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COMPARISON OF RISKS FROM DEEP GEOLOGICAL DISPOSAL AND EXTENDED STORAGE APPROACHES FOR THE LONG TERM MANAGEMENT OF USED FUEL

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ABSTRACT

The Nuclear Waste Management Organization has a mandate from the Government of Canada to consult with the public and to recommend an approach for managing Canada's used nuclear fuel. Three main fuel management methods are being explored and evaluated: disposal in a Deep Geological Repository; reactor-site extended storage; and centralized extended storage, either above ground or below ground. In this study, the management methods were reviewed to estimate potential risks at each stage of their development. The risk assessment presented is based on a combination of operating experience at the nuclear sites in Ontario (Pickering, Darlington, Bruce) as well as Canadian and international assessments.

I. INTRODUCTION

The Nuclear Waste Management Organization (NWMO) has a mandate from the Government of Canada to consult with the public and to recommend an approach for managing Canada's used nuclear fuel. Three main approaches are being explored and evaluated by the NWMO. These are:

- Disposal in a Deep Geological Repository (DGR);
- Extended storage at nuclear reactor sites (RES);
- Centralized extended storage (CES), either above ground or below ground.

Conceptual designs were developed for the used nuclear fuel management options studied by the NWMO (CTECH, 2002; 2003a, b; COGEMA Logistics 2003). All these designs meet regulatory safety and environmental requirements. Regulatory compliance does not imply that these concepts can be implemented under zero-risk conditions. Like any major industrial project, a nuclear used fuel facility may affect the health of project workers and of members of the public living near the site or along affected transportation routes. It is not surprising therefore, that a small risk to human health or the environment would be expected from any of the management options mentioned above. This is the case even though all the relevant regulations are met and particular care is taken to reduce the risk to as low as practically possible.

This paper provides a brief summary of potential risk to the public, risk to workers and risk to the environment for the three approaches listed above (Garisto, 2004). The possible effects associated with the various management options are not limited to those resulting from exposure to radiation, nor to those experienced by individuals working at, or living near, the facility. Equally, they may not be limited to the period during which the facility is built, filled and sealed, but may arise many centuries in the future.

Potential radiological and non-radiological effects are considered in this paper. Furthermore, both routine operating conditions and hypothetical accident scenarios are considered. Where emissions are thought to occur, the resulting exposure doses are compared to existing limits, guidelines and background values for perspective. Where there are gaps in current knowledge, *these gaps are noted*, so they can be addressed in a future analysis, during the step-wise implementation of the approach. Such an analysis will close gaps in the analysis, update the calculations, quantify the risk associated with this option and document the results for communication with the public.

II. OBJECTIVES

The objective of this study is to provide answers to the following questions, based on currently available information:

(i) What can we expect, under normal and off-normal conditions for the three options?

- Are there any potential, significant public health impacts expected?
- Are there any potential, significant worker health impacts expected?
- Are there any potential, significant ecological impacts expected?

(ii) What are the main gaps in the responses to the above questions?

III. STAGES IN THE DEVELOPMENT OF USED FUEL WASTE MANAGEMENT SYSTEMS AND ASSOCIATED POTENTIAL RISKS

This section provides an overview of stages in the development of Used Fuel Waste Management systems and associated risks. It addresses radiological and non-radiological aspects of Used Fuel Waste Management. Further details on radiological aspects are provided in Section IV.

Extensive studies have been conducted on radiological aspects of used nuclear fuel management (see Section IV in this paper). There has been less emphasis in past assessments on exposure to non-radioactive contaminants, because they were perceived to be less hazardous than radioactive contaminants. Recent assessments of sites with mixed contaminants developed comprehensive systematic approaches for considering both radioactive and non-radioactive contaminants (e.g., Garisto, 2002). Based on available screening-level information (e.g., Environmental Assessments on the Extension of Storage Sites for Dry Used Fuel Storage), there are no major issues associated with chemical emissions from dry used fuel storage facilities. Similarly for a DGR, based on Goodwin and Mehta (1994) and Gierszewski *et al.* (2004), it is likely that no exposure to chemical contaminants will occur until containers fail, engineered barriers fail and chemicals gradually disperse into the receiving environment through groundwater transport. An updated analysis of the risk from chemical contaminants will be required as part of the implementation of the approach selected by the federal Government for the long-term management of nuclear fuel waste.

