United States Court of Appeals
For the Fifth Circuit

No. 21-60743

STATE OF TEXAS; GREG ABBOTT, GOVERNOR OF THE STATE OF TEXAS; TEXAS COMMISSION ON ENVIRONMENTAL QUALITY; FASKEN LAND AND MINERALS, LIMITED; and PERMIAN BASIN LAND AND ROYALTY OWNERS,

Petitioners,

v.

NUCLEAR REGULATORY COMMISSION; UNITED STATES OF AMERICA,

Respondents.

APPENDIX VOLUME V

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INDEX TO APPENDIX

[1] "C.I. _" refers to the "Record ID" number associated with each document listed in the Revised Certified Index of Record that the NRC filed on December 6, 2021 (Doc. # 00516117700). A Record ID number followed by a period indicates that the document is part of a "package" including more than one document. The number following the period indicates the document within the package to which the cited material corresponds (*i.e.*, C.I. 5.1 is the first document within the package for Record ID 5).

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CERTIFICATE OF SERVICE

On this 16th day of May, 2022 a true and correct copy of the foregoing was filed with the Clerk's Office of the United States Court of Appeals for the Fifth Circuit, which currently provides electronic service on the counsel of record.

/s/ Allan Kanner
Allan Kanner

CERTIFICATION UNDER ECF FILING STANDARDS

Pursuant to paragraph A(6) of this Court's ECF Filing Standards, I hereby certify that (1) required privacy redactions have been made, 5th Cir. R. 25.2.13; (2) the electronic submission is an exact copy of the paper document, 5th Cir. R. 25.2.1; and (3) the document has been scanned for viruses with the most recent version of a commercial virus scanning program and is free of viruses.

/s/ Allan Kanner
Allan Kanner

Tab 67

SUNI Review Complete
Template=ADM-013
E-RIDS=ADM-03
ADD: James Park

Comment (65)
Publication Date 5/8/2020
CITATION 85 FR 27447
PMD-07201051

PUBLIC SUBMISSION

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Submission Type: Web

Docket: NRC-2016-0231
Waste Control Specialists LLC's Consolidated Interim Spent Fuel Storage Facility Project

Comment On: NRC-2016-0231-0317
Interim Storage Partners Consolidated Interim Storage Facility Project

Document: NRC-2016-0231-DRAFT-0376
Comment on FR Doc # 2020-09795

Submitter Information

Email: a.tennis@kanner-law.com
Organization: Permian Basis Coalition of Land and Royalty Owners and Operators

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General Comment

Please thoughtfully consider the attached comments relating to the Interim Storage Partners Consolidated Interim Storage Facility Project.

Attachments

2020.11.03 Fasken Comments to ISP DEIS

C.I. 1560

November 3, 2020

Office of Administration
Mail Stop: TWFN-7-A60M
Attn: Program Management, Announcements and Editing Staff
U.S. Nuclear Regulatory Commission Washington, DC 20555-0001

Subject: Submittal of Comments on Draft Environmental Impact Statement (DEIS) for Interim Storage Partner's (ISP's) License Application for a CISF in Andrews County, Texas, Docket ID NRC-2016-0231

Reference: 1."Environmental Impact Statement for Interim Storage Partners LLC's (ISP) License Application for a Consolidated Interim Storage Facility (CISF) for Spent Nuclear Fuel in Andrews County, Texas, Draft Report for Comment," NUREG-2239, Date Published: May 2020, Docket ID NRC-2016-0231 (ML20122A220).

2. Federal Register Notice: Extension of Public Comment Period for Draft Environmental Impact Statement for Interim Storage Partners Consolidated Interim Storage Facility License Application, July 30, 2020 (85 FR 27447), (ML20198M580).

Permian Basin Coalition of Land and Royalty Owners and Operators (PBLRO) and Fasken Land and Minerals, Ltd. (FLML or Fasken) have engaged both staff and consultants in the review of the Draft Environmental Impact Statement (DEIS). The Fasken staff comments are presented in Attachment 1 and consultant comments are presented in Attachment 2.

There are systemic regulatory failures in multiple areas of the DEIS demonstrating unrealistic attempts to achieve a zero-risk outcome, as well as a lack of awareness to risk trade-offs and reluctance by the NRC to realistically compare benefits to costs and adopt the most efficient regulatory alternative.

For the record, PBLRO and FLML wish to reemphasize the fact that Governor Abbott of Texas has *again* stated his opposition to the approval of the ISP CISF, today, November 3, 2020. If the NRC were following the statutory requirements of the Nuclear Waste Policy Act, the opposition by the host governor to a proposed CISF site that serves the purpose described in law for a Monitored Retrievable Storage (MRS) facility would be sufficient to end the NRC licensing activity.

The absence of Governor Abbott's approval will also adversely impact the required approvals by Texas state agencies that are assumed to be granted in the DEIS
We look forward to the NRC's responses to our concerns.

Sincerely, Monica R. Perales

Monica Perales
Attorney for Fasken Land and Minerals, Ltd. and Permian Basin Coalition of Land and Royalty Owners and Operators

ATTACHMENT 1

Subject: Permian Basis Coalition of Land and Royalty Owners and Operators (PBLRO) and Fasken Land and Minerals Limited (FLML), comments and concerns regarding the NRC's Draft Environmental Impact Statement (DEIS, ML20122A220) for Interim Storage Partners LLC's (ISP) license application for a Consolidated Interim Storage Facility (CISF) for Spent Nuclear Fuel (SNF) in Andrews County, Texas.

Geophysical Properties of the Central Basin Platform (CBP)

Section 3.4.1.2 and Stratigraphy

Issue: *The geological history of the basin as reported in the DEIS (Section 3.4) is adequate but presents a misleading view of the current tectonic state around the ISP's proposed site location.*

The DEIS cites the (Hills, 1985) description of the tectonic uplift that occurred during the Mississippian and Pennsylvanian ages that setup the Central Basin Platform (CBP) as it resides today (pg 3-12, line 20). The CBP is described as "a steeply fault-bounded uplift of basement rocks" (pg 3-12, line 4). The DEIS also describes the steep angle faulting that bounds the platform's edges.

While this description is true for the Western flank of the CBP, the NRC fails to disclose the heavily faulted nature of the CBP itself in and around the ISP's proposed location (see Figure 1 below).

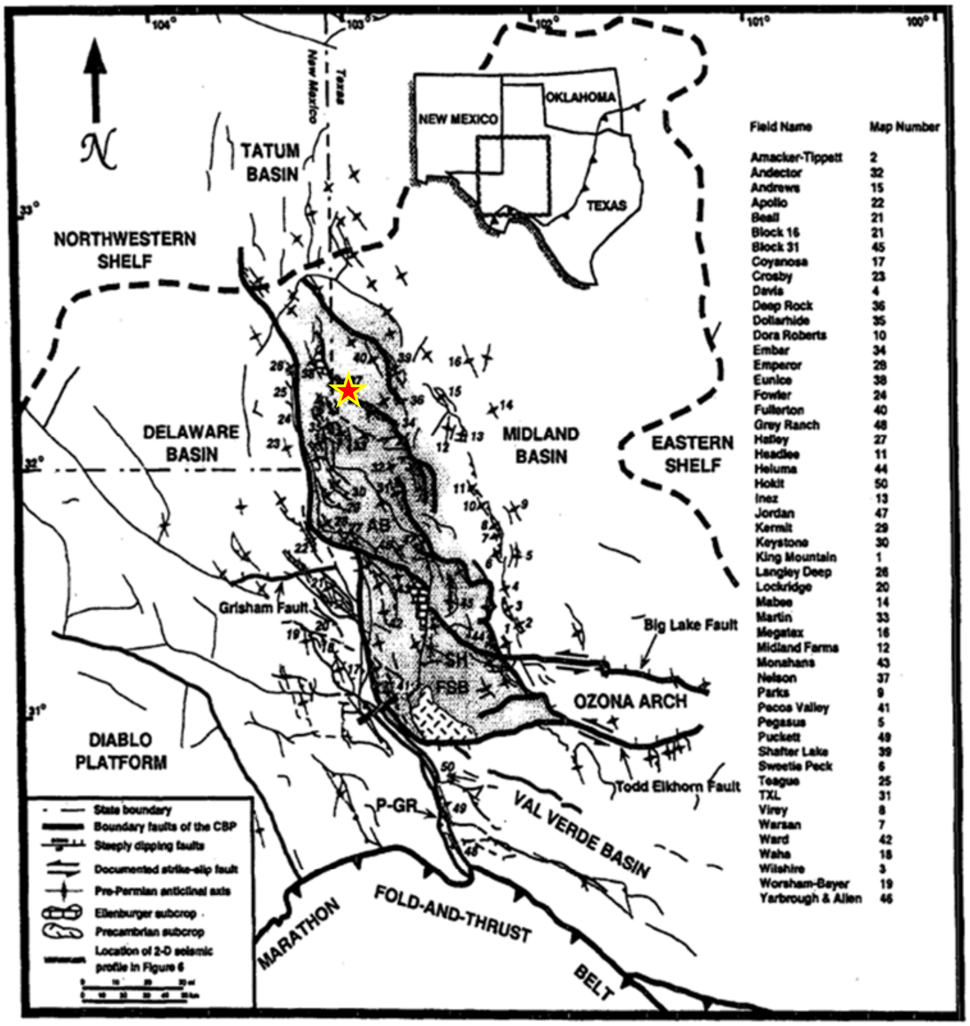

Figure 1. Generalized tectonic map for the Permian Basin, showing the Central Basin Platform, Delaware Basin, and Midland Basin. Modified from GEOPMAP (1983), Ewing (1990), Gardiner (1990a), Comer (1991), Shumaker (1992), and Yang and Dorobek (1995a). The oil-gas fields mentioned in this study are labeled by number. Orientations of the pre-Permian fold axes associated with selected oil-gas fields were compiled from Stipp et al. (1956), Herald (1957), Harrington (1963), Hills (1970), Galloway et al. (1983), GEOMAP (1983), Henderson et al. (1984), and Kosters et al. (1988). The shaded area represents the general outline of the Central Basin Platform. AB = Andector Block; FSB = Fort Stockton Block; SH = Sand Hills Fault; P-GR = Puckett-Grey Ranch Fault Zone.

Figure 1. Image shows highly complex fault network with regional trends through and around the IPS's site location. The west side of the Central Basin Platform (CBP) has "greater structural relief, vertical separation, and basement shortening" than the eastern side (Tai and Dorobek, 2006). Approximated WCS location outlined by red star.

The CBP consists of two main crustal blocks arranged in an echelon pattern with steeply dipping reverse and thrust faults, asymmetrical flower structures, and associated normal faults (Tai and Dorobek, 2006). Once the CBP was uplifted during the Mississippian age, the boundaries of the CBP began to shear against the platform edges aligning to the primary stress direction of the Marathon orogeny causing the CBP to rotate in a clockwise direction.

This rotation of the CBP caused the crustal blocks WITHIN the CBP to rotate in a clockwise pattern causing major deformation and instability within the platform itself. Due to the nature of the transpressional tectonic setting and the degree of rotation, the western side of the CBP has “greater structural relief, vertical separation, and basement shortening” (Tai and Dorobek. 2006).

All of the evidence for deformation of the subsurface listed above shows that the area of interest is in the least stable region of the CBP from a structural geology standpoint and has undergone more fault reactivation in its history than the rest of the CBP.

Section 3.4.5 Seismology

The DEIS then describes the shallow Quaternary faults in the area (pg 3-20, line 36). Quaternary faults are important as they, by definition, have shown movement in the last 1.6 million years at the surface (USGS, 2018).

However, most earthquake epicenters in the ISP’s site are at depths related to basement faulting (see Figure 2 below), showing that the risk in this area comes from reactivation of basement faults propagating energy felt at the surface, not the reactivation of Quaternary age faulting. These Quaternary faults are used as the sole basis for seismic risk stated repeatedly throughout the DEIS (pg 4-27, line 8-10 & 39-45) as proximity to a hazard even though they pose less risk to the site and environment than the above-mentioned subsurface faults.

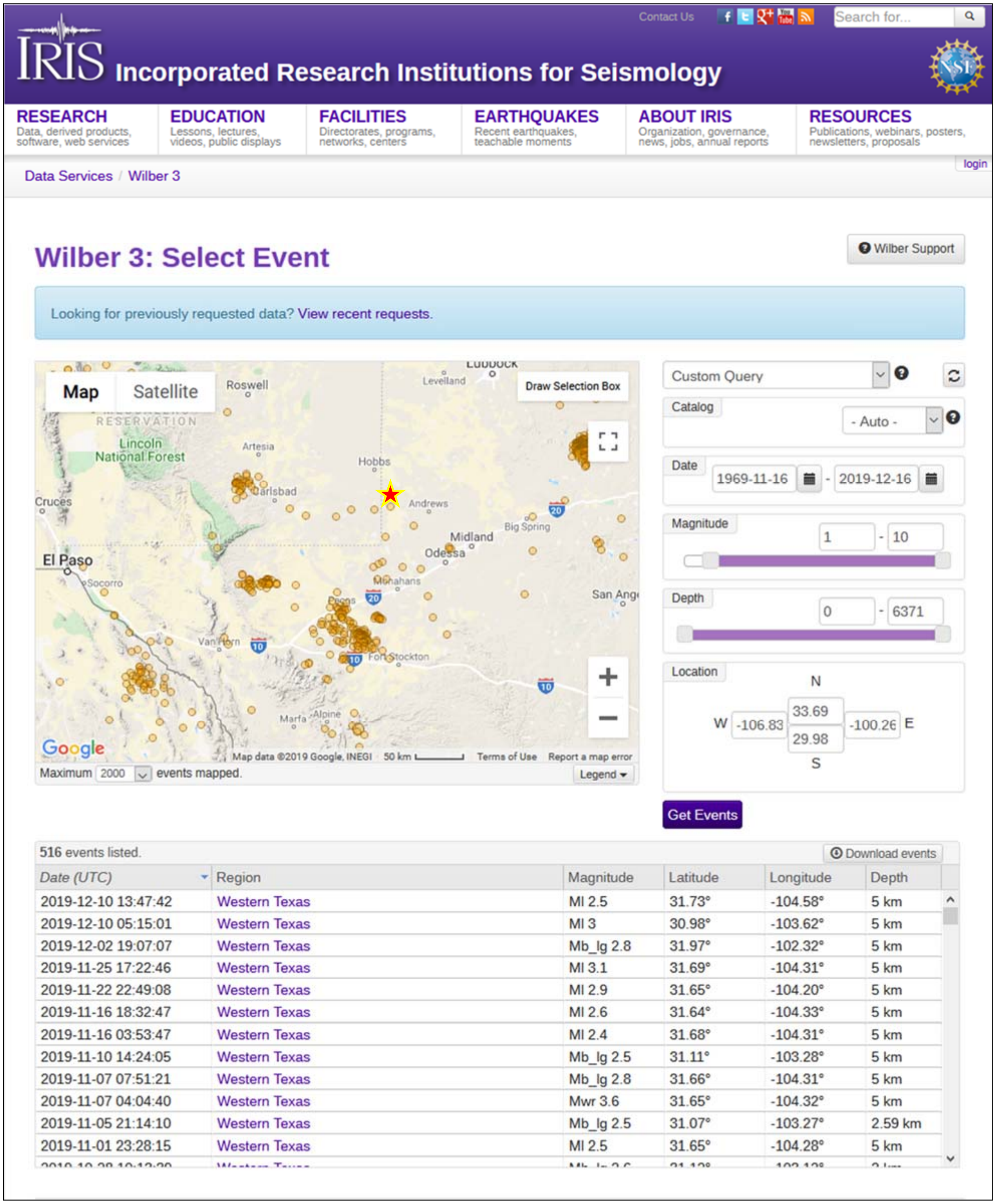

Figure 2. Image taken from IRIS website showing events in and around area with epicenter magnitudes and depth of origination. It can be clearly seen that the events are at estimated depths of 5km (~3.1 mi), showing that the slip/compression events mostly occur at basement depths not within the Quaternary age faults. Approximated WCS location outlined by red star.

C.I. 1560

001161

A comparison of the earthquake data and CBP fault maps show a correlation of events running through and around the ISP proposed CISF site (see Figure 3 below).

