Date: Feb 13, 2018

From: Canadian Environmental Law Association (Kerrie Blaise)

To: Lucia Abellan, Environmental Assessment Officer
Canadian Nuclear Safety Commission

By email: cnsc.ea-ee.ccsn@canada.ca

Subject line: NPD Closure Project

CEAA Reference number: 80121

Comments:

Dear Ms. Abellan,

In response to the CNSC's updated invite for comments (dated Nov 28, 2017), please find attached the Canadian Environmental Law Association's submission regarding the draft environmental impact statement for the in-situ decommissioning of the Nuclear Power Demonstration Closure Project, located in Rolphton Ontario.

Please let me know if there are any questions. Thank you for this comment opportunity.

Regards,

Kerrie

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Kerrie Blaise, Counsel
Canadian Environmental Law Association

Submission to the CNSC on CNL's Draft Environmental Impact Statement
Re: Nuclear Power Demonstration Closure Project (Ref No. 80121)

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SUMMARY OF RECOMMENDATIONS

Recommendation No.1

The Draft Environmental Impact Statement (EIS) should provide the criteria used to identify alternative means as unacceptable, how these criteria were applied, and how the criteria were used to examine the environmental effects of each of the alternative means to identify the preferred means. This should be provided with sufficient detail to allow for meaningful feedback from the public.

Recommendation No. 2

Canadian Nuclear Laboratories (CNL) should describe and demonstrate how risks to environmental components were weighed against each other in the comparative evaluation of alternative means and explain how short-term versus long-term impacts were weighted in its evaluation.

Recommendation No. 3

CNL should explain why its comparative evaluation of alternative means, with respect to each of the environmental components, deviates from internationally relied upon perception of relative risk for each of the alternative means considered.

Recommendation No. 4

CNL should explain why it considers the storage of waste at the CRL site, or any other CNSC approved storage or disposal facility, to pose a greater relative risk to the environmental components than the ISD means.

Recommendation No. 5

CNL should meet the regulatory requirements for an NSDF for the NPDWF site prior to gaining approval for the ISD strategy and, meet or exceed the standards and best practices set by the IAEA and other international jurisdictions with extensive experience in decommissioning nuclear facilities.

Recommendation No. 6

It is not possible to determine whether the calandria should be removed or left in place as CNL has not provided an objective evidence-based analysis of available options. CNL should weigh the various advantages and disadvantages of the alternative means against each other for the specific circumstances of the NPDWF site, provide a coherent explanation of the risks posed to the environmental components by each of the strategies, and provide a rationally based explanation as to why a specific strategy is preferred.

Recommendation No. 7

It is recommended that the federal government conduct a strategic environmental assessment, under the proposed Bill C-69, *An Act to enact the Impact Assessment Act* once adopted. A strategic EA will allow Canada to develop a comprehensive and publicly informed nuclear waste management policy for all types of nuclear waste in Canada.

Recommendation No. 8

CELA recommends that the Ontario Drinking Water Advisory Council/ Advisory Council on Environmental Standards limit for tritium in drinking water be used for evaluation in this EIS - given the possibility of more stringent limits being established by the provincial government and included in federal guidelines. This would contribute both to an assessment against the more health protective standards, and ensure the current project is assessed against a long-term health standard that may well be adopted within the impacting life-span of this project.

SUMMARY OF INFORMATION REQUESTS AND DEFICIENCIES

IR#	Information Request
#1	Provide a description of the sustainability-based criteria that were used to evaluate and compare the alternative means as well as the preferred option.
#2	Describe how the technical feasibility and economic feasibility criteria constitute relevant sustainability considerations.
#3	Provide a comparative evaluation of the alternative means in terms of their relative contributions to sustainability.
#4	Provide a description of the process by which consideration for sustainability was incorporated throughout the assessment and design of the preferred option.
#5	Provide sufficient quantitative information in the alternative means analysis to clearly demonstrate to the public how and why the preferred option was identified.
#6	Provide a detailed breakdown of costs for all phases of the project (decommissioning, institutional control, and post-institutional control) to enable a comprehensive comparative analysis of the alternative means against the economic feasibility criterion.
#7	Describe how the notion of adaptive management capacity was applied in (a) the comparative analysis of alternative means and (b) the assessment and design of the preferred in-situ decommissioning option.
#8	Describe how reversibility, retrievability, diversity, and redundancy were incorporated in (a) the comparative evaluation of alternative means and (b) the assessment and design of the preferred in-situ decommissioning option.
#9	Define the 'defence-in-depth' principle and explain how it was incorporated in the EIS and comparative assessment of alternative means.
#10	Provide a sound justification for using the 50-year timeframe as the basis for asserting that the in-situ decommissioning technology is proven technology.

#11	Provide sufficient data to demonstrate the rate of deterioration of the engineered barriers in relation to the rate at which low- and intermediate-level radioactive waste decays over time.
#12	Provide a sound rationale for discontinuing active controls for surface water and groundwater quality monitoring during the Post-Institutional controls stage.
#13	Explain how the monitoring data collected during the Decommissioning Execution and Institutional Controls phases will be used during the initiative of the Post-Institutional Controls stage. Include a description of the internal process that will be established to ensure this happens.
#14	Describe how the concept of 'rolling stewardship' will be incorporated in monitoring plans.
#15	Provide an in-depth quantitative analysis of cumulative effects that covers: • the long-term timeframe of the project, including all three project phases and >2120; • the interactions among the environmental effects of the project, and past and future projects and activities; • the synergistic effects of the project, and past and future projects and activities; and • how individual thresholds were identified and considered for surface water and groundwater VC
#16	In absence of an in-depth investigation of cumulative effects, provide a sound rationale to ensure the public that the proposed project will not – in combination with other projects – have adverse effects on vital drinking water sources over the lifetime of the project.
#17	The following omissions/errors in Tables referenced in the draft EIS were noted and require rectifying: • Tables 8.3-8 and 8.3-9 should be labelled "radionuclide concentrations" rather than radiation contamination • In Table 4.44-1, Zircalloy is misspelled

#18	The following technical issues were provided little to no description or analysis in the draft EIS and CELA requests they be remedied: • No technical description of the engineered cover system • No technical description of the proposed grout and its properties • No discussion of the doses received during proposed dismantling and grouting • No discussion of hydrogen releases from grout-aluminium reactions • No discussion of collective doses, and • Little discussion of organically bound tritium
#19	AECL (2012) has stated that the 30-year post-shutdown total nuclide inventories were underestimated by factors of 1.46 and 1.26 for the pressure tubes and calandria tubes, respectively. It is not stated by CNL whether these factors have been taken into account in its nuclide inventories.
#20	At this facility, tritium is the most important nuclide, in terms of hazard from radiation exposures for the first 140 years. CNL should provide further analysis and justification for its conclusions in the EIS, taking into account tritium levels and emissions from this facility.
#21	Provide a plan to forthwith cease ongoing tritium emissions to air and discharges to water, due to the hazard posed to local populations.
#22	Estimate the amount of tritium contained in the concrete outside the reactor vault.
#23	Calculate the predicted nuclide concentrations in 100 years' time (ie. as reduced via decay).
#24	Confirm whether CSA's Standard 292.0-14 (*General principles for the management of radioactive waste and irradiated fuel*) (2014b) have been implemented.
#25	Provide the measurements and details used to inform computer modelling.
#26	Provide an explanation why overall amounts of tritium have not declined over time.
#27	Conduct a cumulative effects analysis considering the combined effects from the proposed Rolphton entombment, the proposed Chalk River near-surface facility and

	the remaining Chalk River facilities, and their impacts on the Ottawa River, its downstream residents and ecosystems.
#28	Confirm upon what basis it is known that the grout will perform its function, absent a finalized formula, and whether the grout formula proposed will provide a necessary degree of flowability to ensure (1) voids and sufficiently filled, (2) desired strength and long term stability is achieved and (3) containment mobility is minimized.
#29	Confirm whether monitoring activities and programming, which are to be developed at a later date, will be open to the public for review and comment.
#30	Provide an update on the Historical Site Assessment and comment on (1) the extent to which the suggestions for 'future study' or gaps identified will be responded to and (2) how, given the identified data gaps, adequate contingency planning for unexpected wastes, hazards or structural defects can be established.
#31	Demonstrate how the proposed ISD project meets requisite criteria for the creation of a NSDF, and given the ongoing review of CNL's proposed NSDF, indicate to what extent the cumulative effects or the combined effect of having two NSDFs within a 30 km of each other has factored into CNL's modelling, planning and justification for the project.
#32	Provide sufficient data demonstrating that the effects resulting from significant loading of grout on site has been studied with regard to effects on surrounding soil structure and hydrology.

INTRODUCTION

The Canadian Environmental Law Association ("CELA") submits this report in response to the updated Public Notice dated November 28, 2017 requesting comments on the draft environmental impact statement ("draft EIS") for the in-situ decommissioning of Canadian Nuclear Laboratories ("CNL") Nuclear Power Demonstration Closure Project in Rolphton, Ontario.[1]

CELA is a non-profit, public interest law organization. CELA is funded by Legal Aid Ontario as a speciality legal clinic to provide equitable access to justice to those otherwise unable to afford representation for their environmental problems. For nearly 50 years, CELA has used legal tools to advance the public interest, through advocacy and law reform, in order to increase environmental protection and safeguard communities across Canada. CELA has been involved in number of nuclear facility relicensing and regulatory matters before the Canada Nuclear Safety Commission ("CNSC"), from the relicensing of nuclear generating stations (ie. Point Lepreau; Darlington) to annual regulatory oversight reporting hearings (ie. use of nuclear substances; uranium processing facilities).

Scope of Review

Part I of this report examines the compliance and adequacy of the proposed project in conjunction with the requirements of the *Canadian Environmental Assessment Act, 2012* (CEAA, 2012). In particular, CELA has examined whether the project and its assessment adequately consider the environmental effects of the project, their significance, mitigation measures, adequacy of proposed follow-up programs and description of purpose of the project, alternative means of carrying out the project and other factors listed under section 19 of CEAA, 2012.

Part II reviews the assessment of alternative means for decommissioning undertaken by CNL under the current regulatory framework concerning the decommissioning of nuclear facilities as compared to the regulatory requirements developed by the International Atomic Energy Agency ("IAEA") and implemented in certain jurisdictions.

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[1] Canadian Environmental Assessment Agency "Nuclear Power Demonstration Closure Project – Public Comment Period on Canadian Nuclear Laboratories' Draft Environmental Impact Statement," (28 Nov 2017) online: http://www.ceaa-acee.gc.ca/050/document-eng.cfm?document=121060; Canadian Nuclear Laboratories, "Environmental Impact Statement , Nuclear Power Demonstration Closure Project" (September 2017, Revision 0) online: http://www.ceaa-acee.gc.ca/050/documents/p80121/121057E.pdf [**Draft EIS**]

Part III examines the deficiencies and omissions contained in CNL's draft EIS as it relates to human health, the environment and safety matters. Lastly, Part IV seeks to review international lessons learned in the field of in situ decommissioning and analyze their inclusion or consideration in the draft EIS.

Pursuant to our Participant Funding Program application, CELA has engaged the professional services of Dr. Tanya Markvart and Dr. Ian Fairlie. Parts I and III of this report provide their expert recommendations.

I. SUSTAINABILITY ANALYSIS

1. Introduction

CELA undertook a sustainability-based evaluation of the CNL's draft Environmental Impact Statement for Nuclear Power Demonstration Closure Project.[2] Our analysis rests on the purpose of the *Canadian Environmental Assessment Act, 2012* ("CEAA, 2012"),[3] as set out in sections 4(1)(b), (h), and (i):

> 4(1) The purposes of this Act are
>
> (b) to ensure that designated projects…are considered in a careful and precautionary manner to avoid significant adverse environmental effects;
>
> (h) to encourage federal authorities to take actions that promote sustainable development in order to achieve or maintain a healthy environment and a healthy economy; and
>
> (i) to encourage the study of the cumulative effects of physical activities in a region and the consideration of those study results in environmental assessments.

Our evaluation concentrated on the following essentials of incorporating appropriate attention to sustainable development concerns in environmental assessment (EA):

- Evaluation criteria and process (see Section 2),
- The precautionary principle and associated concepts (see Section 3),
- Long-term monitoring (see Section 4), and
- Cumulative effects (see Section 5).

In the following sections, we briefly describe the key deficiencies in CNL's EIS with respect these sustainability matters. We end with a summary of our Information Requests, which would enhance our understanding of CNL's EIS in these regards (see Table 2).

2. CNL's Consideration of Sustainability

Our analysis was framed by best practices in sustainability-based EA, which have been established by practitioners and scholars in the field (see Gibson, 2005; Gibson, 2017; Pope & Grace, 2006). In previous EIS public comment processes for proposed nuclear waste

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[2] Draft EIS, *supra* note 1

[3] *Canadian Environmental Assessment Act, 2012* (SC 2012, c 19 s 52)

management projects, we provided in-depth explanations of how proponents should fulfill their obligations under CEAA in this regard (e.g., Markvart, 2014). In the following sub-sections, we highlight some key areas where CNL failed to adequately consider sustainability concerns in the EIS of the NPD Closure Project.

