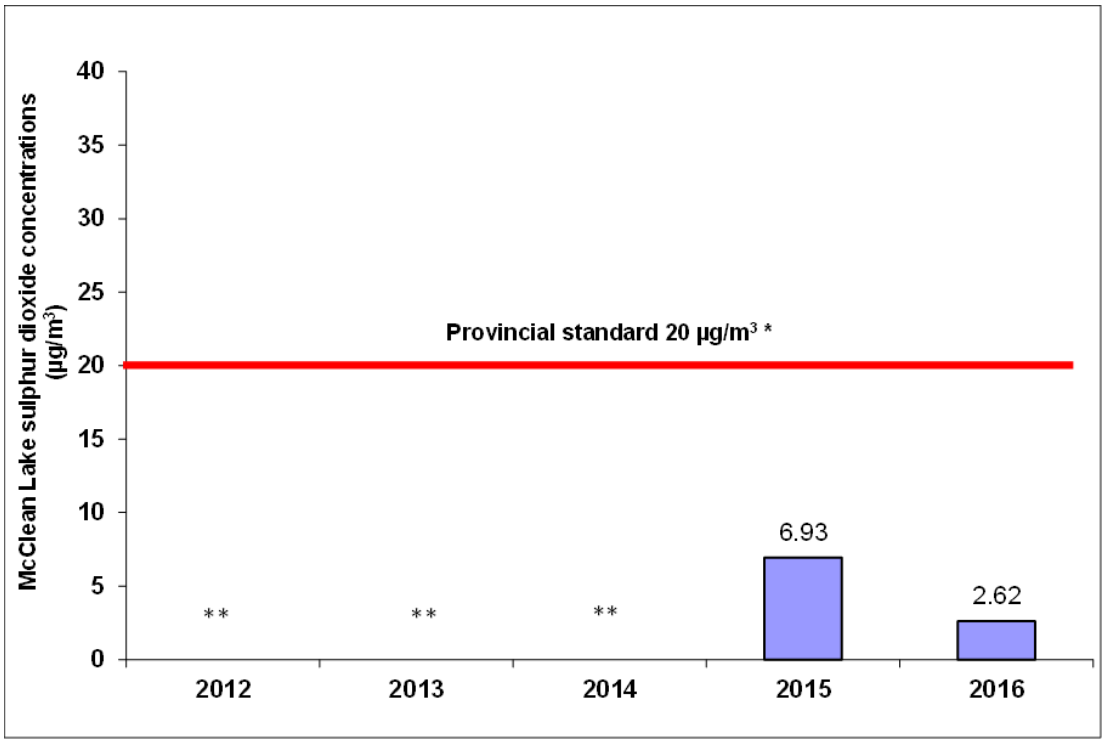
[1] Reference annual air quality levels derived from Ontario's 24-hour ambient air quality criteria (2012).
[2] Reference level from International Commission on Radiological Protection (ICRP) publication 96.
[3] The Province of Saskatchewan's authorized concentration of contaminants monitored for ambient air quality as listed in the facility's approval to operate pollutant control facilities is shown. Values are calculated as geometric means.
* Province of Ontario and ICRP annual air quality levels are shown for reference only. No federal or provincial limits are currently established.

As a result of modifications made to the calciner stack in September 2016, the Saskatchewan Ambient Air Quality Standards (table 20 of the Saskatchewan Environmental Quality Standards) came into effect at the McClean Lake Operation. At that time, the implementation of the air quality standards in Saskatchewan was immediate for any new facility but did not come into effect for existing facilities until the existing approvals to operate were renewed and/or revised. Therefore, these new standards are shown for TSP and sulphur dioxide for the McClean Lake Operation.

A sulphur dioxide monitor is used during operations to continuously measure ambient sulphur dioxide concentrations associated with mill emissions. The monitor is located approximately 200 metres downwind of the sulphuric acid plant stack. The measured sulphur dioxide monitoring data (figure 7.4) show no exceedances of the annual standard of 20 µg/m^3 in 2016.

Actions levels have also been established for ambient sulphur dioxide concentrations. The one- and 24-hour action levels are 0.170 parts per million (ppm) and 0.060 ppm, respectively. In 2016, there were two action level exceedance events for sulphur dioxide. These events were of short duration and most were the result of acid plant start-ups. CNSC staff reviewed initial agency notifications and followed up through planned compliance inspections. CNSC staff have reviewed and are satisfied with the corrective actions implemented by the McClean Lake Operation.

Figure 7.4: Concentrations of ambient sulphur dioxide, McClean Lake, 2012–16



* Province of Saskatchewan's ambient air quality standard is shown.

** Ambient sulphur dioxide (SO_2) was not monitored during the temporary shutdown of the mill. Therefore, ambient SO_2 concentrations were not measured for the years 2011 to 2013. In 2014, measurement of ambient SO_2 concentrations began again on December 29, 2014 when the acid plant restarted.

AREVA's terrestrial monitoring program determines if there is influence on the environment from aerial deposition. Soil and terrestrial vegetation may be affected by the atmospheric deposition of particulate and adsorbed metals and radionuclides associated with onsite activities. This program includes measurements of metals and radionuclides in soil and vegetation.

Soil monitoring results from soil samples collected in 2015 are presented in the 2016 environmental performance report (EPR). The results show that the soil metal parameter concentrations were below the *Canadian Environmental Quality Guidelines* set by the Canadian Council of Ministers of the Environment. Radionuclide concentrations in soils were also low, and near or at background levels and analytical detection limits. CNSC staff concluded that the level of airborne particulate contaminants produced by the McClean Lake Operation is acceptable and does not pose a risk to the environment.

Vegetation sampling was also presented in the 2016 EPR and shows most parameters are within the range of concentrations previously measured in lichen, Labrador tea and blueberry twig samples. The concentrations of metals and radionuclides in lichen, Labrador tea and blueberry twigs have higher-than-background concentrations for some samples located in the immediate vicinity of mining activity, although the concentrations decrease within a short distance. Overall, the results indicated that the McClean Lake Operation has had a localized effect on vegetation in areas of activity. These higher concentrations were below levels that are toxic to plants and decreased to within-background concentrations within a short distance. Therefore, no changes are predicted to terrestrial habitat, both within and outside the site boundary. The elevated concentrations of contaminants within the site boundary were modelled in an ERA, and no adverse effects were predicted for terrestrial non-human biota.

CNSC staff concluded that the level of airborne particulate contaminants produced by the McClean Lake Operation is acceptable and does not pose a risk to browse (twigs and Labrador tea) and lichen consumers such as caribou.

Protection of the public

In 2016, eight events reported to CNSC staff were submitted as releases of hazardous substances to the environment:

- 24 L of anhydrous ammonia released to the ground due to leaks during off-loading of the product.
- 200 kg of molten sulphur released to the ground due to a faulty valve during off-loading of the product.
- 15 L of anhydrous ammonia released to the atmosphere due to a ventilation valve being open during off-loading of the product.
- 4 m^3 (4,000 L) of a water/magnetite mixture released to the ground due to the overfilling of a tank with the ferric sulphate plant.
- 20 L of sulphuric acid released to the ground due to a failed O-ring during off-loading of the product.
- 1 L of anhydrous ammonia released to the ground due to a leak in a threaded flange observed after tank repairs.
- 1 L of anhydrous ammonia released to the ground due to a leaky valve after off-loading of the product had occurred.
- 20 L of precipitated yellowcake solution released to the ground; residual material had accumulated at base of reagent totes and the totes were placed outside, resulting in material dropping to the ground.

All eight spills were minor and reporting met the requirements of RD/GD-99.3, *Public Information and Disclosure*.

Appendix G further describes the spills and corrective actions taken. Due to the actions applied by the McClean Lake Operation, there were no residual impacts to the environment by the spills. CNSC staff were satisfied with the reporting of releases of hazardous materials to the environment and the corrective actions taken. CNSC staff rated all the 2016 spills as being of low significance.

Figure 2.5 in section 2 displays the number of environmental reportable spills that occurred at the McClean Lake Operation from 2012 to 2016.

7.4 Conventional health and safety

For 2016, CNSC staff continued to rate the conventional health and safety SCA as "satisfactory" based on regulatory oversight activities.

McClean Lake conventional health and safety ratings

2012	2013	2014	2015	2016
SA	SA	SA	SA	SA

SA = satisfactory

Practices

As required under the NSCA, AREVA continues to improve performance and maintain health and safety programs at the McClean Lake Operation to minimize occupational health and safety risks. CNSC staff confirmed that the McClean Lake Operation has an effective occupational health and safety committee and completes regular reviews of its safety program.

AREVA's McClean Lake Operation investigates safety concerns and incidents, including near-miss events. In 2016, several investigations were completed using the cause mapping process to determine the cause of incidents, near misses, injuries or property damage. This methodology employs a collaborative group effort to identify a problem, analyze its causes and determine the best solutions. CNSC staff reviewed the investigation results and corrective actions and confirmed AREVA's commitment to accident prevention and safety awareness with a focus on safety culture.

Performance

Table 7.3 shows that from 2012 to 2016, AREVA's McClean Lake Operation reported 10 lost-time injuries (LTIs), including three in 2016.

Table 7.3: Lost-time injury statistics, McClean Lake, 2012–16

	2012	2013	2014	2015	2016
Lost-time injuries[1]	1	0	3	3	3
Severity rate[2]	1.2	0.0	4.3	27.7	10.9
Frequency rate[3]	0.4	0.0	0.4	0.4	0.6

[1] An injury that takes place at work and results in the worker being unable to return to work for a period of time.

[2] The accident severity rate measures the total number of days lost to injury for every 200,000 person-hours worked at the site. Severity = [(# of days lost in last 12 months) / (# of hours worked in last 12 months)] x 200,000.

[3] The accident frequency rate measuring the number of LTIs for every 200,000 person-hours worked at the site. Frequency = [(# of injuries in last 12 months) / (# of hours worked in last 12 months)] x 200,000.

In June 2017, CNSC staff reported the three 2016 LTIs during a Commission public hearing for the McClean Lake Operation licence renewal. Additional details on the 2016 LTIs and corrective actions taken are provided in appendix H.

Corrective actions were implemented with the effectiveness verified and documented by management. CNSC staff observed that the McClean Lake Operation strives to involve all levels of its organization in the health and safety program. Employees are encouraged and trained to continuously identify and assess risks, and propose solutions.

Awareness

CNSC staff observed that the McClean Lake Operation conventional health and safety programs provide education, training, tools and support to ensure worker protection. An active onsite occupational health and safety committee completes regular reviews of its safety program. Through inspections, reviews of incidents and discussions with McClean Lake staff, CNSC staff verified that the McClean Lake Operation is committed to accident prevention and safety awareness. CNSC staff compliance verification activities concluded that the McClean Lake Operation's health and safety program met regulatory requirements in 2016.