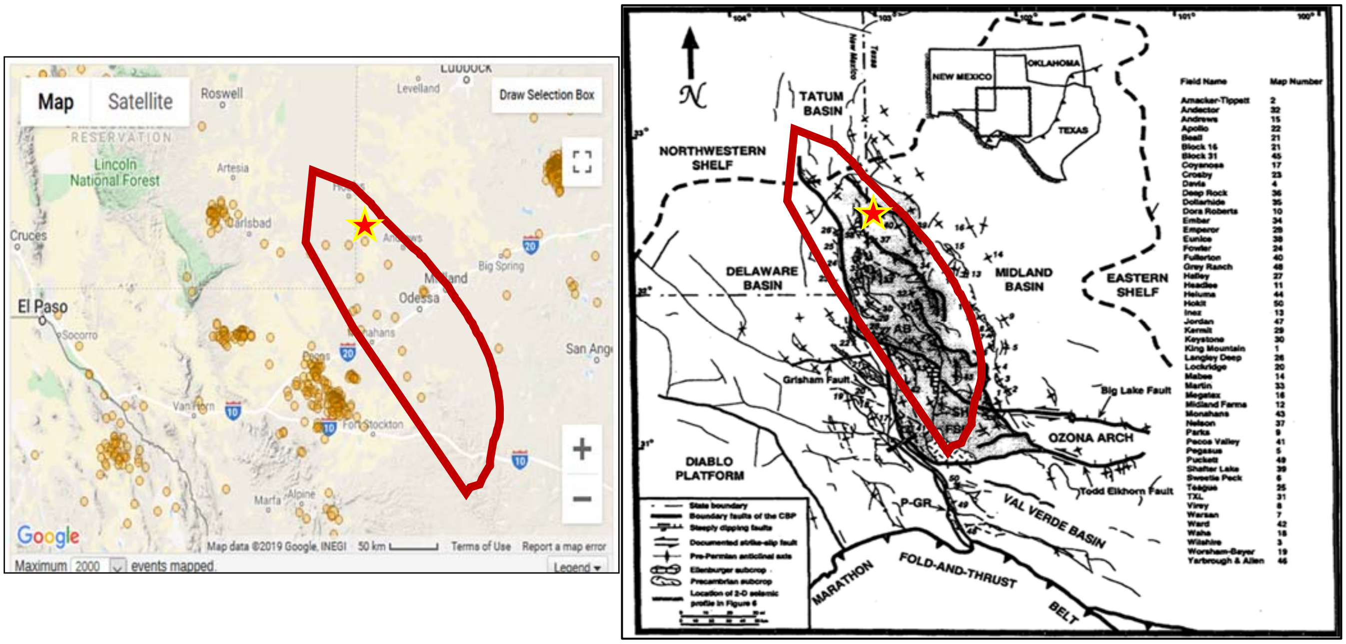

Figure 3. Map comparison of the fault planes within the CBP and public earthquake data from the IRIS website. This figure shows the earthquake epicenters training to the basement faults in the area of interest to WCS and ISP. This shows that the area continues to settle around these faults even when not in the presence of major oil and gas operations, generating acceleration at the surface. Approximated WCS location outlined by red star.

The omission of the obvious risk posed by these basement faults by the NRC in the DEIS gives cause for concern to the Probabilistic Seismic Hazard Analysis (PSHA) performed by the ISP applicant and submitted to the NRC (pg 3-21, line 3-21).

ISP LLC's Submitted Probabilistic Seismic Hazard Analysis (PSHA)

Issue: *The methodology and limited input requirements for PSHA models have been widely discounted by scientists and engineers for decades (Mulargia et al., 2016) as they include parameters known to contradict constants in earthquake physics.*

Major tectonic events have occurred in areas previously deemed "low risk" by PSHA models, because they are based on few known elastic earth properties that are not site specific and therefore cannot create an accurate risk of future earthquakes (San Onofre Safety, unknown). The following are multiple citations on the discreditation of these models and describe the model inputs below.

- Castaños, Heriberta, and Cinna Lomnitz. "PSHA: Is it science?" *Engineering Geology* 66.3-4 (2002): 315-317.

- Frankel, Arthur. "How can seismic hazard around the New Madrid seismic zone be similar to that in California?" *Seismological Research Letters* 75.5 (2004): 575-586.Klügel, Jens-Uwe. "Error inflation in probabilistic seismic hazard analysis." *Engineering Geology* 90.3-4 (2007): 186-192.

- Moschetti, Morgan P., et al. "The science, engineering applications, and policy implications of simulation-based PSHA." *Proceedings of the 11th National Conference in Earthquake Engineering (11NCEE), June*. 2018.

- Musson, R. M. W., et al. "Evaluating hazard results for Switzerland and how not to do it: A discussion of "Problems in the application of the SSHAC probability method for assessing earthquake hazards at Swiss nuclear power plants" by JU Klügel." *Engineering geology* 82.1 (2005): 43-55.

- Stein, Seth, Joseph Tomasello, and Andrew Newman. "Should Memphis build for California's earthquakes?" *Eos, Transactions American Geophysical Union* 84.19 (2003): 177-185.

- Wang, Zhenming, et al. "Communicating with uncertainty: A critical issue with probabilistic seismic hazard analysis." *Eos, Transactions American Geophysical Union* 84.46 (2003): 501-508.

The earthquake data used in the PSHA are based on readings from above-ground seismic monitoring stations. Some of these stations are "permanent" installations while *many others* are temporary stations that are repeatedly moved and experience issues of effective measurement through improper coupling to the earth and local noise variations.

Each time a station is moved, the triangulation methods used to determine epicenter location and magnitude changes and adds errors to the data that are dependent on the distance from the epicenter. These data, as reported in the DEIS, have only been monitored since the 1970's (pg 3-20, line29) and are being used by the ISP applicant and the NRC to determine seismic event risks up to 100 years into the future (pg 9-16, lines 13-14), or over 2 times the length of time that has been monitored.

The PSHA models are simplified for ease of use and negate known physical earth processes such as anisotropic velocity variations that drive the errors found in model outputs. These errors are clearly known by the NRC as they have published internal documents discussing the large amount of uncertainties in these models, and go as far too clearly state that "many of the problems with these models will not even be thought of as they are so limited in scope" (SSHAC,1997).

The DEIS clearly states that the actual damage that results from ground motion depends on "distance to the epicenter, duration of shaking, attenuation of earthquake energy as it propagates from the epicenter to the location…" (pg 3-21, line 17), and it is both alarming and a deficiency in the analysis that the basement fault network around the site was not addressed as a possible source of seismic risk.

Investigation into the input parameters included in the ISP applicant's PSHA that provided the NRC with a LOW risk rating for all geologic hazards was and remains warranted.

Surprisingly the only document submitted on the model is an affidavit submitted by WCS to the NRC that states that the information provided to the NRC, signed by J. Scott Kirk (WCS) on 07 MAR 17, was deemed confidential under ruling 10 CRF 2.390(a)(4), see attached.

It particularly troubling to note that *this is the only document* found that has a request of confidentiality in the geologic section of the ISP's license application.

Even if the algorithm for the PSHA model is proprietary, we as a community should still have access to view the data used to constrain each modeled simulation. As no input parameters can be viewed, we must trust the description of the model provided by the ISP applicant which states that they "incorporate the site-specific effects of the near surface geology on ground motions to design the ISP site" (pg 3-21, line 5).

What is further disturbing, is that this confidential PSHA model, admittedly deficient in its abilities by the NRC, is used to determine the strength of materials used not only in the cask design but also the site's foundational integrity (pg 4-28, lines 19-24). The PSHA results offering the LOW RISK rating are the basis for the impacts outlined in Section 4 of the DEIS, *Environmental Impacts* (pg 4-27, lines 39-45) and Section *5, Cumulative Impacts* (pg 5-20, lines 39-40), but are not mentioned in Mitigation, Monitoring, or the Summary of Environmental Impacts in the EIS. This means, the site will not be required to have a strategic plan for seismic monitoring nor a plan in the event that the site undergoes damage from a seismic surface event.

If the site plans are based on a model that the NRC knows to be inaccurate, and the NRC states that they have zero authority to force ISP LLC to implement stronger safety measures (pg 6-2, lines 21-22) in the event of an earthquake, then the seismic hazard analysis section of the DEIS should have been investigated in more detail by the NRC as the seismically-enhanced potential risks to a radiological leak begins to appear as negligence on the NRC's part.

The NRC has the responsibility to require that ISP or any future proposed site perform a timely and economic collection of 2D or 3D seismic data to get an accurate idea of the tectonic deformation under and around the site's location.

Section 5 Cumulative Impacts

Section 5.4 Geology & Soils

Issue: Section 5.4 of the DEIS includes discussions (pg 5-20, lines 37-44; pg 5-21, lines 1-11) analyzing future risk to the site from outside influences such as industrial operations on the surface and subsurface oil and gas activities, among other concerns. One major admission in this document is the inclusion of a study by Frohlich, et al., (2016) that discusses fluid injection and hydrocarbon production as driving mechanisms for earthquakes recently experienced in the Permian Basin.

Even though there is no consensus between academia, government, and industry at this time on the cause of these seismic events, we must still observe and plan on any eventuality of earthquake activity due to the high level radiological hazard of materials being stored at this location and the enormous potential those highly hazardous materials have to do damage to the environment and harm members of the public.

The DEIS references the Snee and Zoback (2018) study that is cited (pg 5-21, lines 1-11) as giving a LOW RISK evaluation for the site due to future earthquake caused by oil and gas operations. Figure 4 shows very clearly that the fault networks that are used by Snee and Zoback (2018) are surrounded by faults and are in proximity of some that show a 45% likelihood of slip in the future under these conditions.

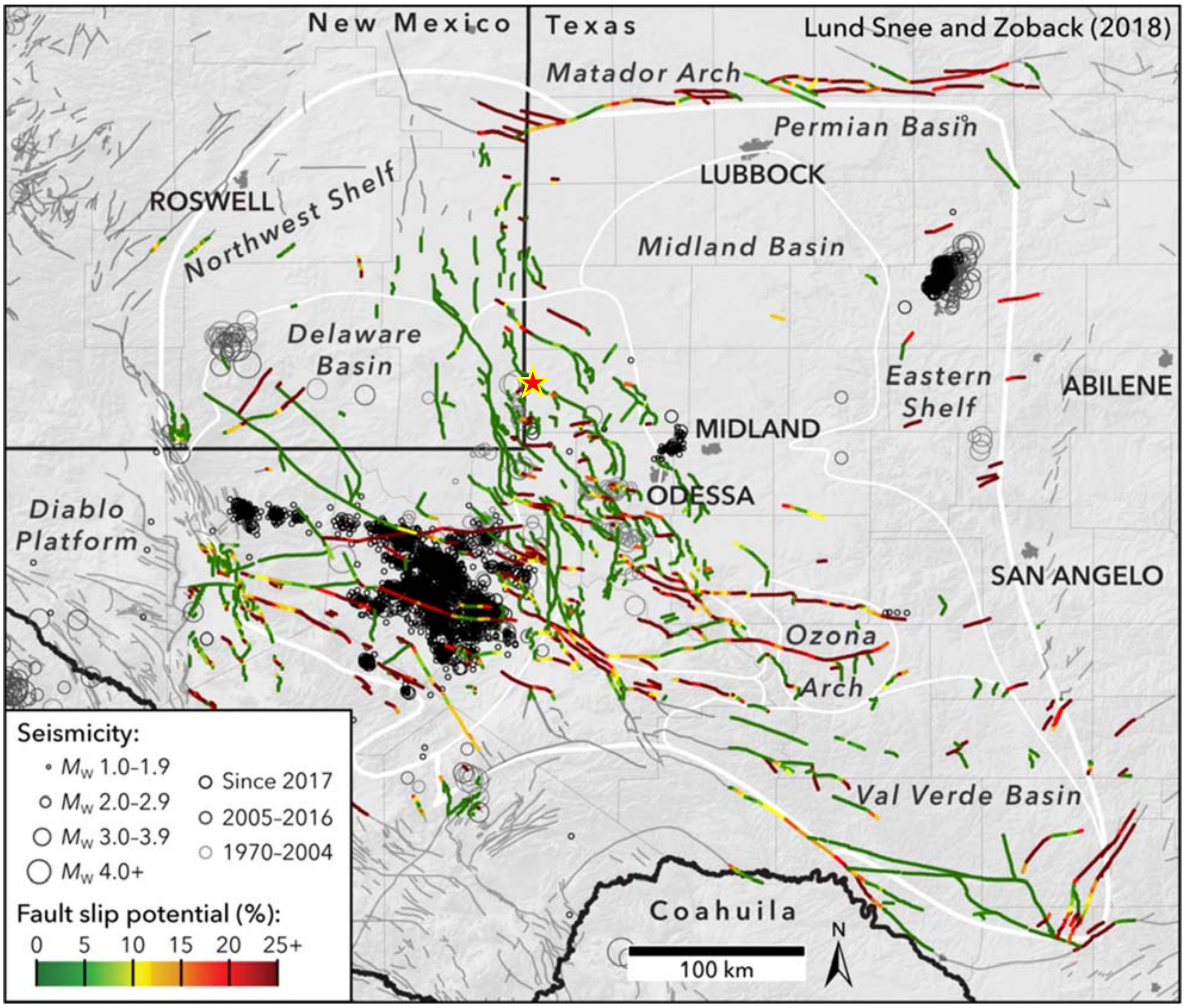

Figure 4. (Snee and Zoback, 2018) Fault slip potential map identifying areas within the ISP's site location. It is shown that this model predicts a highly dense fault network underneath and around the site, with some faults showing greater than 45% probability of slip in the future. This model is represented as having a less than 10% chance of activation in the EIS report (EIS, 5-21, 3-7). Approximated WCS location outlined by red star.

It is hard to see how the ISP applicant declares that the site is at a less than 10% risk of fluid induced fault slip, or how the NRC would accept these findings based on the literature that they have cited as the basis for their analytical findings.

Within this section, the DEIS also describes the risk of sinkholes and karst fissure features (dissolved subsurface caverns that collapse under overburden pressure changes) but states that most sinkholes at the surface are man-made, resulting from oil and gas operations, and that the naturally occurring karsts are prominent along the flanks of the CBP and the Delaware Basin (pg 5-21, lines 12-18), inferring that there is no *real* risk to the site. This again is a very misleading argument as the karst/collapse features presented are those that have already affected the surface through subsidence.

The most significant risk, once again, lies ***beneath*** *the ISP's proposed site location.*

The Ellenberger formation is a major deposition that constitutes a large portion of Ordovician rock present underneath the proposed site. This formation is of interest to this site as it has been subjected to three major diagenetic processes that change the stability and nature of the formation: 1) Dolomitization, 2) Karsting, and 3) Tectonic fracturing.

These diagenetic processes all create further instabilities in the subsurface in the event of a seismic event or regional shift in stresses, and have been studied extensively by the Bureau of Economic Geology (Loucks, 2014) and other institutions of which neither the ISP applicant nor the NRC have consulted on this matter according to the DEIS report. Whether or not these events are caused by industrial activities, or whether they follow the natural stress regimes as described in the geologic overview of the CBP; it is clear that the NRC has not fully investigated the dangers and risks of surface collapse due to diagenetic processes.

Final discussion on Seismic Concerns:

The ISP applicant and the NRC are in clear violation of 10 CFR 72.122(b)(2)(i)(A), for their failure to consider in their protections against environmental conditions and natural phenomena the "*most severe* of the natural phenomena for this site and surrounding area, with appropriate margins to take into account the limitations of the data and the period of time in which the data have accumulated…" The regulation further requires in (3) "Capability must be provided for determining the intensity of natural phenomena that may occur for comparison with design bases of structures, systems, and components important to safety." The DEIS fails to meet these requirements.

Other commenters (including below) have opined to the NRC on the matter of chloride-induced stress corrosion cracking (proposed site located next to a KCL(3) POTASH mine), thin cask design failures, and heat induced stress failures. How much of a seismic force would need to be generated/registered at the site to accelerate an undetected crack growing into a leak? There is no evidence in the DEIS that this scenario has been analyzed.

The DEIS also states that "favorable seismological and geological characteristics" are one of the first-tier attributes that they look for in determining a suitable site location (pg 2-24, line 17). This proves that this issue is one of the most important considerations in the licensing of a CISF to ensure safe operations before construction begins, which causes alarm due to the lack of investigation into this concern.