The risk comparison by stage is provided in a detailed report (Garisto, 2004). Examples of the results are illustrated in Tables 1-3.

Table 1: Overview of Stages in the Development of Deep Geological Disposal and Potential Risks

Stage	Non-radiological Effects		Radiological Effects	
	On site worker	Off site resident	On site worker	Off site resident
Siting				
Construction				
Operation				
Transportation				
Extended Monitoring, Decommissioning and Closure				
Post Closure				
Inadvertent Human Intrusion				

Table 2: Overview of Stages in the Development of Storage at Reactor Sites and Potential Risks

Stage	Non-radiological Effects		Radiological Effects	
	On site worker	Off site resident	On site worker	Off site resident
Site Preparation and Construction				
Operation				
Transportation				
Extended Monitoring				
Facility Repeat				
Repackaging				
Replacement of Modules and Baskets				
Extended Long Term Monitoring				
Inadvertent Human Intrusion				

Table 3: Overview of Stages in the Development of Centralized Storage and Potential Risks

Stage	Non-radiological Effects		Radiological Effects	
	On site worker	Off site resident	On site worker	Off site resident
Site Preparation and Construction				
Operation				
Transportation				
Extended Monitoring				
Facility Repeat				
Repackaging				
Replacement of Modules and Baskets				
Extended Long Term Monitoring				
Inadvertent Human Intrusion				

Green	No significant effect; very small risk of injury
Blue	The potential effect of loss of institutional controls and inadvertent human intrusion was not assessed. The potential effect of fuel bundle disintegration – not assessed.
Purple	Potential exposure in the hypothetical and unlike event of institutional collapse in the near-term and society memory loss of the site. No potential impact from DGR is expected if such a societal collapse occurs in the long term even in the case of human intrusion (because of gradual radioactive decay).
Yellow	Theoretical potential lost time accident
Orange	Theoretical potential fatality

IV. A COMPARISON OF POTENTIAL RADIOACTIVE EXPOSURE

Where emissions are thought to occur, the resulting exposure doses are compared to existing limits, guidelines and background values for perspective. Where there are gaps in current knowledge, these are noted, so that they can be addressed in a future analysis during the implementation of the monitoring program.

Radiological dose rates were estimated for the various stages in the implementation of each of the three types of facilities and for the public, workers and non-human biota (e.g., mammals, birds, fish) in each case.

The dose estimates were made using a comprehensive pathways analysis (see Figure 1, 2 for pathways being considered). The dose estimate results for a deep geological repository and reactor-site extended storage are shown in Figures 3-7, respectively. Other routine and non-routine scenarios are provided in Garisto, 2004.