8 Historic and Decommissioned Sites

In 2016, CNSC staff presented information to the Commission on historic and decommissioned uranium mines and mills in Canada. Information presented established the following:

- Historic and decommissioned sites are in stable or improving condition (a conclusion supported by key performance indicator data in the safety and control areas (SCAs) of "radiation protection", "environmental protection" and "conventional health and safety").
- Waste rock piles, tailings facilities and infrastructure are all in a safe state and monitored to ensure stability.
- Dams are stable and regularly maintained, as verified through regular geotechnical inspections.
- Historic and decommissioned sites have part-time staff. Maintenance and monitoring are carried out as designed in decommissioning plans.

Decommissioned and historic sites in Saskatchewan and the Northwest Territories are located in remote areas and are only occasionally frequented by the general public.

This report includes an update for historic and decommissioned mine sites that had changes to performance ratings, notable events or licensing activities in 2016.

CNSC staff continue to provide regulatory oversight through ongoing compliance activities including reviews of events, monitoring results and licensee submissions in addition to regular inspections.

Beaverlodge

The Beaverlodge decommissioned uranium mine and mill site is located near Uranium City in the northwest corner of Saskatchewan. Following issuance of a 10-year licence in May 2013, Cameco Corporation completed studies and additional remediation work to support an application to release additional properties at the Beaverlodge site into the province of Saskatchewan's institutional control program. Efforts continued throughout 2016 in support of this application, including:

- the completion of a waste rock cover over the Ace stope area crown pillar to mitigate impacts from any future crown pillar collapse
- focused remediation activities, such as rubbish removal

The submission of documentation for the proposed transition of these sites to Saskatchewan's institutional control program is expected in 2017.

CNSC staff continued to provide regulatory oversight of the Beaverlodge site through regular compliance activities, such as completion of a planned annual onsite inspection and the review of licensee submissions.

Cluff Lake

The decommissioned Cluff Lake uranium mine and mill is located in northern Saskatchewan, approximately 75 kilometres south of Lake Athabasca and 30 kilometres east of the provincial border with Alberta. In 2009 AREVA Resources Canada Inc. was issued a 10-year licence, which expires on July 31, 2019. Planned campaign monitoring and maintenance activities continued throughout 2016 at the Cluff Lake site. Results of these activities were reviewed by CNSC staff through regular submissions, such as the Cluff Lake annual report. CNSC staff carried out an annual site inspection and confirmed the site continues to be safe for casual users and the environment. CNSC staff began work on a Commission member document (CMD) for the update of the Cluff Lake financial guarantee. Staff are carrying out discussions with the province of Saskatchewan before concluding their work and submitting the CMD and its recommendations to the Commission for consideration in late 2017 or early 2018.

Deloro

The Deloro mine site is located approximately 65 kilometres east of Peterborough, Ontario. This site was an abandoned gold mine where metallurgical and refining processes related to the production of cobalt oxides and metal, and for the extraction of silver, nickel and arsenic took place. In 2015, CNSC staff rated the licensee's performance for the "management systems" SCA as "below expectations" for the Deloro site due to poor implementation of procedures. In 2016, the licensee (the Ontario Ministry of Environment and Climate Change (MOECC)) made a number of improvements. Based on inspections and other compliance verification, CNSC staff rated the licensee's performance for this SCA as "satisfactory" for the 2016 calendar year. On December 30, 2016 a CNSC designated officer renewed MOECC's waste nuclear substance licence for the Deloro site for a period of 10 months, with an expiry of October 31, 2017.

In September 2016, MOECC submitted information to the CNSC in support of demonstrating that radiation levels at the Deloro site were below the conditional release levels. CNSC staff reviewed and assessed all the information provided by MOECC and determined that only portions of the licensed site were below conditional clearance levels. Subsequently, MOECC applied to renew its licence for five years with an amended site footprint to take into account the areas that are below conditional clearance levels and therefore no longer require a CNSC licence. In the fall of 2017, a designated officer will be issuing a decision on MOECC's application for a licence renewal with a modified footprint for the Deloro site.

Gunnar

The legacy Gunnar uranium mine site is being remediated by the Saskatchewan Research Council (SRC) under a CNSC nuclear substance licence for waste activities. Following a public hearing on September 22, 2016 the Commission removed the Gunnar remediation project phase 2 regulatory hold point. This allows the SRC to proceed with the remediation of waste rock, open pit, mine openings and other debris on site. CNSC staff conducted one site inspection during 2016, which confirmed the site continues to be stable and that SRC is preparing the site for remediation activities by setting up a work camp and associated safety measures.

Port Radium

The Port Radium closed uranium mine site is located in the Northwest Territories on the eastern shores of Great Bear Lake. A CNSC designated officer renewed Indigenous and Northern Affairs Canada's (INAC) nuclear substance licence for waste activities for a period of 10 years on December 31, 2016 to continue the long-term maintenance and monitoring of the Port Radium site. CNSC staff carried out one inspection during 2016 and were satisfied that INAC was implementing its programs consistent with CNSC requirements.

Denison Mines

On May 24, 2016 Denison Mines Inc. informed CNSC staff that a small bush fire had occurred near its licensed area. CNSC staff updated the Commission of the event at the public meeting held on June 23, 2016. The fire had no radiological impact and did not cause any impact to the health and safety of workers or the public. However, there was damage to trees near the Denison Mine tailings dam.

A summary report was submitted on July 31, 2016 to CNSC staff that confirmed the response to the incident was well coordinated and lessons learned have been implemented, including reporting to the CNSC duty officer, improvements to their internal communication protocols, and ensuring local fire services notify the licensee immediately. CNSC staff provided an update to the Commission during the December 14, 2016 public meeting through the 2015 regulatory oversight report and determined the event is closed and no further details are required.

References

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25. Annual Program Report, *Regulatory Oversight Report for Uranium Mines, Mills, Historic and Decommissioned Sites in Canada: 2015*, CMD 16-M49, December 14, 2016.

Glossary

annual collective dose

The annual collective dose is the sum of the effective doses received by all NEWs at a uranium mine and mill in a year. It is also the product of the number of persons (p) in a group and the average dose (mSv) of that group. Therefore it is often expressed in the units p-mSv or p-Sv.

Commission

A corporate body of not more than seven members, established under the *Nuclear Safety and Control Act* and appointed by the Governor in Council, to perform the following functions:

- regulate the development, production and use of nuclear energy and the production, possession, use and transport of nuclear substances
- regulate the production, possession and use of prescribed equipment and prescribed information
- implement measures respecting international control of the development, production, transport and use of nuclear energy and nuclear substances, including those respecting the non-proliferation of nuclear weapons and nuclear explosive devices
- disseminate scientific, technical and regulatory information concerning the activities of the CNSC and the effects on the environment and on the health and safety of persons of the development, production, possession, transport and uses referred to above

Commission member document (CMD)

A document prepared for Commission hearings and meetings by CNSC staff, proponents and intervenors.

effective dose

The sum of the products, in sieverts, obtained by multiplying the equivalent dose of radiation received by and committed to each organ or tissue set out in column 1 of an item of schedule 1 of the *Radiation Protection Regulations*, by the weighting factor set out in column 2 of that item.

equivalent dose

The product, in sieverts, obtained by multiplying the absorbed dose of radiation of the type set out in column 1 of an item of schedule 2 of the *Radiation Protection Regulations* by the weighting factor set out in column 2 of that item.

frequency rate

The accident frequency rate measuring the number of lost-time injuries for every 200,000 person-hours worked at the site. The frequency rate is calculated as follows:

Frequency = [(# of injuries in last 12 months) / (# of hours worked in last 12 months)] x 200,000.

geometric mean

An average that indicates the central tendency or typical value of a set of numbers according to the product of their values (as opposed to the arithmetic mean, which uses their sum):

The geometric mean of a data set (a1, a2, … an) is given by:

$$\left(\prod_{i=1}^{n} a_i\right)^{1/n} = \sqrt[n]{a_1 a_2 \cdots a_n}.$$

The geometric mean is a useful summary when we expect that changes in the data occur in a relative fashion. An example is when filters trap dusts in an amount relative to the amount of air flowing through the filters.

International Atomic Energy Agency (IAEA)

An independent international organization related to the United Nations system. The IAEA works with its member states and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies. The IAEA reports annually to the UN General Assembly and, when appropriate, to the Security Council regarding non-compliance by States with respect to their safeguards obligations, as well as on matters relating to international peace and security.

lost-time injury (LTI)

An injury that takes place at work and results in the worker being unable to return to work for a period of time.

non-compliance

A written notice that the licensee take action to correct a non-compliance that is not a direct contravention of governing regulations, licence conditions, codes or standards, but that can compromise safety, security or the environment. Such non-compliances include:

- failure to satisfy one of the compliance criteria if the criteria are not directly referenced in the governing regulations or licence conditions
- a significant but non-systemic failure to comply with the licensee's own policies, procedures or instructions that it has established to meet licensing requirements (including programs and internal processes submitted in support of a licence application)

severity rate

The accident severity rate measures the total number of days lost to injury for every 200,000 person-hours worked at the site. Severity rate is calculated as follows:

Severity = [(# of days lost in last 12 months) / # of hours worked in last 12 months)] x 200,000.

total number of workers

The total number of workers includes employees and contractors and is expressed as full-time equivalents.

uranium concentrate (yellowcake)

Uranium concentrate, commonly referred to as U_3O_8, is the product created when uranium ore has been mined and milled.

Appendix A: Licence and licence conditions handbook

Table A-1: Uranium mines and mills – Licensing information

Licensee/licence #	Licence effective	Last licence amendment	Licence expiration
AREVA Resources Canada Inc. McClean Lake Operation Uranium mine and mill operating licence UMOL-MINEMILL-McCLEAN.00/2027	July 1, 2017	N/A	June 30, 2027
Cameco Corporation Cigar Lake Operation Uranium mine operating licence UML-MINE-CIGAR.00/2021	July 1, 2013	N/A	June 30, 2021
Cameco Corporation Key Lake Operation Uranium mill operating licence UMLOL-MILL-KEY.00/2023	November 1, 2013	N/A	October 31, 2023
Cameco Corporation Rabbit Lake Operation Uranium mine and mill operating licence UMOL-MINEMILL-RABBIT.00/2023	November 1, 2013	N/A	October 31, 2023
Cameco Corporation McArthur River Operation Uranium mine operating licence UMOL-MINE-McARTHUR.00/2023	November 1, 2013	N/A	October 31, 2023

Table A-2: Uranium mines and mills – Licence conditions handbook changes, 2016

Record of the issuance of licence conditions handbook			
Licensee/licence #	**Licence conditions handbook revision**	**Summary of changes**	**Effective date**
AREVA Resources Canada Inc. McClean Lake Operation Uranium mine and mill operating licence UMOL-MINEMILL-McCLEAN.00/2027	3	▪ Section 2.4: Added text for use of JEB ore pad as a contingency measure ▪ Changed annual production from 13 to 24 million pounds ▪ Section 3.1: Text modified for the sections “Compliance Verification Criteria” and “Recommendations and Guidance” to be consistent with other Directorate of Nuclear Cycle and Facilities Regulation facilities ▪ Section C.1: Updated reference for Radiation Code of Practice ▪ Section C.2: Documents added to the licensing basis ▪ Section D.2: REGDOC-2.2.2 added and updated reference for TPED-01	June 23, 2016

Appendix B: Safety and Control Area Framework for uranium mines and mills

The CNSC evaluates how well licensees meet regulatory requirements and CNSC performance expectations for programs in 14 safety and control areas (SCAs). The SCAs are grouped into three functional areas: management, facility and equipment, and core control processes.