It is also disappointing that the NRC only consulted with the US DOA and the TCEQ (pg 1-12, lines 3-11), neither agencies having any jurisdiction in the lower rock formations that are undergoing and have experienced the most tectonic deformation over time, thus more likely to create a seismic energy release. The Texas Bureau of Economic Geology is the Texas agency with the required expertise and must be consulted on these matters.

Many public institutions have extensive knowledge of the fault networks within the Permian Basin that work freely with governmental agencies on a regular basis. The NRC acknowledges that it has zero authority to impose mitigation outside of its regulatory authority under the Atomic Energy Act (pg 6-2, lines 21-22), and includes mitigation suggestions from ISP and for ISP to follow outlined in DEIS Tables 6.3-1 and 6.3-2. Neither of these mitigations discuss the need for further seismic monitoring on-site or future plans to change the sites infrastructure if additional higher magnitude events reach the site. This again shows a highly misplaced trust in the PSHA model authored, made proprietary, and submitted by the ISP applicant (formerly WCS) that industry has shown to be flawed.

It is for these reasons it is recommended that a "No Action" policy be taken, and the ISP license should be postponed or denied until a wide azimuth seismic survey has been conducted to understand the nature of the deformation under the proposed site location.

Citations in main body:

Cornell, C. Allin. "Engineering seismic risk analysis." *Bulletin of the seismological society of America* 58.5 (1968): 1583-1606.

Francesco Mulargia, Philip B. Stark, Robert J. Geller, "Why is Probabilistic Seismic Hazard Analysis (PSHA) still used?" Physics of the Earth and Planetary Interiors, Volume 264 (2017): 63-75.

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ISSN: 2327-6932 (online)

See Attachment (1)

Regional Geology

Section 3.4.1.2 Structure and Stratigraphy

Issue: The DEIS erroneously states (pg 3-12) that there have been no major tectonic events in North America since the Laramide Orogeny (80 to 40 Million years ago).

The Rio Grande Rift (RGR) is the most recent tectonic event that effected the Permian Basin (Mack and Giles, 2004). The DEIS fails to mention and characterize the RGR, which is critical in understanding the geological and geohydrological history of the aquifers at the CISF. The RGR began in the Middle Cenozoic (29 Million years ago) and continues to present day (Mack and Giles, 2004). The RGR was caused by crustal extension. This extension structurally tilted the Permian Basin up to the east which caused massive meteoric water movement. This structural tilting emplaced and recharged the regional aquifers (Lindsay, 2018). *The RGR is not dormant but active*, from Colorado's central Rocky Mountains to Mexico (Sheehan, 2012).

Mack, G.H. and Giles, K.A., 2004, The Geology of New Mexico: A Geologic History: New Mexico Geological Society Special Publication 11. 474 p.

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Groundwater Resources

Issue: In Table 5.1-1, the DEIS insufficiently and inappropriately projects small, cumulative impacts to groundwater resources.

Geologic, environmental, and mechanical data show groundwater at and beneath the CISF footprint. There are 3 major aquifers at the WCS site that contain shallow, fresh, groundwater. These 3 major aquifers are referred to as the OAG Unit (Granger and Grisak, 2006). The OAG unit consists of the Ogallala, Antler, and Gatuna formations.

These formations are in similar stratigraphic position, are often interbedded, and cross formational flow is known to exist between the Antler and Ogallala (Granger and Grisak, 2006; Lehman and Rainwater, 2000). These units also overlie the Dockum Group, an additional aquifer at the site.

Significant groundwater resources are present within the CISF footprint. There are 13 windmills and 174 water wells that have been drilled within a 10 km radius of the site, many of which produce groundwater at depths of less than 100 feet (Granger and Grisak, 2006). Fresh groundwater from these windmills and water wells are used for domestic potable water, stock, irrigation, and commercial purposes.

Fresh groundwater flows out of the Gatuna aquifer at Baker Spring, near the site (Lehman and Rainwater, 2000). The Antler formation is exposed within the walls of the WCS excavation pit (Granger and Grisak, 2006; Lehman and Rainwater, 2000). Ponded water is present in the base of the pit, as seen from google earth images and could be from groundwater seepage from the Antler and the Dockum aquifers.

The Dockum aquifer is also present at the WCS site and is an extremely widespread aquifer containing 1000's of acre-feet of water and found in 46 Texas counties (Mace and Petrossian, 2011). It is considered a minor aquifer by TWDB because of elevated total dissolved solid (TDS) levels.

At the WCS site and throughout Andrews County the TDS measurements are near 1000 ppm, which is slightly brackish. The Santa Rosa sandstone within the Dockum Group is a significant aquifer in west Texas and is used extensively for agriculture and oil and gas operations. Groundwater from the Dockum is also being treated by reverse osmosis methods throughout the area and used as fresh water. These aquifers should be protected from any contamination, especially radionuclides.

Significant oil and gas activity surround the CISF footprint. There are approximately 4,579 wellbores within a 10-mile radius of the CISF, 1,066 wellbores drilled and plugged prior to 1967. Current plugging procedures ensure protection of contamination to groundwater resources, but wells plugged and abandoned prior to 1967, pose potential risk of contamination. These old abandoned wellbores could be conduits of contamination if there were radionuclide spills at the surface.

The CISF footprint lies in the center of the Permian Basin. This basin contains billions of barrels of hydrocarbons and millions of acre-feet of groundwater. The Permian Basin is the largest and most important hydrocarbon producing basin in the United States.

The Permian Basin produces 50% of domestic hydrocarbons and 5% of global oil (EIA, 2020). These hydrocarbon and groundwater resources ensure domestic energy needs and global security. High level nuclear waste should not be disposed of in the most important hydrocarbon basin in the country.

Granger, D., Grisak, G., 2006, Appendix 2.6.1, Geology Report: Prepared for Waste Control Specialists, LLC.: Cook-Joyce Inc., 219 p.

Lehman, T.M., Rainwater, K., 2000, Geology of the WCS – Flying "W" Ranch, Andrews County, Texas: Texas Tech University Water Resources Center. 81p.

George, P.G., Mace, R.E., Petrossian, R., 2011, Aquifers of Texas: Texas Water Development Board Report 380, 172p.

EIA, 2020, Permian Region: Drilling Productivity Report. https://www.eia.gov/petroleum/drilling/pdf/permian.pdf

Health Physics & Nuclear Safety

In the Interim Storage Partners, LLC (ISP) DEIS, the NRC fails to comply with its legal obligations to conduct a thorough and complete analysis of the environmental impacts of the proposed CISF, specifically as evidenced by the following:

1. *Failure to Analyze Major Points of View.* Pursuant to 10 CFR 51.71, the DEIS is required to "analyze major points of view, and to the extent sufficient information is available", the DEIS is required to "consider major points of view concerning the environmental impacts of the proposed action" and "contain an analysis of significant problems raised" by other Federal agencies. Yet, nowhere in the 484-pages of the ISP DEIS is the significant concern of chloride-induced stress corrosion cracking (CISCC) mentioned or analyzed in terms of the severe environmental impact that could result from this "significant problem" raised by ***both*** the NRC and the Department of Energy (DOE).

   Beginning in November of 2012, the NRC notified its 10 CFR 72 licensees and certificate of compliance holders that the problem of CISCC was a "high priority data gap" and was only just being recognized. Additionally, researchers did not "... yet fully understand the relationship between the proximity to a salt-water body and the potential for chloride deposition on a dry cask storage system canister. However, it should be noted that many ISFSIs are located near salt-water bodies ***or other sources of chlorides, such as salted roads*** or condensed cooling tower water."[1] (emphasis added)

2. *Failure to Address Status of Compliance.* The NRC (2012) continued to identify impacts to the "status of compliance"[2] that a failure of the confinement systems would have and the violations of federal regulations (and licenses and COCs) that would occur, including violations of 10 CFR 72.120(d), 72.122(b)(1), 72.122(h)(1), 72.122(h)(4), 72.122(l), 72.236(d), and 72.236(l), should the "significant problem" of CISCC result in a failure of a dry storage canister (DSC) and subsequent uncontained release to the environment. However, despite the requirement to address potential impacts to status of compliance for known, significant problems documented completely within its own regulatory system, the NRC fails to comply with the requirements of the statute in the ISP DEIS.

3. *Failure to Analyze Effects of a CISCC-Induced Release on the Public and the Environment.* As a result of ignoring the imminent environmental impacts from the DSC failure caused by CISCC, the NRC ultimately fails to analyze the most significant threat to the public and the environment within the context of the proposed licensed activity and therefore fails to comply with 10 CFR 51.71(d). In failing to perform this analysis, the NRC also fails to assess the economic costs such a radioactive release would bring to the

[1] NRC Information Notice 2012-20, Potential Chloride-Induced Stress Corrosion Cracking of Austenitic Stainless Steel and Maintenance of Dry Cask Storage System Canisters, November 14, 2012, ML12319A440

[2] 10 CFR 51.71(c)

region and to the country as a whole, as well as impacts to the nuclear industry in particular from a public loss of confidence in the safety of these unmonitored SNF storage systems placed in vulnerable communities throughout the country.

4. *Failure to Address Policy Implications.* The DEIS also fails to address the policy implications that the proposed ISP facility has been proposed to serve, in the NRC's own words as a Monitored Retrievable Storage (MRS) Facility — not an ISFSI — as described both in 10 CFR 72 and in the Nuclear Waste Policy Act.

ISP DEIS

"PURPOSE AND NEED FOR THE PROPOSED ACTION

"The purpose of the proposed ISP CISF is to provide an option for storing SNF, GTCC, and a small quantity of MOX from nuclear power reactors ***before a permanent repository is available***. These waste materials would be received from operating, decommissioning, and decommissioned reactor facilities." (DEIS, Executive Summary, page xviii, lines 14-18 and §1.3, pg 1-3, Lines 26-30) (emphasis added)

10 CFR 72.3

"Monitored Retrievable Storage Installation or MRS means a complex designed, constructed, and operated by DOE for the receipt, transfer, handling, packaging, possession, safeguarding, and storage of spent nuclear fuel aged for at least one year, solidified high-level radioactive waste resulting from civilian nuclear activities, and solid reactor-related GTCC waste, ***pending shipment to a HLW repository or other disposal***." (emphasis added)

Nuclear Waste Policy Act, 42 U.S.C. 10161(b)(1)

"1) On or before June 1, 1985, the Secretary shall complete a detailed study of the need for and feasibility of, and shall submit to the Congress a proposal for, the construction of one or more monitored retrievable storage facilities for high-level radioactive waste and spent nuclear fuel. Each such facility shall be designed –

"(A) to accommodate spent nuclear fuel and high-level radioactive waste resulting from civilian nuclear activities;

"(B) to permit continuous monitoring, management, and maintenance of such spent fuel and waste for the foreseeable future;

> "(C) to provide for the ready retrieval of such spent fuel and waste for further processing or disposal; and
>
> "(D) to safely store such spent fuel and waste as long as may be necessary by maintaining such facility through appropriate means, including any required replacement of such facility."

Despite the NRC's strenuous attempt to "rebrand" from the MRS description in the Nuclear Waste Policy Act to a simple 10 CFR Part 72 "Away from Reactor" (AFR) ISFSI, by ignoring the impacts of the violation of obligations under the NWPA, the NRC is allowing the licensing of a facility woefully inadequate to address the long-lasting concerns associated with CISCC and the need to have hot cells present to repackage SNF whose canisters can no longer perform their designed and licensed confinement function due to CISCC.[3]

5. *Failure to Address the Impacts of the Geology and Soils* <u>*on the CISF Operations*</u>*.* Section 4.4 of the DEIS fails to evaluate the most grave and significant hazard acknowledged by the NRC of salts present in the soils surrounding the proposed ISP site. This is a direct violation of 10 CFR 72.122(b)(2) where "[s]tructures, systems, and components important to safety" <u>*have not been*</u> designed to withstand the effects of natural phenomena and the design bases for these structures, systems, and components <u>*do not include*</u> "[a]ppropriate consideration of the most severe of the natural phenomena reported for the site and surrounding area, with appropriate margins to take into account the limitations of the data and the period of time in which the data have accumulated," <u>*or*</u> "[a]ppropriate combinations of the effects of normal and accident conditions and the effects of natural phenomena."

   The significant detrimental effects of naturally occurring materials and meteorological phenomena on the integrity of the SNF confinement barriers have been repeatedly acknowledged by the NRC, DOE, NWTRB and the GAO since the NRC first information notice in the topic in 2012. The specific cause of the "high priority data gaps" is the phenomenon of CISCC.

   Chloride-Induced Stress Corrosion Cracking (CISCC)

   The phenomenon of CISCC obviously requires chloride bearing salts (NaCl, KCl, MgCL, etc.) to be present as an initial condition. The initial condition is more than met with the proposed ISP CISF being sited in the midst of the massive Salado ("Salt") Formation:

[3] Blue Ribbon Commission on America's Nuclear Future, §5.2.6, pg. 39, January 2012

"SALADO FORMATION

"The Salado formation, unlike the Castile formation, is not confined to the Delaware basin but extends more than 100 miles north and 100 miles east of the basin and underlies an area of about 25,000 square miles.

"The Salado formation consists of salt, anhydrite, and potassium salts with varying amounts of clastic material. Salt comprises about 75 to 90 percent of the formation except in areas where subsurface solution has removed much of it, and toward the depositional edges of the formation where variegated mudstone predominates (Maley and Huffington, 1953). The next most abundant constituent in the formation is anhydrite. The remainder of the formation consists of sandstone, siltstone, shale, polyhalite, and numerous less abundant potassium minerals.

"The most abundant potassium minerals in the formation are polyhalite (K2SO4-MgSO4-2CaSO4-2H2O), sylvite (KCl), langbeinite (K2SO4-2MgS04), carnallite (KCl-MgCl2-6H20), kainite (KCl-MgS04-3H20), and leonite (K2S04-MgS04-4H2O). Of these minerals polyhalite is the most abundant and widespread …" [4]

[4] Geological Survey Bulletin 1148, "Summary of Rock Salt Deposits in the United States as Possible Storage Sites for Radioactive Waste Materials," US Department of the Interior (DOI), 1962

36 STORAGE SITES FOR RADIOACTIVE WASTE

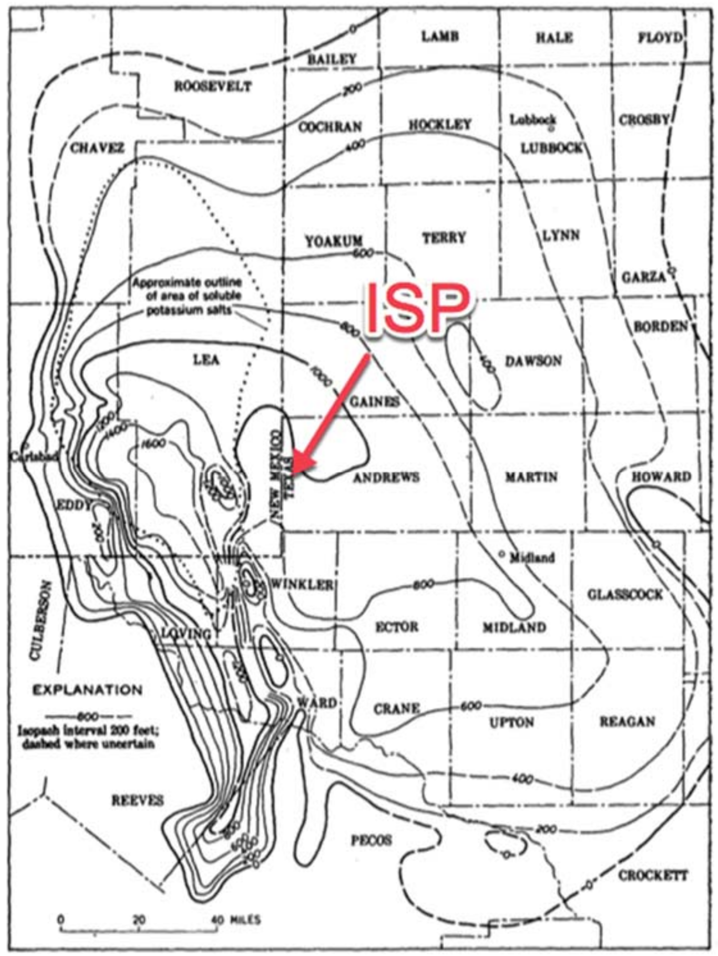

FIGURE 13.—Map showing aggregate thickness of salt in Salado formation, Ochoa series, New Mexico and Texas (compiled by P. T. Hayes, 1957).