Figure 1: Key Aquatic Exposure Pathways for Underground Facilities

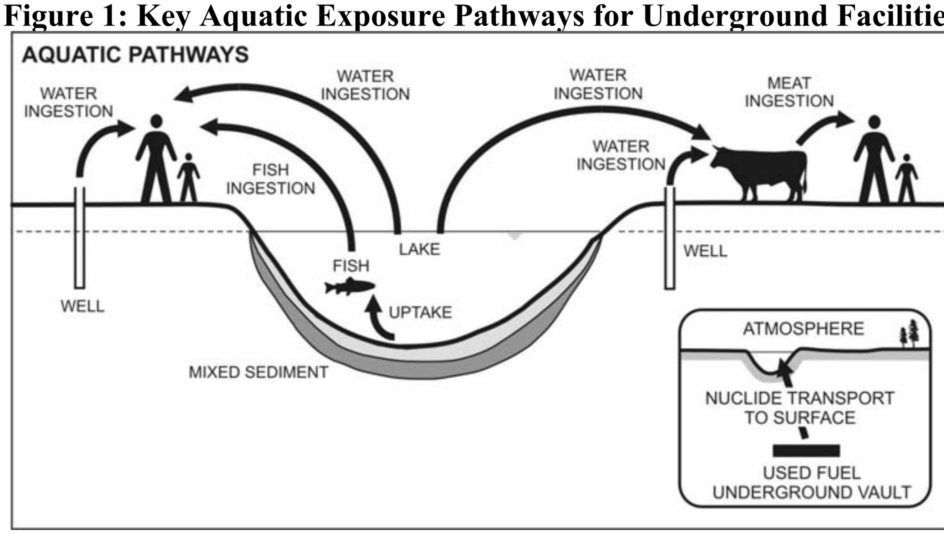


Figure 2: Key Terrestrial Exposure Pathways