Table B-1: Safety and Control Area Framework

Functional area	Safety and control area	Definition	Specific areas
Management	**Management system**	Covers the framework that establishes the processes and programs required to ensure an organization achieves its safety objectives, continuously monitors its performance against these objectives, and fosters a healthy safety culture.	▪ management system ▪ organization ▪ performance assessment, improvement and management review ▪ operating experience (OPEX) ▪ change management ▪ safety culture ▪ configuration management ▪ records management ▪ management of contractors ▪ business continuity
	Human performance management	Covers activities that enable effective human performance through the development and implementation of processes that ensure a sufficient number of licensee personnel are in all relevant job areas and have the necessary knowledge, skills, procedures and tools in place to safely carry out their duties.	▪ human performance program ▪ personnel training ▪ personnel certification ▪ initial certification examinations and requalification tests ▪ work organization and job design ▪ fitness for duty
	Operating performance	Includes an overall review of the conduct of the licensed activities and the activities that enable effective performance.	▪ conduct of licensed activity ▪ procedures ▪ reporting and trending ▪ outage management performance ▪ safe operating envelope ▪ severe accident management and recovery ▪ accident management and recovery
Facility and equipment	**Safety analysis**	Covers maintenance of the safety analysis that supports the overall safety case for the facility. Safety analysis is a systematic evaluation of the potential hazards associated with the conduct of a proposed activity or facility and considers the effectiveness of preventive measures and strategies in reducing the effects of such hazards.	▪ deterministic safety analysis ▪ hazard analysis ▪ probabilistic safety analysis ▪ criticality safety ▪ severe accident analysis ▪ management of safety issues (including research and development programs)

Functional area	Safety and control area	Definition	Specific areas
	Physical design	Relates to activities that impact the ability of structures, systems and components to meet and maintain their design basis given new information arising over time and taking changes in the external environment into account.	▪ design governance ▪ site characterization ▪ facility design ▪ structure design ▪ system design ▪ component design
	Fitness for service	Covers activities that impact the physical condition of structures, systems and components to ensure that they remain effective over time. This area includes programs that ensure all equipment is available to perform its intended design function.	▪ equipment fitness for service/equipment performance ▪ maintenance ▪ structural integrity ▪ aging management ▪ chemistry control ▪ periodic inspection and testing
Core control processes	**Radiation protection**	Covers the implementation of a radiation protection program in accordance with the *Radiation Protection Regulations*. The program must ensure that contamination levels and radiation doses received by individuals are monitored, controlled and maintained as low as reasonably achievable (ALARA).	▪ application of ALARA ▪ worker dose control ▪ radiation protection program performance ▪ radiological hazard control ▪ estimated dose to public
	Conventional health and safety	Covers the implementation of a program to manage workplace safety hazards and to protect personnel and equipment.	▪ performance ▪ practices ▪ awareness
	Environmental protection	Covers programs that identify, control and monitor all releases of radioactive and hazardous substances and effects on the environment from facilities or as the result of licensed activities.	▪ effluent and emissions control (releases) ▪ environmental management system ▪ assessment and monitoring ▪ protection of the public ▪ environmental risk assessment
	Emergency management and fire protection	Covers emergency plans and emergency preparedness programs that exist for emergencies and for non-routine conditions. This area also includes any results of participation in exercises.	▪ conventional emergency preparedness and response ▪ nuclear emergency preparedness and response ▪ fire emergency preparedness and response
	Waste management	Covers internal waste-related programs that form part of the facility's operations up to the point where the waste is removed from the facility to a separate waste management	▪ waste characterization ▪ waste minimization ▪ waste management practices ▪ decommissioning plans

Functional area	Safety and control area	Definition	Specific areas
		facility. This area also covers the planning for decommissioning.	
	Security	Covers programs required to meet security requirements stipulated in the regulations, the licence, orders or expectations for the facility or activity.	▪ facilities and equipment ▪ response arrangements ▪ security practices ▪ drills and exercises
	Safeguards and non-proliferation	Covers programs and activities required to meet obligations of the Canada/International Atomic Energy Agency (IAEA) safeguards agreements, as well as all other measures arising from the *Treaty on the Non-Proliferation of Nuclear Weapons*.	▪ nuclear material accountancy and control ▪ access and assistance to the IAEA ▪ operational and design information ▪ safeguards equipment, containment and surveillance ▪ import and export
	Packaging and transport	Programs that cover the safe packaging and transport of nuclear substances to and from the licensed facility.	▪ package design and maintenance ▪ packaging and transport ▪ registration for use
Other matters of regulatory interest			
▪ Environmental assessments ▪ CNSC consultation – Indigenous communities ▪ CNSC consultation – other ▪ Cost recovery ▪ Financial guarantees ▪ Improvement plans and significant future activities ▪ Licensee public information program ▪ Nuclear liability insurance			

Appendix C: Rating methodology and definitions

Performance ratings used in this report are defined as follows:

Fully satisfactory (FS)

Safety and control measures implemented by the licensee are highly effective. In addition, compliance with regulatory requirements is fully satisfactory, and compliance within the safety and control area or specific area exceeds requirements and Canadian Nuclear Safety Commission (CNSC) expectations. Overall, compliance is stable or improving, and any problems or issues that arise are promptly addressed.

Satisfactory (SA)

Safety and control measures implemented by the licensee are sufficiently effective. In addition, compliance with regulatory requirements is satisfactory. Compliance within the safety and control area or specific area meets requirements and CNSC expectations. Any deviation is only minor, and any issues are considered to pose a low risk to the achievement of regulatory objectives and the CNSC's expectations. Appropriate improvements are planned.

Below expectations (BE)

Safety and control measures implemented by the licensee are marginally ineffective. In addition, compliance with regulatory requirements falls below expectations. Compliance within the safety and control area or specific area deviates from requirements or CNSC expectations to the extent that there is a moderate risk of ultimate failure to comply. Improvements are required to address identified weaknesses. The licensee or applicant is taking appropriate corrective action.

Unacceptable (UA)

Safety and control measures implemented by the licensee are significantly ineffective. In addition, compliance with regulatory requirements is unacceptable and is seriously compromised. Compliance within the overall safety and control area or specific area is significantly below requirements or CNSC expectations or there is evidence of overall non-compliance. Without corrective action, there is a high probability that the deficiencies will lead to an unreasonable risk. Issues are not being addressed effectively, no appropriate corrective measures have been taken, and no alternative plan of action has been provided. Immediate action is required.

Appendix D: Safety and control area rating summaries

Table D-1: Safety and control area summary, Cigar Lake Operation, 2012–16

Safety and control areas	2012	2013	2014	2015	2016
Management system	SA	SA	SA	SA	SA
Human performance management	SA	SA	SA	SA	SA
Operating performance	SA	SA	SA	SA	SA
Safety analysis	SA	SA	SA	SA	SA
Physical design	SA	SA	SA	SA	SA
Fitness for service	SA	SA	SA	SA	SA
Radiation protection	SA	SA	SA	SA	SA
Conventional health and safety	SA	FS	SA	SA	SA
Environmental protection	SA	SA	SA	SA	SA
Emergency management and fire protection	SA	SA	SA	SA	SA
Waste management	SA	SA	SA	SA	SA
Security	SA	SA	SA	SA	SA
Safeguards and non-proliferation	SA	SA	SA	SA	SA
Packaging and transport	SA	SA	SA	SA	SA

Table D-2: Safety and control area summary, McArthur River Operation, 2012–16

Safety and control areas	2012	2013	2014	2015	2016
Management system	SA	SA	SA	SA	SA
Human performance management	SA	SA	SA	SA	SA
Operating performance	SA	SA	SA	SA	SA
Safety analysis	SA	SA	SA	SA	SA
Physical design	SA	SA	SA	SA	SA
Fitness for service	SA	SA	SA	SA	SA
Radiation protection	SA	SA	SA	SA	SA
Conventional health and safety	SA	SA	SA	SA	SA
Environmental protection	SA	SA	SA	SA	SA
Emergency management and fire protection	SA	SA	SA	SA	SA
Waste management	SA	SA	SA	SA	SA
Security	SA	SA	SA	SA	SA
Safeguards and non-proliferation	SA	SA	SA	SA	SA
Packaging and transport	SA	SA	SA	SA	SA

Table D-3: Safety and control area summary, Rabbit Lake Operation, 2012–16

Safety and control areas	2012	2013	2014	2015	2016
Management system	SA	SA	SA	SA	SA
Human performance management	SA	SA	SA	SA	SA
Operating performance	SA	SA	SA	SA	SA
Safety analysis	SA	SA	SA	SA	SA
Physical design	SA	SA	SA	SA	SA
Fitness for service	SA	SA	SA	SA	SA
Radiation protection	SA	SA	SA	SA	SA
Conventional health and safety	SA	SA	SA	SA	SA
Environmental protection	SA	SA	SA	SA	SA
Emergency management and fire protection	SA	SA	SA	SA	SA
Waste management	SA	SA	SA	SA	SA
Security	SA	SA	SA	SA	SA
Safeguards and non-proliferation	SA	SA	SA	SA	SA
Packaging and transport	SA	SA	SA	SA	SA

Table D-4: Safety and control area summary, Key Lake Operation, 2012–16

Safety and control areas	2012	2013	2014	2015	2016
Management system	SA	SA	SA	SA	SA
Human performance management	SA	SA	SA	SA	SA
Operating performance	SA	SA	SA	SA	SA
Safety analysis	SA	SA	SA	SA	SA
Physical design	SA	SA	SA	SA	SA
Fitness for service	SA	SA	SA	SA	SA
Radiation protection	SA	SA	SA	SA	SA
Conventional health and safety	SA	SA	SA	SA	SA
Environmental protection	SA	SA	SA	SA	SA
Emergency management and fire protection	SA	SA	SA	SA	SA
Waste management	SA	SA	SA	SA	SA
Security	SA	SA	SA	SA	SA
Safeguards and non-proliferation	SA	SA	SA	SA	SA
Packaging and transport	SA	SA	SA	SA	SA

Table D-5: Safety and control area summary, McClean Lake Operation, 2012–16

Safety and control areas	2012	2013	2014	2015	2016
Management system	SA	SA	SA	SA	SA
Human performance management	SA	SA	SA	SA	SA
Operating performance	SA	SA	SA	SA	SA
Safety analysis	SA	SA	SA	SA	SA
Physical design	SA	SA	SA	SA	SA
Fitness for service	SA	SA	SA	SA	SA
Radiation protection	SA	SA	SA	SA	SA
Conventional health and safety	SA	SA	SA	SA	SA
Environmental protection	SA	SA	SA	SA	SA
Emergency management and fire protection	SA	SA	SA	SA	SA
Waste management	SA	SA	SA	SA	SA
Security	SA	SA	SA	SA	SA
Safeguards and non-proliferation	SA	SA	SA	SA	SA
Packaging and transport	SA	SA	SA	SA	SA

Appendix E: Financial guarantees

The following table outlines the financial guarantees as of December 31, 2016 for the five uranium mine and mill facilities.