Figure 5. Salado Formation

Within this area, there are numerous surface salt basins and playas that are a source of airborne chlorides from meteorological events.

"Salt Basin West of Guadalupe Mountains

"Rather extensive deposits of salt are exposed in a salt basin west of the Guadalupe Mountains in western Texas and southeastern New Mexico, about 70 miles southwest of Carlsbad, N. Mex. (Richardson, 1904, p. 61-64; King, 1948, p. 160-162). ... ***These deposits are in or near existing salt lakes.*** It is not known whether the salt is introduced into the waters of the lakes as a dissolved constituent in surface water or by the percolation of ground water from deeply buried salt beds."[5] [emphasis added]

[5] DOI, 1962

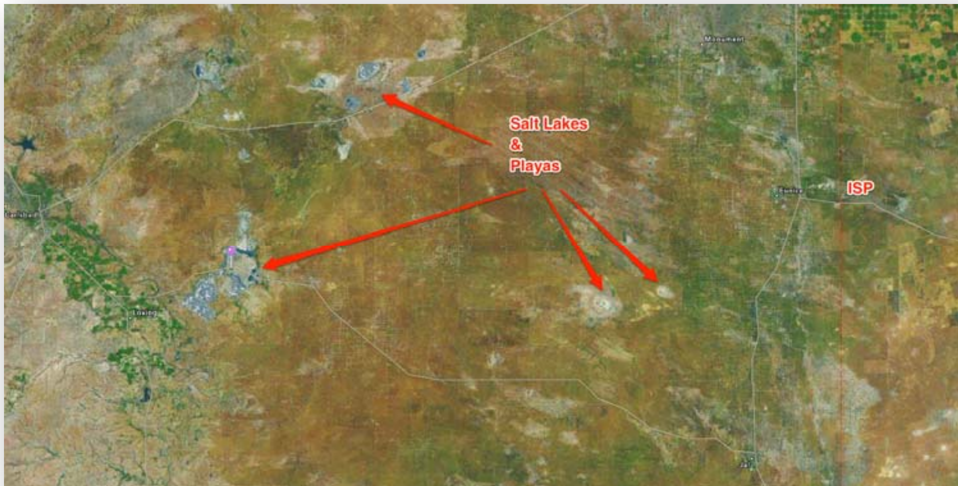

Figure 6. Salt Lakes & Playas Near ISP, West

Figure 7. Salt Lakes & Playas Near ISP, East

While this readily available source term of the material required to initiate CISCC is present in enormous quantities, the NRC makes no connection to its significant, publicly stated concerns that sources of chlorides (and something as simple as "salted roads") should be evaluated as sources potentially triggering CISCC and resulting in DSC confinement failures of "engineering significance" (i.e., DSC breach and environmental release).[6]

How are surface salt deposits in the immediate vicinity of the proposed ISP facility a threat to the SNF storage operations? The growing frequency of the meteorological phenomenon of "haboobs" and sandstorms in the region are a highly effective means of delivering tons of surface sediment to the SNF operations, even in a single haboob event (Figures 4 and 5).[7]

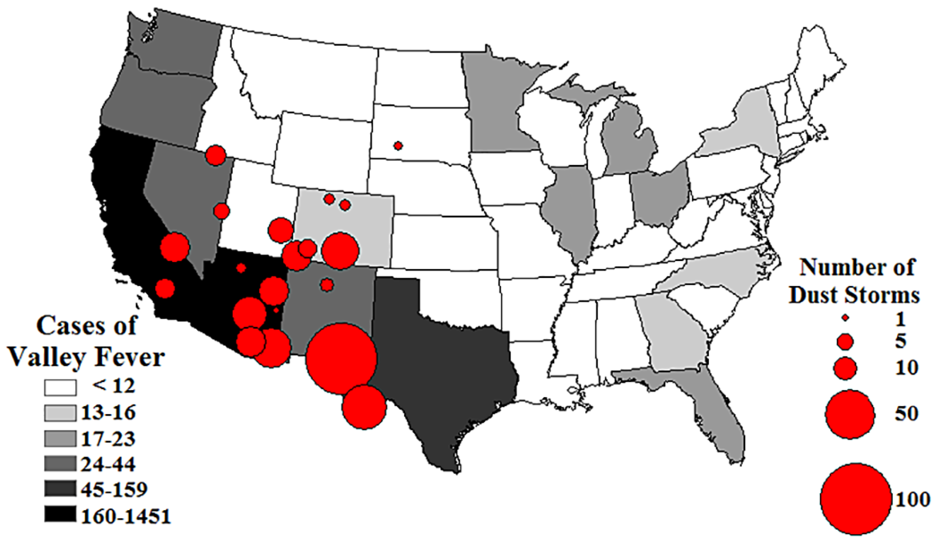

Figure 8. NOAA Dust Storm Frequencies, 1988-2011

As reported by NOAA, the area of the US with the highest frequency of dust storms is an area of southeastern New Mexico and West Texas that includes the Salado Formation and the proposed ISP site. In recent years, the dust storms have frequently been manifested as Haboobs in eastern New Mexico and West Texas.

[6] NUREG-2214, Managing Aging Processes In Storage (MAPS) Report, §6.5, pg. 6-4

[7] https://research.noaa.gov/article/ArtMID/587/ArticleID/162/Research-finds-spike-in-dust-storms-in-American-Southwest-driven-by-ocean-changes

Figure 9. Haboob. Midland, TX.

While the NRC has located several individual SNF DSCs across the US that have surface deposits of salt in sufficient quantities to initiate CISCC, the NRC is proposing to move *the entire inventory* of SNF DSCs to a region of the country where ***ALL*** DSCs would be exposed to salt deposition for extended periods with no means to inspect or repair the canisters should a leak occur, and no means to detect a leak at its source should one occur.

In the 8 years since the issuance of its initial Information Notice regarding the concern of CISCC and its unknown extent within the existing national SNF inventory, the NRC, the DOE, the Nuclear Waste Technical Review Board, and the nuclear industry's Nuclear Energy Institute have invested tens of millions of dollars into the study and characterization of the magnitude of the hazard affecting SNF DSCs as it relates to CISCC and — more importantly — how to even inspect loaded SNF DSC canisters (in the presence of lethal radiation fields) or detect a breaching canister or what can be done with a failed canister when and if it can be identified.

To date, neither the magnitude of the hazard, the manner in which CISCC propagates and under what conditions, nor the extent of its presence on the current installed inventory of over 2,000 DSCs throughout the country is fully understood to allow an adequate safety basis to be developed and constitute a viable license with controls adequate to protect the public and the environment. [8] [9] [10] [11] [12] [13] [14] [15]

As recently as December 2019,[16] the DOE and NRC published revised research priorities that clearly show what is being learned in regard to CISCC and what urgent actions those findings are driving:

- Welded Canister Corrosion (Priority 1) — This was moved from Priority 3 to Priority 1.

  "Three main parameters have been shown to affect stress corrosion cracking (SCC): environment (salt content, salt stability, humidity, and temperature); material (stainless steel(SS)304/304L is used in dry storage canisters); and loading (high tensile stresses in weld zones could support through-wall SCC). Surface samples from canisters at several different sites indicated soluble salt deposition, but the concentrations varied widely, and the presence of corrosion-inducing chloride also varied widely. Four-point bend tests on SS 304L coupons loaded with sea salt did not

[8] SAND2015-7068 R, "Status Report: Characterization of Weld Residual Stresses on a Full-Diameter SNF Interim Storage Canister Mockup," August 21, 2015. "The potential for stress corrosion cracking (SCC) of welded stainless steel interim storage containers for spent nuclear fuel (SNF) has been identified as a high priority data gap by the Nuclear Waste Technical Review Board (NWTRB), the Electric Power Research Institute (EPRI), the Department of Energy (DOE) Fuel Cycle Research and Development (FCRD) programs Used Fuel Disposition (UFD) campaign (Hanson et al, 2012), and the Nuclear Regulatory Commission (NRC 2012a; 2012b). Uncertainties exist both in the understanding of the environmental conditions on the surface of the storage canisters and in the textural, microstructural, and electrochemical properties of the storage containers themselves. The canister surface environment is currently being evaluated by Sandia and EPRI; **however, little has been done to assess canister material properties and their impact on corrosion. Of specific interest are weld zones on the canisters, because the welding process modifies the microstructure of the stainless steel as well as its resistance to localized corrosion. In addition, welding introduces high tensile residual stresses that can drive the initiation and growth of SCC cracks.**"

[9] SAND2015-8668C, "Understanding the Risk of Chloride Induced Stress Corrosion Cracking of Interim Storage Containers for the Dry Storage of Spent Nuclear Fuel: Residual Stresses in Typical Welded Containers," October 2015.

[10] NWTRB-2017, "Chloride-Induced Stress Corrosion Cracking Potential in Dry Storage Canisters for Spent Nuclear Fuel," U.S. Nuclear Waste Technical Review Board, March 01, 2017

[11] SAND2017-2584PE, "Evaluating Stress Corrosion Cracking of Spent Nuclear Fuel Interim Storage Canisters," Charles Bryan, Sandia National Laboratories, Used Fuel Disposition Program, Colorado School of Mines, Presentation to DOE Fuel Cycle Technologies Meeting, March 9, 2017

[12] IHLRWM 2017, "Spent Fuel Dry Storage Aging Management: Development of the Managing Aging Processes in Storage (Maps) Report," USNRC, et al, April 9, 2017

[13] PNNL-28427, Evaluation of Nondestructive Examination Responses from Chloride-Induced Stress Corrosion Cracks, Fabrication of Base Metal Test Specimens," September 2019

[14] PNNL-28643, "Dry Storage System Test Facility for Evaluating Canister Inspection Technologies," September 2019

[15] IAEA-TECDOC-1878, "Demonstrating Performance of Spent Fuel and Related Storage System Components during Very Long-Term Storage, Final Report of a Coordinated Research Project," 2019

[16] SAND2019-15479R, "Gap Analysis to Guide DOE R&D in Supporting Extended Storage and Transportation of Spent Nuclear Fuel: An FY2019 Assessment," DOE, December 23, 2019

indicate enhanced pitting densities as a function of stress. Ongoing work will continue to focus on the three main parameters. This includes (1) quantifying the brine stability of salts present in the environment, (2) understanding material and surface environment effects on electrochemistry and pit formation, and (3) tensile stress tests to identify characteristic features controlling pit-to-crack transition. A major push will be to evaluate pit formation and SCC initiation and growth rates (i.e., pit-to-crack transition) as a function of environmental parameters (salt load, temperature, and salt/brine composition), material properties (e.g., degree of sensitization, surface roughness, degree of cold work), and stress state and to investigate the consequences of gas and particle transport in through-wall cracks."

These are enormous and significant unknowns that prevent the NRC from understanding the full magnitude of the threat of CISCC as well as the exact mechanisms that lead to its creation. However, the fact that "salts present" in the proposed ISP CISF environment are in the ranges of hundreds of tons resident on the surface of the salt playas, the principal initiating agent is present and in quantities that can only represent a significant concern that must be analyzed for impacts to the environment as required by 10 CFR 51.71(d).

Table ES-1. List of Highest Priority Gaps

Gap	2019 Priority	2017 Priority	2012 Priority	Comments
Thermal Profiles	1	1	1	No change in priority
Stress Profiles	1	1	1	No change in priority
Drying Issues	2	2	6	No change in priority
Monitoring - External	3	3	2	No change in priority
Welded Canister – Atmospheric Corrosion	1	3	2	Change in priority due to near-term need to acquire stress corrosion cracking (SCC) data
Cladding – H_2 Effects: Hydride Reorientation and Embrittlement	3	3	7	No change in priority
Consequence Assessment of Canister Failure	3	N/A	N/A	New gap to assess radiological risk due to loss of confinement caused by SCC
Fuel Transfer Options	3	4	3	Change in priority due to need for data for surface storage facility design

Figure 10. Table ES-1 from SAND2019-15479R

- Consequence of Canister Failure (Priority 3) — This was not even on the list of priorities as late as 2018.

  "The focus is to develop [sic] technically defensible assessment of gaseous and particulate releases and radiological consequences through SCC breaches."

Now that the probability of canister failure is deemed likely, the absence of a realistic assessment of the consequences of DSC failure is now a "High Priority Gap" for the NRC and DOE, but is inexplicably absent from the ISP DEIS, in violation of 10 CFR 51.71(d).

- Fuel Transfer Options (Priority 3) — This initiative has increased in priority given the likelihood that CISCC will lead to DSC breach and failure.

  "Data is [sic] needed to support facility design concept for opening a cask for inspection and transfer/repackaging."

  As noted *supra*, there is no capability at the proposed ISP CISF to transfer or repackage SNF from a failed and leaking DSC. In fact, the Holtec CEO made the following statements on this topic in an October 14, 2014 address to the Edison Community Engagement Panel[17]:

  "If that canister were to develop a leak, let's be realistic, you have to find it, that crack, where it might be, and then find the means to repair it."

  "You will have, in the face of millions of curies of radioactivity coming out of the canister … we think it's not a path forward …"

  "A canister that develops a microscopic crack … all it takes is a microscopic crack to get the release… to locate it …"

  "And then if you try to repair it … remotely by welding … the problem with that is that you create a rough surface which becomes a new creation site for corrosion down the road."

  "ASME Section 3, Class 1 has some very significant requirements for making repairs of Class 1 structures like the canisters …"

  "So I, as a pragmatic technical solution, I don't advocate repairing the canister."

  A DSC loaded with SNF presents a lethal radiation environment that requires a multi-million-dollar hot cell facility to attempt to remotely/robotically repair or repackage the SNF from a leaking DSC to an intact DSC. Dried SNF cannot be reinserted into a spent fuel pool due to the thermal shocks caused by "rewetting." As such, the only option is to use a hot cell for a fuel transfer.

  However, no such hot cell will be constructed at the ISP CISF, and therefore the only option would be to place an actively-leaking DSC into a transportation cask, "in the face of millions of curies," as described by the Holtec CEO, "of radioactivity coming out of the canister." The leak would have to first be detected, then the extraction

[17] https://youtu.be/euaFZt0YPi4

process that would take hours or days would proceed as the active release was taking place and continuing to harm the workers, the public and the environment.

While within the transportation cask, there is (1) no current understanding as to how the now leaking spent fuel would behave in this unanalyzed environment or (2) how long it could be safely contained or (3) how a transportation cask could be moved or transported while holding a leaking DSC that violates its certification requirements. These are significant matters of operations and transportation with attendant impacts to the workers, the public and the environment that have not been analyzed.

The absence of any capability to safely contain a leaking DSC before it creates massive harm to the public and environment is a significant flaw in the ISP DEIS analysis and a violation of 10 CFR 51.71(d). This "high priority data gap" fully acknowledged by the NRC and DOE in public reports is a "major point of view" that must be addressed to meet the requirements of US law. It's absence in the ISP DEIS is unacceptable.

Based on the failure of the NRC to address the real and acknowledged threats to the public and the environment from CISCC, the following NRC conclusions are without basis and provably false:

"Overall, based on the preceding analysis that considers (i) occupational dose estimates for operations that are below applicable NRC standards, (ii) public dose estimates from CISF storage operations that are well below NRC standards and a small fraction of background radiation exposure, and (iii) low occupational injury estimates, the NRC staff concludes that the radiological and nonradiological public and occupational health impacts from the operations stage of the proposed action (Phase 1) and full build-out (Phases 1-8) would be SMALL." (DEIS, §4.13.1.2, pg 4-86, lines 26-31)

In fact, the NRC cannot perform a legally-compliant assessment of the environmental impacts of the proposed ISP CISF, nor can it issue a license with sufficient controls protective of the public and the environment when the significant "high priority data gaps" remain regarding a full understanding of the magnitude of the problems presented by CISCC, especially when "completely surrounded by" the chloride-bearing salts that are required to initiate a DSC breach.

