Annual Safety Report

ENVIRONMENTAL MONITORING IN 2013 AT CHALK RIVER LABORATORIES

CRL-509243-ASR-2013

Revision 0

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Chalk River Site Documentation

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<table>
<thead>
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<th>Revision History / Liste de révisions</th>
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SUMMARY

Overview

This report reviews and summarizes the results of the Chalk River Laboratories (CRL) Environmental Monitoring Program (EMP) for the calendar year 2013. Atomic Energy of Canada Limited (AECL) reports the monitoring results annually to the Canadian Nuclear Safety Commission (CNSC) as a condition of the Nuclear Research and Test Establishment Operating Licence [1] and as per the compliance verification criteria in the Licence Conditions Handbook for Chalk River Laboratories [2], issued by the CNSC.

AECL maintains a comprehensive EMP for CRL to verify that radiation doses to members of the public as a result of radioactive releases from the CRL site remain as low as reasonably achievable, social and economic factors being taken into account. The program demonstrates that the radiation dose to the most exposed members of the public (i.e. critical groups) due to CRL operations does not exceed regulatory limits, and also serves to verify that non-radioactive releases do not pose hazards to human health, and that neither radioactive nor non-radioactive releases pose hazards to the environment.

The comprehensive EMP is comprised of three components; radioactive environmental monitoring; non-radioactive environmental monitoring; and groundwater monitoring. Together, these three components provide for contaminant pathways monitoring at the CRL site, enabling the monitoring of contaminant levels in abiotic and biotic components in the environment.

Monitoring is conducted through the routine collection and analysis of environmental samples from numerous locations at the CRL site and in surrounding communities in order to measure the concentrations of contaminants in every significant environmental compartment involved in the migration of contaminants throughout the environment. Monitored media include ambient air, foodstuff (e.g. milk, fish, garden produce, large game, and farm animals), groundwater, Ottawa River water, and other surface waters on and off-site. Monitoring of beach sand, ground surfaces, and meteorological conditions is also performed.

Results for 2013 verified that environmental monitoring trends at off-site locations were reasonably consistent with radioactive releases from the CRL site. The 2013 dose assessment showed (as in previous years) that radiation to the public from CRL operations continues to be a very small fraction (6.9 %) of the annual dose limit of 1 mSv in a year for the most exposed members of the public, and that the dose to public due to the sum of all releases from CRL in 2013 did not exceed 0.3 mSv in any period of 12 consecutive months (Table 1). The majority of this dose is from external exposure to radioactive noble gases (primarily $^{41}$Ar) from NRU reactor operations, with the dose from liquid effluent pathways being negligible.

Based on the results of on-site monitoring only $^{90}$Sr in surface waters of the Perch Lake basin was considered to be of moderate impact, with all other contaminants having a low environmental impact. However, all of the related source areas were shut down decades ago, and the elevated concentrations of $^{90}$Sr occur over relatively small regions of the basin. Contaminant concentrations at the outlet of the drainage system, although gradually increasing in recent years, remained below the benchmark value i.e. the level above which ecological effects could potentially occur (183 Bq/L), and releases to the river continued to represent a small fraction of
the release limit. The impacts of $^{90}$Sr migration in the Perch Lake basin are mitigated by the continuing operation of two groundwater treatment systems, and the recent addition of a third treatment system located at South Swamp completed in 2013 August.

Overall, the 2013 radioactive environmental monitoring results indicate stability in the performance of facilities and operations at CRL, and that the controls for the release of radioactive contaminants currently in place at CRL continue to provide reasonable protection to the environment and the public.