2.1 CNL's Evaluation Criteria and Process

Gibson (2005) provides a comprehensive set of sustainability criteria for application in EA. They are rooted in a fundamental concern for the interconnections and interdependencies within and between human and biophysical systems, multiple scales, and present and future generations, especially with respect to effects on inter- and intragenerational equity, livelihood sufficiency, ecological system integrity, and governance capacity. In addition, Gibson explains the process by which sustainability considerations should be incorporated throughout the EA process to select and evaluate the best option.

An adequate consideration of sustainability in EA should demonstrate that:

- the preferred option emerged from a comparative evaluation of options in light of their relative contributions to sustainability,
- further evaluation of the preferred option explicitly incorporated sustainability concerns throughout, and
- sustainability considerations influenced the design of the preferred option.

The proponent must clearly demonstrate that the preferred option would contribute social, economic, and environmental benefits to society while avoiding significant adverse effects.

In its evaluation of alternative means, CNL defined and used two criteria (technical feasibility and economic feasibility) as well an assessment of potential effects on Valued Components (VCs). But CNL did not discuss the relative contributions of the alternative means to sustainability. Nor did CNL explain the process by which it incorporated sustainability concerns in its evaluations. A clear demonstration to the public that the in-situ decommissioning option is the best option in light of contributions to sustainability requires the following additional information:

- a description of the sustainability-based criteria that CNL adopted to evaluate and compare the alternative means;
- a description of how the two criteria (technical feasibility and economic feasibility) and VCs approach that CNL used to evaluate and compare the alternative means constitute relevant

sustainability considerations;

- a description of the process by which CNL incorporated consideration for net sustainability contributions in the alternative means assessment; and
- a description of the relative contributions to sustainability of the alternative means.

It is important to note that CNL's analysis of alternative means was too qualitative to give an accurate and comprehensive portrait of the relative contributions of each alternative to sustainability. For example, CNL's assessment of potential effects provided no dose estimates and no quantitative data on the non-radiological effects of each alternative.

In addition, CNL's evaluation of alternative means against the economic feasibility criteria did not provide a detailed breakdown of costs to enable a comprehensive comparative analysis. CNL's evaluation focused solely on the Decommissioning phase, which excluded the costs of subsequent phases. Given that the project will be radioactive for thousands of years, it is important for CNL to ensure the public that it is planning for these costs and has the resources in place to respond effectively in perpetuity. Otherwise, the burden of these costs will be placed upon future generations who are not responsible for the nuclear waste and its associated hazards.

Finally, CNL did not show how sustainability concerns influenced all components of the assessment of the preferred in-situ decommissioning option, including the following analyses: environmental effects, accidents and malfunctions, cumulative effects, residual effects analysis, and effects of the environment on the project. The public must have a clear understanding of how the results of these analyses influence the project's contributions to sustainability over the long term.

3. CNL's Consideration of the Precautionary Principle

The purpose of CEAA 2012 to ensure that designated projects are considered in a careful and precautionary manner applies to all aspects of the assessment process. One overarching concept central to a precautionary approach in nuclear waste management is 'adaptive management capacity', which was incorporated in previous EIS Guidelines for the management of low- and intermediate-level radioactive waste (e.g., CEAA 2009) under CEAA. The concept of adaptive management has been widely adopted in energy and natural resource management sectors as an iterative approach to management in the face of

- scientific uncertainty and human error;
- technological innovations and/or advances in scientific understanding;

- new technical or scientific information regarding the design and operation of a project;
- changes in social and political opinion;
- changes in policy and regulatory frameworks, including safety standards; and
- unforeseen events (including natural disasters, malfunctions, accidents and malevolent acts).

Associated design concepts that may increase the level of adaptive management capacity in nuclear waste management facilities include reversibility, retrievability, diversity and redundancy (see OECD, 2001, 2012).

Reversibility is the possibility of reversing one or a series of decisions taken during the lifetime of a nuclear waste management project. Reversal is the actual action of changing a previous decision. The associated implication for design include making provisions for reversal should it be required. Retrievability denotes the action of recovery of the waste, which enhances the reversibility of decisions by providing an additional degree of flexibility.

Diversity and redundancy are major sources of adaptive management capacity (see Walker & Salt, 2006). The diversity requirement seeks to ensure that decision makers evaluate and compare a range of different alternatives that could achieve the same objective. If the preferred option fails there should be sufficient knowledge about other options to make adaptation feasible. The concept of redundancy is central to enhancing the safety and reliability of complex technologies. An element of a system is redundant if there are backups to do its work if it fails.

It is unclear how the notion of adaptive management capacity (including the associated concepts of reversibility, retrievability, diversity and redundancy) influenced CNL's evaluation of alternative means, its assessment of the preferred in-situ decommissioning option, and its long-term monitoring program. It is in the public's best interest to have a good understanding of how CNL incorporated and operationalized the concept of adaptive management capacity throughout the EIS as it is critical to the long-term safety of the proposed project.

The inadequacy of CNL's assessment with respect to how it considered adaptive management capacity is significant because CNL's conclusion that the NPD Closure project will have no adverse residual effects rests in part on its assertion that the engineered barriers (concrete walls, grout backfill, concrete slab) will adequately contain and isolate the radioactive waste for thousands of years into the future, and failure of any of the engineered barriers will not compromise the performance of the system (see CNL 2017, pp. 60-61). To CNL's credit, it incorporated the defence-in-depth principle in its postclosure safety analysis, but CNL did not define and operationalize this principle in the EIS. Moreover, it is unclear how this principle influenced the comparative assessment of alternative means.

In addition, CNL rests its safety case in part on the idea that the in-situ decommissioning option represents proven technology because it has been in use for 50 years. Given that the proposed technology must isolate and contain radioactive waste for thousands of years into the future, and given the uncertainties and risks associated with the project, it seems unlikely that 50 years is enough time to prove the safety and technological efficacy of the in-situ decommissioning method of managing long lived radioactive waste. CNL must provide a sound justification for how the proposed in-situ decommissioning option has been proven for long-lived radioactive waste.

4. CNL's Long-Term Monitoring Plans

Long-term monitoring is an essential element of adaptive management capacity. Active monitoring of key indicators generates information about the long-term impacts of a project, which can be understood in light of sustainability concerns (see Contador, 2005). In Section 5, CNL sets out the temporal boundaries for the EA: Decommissioning Execution (2019-2020), Institutional Controls (2020-2120), and Post-Institutional Controls (>2120). The temporal scope of CNL's 'follow-up monitoring program', however, covers only the decommissioning and institutional controls phases.

Critical public concerns remain unaddressed by the short-sighted timeframe of CNL's follow-up monitoring program. Chief among these concerns is the long-term integrity of the grout backfill, concrete slab, and other 'in-design mitigation measures' for the NPDWF, as CNL lists in sub-section 4.1.1 (see CNL 2017, p. 92). CNL rightly admits that these 'engineered barriers' will degrade over time. But CNL assumes that this deterioration will not undermine the integrity of the system because, as CNL states, "…the effectiveness of the engineered barriers over time and as they progressively degrade is adequate to protect the ever-decreasing radiological hazard at any given point in time" (see p.61).

CNL does not provide sufficient data to demonstrate that the rate of deterioration of the engineered barriers and the rate at which low- and intermediate-level radioactive waste decays over time will occur in tandem to the extent that the isolation and containment functions of the engineered barriers will effectively function for tens of thousands of years into the future.

Hundreds of thousands of people rely (and will continue to rely) on the surface water of the Ottawa River and the groundwater systems directly below and surrounding the NPD site for drinking water. CNL rightly admits that the in-situ decommissioning design will potentially impact groundwater and surface water quality over the lifetime of the project. The public, therefore, must be reassured that long-term monitoring plans and mitigation measures are in place – beyond 2120 – to verify the accuracy of CNL's EA predictions and determine the effectiveness of the engineered barriers/in-design mitigation measures.

CNL must provide a sound rationale for discontinuing active controls for surface water and groundwater systems monitoring during the post-institutional control stage (>2120). In addition, CNL must provide data to support its argument that the engineered barriers will continue to function effectively as they degrade relative to the rate of decay of low- and intermediate-level radioactive waste over tens of thousands of years.

Indeed, at this juncture in the EA process CNL has an opportunity to incorporate the concept of 'rolling stewardship' in planning for the long-term monitoring and safety of the NPD Closure project. As the Canadian Coalition for Nuclear Responsibility explains, rolling stewardship involves

- plans for the accurate transmission of information from one generation to the next;
- plans for the transfer of responsibility from one generation to the next, e.g., a 'changing of the guard' every 20 years;
- plans for the recharacterization of the waste when necessary;
- plans to rapidly detect and correct any leakages or other problems;
- plans for the retrieval of waste as appropriate; and
- plans for continual adaptive management and monitoring.

In sub-section 9.1.2.3 of the EIS, CNL states that recommendations will be made on how the monitoring data collected during the Decommissioning Execution and Institutional Controls phases can be used during the initiation of the Post-Institutional Controls stage. This statement evidences some appropriate foresight with respect to the transmission of information from one generation to the next. CNL, however, does not provide guidelines that clearly set out the process by which these recommendations will be made.

Given that the waste in the NPD Closure project will be radioactive for many thousands of years, CNL must provide appropriate guidelines that ensure rolling stewardship with respect to transmission of information, transfer of responsibility, recharacterization of waste, mitigation of problems, retrieval of waste as appropriate, and continual adaptive management.

5. CNL's Consideration of Cumulative Effects

In sub-section 9.12.2 of the EIS, CNL states that, "Since the project has no residual effects, cumulative effects assessment is therefore not required" (CNL 2017, p. 524). CNL then continues to provide a discussion about the potential cumulative effects of two dam projects upstream of the NPD site and several projects that may take place at the CRL site.

Given the uncertainties and risks surrounding the effects of the NPD Closure project on vital surface water and groundwater resources over millennia, CNL must provide an in-depth quantitative analysis of cumulative effects that covers the following concerns, as per CEAA's published guidelines on addressing cumulative environmental effects:

- the long-term timeframe of the project, including all three project phases and >2120;
- the interactions among the environmental effects of the project, and past and future projects and activities;
- the synergistic effects of the project, and past and future projects and activities; and
- how individual thresholds were identified and considered for surface water and groundwater VCs.

In absence of such an in-depth investigation of cumulative effects, CNL must provide a sound and detailed rationale to ensure the public that the NPD Closure project will not – in combination with other projects – have adverse effects on vital drinking water sources over the lifetime of the project.

In Section 6 below we provide a summary of the major deficiencies that we identified with respect to the above described components of CNL's EIS. We end with a table that presents our associated Information Requests.

6. Summary of Deficiencies and Information Requests

CNL defined and used two criteria (technical feasibility and economic feasibility) to evaluate the alternative means. But CNL did not incorporate the following sustainability considerations in its evaluation:

- An explanation of how technical and economic feasibility criteria constitute relevant sustainability concerns.
- A description of the sustainability-based criteria that were used evaluate and

compare the alternative means.

- An explanation of the relative contributions of the alternative means to sustainability.
- An explanation of the process by which it incorporated sustainability concerns in its evaluations.
- A clear demonstration of how sustainability concerns influenced all components of the assessment of the preferred option.

CNL's analysis of alternative means was too qualitative to give an accurate and comprehensive portrait of the relative contributions of each alternative to sustainability.

CNL's evaluation of alternative means against the economic feasibility criteria did not provide a detailed breakdown of costs to enable a comprehensive comparative analysis, and it focused solely on the Decommissioning Execution phase.

CNL considered adaptive management in the design of its monitoring program. It is unclear, however, how the notion of adaptive management capacity and associated concepts influenced CNL's evaluation of alternative means as well as its assessment of the preferred option.

CNL incorporated the defence-in-depth principle in its postclosure safety analysis, but CNL did not define and operationalize this principle in the EIS. Moreover, it is unclear how this principle influenced the comparative assessment of alternative means.

CNL rests its safety case in part on the idea that the in-situ decommissioning option represents proven technology because it has been in use for 50 years. But CNL does not provide a sound justification for using this 50-year timeframe, especially in light of the long-term nature of the NPD Closure project, as the basis for its assertion that the in-situ decommissioning technology has been proven.

CNL's monitoring plans for surface water and groundwater quality do not extend into the post-institutional control phase of the NPD Closure project. CNL must provide a rationale for discontinuing active controls for groundwater and surface water quality monitoring during the post-institutional control stage. At this juncture in the EA process, CNL has an opportunity to incorporate the concept of 'rolling stewardship' in planning for the long-term monitoring and safety of the project.

CNL does not provide sufficient data to demonstrate that the rate of deterioration of the engineered barriers and the rate at which low- and intermediate-level radioactive waste decays over time will occur in tandem to the extent that the isolation and containment functions of the engineered barriers will effectively function for tens of thousands of years into the future.

Given the uncertainties and risks surrounding the effects of the NPD Closure project on vital surface water and groundwater resources over millennia, CNL must provide an in-depth quantitative analysis of cumulative effects. In absence of such an in-depth investigation of cumulative effects, CNL must provide a sound and detailed rationale to ensure the public that the NPD Closure project will not – in combination with other projects – have adverse effects on vital drinking water sources over the lifetime of the project.

To clearly demonstrate to the public that the in-situ decommissioning option is the best option, CNL must respond to the following Information Requests (see Table 1).