for Underground Facilities

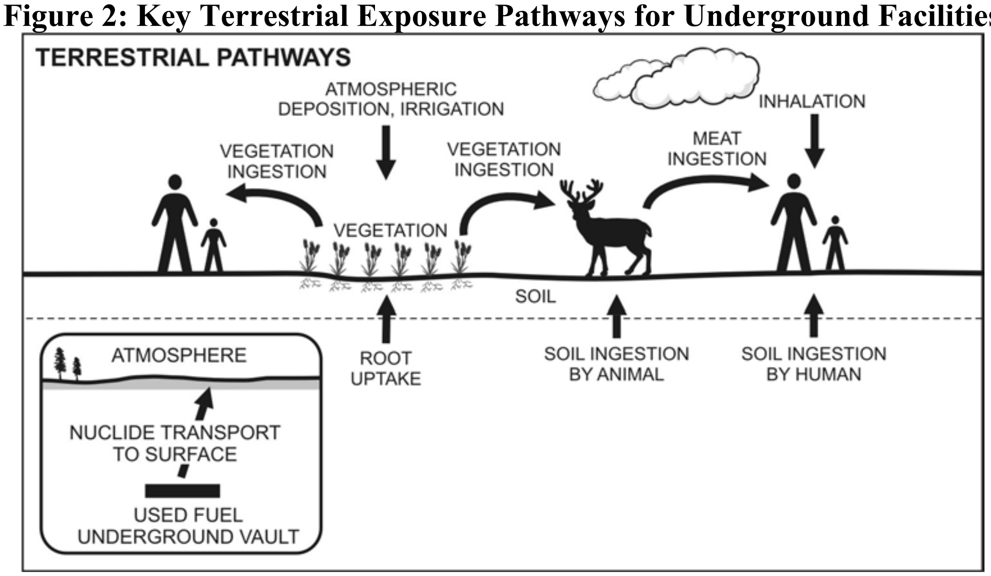
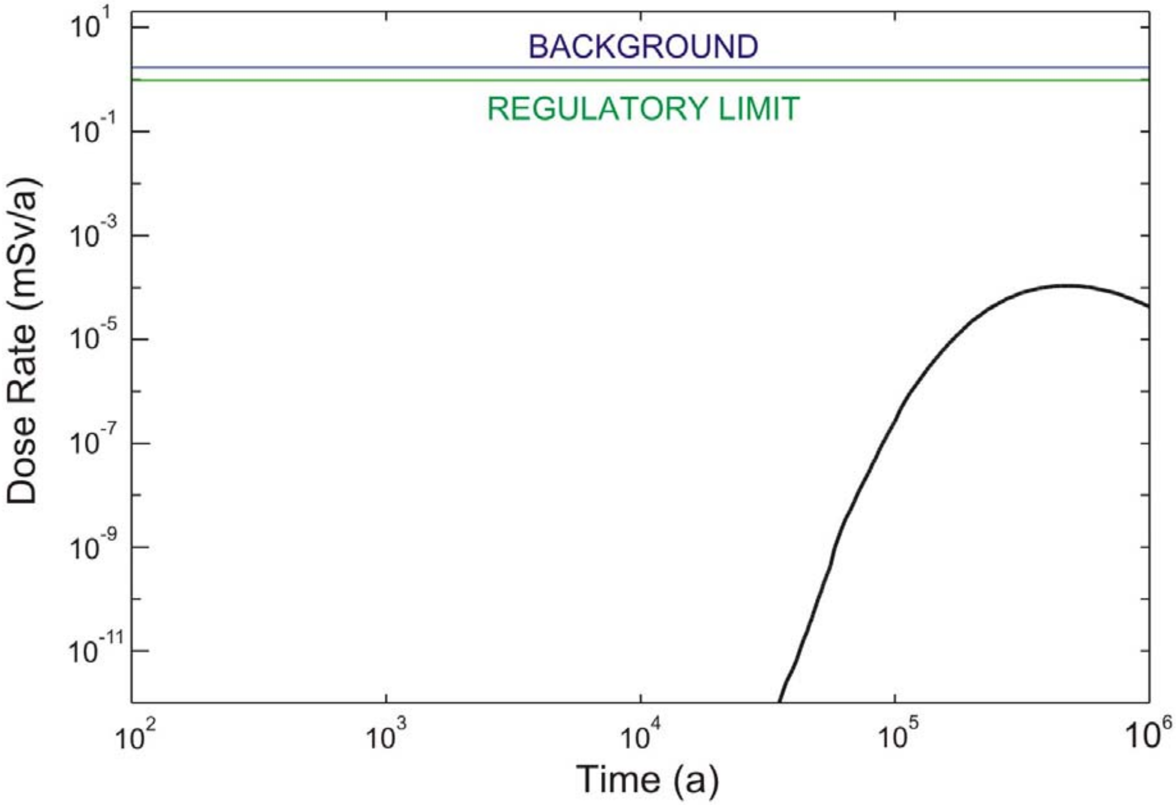
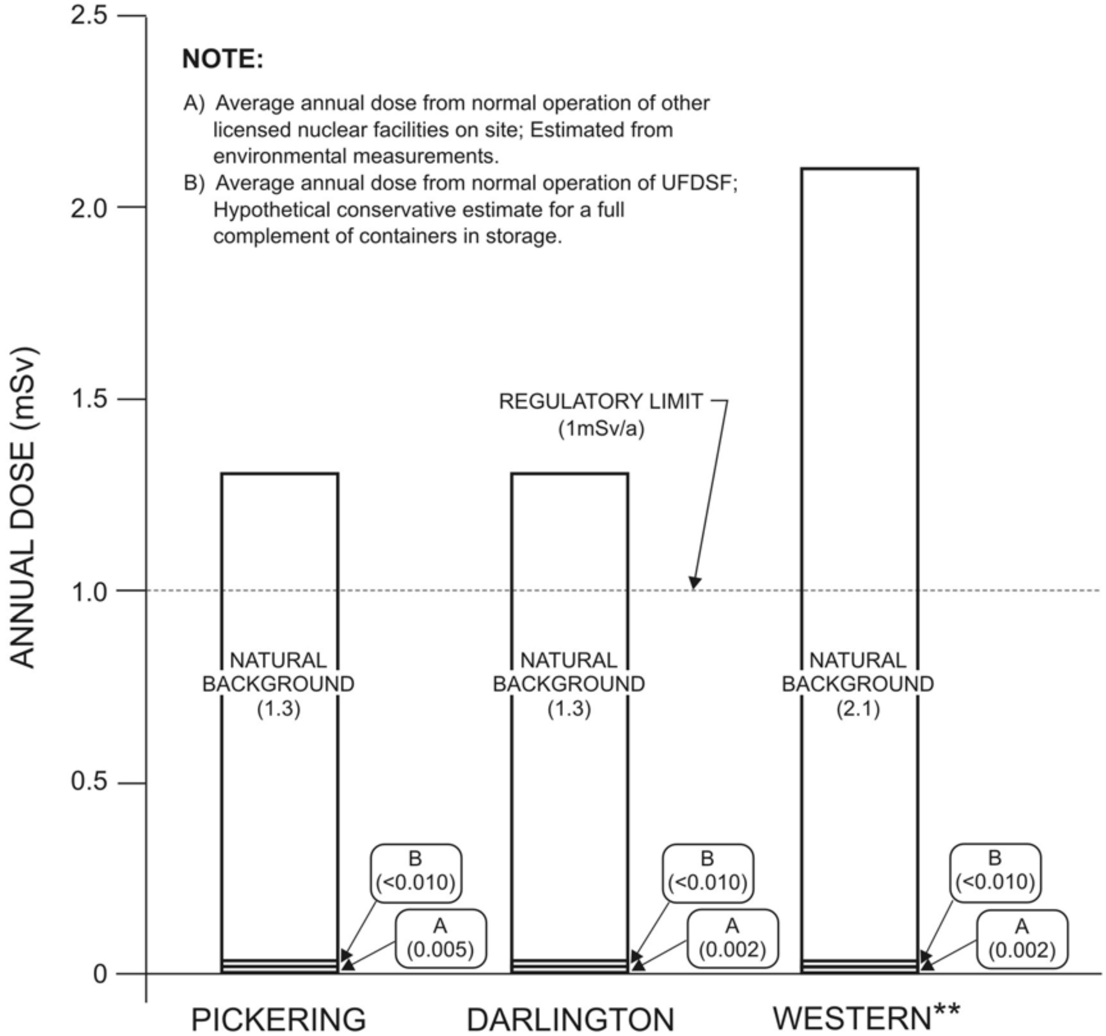


