

PROPOSED NEED AND JUSTIFICATION FOR COMPREHENSIVE RADIOLOGICAL HEALTH RISK EVALUATIONS FOR THE TRANSPORT OF USED NUCLEAR FUEL TO THE PLANNED DGR SITE

The following paper which endeavors to address the need and justification for a comprehensive nationwide transportation radiological risk evaluation to be performed in support of the DGR Project's evolving impact assessment effort, has been provided by the United States-based consulting and engineering firm of SC&A, Inc., an employee-owned Virginia corporation founded in 1981 to support radiation-related and nuclear programs for the government and the private sector. SC&A is known for its superior work in regulatory and policy analyses of environmental and health safety issues, particularly those related to radiation and the nuclear industry. SC&A also provides engineering, health physics, and nuclear fuel cycle consulting services; mathematical modeling and computer code development; and transportation, environmental, economic, and regulatory impact analyses of federal actions. Much of SC&A's work has historically been tied to helping the U.S. government evaluate a number of unique nuclear-safety and environmental-related challenges. SC&A has supported, in particular, the U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management, the U.S. Environmental Protection Agency (EPA), and Clark County, Nevada, by thoroughly researching the regulatory issues and performance assessments associated with the proposed DOE spent nuclear fuel and high-level-waste repository at Yucca Mountain, Nevada. For the EPA, in support of the State of New Mexico Environmental Evaluation Group and the DOE (via its prime contractors), SC&A addressed a wide variety of environmental and nuclear safety issues relating to the Waste Isolation Pilot Plant (WIPP) that is currently the singular repository facility for transuranic waste disposal within the United States.

In essence, SC&A was tasked by the Nishnawbe Aski Nation ("NAN") to produce this initial paper which addresses the question of scoping radioactive waste (i.e., used nuclear fuel) transportation within the DGR's impact assessment process. Specifically, the NAN has requested that a comparison be performed which examines the proposed impact assessment process plan with the mechanisms typically employed under the United States' federal regulatory regime. As a key component of this comparison effort, experiences associated with the transportation impact assessment process for the proposed Geological Repository for the Disposal of Spent Nuclear Fuel and High-level Radioactive Waste at Yucca Mountain in Nevada were delineated as a basis for technical equivalency.

Inclusive discussions focus largely upon considerations with regard to assessing *direct* potential radiological transportation impacts (i.e., estimated doses) that First Nation peoples, as well as other rights-holders, may theoretically incur. *Indirect or secondary* impacts/concerns (e.g., psychological), however, that may ultimately result from said transportation undertakings, such as the perception of risk, fear, or possible dread, and the manners in which these facets may affect overall behaviors and land-use activities are accordingly not addressed herein. In addition, any potentially perceived logistical hazards associated with radiological transportation within the northern Ontario corridor (e.g., a need for expansive road-widening or -twinning) that may ultimately be considered as part of the overall impact assessment process are likewise not addressed below.

Upon review of the *Draft Integrated Tailored Impact Statement Guidelines: Deep Geological Repository for Canada's Used Nuclear Fuel Project* (dated April 10, 2026), an expansion of the present scope within the subject *Guidelines* report regarding transportation risk "assessment-needs" is recommended from a historical United States-based regulatory benchmarking perspective. Such an expansion, along with subsequently performed risk modeling efforts that would ultimately support this broader scope, would effectively and impartially serve affected rights-holders' requests for a "country-wide" level of risk-assessment that is in need of performance with regard to Canada's upcoming years-long proposed mission of transporting its present stockpile of used nuclear fuel to its planned Deep Geological Repository (DGR) site location in northwestern Ontario.

Numerous concerns from the general public across the country, as well as from a variety of Indigenous Nations, have been focused on a perceived need for additional impact assessments to be performed with regard to potential risks from used nuclear fuel being shipped through their communities to the DGR site. Such an impact assessment would ideally include, but not necessarily be limited to, radiation dose and cancer risk assessments to members of nearby populations that may be

exposed to radiation from incident-free transport of the used-fuel through their communities as well as from a hypothetical worst-case accident event that could result in a material release and potential dispersion scenario.