Table 1
Total Dose to Critical Groups outside the Chalk River Laboratories Boundary based on Environmental Monitoring Results – 2008-2013

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Airborne Effluent Pathway</th>
<th>Liquid Effluent Pathway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bounding Age Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013 Total Effective Dose (mSv/a)</td>
<td>Infant 0.069 ± 0.005</td>
<td>Adult 0.00017 ± 0.00008</td>
</tr>
<tr>
<td>Total Dose (as % of annual public dose limit, 1 mSv)</td>
<td>6.9 ± 0.5</td>
<td>0.017 ± 0.008</td>
</tr>
<tr>
<td>Total Dose (as % of typical background radiation dose in Canada)</td>
<td>2.1 ± 0.1</td>
<td>0.005 ± 0.002</td>
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<tr>
<td>2012 Total Effective Dose (mSv/a)</td>
<td>0.063</td>
<td>0.00070</td>
</tr>
<tr>
<td>2011 Total Effective Dose (mSv/a)</td>
<td>0.059</td>
<td>0.00033</td>
</tr>
<tr>
<td>2010 Total Effective Dose (mSv/a)</td>
<td>0.032</td>
<td>0.00036</td>
</tr>
<tr>
<td>2009 Total Effective Dose (mSv/a)</td>
<td>0.044</td>
<td>0.0011</td>
</tr>
<tr>
<td>2008 Total Effective Dose (mSv/a)</td>
<td>0.092</td>
<td>0.013</td>
</tr>
</tbody>
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Notes:
1. The total dose to off-site members of the public was not calculated based on a single critical group, rather the dose to the most sensitive critical group was selected for each given exposure pathway resulting in a dose to a hypothetical individual living off-site.
2. Uncertainties on dose include analytical uncertainties on measured environmental concentrations.
Introduction

AECL’s CRL site operates a variety of nuclear facilities, including the National Research Universal (NRU) reactor, the Molybdenum-99 Production Facility, the Waste Management Areas (WMA), the Universal Cells, the Fuels and Materials Cells, and the Waste Treatment Centre and Associated Facilities (WTC). The CRL site also houses a variety of smaller research, development, and analytical laboratories. Most of the activities are conducted within the CRL Controlled Areas. The CRL site also houses several permanently shutdown facilities that are at various stages of decommissioning, including the National Research Experimental (NRX) reactor.

The CRL site, which has a total area of about 40 km², is located in Renfrew County, Ontario on the south shore of the Ottawa River, about 200 km northwest of Ottawa. The population surrounding CRL lives in Renfrew County, Ontario. Nearby communities include the Village of Chalk River, the Town of Deep River, the Town of Petawawa and the Canadian Forces Base Petawawa, and the City of Pembroke. The portion of Pontiac County in the Province of Québec that lies north of the river and opposite the CRL site is normally uninhabited except during the summer months, when a few cottage dwellers may be present.

The primary objectives for the EMP are to achieve the following:

- To assess the level of risk on human health and safety, and the potential biological effects in the environment from the contaminants and physical stressors of concern arising from CRL;
- To demonstrate compliance with limits on the concentration and/or intensity of contaminants and physical stressors in the environment or their effect on the environment;
- To check, independently of effluent monitoring, on the effectiveness of containment and effluent control, and provide public assurance of the effectiveness of containment and effluent control;
- Where waste storage facilities and contaminated lands exist, to provide an early indication of unusual or unforeseen conditions that might require corrective action or additional monitoring; and
- To verify the predictions made by the Environmental Risk Assessment, Derived Release Limit model, and Environmental Assessments, refine the models used, and reduce the uncertainty in the predictions made by these assessments and models.

The Program is also designed to provide data required to support site restoration programs, site operations or to plan for future stages of the facility lifecycle (e.g. decommissioning); to provide resources and data that can be of value during the response to an accident or upset, and in the recovery from such an event; to demonstrate due diligence; and to meet a stakeholder commitment. The design of the Program takes into account the facilities and processes at the site, the actual radioactive and non-radioactive emissions from the site at present and in the past, the environmental pathways leading to radiation dose to critical groups as identified by the Derived Release Limit calculations, as well as various other scientific, historic and public considerations.

The EMP operates under the direction of AECL’s Environmental Protection Program. The radioactive and non-radioactive components are managed by Environmental Protection Program...
staff, while the groundwater monitoring component is managed and operated by Environmental Technologies Branch staff. Analysis of samples is conducted by AECL laboratories as well as external laboratories. Results are reported regularly to designated staff and to facility management, where applicable. The evaluation of results is performed by Environmental Protection Program staff and Environmental Technologies Branch geoscience staff. Results, including non-conformances identified in the monitoring, are reported to Environmental Protection Program staff as well as staff and management associated with the facilities subject to monitoring.