Figure 3: Dose Rate as a Function of Time for the Post-Closure Stage of a Deep Geological Repository



SOURCE: Adapted from Garisto et al, 2004

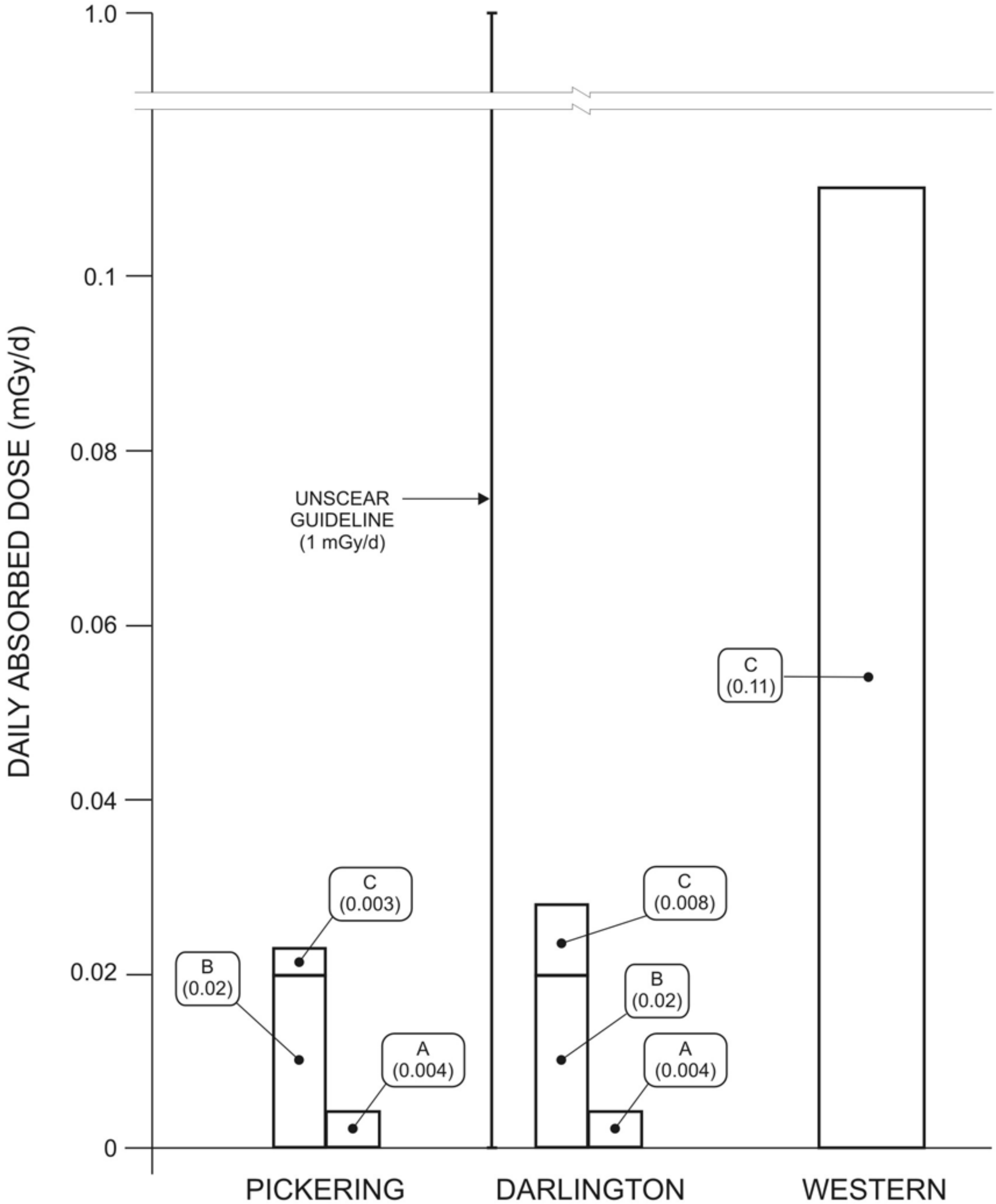
Figure 4: Annual Dose to a Member of the Public for Reactor-Site Extended Storage: Operating Conditions in Existing Facilities*