With general regard to radiological-transportation logistics, Canada has been transporting such materials for decades; however, the anticipated scale required for the DGR will be unprecedented. Such details include the need for the used-fuel to be moved from current interim storage containers into certified transport packages and then regularly shipped across considerable distances across Canada to the DGR site over a number of years. Many such shipping efforts are expected to be conducted through dangerous winter-weather conditions as well as on narrow secondary roadways, making the likelihood of an accident event occurrence notably higher than what would be expected from normal freeway travel during fair-weather periods.

Radiological-transportation-related historical research generated from Canada's Nuclear Waste Management Organization (NWMO) and the Atomic Energy of Canada Limited (AECL) has primarily focused on probabilistic risk assessment, regulatory crash testing, and environmental impact simulations that essentially deployed a *generic-based* methodology in support of their determinations, as opposed to a more *wide-reaching* analytical approach (e.g., projected doses to exposed populations expected to live near/along anticipated transit routes throughout Canada). To these regards, the AECL's Conceptual Assessment approach had generated a series of foundational studies that *generically* evaluated the safety of transporting used-fuel from stations in Ontario, Quebec, and New Brunswick to a *conceptual disposal site*. However, given the unprecedented scale of transportation logistical requirements and sheer numbers of expected shipments to be required to the DGR, an in-depth and refined radiological health risk analysis to affected populations and transport-crews should be set forth for ensuring that necessitated levels of transparency and information are provided to any/all potentially affected parties, including rights-holders, decisionmakers, and other stakeholders.

The National Environmental Policy Act of 1969 (NEPA) has been the ongoing regulatory mechanism in place for the United States that has required a widespread degree of evaluation for radiological-transportation actions over the last several decades. The extent of such evaluations has regularly included wide-reaching (both in terms of expansive transport-mileages/areas and assessment scope) accident and incident-free radiological-shipping analyses. ***A comparable level of evaluation is accordingly recommended for ultimate inclusion within an expanded transportation impact assessment effort for the DGR project.*** NEPA is often cited as the "Magna Carta of Environmental Law" due to its often being regarded internationally as having set the benchmark for environmental protection, which by definition, includes a specific focus on the *human-health* environment. The preparation of an Environmental Impact Statement (EIS) under NEPA for any major proposed federal action that may significantly affect the quality of the *human-health* environment (such as the large-scale transportation of used nuclear fuel) is typically undertaken to perform comprehensive assessments via the use of various sanctioned computer codes, models, and/or other analytical tools. This very type of effort was set forth in support of the *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (Yucca Mountain EIS), published in 2002. As is well-established, the Yucca Mountain Project was the United States' official proposed DGR location for over two decades; although technically defunded and inactive at present, it has not (yet) been legally repealed. This paper thus endeavors to summarize and ultimately advocate the principal strategies behind the radiological transportation risk assessment methodology/approach that was set forth within the Yucca Mountain EIS, as it likely serves as the most applicable contemporary framework for the Canada DGR project to benchmark as an endorsed (by the U.S. Nuclear Regulatory Commission) "long-distance-shipping-model-based" ***analog***, in an attempt to reconcile any/all additionally perceived impact-assessment needs related to used nuclear fuel transport across greater Canada.

NEPA requirements altogether mandate a comprehensive analysis of radiological transportation be performed to evaluate potential environmental and safety impacts, ensuring public safety and regulatory compliance criteria are satisfactorily met. Assessments are performed for determining the impacts of both normal (incident-free) shipment radiation doses and potential accident scenarios, including identifying risks, mitigating dangers, and fulfilling public disclosure requirements for federal projects. The key reasons for analyzing radiological transportation under NEPA include the following:

- **Protection of Public and Environment:** Transportation moves radioactive materials outside controlled facilities and into the public domain, necessitating rigorous evaluation of potential exposures.
- **Safety Risk Evaluation:** Analyses cover incident-free transport (routine radiation doses to crew/public) and transportation accident risk. Accident risks involve evaluating potential radiological releases, direct radiation exposure, and criticality scenarios.
- **Regulatory Compliance and Efficiency:** Such analyses are essential for EISs and Environmental Assessments prepared under NEPA.
- **Documentation and Disclosure:** NEPA mandates documenting and disclosing environmental consequences, and such practices help to continually ensure a very low risk of accident events.
- **Emergency Planning:** These analyses contribute to identifying the need for emergency plans and/or procedures, as per International Atomic Energy Agency guidelines.