**Sampling and Analysis**

Monitoring is conducted through the routine collection and analysis of environmental samples from numerous locations at the CRL site and in surrounding communities. Releases from CRL facilities and operations may be to the atmosphere or to water. Atmospheric releases arise from stacks and vents associated with operations and facilities in the built-up portion of the site and waterborne releases can be as piped discharges to the Ottawa River, as direct groundwater discharge to the Ottawa River, or as surface water drainage from facilities in the site’s Outer Area. Release points that have the potential for appreciable contaminant releases are routinely monitored as part of the Effluent Verification Monitoring Program. For a number of CRL facilities, contaminant releases can (and in some cases do) also occur to local groundwater flow systems.

The measurement of groundwater quality around the perimeters of operating areas provides a means of monitoring the conditions and behaviour of the facilities and operations at the CRL site. A significant fraction of the monitoring is carried out around the CRL WMAs. In total, 180 monitoring wells are subject to radioactive and non-radioactive monitoring downstream of WMAs and facilities.

The sampling of lakes and streams on the CRL site is an important component of the environmental monitoring network. In total, surface waters on the CRL site are routinely monitored at 41 locations for radioactive contaminants, and at nine locations for non-radioactive contaminants and other water quality indicators. The selection of parameters for analysis in on-site surface waters is based on the results of groundwater monitoring, information from upstream monitoring points, and information on potential source facilities.

The radioactive monitoring of environmental media in communities surrounding the CRL site focuses on exposure pathways for critical groups and populated areas in the vicinity of the CRL site. Monitoring of air effluent exposure pathways includes the measurement and recording of meteorological conditions as well as sampling and analysis of ambient air, milk, garden produce, locally raised farm animals, and large game animals. Monitoring of liquid effluent exposure pathways includes sampling and analysis of Ottawa River surface water, fish, and beach sand. Some aspects of the monitoring program, for example the monitoring of off-site surface waters, land gamma radiation on roadways, and atmospheric deposition, although not used directly in the calculation of dose to the public, provide valuable information on the fate of airborne effluents on and around the CRL site.
Quality Assurance

Quality Assurance is applied to the monitoring program using a range of factors that include performance verification (assessing the quality of sampling and laboratory analysis activities), the application of sampling and analysis procedures, program reviews and audits, and records management. General Quality Assurance objectives for AECL’s EMP are set out in the Environmental Protection Program Radiological and Non-Radiological Monitoring Services Quality Assurance Plan [3], and in the CRL Dosimetry Services Quality Assurance Manual [4], specific for thermoluminescent dosimeters.

With regard to laboratory quality verification, the evaluation of data quality uses the Quality Control parameters adopted under the Quality Assurance programs of the laboratories performing the analyses. These laboratories utilize Quality Control tools such as blanks, spiked blanks, and replicate samples to address precision, accuracy, sensitivity, and to detect errors in the data. The quality verification data generated at the performing laboratories are evaluated against acceptance criteria. Verification of the quality of sampling activities (field quality verification) is conducted using the results of travelling blanks and duplicate samples, the results of which are used to assess cross-contamination and reproducibility. Data quality verification testing is also inherent in the process of reviewing the monitoring results to evaluate environmental performance and in comparing the monitoring results from year to year (i.e. trending). Any issues related to sampling operations or sample analyses, as reported by staff, are examined and corrective measures developed to address the problems.

These methods of quality evaluation were applied to the 2013 EMP data. The results met the applicable quality verification criteria (where available), with a few minor and isolated exceptions.

Environmental Monitoring at the Chalk River Laboratories Site

Affected areas on the CRL site are subject to routine groundwater, surface water, and ambient air monitoring. Performance in this context was evaluated by characterizing the concentrations of contaminants of concern in environmental compartments, comparing the concentrations to available benchmark values (i.e. the levels at which ecological effects could potentially occur), and by reviewing contaminant concentration and loading trends.