* The operating experience from existing facilities has confirmed that the current dose rate to the public at the property boundary is less than 1% of the regulatory limit.

** Western refers to the Western Management Facility at the Bruce Site

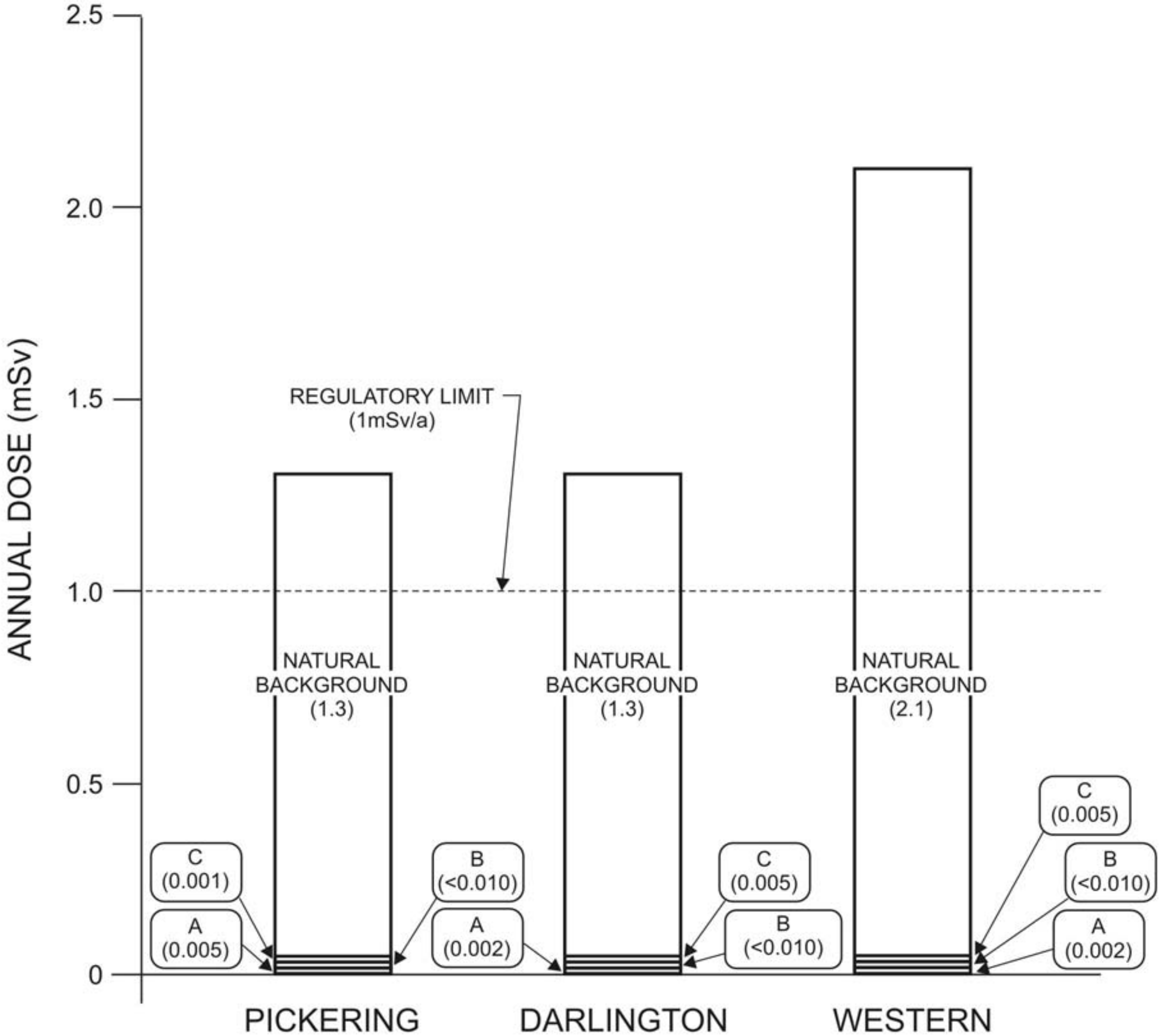
Figure 5: Daily Dose to Non-Human Biota (Operational – Normal)