As freely acknowledged by the NRC, the materials required to initiate CISCC are present in abundant quantities. Historic weather patterns demonstrate that meteorological events (windstorms, sandstorms, haboobs, rain, mist and fog) occur with sufficient frequency and intensity to deliver the chloride-bearing materials to canister surfaces and initiate attacks on the stainless steel DCSs.

As evidenced by this exchange during a 2018 NRC Commission meeting, it appears that the NRC is taking the path of allowing the industry to dictate what operation is or is not considered "safe" or which "engineered barrier failures" caused by environmental forces of salt and water vapor are deemed credible:

> COMMISSIONER WRIGHT: "... And I've got one last question, and I'm going down to Christian. So I appreciate the discussion on research into the potential aging relating degradation mechanisms for the fuel cask. It's my understanding that industry's exploring several repair and mitigation techniques, you know, as well as the use of robotics for inspection. To what extent have you engaged the industry in these matters, and what's been the outcome of that?"
>
> MR. ARAGUAS: "So thank you for that question. So what I can tell you is we've been engaged with the industry, specifically with EPRI, through their ESCP program, this is extended storage and collaborative programs. And under that program they have a number of subcommittees, one of which talks about aging management and NDE techniques. And they've been in front of ***trying to develop* techniques to be able to inspect, you know, casks in service**. So we've been plugged into that, I think in lockstep with the industry to develop understanding how they're progressing in those initiatives.
>
> "Separately, we do have a contract with PNNL, one of the DOE laboratories, to set up a mockup of a cask to collaborate with EPRI to actually see how the robotics, how these tools are resulting in the inspections to actually assess and see, can they detect the flaws, can they understand and characterize the flaws.
>
> "So I think it's progressing well, ***I think we have confidence in the industry and the direction they're going to be able to inspect these in the future.***"[18] (emphases added)

It should be stated that the Federal Aviation Administration also had "confidence in Boeing" to carry out the critical independent verification measures that defines the role of an independent regulator. That misplaced confidence ended tragically for 692 souls.

Pretending that the environment will not adversely impact the function of the SNF DSC confinement barriers ignores the repeated and publicly stated significant concerns represented in thousands of pages of documents and millions dollars invested by the NRC and DOE to solve the very real problem of CISCC, and creates an unacceptable analytical deficiency in the ISP DEIS.

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[18] NRC Meeting Transcript: "Strategic Programmatic Overview of The Decommissioning and Low-Level Waste and Spent Fuel Storage and Transportation Business Lines," October 11, 2018, ML18295A698.

Attachment:
WCS/ISP 10 CRF 2.390(a)(4) Affidavit Regarding Proprietary Content in PSHA

WASTE CONTROL SPECIALISTS LLC

AFFIDAVIT

I, J. Scott Kirk, Vice President of Licensing and Regulatory Affairs at Waste Control Specialists LLC (WCS), am making the following representations that to the best of my knowledge and beliefs:

1. The following document which WCS wishes to have withheld from public disclosure is:

   The Proprietary Response to Supplemental Information 2.1 related to Seismic Hazard Analysis, Chapter D, dated July 20, 2016.

2. The information contained in the document cited in 1 above is considered confidential information pursuant to Title 10 of the Code of Federal Regulations (CFR), Part 2.390(a)(4) and is thereby protected from public disclosure by regulation.

3. Pursuant to 10 CFR 2.390, the information contained in the document cited in 1 above is protected from public disclosure by regulation because it includes correspondences and reports to the NRC which contain trade secrets or commercial information pursuant to 10 CFR 2.390(a)(4).

4. The information contained in the document cited in 1 above has not been made available to public sources by WCS, nor has WCS authorized that it be made available.

J. Scott Kirk — July 20, 2016
J. Scott Kirk — Date
Vice President
Licensing and Regulatory Affairs

I certify the above named person appeared before me and executed this document on this the 20TH day of July 2016

Notary Public — My commission expires: 3-07-17

CYNTHIA ELEANOR CARTER
Notary Public, State of Texas
Comm. Expires 03-07-2017
Notary ID 124540060

ATTACHMENT 2

Comments on the Cost-Benefit Analysis in Draft Environmental Impact Statement for Interim Storage Partners LLC's License Application for a Consolidated Interim Storage Facility for Spent Nuclear Fuel in Andrews County, Texas (NUREG-2239)

November 1, 2020

I. Summary

This review evaluates the cost-benefit analysis (CBA) contained within the Draft Environmental Impact Statement (Draft EIS) for the proposed Interim Storage Partners (ISP) consolidated interim storage facility (CISF) for spent nuclear fuel (SNF) and other high level waste. It is a key document for informing the public and the U.S. Nuclear Regulatory Commission's (NRC's) licensing decision. The EIS process under the National Environmental Policy Act (NEPA) supplements but does not supplant NRC's statutory decision-making authority. Nor are the statutory and regulatory requirements for licensing identical to NEPA requirements for EISs. It is understood that NRC will take public comments into account as it prepares the Final EIS.

Minimum practice in CBA requires all significant effects be analyzed and, to the extent practicable, objectively quantified and monetized. That is, CBA provides a structured format for capturing disparate effects and enabling them to be examined using common metrics. This requires monetization – i.e., the conversion of environmental impacts into dollars. Of course, some environmental impacts are difficult to quantify, and some that can be quantified are difficult to monetize. That means every CBA will be incomplete, just like every other body of knowledge.

This review begins with a characterization of the baseline from which environmental impacts, costs, and benefits attributable to the proposed project are estimated. Other fundamental attributes of CBAs are then identified, including the alternatives to be analyzed and an array of technical matters, such as valuation, discounting, and distributional impacts. A special form in which distributional impacts are assessed takes account of disproportionate and adverse effects on minority and/or low-income communities ("environmental justice," or EJ). The Draft EIS includes an EJ analysis that has been reviewed as part of the CBA.

A. Key conclusions

The Draft EIS CBA contains numerous material structural and technical defects. Greater detail is provided in Section IV.H below, beginning on page 70.

1. Material structural defects

a. *The Draft EIS CBA does not comply with 10 CFR §51.70(b).*

NRC regulations require that "[t]he NRC staff will independently evaluate and be responsible for the reliability of all information used in the draft environmental impact statement."[1] There is considerable evidence that NRC staff independently *evaluated* critical third-party information on which it relied. However, there is no affirmative evidence that the NRC staff evaluated its *reliability*.

Why is this a material structural defect? Normally, only final agency actions are subject to judicial review under the Administrative Procedure Act (APA). In this case, however, NRC's regulation applies to a *nonfinal* action – the publication of a *draft* EIS. Thus, the Draft EIS CBA may be vulnerable to APA challenge.

b. *The Draft EIS CBA does not comply with 10 CFR §51.71(d).*

NRC regulations require that an EIS CBA include certain minimum components.[2] Key components are missing, however. The CBA does not include alternatives to the proposed action; the only purported "alternative" is indistinguishable from the analytic baseline. The CBA does not include estimates of social costs of the project and its alternatives; it includes only estimates of expenditures likely to be made by the applicant. The CBA does not include credible analysis of social benefits for the project and its alternatives; it includes no benefits at all, save potential private cost savings to the applicant's potential customers and certain transfer payments that are not even benefits.

Why is this a material structural defect? Comparisons between social costs and social benefits cannot be made if a CBA lacks this information.

c. *The Draft EIS CBA does not adhere to key provisions of applicable NRC guidance.*

Several NRC guidance documents apply to the Draft EIS CBA.[3] Key sections of the CBA do not comply, however. For example, NRC guidance requires the Draft EIS CBA to include credible alternatives and estimates of social costs and social benefits for each alternative. This information is missing. The CBA further commits two elementary errors:

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[1] U.S. Nuclear Regulatory Commission (2020b).

[2] U.S. Nuclear Regulatory Commission (2020c).

[3] U.S. Nuclear Regulatory Commission (2003b), U.S. Nuclear Regulatory Commission (2004b), U.S. Nuclear Regulatory Commission (2017).

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improperly counting certain transfers as social benefits, and calculating net benefits incorrectly.

Why is this a material structural defect? Guidance is not always dispositive, but agency staff ordinarily should comply unless there is a persuasive reason not to do so. For example, compliance with guidance is not appropriate if that guidance includes manifest error or does not reflect the current state of knowledge. The Draft EIS CBA does not comply with key provisions of applicable NRC guidance and offers no justification for its departures.

d. The Draft EIS does not comply with applicable information quality guidelines that parallel requirements in NRC's NEPA regulations.

The requirement in 10 CFR §50.70(b), noted in paragraph (a) above, parallels government-wide information quality guidelines published in 2002 by the Office of Management and Budget and affirmed by NRC.[4] All federal agencies must perform pre-dissemination reviews to ensure the objectivity, utility, and integrity of influential information they disseminate. There is no evidence in the Draft EIS CBA suggesting that the NRC staff conducted a pre-dissemination review.

Why is this a material structural defect? Compliance with 10 CFR §51.70(b) and the information quality guidelines is essential for the public to have confidence in the quality of the Draft EIS CBA.

e. The Draft EIS CBA fails to fulfill NEPA's statutory purpose.

NEPA §102(B) makes clear that the purpose of conducting environmental analysis, is to ensure that "presently unquantified environmental amenities and values" are taken into account in federal decision-making. But the Draft EIS CBA includes no estimates of "presently unquantified environmental amenities and values."

Why is this a material structural defect? Nothing in NEPA §102(B) suggests that an EIS CBA should, as this one does, fail to quantify (and to the extent feasible, monetize) "presently unquantified environmental amenities and values." Completeness, transparency, and consistency with generally accepted professional standards certainly support the inclusion of *all* social costs and benefits, even those not expressly required by NEPA. Nonetheless, compliance with the scope of analysis set forth by NEPA should not be optional. Nothing in NEPA suggests that an EIS CBA should, as this one does, focus

[4] Office of Management and Budget (2002), U.S. Nuclear Regulatory Commission (2002).

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exclusively on private costs to the applicant and ignore the costs and benefits of external environmental impacts.

f. *The environmental justice (EJ) analysis in the Draft EIS is not designed to detect disproportionate and adverse effects on minority and low-income communities.*

EJ analysis is a specialized way to examine distributional effects that otherwise might be missed due to averaging. In particular, EJ analysis is supposed to enable analysts to determine if there are minority or low-income communities that bear disproportionately high adverse risks.[5] The way EJ analysis is conducted in the Draft EIS, however, any such effects would not be detectable. The area of concern was defined to be identical to the spatial area used as a control. No differences, no matter how large, can be observed when treatment and control groups are identically defined.

Why is this a material structural defect? The EJ analysis is unable to discern whether potential EJ-related effects even exist, never mind whether they are disproportionately adverse. A complete revision of the EJ analysis is required to answer these questions.

2. Material technical defects

a. *The scope of the Draft EIS CBA is technically incorrect.*

If granted a license from NRC, the ISP CISF will accept SNF from any reactor in the United States. Therefore, the U.S. is proper scope for potential environmental impacts. However, the only environmental impacts considered by NRC staff are those which would be locally manifest, or associated with SNF transportation. Environmental impacts resulting from the removal of SNF from onsite reactor storage were not included.

Why is this a material technical defect? Environmental impacts at reactor sites are clearly relevant, but the CBA assumes them away. These impacts should be estimated, and net impacts obtained by subtracting the estimated baseline environmental impacts of removal to a permanent repository.

b. *The Draft EIS CBA includes no estimates of environmental impacts in the baseline.*

Estimates of environmental impacts in the baseline are required to derive monetized and/or quantified estimates of the incremental impacts of the project (as well as each credible alternative). Incremental impacts are obtained by obtained by subtracting

[5] Clinton (1994), U.S. Nuclear Regulatory Commission (2004a).

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each relevant baseline impact from the relevant estimated impact attributable to the proposed facility. The Draft EIS and CBA include no estimates of environmental impacts for the baseline.

Why is this a material technical defect? The incremental environmental impacts of the proposed CISF (as well as each credible alternative) cannot be estimated without subtracting estimated environmental impacts in the baseline. Thus, incremental social benefits and costs are impossible to estimate.

c. The Draft EIS CBA lacks analysis of credible alternatives.

Both NRC regulations (10 CFR §51.71(d)) and NRC guidance require the analysis of reasonable alternatives.[6] The Draft EIS CBA considers none. The CBA purports to include no-action as an "alternative," but "no-action" is just the analytic baseline for evaluating costs and benefits of the proposed project and every bona fide alternative considered.

An obvious alternative to the proposed ISP CISF is the proposed Holtec International CISF. The Draft EIS CBA does not includes a comparative analysis of these proposals.[7]

Why is this a material technical defect? Without a comparative analysis, the Commission lacks a rationale for choosing to license only one proposed CISF. The public is unable to consider which proposal it prefers if NRC determines that at least one of them is essential.

Another obvious alternative is a combination of both proposed CISFs. The Draft EIS CBA has a brief qualitative discussion of this, but it does not include any serious analysis.[8] In lieu thereof, the CBA offers mere speculation.

Why is this a material technical defect? Each CISF proposal is proceeding along a separate track in a way that essentially denies the relevance of the other. The combined effects of both CISFs is an obvious interest to the Commission and the public.

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[6] See footnote 3.

[7] The Draft EIS CBA for the proposed Holtec CISF [U.S. Nuclear Regulatory Commission (2020e)] also briefly discussed the proposed ISP CISF, but it did not include a comparative analysis.

[8] The combined environmental impacts for both CISFs is not necessarily the sum of their individual impacts.

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d. The Draft EIS CBA includes analysis of an irrelevant alternative.

Reasonable alternatives to the proposed project are those which could meet its objectives of the project but in a different manner. Because ISP's application is limited to Phase 1, every reasonable alternative examined must be consistent with this scope and scale. In lieu of considering reasonable alternatives, the Draft EIS CBA includes analysis of the buildout of all eight Phases – a vastly larger project than actually proposed.

Why is this a material technical defect? Full buildout of all eight phases is not a reasonable alternative to Phase 1. The proper place for considering full buildout is in a sensitivity analysis.

e. The Draft EIS CBA does not monetize environmental impacts.

The Draft EIS CBA characterizes most environmental impacts as SMALL or MODERATE without quantification, and does not monetize them. The NCR staff define SMALL impacts as indistinguishable from zero, so their absence from the CBA may not be not material. However, MODERATE impacts presumably have values greater than zero, so an attempt should be made to value them and incorporate these values in the CBA.

Plausible reasons not to include valuations for MODERATE impacts in the CBA is that the NRC staff cannot sufficiently quantify them, or reliable methods do not exist to monetize them. These are fair points. However, the Draft EIS includes quantitative estimates of public health and occupational risks, and there is NRC guidance which prescribes how to monetize them.[9] The CBA does not monetize these impacts, either.

Why is this a material technical defect? The purposes of CBA are frustrated when impacts cannot be quantified or monetized. In some cases, however, quantification is feasible but not attempted. In other cases, quantitative estimates are available and tools for monetizing them exist, but for some reason the minimal effort required to complete the task is not expended. Both the Commission and the public would benefit from full monetization when data and methods are available, and greater effort made to quantify effects rather than resort to qualitative descriptors like MODERATE, which have limited utility.

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[9] See, e.g., U.S. Nuclear Regulatory Commission (1995), U.S. Nuclear Regulatory Commission (2015).

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f. The Draft EIS CBA does not estimate social costs.

NRC guidance is clear that an EIS CBA "should not be limited to a simple financial accounting of project costs."[10] However, all the Draft EIS CBA contains is "a simple financial accounting of project costs."

Why is this a material technical defect? The cost to ISP of constructing and operating the proposed CISF is wholly unrelated to the purpose of performing CBA under NEPA. To focus on private costs, and exclude the social costs of environmental impacts, is inconsistent with NEPA's purposes. The CBA is little more than a private financial analysis for which NRC lacks requisite expertise and is incompatible with NRC's mission as the Commission understands it.

g. The Draft EIS CBA lacks an assessment of social benefits.

Professional practice requires that every CBA include an assessment of social benefits as well as social costs.[11] This is the standard for federal regulation,[12] federal programs,[13] federally-funded highway projects and aviation,[14] health regulation and programs,[15] and federally-funded water resources projects,[16] just to name a few. It is also the standard for nuclear facility regulations and projects, as NRC guidance confirms.[17]

The Draft EIS CBA includes no benefits assessment. It purports to include benefits, but it includes only sum of estimated expenditure reductions that ISP's putative customers could obtain by transferring SNF to ISP's CISF. This is not the same thing as social benefits, and it has no practical information value to the Commission or the public.