Table E-1: Uranium mines and mills – Financial guarantees

Facility	Canadian dollar amount
Cigar Lake Operation	$49,200,000
McArthur River Operation	$48,400,000
Rabbit Lake Operation	$202,700,000
Key Lake Operation	$218,300,000
McClean Lake Operation (July 2017)	$107,241,000
Total	**$625,841,000**

Appendix F: Worker dose data

Table F-1 shows the total number of nuclear energy workers (NEWs) monitored at each of the five operating mines for 2016. An individual who is required to work with a nuclear substance or in a nuclear industry is designated as a NEW if he or she has a reasonable probability of receiving an individual effective dose greater than the prescribed effective dose limit for a member of the public (i.e., 1 millisievert (mSv) in a calendar year).

Table F-1: Total number of nuclear energy workers at the five operating facilities, 2016

	Cigar Lake	McArthur River	Rabbit Lake	Key Lake	McClean Lake
Total NEWs	1,243	1,064	739	837	510

The following table compares the average and maximum individual effective dose for all five operating uranium mines and mills.

Table F-2: Radiation dose data to nuclear energy workers at uranium mines and mills, 2016

Facility	Average individual effective dose (mSv/year)	Maximum individual effective dose (mSv/year)	Regulatory limit
Cigar Lake Operation	0.39	5.53	**50 mSv/year**
McArthur River Operation	0.85	7.02	
Rabbit Lake Operation	0.85	4.95	
Key Lake Operation	0.62	5.37	
McClean Lake Operation	1.04	6.94	

The following tables provide a five-year trend (2012 to 2016) of the average and maximum effective annual doses received at the various operations. Each table also identifies the maximum five-year dose for a worker at each operating uranium mine and mill. In 2016, no radiation dose at any operating facility exceeded a regulatory effective dose limit.

Table F-3: Worker effective dose, Cigar Lake Operation, 2012–16

Dose data	2012	2013	2014	2015	2016	Regulatory limit
Total NEWs	2,420	3,039	1,458	1,222	1,243	**N/A**
Average individual effective dose (mSv)	0.14	0.27	0.16	0.45	0.39	**50 mSv/ year**
Maximum individual effective dose (mSv)	2.87	2.21	2.04	5.99	5.53	**50 mSv/ year**
Maximum five-year dose for an individual (mSv) 2016–20	5.53					**100 mSv/ 5 years**

Table F-4: Worker effective dose, McArthur River Operation, 2012–16

Dose data	2012	2013	2014	2015	2016	Regulatory limit
Total NEWs	1,276	1,302	1,149	1,360	1,064	**N/A**
Average individual effective dose (mSv)	0.97	0.89	1.03	1.00	0.85	**50 mSv/ year**
Maximum individual effective dose (mSv)	9.26	7.58	7.91	7.40	7.02	**50 mSv/ year**
Maximum five-year dose for an individual (mSv) 2016–20	7.02					**100 mSv/ 5 years**

Table F-5: Worker effective dose, Rabbit Lake Operation, 2012–16

Dose data	2012	2013*	2014	2015	2016	Regulatory limit
Total NEWs	1,257	1,178	964	958	739	**N/A**
Average individual effective dose (mSv)	1.22	1.30	1.32	1.36	0.85	**50 mSv/ year**
Maximum individual effective dose (mSv)	18.76*	11.67	8.84**	9.14	4.95	**50 mSv/ year**
Maximum five-year dose for an individual (mSv) 2016–20	4.95					**100 mSv/ 5 years**

* In 2013, the 2012 maximum individual effective dose was modified from 14.37 mSv (as stated in the *CNSC Staff Report on the Performance of Canadian Uranium Fuel Cycle and Processing Facilities: 2012*), as a result of approved dose changes following an injury to an underground worker (for further information see section 5.2 of the 2013 report).

** During a dosimetry database upgrade, some errors associated with timecard and database entries were identified that affected some dose assignments at Rabbit Lake, Cigar Lake and McArthur River. The errors were not significant and did not result in any changes

to the data reported in last year's regulatory oversight report with the exception of the 8.84 mSv value, which was previously reported as 8.64 mSv.

Table F-6: Worker effective dose, Key Lake Operation, 2012–16

Dose data	2012	2013	2014	2015	2016	Regulatory limit
Total NEWs	1,345	1,380	1,170	1,191	837	**N/A**
Average individual effective dose (mSv)	0.61	0.62	0.63	0.55	0.62	**50 mSv/ years**
Maximum individual effective dose (mSv)	5.76	5.67	6.21	7.56	5.37	**50 mSv/ years**
Maximum five-year dose for an individual (mSv) 2016–20	5.37					**100 mSv/ 5 years**

Table F-7: Worker effective dose, McClean Lake Operation, 2012–16

Dose data	2012	2013	2014	2015	2016	Regulatory limit
Total NEWs	174	308	894	508	510	**N/A**
Average individual effective dose (mSv)	0.32	0.36	0.37	0.89	1.04	**50 mSv/ year**
Maximum individual effective dose (mSv)	1.30	3.44	2.03	5.28	6.94	**50 mSv/ year**
Maximum five-year dose for an individual (mSv) 2016–20	6.94					**100 mSv/ 5 years**

Appendix G: Reportable releases to the environment and CNSC rating definitions

Canadian Nuclear Safety Commission (CNSC) staff were satisfied with the remedial actions taken by the licensees for the spills presented in table G-1 and concluded that these spills resulted in no residual impacts to the environment. Table G-1 notes the details of each spill, the corrective actions taken and spill significance ratings. Table G-2 lists the spill rating definitions.

Table G-1: Uranium mines and mills reportable releases to the environment, 2016

Facility	Details	Corrective actions	Significance rating
Cigar Lake Operation	On February 3, 2016, one of the condenser tubes failed on modular freeze plant No. 4, causing anhydrous ammonia to leak from the system. Approximately 15 lb (7 kg) of anhydrous ammonia was released into the atmosphere.	To prevent similar releases, the Cigar Lake Operation replaced the evaporative style condensers on the modular freeze plant (which were made of aluminum) with steel condensers. The replacement was confirmed in an August 2016 inspection by CNSC staff. CNSC staff are satisfied with the corrective actions.	Low
Cigar Lake Operation	On February 8, 2016, one of the condenser tubes failed on modular freeze plant No. 2, causing anhydrous ammonia gas to leak from the system. Approximately 600 lb (273 kg) of anhydrous ammonia was released into the atmosphere.	To prevent similar releases, the Cigar Lake Operation replaced the evaporative style condensers on the modular freeze plant (which were made of aluminum) with steel condensers. The replacement was confirmed in an August 2016 inspection by CNSC staff. CNSC staff are satisfied with the corrective actions.	Low
Cigar Lake Operation	On April 4, 2016, one of the condenser tubes failed on modular freeze plant No. 4, causing anhydrous ammonia to leak from the system. Approximately 450 lb (204 kg) of anhydrous ammonia was released into the atmosphere.	To prevent similar releases, the Cigar Lake Operation replaced the evaporative style condensers on the modular freeze plant (which were made of aluminum) with steel condensers. The replacement was confirmed in an August 2016 inspection by CNSC staff. CNSC staff are satisfied with the corrective actions.	Low
Cigar Lake Operation	On November 9, 2016, a release of anhydrous ammonia occurred on modular freeze plant No. 4 when a relief valve fitting on the sub-cooler failed. The failure resulted in approximately 10 lb (4.5 kg) of ammonia gas to be released to the atmosphere.	The failure was caused by vibration resulting from mechanical failure of the motor. The motor was replaced and the plant returned to full operation. CNSC staff are satisfied with the corrective actions implemented.	Low
Cigar Lake Operation	On December 15, 2016, the return line from a freeze hole to the brine system developed a	To prevent reoccurrence, inspection and monitoring procedures for the freeze pad were updated. This	Low

Facility	Details	Corrective actions	Significance rating
	small leak during the night, releasing approximately 16 m^3 (16,000 L) of calcium chloride to the ground. A vacuum truck was used to recover a majority of the discharge, which was then properly disposed of.	included procedures for system checks to ensure that any releases are identified and mitigated earlier to minimize the volume of the release. CNSC staff are satisfied with the corrective actions implemented.	
McArthur River Operation	On November 16, 2016, the smell of ammonia was noted in modular freeze plant No. 2. The condenser unit was inspected using a bore scope, but nothing notable was observed. Subsequent investigation revealed the smell could have been coming from a weld U-bend in the condenser. It is unknown precisely how much anhydrous ammonia was released but is believed to be a small quantity and thus difficult to estimate.	Equipment identified as an operational control to mitigate the risk of an environmental aspect has been flagged in the preventive maintenance (PM) system. These PMs are given priority to ensure operational controls remain effective and compliance to the PM system is tracked. CNSC staff inspected all freeze plants in March 2017. CNSC staff are satisfied with the corrective actions implemented.	Low
Rabbit Lake Operation	On April 19, 2016, a mill operator passing by the B-Zone ore pad observed a small stream of water emerging from the west edge of the haul road adjacent to the B-Zone ore pad. Upon investigation, the water appeared to be leaking from a damaged culvert containing the B-Zone ore pad sump pipeline, which was not running at the time. An unusually rapid snow melt caused runoff to accumulate quickly within the B-Zone ore pad ditch. Pressure on the sealed end of a culvert extending under the haul road appears to have caused a portion of the seal to fail, allowing water to flow from the ditch into the culvert. Water emerged through the road bed and onto the roadway. Approximately 330 m^3 (330,000 L) of snow melt water from the B-Zone ore pad was released onto the ground.	An investigation was completed and corrective actions assigned to replace the failed culvert and improve water handling capabilities during spring runoff or major precipitation events. CNSC staff are satisfied with the corrective actions implemented.	Low
Rabbit Lake Operation	On September 13, 2016, while investigating a lower effects limit alarm reported by mill operations, maintenance personnel discovered a propane gas leak at the mill propane farm pump house. Propane odour was detectable at a distance and propane	The loosened pump fitting was replaced, properly sealed and tested prior to returning to service. The bases of both pumps were adjusted to ensure proper pump balancing. To provide additional clarity to the control room operator's monitoring system alarms, information on lower	Low