There are three main drainage basins that are directly affected by CRL operations, including the Ottawa River Direct basin, Perch Lake basin, and Maskinonge Lake basin (Figure 1). Figure 2 is a schematic diagram that relates the CRL facilities of interest and the drainage basins and paths along which groundwater or surface water contaminants travel on their way to the Ottawa River. For groundwater and surface water contaminants, the environmental performance review is presented on a watershed basis, in consideration of these three major drainage basins.
Figure 1 Chalk River Laboratories Drainage Basin Overview
Figure 2 Chalk River Laboratories Site Model Overview

*Ottawa River Direct Basin*

This Ottawa River Direct basin drains approximately 12% of the CRL site, and includes the built-up area of the site where most of the operational nuclear and industrial facilities are located. Most of the air and waterborne effluents resulting from CRL operations are released from this zone, with all liquid effluents being discharged directly to the Ottawa River. This region also includes several landfill facilities and two groundwater contaminant plumes (from the NRX and NRU reactor facilities) that slowly discharge to the Ottawa River through regions of the riverbed (see Figure 2). Within the Ottawa River Direct basin, potential impacts are associated with liquid releases of tritium, gross beta (primarily $^{90}\text{Sr}$), and phenolics to the Ottawa River.

The main sources of tritium to the Ottawa River are the Process Outfall (associated with NRU secondary cooling and WTC effluents), Perch Creek (associated with the WMAs located in the Perch Lake basin), and the groundwater plume arising from the NRU fuel storage bays (a portion
of which is discharged to the river via Manhole 4F6). These three sources represented 84% of the tritium releases to the Ottawa River in 2013. Monitoring in 2013 confirmed stability in tritium concentrations in the Ottawa River near CRL and further downstream at Petawawa and Pembroke, consistent with effluent releases from the Chalk River site. Tritium in the Ottawa River decreased with distance from CRL, as full-mixing was achieved, reaching background levels in Petawawa and Pembroke (∼2 Bq/L). Tritium concentrations at all monitoring locations were well below the Canadian drinking water guideline of 7,000 Bq/L [5] and the benchmark value of 17.4 MBq/L. While it may appear in Figure 3 as though there was a decrease in tritium from 2012 to 2013, concentrations in the Ottawa River were in fact very similar from one year to the next. The decrease stems from a change in the way in which values that fall below the L_C or L_D were used in calculations in 2013, whereby the actual numerical measurement result is used, if available. Prior to 2013, a value equal to the L_C or L_D was used instead of the actual numerical measurement result.

The primary sources of waterborne gross beta to the Ottawa River are Perch Creek (associated with the WMAs located in the Perch Lake basin), the 04 Storm Outfall (affected by the NRX Rod Bays plume), and to a lesser extent the Process Outfall (associated with WTC operations). These three sources represented 90% of the gross beta releases to the Ottawa River in 2013. Despite an increasing trend in gross beta releases from Perch Creek and Storm Outfall 04, monitoring in 2013 confirmed stable trends in gross beta activity in the Ottawa River near CRL and further downstream at Petawawa, where gross beta levels averaged 0.045 Bq/L.

Figure 3 Tritium Concentrations in the Ottawa River Upstream (ORR, ORD) and Downstream (PET, ORP) of the Chalk River Laboratories

The primary sources of waterborne gross beta to the Ottawa River are Perch Creek (associated with the WMAs located in the Perch Lake basin), the 04 Storm Outfall (affected by the NRX Rod Bays plume), and to a lesser extent the Process Outfall (associated with WTC operations). These three sources represented 90% of the gross beta releases to the Ottawa River in 2013. Despite an increasing trend in gross beta releases from Perch Creek and Storm Outfall 04, monitoring in 2013 confirmed stable trends in gross beta activity in the Ottawa River near CRL and further downstream at Petawawa, where gross beta levels averaged 0.045 Bq/L.
Concentrations of the anthropogenic gross beta constituents $^{137}$Cs and $^{90}$Sr were only a small fraction of the Canadian Drinking Water Guidelines (10 and 5 Bq/L, respectively) [5] and the benchmark values (72.7 and 183 Bq/L, respectively).