Table 1. Information Requests

IR#	Information Request
#1	Provide a description of the sustainability-based criteria that were used to evaluate and compare the alternative means as well as the preferred option.
#2	Describe how the technical feasibility and economic feasibility criteria constitute relevant sustainability considerations.
#3	Provide a comparative evaluation of the alternative means in terms of their relative contributions to sustainability.
#4	Provide a description of the process by which consideration for sustainability was incorporated throughout the assessment and design of the preferred option.
#5	Provide sufficient quantitative information in the alternative means analysis to clearly demonstrate to the public how and why the preferred option was identified.
#6	Provide a detailed breakdown of costs for all phases of the project (decommissioning, institutional control, and post-institutional control) to enable a comprehensive comparative analysis of the alternative means against the economic feasibility criterion.

#7	Describe how the notion of adaptive management capacity was applied in (a) the comparative analysis of alternative means and (b) the assessment and design of the preferred in-situ decommissioning option.
#8	Describe how reversibility, retrievability, diversity, and redundancy were incorporated in (a) the comparative evaluation of alternative means and (b) the assessment and design of the preferred in-situ decommissioning option.
#9	Define the 'defence-in-depth' principle and explain how it was incorporated in the EIS and comparative assessment of alternative means.
#10	Provide a sound justification for using the 50-year timeframe as the basis for asserting that the in-situ decommissioning technology is proven technology.
#11	Provide sufficient data to demonstrate the rate of deterioration of the engineered barriers in relation to the rate at which low- and intermediate-level radioactive waste decays over time.
#12	Provide a sound rationale for discontinuing active controls for surface water and groundwater quality monitoring during the Post-Institutional controls stage.
#13	Explain how the monitoring data collected during the Decommissioning Execution and Institutional Controls phases will be used during the initiative of the Post-Institutional Controls stage. Include a description of the internal process that will be established to ensure this happens.
#14	Describe how the concept of 'rolling stewardship' will be incorporated in monitoring plans.
#15	Provide an in-depth quantitative analysis of cumulative effects that covers: • the long-term timeframe of the project, including all three project phases and >2120; • the interactions among the environmental effects of the project, and past and future projects and activities; • the synergistic effects of the project, and past and future projects and activities; and • how individual thresholds were identified and considered for surface

	water and groundwater VC
#16	In absence of an in-depth investigation of cumulative effects, provide a sound rationale to ensure the public that the proposed project will not – in combination with other projects – have adverse effects on vital drinking water sources over the lifetime of the project.

II. ASSESSMENT OF ALTERNATIVES

This section of CELA's submission reviews the assessment of alternatives means for decommissioning the Nuclear Power Demonstration Waste Facility ("NPDWF") undertaken by Canadian Nuclear Laboratories ("CNL") under the current regulatory framework concerning the decommissioning of nuclear facilities as compared to the regulatory requirements developed by the International Atomic Energy Agency ("IAEA") and implemented in certain jurisdictions.

1. The Selection of In-situ Decommissioning

According to the Draft EIS,[4] the preferred means of carrying out the decommissioning of NPDWF is In-situ decommissioning ("ISD"), where the source term will be isolated inside the below grade structure and systems to allow for continued radioactive decay. The draft EIS references the following advantages of ISD:[5]

- Reduced risk for radiological and industrial hazards exposure to workers meets the As Low As Reasonably Achievable ("ALARA") principle for worker protection
- Reduced transport/waste handling risks to the public and environment
- Effective reduction of the nuclear liability (e.g., eliminates interim waste storage at CRL)
- Eliminates the risk associated with multiple handling of waste packages to and from interim storage and final disposal
- Lowest cost option for the Canadian tax payer
- Allows for the early release of non impacted NPD property for alternate uses.

According to the EIS, the disadvantages of ISD include:

- Additional long term monitoring of the impacted area

Following ISD, institutional controls and surveillance activities will be required to monitor environmental performance of the entombed material at the NPD site.

The proponent's basis for selecting ISD, as the preferred means of carrying out the project rested on the analysis of and elimination of three other alternatives:

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[4] Draft EIS, *supra* note 1, pg. 4-11.

[5] Titterington, S. 2016. *Environmental Assessment (and/or Environmental Effects Review): Project Description – NPD Closure Project.* 64-509200-ENA-003. Prepared for CNL. March. Page 3-2.

1. Continued Storage with Surveillance (SwS).
    a. this approach involves continuing to defer decommissioning by maintaining the NPDWF in the SwS phase, thereby allowing for further radioactive decay.
    b. it is used as a baseline case against which the other alternative means are compared.
2. Partial Dismantling and Removal
    a. Partial removal of the source term (i.e., reactor systems and components) for interim storage at an alternate CNL site until final disposal options are available.
3. Full Dismantling and Removal
    a. Full dismantling and removal of all systems, structures and components for interim storage at an alternate CNL site until final disposal options are available.

The three alternatives were analysed based on their relative risk compared to continued SwS and their absolute risk during the three decommissioning phases, Decommissioning Execution, Institutional Controls, and Post-Institutional Controls. The five criteria considered included, Environmental Effects, Miscellaneous Physical Effects, Socioeconomic Effects, Effects on Aboriginal People, and Health Effects (Normal). The results were summarised in three separate tables (4.2-2, 4.2-3, and 4.2-4) corresponding to each of the three decommissioning phases.

2. Insufficient Detail in the Alternative Means Analysis

While the three tables do illustrate the result of the alternatives means analysis in a clear and concise manner, the section, and the draft EIS in general, does not provide a sufficiently detailed explanation of how the analysis of alternative means was conducted or the basis for the conclusions reached. This undermines the opportunity of stakeholders to assist the CNSC in it decision because it does not allow for meaningful input on the matter.

The Generic Guidelines for the Preparation of an Environmental Impact Statement indicates that:[6]

> …the EIS should identify and consider the effects of alternative means of carrying out the project that are technically and economically feasible as described in appendix A, section A.3.2 Alternative means for carrying out the project, of the CNSC's REGDOC-2.9.1…

[6] Canadian Nuclear Safety Commission (CNSC), *Generic Guidelines for the Preparation of an Environmental Impact Statement pursuant to the Canadian Environmental Assessment Act, 2012*, Ottawa, Canada, 2016. <online: http://nuclearsafety.gc.ca/eng/pdfs/Environmental-Assessments/CEAA-2012-Generic-EIS-Guidelines-eng.pdf.>

According to the CNSC's REGDOC 2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures*:[7]

> The EIS should…describe the environmental effects of each alternative means. The criteria used to identify alternative means as unacceptable, and how these criteria were applied, should be described, as should the criteria used to examine the environmental effects of each remaining alternative means to identify the preferred alternative.

For further guidance, REGDOC 2.9.1 directs a proponent to "Addressing "Purpose of" and "Alternative Means" under the *Canadian Environmental Assessment Act, 2012*",[8] which stipulates:

> To identify a preferred means among the alternative means of carrying out the designated project, the proponent should:
>
> - determine and apply criteria to examine the environmental effects of the technically and economically feasible alternative means.
> - compare the alternative means on the basis of environmental effects, as well as technical and economic feasibility; and
> - identify the preferred alternative means based on the relative consideration of environmental effects, and of technical and economic feasibility.
>
> If a preferred means is selected, the analysis and the rationale for the choice should be explained from the perspective of the proponent, and be documented in the EIS in sufficient detail to provide context for public and technical comment periods during the project EA, and ultimately to allow the decision maker to understand the choice.

The alternative means analysis undertaken by CNL, found in Section 4.2 of the Draft EIS indicates that the relative risk to the valued components for the four alternative means chosen were assessed with respect to "1. continued SwS" as the baseline. The results of the assessment are presented in Tables 4.2-1 to 4.2-3. Unfortunately, as detailed by the rest of this section, the draft EIS does not provide any specific, known or assumed, adverse effects of the individual alternative means with respect to the environmental components selected. There is also no explanation of how these effects were compared to select a preferred alternative mean. Furthermore, the draft EIS provides no description of the severity of an environmental effect

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[7] CNSC, REGDOC-2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures*, Ottawa, Canada, 2016.

[8] CEAA, *Operational Policy Statement Addressing "Purpose of" and "Alternative Means" under the Canadian Environmental Assessment Act, 2012*, Ottawa, Canada, 2015.

CNL would deem unacceptable for a viable decommissioning strategy, nor the manner in which the alternative means were tested to determine their compliance with the selected criteria.

For example, the assessment for the relative risk to the aquatic environment during the post-institutional control phase indicates that the ISD strategy presents the least risk, followed by partial dismantling, with full dismantling and removal presenting the greatest relative risk. The draft EIS does not provide the risks each alternative is expected to pose, nor any of assumptions underlying the comparative assessment. Questions such as what characteristics of each of the alternative posed a risk to the aquatic environment, what time frame is being considered, or or what external factors were considered to exacerbate the risks? Without such detail, the public is left in the dark about what factors were considered relevant, what were deemed irrelevant and how they were measured and then weighed against each other for the proponent to come to its decision on a preferred decommissioning strategy.

In short, the information provided by CNL to describe its alternatives means assessment is insufficient for a member of the public, or indeed any person who did not conduct the analysis to provide any meaningful feedback on the analysis.

Recommendation No.1

The EIS should provide the criteria used to identify alternative means as unacceptable, how these criteria were applied, and how the criteria were used to examine the environmental effects of each of the alternative means to identify the preferred means. This should be provided with sufficient detail to allow for meaningful feedback from the public.

3. Inadequate Relative Consideration of Environmental Components of Alternative Means

As mentioned above, the Generic Guidelines suggest that the proponent identified the preferred alternative means based on the relative consideration of environmental effects, and of technical and economic feasibility. CNL has indicated that all the alternative means are technically and economically feasible, leaving the need to conduct an alternative means analysis for environmental components.[9] Unfortunately, the relative consideration of environmental components summarised in Tables 4.2-2, 4.2-3, and 4.2-4 leave several comparisons among the alternative means unaddressed or confusing.

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[9] Draft EIS, *supra* note 1, at pg. 4-6.

As also noted by CELA in its submission on the decommissioning of the Whiteshell reactor, CNL has not clarified did not clarify how its alternative means evaluation weighed the risk to different environmental components. Similar to the alternative means evaluation found in the draft EIS for the decommissioning of the Whiteshell reactor, CNL has used a relative risk scale with 'less risk than baseline' at the highest end, 'approximately same risk as baseline' in the middle or neutral point, and 'more risk than baseline' at the lowest end. Based on this scale, CNL has identified the most desirable alternative by determining which option received the greatest number of 'less risk than baseline' scores. This evaluation does not capture the complexities in the decisions that must be made in an alternative means assessment. [10]

Recommendation No. 2

CNL should describe and demonstrate how risks to environmental components were weighed against each other in the comparative evaluation of alternative means and explain how short-term versus long-term impacts were weighted in its evaluation.

4. Attributed Relative Risks Seemingly Contradict Established International Consensus

In addition to the simplistic weighing of risk to environmental components amongst the alternatives, the comparative level of risk attributed to the alternative means with respect to their environmental effects is confusing and seemingly contradictory to international standards.

For example, according to CNL's analysis, the in-situ decommissioning option would be the most favourable option in terms of radiation and radioactivity environment during the post-institutional control phase; while the full-dismantling and removal means would present a slightly greater risk than the baseline. This is confusing considering the full-dismantling and removal means would have dismantled and removed all radioactive material from the site during the decommissioning phase. As explained by CNL in the Draft EIS,[11]

> this [full-dismantling and removal] means involves removing all radioactive material from the site and storing it temporarily at another CNL facility (most likely CRL), until a final disposal location is available. The structures on site would then be demolished and removed from the site, along with any nuclear or hazardous waste. This would include the removal of the reactor and the associated systems. The site would be remediated

[10] CELA submission on Whiteshell WR-1 at pg. 37.
[11] Draft EIS, *supra* note 1, at pg. 4-6.

> following the removal of all structures including the ventilation stack. It has also been assumed that the waste will be stored off-site in containers within a building due to the lack of a disposal facility at the time of waste removal.

It is difficult to imagine a scenario where a remediated site, that no longer houses any radioactive material, nuclear or hazardous waste, could pose a greater risk compared to a scenario where all of the nuclear facilities, and nuclear and hazardous waste, are still present.

This finding also contradicts the recommendations of the International Atomic Energy Agency ("IAEA") and other jurisdictions that have decommissioning experience on the risk posed by the full-dismantling and removal means. IAEA Safety Reports Series No. 50, *Decommissioning Strategies for Facilities Using Radioactive Material*, list the advantages of immediate dismantling as including:[12]

(a) All radioactivity above specified levels is removed and properly disposed of or stored at an interim facility.
(b) The site may be used as soon as possible for other activities.
(c) The operating workforce, which is highly knowledgeable about the facility, is available to support (and possibly plan and carry out) the decommissioning activities.
(d) Potential limitation of the social impact of shutdown on the local community.
(e) Utilizing currently available waste disposal facilities removes any uncertainty with respect to their future availability.
(f) Potential cost savings resulting from future price escalation (because most activities that are undertaken during immediate dismantling would also be performed during deferred dismantling).

Disadvantages of immediate dismantling include: [13]

(a) The potential for higher worker exposure;
(b) A larger initial commitment of financial resources;
(c) A larger immediate commitment for waste disposal or storage space.

SRS 50 also list the advantages of entombment (in-situ decommissioning) as including: [14]

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[12] IAEA, Decommissioning of Facilities Using Radioactive Material, IAEA Safety Series No. 50, IAEA, Vienna (2007), at pgs. 23-24. <online: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1281_web.pdf> [SRS 50]
[13] *Ibid*. at pgs. 23-24.
[14] *Ibid*. at pgs. 27.