Facility	Details	Corrective actions	Significance rating
	vapour was observed emanating from the small pump house. Investigation indicated that a threaded coupling on top of the propane pump had vibrated loose, allowing approximately 150 kg of propane gas to be released to the atmosphere.	effects limit alarm protocols were updated on the distributed control system. CNSC staff are satisfied with the corrective actions implemented.	
Key Lake Operation	On August 2, 2016, following the excavation of a depression in the mill terrace behind the administration building, a contaminated sewer line was found to be cracked and releasing approximately 1,000 m^3 (1,000,000 L) of contaminated water. Based on an investigation into the sewer line configuration, it was determined that the mill maintenance wash bay sump was one of the arteries feeding into this line.	The discharge line from the sump in the former boiler plant was isolated and abandoned. The discharge end of the pipe that connected to the contaminated sewer line was disconnected and a straight piece was installed, ensuring only water from the administration building/mill maintenance wash bay reports to that section of line leading to manhole No. 12. The area was inspected by CNSC staff in September 2016. CNSC staff are satisfied with the corrective actions implemented.	Low
McClean Lake Operation	On February 14, 2016, after offloading anhydrous ammonia, approximately 24 L of anhydrous ammonia leaked to the ground through the offloading nozzle.	The offload nozzle, the breakaway valve and the sighting glass gasket were all repaired or replaced. The ammonia handling procedure was updated. CNSC staff are satisfied with the corrective actions implemented.	Low
McClean Lake Operation	On April 22, 2016, approximately 200 kg of molten sulphur was released to the ground. The sulphur offloading valve on the sulphur transport truck had failed to close properly.	The hammer from the valve body on the transport truck was removed and the valve replaced. A procedure was created for offloading sulphur when potential valve problems are identified. CNSC staff are satisfied with the corrective actions implemented.	Low
McClean Lake Operation	On July 17, 2016, a release of approximately 15 L of anhydrous ammonia to the atmosphere occurred. The anhydrous ammonia was released to the atmosphere due to a ventilation valve being inadvertently left open when the truck driver began offloading the product.	A ball valve closed-locking system was installed on the trailer ammonia ball valves. In addition, signage and barricades have been created to ensure all personnel stay out of the area while offloading is in progress. CNSC staff are satisfied with the corrective actions implemented.	Low
McClean Lake Operation	On July 29, 2016, a release of approximately 4 m^3 (4,000 L) of a water/magnetite mixture from	Mill operators were reminded to complete tasks before moving on to the next one and the high-level	Low

Facility	Details	Corrective actions	Significance rating
	the ferric sulphate plant to the ground occurred. The area operator left to help out in another area before completing maintenance that was being performed in the plant. The high-level alarm in the sump failed. The sump overfilled and the mixture flowed outside of the building.	alarm in the sump was repaired. CNSC staff are satisfied with the corrective actions implemented.	
McClean Lake Operation	During the day shift on August 4, 2016, 1,937 m^3 (1,937,000 L) of effluent was released with a pH of 9.14, exceeding the action level of 9.0. Regulatory limits were not exceeded. Issues relating to procedural misunderstanding were identified as the cause.	AREVA Resources Canada Inc. held information sessions with its staff on the differences between action and administration levels. Additionally, the emergency response plan for discharge-limit exceedances in 2016 was expanded to include action level exceedances. CNSC staff reviewed initial event notifications and follow-up reports outlining corrective actions. CNSC staff conducted follow-up inspections and are satisfied with the corrective actions taken by AREVA.	Low
McClean Lake Operation	During the night shift on August 4, 2016, 2,481 m^3 (2,481,000 L) of effluent was released with pH of 9.0 exceeding the action level of 9.0. Regulatory limits were not exceeded. Issues relating to procedural misunderstanding were identified as the cause.	AREVA held information sessions with its staff on the differences between action and administration levels. Additionally, the emergency response plan for discharge-limit exceedances in 2016 was expanded to include action level exceedances. CNSC staff reviewed initial event notifications and follow-up reports outlining corrective actions. CNSC staff conducted follow-up inspections and are satisfied with the corrective actions taken by AREVA.	Low
McClean Lake Operation	On September 29, 2016, a release of approximately 20 L of sulphuric acid to the ground occurred. During offloading of sulphuric acid from a transport trailer, an O-ring on an offloading hose connection coupling was either improperly installed or defective.	Proper gaskets have been added to onsite inventory in the event similar repairs are required in the future. The importance of completing thorough line inspections before beginning to offload product was discussed with the transportation company. CNSC staff are satisfied with the corrective actions implemented.	Low
McClean Lake Operation	On October 10, 2016, a release of approximately 1 L of anhydrous ammonia to the atmosphere occurred. During commissioning of the	Upgrades to the anhydrous ammonia storage area are scheduled in 2017. AREVA will review the offload purge system as part of the storage system	Low

Facility	Details	Corrective actions	Significance rating
	anhydrous ammonia tank after repairs and piping modifications, a small leak was discovered at a threaded flange connection at the tank.	upgrade project to examine if improvements for such circumstances can be made. This project is scheduled for completion by late 2017. CNSC staff are satisfied with the corrective actions implemented to date and will inspect the upgrades once work is completed to verify the adequacy of these additional measures.	
McClean Lake Operation	On December 20, 2016, a release of approximately 1 L of anhydrous ammonia to the ground occurred. In the early morning of December 14, 2016 an offload was completed into the McClean Lake mill anhydrous ammonia storage tanks. A small amount of anhydrous ammonia remained in liquid state within the offload line after the vapour had been purged. On the morning of December 20, 2016 it was discovered that approximately 1 L of liquid anhydrous ammonia had leaked past a valve on the end of the offload line on to the ground.	Upgrades to the anhydrous ammonia storage area are scheduled in 2017. AREVA will review the offload purge system as part of the storage system upgrade project to examine if improvements for such circumstances can be made. This project is scheduled for completion by late 2017. CNSC staff are satisfied with the corrective actions implemented to date and will inspect the upgrades once work is completed to verify the adequacy of these additional measures.	Low
McClean Lake Operation	On December 25, 2016, a release of approximately 20 L of precipitated yellowcake solution occurred. During an upset condition in the new solvent extraction circuit, reagent totes were immersed in precipitated yellowcake solution, which leaked out of voids at the base of the reagent totes as they were moved from inside the new solvent extraction circuit to outside Door No. 4 is to be scanned by the radiation group.	Stands are to be built that will hold the totes above the floor in the solvent extraction building to prevent contamination of the totes during upset conditions.	Low

Table G-2: CNSC spill rating definitions

Functional area:	Radiation protection		Environmental protection	
Safety significance	**Definition**	**Directorate-specific examples**	**Definition**	**Directorate-specific examples**
High	Exposures to multiple workers in excess of regulatory limits. Widespread contamination to several persons or to a place.	Incident that results in, or has reasonable potential for, a worker to exceed regulatory limits. Examples: ▪ nuclear energy worker (NEW) exceeding 20 millisievert (mSv)/year or 100 mSv/five years ▪ Non-NEW exceeding 1 mSv	Nuclear or hazardous substances being released to the environment exceeding regulatory limits (including public exposure) or that results in significant impact to the environment.	Incident that results in, or has reasonable potential to have, a significant or moderate impact or extensive future remediation. Examples: ▪ impairment of ecosystem functions ▪ effluent licence limit exceedance ▪ spill into fish bearing water ▪ fish kill
Medium	Exposure to a worker in excess of regulatory limits. An incident that would result in a licensee exceeding action level. Limited contamination that could affect a few persons or a limited area.	Incident that results in or has reasonable potential to exceed an action level. Example: ▪ doses to workers of 1 mSv/week or 5 mSv/quarter	Nuclear or hazardous substances being released to the environment exceeding action levels (including public exposure) or that result in impact to the environment outside the licensing basis.	Incident that results in, or has reasonable potential to have, a minor impact or that requires some future remediation. Examples: ▪ effluent action level exceedance ▪ spills to environment (including atmosphere) with short-term or seasonal impacts
Low	Increased dose below reportable limits. Contamination that could affect a worker.	Incident that results in, or has reasonable potential to exceed, the highest administrative level.	Release of hazardous or nuclear substances to the environment below regulatory limits.	Incident that results in, or has reasonable potential to have, a negligible impact. Examples: ▪ effluent administrative level-exceedance ▪ spills to environment (including atmosphere) with no future impacts

Appendix H: Lost-time injuries

Table H-1: Uranium mines and mills – Lost-time injuries (LTIs), 2016

Facility	Incident	Corrective action
Cigar Lake Operation	On January 26, 2016, an employee did not notice a short, 45 degree ramp leading up to a curb when the employee attempted to step up onto the curb. The employee slipped on the ramp, resulting in the employee falling and injuring a knee.	As a result of this incident, the ramp area has been redesigned and better flagged for worker awareness.
McArthur River Operation	On December 14, 2016, an employee was loading 10 kg bags onto the silica conveyor behind the batch plant. Five bags started to slip backwards. The worker tried to stop the bags from slipping, which resulted in a strain to the forearm.	Operation of the conveyor belt was modified to include a warm-up period to remove any snow and ice buildup and to ensure the belt is pliable.
Rabbit Lake Operation	On August 10, 2016, a Cameco employee was walking through the doorway between the mill administration offices and laboratory access hallway, and tripped over a slight step at the transition between the two areas and stumbled into the adjacent wall. After reporting to the supervisor, the employee was assessed by the site nurse and sent for further diagnostics upon returning home. Based on the injuries, the employee was unable to return to work for the next shift and the event was classified as a LTI. On August 31, 2016, the employee was admitted to hospital due to ongoing complications. As of December 31, 2016, the employee has remained away from work as a result of the event.	Information of causal factors is provided below: ▪ The bus transporting workers between the camp and mill arrived late to the mill. This resulted in the employee rushing to make a scheduled meeting. ▪ The ledge was previously identified as a tripping hazard and had been marked with high-visibility paint and warning signage. However, the increased visibility did not prevent the employee from tripping. ▪ The opportunity to remove the hazard had been missed during previous renovation activities. Based on the identified causal factors, Cameco initiated the construction/installation of a ramp at the transition between the two areas.
Key Lake Operation	On April 9, 2016, a Northern Resource Trucking (NRT) truck delivering sulphur arrived at Key Lake. The truck driver and the acid plant operator began the process for unloading the sulphur. During this process, the truck driver fell from the rear sulphur trailer and was injured. It was unclear what caused the driver to fall or from what height. The worker sustained serious injuries that required hospitalization for greater than 72 hours.	Comprehensive investigations were completed by both Cameco and NRT, including a third-party safety assessment of the sulphur unloading procedure. Fall-arrest equipment was already a requirement for accessing the sulphur trailers. A full-face passive respirator with protection against both sulphur dioxide and hydrogen sulphide must also be worn by NRT truck drivers when opening the hatches on the sulphur trailer. Unloading of all bulk goods was reviewed and additional safety measures implemented for the lime unloading procedure. CNSC staff are satisfied with the corrective actions implemented.
Key Lake Operation	On May 26, 2016, an employee rolled their ankle on a raised containment sill while exiting the mobile maintenance shop. The employee worked modified duties for a	Immediately following the event, the raised containment was painted yellow and warning signs were posted on both the interior and exterior window of the doorway to better alert