Another source of gross beta activity to the Ottawa River includes groundwater migration of gross beta (primarily $^{90}$Sr) from the NRX Rod Bays, which has resulted in a localized groundwater plume extending to the river. This source represented 8% of the gross beta releases to the Ottawa River in 2013. Elevated concentrations of gross beta activity continued to be measured in groundwater immediately downgradient of the Rod Bays with lower concentrations (188 Bq/L) occurring near the discharge zone along the shoreline region. The beta activity concentrations at the shoreline in 2012 and 2013 were slightly higher than the levels observed in most recent years but similar to historical trends. Gross beta activity releases from the plume are expected to gradually decline because inputs to the plume were stopped in 2006 when the Rod Bays were drained. Where the groundwater discharges into the Ottawa River through the riverbed, concentrations are estimated to be slightly above the benchmark value (183 Bq/L), conservatively assuming that the concentrations near the discharge zone in the riverbed (where ecological receptors would reside) are similar to those observed in the shoreline groundwater monitoring.

Overall, the impacts of tritium and gross beta releases to the Ottawa River are very low and the release trends have remained stable.

The main source of phenolics to the Ottawa River is the Process Outfall (associated with detergent use at the Decontamination Centre). Efforts are underway to reduce this contaminant. Monitoring confirmed that there was no increase in the release of phenolics to the Ottawa River in 2012. The impact on the environment is therefore characterized as being of low risk.

**Perch Lake Basin**

The Perch Lake basin drains approximately 18% of the CRL site. Many of the site’s WMAs, including WMAs A and B, and the Liquid Dispersal Area (which includes Reactor Pit 1, Reactor Pit 2, and the Chemical Pit) are in this basin (see Figure 2).

The main contaminant of concern associated with the Perch Lake basin continues to be gross beta activity, primarily $^{90}$Sr. The most significant sources of $^{90}$Sr are WMA A, the Liquid Dispersal Area, and WMA B. Waste Management Area A received solid wastes, wastewaters from the NRX accident, and waste solutions from fuel reprocessing experiments between 1946 and 1955. The Liquid Dispersal Area, primarily the Chemical Pit (1956-1994) and Reactor Pit 2 (1956-2000), were used to discharge low-radioactivity wastewaters and were designed to promote wastewater infiltration to groundwater. A portion of the groundwater plume from the Chemical Pit is pumped and treated by a groundwater treatment facility, before being discharged to East Swamp Stream. Contaminants are transported from WMA A and the Liquid Dispersal Area via groundwater to nearby wetlands (South and East Swamp) and streams (Main Stream), and to Perch Lake.

The northwest corner of WMA B is occupied by unlined sand trenches that were used to bury low and intermediate level solid wastes between 1953 and 1963. It is this plume that has caused the radioactive contamination in West Swamp. A portion of this plume is treated by the Spring B
Treatment System that has operated since 1992. Because a portion of the groundwater from the unlined trenches goes untreated, the West Swamp continues to receive gross beta activity. Contaminants are transported in surface water from West Swamp to Perch Lake.

The risks associated with the presence of $^{90}$Sr in the Perch Lake basin are considered to be moderate; that is, contaminant concentrations exceed the benchmark value in localized regions of the drainage basin. Trending of beta activity in Perch Creek before it enters the Ottawa River (9 Bq/L) shows a gradually increasing trend in beta activity (Figure 4). At this point in the drainage system, gross beta concentrations are a small fraction of the Derived Release Limit and benchmark value (183 Bq/L).