Moreover, NEPA requires radiological transportation analyses to fulfill its mandate that U.S. federal agencies assess environmental and safety impacts before taking action. The analyses ensure that both incident-free transportation risks (routine exposure) and accident scenarios are evaluated to inform decisionmakers and the public about potential human health risks. Key rationales that support the extent of such analyses include the need for the following:

- **Safety and Risk Assessment:** This assessment quantifies the potential risk to transport-crew members and the public from both routine radiation exposure (incident-free) and the low-probability, high-consequence potential of accidents.
- **Overall Compliance with NEPA Objectives:** Federal agencies must analyze reasonably foreseeable environmental effects. For projects involving radioactive materials, transportation is a *major* environmental factor.
- **Comparing Alternatives:** The assessment allows decisionmakers to weigh the environmental impacts (e.g., radiation dose to the public) of different transport routes, modes, or packaging methods.
- **Public Safety and Transparency:** The analyses estimate potential doses and health effects, demonstrating that safety procedures and packaging are adequate to protect public health.

As a point of reference, The NWMO emphasized in their 2021 *Moving Forward Together: An Update on the Transportation Planning Framework and Preliminary Transportation Plan* that in regard to overall radiological safety: (1) packages used to transport used nuclear fuel must meet radiation level requirements prescribed by the CNSC’s *Packaging and Transport of Nuclear Substances Regulations, 2015*, and (2) regulatory requirements for such packages must ensure that the public and workers will remain safe. The *Preliminary Transportation Plan* moreover mandated that packages shall be designed and tested to ensure that in the event of an accident, any radiological release will not exceed established regulatory limits. Per Canada’s *Nuclear Safety and Control Act* (SOR/2000-203; SOR/2020-237, as amended), CNSC’s radiation protection regulations enforce an annual radiation dose limit for members of the public to 1 mSv (100 millirem) per year to limit exposure from nuclear-related activities, including those that may result from radiological material transportation. Along key related lines of inquiry from the general public, rights-holders, and other various stakeholders, the *Preliminary Transportation Plan* likewise discussed the “need” to orient future related work within this area **toward including more detailed studies of accident scenarios**, including assessing potential radiological doses to members of the public and workers that could hypothetically result from such events. This acknowledged “need” is congruous with the present-state of recognition that the 2021 *Plan* is unfortunately outdated in several key aspects, and as a result, likely lacks pertinent contemporary details such as the final selection of a/the singular DGR site location, as opposed to the two potential candidate sites that were originally under consideration back in 2021. Although the NWMO is to undertake the endeavor of updating the 2021 *Plan* at the end of the next phase of the assessment process, a concern exists that there may arguably not be enough

specific information with regard to transportation impact assessment contained within the update to serve at a high level of utility for supporting an eventual full-scale radiological transportation modeling effort as advocated for within this paper.

Comments received from Indigenous Nations and communities, the general public, government authorities, and other participants during the DGR project's Planning Phase have bolstered the overarching determination that DGR project-related transportation has the potential to result in adverse health effects within areas of federal jurisdiction. Emergency response measures to protect the public, workers, and the environment is also understandably designated as an area of prime importance. An emergency management and response plan that describes measures to be taken should an accident or malfunction occur would be expected to include protocols regarding training and coordination with Indigenous Nations and communities, first responders and emergency agencies, and high-level immediate response procedures undertaken by carriers. Such emergency planning strategies are in consistent alignment with such requirements governed by the U.S. Nuclear Regulatory Commission, the U.S. Department of Energy, U.S. Department of Transportation, and the U.S. Federal Emergency Management Agency.