Facility	Incident	Corrective action
	single day before returning to full duties. The worker was reassessed on June 23, 2016 and was recommended for day-surgery. As a result of the surgery and recovery period, the injury was reclassified as an LTI. The worker has since returned to full duties.	employees of the tripping hazard. The sill was later removed entirely and the door reseated to be level with floor. CNSC staff are satisfied with the corrective actions implemented.
McClean Lake Operation	On January 10, 2016, an employee was loading a truck with ammonium sulphate crystal. The product became plugged in the bin chute and the worker began using tools including a long rod in an effort to release the plugged material. While manually unplugging the material through the inspection hatch, the worker's finger made contact with the side of the hatch opening. The worker was wearing the proper personal protective equipment at the time of the incident; however, the gloves being worn were unable to prevent the injury. The employee was unable to return to work on January 11, 2016 and lost two work days.	A moisture analyzer has been installed that gives employees better visibility on product quality, reducing the potential for plugging in the storage bin. The actuator on the slide gate has been changed to improve product flow. AREVA Resources Canada Inc. engaged an engineering firm to assess the existing storage bin cone and provide a plan for repair or replacement as needed. As an interim measure, a tool was designed to improve hand protection when manual unplugging of the chute is required.
McClean Lake Operation	On July 17, 2016, an anhydrous ammonia truck arrived on site and began to offload the product. The locking mechanism on the main valve, designed to ensure it is fully closed, did not function. This resulted in an uncontrolled release of 15 L of product before the driver realized the issue and closed the bleed valve. Wearing a respirator, the driver did not smell any ammonia. A second operator arrived and noticed a cloud coming from the anhydrous ammonia tank area and immediately left the area. The operator began to experience breathing difficulties and contacted the supervisor to report the event. The second operator saw a healthcare professional during their week off and was required to take seven days off before returning to work. As such, this incident was reclassified as an LTI.	A ball valve closed-locking system was installed on the trailer ammonia ball valves. In addition, signage and barricades have been created to ensure all personnel stay out of the area while offloading is in progress.
McClean Lake Operation	On October 13, 2016, an operator was descending a set of stairs, caught their boot heel on a stair and fell. The worker was using three points of contact and injured their arm while gripping the railing. The worker reported the incident to the supervisor and visited the health centre for treatment and assessment. The worker lost 13 work days due to the injury. Initially this case was classified as a modified work injury but was reclassified as an LTI on October 25, 2016.	To promote building safety culture, a site-wide communication was sent reminding all personnel to focus on current tasks and use three points of contact while descending stairs. This topic was also added to the next "safety huddle" for each department.

Appendix I: Radiological action level exceedances reported to the CNSC

Table I-1: Uranium mines and mills – Radiological action level exceedances in 2016

Facility	Action level exceedance	Corrective action
McArthur River Operation	Weekly action level: January 2016 personal alpha dosimeter results returned for two Cubex long hole drillers had combined radon progeny and long-lived radioactive dust (LLRD) doses of 2.59 millisieverts (mSv) and 2.06 mSv – greater than the 1 mSv/week action level. One worker had a recorded radon progeny dose of 2.58 mSv and the other had a recorded radon progeny dose of 2.03 mSv. The workers were drilling in the zone 4 area.	To address this, a number of engineered and administrative controls were implemented to ensure all exposures remained as low as reasonably achievable (ALARA). Specifically: ▪ temporary shutdown of zone 4 until radon bearing water could be brought fully under control ▪ access control measures (e.g., signage and barriers) were deployed to prevent any workers from being exposed to a hazard unknowingly ▪ mandatory radiation work permits were put in place for work in these areas to control worker entries and exposures ▪ additional continuous working level monitors (referred to as prisms) were deployed to provide timely detection of elevated hazard levels ▪ prism placement drawings were implemented in these areas to ensure that continuous working-level monitors were optimally located and their locations were known to workers CNSC staff verified the implementation of these additional controls as part of regular compliance activities.
Key Lake Operation	Weekly action level: In May 2016, a worker failed to submit a post-entry uranium-in-urine sample following work in the calciner room. As a result, the respirator use credit could not be assigned to the worker and an uncredited LLRD dose of 1.98 mSv was assigned.	The investigation determined this event to be a failure of the employee to follow procedural requirements.
McClean Lake Operation	Weekly action level: In December 2016, a mill operator received an effective dose of 1.94 mSv while performing non-routine tasks in the slurry receiving circuit. The majority of the dose was due to LLRD, 1.80 mSv, with 0.11 mSv from radon progeny (RnP) and 0.03 mSv from gamma radiation.	The investigation determined the exposure event would not have taken place had the worker and supervisor followed procedures and the radiation work permit. Additional efforts were taken to eliminate the hazard by improving compressor reliability to prevent backflow of slurry from the Pachuca tanks into the sparge. Sparge airline pressure alarms were also installed. CNSC staff reviewed the initial event notifications and follow-up reports with corrective actions. CNSC staff also followed up during a February 28 to March 2, 2017 radiation-focused compliance site inspection and are satisfied with the corrective actions taken and implemented by AREVA Resources Canada Inc.

Facility	Action level exceedance	Corrective action
McClean Lake Operation	Weekly action level: In December 2016, a mill operator working in the slurry receiving circuit received a dose of 3.23 mSv while performing regular duties. The majority of the worker dose was due to LLRD, 2.38 mSv, 0.56 mSv from RnP and 0.29 mSv from gamma radiation. Three possible occasions where the worker could have been exposed to elevated LLRD were identified.	The investigation determined one event involved slurry line discharge to the sump within the pulp storage enclosure. Two other events occurred when slurry material was sprayed from a pump due to worn out packing material. Corrective actions included the establishment of dedicated hoses and connections on flush lines leading to the sump, better storage location for face shields and rain slickers, and an update to the radiation protection code of practice to clarify situations where radiation work permits may be required for routine work. CNSC staff followed up during a radiation-focused compliance inspection at the site conducted from February 28 to March 2, 2017 and are satisfied with the corrective actions taken and implemented by AREVA.

Appendix J: CNSC inspections

Facility	Safety and control area	Inspection report issued
Cigar Lake Operation	General, physical design, waste management	June 9, 2016
	Safeguards	June 28, 2016
	General, operating performance, conventional health and safety	October 7, 2016
	Emergency management and fire protection	November 21, 2016
	Management system	December 23, 2016
	General, radiation protection, conventional health and safety, environmental protection	January 11, 2017
McArthur River Operation	Management system	April 26, 2016
	Radiation protection	July 5, 2016
	Management system	October 17, 2016
	Emergency management and fire protection	October 25, 2016
	Operating performance	November 22, 2016
	General, operating performance, radiation protection, safety analysis, packaging and transport	December 23, 2016
Rabbit Lake Operation	General, operating performance	September 23, 2016
	Fire protection	August 31, 2016
	General, operating performance	November 17, 2016
	General, waste management, environmental protection, radiation protection	February 24, 2017
	Operating performance, environmental protection, physical design, fitness for service	March 2, 2017
	Radiation protection	June 16, 2017
Key Lake Operation	General, management systems, operating performance, conventional health and safety, environmental protection, and radiation protection	March 18, 2016
	General	August 22, 2016
	Human performance management (training focused), conventional health and safety	August 31, 2016
	General, environmental protection, management system and waste management	December 23, 2016
	General, management system, physical design and conventional health and safety	November 25, 2016
	General, conventional health and safety, radiation protection and environmental protection	February 17, 2017

Facility	Safety and control area	Inspection report issued
McClean Lake Operation	Human performance, operating performance, safety analysis, conventional health and safety, fitness for service, security	March 16, 2016
	Operating performance, safety analysis, physical design, radiation protection, conventional health and safety, environmental protection, emergency management, fire protection	April 6, 2016
	Safeguards	November 21, 2016
	General, management system, physical design, radiation protection, environmental protection	June 30, 2016
	Environmental protection	August 19, 2016
	Packaging and transport	January 20, 2017
Beaverlodge	General, management system, radiation protection, conventional health and safety and environmental protection	September 27, 2016
Cluff Lake	General	August 19, 2016

Appendix K: Status report on Rio Algom Limited Elliot Lake historic mine and tailings management sites

1. Introduction

This section presents a status report on the environmental performance of Rio Algom Limited's Elliot Lake historic mine sites from January 2010 to December 2016.

In December 2005, the Commission issued a waste facility operating licence of indefinite term to Rio Algom for the Elliot Lake sites (WFOL-W5-3101.03/indf). The Commission accepted Canadian Nuclear Safety Commission (CNSC) staff's recommendation for an indefinite term for the licence because the sites are in a closed, static state with only care and maintenance as planned activities. In the associated *Record of Proceedings, Including Reasons for Decision,* the Commission requested that CNSC staff provide periodic updates on the performance of the Elliot Lake sites to coincide with the publication of the five-year state of the environment (SOE) report for the Elliot Lake sites.