The potential impacts of $^{90}$Sr in the Perch Lake basin are mitigated through the operation of two groundwater plume treatment systems that remove $^{90}$Sr from the WMA B and Chemical Pit plumes. Extended outages at both of these groundwater treatment facilities occurred in 2009 and 2010, but both treatments systems returned to full capacity from 2011 to 2013, reducing the amount of radioactivity being released to nearby wetlands and surface waters. As well, construction of a new plume treatment system to capture and treat a third $^{90}$Sr plume was completed, with the new system coming on line in the fall of 2013 to further reduce the impacts of $^{90}$Sr migration in the Perch Lake basin.

![Graph showing $^{90}$Sr Concentrations in Perch Lake and Perch Creek](image)

**Figure 4** $^{90}$Sr Concentrations in Perch Lake and Perch Creek

In addition to $^{90}$Sr, tritium contamination is present across the Perch Lake basin. The main sources of tritium contamination in the Perch Lake basin are the circular bunkers in the southern portion of WMA B and former operations at Reactor Pit 2. The southern portion of WMA B houses concrete bunkers used to store low to intermediate level solid wastes. Some of these bunkers are the source of elevated tritium concentrations in the groundwaters and surface waters.
around WMA B, which eventually flow into Perch Lake. Tritium migration from Reactor Pit 2 has resulted in the development of a groundwater tritium plume that extends to Perch Lake and Perch Creek. There have been no tritium inputs to Reactor Pit 2 since 2000. Groundwater monitoring adjacent to the pit has shown that releases from Reactor Pit 2 have essentially ended, but the groundwater transit time for the flow system is about 20 years, so Perch Creek will continue to receive tritium inputs from Reactor Pit 2 for several more years.

In Perch Creek (PCW), tritium concentrations and loadings appeared to be gradually decreasing over time, with an average of 3.4 kBq/L in 2013 (Figure 5). The Perch Lake basin is affected by tritium migration from past waste management practices; however, the concentrations are a small fraction of the benchmark values (17.4 MBq/L). Tritium releases from Perch Creek to the Ottawa River represent 0.002 % of the Derived Release Limit. Tritium in the Perch Lake basin does not represent a significant risk to the environment.

Other contaminants of concern within the Perch Lake basin include mercury and chlorinated solvents, which are present only in small, localized areas of the basin. The Chemical Pit was used to disperse low activity laboratory waste solutions (including mercury) for decades. Because of its past use in nuclear labs, mercury is monitored closely in the groundwaters and surface waters immediately downgradient of the Chemical Pit. There continues to be no indication of mercury migration beyond the groundwater compartment therefore the impact of mercury in the Perch Lake basin is of low risk.

A range of chlorinated volatile organic compounds are detected in the groundwaters at the northeast corner of WMA B. These contaminants form a groundwater solvent plume emanating from the eastern section of unlined sand trenches, with the main contaminant of concern.
being 1,1,1-trichloroethane. This contaminant continued to be undetectable in surface waters downgradient of the solvent plume in 2013. The continuing absence of these compounds supports the expectation that upon reaching surface waters the compounds rapidly volatilize, dispersing into the atmosphere and then degrading, limiting the potential for ecological effects. The impact of volatile organic compounds in the Perch Lake basin is therefore characterized as being of low risk.

**Maskinonge Lake Basin**

The Maskinonge Lake basin drains almost 40% of the CRL site. Drainage from this basin is into Chalk Lake, then into the Ottawa River. A number of WMAs are located within this basin, including WMA C, the Nitrate Plant, and the Thorium Pit (see Figure 2).

The main contaminant of concern associated with the Maskinonge Lake basin is tritium associated with WMA C, where low level solid wastes were buried in unlined trenches between 1963 and 2000. The groundwater tritium plume arising from the WMA discharges to two nearby wetlands and streams, which in turn drain through Duke Stream (DSW), Bulk Storage Stream (BSW), and Lower Bass Creek (LBL), and eventually drain into Maskinonge Lake (MLO). The tritium concentrations in surface waters along the drainage routes near WMA C have been decreasing, and this trend continues in 2013 (Figure 6).