(a) Relatively low cost of associated waste transport and disposal;
(b) Reduced amount of work involved in encasing the facility in a structurally long lived substance;
(c) Reduced worker exposure compared with the exposure from decontaminating and dismantling the facility;
(d) Reduced public exposure from transported waste to waste storage, processing or disposal sites;
(e) Reduction in the size of the controlled area;
(f) Possible reuse or conversion of the site to a waste disposal site for other facilities.

The disadvantages of entombment include:

(a) Unsuitability for facilities with long lived radionuclides;
(b) Cost of long term monitoring and institutional controls;
(c) Public acceptance of creation of a near surface waste disposal site.

Similar findings have also been made by the OECD,[15] and Germany in particular,[16] a jurisdiction that has decommissioned over 20 nuclear facilities.[17] Indeed, the disadvantage of ISD are substantial enough for the IAEA to have determined, in its Safety Standards Series No. GSR Part 6, that ISD or entombment is not a suitable means for decommissioning:[18]

Entombment, in which all or part of the facility is encased in a structurally long lived material, is not considered a decommissioning strategy and is not an option in the case of planned permanent shutdown. It may be considered a solution only under exceptional circumstances (e.g. following a severe accident).

Surprisingly, as illustrated in Tables 4.2-2, 4.2-3, and 4.2-4, CNL has found in-situ decommissioning to be the most favourable, or equally favourable means for all phases of the

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[15] OECD Nuclear Energy Agency, Costs of Decommissioning Nuclear Power Plants, OECD NEA No. 7201 (2016), at pgs. 45-48. <online: https://www.oecd-nea.org/ndd/pubs/2016/7201-costs-decom-npp.pdf>
[16] Dr. M Knaack, Decommissioning – three main strategies: Immediate dismantling, Safe enclosure (Deferred dismantling), Entombment, TÜV NORD SysTec GmbH, presented at IAEA RER/9/120 26-30 November 2012. <online: https://www.iaea.org/OurWork/ST/NE/NEFW/WTS-Networks/IDN/idnfiles/WkpPlanLicencingDecomProjetc_Germany2012/WkpPlanLicencingDecomProjetc_Germany2012-Decommissioning_Strategies-Knaack.pdf>
[17] World Nuclear Association, Decommissioning Nuclear Facilities (Updated 8 September 2017) <online: http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/decommissioning-nuclear-facilities.aspx>
[18] Decommissioning of Facilities Using Radioactive Material, IAEA Safety Standards Series No. GSR Part 6, IAEA, Vienna (2016), Section 1.10. <online: http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1652web-83896570.pdf> [GSR Part6],

NPD Closure Project with respect to the relative risk posed to the environmental components assessed. While ISD has been found to pose the least risk for certain environmental components during certain phases, for example worker safety during the decommissioning execution timeframe, for the reasons noted above, a finding that ISD poses the least or equivalent risk for every environmental component during every phase of decommissioning seems implausible.

CNL has also indicated that the determination of relative risk for immediate dismantling accounted for the storage of nuclear waste at an offsite location, likely the Chalk River Laboratories ("CRL") site.[19] CNL asserts that because the risk posed by the storage of waste at the off-site location is unknown, it was assumed to pose a greater risk than the continued SwS means (the baseline). It is important to note that CNL itself is the operator of the off-site storage facilities.

If the dismantled NPDWF structures and waste were to be stored at CRL, the assumption that this course of action may pose a greater risk to the environment than the baseline also contradicts previous assertions by CNL and CNSC staff that the operations at CRL are safe. Recent examples of this include CNL's application to renew its operating licence for the CRL and the CNSC staffs review of CNL's performance as part of the renewal application.[20]

Recommendation No. 3

CNL should explain why its comparative evaluation of alternative means, with respect to each of the environmental components, deviates from internationally relied upon perception of relative risk for each of the alternative means considered.

Recommendation No. 4

CNL should explain why it considers the storage of waste at the CRL site, or any other CNSC approved storage or disposal facility, to pose a greater relative risk to the environmental components than the ISD means.

5. The Creation of a Near Surface Disposal Facility

The existing inventory of waste that would remain in NPDWF as part of the ISD strategy

[19] Draft EIS, *supra* note 1, at pg. 4-6.

[20] Commission Member Document, CMD-18-H2.

includes the radionuclides that are primarily associated with the reactor system (pressure tubes, calandria, and associated structures), as well as contamination within the heat transfer system, equipment for spent fuel storage and handling, facility structure and historic drummed waste.[21]

The fact that radioactive material will remain on the site means that the facility will eventually become designated as a near-surface disposal of radioactive waste or near-surface disposal facility ("NSDF") and criteria for such a facility will need to be met.[22] Since the end state of an ISD site is equivalent to a waste disposal site, the end state cannot satisfy unrestricted release conditions; it will require some measure of institutional control well into the future.[23] This necessarily entails that, in addition to the decommissioning regulations for an ISD, there will also need to be regulations for an NSDF. Since it is also unlikely that the site of the nuclear facility was assessed to serve as an NSDF, such an evaluation may need to be conducted as part of the approval process for the ISD.[24]

Recommendation No. 5

CNL should meet the regulatory requirements for an NSDF for the NPDWF site prior to gaining approval for the ISD strategy and, meet or exceed the standards and best practices set by the IAEA and other international jurisdictions with extensive experience in decommissioning nuclear facilities.

6. Disposal of the Calandria

Concern with the disposal of the calandria presents a disquieting example of the inadequate alternative means analysis provided by CNL. According to the draft EIS, the disused reactor core, the calandria, will be grouted in place within the building as a means of decommissioning.[25] This is where 75% of the radioactivity of the site is associated.[26] Despite the threat posed by the long term storage of the reactor in an NSDF, CNL determined that its presence did not create a relative risk that rendered any of the other alternative means less risky. This was so even though the presence of the calandria would arguably contravene IAEA standards and internationally accepted waste acceptance criteria for an NSDF.

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[21] Draft EIS, *supra* note 1, at pg. 4-19.
[22] SRS 50, *supra* note 12, at 2.4.
[23] *Ibid,* at 3.3.3.
[24] *Ibid,* at 3.3.4.
[25] Draft EIS, *supra* note 1, at pg. 4-6
[26] Draft EIS, *supra* note 1, at pg. 4-20

Since the publication of the draft EIS, however, CNL has indicated in its Post-Closure Safety Assessment report that the calandria may be removed before entombment and not form part of the waste inventory at the NPD site. It is uncertain whether CNL intends to remove the calandria immediately during decommissioning or defer its removal to a later date. The alternatives means analysis does not provide insight into which strategy might be preferable and it is unclear whether CNL has in fact undertaken any relative risk assessment on the matter.

While the removal of the calandria eliminates some long-lived nuclides (though not C-14 and tritium) there are few net savings as illustrated by Figures G-9 and G-70 reproduced below from Appendix G of the Post-Closure Safety Assessment report. While there may be little difference between rates of release (with the exception of some nuclides 800 to 1000 years post-closure), what these figures do not capture is a comparison of worker radioactive exposures and doses, the availability and options for off-site disposal, and intergenerational and future ecosystem impacts.

Figure G-9. Release of Radionuclides from Reactor Vault to Boiler Room

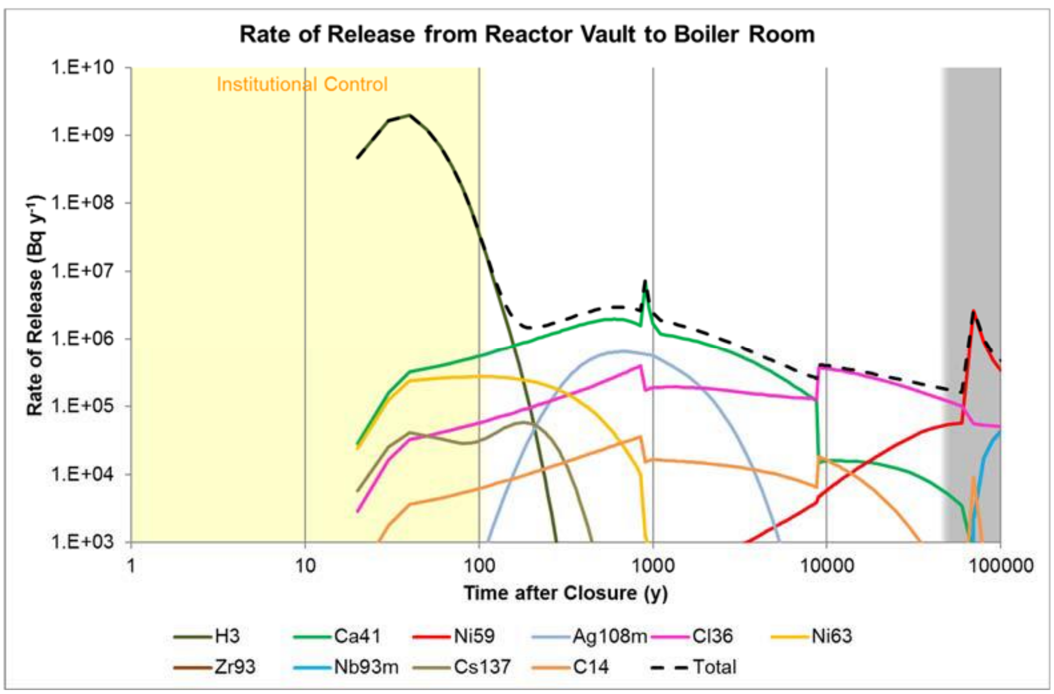
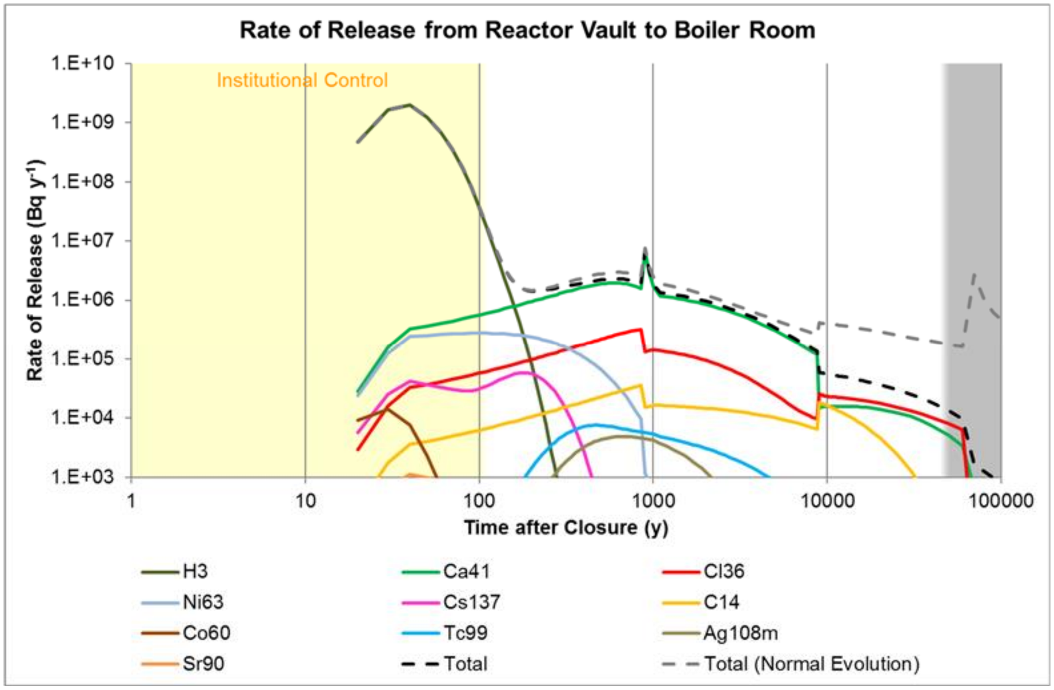


Figure G-70. Release of Contaminants from Reactor Vault (No Calandria Case)



The concerns that must be weighed in determining whether the calandria should remain on site or be removed as soon as reasonably possible, include considerations such as:

- Based on the radiological inventory of the calandria, wouldn't worker dose level remain largely the same even after deferring the calandria's decommissioning?
- Would there be any capacity to decommission and remove the calandria in 100 to 300 years? Likewise, would the expertise, or funding exist?
- Regardless of the benefits of deferring, would removal of the calandria reduce the relative risk to the Ottawa river?
- A comparison of CNL's figures G9 and G70 in Appendix G of the Post-Closure Safety Assessment report indicate there is little difference between either strategy with respect to release of radionuclides, except for lower amounts of some nuclides 800 to 1000 years post-closure.
- While deferring removal would eliminate some long-lived radionuclides, would removal result in an overall benefit?
- What are the costs associated for each strategy?

These questions essentially direct CNL to weigh the advantages and disadvantages of the deferred dismantling strategy compared to those of the other alternative means. They are meant to be addressed by a regulatory framework that weighs these issues and comes to a reasoned strategy for the decommissioning of a specific facility. It is not possible to determine whether it is better to leave the calandria in place, based on an objective evidence-based analysis of the available options since the current alternatives analysis does not provide an adequate comparison.