Why is this a material technical defect? A social benefits assessment is necessary to allow social costs and benefits to be properly compared, and in particular, for social costs

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[10] U.S. Nuclear Regulatory Commission (2017) at 4-3.

[11] See, e.g., Boardman, et al. (2018), Dudley, et al. (2017), Jenkins, et al. (2019).

[12] Office of Management and Budget (2003).

[13] Office of Management and Budget (1992).

[14] Federal Aviation Administration (1998), Federal Aviation Administration (2020a), Federal Highway Administration (2018).

[15] U.S. Department of Health and Human Services (2016).

[16] U.S. Water Resources Council (1983).

[17] U.S. Nuclear Regulatory Commission (2003b), U.S. Nuclear Regulatory Commission (2004b), U.S. Nuclear Regulatory Commission (2017).

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to be subtracted from social benefits to ascertain whether the project is expected to provide net social benefits. By not including a legitimate social benefits assessment, the Draft EIS CBA fails to fulfill the key purpose of every CBA.

h. The Draft EIS CBA incorrectly characterizes transfers as benefits.

The Draft EIS CBA purports to summarize the beneficial environmental impacts of the proposed ISP CISF. However, the only item listed is the additional tax revenue received by local governments. Taxes are transfers, however; they are not cognizable as benefits in CBA. Even if taxes were counted, local governments' tax receipts would exactly equal the sum of firms' and individuals' tax payments, resulting in a net impact of zero.[18]

Why is this a material technical defect? Transfers should never be misclassified as social benefits.

i. The Draft EIS CBA incorrectly calculates net benefits.

The focus of CBA under NEPA §102(B) is the estimation of "presently unquantified environmental amenities and values" – which, for shorthand, can be understood as the value of environmental impacts, regardless of sign. Net benefit is the difference between the value of the environmental impacts of the project and the value of the environmental impacts in the baseline. NRC guidelines refer to the net benefit concept as "net value."

The Draft EIS CBA does not calculate net value as prescribed by NRC guidance. Rather, it calculates the potential financial savings to ISP's presumed customers and subtracts ISP's expected expenditures. This difference has nothing whatsoever to do with net benefits. It is the financial value to ISP of compelling reactor owners and operators to ship SNF to ISP and allowing ISP to engage in first-degree price discrimination. Neither of these conditions would ever apply, so the calculation has no practical value to the Commission or the public.

Why is this a material technical defect? The calculation of net social benefit is the culmination of every CBA. No one is informed when this is done wrong.

j. Cost estimates in the Draft EIS CBA are suffused with excess precision.

The Draft EIS CBA reports expenditure estimates with up to 11 significant figures. For example, the CBA reports total undiscounted expenditures in the baseline as great as

[18] Curiously, tax payments made to federal and state governments are not included in the CBA.

$10,771,948,925. This level of precision implies accuracy ± $0.50. This level of precision is not merely misleading; it is impossible.

Why is this a material technical defect? Excess precision is inherently misleading. It violates the information quality standard of presentational objectivity. Estimates with excess precision are not "accurate, clear, [or] complete," even if they are "unbiased."

k. The Draft EIS CBA does not account for uncertainty about the value of environmental impacts.

Conventional practice and NRC guidance require CBAs to account for uncertainty. The Draft EIS CBA ignores uncertainty, however. Indeed, it does not even acknowledge that its estimates of ISP expenditures are uncertain. The CBA also includes sensitivity analysis, but only for arbitrary scenarios that have little or no informational value. Further, the CBA denies the public sufficient information to conduct its own sensitivity analysis with respect to margins that actually matter.

The limited sensitivity analysis included does not capture any technical uncertainty that is meaningful with respect to environmental impact assessment. The two scenarios examined differ only with respect to the NRC staff's opinion about ISP's business judgment. This opinion is not relevant to NEPA, nor is it relevant to NRC's statutory authority to issue or deny ISP a license for its proposed CISF.

Why is this a material technical defect? The purpose of sensitivity analysis is to better understand how net social benefits differ when key technical or policy uncertainties are allowed to vary. It is not to examine irrelevant hypotheticals that have no relationship to agency decision-making.

B. Recommendations

1. Revise the Draft EIS CBA so that it complies with applicable NRC regulations and guidelines, and adheres to accepted professional practices.

As summarized above and explained throughout Section IV below, the Draft EIS CBA violates NRC regulations and guidance and accepted professional standards in CBA. These violations are highly significant, making the CBA unacceptable for its intended use. Neither the Commission nor the public can rely upon it to inform prudential judgment. Unless and until these defects are corrected, NRC will not have complied with NEPA, and ISP's project will be mired in unnecessary controversy.

The experience of reviewing Draft EIS CBAs for two different CISF proposals,[19] both of which contain the same structural and technical defects, suggests a systemic failure. Both CBAs should be corrected and distributed again for public comment. Choosing not to correct errors will cause unnecessary controversy, delay, and possibly litigation.

2. In the revised draft EIS CBAs, include bona fide alternatives.

"No action" is correctly characterized in the Draft EIS CBA (and the Holtec Draft EIS CBA) as the analytic baseline. This is needed to estimate the magnitude and value of significant environmental impacts reasonably foreseeable from licensure of the relevant CISF and other bona fide alternatives. But no-action cannot be both the baseline and an "alternative." A baseline cannot be an "alternative" because it cannot achieve, through alternative means, the same objectives as the proposed project. By definition, the only things that happens in the baseline are things that would have occurred anyway.

Each draft CBA must be revised to include reasonable alternatives that inform the Commission and the public. As noted above, there are two obvious alternatives: (a) licensure of the proposed Holtec CISF instead, and (b) licensure of both proposed CISFs.[20] Alternative (a) is easy to include by conducting a comprehensive, rigorous comparison of environmental impacts reasonably expected to occur from each project. Comparative analysis does not require any original analytic effort. Rather, it requires a thoughtful side-by-side analysis that highlights every material difference between them that affects social costs and social benefits. Alternative (b) requires more effort. It is not simply the sum of environmental impacts from each proposed CISF. While some impacts may be additive, others may be systematically related because their locations are so close, and their prospective customers overlap.

Other alternatives also may deserve consideration as well. The "correct" number of alternatives is not set in stone, nor can it be divined from theory. The only factual statement that can be made about the "correct" number of alternatives is that it is not zero – the number of alternatives included in each draft EIS CBA.

3. In the revised draft EIS CBAs, estimate, and monetize to the extent practicable, the costs and benefits of all significant environmental impacts.

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[19] U.S. Nuclear Regulatory Commission (2020e) [Holtec International, Inc.] and U.S. Nuclear Regulatory Commission (2020d) [Interim Storage Partners LLC].

[20] In the same way, the proposed ISP CISF is a bona fide alternative to the proposed Holtec CISF.

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Both draft EIS CBAs include no monetized and/or quantified estimates of external environmental impacts – the kind of impacts for which NEPA's environmental review process was intended. In lieu of what the law requires, both CBAs estimate only private costs to the respective applicant and do not estimate benefits.

4. In the revised draft EIS CBAs, examine marginal changes in the proposal to identify potential mitigation opportunities.

The purpose of an EIS is threefold: (a) identify all potential environmental impacts; (2) quantify and monetize all environmental impacts determined to be significant; and (3) identify ways to mitigate adverse environmental impacts. These purposes are clearly stated in applicable NRC regulations,[21] but the third gets much less attention than the second (which gets less attention than the first).

CBA is a commonly used tool for identifying ways to reduce social costs, increase social benefits, or both. Once these opportunities are identified, when properly conducted CBA subjects them to analytic scrutiny to ensure that intuitive expectations are supported by rigorous analysis. If analysis is not performed, it is easy for mitigation alternatives to be identified and selected without regard for their effectiveness, efficiency, and potential unintended consequences.

5. In the revised draft EIS CBAs, examine alternative interim storage periods.

Like the Draft EIS CBA for the proposed Holtec CISF,[22] this Draft EIS CBA assumes that a permanent waste repository will be licensed, constructed, and operational in time for SNF to be defueled and transported there before the license term expires. This could happen, but there is little evidence suggesting that it will and substantial evidence indicating that it won't. Whether a permanent waste repository is timely available is a key policy uncertainty in both CBAs, yet neither CBA analyzes environmental impacts under alternative assumptions about the status of a permanent waste repository. Both CBAs

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[21] See also U.S. Nuclear Regulatory Commission (2020a). Paragraph (c) concerns the environmental report, a document license applicants prepare and upon which NRC relies to produce the EIS: "The environmental report must include an analysis that considers and balances the environmental effects of the proposed action, the environmental impacts of alternatives to the proposed action, *and alternatives available for reducing or avoiding adverse environmental effects*" (emphasis added). Mitigation is the subject of Chapter 6 of each Draft EIS, but the relevant CBA (Chapter 8) is silent about it.

[22] U.S. Nuclear Regulatory Commission (2020e).

simply ignore these environmental impacts. Neither the public nor the Commission is properly served by CBAs that pretend this uncertainty does not exist.

Revised CBAs should explicitly include several alternative time periods beyond the proposed license during which the CISF would in fact be operational. For example, NRC staff could estimate and monetize the environmental impacts of each of the following CISF storage term scenarios: (a) 1.5x the license period; (b) 3x the license period, and (3) de facto permanent disposal. The public would be better informed if these scenarios (and perhaps others) were transparently analyzed.

II. Background

A. NRC requirements with respect to EISs

Environmental Impact Statements (EISs) are conducted as required by the National Environmental Policy Act (NEPA),[23] Council on Environmental Quality (CEQ) regulations,[24] NRC regulations,[25] and NRC guidance.[26] As required by NRC licensing regulations, ISP submitted as part of its application an Environmental Report (ER)[27] and Safety Analysis Report (SAR).[28] The ER must comply with 10 C.F.R. § 45(c), which says in part:

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[23] National Environmental Policy Act (1970).

[24] 40 CFR Parts 1500-1508, as amended by Council on Environmental Quality (2020).

[25] 10 CFR §§51.10–17.

[26] U.S. Nuclear Regulatory Commission (2003b), Chapters 4 and 5 (environmental reviews); U.S. Nuclear Regulatory Commission (2004b) [Revision 4], U.S. Nuclear Regulatory Commission (2017) [Draft Revision 5] (regulatory analysis); and U.S. Nuclear Regulatory Commission (1995) [Final], U.S. Nuclear Regulatory Commission (2015) [Draft] (normal risk values and valuation of avoided radiation exposure).

[27] The most recent ISP ER appears to be Revision 3. See Interim Storage Partners LLC (2020). ISP is the successor in interest to Waste Control Specialists (WCS), which submitted the original license application and numerous supporting documents.

[28] The most recent substantive ISP SAR appears to be Revision 2. See Interim Storage Partners LLC (2018). Declarations and affidavits to withhold, as confidential commercial information and/or trade secrets, certain parts of Revision 3 are available at ADAMS Accession No. ML20150A339, but no complete version of Revision 3 appears to be publicly available.

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> The environmental report must include an analysis that considers and balances the environmental effects of the proposed action, the environmental impacts of alternatives to the proposed action, and alternatives available for reducing or avoiding adverse environmental effects...
>
> The analyses for environmental reports shall, to the fullest extent practicable, quantify the various factors considered. To the extent that there are important qualitative considerations or factors that cannot be quantified, those considerations or factors shall be discussed in qualitative terms. The environmental report should contain sufficient data to aid the Commission in its development of an independent analysis.

The SAR must comply numerous provisions in 10 CFR Part 72, applicable Regulatory Guides,[29] and NUREG-1567.[30] The ER and SAR are especially relevant insofar as NRC disseminates information from them in the Draft EIS and conveys its substantive agreement with information contained therein. Third-party information disseminated by a federal agency in a manner reasonably interpreted to constitute agency endorsement must adhere to information quality guidelines in the same manner as if the information had been produced by the agency itself.[31]

The scope of an NRC EIS is guided by NUREG-1748,[32] Required content is set forth in Section 5; matters related to safety, public health, and security are not directly identified as "environmental impacts," but they are included in the Draft EIS, albeit asymmetrically. For example, NUREG-1748 Sec. 4.2.5.3 requires that a key category of public health *costs* be addressed ("Are there *undesirable* public health or safety effects?" [emphasis added]) but not public health *benefits* ("Are there *reductions* in public health or safety effects compared to the no-action alternative?" [emphasis added]).

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[29] NRC has published 10 Regulatory Guides. See U.S. Nuclear Regulatory Commission (2019).

[30] U.S. Nuclear Regulatory Commission (2000).

[31] Office of Management and Budget (2002) at 8454 ("[I]f an agency, as an institution, disseminates information prepared by an outside party in a manner that reasonably suggests that the agency agrees with the information, this appearance of having the information represent agency views makes agency dissemination of the information subject to these guidelines.") Also, 10 CFR §51.70(b) requires NRC staff to "independently evaluate and be responsible for the reliability of all information used in the draft environmental impact statement."

[32] U.S. Nuclear Regulatory Commission (2003a), most notably Section 4.2.

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B. NRC requirements with respect to CBA

Other guidance also applies, including guidance on the conduct of CBA.[33] The asymmetry noted above with respect to costs and benefits in NUREG-1748 is impermissible in CBA. *All* significant environmental impacts must be counted, quantified if they are significant, and monetized wherever feasible – not just adverse environmental impacts.[34]

As part of its NEPA responsibilities, NRC is required to conduct a CBA for the proposed project within the Draft EIS. This subsection briefly summarizes relevant NRC guidance on its CBA practices, which is found in NUREG/BR-0058.[35]

CBA is a policy-neutral tool for assembling all information material to a decision; characterizing that information as a cost, benefit, or transfer; and monetizing each information characterization to the extent practicable and appropriate to inform decision-making. Prerequisite to these tasks is a clear statement of the problem to be solved, for that establishes analytic scope, guides the development of the alternatives to be analyzed, and informs analysts about the appropriate level of detail.

The purpose of the Draft EIS CBA is to inform decision-making concerning whether to issue a license for the construction, operation, defueling, and decommissioning of ISP's proposed CISF. Because this CBA is conducted within the context of an EIS performed pursuant to NEPA and NRC implementing regulations, the scope of the CBA should be limited to quantifying and monetizing environmental impacts of the proposal and relevant alternatives. Except in rare circumstances, these environmental impacts must be external to the project – i.e., manifest beyond the project area. The costs and benefits of

[33] U.S. Nuclear Regulatory Commission (2004b), U.S. Nuclear Regulatory Commission (2017). "Cost-benefit analysis" (CBA) and "benefit-cost analysis" (BCA) are alternative names for the same analytic technologies. Some federal agencies use CBA; most use BCA. In this review, the term cost-benefit analysis or CBA is used to ensure consistency with NRC practice.

[34] See, e.g., Dudley, et al. (2017) at 14, Boardman, et al. (2018) at 1, Jenkins, et al. (2019) at 32. The purpose of CBA is to inform decision-making, not delay or frustrate it. Therefore, costs and benefits too small to credibly affect a decision need not be included.

[35] U.S. Nuclear Regulatory Commission (2017) (Draft Rev. 5) and U.S. Nuclear Regulatory Commission (2004b) (Final Rev. 4).

environmental impacts that are strictly onsite are capitalized into ISP's balance sheet, and therefore are not external and should not be included.[36]

Specific requirements for CBA are discussed in Section III below.

C. Information quality

Certain other administrative and regulatory requirements also apply to the Draft EIS (and later, to the Final EIS). In particular, influential information disseminated by NRC is subject to government-wide[37] and NRC-specific[38] information quality guidelines (IGQs). The IQGs define *information* broadly:

> "Information" means any communication or representation of knowledge such as facts or data, in any medium or form, including textual, numerical, graphic, cartographic, narrative, or audiovisual forms. This definition includes information that an agency disseminates from a web page, but does not include the provision of hyperlinks to information that others disseminate. This definition does not include opinions, where the agency's presentation makes it clear that what is being offered is someone's opinion rather than fact or the agency's views.[39]

Generally, the IQGs apply to information disseminated by federal agencies, though with important exceptions:

> "Dissemination" means agency initiated or sponsored distribution of information to the public (see 5 CFR 1320.3(d) (definition of "Conduct or Sponsor")). Dissemination does not include distribution limited to government employees or agency contractors or grantees; intra- or inter-

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[36] The Draft EIS clearly states that "the NRC has no role in a company's business decision to submit a license application to operate a CISF at a particular location." See U.S. Nuclear Regulatory Commission (2020d) at xviii. For this reason, the Draft EIS CBA should not include (much less focus incessantly on) the private costs and benefits of the project. Not only is this information irrelevant to an assessment of *environmental impacts*, it also is irrelevant to NRC's decision whether to issue a license. Further, there is no reason to believe that NRC staff can do a better job of private financial project evaluation than ISP.