Along with the above, given that the NWMO is evaluating both truck and rail as potential alternatives for used-fuel shipping options to the DGR, it is advised that the following additional key details/discussions be accordingly focused upon within the scope of updated impact-assessment planning:

- **Two Primary Candidate Shipping Approaches:** The primary options of either an all-road system *or* a road-rail *hybrid* system for transport of used-fuel bundles are most likely to be deployed.
- **Methodology:** Train transport is preferred for larger capacities, while specialized road transport is crucial for handling large pieces of equipment and bridging the gap between facilities and transport hubs.
- **Locational and Logistical Constraints:** While many nuclear plants have rail access, some sites require trucks, with the TransCanada Highway being a primary potential route for truck transport.

Given that all of the above-discussed facets recommended for inclusion within the updated impact-assessment scope appear to mesh quite well with numerous facets of the required scope of NEPA transportation impact assessments, it is thus recommended that the radiological transportation risk assessment methodology/approach that was set forth within the aforementioned Yucca Mountain EIS be employed as a definitive benchmark (or baseline) from which the future direction of the DGR project's quantitative impact evaluations for transportation may be conducted. If the decision is ultimately made to employ this subject recommended approach, the listing below provides a condensed summary of the key analytical tools/methodologies that would be accordingly emphasized in support of rendering the level of DGR transportation impact analysis that is being requested from Indigenous Nations and communities (i.e., rights-holders), the general public, government authorities, various stakeholders, and other interested parties:

- The CALVIN computer program (data now presently integrated into the U.S. Department of Energy's [DOE's] "NextGen SAM" module) was used to estimate numbers of shipments of spent nuclear fuel from commercial sites. The program deploys information on used nuclear fuel stored at each reactor site and an assumed scenario for picking up that fuel from each site. The program also used information on the capacity of shipping casks that could be used. CALVIN is viewed as a unique tool due to its capacity to serve as a queuing and inventory model. It specifically provides answers to key logistical questions that are critical for used-fuel shipment planning by addressing such pivotal aspects as thermal-loading, cask optimization, and site-sequencing.
- The HIGHWAY computer program (now effectively replaced by "WebTRAGIS") is a routing tool used to select existing highway routes that satisfy route-selection regulations that may be used to ship used nuclear fuel.
- The INTERLINE computer program (now effectively replaced by "WebTRAGIS") is a routing tool used to select existing rail routes that railroads would be likely to use to ship used nuclear fuel.

- The RADTRAN computer program (latest version “NRC-RADTRAN v1.1” per deployment of RADTRAN 6.02.1 engine) is used in estimating radiological doses and resulting health risks (in measures of latent cancer fatalities [LCFs]) to populations and transportation workers resulting from incident-free transportation, as well as doses/risks to the general population from postulated accident scenarios. For the analysis of incident-free transportation risks, the code models scenarios for persons who would share transportation routes with shipments, persons who live along routes of travel, and persons exposed at truck- or rest-stops. For accident risks, the code evaluates the range of possible accident scenarios from high-probability / low-consequence to low-probability / high-consequence. RADTRAN was created to calculate population risks associated with the transportation of radioactive materials by a variety of modes, including truck, rail, air, ship, and barge. The code, which has undergone extensive periodic reviews and updates since the late-1970s, has remained a primary tool utilized by the U.S. DOE for transportation risk assessment endeavors.
- The RISKIND computer program (latest version “RISKIND-2.0”) is used to estimate radiological doses to maximally exposed individuals (MEIs) for incident-free transportation, and to populations and MEIs for accident scenarios. To estimate incident-free doses to MEIs, RISKIND uses assumed geometric configurations/arrays to calculate a dose rate at specified locations that would arise from a source of radiation. For RISKIND’s accident dose/risk assessment methodology tied to a postulated material-release scenario, the program employs a specialized Gaussian plume puff model, which conservatively simulates the specific downwind impacts resulting from a singular worst-case accident scenario. A unique feature of RISKIND’s accident modeling is its ability to provide spatial resolution. It does not just provide one number; it generates a map or table showing how the dose drops off the farther one moves away from the accident site (or the farther one moves away from the centerline of the wind’s path). This information accordingly allows planners to identify evacuation zones or shelter-in-place distances for specific communities.