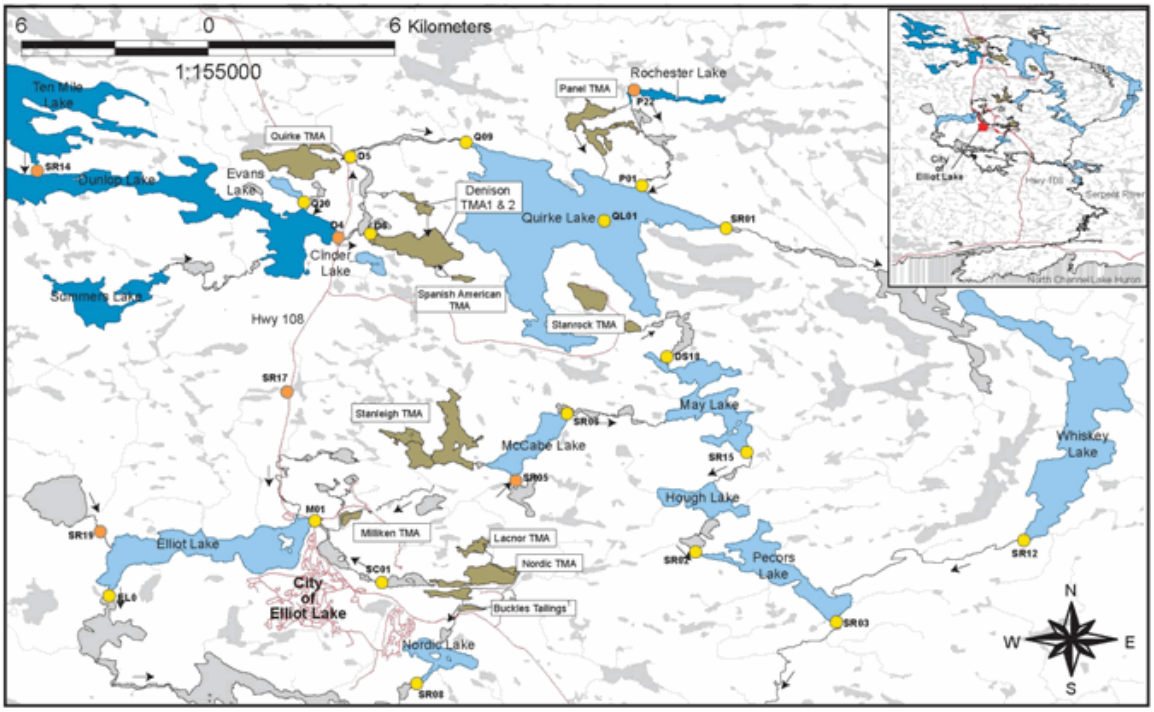
The last status report was provided to the Commission on March 29, 2012 (CMD#12-M14) and included the SOE from 2005 to 2010. This status report focuses on the SOE that covered the period from 2010 to 2015. CNSC staff's assessment of environmental performance is based on CNSC requirements for the "environmental protection" safety and control area (SCA).

1.1 Background

There are 11 decommissioned uranium mine sites and associated tailings management areas (TMAs) in Elliot Lake, Ontario, that resulted from historic uranium mining operations (figure K-1). Rio Algom is the owner and licensee of eight of the decommissioned sites, which include Stanleigh, Quirke, Panel, Spanish-American, Milliken, Lacnor, Buckles and Pronto. These eight sites are consolidated under one CNSC licence (CNSC waste facility operation licence WFOL-W5-3101.01/indf). Denison Mines Inc. is the owner and licensee of the other three sites – Denison I, Denison II and Stanrock – which are grouped into two licences (UMDL-Minemill-Denison.01indf and UMDL-Minemill-Stanrock.02/indf).

There are no mining or milling structures remaining on any site and all mine openings have been sealed. The TMAs are in the long-term care and maintenance phase that includes water treatment, environmental monitoring and maintenance of retaining structures (dams, berms, spillways).The risks associated with the licensed activities at the Elliot Lake sites are low and related primarily to the competence of the engineering features associated with the containment of nuclear substances, the operations and monitoring of the facility water treatment plants and the competence of other static structures to minimize contaminants released to the environment. The long-term plan for the site (more than 200 years) is to reach a state where water treatment is no longer required and reliance on engineered structures can be reduced.

Figure K-1: Map of the Elliot Lake historical mine sites



Source: Rio Algom Limited, 2016.

The overall performance for Rio Algom's sites was last presented in the *Regulatory Oversight Report for Uranium Mines, Mills, Historic and Decommissioned Sites in Canada: 2015* (CMD 15-M35). CNSC staff confirmed that performance at the Elliot Lake sites in 2015 was stable and met *Nuclear Safety and Control Act* (NSCA) requirements and its associated regulations and was satisfactory in all applicable SCAs. The next regulatory oversight report on the performance of the Elliot Lake sites is scheduled for December 2018.

The overall performance for Rio Algom's site for the year 2015 was presented in the *Regulatory Oversight Report for Uranium Mines, Mills, Historic and Decommissioned Sites in Canada: 2015* (CMD#15-M35). CNSC staff concluded that performance at the Elliot Lake sites in 2015 was satisfactory in all applicable SCAs. The next regulatory oversight report, which will include the overall performance of the Elliot Lake sites, is scheduled for December 2018.

Monitoring programs for each of the Elliot Lake areas have been developed by Rio Algom and Denison Mines in consultation with and approval by the Elliot Lake Joint Review Group (JRG). The JRG is a multi-stakeholder committee comprising representatives from the CNSC, Fisheries and Oceans Canada, Environment and Climate Change Canada, the Ontario Ministry of the Environment and Climate Change, the Ontario Ministry of Natural Resources and Forestry, the Ontario Ministry of Labour, and the Ontario Ministry of Northern Development and Mines. The JRG continues to participate in the programs through the review of monitoring and design reports for the source area monitoring program (SAMP), the tailings operational monitoring program (TOMP) and the Serpent River watershed monitoring program (SRWMP).

2. Assessment and monitoring of environmental protection performance

The following sections provide CNSC staff's evaluation of the environmental performance of Rio Algom's Elliot Lake sites for the reporting period from January 2010 to December 2016. CNSC staff's assessment of environmental performance is based on the results of CNSC staff inspections and reviews of Rio Algom's submissions. Specifically, Rio Algom and Denison Mines jointly submitted the SOE report for the period of 2010 to 2015 to CNSC staff in January 2016. CNSC staff, with the support of the JRG, reviewed and accepted the report in 2017.

2.1 Description of environmental monitoring at Elliot Lake sites

All TMAs at the Elliot Lake sites discharge to the Serpent River watershed except Pronto, which discharges to the north shore of Lake Huron. Rio Algom, in conjunction with Denison Mines, implements a comprehensive set of monitoring programs to assess environmental impacts and facilitate improvements to the sites.

The monitoring programs include three components:

- the SRWMP, which monitors and assesses the aquatic environmental conditions in the watershed downstream of the mine sites
- the TOMP, which measures TMA performance
- the SAMP, which monitors the constituents being discharged from the TMAs to the Serpent River watershed

The SOE report integrates data from the TOMP, SAMP and SRWMP to provide an assessment of TMA performance and the conditions in the downstream Serpent River watershed. The results of the TOMP, SAMP and SRWMP programs for 2010 to 2015 inclusively were analyzed and summarized in the SOE submitted to CNSC staff in January 2016.

2.2 Description of geotechnical monitoring of containment structures

Rio Algom's geotechnical inspection program is undertaken in conformance with the Canadian Dam Association's *Dam Safety Guidelines*. Key program components include routine (monthly or quarterly) inspections by Rio Algom's staff of all dams, dykes, berms and their appurtenant structures, and annual inspections and performance reviews by a qualified, third-party professional engineer. In addition, a dam safety review is conducted by an independent, qualified review engineer every seven years in accordance with the *Dam Safety Guidelines*.

2.3 CNSC staff review and assessment

CNSC staff reviewed the results from Rio Algom's environmental monitoring programs and the SOE and noted the following for the 2010 to 2016 reporting period:

- Rio Algom has effectively implemented environmental protection programs that include measures to control the releases of nuclear substances and other hazardous substances from the facility.

- Concentrations of all constituents in effluent waters from all TMAs were below CNSC licence limits.
- Concentrations of all constituents in all TMA effluents have generally decreased or remained stable since decommissioning. The exception is at the Stanleigh TMA, where concentrations of radium-226 and barium in the treated effluent have shown a slight increase over the past five years. In 2016, Rio Algom reported an action level exceedance of radium-226 for a grab sample (0.408 Bq/L compared to the action level of 0.37 Bq/L); however, the monthly average that included that sample was still well below the monthly compliance limit of 0.37 Bq/L. Rio Algom is in the process of addressing this issue mainly by improving radium-226 removal efficiency in the water treatment system. CNSC staff are being provided with monthly updates on the progress of this project and continue to monitor water quality concentrations closely to ensure they remain below effluent release limits.
- Water quality in the Serpent River watershed has generally improved over the reporting period. All annual mean concentrations of constituents of concern measured in the Serpent River watershed were below the Canadian Council of Ministers of the Environment (CCME) guidelines and water quality objectives for the Serpent River watershed (table K-1).

Table K-1 Receiving environment water quality objectives, Serpent River, 2010–16

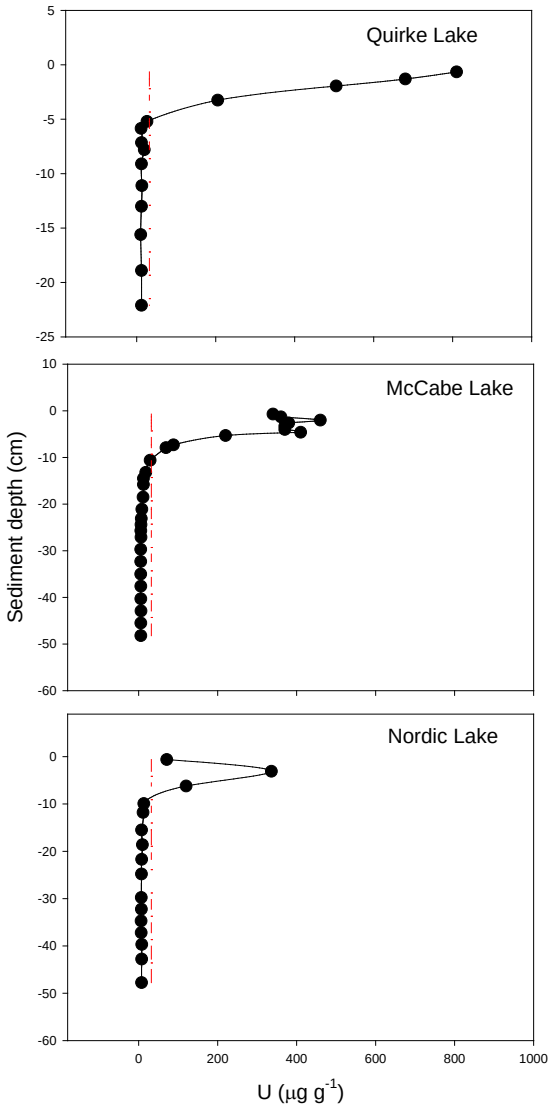
Constituent	Water quality objectives (CCME unless otherwise noted)
Barium (mg/L)	1.0[1]
pH (pH units)	6.5–9.0
Radium-226 (Bq/L)	1.0
Sulphate (mg/L)	100[2]
Uranium *(mg/L)*	0.015

1 Health Canada *Canadian Drinking Water Guidelines* maximum acceptable concentration
2 British Columbia Ministry of Environment sulphate guideline used; there are no provincial water quality objectives for sulphate.