[37] Office of Management and Budget (2002), as authorized by 42 U.S.C. 3516 note. NRC is a covered federal agency pursuant to 44 U.S.C. 3502(1) (definition of *agency*).

[38] U.S. Nuclear Regulatory Commission (2002)

[39] Office of Management and Budget (2002) at 8460 [Sec. V.5].

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> agency use or sharing of government information; and responses to requests for agency records under the Freedom of Information Act, the Privacy Act, the Federal Advisory Committee Act or other similar law. This definition also does not include distribution limited to correspondence with individuals or persons, press releases, archival records, public filings, subpoenas or adjudicative processes.[40]

In addition, agencies are responsible for the quality of third-party information they disseminate "in a manner that reasonably suggests that the agency agrees."[41] Thus, the IQGs apply to information NRC derives from third-party information (such as the ISP ER and SAR) and disseminates in a manner that conveys agency agreement.

Finally, EISs are per se covered by the IQGs because they unambiguously meet the definition of *influential* information:

> ''Influential", when used in the phrase "influential scientific, financial, or statistical information", means that the agency can reasonably determine that dissemination of the information will have or does have a clear and substantial impact on important public policies or important private sector decisions...[42]

By NRC's own regulations, its CBAs must rely on reliable information, including information received from third-parties such as ISP, and NRC is responsible for the quality of its CBAs:

> The NRC staff will independently evaluate and be responsible for the reliability of all information used in the draft environmental impact statement.[43]

In short, EIS CBAs must comply with applicable information quality principles and guidelines, including the procedural requirement for pre-dissemination review, because its own regulations require it to do so.

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[40] at 8460 [Sec. V.8].

[41] at 8460 [Sec. V.8].

[42] at 8454: "[I]f an agency, as an institution, disseminates information prepared by an outside party in a manner that reasonably suggests that the agency agrees with the information, this appearance of having the information represent agency views makes agency dissemination of the information subject to these guidelines."

[43] 10 CFR §51.70(b).

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Information quality concerns also are reflected in CEQ's recent revision of its rules for NEPA compliance.[44] New § 1502.23 requires agencies to "ensure the professional integrity, including scientific integrity, of the discussions and analyses in environmental documents;" "make use of reliable existing data and resources"; and "identify any methodologies used and [] make explicit reference to the scientific and other sources relied upon for conclusions." As an independent agency, NRC has long taken the position that it is not legally required to comply with regulations issued by CEQ, an Executive branch agency. Nonetheless, NRC has modeled its NEPA regulations implementing NEPA to mimic CEQ regulations. Thus, the new CEQ regulations do not impose any additional burden on NRC.

III. NRC Guidance Relevant to EIS CBAs

There are two relevant versions of NUREG/BR-0058, NRC's guidance documents for regulatory analysis including CBA: (1) Revision 4, the most recent finalized version,[45] and (2) Revision 5, which is in draft.[46] Revision 5 includes a separate chapter on CBAs conducted pursuant to NEPA. Neither version is referenced in the Draft EIS, however, so it is unclear which version was relied upon (if any). Draft Revision 5 is more than a decade newer, and more than three years have elapsed since it was published for comment. Because it does not display the required disclaimer for draft documents distributed for comment or peer review,[47] so the public may reasonably infer that it is operative. With that in mind, this analysis relies on Draft Revision 5 except insofar as it is inconsistent with Revision 4, in which case Revision 4 is used as the standard for review.[48]

Draft Revision 5 consists of a main document, which includes chapters on methods for regulatory analysis, and 12 appendices. Methods chapters deal with general CBA

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[44] Council on Environmental Quality (2020) at 43367. The revised regulations are binding on NEPA actions begun after September 14, 2020. However, "[a]n agency may apply the regulations in this subchapter to ongoing activities and environmental documents begun before September 14, 2020" (at 43372-43373).

[45] U.S. Nuclear Regulatory Commission (2004b).

[46] U.S. Nuclear Regulatory Commission (2017).

[47] Office of Management and Budget (2005) at 2667.

[48] The extent to which non-NRC guidance documents substantively apply to its CBAs is unclear. A reasonable case can be made that they do. For example, NRC's current guidance on radiological risk valuation explicitly acknowledges Executive Orders 12,291 Reagan (1981) and 12,866 Clinton (1993), guidance accompanying EO 12,866 Office of Management and Budget (1996), and Office of Management and Budget (2003) (OMB Circular A-4). See U.S. Nuclear Regulatory Commission (2015).

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elements (Chapter 2) and the identification and quantification of costs and benefits (Chapter 5). Chapter 4 concerns requirements specifically related to NEPA analyses, including CBA, environmental justice, and public and occupational health impact analysis. Relevant appendices deal with "best practices" in cost estimation (Appendix B), uncertainty (Appendix C), special circumstances and related procedural requirements (Appendix E), severe accident consequence analysis (Appendix H), and morbidity (Appendix K).[49]

Section 4 (and especially §4.2) of Draft Revision 5 specifically addresses environmental analyses (including EISs) performed in compliance with NEPA;. CBAs must be complete and quantitative, with limited exceptions,[50] and may rely on "an independent analysis of benefits and costs by State or regional authorities, [or] the applicant's analysis."[51]

A. Scope

NRC guidance defines the proper scope of CBAs conducted in support of Commission actions.[52] Governmental and private CBAs differ with respect to their scope because their purpose are different. A private CBA legitimately may be constrained to

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[49] Like Revision 4, Draft Revision 5 has notable weaknesses. For example, it gives little attention to benefits, and for NEPA applications it improperly dwells on private costs. Thus, comparisons of the proposal and other alternatives to the baseline are likely to be comparisons of relative private costs, as if social costs and social benefits do not differ or do not matter. Missing from Appendix E is any consideration at all of information quality, yet adherence to information quality principles and guidelines is essential for an EIS to be a reliable aid for decision-making. Appendices H (severe accident consequences), I (NEPA), and K (morbidity) are only placeholders for future content.

[50] U.S. Nuclear Regulatory Commission (2017) at 4-2: "When cost-benefit analyses are required, they will, *to the fullest extent practicable*, quantify the various factors considered. To the extent that there are important qualitative considerations or factors that cannot be quantified, those considerations or factors will be discussed in qualitative terms" (emphasis added).

[51] As noted in Section II.C above, when an agency disseminates information from external sources in a manner that conveys agreement (including the reliance on information from external sources for decision-making), they are responsible for ensuring that such information adheres to applicable information quality guidelines in the same manner and to the same extent that would apply if the information was produced by the agency.

[52] U.S. Nuclear Regulatory Commission (2017) at 2-8 to 2-9 ["Statement of the Problem and Objective"].

estimate net benefits to a particular entity or estimate the return on investment made by such an entity. However, federal agency CBAs almost always require a nationwide scope. Such a scope is clearly appropriate for estimating the environmental impacts of a CISF that could accept waste from any reactor in the United States. While it is likely true that most environmental impacts associated with the facility would be local or perhaps regional, environmental impacts related to transportation would be national. Environmental impacts also may arise at any reactor from which SNF would be transported.

Nationwide scope, in turn, requires that the *aggregate* values be estimated; local or regional values are insufficient. Costs borne by and benefits that accrue to individuals and private entities matter only insofar as they are building blocks for aggregate nationwide estimates.[53]

B. Level of detail[54]

The appropriate level of detail "varies, depending on the particular circumstances." NRC staff are directed to consider five factors:

> (1) the complexity and policy significance of the particular problem being addressed
> (2) the magnitude and likelihood of costs and benefits
> (3) the relative amount by which projected benefits exceed costs
> (4) the immediacy of the need for a regulatory action and time constraints imposed by legislation or court decisions
> (5) any supplemental direction provided by the Commission, the Office of the EDO, or an NRC Office Director[55]

NRC's decision whether to license ISP's proposed CISF has national policy significance. The facility could receive SNF from any reactor in the country. Thus, the scope of environmental costs and benefits in the EIS CBA must also be national.

Environmental impacts are clearly material if the product of their magnitude and likelihood (i.e., their expected value) is relevant to decision-making. Because SNF involves potentially catastrophic risks, however, some environmental impacts that have relatively low expected value because they are extraordinarily unlikely also may be relevant to decision-making, and thus be included in the CBA. There is an extensive scholarly and

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[53] See also Office of Management and Budget (2003).

[54] U.S. Nuclear Regulatory Commission (2017) at 2-3 to 2-4.

[55] at 2-3.

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applied literature concerning how to analyze low probability/high consequence events, and the CBA should utilize that literature.

This does not mean that the CBA should include speculative environmental impacts, or impacts for which credible probabilities or effect magnitudes cannot be estimated. When these circumstances arise, CBA can help identify productive areas for additional short-term information collection within the instant analysis or long-term research to improve general practice in the field outside the specific review.

C. Required elements in an EIS CBA[56]

NRC guidance identifies six required elements:

(1) *statement of the problem and objective*, which establishes the scope of the CBA

(2) *identification and preliminary analysis of alternative approaches*, which should be broad and comprehensive, and "represent the spectrum of reasonable possibilities" available

(3) *estimation and evaluation of costs and benefits*, quantifying and monetizing them whenever possible (while separately handling effects that cannot be quantified or monetized), and performing sensitivity or uncertainty analysis on key parameters

(4) *presentation and summary of results*, as

(a) estimated expected value of net benefits;

(b) estimate costs and benefits for each attribute of each alternative;

(c) the distribution of estimated costs and benefits;

(d) a discussion of key assumptions and results of sensitivity or uncertainty analysis;

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[56] at 2-8 to 2-14, and Appendices A, B, and C. NRC guidance uses the catch-all term "regulatory analysis" to refer to work products in which CBA is the keystone but not the only content.

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(5) *a decision rationale*, with the default being the maximization of net social benefits constrained by the NRC's statutory authority, safety goals, and policy; and

(6) *an implementation schedule.*

NRC guidance further requires that CBAs identify and analyze alternative approaches that could achieve the desired objectives, and that "no preferable alternative" (i.e., an alternative superior to the project on net-benefit grounds) be left out.[57] These elements are consistent with other government guidance.[58]

A CBA is per se noncompliant with NRC guidance if it lacks alternatives, does not estimate social costs and benefits, fails to report net benefits in expected value terms, does not address uncertainty and include sensitivity or uncertainty analysis, or report distributions for costs and benefits.

D. Required elements in an EIS CBA[59]

CBAs prepared to comply with NEPA are a special case, but the principles guiding them are no different. Therefore, an EIS CBA must adhere to the same requirements, use the same analytic methodologies, and adhere to the same professional standards. The key difference is an EIS CBA should be focused on external environmental impacts and need not address matters that lie beyond NEPA. NRC's EIS regulations demonstrate this focus:

> The draft environmental impact statement will be concise, clear and analytic, will be written in plain language with appropriate graphics, will state how alternatives considered in it and decisions based on it will or will not achieve the requirements of sections 101 and 102(1) of NEPA and of any other relevant and applicable environmental laws and policies, will identify any methodologies used and sources relied upon, and will be supported by evidence that the necessary environmental analyses have been made.[60]

NRC guidance reiterates that these requirements unless an explicit exception applies.[61]

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57 at 2-1.

58 *Cf*. Office of Management and Budget (2003).

59 U.S. Nuclear Regulatory Commission (2017), Chapter 4.

60 U.S. Nuclear Regulatory Commission (2020b).

61 U.S. Nuclear Regulatory Commission (2017) at 4-1.

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NRC guidance concerning NEPA CBAs does not distinguish between private costs and benefits (i.e., those resulting from arm's-length market exchanges), external costs and benefits (i.e., externalities not reflected in market prices), or the costs and benefits attributable to external environmental impacts.[62] Nonetheless, NRC guidance explicitly directs staff not to limit a NEPA CBA to "a simple financial accounting of project costs for each alternative."[63] NRC guidance requires NRC staff to conduct what the information quality guidelines call *pre-dissemination review* to avoid disseminating noncompliant information.[64]

Streamlined regulatory requirements apply to applications for license renewals, to avoid unnecessary or duplicative analytic burden. ISP plans to subsequently apply for one or more facility expansions, and each such application would be subject to a new round of NEPA review. Therefore, it is reasonable to expect that NRC would not reproduce in supplemental EISs the vast majority of material included in this Draft EIS. For that very reason, however, it is essential to ensure that this Draft EIS and CBA are properly performed, in full compliance with NRC guidelines and external professional standards. Failing to comply at the outset will make subsequent NEPA reviews more contentious.

E. Environmental justice[65]

The term environmental justice (EJ) derives from a 2004 presidential executive order, not NEPA or any other statute.[66] The purpose of EJ analysis is to determine whether a regulation of project may have "disproportionately high and adverse human health or

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[62] at 4-1 to 4-2.

[63] at 4-1.

[64] *Cf.* [64] Office of Management and Budget (2002) ("As a matter of good and effective agency information resources management, agencies shall develop a process for reviewing the quality (including the objectivity, utility, and integrity) of information before it is disseminated. Agencies shall treat information quality as integral to every step of an agency's development of information, including creation, collection, maintenance, and dissemination.") with U.S. Nuclear Regulatory Commission (2017) at 4-3 ("The reviewer should also verify that analyses were performed in accordance with appropriate cost-benefit guidance.") .

[65] U.S. Nuclear Regulatory Commission (2017) at 4-3 to 4-4.

[66] Clinton (1994). The provisions of this Executive order apply only to the extent they are not inconsistent with NEPA, which is silent, and does not create any right to judicial review to enforce agency compliance.

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environmental effects … on minority populations and low-income populations."[67] Within a NEPA CBA, EJ analysis is best understood as a specialized way to examine distributional impacts.

NRC has published a policy statement[68] and EJ-specific guidance[69] explaining how NRC intends to account for EJ concerns "through the normal and traditional NEPA review process."[70] There is conceptual tension between EJ and CBA, however. Whereas EJ focuses solely on the estimation of adverse effects to specified subpopulations, CBA is neutral with respect to the sign of these effects and subpopulation identity.[71]

F. Public and occupational health impacts[72]

NRC guidance requires CBA's conducted for NEPA purposes to include information concerning public and occupational health impacts in the baseline and "all pathways necessary to calculate public and occupational exposure."[73] The guidance does not specify how these risks should be characterized. However, because CBA always requires unbiasedness, expected value estimates must be included.

G. Details in an EIS CBA[74]

1. Baseline

A baseline is needed from which incremental costs and benefits are estimated for each alternative, including but not limited to the proposed project. NRC guidance correctly defines the baseline as no-action – i.e., "how things would be" if the project were not licensed and completed).[75] This is consistent with government-wide guidance,[76] guidance

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[67] , Secs. 1-101 and 3-302.

[68] U.S. Nuclear Regulatory Commission (2004a).

[69] U.S. Nuclear Regulatory Commission Office of Nuclear Reactor Regulation (2009).

[70] U.S. Nuclear Regulatory Commission (2017) at 4-3.

[71] Office of Management and Budget (2003) at 14.

[72] U.S. Nuclear Regulatory Commission (2017) at 4-4 to 4-7.

[73] at 4-4.

[74] , Chapter 5.

[75] at 5-7.

[76] Office of Management and Budget (2003) at 2.

and practice of other agencies,[77] and advice provided by nongovernmental experts.[78] For every bona fide alternative examined on a CBA, incremental effects must be estimated with respect to the same baseline and be based on consistent methods.[79]

To perform the calculations necessary to estimate the incremental effects, the analyst must separately estimate the environmental impacts of both the baseline and each alternative. Incremental impacts are obtained by subtracting estimated effects in the baseline from the alternative.