In addition, the questions noted above coincide with the advantages and disadvantages of the deferred dismantling strategy enumerated by the IAEA. As noted above, SRS 50 addresses the selection process for a decommissioning strategy and includes some advantages and disadvantages for each. These have already been provided for entombment and immediate dismantling above. The advantages of the deferred dismantling strategy include: [27]

(a) Initial lower cost immediately following permanent cessation of operations;
(b) Reduction in radioactivity as a result of radioactive decay during the enclosure period;
(c) Possible reduction in worker radiation dose during the dismantling phase;
(d) Potential reduction in the amount of space required for waste disposal;
(e) Potential reduction in public exposure because of fewer shipments of radioactive material;
(f) Increased time to acquire the necessary decommissioning funds.

The disadvantages of the deferred dismantling strategy include: [28]

(a) The site will not be available for alternative use during the extended enclosure period.
(b) If dismantling is deferred to a much later time, the facility personnel will probably no longer be available and their expertise will be lost to the decommissioning team.
(c) Uncertainties regarding potential changes in regulations, availability of funds, and availability and costs of radioactive waste sites will become more important.
(d) There will be a continuing need for maintenance, security and surveillance and their associated funds.
(e) The potential for higher total cost for the subsequent decontamination and dismantling will increase.

Recommendation No. 6

It is not possible to determine whether the calandria should be removed or left in place as CNL

[27] SRS 50, *supra* note 12, at pg. 25.
[28] *Ibid*.

has not provided an objective evidence-based analysis of available options. CNL should weigh the various advantages and disadvantages of the alternative means against each other for the specific circumstances of the NPDWF site, provide a coherent explanation of the risks posed to the environmental components by each of the strategies, and provide a rationally based explanation as to why a specific strategy is preferred.

III. HUMAN HEALTH, THE ENVIRONMENT AND SAFETY

This chapter will discuss the technical deficiencies and omissions related to human health and safety matters, contained in CNL's draft EIS for the NPD Closure Project.

While our comments below discuss the extent to which certain technical matters have been reviewed by CNL, we query whether they are the most appropriate proponent for this project. It is understood that the Rolphton site will be returned to Atomic Energy Canada Limited (AECL) for institutional control. With the proposed entombment, CNL appears to be making commitments on the part of AECL - and by extension the Government of Canada - that could last for hundreds of years. The proponent must be accountable for the entire life of the project (i.e. its design, construction, commissioning, operations up to and including final abandonment). Given that CNL's contract with AECL is for a maximum of 10 years, it is questionable whether CNL is the most appropriate and only proponent.

1. Long-Lived Radionuclides

The proposed in situ decommissioning (ISD) at the Rolphton site would result in subsurface reactor systems, components, structures and their associated hazards being (1) permanently buried, along with the below grade reactor, (2) encased with grout and (3) topped with an engineered cover.

Based on project's description, CNL proposing to entomb in perpetuity, radionuclides at Rolphton site, many of which are:

(a) highly radiotoxic (ie dangerous to humans and the environment);
(b) exist in high concentrations; and
(c) have long radiological half-lives (ie. will exist for hundreds of thousands of years)

The long-lived nature of these radionuclides means that considerable attention must be devoted to the form and nature of their disposals. In addition, although tritium has a relatively short half-life of 12.3 years, its large inventory means that significant amounts would remain for more than a century.

Recommendation No. 7

It is recommended that the federal government conduct a strategic environmental assessment, under the proposed Bill C-69, *An Act to enact the Impact Assessment Act* once adopted. A strategic EA will allow Canada to develop a comprehensive and publicly informed nuclear waste management policy for all types of nuclear waste in Canada.

2. Large Quantities of Radionuclides

The draft EIS (Table 4.4-1) states that the nuclide inventory in the reactor core and biological shield is 5.19E+13 Bq, and the inventory associated with the boiler room (i.e., primary heat transport, moderator and other nuclear systems) is 3.62E+11 Bq. It states the dominant radionuclides present by total radioactivity are H-3, C-14, Co-60, Ni-59, Ni-63, Zr-93, Nb-93, Ag-108m, Sn-121m, Eu-152, and Pu-241.

Table 2, reproduced below from Table 4.4-1 of the draft EIS, reveals the large amounts of nuclides which are estimated to still be contained in the Rolphton reactor, 30 years following its shutdown in 1987. Table 2 measures the amount in becquerels (Bq) as this is the unit for radioactive decay (ie. one nuclear disintegration occurs every second).

Table 2. Radioactivity (Bq in 2018) of the Reactor Vault (Source: PostSA TSD Table 3-1

Nuclide	Half-life (y)	Aluminium	Concrete	Carbon Steel	Stainless Steel	Zircalloy	Contamination
H-3	$1.23x10^1$	$9.13x10^9$	$1.41x10^{12}$	$2.35x10^8$	$1.36x10^1$ (?)*	$2.11x10^{11}$	
C-14	$5.70x10^3$	$5.26x10^{11}$	$2.40x10^{10}$	$8.13x10^7$	$1.11x10^{10}$	$1.13x10^{12}$	
Cl-36	$3.01x10^5$	$1.45x10^{10}$	$2.20x10^9$	$1.09x10^7$	$1.42x10^7$	$2.53x10^{10}$	
Ca-41	$1.02x10^5$	-	$7.62x10^9$	-	-	-	
Co-60	5.27	$2.98x10^{12}$	$3.18x10^{11}$	$2.61x10^{10}$	$2.90x10^{12}$	$6.70x10^{12}$	
Ni-59	$1.01x10^5$	$8.58x10^9$	-	-	$4.06x10^{10}$	$1.71x10^{11}$	
Ni-63	$1.00x10^2$	$1.35x10^{12}$	$6.83x10^{10}$	$4.39x10^9$	$6.38x10^{12}$	$2.63x10^{13}$	
Se-79	$2.95x10^5$	-	-	-	-	-	$5.07x10^5$
Sr-90	$2.88x10^1$	-	-	-	-	-	$2.63x10^{10}$
Zr-93	$1.53x10^6$	-	-	-	-	$2.00x10^{11}$	$2.50x10^6$
Nb-93m	$1.61x10^1$	-	-	-	-	$1.66x101^1$	$2.81x10^5$
Nb-94	$2.03x10^4$	-	-	$7.47x10^6$	$5.10x10^8$	$1.85x10^8$	$1.60x10^2$
Tc-99	$2.11x10^5$	-	-	-	-	-	1.89x107
Ag-108m	$4.18x10^2$	-	-	$2.17x10^9$	$2.86x10^{11}$	$3.24x10^6$	-
Sn-121m	$4.39x10^1$	-	-	-	-	$3.98x10^{11}$	$8.75x10^4$
Sn-126	$2.30x10^5$	-	-	-	-	-	$6.21x10^5$
Sb-125	2.76	-	-	-	-	-	$2.69x10^{10}$
I-129	$1.57x10^7$	-	-	-	-	-	$3.71x10^4$
Cs-135	$2.30x10^6$	-	-	-	-	-	$9.16x10^5$
Cs-137	$3.02x10^1$	-	-	-	-	-	$6.77x10^{10}$
Sm-151	$9.00x10^1$	-	-	-	-	-	$2.82x10^8$

Eu-152	$1.35x10^{1}$	$2.76x10^{8}$	$1.23x10^{11}$	$5.92x10^{7}$	$9.52x10^{7}$	$3.48x10^{9}$	$3.06x10^{6}$
U-234	$2.46x10^{5}$	-	-	-	-	-	$5.14x10^{5}$
U-235	$7.04x10^{8}$	-	-	-	-	-	$1.55x10^{3}$
U-236	$2.34x10^{7}$	-	-	-	-	-	$3.75x10^{5}$
U-238	$4.47x10^{9}$	-	-	-	-	-	$1.98x10^{5}$
Np-237	$2.14x10^{6}$	-	-	-	-	-	$1.12x10^{5}$
Pu-238	$8.77x10^{1}$	-	-	-	-	-	$1.55x10^{9}$
Pu-239	$2.41x10^{4}$	-	-	-	-	-	$5.07x10^{8}$
Pu-240	$6.56x10^{3}$	-	-	-	-	-	$8.05x10^{8}$
Pu-241	$1.44x10^{1}$	-	-	-	-	-	$8.05x10^{9}$
Pu-242	$3.75x10^{5}$	-	-	-	-	-	$9.98x10^{5}$
Am-241	$4.32x10^{2}$	-	-	-	-	-	$1.28x10^{9}$
Am-242m	$1.41x10^{2}$	-	-	-	-	-	$8.67x10^{6}$
Am-243	$7.37x10^{3}$	-	-	-	-	-	$1.79x10^{6}$
Cm-243	$2.91x10^{1}$	-	-	-	-	-	$1.10x10^{6}$
Cm-244	$1.81x10^{1}$	-	-	-	-	-	$9.57x10^{6}$

NB: Generic contamination levels are applied to the whole of the concrete structure of the NPDWF
** Please see explanation in section 7 below*

3. Tritium Amounts in Reactor Vault Concrete and other Structure Concrete

An email dated 12 Dec 2017 to Dr. Ian Fairlie from Meggan Vickerd, NPD Decommissioning Manager at Canadian Nuclear Laboratories, contained CNL's estimated tritium concentration at present in the **reactor vault** concrete (see Appendix 1).[29] This is set out in Table 2a below.

Table 2a. Tritium in Reactor Vault concrete at Rolphton as stated by CNL

Radionuclide	CNL Reference Inventory in Reactor Vault Concrete (Bq)	CNL Radionuclide Concentrations in Reactor Vault Concrete (Bq/g)
H-3	1.41E+12	3.22E+03

The email also stated that the mass of the concrete structures at NPD was estimated at 5,250,000 kg = 5.25E+09g.

However, it is estimated by CELA that the "reactor vault" only constitutes about 1/12 of the total mass of the reactor building: the remainder is contained in all the other concrete structures of the reactor. As discussed by Krasznai (1993), the NPD reactor is made of both **high density** concrete (in the reactor vault) and **regular density** concrete surrounding the rest of the reactor structure. The mass of the latter is much greater than the former.

Not only is the amount of regular concrete greater: its tritium concentration was found by

[29] Email communication, 20 Dec 2017, from Meggan Vickerd (meggan.vickerd@cnl.ca)

Krasznai (1993) to be approximately 5 times greater than that in high density concrete mainly because of the latter's lower pore volume.

In other words, the amount of tritium in regular density concrete structures in the NPD reactor building considerably exceeds the amount of tritium in "reactor vault" concrete, perhaps by as much as a factor of 5 x 12 = 60. It is recommended that CNL should make its own estimate of the amount of tritium contained in the concrete outside the reactor vault. It is likely to be large as the annual tritium emissions/releases to air and water from the NPD are still in GBq (10^9 Bq) amounts even today, 32 years after the cessation of operations.

If the above factor of a 60 fold increase were conservatively adopted, then the amount of tritium in all concrete structures at the NPD would increase to 1.41E+12 x 60 = 8.46E+13 Bq.

At present, the total nuclide inventory at Rolphton as estimated by CNL to be 5.19 E+13 Bq. If the above larger tritium estimate in concrete were used, the total nuclide inventory would increase to 1.39 E+14 Bq, a 160% increase.

In addition, it is noted that AECL (2012) has stated that the 30-year post-shutdown total nuclide inventories were underestimated by factors of 1.46 and 1.26 for the pressure tubes and calandria tubes, respectively. It is not stated by CNL whether these factors have been taken into account in its nuclide inventories.

4. Characterizing Radioactive Wastes as ILW

Intermediate-Level Waste (ILW) is defined by the CNSC as waste "that contains long-lived radionuclides in concentrations that require isolation and containment for periods beyond several hundred years."[30]

The Canadian Standards Association (CSA, 2014) standard, N292.0-14, contains an approximate boundary for radioactivity concentrations in ILW and LLW. It recommends limiting the amount of long-lived beta and/or gamma-emitting radionuclides (including C-14, Cl-36, Ni-63, Zr-93, and Nb-94) in LLW to "an average of up to tens of kBq/g". In other words, concentrations above this level (~E+04 Bq/g) constitute ILW.

In more detail, the CSA's standard N292.0-14 states that the numerical limits for LLW and ILW are "for orientation purposes and not rigid limits, as acceptable concentrations will differ

[30] CNSC, "Low- and intermediate-level radioactive waste," online: http://nuclearsafety.gc.ca/eng/waste/low-and-intermediate-waste/index.cfm#intermediate-level

between individual radionuclides or groups of radionuclides." However, as Table 3 below illustrates, individual concentrations of radionuclides (ie. not an average in a mixture) in each case (with the exception of Cl-36) exceed this CSA standard. Accordingly, they are all considered to constitute ILW and such wastes require rigorous levels of containment and isolation and specifically state that they must not be placed in near surface facilities. The proposed ISD at Rolphton is a near-surface facility (please see further discussion on this point at Part II section 5, and Part IV section 4 of this submission).

Recently CNL was required by CNSC to ensure that ILW would not be disposed of in its proposed near-surface facility at Chalk River. The same logic applies to the present proposal at Rolphton. In other words, the high concentrations of long-lived nuclides at Rolphton constitute ILW and should not be disposed of in the proposed entombment which is also a near-surface facility.

5. Failure to meet CNSC Unconditional Clearance Criteria

Section 26 of the *Nuclear Safety and Control Act,* SC 1997, c 9, provides that no person shall "decommission or abandon a nuclear facility" except in accordance with a licence. CNL could presumably apply for a licence to decommission or abandon the Rolphton nuclear facility at the end of its proposed institutional control period of 100 years.