![Figure 6 Tritium Concentrations in Surface Waters of the Maskinonge Lake Basin](image_url)

This improvement is reflective of natural recovery from a pulse release of tritium from the WMA that arrived at Bulk Storage Stream in 2004. This declining trend is also present in surface waters of Maskinonge Lake (418 Bq/L) and Chalk Lake (43 Bq/L). These concentrations remain a negligible fraction of the benchmark value (17.4 MBq/L). In terms of the potential impacts to
members of the public, the releases of tritium from the Maskinonge Lake basin were a small fraction of the applicable Derived Release Limit.

Substantially elevated concentrations of gross beta activity (primarily $^{90}$Sr and $^{90}$Y) continued to be measured in groundwaters immediately downgradient of the Nitrate Plant (7.3 kBq/L). Operations in the Nitrate Plant compound in 1953-54 led to several releases of highly radioactive waste solutions, and subsequent migration of $^{90}$Sr. The “Wall and Curtain” passive groundwater treatment facility removes $^{90}$Sr from the groundwaters downgradient of the Nitrate Plant. This reduces the groundwater concentrations of gross beta from hundreds of Bq/L upgradient of the treatment system to roughly 0.3 Bq/L in the system’s effluent, which is discharged to Lower Bass Creek. It should be noted, however, that groundwater sampling carried out around the Wall and Curtain treatment system has revealed that a small part of the plume has been bypassing the system in recent years. In 2013, attempts were made to re-align the plume and an evaluation of the distribution of $^{90}$Sr across the face of the Wall and Curtain and of the bypass is planned, in order to confirm the effectiveness of changes made to realign the plume. Elevated concentrations of gross beta also continued to be measured in groundwaters below the Thorium Pit in 2013 (212 Bq/L), located adjacent to the Nitrate Plant. Surface water from these two source areas flows through Lower Bass Creek (LBL) and in 2012 the concentrations of gross beta, although still low (3.2 Bq/L), have continued the slow increase that began in 2004 – 2005 (Figure 7). The current concentration of gross beta (half of which is $^{90}$Sr) is a very small fraction of the benchmark value (183 Bq/L). Further along this drainage system (in Maskinonge Lake) the beta activity concentrations are close to background (~0.1 Bq/L). In terms of the potential impacts to members of the public, releases of gross beta from the Maskinonge Lake basin were a small fraction of the applicable Derived Release Limit.

Figure 7 Gross Beta Concentrations in Surface Waters of the Maskinonge Lake Basin
A number of chlorinated volatile organic compounds are detected in the groundwaters along both the west and south perimeters of WMA C, including chloroform, trichloroethylene, 1,1,1-trichloroethane, and 1,1-dichloroethane. Monitoring in 2013 indicated general stability in their concentrations, and the compounds continued to be undetectable in surface waters downgradient of the solvent plume, with the exception of chloroform which was present at levels close to the detection level. This supports the expectation that upon reaching the surface water environment, the compounds rapidly volatilize, dispersing into the atmosphere and thereby limiting the potential for ecological effects.

Overall, for all of the contaminants of concern in the Maskinonge Lake basin, risks are judged to be low with stable or improving performance.

**Airborne Contaminants**

Throughout 2013, the predominant airborne emissions resulting from CRL operations continued to be mixed noble gases (primarily $^{41}$Ar), tritium, and sulphur dioxide. The primary sources of mixed noble gases (including $^{41}$Ar) from CRL are the NRU reactor stack that exhausts ventilation and cooling air from the NRU reactor, and the 61-metre stack that exhausts the $^{99}$Mo Processing Facility. Consistent with emissions from these sources, levels of mixed noble gases at off-site locations were similar to results in 2012. Monitoring of mixed noble gases confirmed that levels of radiation in the environment from CRL operations were below regulatory limits and below levels at which ecological effects could potentially occur. The impact of mixed noble gas contaminants on the environment is therefore characterized as being of low risk and stable.