With regard to the above catalog of potential tools presently available for high-fidelity radiological transportation risk evaluation, the tandem use of the RADTRAN and RISKIND models should be viewed as the optimal (i.e., state-of-the-art or best-in-class) approach for estimating the full compendium of potential radiological impacts that could be theoretically incurred to members of the public and transport-crews during the shipment of used nuclear fuel. The codes’ extensive array of peer-reviewed databases, innovative calculational architectures, and steadfast legacy of performance accuracy continue to qualify them as the consensus go-to for radiological transportation impact analysis within the western-based nuclear regulatory and analytical community. The codes’ focus on ensuring high levels of accuracy and rigor related to key input parameters such as accident severity fractions, release fractions, transportation modes, accident rates, likely population densities within various shipping zones (rural, suburban, and urban), and well-defined meteorological conditions that account for both wind speed and atmospheric stability is well documented. On the output side, the codes are designed to methodically determine doses and resultant risks through a variety of potential exposure pathways, including external exposure to a passing radioactive cloud, external exposure to contaminated ground, internal exposure from inhalation of airborne contaminants, and internal exposure from ingestion of contaminated food. Radiation dose calculations from the ingestion or inhalation of radionuclides are aided by the use of standard dose-conversion-factors published by the U.S. Environmental Protection Agency’s *Federal Guidance Report* library.

In total, a prescribed sequence of analysis is conventionally performed via the use of the aforementioned tools to ultimately generate final estimates of radiological transportation risks. The sequence typically consists of the following steps: (1) determination of shipped radiological inventories and their associated characteristics, (2) estimation of shipment requirements, (3) determination of route characteristics, (4) calculation of radiation doses to exposed individuals (including estimation of environmental transport and uptake of radionuclides), and (5) estimation of resultant health effects (LCFs).

In addition to radiological risks posed by transportation activities, under NEPA, it is conventional for straight vehicle-related accident risks to also be assessed for non-radiological causes (i.e., causes directly related to the transport vehicles themselves and not the radioactive cargo) for utilized transportation routes. This separate assessment endeavor helps to provide a relative “quantitative comparison” framework to “compare” to assessed radiological-accident risks in play during shipping.

Transportation workers/crews are typically defined and modeled as truck and rail crew members involved in the transportation and inspection of radiological cargo. The general public typically includes all persons who could be exposed to a shipment while it is moving or stopped during transit. For incident-free transport, potentially affected populations include those individuals living within 800 meters (0.5 mile) of each side of a road or rail line, with potential risks estimated for both the affected populations as well as a hypothetical MEI. The MEI is typically assumed to be a resident living near a highway or rail line and is exposed to all shipments transported along that road or rail line. In line with NEPA's approach, all of these incident-free transport receptors (or receptor groups) should be evaluated for potential radiological exposure along any/all candidate transportation routes/segments across Canada.

For accident conditions, the affected population typically includes individuals residing within 80 kilometers (50 miles) of the accident, and the MEI would be an individual located 100 meters (330 feet) directly downwind from the accident. The overall risk to the affected population is a measure of the radiological risk posed as a collective whole to that population group (i.e., total number of expected LCFs). Potential impacts from transportation accidents are expressed in terms of *probabilistic risk*, which is the probability of an accident *multiplied* by the consequences of that accident and summed over all reasonably conceivable accident conditions.

In conclusion, as a meaningful point of reference, the map provided below from the Yucca Mountain EIS depicts the originally planned *extensive network of high-mileage shipping routes* across the United States to the Yucca Mountain repository associated with its truck-transport options. The map provides a substantive depiction of the extent to which widespread (i.e., nation-wide) radiological impact modeling was (and is) deemed necessary under NEPA.