CNSC Guide G-320 contains provisions which apply to such future time frames.[31] The regulatory guide states "the predicted impact on the health and safety of persons and the environment from the management of radioactive waste {must be} no greater than the impacts that are permissible in Canada at the time of the regulatory decision" (emphases added).[32]

This means that at the time of the granting of any licence for the decommissioning or abandonment of a nuclear facility, the CNSC must consider whether the predicted (future) residual radioactivity in the grouted reactor site would meet the CNSC's current Unconditional Clearance Criteria for radionuclides, as set out in its "Radionuclide Information Booklet."[33]

Therefore, the predicted nuclide concentrations in 100 years' time (ie. as reduced via decay) should have been calculated by CNL. As far as can be ascertained, our review indicates that this has not occurred. These calculations have instead been carried out by CELA in Table 3 below.

[31] CNSC (2006) Regulatory Guide G–320. Assessing the Long Term Safety Of Radioactive Waste Management
[32] *Ibid,* s 7.4, p 24.
[33] Canadian Nuclear Safety Commission, "Radionuclide Information Booklet" (February 2017), online: http://www.nuclearsafety.gc.ca/pubs_catalogue/uploads/Radionuclide-Information-Booklet-2016-eng.pdf

Table 3. Activities and concentrations remaining after 100 years (ie the end of institutional control) as estimated (in red) by Dr. I. Fairlie

Radionuclide	Half-life (y)	Current Activity (Bq)	Estimated Activity after 100y (GBq)	Concentration after 100 y (Bq/g)*	CNSC Unconditional Clearance Level (Bq/g)	Whether the current CNSC unconditional clearance level is exceeded
H-3	$1.23x10^1$	8.46×10^{13}	300	57	100	
C-14	$5.70x10^3$	1.66×10^{12}	1640	312	1	×
Cl-36	$3.01x10^5$	4.2×10^{10}	420	80.8	0.1	×
Ca-41	$1.02x10^5$	91.4×10^9	91.4	17.4	1	×
Co-60	5.27	12.9×10^{12}	2.5×10^{-5}	2.5×10^{-15}	0.1	
Ni-59	$1.01x10^5$	0.17×10^{12}	170	32	100	
Ni-63	$1.00x10^2$	34.0×10^{12}	17,020	3,240	100	×
Cs-137	$3.02x10^1$	$6.77x10^{10}$	6.74	1.3	0.1	×
Sr-90	$2.88x10^1$	$2.63x10^{10}$	2.63	0.50	1	
Pu-241	$1.44x10^1$	$8.05x10^9$	0.064	0.0064	100	
Pu-238	$8.77x10^1$	$1.55x10^9$	0.703	0.133	0.1	×
Am-241	$4.32x10^2$	$1.28x10^9$	1.09	0.21 + ingrowth from Pu-241 decay	0.1	×
Pu-240	6.56x103	$8.05x10^8$	0.80	0.15	0.1	×
Pu-239	2.41x104	$5.07x10^8$	0.50	0.09	0.1	
Sm-151	9.00x101	$2.82x10^8$	0.13	0.02	0.1	
Eu-152	1.35x101	$1.23x 10^{11}$	0.732	0.14	0.1	×
Zr-93	1.53x106	$2.00x10^{11}$	200	38.1	100	
Nb-93m	1.61x101	1.66×10^{11}	2.23	0.42	100	

Generic contamination levels are applied to the whole of the concrete structure of the NPDWF
* divide by CNL estimate of 5.25 E+09 g

Table 3 illustrates that the CNSC's Unconditional Clearance Levels are exceeded (noted by "(×)") in the cases of at least 9 nuclides.

6. CSA Standards for LLW and ILW

In previous comments on the draft environmental impact statements for the NSDF at Chalk River and the decommissioning of the Whiteshell reactor, the CNSC has emphasised the need for CNL to observe the Canadian standards for nuclear waste treatment laid down by the Canadian Standards Association (CSA). In particular, the CNSC has specified that the CSA's Standard 292.0-14 (*General principles for the management of radioactive waste and irradiated* *fuel*) (2014b) should be implemented.

This is an important matter as Annex 5 of CSA 292.0-14 recommends the use of a numerical threshold to differentiate between LLW and ILW. Where a nuclide concentration exceeds an average of "tens of kBq/g" this is classified as ILW.

Indeed, the drat EIS itself recognizes this and states (see section 4 page 4-25) that CSA Standard 292.0-14 suggests limiting the amount of long-lived beta and/or gamma emitting radionuclides (C-14, Cl-36, Ni-63, Zr-93, and Nb-94) in LLW to an average of up to tens of kBq/g. The draft EIS then adds that "Radionuclides such as C-14, Ni-63 and Zr-93 are present in the reactor system at concentrations exceeding this value" and that these "could be classified as ILW and therefore require the degree of containment and isolation afforded by the reactor vault shielding."[34]

However, the draft EIS does not seem to have addressed this vital issue in its draft EIS apart from one suggestion – the possible removal of the calandria (please see Part II, Section 6 for further discussion on this point).

7. High Tritium Concentrations in Decommissioned Reactors

As partly recognized in the draft EIS, tritium is the most significant nuclide at the Rolphton site due to its remaining large inventory and its high current annual releases.

According to Krasznai (1993), in the early 1990s, high tritium concentrations up to 82,000 Bq/g were found in the concrete structures at the NPD at Rolphton. These tritium concentrations were very high compared with ~300 Bq/g for C-14 the next highest concentration of a nuclide (Krasznai, 1993). Thirty years after cessation of the reactors in 1987, the H-3 concentration (without remediation) would now have decayed to ~15 kBq/g. This means that 80 TBq of tritium is still remaining in the concrete facility.

These high tritium concentrations in decommissioned reactors are due to neutron activation of hydrogen, deuterium and Li-6 impurities, tertiary fission (fission yield <0.01%) and diffusion from high levels of tritium in cooling water and moderator (Kim et al, 2008). As stated by Kim (2009):

> During the lifetime of nuclear sites (especially those involving heavy water) tritium becomes incorporated into the fabric of the buildings. When nuclear decommissioning

[34] Draft EIS, *supra* note 1, s 4, p 4-25.

> works and environmental assessments are undertaken it is necessary to accurately evaluate tritium activities in a wide range of materials prior to any waste sentencing.

In our view, CNL has not evaluated tritium activities in a wide range of materials prior to waste sentencing.

Conventional computer models can give unreliable predictions of tritium concentrations in decommissioned reactors. For example, according to Corcoran et al (2017), steel containment vessels used for >20 years "exhibit tritium burdens greatly exceeding those predicted by simple gas solution in the parent metal." Investigations into the location of, and activity release from, vessel materials indicate the existence of two major tritium sources: (1) the bulk metal where in-depth contamination arises from diffusion/solution; and (2) a highly active surface layer, responsible for holding the main tritium inventory (Corcoran et al, 2017). Models based on neutron activation codes alone may have incorrectly predicted tritium levels. As stated by Kim et al (2008) "Without an appreciation that two forms of tritium exist in concrete reactor bioshields, the H-3 content of samples may be severely underestimated using conventional analytical approaches."

The two forms are strongly-bound tritium and loosely-bound tritium. The former originates from neutron capture mainly on trace (1 part per 20,000) lithium (Li-6) within mineral phases, and requires temperatures in excess of 800 °C to achieve quantitative recovery. The weakly-bound form of tritium can be liberated at lower temperatures (100 °C) as HTO and is associated with dehydration of hydrous mineral components," As stated by Kim et al (2008) "These findings exemplify the need to develop robust radioactive waste characterization procedures in support of nuclear decommissioning programs".

In metals, tritium is retained by absorption of free water in the hydrated surface oxidation layer, by H ingress into bulk metal and also as lattice-bound tritium produced by neutron activation. (Nishikawa M et al, 2006). In addition, Croudace et al (2014) found that significant tritium was incorporated in non-irradiated metals (e.g., stainless steel and copper), following prolonged exposure to tritiated water vapour (HTO) and/or tritium/hydrogen gas (HT) in nuclear facilities. In irradiated metals, an additional type of tritium was formed internally through neutron capture reactions. The amount formed depended on the concentration and distribution of trace lithium and boron in the metal.

The above studies render questionable, for example, CNL's estimate of 13.6 Bq of tritium in the 5,500 tonnes of stainless steel in the NPD reactor – as stated in Table 3 above.

The draft EIS states their computer models provide higher estimates (of nuclide amounts) than their measurements, so they use model results to be conservative. But the details of their measurements are not provided, (eg. where were they taken). For example, if they measure nuclide levels of the concrete bioshields on their external surfaces, that is where the lowest levels are while the highest levels are on the other end, nearest the reactor core.

8. Continuing Tritium Releases

These high tritium concentrations diffuse very slowly out of concrete, at a rate of ~2 cm^2 per year (Krasznai JP, 1993). This is evidenced by the continued high emissions of tritium from decommissioned reactors even 30 years after their cessation, including the reactors at Whiteshell and Rolphton.

In fact, it is a matter of concern that, 30 years after the NPD reactor ceased operations in 1987, major tritium releases to air and water are <u>still</u> occurring. The draft EIS reported (Table 8.2-10. Specific Values of Total Airborne Releases from the Ventilation Stack) that 215 GBq of tritium was emitted to air from the Rolphton stack in 2015. In addition, (from table 8.3-1), 66.1 GBq of tritium were discharged from the Wells Area Sump to water, to make a total release of 280 GBq in 2015. This is similar to the tritium emissions from the WR-1 reactor at Whiteshell where 61 GBq of tritium are still released annually to air. (See Table 3-12: Summary of Atmospheric Tritium Release Rates from WR-1 from 2011 to 2015 in WLDP-26000-REPT-006.)

It is worrying that these tritium releases, in overall terms, are not declining. This fact remains unexplained in the draft EIS and CNL should discuss this matter. One explanation is that the computer models used to estimate nuclide generation via activation and fission underestimate the amounts of tritium created and that a very large inventory of tritium remains in the reactor and in its component structures.

9. Dilution and Dispersion

The draft EIS states the buried reactor vault will become flooded after 40 to 60 years and the nuclides will travel underground to the Ottawa River where they will be diluted. This assumes dilution and dispersion is an acceptable method of dealing with radionuclides. We submit dilution is not the solution to pollution.

10. Cumulative Effects

As stated in Part I, section 5 above, we reiterate our finding that the draft EIS does not appear to consider the cumulative effects from the proposed Rolphton entombment plus the proposed Chalk River near-surface facility, plus the remaining Chalk River facilities on the Ottawa River and its downstream residents and ecosystems.

11. Tritium Limits in Drinking Water

At various points[35], the draft EIS refers to Health Canada's "safe" limit for tritium in drinking water of 7,000 Bq per litre. This limit was set over two decades ago and is outdated compared to limits used by other agencies (see Table 4 below).

Table 4. Tritium Limits in Drinking Water (Bq per litre)

Agency	Tritium Limit in Drinking Water
Health Canada	7,000
US EPA*	740
European Union**	100
Ontario Government's ODWAC in 2009 (recommendation)	20
Ontario Government's ACES in 1994 (recommendation)	20
US State of Colorado (recommendation)	18.5
US State of California (advisory)	15

*EPA (1999)
**European Commission (1998)

Canada's current federal limit for tritium in drinking water is 7,000 Bq/L. This is out of date and unsafe when compared to the limits set by the European Commission and the US EPA. The current US limit[36] is 740 Bq/L, based on a maximum dose to the public of 40 µSv per year from drinking water. The European Commission's limit is 100 Bq per litre.

The State of Colorado in the US has set a stricter standard for tritium in surface water of

[35] Table 8.5-1 of the EIS indicates that soil tritium concentrations in 2 out of 8 samples exceeded the 20 Bq/l level in 2015. And in previous years this limit was routinely exceeded. Ditto in table 8.5-3, this level was routinely exceeded in the past at regional monitor points. Similarly in Table 8.5-4. Concentrations of HTO in Vegetation Samples on NPD Site (in Bq/L) almost all samples exceeded 20 Bq /l some by considerable margins. Similarly in OBT Table 8.5-5. Concentrations of OBT in Vegetation Samples on NPD Site (in Bq/L). Also on page 9-60 , during the Institutional Controls phase, the concentrations in the surrounding groundwater are dominated by tritium, peaking at around 1,000 Bq/L. This is 50 times the 20 Bq/l limit for tritium in drinking water guideline as recommended by ODWAC.
[36] 20,000 picocuries per litre.

18.5 Bq/L.[37] For example, the US Department of Energy specified the Colorado state action level for tritium in surface water in its clean-up program at the Rocky Flats plutonium plant in Colorado. The US state of California recommends a limit of 15 Bq/L.[38] Both limits are based on a 10^{-6} lifetime risk of a fatal cancer, which is the clean-up goal under the US Comprehensive Environmental Response Compensation and Liability Act (CERCLA), more commonly known as the Superfund Act.

Health Canada's limit for tritium corresponds to a risk of 350 excess fatal cancers per million people which is considerably more lax than the 1 to 10 excess fatal cancers per million normally used in toxicity limits. For example, Health Canada's drinking water objectives for **chemicals** only allow a lifetime risk of 1–10 fatal cancers per million people. The primary reason for the difference is that the predicted radiogenic cancers are calculated using ICRP dosimetry, which assumes only ***one year's*** consumption of drinking water. With chemicals, it is assumed that people consume drinking water for their whole lifetime - commonly set at 70 years.