NOTE:

A) Low end of range of daily dose from natural background.
B) High end of range of daily dose from natural background.
C) Average daily dose from normal operation at Used Fuel Dry Storage Facility (UFDSF).

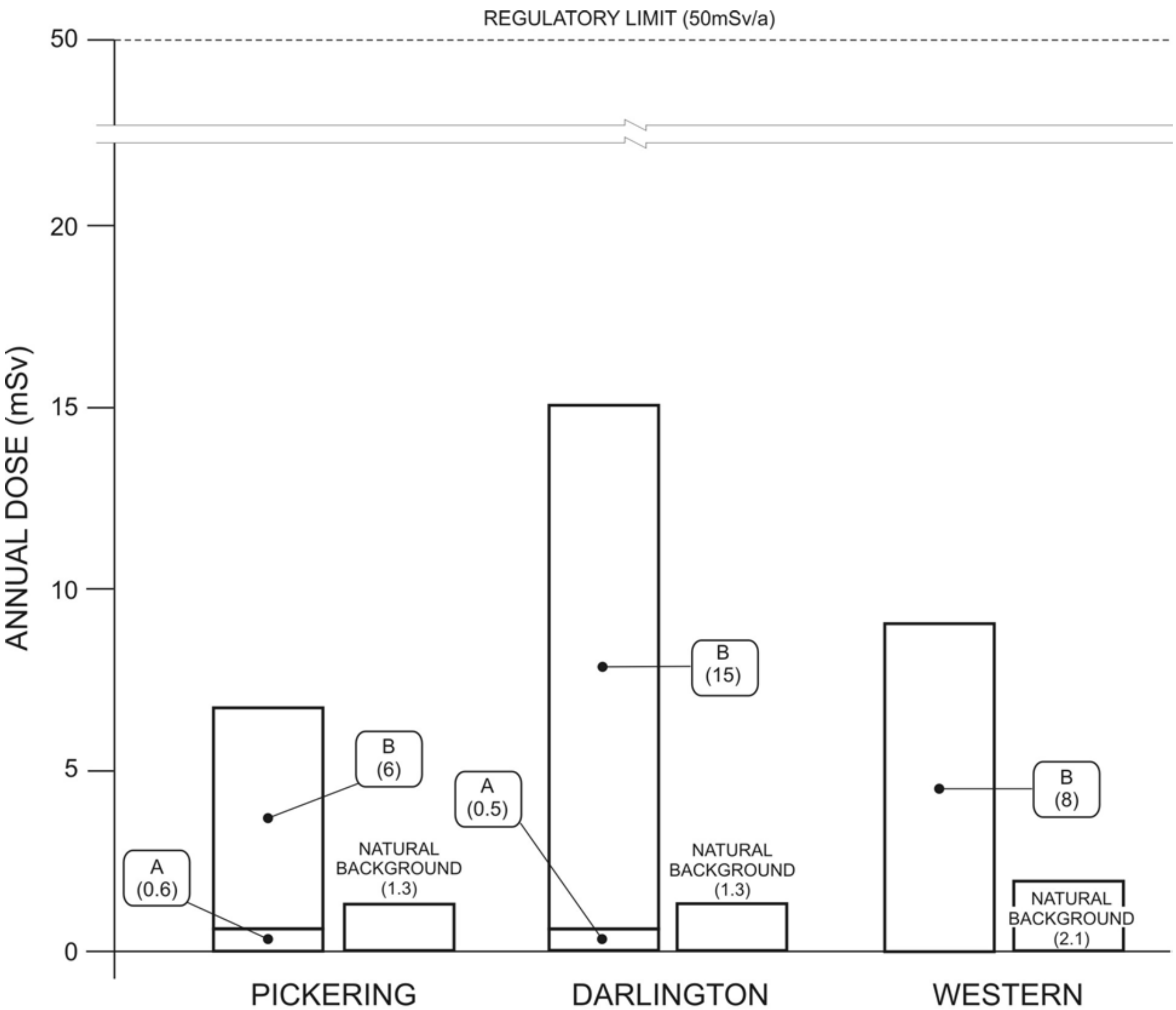
Figure 6: Dose to a Member of the Public During a Hypothetical Year in Which a Bounding Malfunction/Accident Occurs at UFDSF