The NRU reactor continued to be the main source of tritium at the CRL site. Although tritium emissions in 2013 were higher than in 2012, they were about three times lower when compared to average tritium emissions reported from 2006 to 2008, prior to the extended NRU shutdown. This decrease can be attributed to the replacement of the NRU heavy water moderator during August of 2010. Trends in ambient tritium in air around the CRL site in 2013 were consistent with emissions from the CRL site. The tritium concentrations in air at the site boundary monitoring locations (0.70 Bq/m$^3$) were distinguishable from natural background levels in Ontario, which range from 0.09 to 0.26 Bq/m$^3$. Concentrations at off-site monitoring locations (0.1 Bq/m$^3$) remained near the limit of detection. Levels of tritium in the environment from CRL operations were below regulatory limits and below levels at which ecological effects could potentially occur. The impact of airborne tritium on the environment is therefore characterized as being of low risk.

**Assessment of Dose to the Public**

The monitoring of environmental pathways conducted as part of the EMP was used to assess the radiation doses due to emissions from CRL, during 2013, to the most exposed members of the public (i.e. critical groups). Calculated doses were compared to the regulatory limit for effective dose to members of the public of 1 mSv in a year, and as required by the site licence, were used to verify that doses did not exceed 0.3 mSv in any period of 12 consecutive months.

Doses are based on environmental concentrations of radionuclides measured in the environment near critical group locations. The radionuclides included in the dose assessment are those that are
known or expected to be released from CRL and are detectable in the environment, or have the potential to contribute significantly to dose. The pathways included in the dose assessment are those that have the potential to contribute significantly to the dose to any critical group. Other radionuclides and environmental exposure pathways for which the dose contribution is negligible were not included in the dose assessment (e.g. ingestion of well water).

The doses to critical groups from both air and liquid effluent pathways for 2013 and the previous five years are summarized in Table 1 and Figure 10.

The final dose is broken up into two components:

- The dose from **air effluent pathways**, which include air inhalation and immersion, consumption of garden produce and terrestrial animal produce (i.e. milk, beef, pork, and wild game), is portrayed in Figure 8.

- The dose from **liquid effluent pathways**, which include ingestion of water, consumption of fish, and external exposure to beach sand, is portrayed in Figure 9.

In 2013, the total estimated doses to individual adult and infant members of the public for all air effluent exposure pathways, as summarized in Table 1, represented 5.7% and 6.9% of the regulatory public dose limit of 1 mSv, respectively. The total estimated dose to individual adult and infant members of the public for all liquid effluent exposure pathways, as summarized in Table 1, represented 0.017% of the regulatory public dose limit of 1 mSv. As expected, the dose from liquid effluent exposure pathways made up a very small portion of the total dose to the public. These doses are slightly higher than those reported in 2012. While the results of effluent monitoring in 2013 did not show an increase in total noble gas emissions from the site, it is possible for a higher dose to be measured in Balmer’s Bay if, in 2013, meteorological conditions (i.e. wind speed, wind direction, and stability class) caused the airborne noble gas plume to travel towards Balmer’s Bay more frequently than expected.

The total doses as a percent of the public dose limit presented in Table 1 were compared to the 2013 results of the Effluent Verification Monitoring Program reported in [6] as a verification of the adequacy of effluent monitoring. The results were very similar, with an average of 6.37% of the DRL for airborne emissions, and 0.07% of the DRL for liquid emissions.

**Conclusion**

The EMP met its objectives. During the 2013 calendar year, over ten thousand measurements of radioactive and non-radioactive contaminants were completed on samples collected from several hundred locations at and around the CRL site. These metrics provide evidence that the EMP continues to supply valuable information on the effectiveness of AECL’s Environmental Protection Program with regards to the management of emissions from CRL operations.
Figure 8 Conceptual Diagram of Exposure Pathways from CRL Airborne Emissions  
(Note: Doses are Expressed as a Percentage of the Public Dose Limit of 1 mSv per year)

Figure 9 Conceptual Diagram of Exposure Pathways from CRL Liquid Emissions  
(Note: Doses are Expressed as a Percentage of the Public Dose Limit of 1 mSv per year)
Figure 10: Dose Trends from 2006 to 2013

- Effective Dose (mSv/a)
- Airborne effluent exposure pathway
- Liquid effluent exposure pathway
References