- With respect to concentrations of constituents in sediments, the 2010–15 SOE did not provide sediment data since sediments are only sampled every 10 years. The sediment concentrations will be reported in the next SOE, which is expected in 2020. The last SOE showed that sediment quality is progressively recovering from historical contamination in Nordic Lake downstream of the Nordic and Lacnor TMAs, and McCabe Lake downstream of the Stanleigh TMA. Sediment recovery in Quirke Lake is not evident yet, which is to be expected due to the size of the lake and low depositional rates (figure K-2). Levels of uranium and radium in Elliot Lake sediments are at an acceptable level within regional background.
- Figure K-2 shows the changes in uranium concentrations with depth of the sediments in Quirke, McCabe and Nordic lakes. Low uranium concentrations in deep sediments represent background concentrations. Peak in uranium concentrations in shallower sediments corresponds with peak mining activities. The decrease in uranium concentrations in surface sediment corresponds with the end of mining activities in

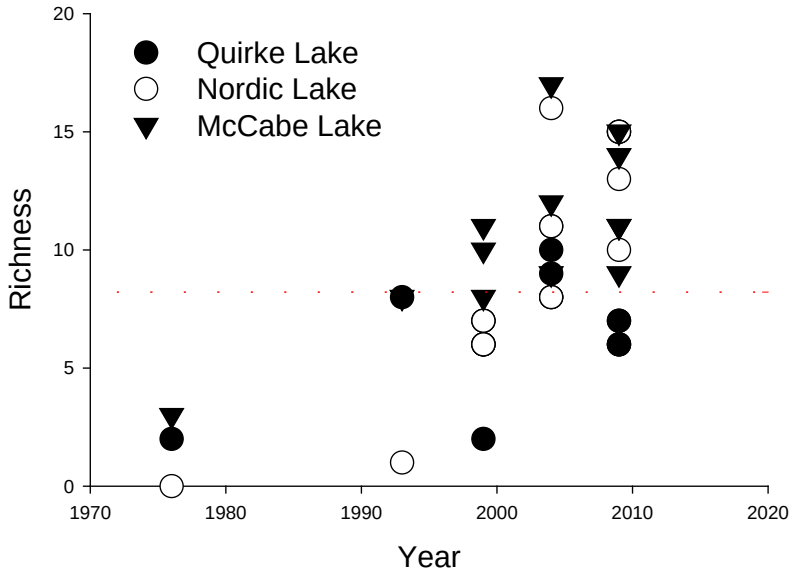
the region, which indicates recovery of sediment quality. The dashed red lines represent uranium concentrations safe to aquatic organisms.

Figure K-2: Changes in uranium concentrations with depth of sediments in Quirke, McCabe and Nordic lakes



- Following recovery of sediments, the health of benthic organisms has almost fully recovered in downstream water bodies compared to when the mines operated and impacts were evident (figure K-3). Lower benthic invertebrate richness downstream of the Quirke, Denison and Stanleigh TMAs in Quirke Lake are still measurable when compared to background values, which support the lower recovery of sediment quality in Quirke Lake.
- Figure K-3 shows the richness of benthic organisms in Quirke Lake, Nordic Lake and McCabe Lake. The red lines indicate the minimum number of benthic invertebrate families in reference areas.

Figure K-3: Richness of benthic organisms in Quirke, Nordic and McCabe lakes



- The lakes downstream of the mine sites are in good condition and the fish in those water bodies are in good health and are safe for human consumption.
- The estimates of public dose from 2009 that considered dietary exposure and showed doses would be well below the public limit are still valid, but will be updated during the next five-year period and incorporated into the SOE for 2020. The dose is expected to be lower due to the significant improvements observed around the Elliot Lake sites over the past decade.
- CNSC staff reviewed the licensees' annual inspection reports and dam safety review reports to assess the performance of the containment structures and conducted three compliance geotechnical inspections in 2012, 2014 and 2016 to observe the site condition and confirm the integrity of all containment structures. CNSC staff concluded that the integrity of all containment structures at Elliot Lake is maintained and all dams are safe under current conditions.

CNSC staff are satisfied with the environmental performance of Rio Algom's decommissioned mine sites for the reporting period. Rio Algom's environmental protection program that consists of contaminant source control, water treatment and monitoring is being effectively implemented and meets CNSC requirements for environmental protection. CNSC staff confirm Rio Algom has demonstrated the application of the principle of continuous improvement by using monitoring results to inform and improve water treatment efficiency and source control at the mine sites. In addition, CNSC staff confirm Rio Algom operates the TMAs safely by ensuring containment structures such as dams are well-managed and maintained, and water quality continues to be at or near values predicted in the environmental impact statement (1996).

According to CNSC staff's risk-informed inspection planning, Rio Algom is required to undergo a minimum of one compliance inspection annually and one geotechnical

inspection every two years. CNSC staff conducted annual compliance inspections in each year for the reporting period of 2010 to 2016 along with three geotechnical inspections. Based on the results of all inspections, CNSC staff conclude that the site was in good condition and well managed by the licensee.

3. Independent Environmental Monitoring Program

To complement ongoing compliance activities, the CNSC implements an Independent Environmental Monitoring Program (IEMP) to independently verify that the public and the environment around licensed nuclear facilities are protected. The IEMP involves taking samples from public areas around the facilities and measuring and analyzing the amount of radiological (nuclear) and non-radiological (hazardous) substances in those samples. CNSC staff collect the samples and send them to the CNSC's state-of-the-art laboratory for testing and analysis.

An IEMP sampling plan was undertaken for the Elliot Lake site in 2015 that focused on both nuclear and hazardous contaminants. A site-specific sampling plan was developed based on Rio Algom and Denison Mine's approved environmental monitoring program, CSA Group standards and the CNSC's regulatory experience with the site. In 2015, samples were collected in publicly accessible areas outside licensed areas of the Elliot Lake site for Rio Algom and Denison Mines and included surface water, sediment and sand. The results were made available on the CNSC's website in 2016.

CNSC staff confirmed the measured radioactivity levels in water samples were below federal and provincial drinking water quality guidelines. Based on the measured radioactivity in the samples collected, no health impacts are expected as a result of exposure to the water sampled.

The radioactivity levels measured in sand and sediment samples were below existing federal/provincial guidelines and CNSC reference levels. CNSC reference levels are based on conservative assumptions about the exposure that would result in a dose of 0.1 millisieverts (mSv)/year, which is one-tenth of the regulatory limit of 1 mSv/year. Based on the radionuclide activity concentrations measured in the samples collected, CNSC staff conclude no health impacts are expected.

With respect to the non-radiological analysis, the concentrations of analyzed substances in water were below the CCME guidelines and the natural background levels. No health or environmental impacts are expected at these levels. The concentrations of analyzed substances in three sediment samples had elevated heavy metal concentrations of lead, zinc, nickel, arsenic and copper that exceeded the CCME *Interim Sediment Quality Guidelines* but remained below the CCME's probable effect levels and the severe effect levels set by the *Provincial Sediment Quality Guidelines*. It is not uncommon that metal concentrations in sediments – especially close to historical industrial activities – can be elevated. CNSC staff have recommended, through the licensing and compliance division, that Rio Algom and Denison Mines include more locations in their environmental protection program. CNSC staff will continue to monitor and collect water and sediment samples at this location in future IEMP sampling campaigns.

The IEMP results indicate that the public and the environment in the vicinity of the Elliot Lake site are protected from the operation of this facility.

3.1 Aboriginal consultation

CNSC staff keep apprised of the information that the licensees, Rio Algom and Denison Mines, send out to Serpent River First Nation. CNSC staff have not received any feedback from Serpent River First Nation on the most recent SOE report that was sent.

4. Conclusion

Based on CNSC staff's review of the SOE, supporting monitoring programs, and compliance inspection results for the period of 2010 to 2016, CNSC staff conclude that the environmental performance for Rio Algom's Elliot Lake sites continues to be satisfactory. Rio Algom's environmental protection program that consists of contaminant source control, water treatment and monitoring is being effectively implemented and meets CNSC requirements for environmental protection. The integrity of all containment structures at Elliot Lake is well-maintained and all dams are safe under current conditions.

CNSC staff confirm that environmental conditions are improving at the Elliot Lake sites as evidenced by improvements to water quality in the downstream environment and health of benthic organisms in sediments.

Appendix L: Website links

AREVA Resources Canada Inc.

AREVA Resources Canada Inc. – McClean Lake Operation

Cameco Corporation

Cameco Corporation – Cigar Lake Operation

Cameco Corporation – McArthur River/Key Lake Operations

Cameco Corporation – Rabbit Lake Operation

CNSC Independent Environmental Monitoring Program

Eastern Athabasca Regional Monitoring Program

Indigenous and Northern Affairs Canada

Appendix M: Acronyms and abbreviations

ALARA	as low as reasonably achievable
CMD	Commission member document
CNSC	Canadian Nuclear Safety Commission
COPC	constituents of potential concern
EARMP	Eastern Athabasca Regional Monitoring Program
EPR	environmental performance report
ERA	environmental risk assessment
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IEMP	Independent Environmental Monitoring Program
INAC	Indigenous and Northern Affairs Canada
JEB	John Everett Bates
JRG	Joint Review Group
LCH	licence conditions handbook
LLRD	long-lived radioactive dust
LTI	lost-time injury
MMER	*Metal Mining Effluent Regulations*
MOECC	Ontario Ministry of Environment and Climate Change
mSv	millisievert
NEW	nuclear energy worker
NSCA	*Nuclear Safety and Control Act*
PAD	personal alpha dosimeters
PFP	Participant Funding Program
PM	preventive maintenance
PPE	personal protective equipment
ppm	parts per million
RnG	radon gas
RnP	radon progeny
RPCP	radiation performance confirmation plan
SAMP	source area monitoring program
SCA	safety and control area

SOE	state of environment report
SRC	Saskatchewan Research Council
SRWMP	Serpent River watershed monitoring program
TMF	tailings management facility
TMA	tailings management areas
TOMP	tailings operational monitoring program
TSP	total suspended particulate
TSS	total suspended solids