NOTE:

A) Average annual dose from normal operation of other licensed nuclear facilities on site.
B) Dose from normal operation of UFDSF at year end when malfunction/accident occurs.
C) Dose from bounding malfunction/accident at Used Fuel Dry Storage Facility (UFDSF).

Figure 7: Nuclear Energy Worker (NEW) Dose During a Hypothetical Year in Which a Bounding Malfunction/Accident Occurs at UFDSF



NOTE:

A) Average occupational dose at year end when malfunction/accident occurs.
B) Expected dose from malfunction/accident.

V. CONCLUSIONS

The main conclusions from the risk-analysis are:

- Under current routine conditions, and based on available information, no significant impacts on human health or the environment, from any of the proposed management approaches are expected.
- Conventional industrial and/or transportation accidents may occur in the implementation of these methods, as with any large industrial project. Such risks can be mitigated by the implementation of safety programs including worker education, strict implementation of safety procedures, and monitoring of this implementation. Some small differences between the options can be expected regarding risk from conventional accidents. For example, transportation risk is smaller for storage at reactor site than at a centralized facility.
- Overall, except for negligible changes in radiological dose after container failure, the total risk from a Deep Geological Repository decreases with time due to radioactive decay and the inherent passive nature of this disposal method.
- Dose from inadvertent human intrusion was estimated for Deep Geological Disposal and shown to diminish with time. The probability of exposure was estimated to be less than one-in-a-million per year for the first 1000 years after disposal. Site accessibility is expected to be higher for surface storage facility, especially in the event of institutional collapse. However, no analogous assessment is available for long-term storage facilities.
- Over the long term, there may be a requirement to relocate the used fuel for the reactor-site extended storage and perhaps centralized extended storage (e.g., for above-ground facilities). This may be due to potential rise in surface water levels caused by climate-change factors such as global warming. Monitoring of climate conditions may be used to warn of the need for used-fuel facility relocation. Also, the impact of a far-future glaciation scenario has not been addressed in existing documentation on reactor-site extended storage and centralized extended storage. The consideration of such a scenario may result in such facilities having to be relocated, prior to glaciation, to avoid glaciation related impacts.

  The risks associated with the extension of storage time at either reactor sites or a centralized location to very long times has not been studied quantitatively in detail. Such an assessment requires for example, an understanding of risks associated with potential loss of integrity of the fuel bundles (i.e., the cladding and potentially the fuel). However, a specific monitoring program can be developed to focus on this aspect of the performance of storage systems, to determine potential risk and decide on mitigation measures.
- Although radioactivity is often perceived as being a high risk factor associated with used fuel management, the estimated exposure doses for the various options are generally low in comparison to established national and international benchmarks.
- Current information on risks associated with the various approaches supports the safety of these systems under current conditions. Security risks such as acts of terrorism have not been evaluated in the present study.

- Several gaps in the risk estimates and its documentation were noted. However, none of these are considered to affect the overall conclusions from this study. They include a need:
    1. to update the documentation of risk assessments to ensure that they consider the current reference design concepts and alternatives studied by the NWMO;
    2. to complete the documentation of risk assessment from chemical emissions;
    3. to directly address potential specific human receptors (e.g., a specific documentation of potential risk to Aboriginals would enhance the transparency of the assessment, although most diets assumed in the current assessment encompass those of Aboriginal receptors);
    4. to complete and update the assessment of ecological risk to non-human biota (e.g., mammals, birds, fish).
    5. to re-evaluate the risk from transportation and if necessary, to develop mitigation measures to improve transportation safety.

In our opinion, these gaps will need to be addressed as part of the implementation of the approach selected by the federal Government for long-term management of nuclear fuel waste.

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