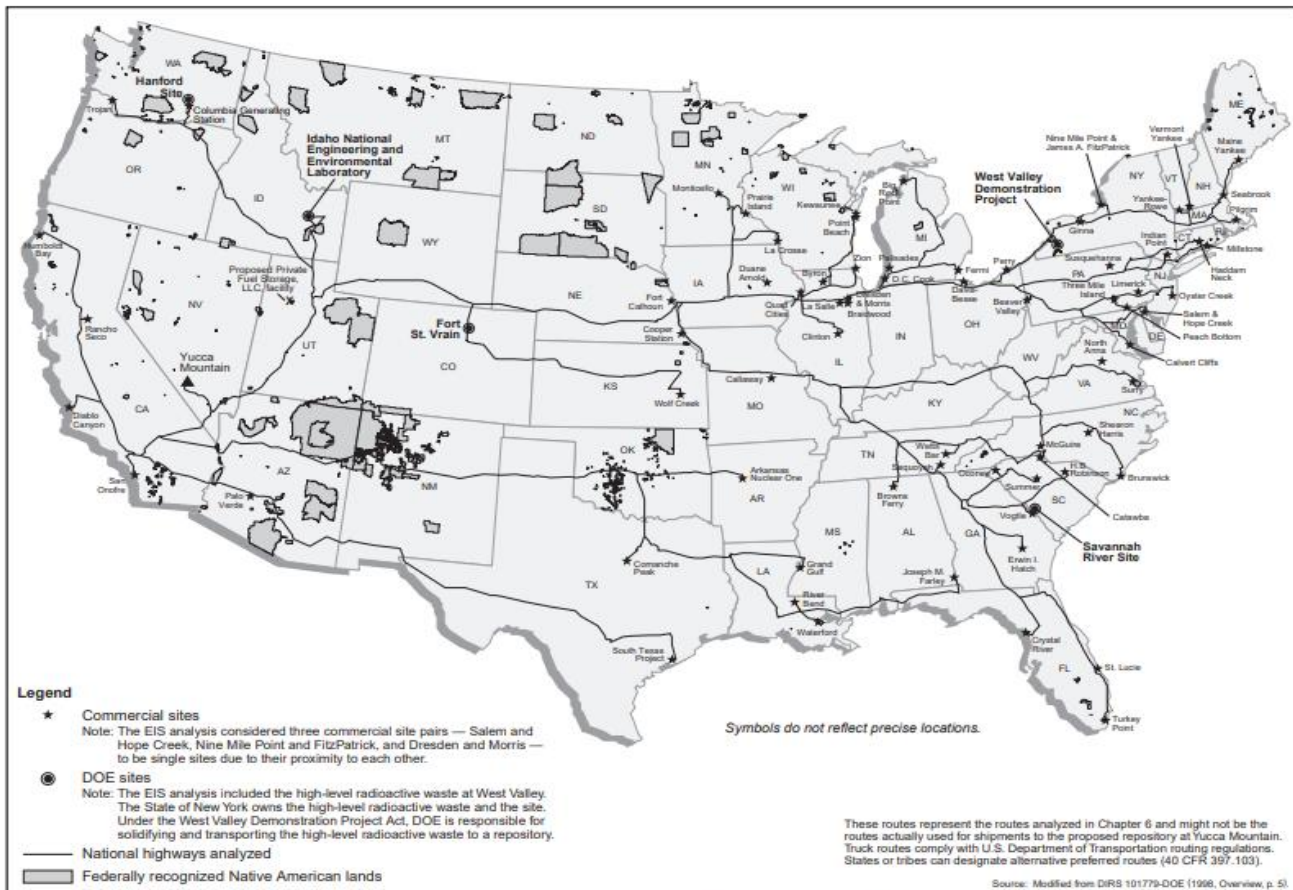


Figure J-5. Representative truck routes from commercial and DOE sites to Yucca Mountain analyzed for the Proposed Action and Inventory Modules 1 and 2.

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