In 2009, the Ontario Government's Ontario Drinking Water Advisory Council (ODWAC) published a comprehensive report which recommended that the tritium limit in drinking water should be tightened to 20 Bq per litre, annualized.[39] The difference between 7,000 and 20 Bq/L was due to ODWAC's choice of a stricter fatal cancer risk factor of 10^{-6} and its use of a lifetime instead of first year risk. Interestingly, the 2009 ODWAC report's recommendations were similar to a 1994 report by the Ontario Government's Advisory Council on Environmental Standards (ACES) on tritium.

Recommendation No. 8

CELA recommends that the ODWAC/ACES limit for tritium in drinking water be used for evaluation in this EIS, given the possibility or even likelihood of more stringent limits being established by the provincial government and included in federal guidelines, based on the previous reviews and other jurisdictions' assessments as noted above. This would contribute both to an assessment against more health protective standards, and ensure the current project is assessed against a long-term health standard that may well be adopted within the impacting life-span of this project.

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[37] 500 picocuries per litre.
[38] 400 picocuries per litre.
[39] *See* online: http://www.odwac.gov.on.ca/reports/minister%20reports/minister_reports.htm

12. Shortcomings with Tritium's Dosimetry

Critical views about tritium's official dosimetry have existed for decades. Many scientists continue to express concerns about tritium's low dose factors and its acute radiotoxicity.[40] The reason is that when determining tritium's hazards, official radiation protection precepts and procedures are deficient, as follows:

1. Tritium's unusual properties of extreme solubility, mobility, exchangeability, high RBE value and binding with organic materials are not recognised by official dose models.
2. Because of the short range of tritium's beta particle, tritium's damage depends on its location in the body. For example, tritium next to a DNA molecule exerts more damage than tritium located, say, in extracellular water. At present, it is not possible to model where tritium goes in the body with accuracy. Official models assume that tritium (HTO) is equally distributed throughout the whole body, thus lowering its concentration and dangers, but this assumption is profoundly unconservative. Many scientists think we should use safer models, in case homogeneous distribution turns out to be incorrect.
3. Tritium is often described as a "weak" beta-emitter, but in radiation biology, so-called "weak" beta particles are more dangerous than energetic ones. This is especially the case with tritium, but this is not acknowledged in setting its dose factor. In fact, much evidence indicates that tritium's RBE (in radiation biology experiments comparing tritium with gamma rays) is two or three times that recognised by the ICRP (Fairlie, 2007).
4. Little official recognition is given to tritium's ability to incorporate in organic molecules to high levels as a result of chronic environmental exposures. Official dose models for OBT therefore significantly underestimate its doses.

In conclusion, current official models on tritium are unscientific and incorrect. Recent discussions of tritium's hazards should be acknowledged by radiation protection agencies in Canada. A precautionary approach should be adopted with the inhalation and ingestion dose factors for HTO and OBT being increased by a factor of 20.

13. Conclusions and Information Requests

Our review of the human health and safety effects resulting from the proposed ISD allow us to conclude that that CNSC should not license CNL's entombment proposal at Rolphton at present for the following reasons:

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[40] *See* Fairlie, 2007; AGIR, 2007, Makhijani et al, 2006, and CERRIE, 2004.

- There are too many long-lived ILW at Rolphton for a near-surface facility, and
- The CNSC's unconditional clearance levels for radionuclides will still be exceeded after active institutional controls are ended in 100 years' or even 300 years' time.

We noted the following omissions/errors in the draft EIS and request CNL to respond to the following Information Requests (see Table 5).

Table 5. Information Requests

IR#	Information Requests
#17	The following omissions/errors in Tables referenced in the draft EIS were noted and require rectifying: • Tables 8.3-8 and 8.3-9 should be labelled "radionuclide concentrations" rather than radiation contamination • In Table 4.44-1, Zircalloy is misspelled
#18	The following technical issues were provided little to no description or analysis in the draft EIS and CELA requests they be remedied: • No technical description of the engineered cover system • No technical description of the proposed grout and its properties • No discussion of the doses received during proposed dismantling and grouting • No discussion of hydrogen releases from grout-aluminium reactions • No discussion of collective doses, and • Little discussion of organically bound tritium
#19	AECL (2012) has stated that the 30-year post-shutdown total nuclide inventories were underestimated by factors of 1.46 and 1.26 for the pressure tubes and calandria tubes, respectively. It is not stated by CNL whether these factors have been taken into account in its nuclide inventories.
#20	At this facility, tritium is the most important nuclide, in terms of hazard from radiation exposures for the first 140 years. CNL should provide further analysis and justification for its conclusions in the EIS, taking into account tritium levels and emissions from this facility.

#21	Provide a plan to forthwith cease ongoing tritium emissions to air and discharges to water, due to the hazard posed to local populations.
#22	Estimate the amount of tritium contained in the concrete outside the reactor vault.
#23	Calculate the predicted nuclide concentrations in 100 years' time (ie. as reduced via decay).
#24	Confirm whether CSA's Standard 292.0-14 (*General principles for the management of radioactive waste and irradiated fuel*) (2014b) have been implemented.
#25	Provide the measurements and details used to inform computer modelling.
#26	Provide an explanation why overall amounts of tritium have not declined over time.
#27	Conduct a cumulative effects analysis considering the combined effects from the proposed Rolphton entombment, the proposed Chalk River near-surface facility and the remaining Chalk River facilities, and their impacts on the Ottawa River, its downstream residents and ecosystems.

IV. INTERNATIONAL GUIDANCE AND LESSONS LEARNED ON ISD

CELA submits that a review and integration of lessons learned from completed in situ decommissioning projects and studies is necessary before the described project is approved for undertaking. The reason for this is twofold: first, as described by the IAEA in its Technical Reports Series No.439, a recurrent problem during decommissioning is that of "carefully evaluating at what point a new technique has reached a sufficient degree of maturity" in or to have substantial benefit and minimize risk. The IAEA recommends that current and future decommissioning planning integrate lessons learned from completed projects in order to not 'reinvent the wheel'[41] and inadvertently introduce adverse risk.

Secondly, a high level of preparation is required in order to minimize the extent to which unexpected conditions arise. It is a standard lesson learned from decommissioning projects that unexpected conditions *will* be encountered,[42] and alternative methods must be considered pre-emptively. Thus, it is advantageous that an iterative approach, cognizant of lessons learned, as summarized below, be adopted by the CNSC in its review of the proposed decommissioning project.

1. CNL's Grout Formulation

The formulation of grout used in the proposed in situ decommissioning will determine its ability to provide long-term stability and the minimize containment mobility, commensurate to the wastes that are being confined.

According to the grout formulation provided to CELA by CNL on February 1, 2018 (see Appendix 2), "the grout formulation is not finalized." CELA submits that this is a crucial oversight as the success of the proposed decommission activity is inextricably dependent upon the grout's features. Absent a grout formulation against which models have been run and tests conducted, the long-term performance of the grout infill and barriers is hypothetical.

According to a 2009 report by the Savannah River National Laboratories, which sought to identify the technical barriers and technology development needs for the optimal implementation of in situ decommissioning, it is incumbent that the grout formula used for the

[41] Decommissioning of Underground Structures, Systems and Components, IAEA Technical Reports Series No. 439, IAEA, Vienna (2006), p 81. <online: http://www-pub.iaea.org/MTCD/Publications/PDF/TRS439_web.pdf> [IAEA No. 439]

[42] Charles A. Neguin et al, "In Situ Decommissioning Lessons Learned – 14042" (March 2014) p 12, <online: http://www.wmsym.org/archives/2014/papers/14042.pdf>.

proposed decommissioning project provide a necessary degree of flowability to ensure (1) voids and sufficiently filled, (2) desired strength and long term stability is achieved and (3) containment mobility is minimized.[43]

It is unclear from the CNL documents to what extent these factors have been analyzed and modelled. While CNL's description of the project states 'gaps and crevices through the facility will be filled with a concrete-like mixture,'[44] we find this statement unhelpful as it presumes the yet-to-be-finalized grout will have the requisite rheological characteristics to do so.

We request that CNL confirm upon what basis it is known that the grout will perform its function, absent a finalized formula. We also question whether at this time CNL has conducted an assessment for these attributes, listed above, and upon what basis can it justifies its currently proposed grout formula.

2. Proposed Monitoring Programs

The draft EIS notes that due to the conceptual nature of the NPD closure project, a "detailed follow-up monitoring program will be developed incorporating federal reviewer and stakeholder feedback from the draft EIS review."[45]

CELA submits the draft EIS should have included a more detailed analysis of monitoring for the proposed ISD. The extent of monitoring considerations in the draft EIS can be briefly summarized as follows:

- Monitoring will continue for chimney swifts at the site[46]
- Emissions and effluent monitoring will occur during the demolition/grouting phase
- Visual inspections and groundwater monitoring will be carried out during the Institutional Control phase[47]
- Checks or species at risk will occur on a "per-event basis"[48]

Our review of the draft EIS and supplemental documents does not support a finding that

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[43] Patricia Lee et al, "Technology Requirements for In Situ Decommissioning Workshop Report" Savannah River National Laboratories (June 2 2009), <online: https://www.energy.gov/sites/prod/files/ISD_Workshop_Report_Final_June_18_2009.pdf> [Savannah River National Laboratories 2009]

[44] Draft EIS, *supra* note 1, at pg. 2-3

[45] *Ibid,* pg. 2-9

[46] *Ibid,* pg. 12-12

[47] *Ibid,* pg. 2-9

[48] *Ibid,* pg. 2-19

monitoring, specifically responsive to the form of decommissioning beyond proposed, has been adequately considered by the proponent. Therefore, CELA reiterates the findings of the 2009 Savannah River National Laboratories report and recommends the following be adopted before, during and after ISD activities:

- Develop innovative monitoring schemes and sensors for grout placement verification (e.g. grout lift temperature, measure off-gas production, vertical settlement and displacement) and combine with surrounding groundwater monitoring wells and structural settlement monitoring[49]
- Develop long term sustained performance monitoring schemes and sensors to measure grout monolith curing, remaining structure stability and performance, and combine with surrounding groundwater and ecological monitoring[50]
- Install and collect laser monitoring of elevations to monitor for structural subsidence -
- Install instruments nearby shallow groundwater wells with transducers to measure effects on the shallow groundwater elevation[51]

These recommendations, while far from exhaustive, are examples of monitoring schemes which are directly related to the project proposed by CNL. This level of depth or detail does not appear in the draft EIS. While CNL states during institutional control, "it is expected that monitoring activities will verify the robustness and integrity of containment and that releases carry no undue risk under normal operating conditions"[52] we request they substantiate the methods and mechanism justifying this assertion.

3. Historical Site Assessment

A historical site assessment is an essential pre-requisite before engaging in activities at an older site. Historical site assessments are generally helpful in identifying construction quality issues (ie. for facilities constructed at a time when standards many have been less rigorous than those currently in use), interpreting process line drawings which may not be accurate or discovering hazards, resulting from currently unknown historical activities or incidents. [53]

While the draft EIS includes some references to the historical site assessment, it does not seek to respond to the gaps or information deficiencies identified in the assessment.[54] The historical

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[49] Savannah River National Laboratories 2009, *supra* note 43, pg. 19
[50] *Ibid*
[51] *Ibid,* pg. 26
[52] Draft EIS, *supra* note 1, at pg. 4-11
[53] IAEA No. 439, *supra* note 41, pg. 189, 195 f
[54] *Please note:* as confirmed in an email from CNL to Kerrie Blaise (dated 8 Feb 2018) the draft EIS in error

site assessment qualifies its conclusions within identified data gaps and specific paucities of information. The language of the text alludes to gaps and also further areas for study, as illustrated by the following statements:

- "Based on available information" [55]
- "If re-sampled, the groundwater analyze list should include" [56]
- "Existing data set is limited too….and future characterization efforts should" [57]
- "A robust random/systematic sampling campaign should be performed to quantify the surface contamination levels" [58]
- "A robust random/systematic sampling campaign should be performed to quantify the surface and volumetric contamination levels" [59]

Based on the foregoing, CELA requests (1) that CNL provide an update on the Historical Site Assessment and comment on the extent to which the suggestions for 'future study' or gaps identified will be responded to and (2) how, given the identified data gaps, adequate contingency planning for unexpected wastes, hazards or structural defects can be established.[60]

The draft EIS states that "Due to the conceptual nature of the NPD closure project at this point, further details of the follow-up program and schedule will be developed at a later date . . . once the details are known, CNL will also develop contingency procedures" (emphasis added). [61]

CELA requests the CNSC confirm whether these programs, once developed 'at a later date', will be open to the public and will provide an opportunity to review and respond their sufficiency. CELA also submits that our review of the draft EIS, its proposal and outcomes, would have been better informed had CNL detailed their future plans, program and procedures, even if only conceptually.

4. Near Surface Characterization and Cumulative Effects

A discrepancy exists between CNL's characterization of the site, post decommissioning, and characterizations used by nuclear law journals and international guidance. Alluding to the distinction between in situ decommissioning (ISD) and a near surface facility (NSF), the draft EIS

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references King 2016. It should read King 2017.

[55] King, D.A. 2017. Historical Site Assessment Report for the Nuclear Power Demonstration Waste, pg 2

[56] *Ibid,* pg 3

[57] *Ibid* pg. 2

[58] *Ibid*, pg 45

[59] *Ibid,* pg 65

[60] IAEA No. 439, *supra* note 41, pg 189

[61] Draft EIS, *supra* note 1, pg. 12-12

states:

> [T]he differences between the alternative means are more pronounced, especially under disruptive event scenarios and long term processes such as climate change. For "1. continued SwS", "2. partial dismantling and removal", and "3. full dismantling and removal", where waste is being stored, there is an increased risk of effects as a result of the waste being stored above ground, or near surface. "4. in-situ decommissioning" does not have the same risk because all waste is emplaced and grouted below ground in bedrock, thereby limiting the risk.[62]

According to this statement, it appears the draft EIS does not consider the proposed ISD – once finished - to be a near surface facility. In particular, the above draft EIS' assertion of "limiting the risk" is devoid of backup or justification. The point is that wastes are emplaced and grouted below ground in both the proposed ISD and in a NSF. The "bedrock" point is misleading as the proposed ISD is mostly located in surface deposits above bedrock.

On the other hand, as the National Nuclear Safety Journal, "the fact that radioactive material will remain on site means that the facility will eventually become designated as a near surface waste disposal site and criteria for such a facility will need to be met."[63]

In addition, the project description fits well within the IAEA's definition of near surface disposal facility:

> (1) Near-surface disposal facilities at ground level. These facilities are on or below the surface where the protective covering is of the order of a few metres thick. Waste containers are placed in constructed vaults and when full the vaults are backfilled. Eventually they will be covered and capped with an impermeable membrane and topsoil. These facilities may incorporate some form of drainage and possibly a gas venting system.
>
> (2) Near-surface disposal facilities in caverns below ground level. Unlike near-surface disposal at ground level, where the excavations are conducted from the surface, shallow disposal requires underground excavation of caverns. The facility is at a depth of several tens of metres below the Earth's surface and accessed through a drift.[64]

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[62] *Ibid,* pg. 4-11

[63] Laraia, M. (2014). Entombment: A Viable Decommissioning Strategy for Research Reactors? *National Nuclear Safety Journal,* 3(4), 1 – 10, pg. 1 [Nuclear Safety Journal]

[64] World Nuclear Association, "Storage and Disposal of Radioactive Waste" (July 2017), <online: http://www.world-

The proposed project by CNL appears to fit, in part, within both of the above IAEA definitions of near surface disposal facility. Thus, CELA submits that the entombment of the facility at Rolphton by way of its proposed in situ decommissioning, creates a near surface disposal facility (NSDF). [65]

CELA requests CNL to demonstrate how its proposed project meets all requisite criteria for the creation of a NSDF, and given the ongoing review of CNL's proposed NSDF, indicate to what extent the cumulative effects or the combined effect of having two NSDFs within a 30 km of each other has factored into their modelling, planning and justification for the project (see further discussion on this point at Part II, section 5 above).

5. Physiological Effects

A final lesson learned that emerged in CELA's review of literature and international guidance was whether the physiographic effects on the area which will result when a large quantity of grout is placed within on-site structures (ie. impacts on surrounding soil structure and water table) is understood and has been modelled.[66]

CELA recommends that the effects resulting from significant increased loading due to the large quantity of grout material added on the surrounding soil structure and water table be modelled and reported on for review.

CONCLUSION

CELA has sought to identify the gaps in the existing draft EIS, its consideration of international guidance and alignment with the purposes of *CEAA, 2012,* and the project's impacts on human health and safety.

CELA requests that all recommendations (see pages 3-4) and information requests (see pages 5-8) be provided before the proposed project proceeds for further review.

As it stands, Canada lacks acceptable policies and strategies for managing radioactive wastes that is reflective of international best practices and standards. This should be a prerequisite to

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nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/storage-and-disposal-of-radioactive-waste.aspx> citing Technical Considerations in the Design of Near Surface Disposal Facilities for Radioactive Waste, IAEA (Vienne 2001), <online: http://www-pub.iaea.org/MTCD/publications/PDF/te_1256_prn.pdf>

[65] Nuclear Safety Journal, *supra* note 63, pg. 2

[66] Savannah River National Laboratories 2009, *supra* note 43, p.26

any consultation on proposed decommissioning strategies. It is recommended that a strategic environmental assessment be conducted under the newly proposed Bill C-69, *An Act to enact the Impact Assessment Act,* once adopted. A strategic EA will allow Canada to develop a comprehensive and publicly informed policy approach to all types of nuclear waste in Canada.

Lacking a nation-wide discussion on Canada's approach to nuclear waste, the proven lack of technology and real risks posed to people and the environment, the project as proposed by CNL should not proceed and the Rolphton site should instead remain under active management. Furthermore, given that the waste in the NPD Closure project will be radioactive for many thousands of years, CNL must provide appropriate guidelines that ensure rolling stewardship with respect to transmission of information, transfer of responsibility, recharacterization of waste, mitigation of problems, retrieval of waste as appropriate, and continual adaptive management.

All of which is respectfully submitted this 13th day of February, 2018:

CANADIAN ENVIRONMENTAL LAW ASSOCIATION
Per

<Personal Information Redacted>

Theresa A. McClenaghan
Executive Director and Counsel

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Appendix 1 – Radiological Inventory (CNL)

Gmail by Google

Kerrie Blaise <kerrie@cela.ca>

FW: Request for Clarification from CELA - Radiological Inventory for the NPDWF (Table 4.4-1)

Vickerd, Meggan <Personal Information Redacted> Wed, Dec 20, 2017 at 9:46 AM
To: <Personal Information Redacted>
<Personal Information Redacted>

OFFICIAL USE ONLY / À USAGE EXCLUSIF

Good morning Dr. Fairlie,

Thank you for your interest in the NPD Closure Project. Given your line of technical questions I suggest reviewing the Post-closure Safety Analysis (PostSa) Technical Support Document (64-508760-ASD-003), as it will provide the technical information you are looking for. We have made this document available to the Canadian Environmental Law Association (CELA) through our Secure File Transfer Protocol site (see below for login details). Specifically, I would draw your attention to Appendix B (Systems Description) where the development of the reference inventory is discussed in more detail.

Please also see below answers to your questions regarding the NPD reference inventory. If you have any further questions I would be happy to continue this dialogue in any manner of convenience to yourself and CELA. For instance, we would be happy to provide a tour of the NPD facility and face to face discussion, if you are interested.

> ***I still do not think that the quoted tritium value of 1.36×10^1 Bq is correct for stainless steel in table 4.4.1.***
>
> This quoted value of 1.36E+01 Bq is the inventory produced by activation of the stainless steel components. Only very small amounts of tritium are produced by activation of stainless steel end fittings. Tritium inventory within NPD reactor systems is primarily from surface contamination from contact with heavy water (e.g. zircaloy pressure tubes).
>
> ***How many tonnes of stainless steel are in the NPD reactor?***
>
> Stainless steel was only used in the construction of the end fittings of the NPD reactor, this stainless steel adds up to a total of 5529 kg (5.529 tonnes). The NPD calandria was constructed from aluminium and the fuel channels contained within are constructed of zircaloy with stainless steel end fittings, as referenced above.
>
> ***What are the units for "Contamination"? Bq or Bq per g? Normally, contamination figs refer to concentrations.***
>
> The units for "Contamination", as well as all other inventory presented in other columns in Table 4.4-1 (a) are in Bq. We apologize for the oversight of note including the unit directly in columns of Table 4.4.-1 (a), however, it is provided in the title "Reference Activity (Bq at 2018) of the Reactor Vault". Please note that the appropriate units are provided for Table 4.4.-1 (b) "Reference Inventory of Fission Products and Actinides in other Rooms".

Where are the Bq data for Fe-55? (As in listed the EISs for CRL and Whiteshell).

The EIS has listed only the radiological contaminants of interest. The inventory of Fe-55 is 2.94E+11 Bq. However, it was screened out as a radiological contaminant of interest for NPD as Fe-55 peak dose was relatively low at 1.25E-12 Sv/y. Please see Section 4.3.1 of the PostSA for a description of the screening process applied to determine the radiological contaminants of interest.

What are the contamination figures (whole concrete structure) for H-3, C-14, Cl-36, Ca-41, Co-60, Ni-59, Ni-63, and Ag-108m?

The NPD reference inventory contains two separate concrete components which have different inventories dependent on proximity to the reactor. The reference inventory in the concrete immediately surrounding the reactor is presented in Table 4.4-1 (a) as "Concrete". The reference inventory of the whole concrete facility structure is presented in Table 4.4-1 (b) as "Generic Contamination".

Reference inventory in the reactor vault concrete includes H-3, C-14, Cl-36, Ca-41, Co-60, Ni-63, and Eu-152 as a result of activation of concrete directly surrounding the reactor. This reference inventory was derived from a combination of neutron flux calculations as well as direct measurements (e.g. sampling and analysis). Ni-59 and Ag-108m are not activation products present in concrete.

Reference inventory in the concrete facility structure includes H-3, C-14, Co-60, Sr-90, Cs-137 and low levels of actinides as a result of surface contamination. This reference inventory was derived from direct measurements (e.g. sampling and analysis).

It is necessary to work with concentration figures i.e. Bq/g. Could you present these for the above nuclides? Thanks.

As requested, please see the table below for the concentrations of the radionuclides present in the reactor vault concrete:

Radionuclide	Reference Inventory Concrete (Bq)	Concrete Radionuclide Concentrations (Bq/g)
H-3	1.41E+12	3.22E+03
C-14	2.40E+10	5.49E+01
Cl-36	2.20E+09	5.57E+01
Ca-41	7.62E+09	1.74E+01

Co-60	3.18E+11	7.27E+02
Ni-63	6.83E+10	1.56E+02
Eu-152	1.23E+11	2.80E+02

The contamination of the whole facility concrete structure ("Generic Contamination") presented in Table 4.4-1 (b) is presented in Bq/g.

What is the estimated mass of the whole concrete structure of the NPD?

The estimated mass of the concrete facility structure of NPD is 5,250,000 kg.

We have a file transfer site set up to share all the technical support documents (TSDs) mentioned in the draft EIS, including the Post-closure Safety Analysis. Please use the user name and password below to access the site:

User name: NPD_Closure_Project

Password: npdenvironimpact_jan26

Please do not hesitate to contact me if there is any trouble downloading the files through the file transfer site or if you would like more information on the NPD Closure Project.

Regards and have a happy holiday,

Meggan Vickerd

NPD Decommissionin Manager

Canadian Nuclear Laboratories

<Personal Information Redacted>

Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens

Appendix 2 – Grout Formulation (CNL)

Grout Formulation for Nuclear Power Demonstration Closure Project.

To assist with defining the grout properties and formulations, CNL worked closely with the U.S. Department of Energy, Savannah River Nuclear Labs (SRNL). This group has decades of experience in developing grouts and concretes for the numerous waste facilities, underground tanks and research reactors within its responsibility. The SRNL staff have visited the NPD and toured all the areas. They then provided a recommended grout formulation that they have developed and were successful in applying at several facilities in the United States.

The following table is the grout formula that CNL will be using as a basis for the grout used at NPD*:

Material	Proportion kg / m^3 or as indicated.
Portland Cement Type I/II (ASTM C150)	89
Fly Ash Class F (ASTM C618)*	297
Sand (quartz) (ASTM C33)	1097
Gravel (granite) No. 8 (ASTM C33)	475
Water	247
Polycarboxylate polymer (ASTM C494 B & F) HRWR max.	0.30 Liters/m^3
Diutan Gum based VMA (ASTM C494)	262 g/m^3

CNL is currently working with Golder Associates to validate this grout formulation will meet the grout requirements listed in the table below using locally sourced materials. There could be differences in the sand and gravel that were sourced in South Carolina versus what is readily available in Renfrew County. The testing will also find a substitute for fly ash. Since the Province of Ontario closed down its coal fired plants, (the source of fly ash), Ontario concrete suppliers have successfully substituted blast furnace slag, obtained from Hamilton. The Golder laboratory testing will confirm the blast furnace slag as a suitable substitute for fly ash.

Using the appropriate American Society of Testing Materials and American and Canadian Concrete Institutes standards the Golder lab will confirm the grout formula will meet the following performance requirements.

*Please note the grout formulation is not finalized.

Property	**Requirement**	**Basis**
Slump Flow	508-762 mm	SRNL Recommended. A measure of the ability to flow.
Static Working Time	≥ 30 minutes	Grout should remain pumpable and flowable to recover from a pump failure.
Dynamic Working Time	60 Minutes	Grout should remain pumpable and flowable while being stirred or recirculated.
Air content	< 8 (vol. %)	Frothing/air entrainment can hinder pumping.
Set time	< 24 hrs	Long enough to enable placement but short enough to mitigate settling. To avoid lengthy delay when filling demolition rubble.
Bleed Water after 24 hr. (vol. %)	0	Eliminate need for liquid removal, transport of contaminants and creating undue wall pressures.
Segregation/stability	None	Stable slurry, no bleed. Uniform mix.
Maximum temperature rise during curing	< 25 ^{o}C above ambient	
pH	9-10 for low pH grout. < 13.5 for area fill grout	Low pH grout formula required in Fuel Machine room to account for a higher quantity of lead shielding.
Compressive strength	> 3.4 MPa at 28 days	Non-structural grout.