2. Categories of environmental impacts[80]

A key purpose of a CBA is to "identif[y] and estimate[] the relevant costs and benefits likely to result from a proposed NRC action" through "a systematic definition and evaluation of those costs and benefits."[81] NRC guidance identifies six categories of costs and benefits:

i. Effects on public health from accidents
ii. Effects on public health from routine operations
iii. Effects on occupational health from accidents
iv. Effects on occupational health from routine operations
v. Effects on offsite property
vi. Effects on onsite property

Three of the six categories are partially or wholly accounted for by market transactions, which means that costs are partially or wholly offset by benefits. These include occupational risks and onsite environmental impacts. It is improper to include them asymmetrically.

Incremental occupational risks are offset by risk premia in wage rates in labor markets where risks are known, effectively communicated, and thoroughly regulated. The early literature on the valuation of preventing premature mortality consisted of empirical

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[77] See, e.g., Federal Aviation Administration (1998), Federal Aviation Administration (2020a); Federal Highway Administration (2018) , Sec. 5.1; U.S. Environmental Protection Agency (2016) , Chapter 5; U.S. Department of Health and Human Services (2016) , Chapter 2.2; U.S. Water Resources Council (1983), Sec. 1.4.9.

[78] See, e.g., Dudley, et al. (2017) at 8.

[79] U.S. Nuclear Regulatory Commission (2017) at A-2.

[80] at Sec. 5.2. NRC guidance calls categories of environmental impacts *attributes*)

[81] at 5-1.

estimates of wage premia for occupational safety risks.[82] The value of occupational risks attributable to any alternative is the value of the risk less the risk premium paid to bear it. A second-best approach, which makes sense if wage premia cannot be estimated, is to calculate the wage premium sufficient to fully compensate workers for risk-bearing, and treat this as a potential cost if the premium is so large that it is highly unlikely to be included in wage rates.[83]

Similarly, for a site used as a CISF the value of onsite physical impacts is expected to be capitalized as a discount in real property values, with the magnitude of the discount depending on how the market values these impacts. Market prices would include a discount at least until successful decommissioning, and even longer if potential buyers are not fully convinced that decommissioning eliminated all hazards.

NRC guidance does not explain the rationale for including these impacts without adjustment. Elsewhere, the guidance is clear that environmental impacts should be monetized as expected values. Therefore, it seems plausible (if not likely) that this is an unintended error resulting from, for example, limited familiarity with the extensive literature on occupational risk premia and the capitalization of environmental disamenities.

3. Alternatives

NRC guidance requires that a wide ranging preliminary analysis of potential alternatives be preliminarily considered,[84] with detailed quantitative examination in the EIS be limited to the "most promising"[85] "selected"[86] alternatives that meet the objectives

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[82] See, e.g., Viscusi (1979).

[83] NRC guidance directs staff to use nationwide mean hourly earnings from wage rates obtained from the Bureau of Labor Statistics (BLS). See U.S. Nuclear Regulatory Commission (2017) at 5-42. Problems arise if BLS data do not fully capture risk premia.

[84] at 2-10 to 2-11: "The initial set of alternatives should be broad and comprehensive but should also be sufficiently different to provide meaningful comparisons and to represent the spectrum of reasonable possibilities. Alternatives that are minor variations of each other should be avoided. Taking no action should be viewed as a viable alternative, except in cases where action has been mandated by legislation or a court decision. If a viable new alternative is identified after analysis has begun, it should be added to the list of alternatives and treated in the same manner as the original alternatives" (at 2-10).

[85] at 2-1.

[86] at 5-1.

of the proposed project. No specific number of alternatives is required, but under no circumstances would the correct number of alternatives be zero.[87]

4. Valuation[88]

Human health and safety impacts can be radiological or non-radiological. NUREG/BR-0058 establishes default methods for valuing non-radiological impacts to persons or property.[89] Radiological risks have greater interest because of their particular salience in the context of a CISF.

Radiological risk valuation is governed by NUREG-1530. The most recent final version dates from 1995,[90] and a draft revision was published in 2015 but has not been finalized.[91] The 1995 version updated NRC's previous default conversion factor from $1,000 to $2,000 per person-rem. The 2015 draft revision updated the 1995 default to $5,100 per person-rem ($2019), with low and high values established for sensitivity analysis and established procedures for automatically updating these figures over time.[92] The 2015 draft is used for this review.

NUREG-1530 directs NRC staff to apply these default values in the year in which exposure is expected to occur, then discount to obtain present value.[93] Thus, a 1 person-rem radiological risk impact has a present value that ranges from $5,100 ($2014, in year 0) to $340.58 ($2014, in year 40), discounted at 7%. If this risk occurs randomly over the 40-year operating period (i.e., it is equally likely to occur during any year), the present value is $1,700 ($2014).

NUREG-1530 does not adjust for latency, however, meaning that the adverse health effects of radiation exposure are assumed to be manifest in the same year exposure occurs.

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[87] Fraas and Lutter (2013) characterize the absence of alternatives as "first among the cardinal sins that tempt regulators."

[88] U.S. Nuclear Regulatory Commission (2017) at 5-9 to 5-41.

[89] at 5-26 to 5-28.

[90] U.S. Nuclear Regulatory Commission (1995).

[91] U.S. Nuclear Regulatory Commission (2015).

[92] The 2015 default value assumes a nominal risk coefficient factor of 5.7×10^{-4} per person-rem and value of statistical life (VSL) of $9 million. See [Chapters 5 and 6, respectively]. Note that this guidance is intended to apply to power plants, not storage or disposal facilities. See U.S. Nuclear Regulatory Commission (2017), Sec. 5.3.2.

[93] U.S. Nuclear Regulatory Commission (2015) at 8.

This assumption is inconsistent with radiation risk theory. **Table 1** shows present value under alternative assumptions about latency.

Table 1: Present Value of 1 Person-REM Exposure Occurring Randomly During a 40-Year Operating Period

	Latency Period (Years) 0	5	10	20	35
Avg Value Over 40 Years	$ 1,670	$ 1,212	$ 864	$ 439	$ 159
% of Value without Latency	100%	71%	51%	26%	9%

NRC guidance is generally consistent with key elements of the information quality guidelines. For example, "cost-benefit analysis should be transparent and the results should be reproducible."[94] Moreover, "[a] qualified individual reading the analysis should be able to understand the basic elements of the analysis and the way in which estimates were developed."[95] However, NRC's default factors for converting radiological exposure into risk and risk into value[96] may not satisfy the objectivity standard for multiple reasons, including latency.

5. Discounting[97]

Consistent with OMB Circular A-4, NRC guidance prescribes the use of a 7% real discount rate on future costs and benefits, with 3% used for sensitivity analysis to "indicate the robustness of the results to the choice of discount rate." Circular A-4 advises analysts to present tables showing the streams of costs and benefits by year they are expected to be

[94] U.S. Nuclear Regulatory Commission (2017) at 5-9.

[95] at 5-9.

[96] NRC assumes that radiological exposure is transformed into risk using a linear no-threshold (LNT) formula. This formula has become increasingly controversial. See, e.g., Health Physics Society (2019), opposing the use of the LNT model for objectively estimating low-dose risks and othe use of collective dose metrics.

[97] U.S. Nuclear Regulatory Commission (2017) at 5-42 to 5-46.

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realized.[98] Nongovernmental experts offer similar advice, emphasizing that costs and benefits must be treated symmetrically.[99]

6. Distributional effects and environmental justice

1. Effects on onsite property[100]

The first two categories involve external effects, in accordance with the purposes of NEPA. The third and fourth are not necessarily external, however, because occupational risks may be compensated in wage premia. Category five involves external effects; category six does not. The inclusion of non-external impacts diverts attention from NEPA's fundamental purpose, which was to "insure [sic] that *presently unquantified* environmental amenities and values may be given appropriate consideration in decisionmaking."[101] Effects that are borne by or accrue to a project owner or operator such as ISP are rarely unquantified. The costs of constructing, operating, defueling, and decommissioning a CISF are the most rigorously quantified of all.

All significant external environmental impacts must be included, quantified to the extent possible, and reported in the form of net benefits. Consistent with longstanding principles of welfare economics, quantitative estimates are summed without regard for the identities of those persons who benefit or bear costs. All effects are estimated compared to the baseline, which is the no-action alternative.[102]

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[98] Office of Management and Budget (2003) at 18.

[99] See, e.g., Dudley, et al. (2017) at 14.

[100] U.S. Nuclear Regulatory Commission (2017) at 5-2.

[101] National Environmental Policy Act (1970), §102(B) [42 USC § 4332], emphasis added.

[102] NRC regulations direct NRC staff to assume full regulatory compliance in the baseline, even if full compliance does not result in zero external environmental impacts. See U.S. Nuclear Regulatory Commission (2017) at B-36 and 5-7. "In establishing the baseline case, an assumption should be made that all existing NRC and Agreement State requirements and written licensee commitments are already being implemented and that costs and benefits associated with these requirements are not part of the incremental estimates prepared for the regulatory analysis." Whether the costs and benefits of industry initiatives taken outside of or beyond NRC regulations belong in the baseline is a separate

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H. Cumulative impacts

Cumulative impact assessment (i.e., impacts likely to result from the project *and* an array of other actions or events) is inherently fraught with analytic difficulties, most relevantly due to uncertainty. Each impact assessment is uncertain, and when multiple independent effects are combined to assess cumulative impacts, uncertainty increases by the product of the individual uncertainty bounds. This means cumulative impact assessment is inherently misleading if uncertainty is not taken into account, and if it is accounted for it may have limited practical utility for decision-makers facing discrete policy choices or, in this case, licensing decisions.

Note that NRC guidance does not require a CBA to *estimate* cumulative impacts. Rather, cumulative impacts are to be *discussed qualitatively*.[103]

I. Distributional effects

Likely because of its age, NUREG-1748 does not include the consideration of distributional effects. The section on "socioeconomics" does not define the term, and the information it directs be included in an EIS is vague.[104] Because of its ambiguity, this provision is largely hortatory and does not translate into an analytic requirement the absence or insufficiency of which could be demonstrated or disproved.

NRC's CBA guidance (NUREG/BR-0058) is more useful. It acknowledges that project-related costs and benefits may not be distributed equally or evenly, and thus a distributional analysis may be needed to illuminate unequal or uneven impacts:[105]

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and complex question, but it is less relevant for EISs than for regulatory cost-benefit analysis.

[103] at 5-43 to 5-46

[104] U.S. Nuclear Regulatory Commission (2003a) at 5-12 to 5-13 [Sec. 5.3.10]: "relevant past and current population distributions," "permanent and transient populations," and "low-income and minority populations."

[105] U.S. Nuclear Regulatory Commission (2017) at 2-9.

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> Significant differences may exist between the recipients of benefits and those who incur costs. The distribution of costs and benefits on various groups should be *presented* and discussed.[106]

This guidance is minimally consistent with government-wide guidance on regulatory analysis,[107] guidance issued by other federal agencies,[108] and advice from CBA practitioners.[109]

J. Environmental justice

A separate and distinct form of distributional analysis is an examination of "environmental justice" (EJ), a shorthand term for disproportionately adverse impacts on minority and/or low-income subpopulations.[110] NRC regulatory analysis guidance on how to incorporate EJ concerns into EIS CBAs identifies four external guidance documents, two of which are relevant to the CISF proposal.[111] The earliest of the two, NUREG-1748, includes references to a planned NRC Policy Statement on the Treatment of Environmental

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[106] at 5-2, emphasis added.

[107] Office of Management and Budget (1990) at 659-660, Office of Management and Budget (1996) ["General Principles" Sec. 8], Office of Management and Budget (2003) at 14.

[108] See, e.g., U.S. Environmental Protection Agency (2016) {Chapter 9].

[109] But see Dudley, et al. (2017) at 13-14, pushing back on federal agencies' tendency to simply deny that distributional analysis is important: "If [a CBA] ignores distributional effects – implying that they are not 'thought to be important' by the promulgating agency – one should look for a compelling explanation, based on logic and evidence, that costs and benefits generally fall on the same groups of people." Absent a "compelling explanation," distributional analysis should be conducted if unequal or uneven effects are reasonably expected or otherwise a matter of concern. Distributional effects are the foundation of environmental justice, discussed in subsection J below, so distributional analysis is its *sine qua non.*

[110] See Clinton (1994), which does not apply to independent agencies such as NRC, and U.S. Nuclear Regulatory Commission (2004a), which implements EJ-related matters to the extent required by NEPA. EJ analysis is asymmetric insofar as it ignores disproportionately *beneficial* effects. When EJ analysis is conducted within a CBA, this asymmetry is impermissible because CBA requires that costs and benefits be treated the same (see footnote 34 *infra*).

[111] U.S. Nuclear Regulatory Commission (2017) at 4-3 to 4-4.

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Justice and an appendix explaining how to implement it.[112] The later of the two, NRR Office Instruction LIC-203 (Rev. 3),[113] expands upon the first, but how to reconcile conflicts between them isn't clear.

Both guidance documents set forth a similar procedure for evaluating EJ concerns. Neither methodology is well-designed to detect EJ impacts if they exist; the more recent methodology appears to be designed not to detect any.

1. NUREG-1748 (2003)

NUREG-1748 prescribes four steps for EJ analysis, summarized below:

i. Determine "the area for assessment," which for a rural area "a radius of approximately 4 miles (50 square miles) should be used," recognizing that "the geographic scale should be commensurate with the potential impact area" such that "the 'communities,' neighborhoods, or areas that may be disproportionately impacted" are evaluated;
ii. "[O]btain demographic data (census data) for the immediate site area and surrounding communities," which are not defined;
iii. "[C]ompare the percentage of minority population in the block groups in the area for assessment to the state and county percentages of minority population and to compare the area's percentage of economically stressed households to the state and county percentages of economically stressed households"; and
iv. "[D]etermine if there is a 'disproportionately high and adverse' impact (human health or environmental effect) to the minority or low-income population near the site," performed by (i) evaluating which "impacts of the proposed action … determined in the usual manner … affect these populations," (ii) "assess if the impacts disproportionately impact the minority or low-income population," and (iii) "determine if the impacts are high and adverse."

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[112] U.S. Nuclear Regulatory Commission (2003b) at 5-22 and Appendix C . The policy statement is U.S. Nuclear Regulatory Commission (2004a).

[113] U.S. Nuclear Regulatory Commission Office of Nuclear Reactor Regulation (2013) at 2 to 4, 8 to 9, C-3, and Appendix D.

If the answer to this determination is affirmative, the EJ analysis must "look at mitigative measures and benefits."[114]

2. NRR Office Instruction LIC-203 (Rev. 3) (2013)

This revised EJ methodology is procedurally similar. It requires an EJ analysis if "there is a clear potential for significant offsite impacts from the proposed action." The analysis may "provide a basis for concluding that there are no unique impacts that would be significant," or, "[i]f the impacts are significant because of the uniqueness of the affected minority and/or low-income populations, then a finding of no significant impact (FONSI) may not be possible and mitigation (if authorized) or an EIS may be necessary." No analysis is required "[i]f it is determined, however, that a particular action would have no significant health or environmental impact."[115]

If an EJ analysis is conducted, NRC staff should "consider the demographic composition of the affected area to determine the location of minority and/or low-income populations and whether they may be affected by the proposed action." NRC staff then should "determine if the proposed action would cause any human health or environment effects and if so, whether these effects would be disproportionately high and adverse on minority or low-income populations."[116]

In short, LIC-2013 (Rev. 3) prescribes a series of nested steps:

i. Determine if there is "clear potential" for EJ impacts to occur;
ii. If so:

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[114] U.S. Nuclear Regulatory Commission (2003a) at C-4 to C-7. A key limitation in this methodology is EJ impacts are assumed to be adverse. However, there is no theoretical reason why effects on minority and/or low-income communities could not be beneficial. Moreover, the purpose of EJ analysis is not limited to identifying disproportionately large adverse effects. It is, rather, the predicate for identifying mitigative alternatives and estimating their relative benefits. The NUREG-1748 methodology is therefore structurally flawed because it does not account for potential beneficial effects, or allow beneficial effects to be estimated and compared across alternatives, both of which are necessary for identifying mitigative alternatives and estimating their relative benefits. On the other hand, as shown below, the more recent EJ methodology in LIC-203 (Rev. 3) establishes a 50-mile radius for the "potentially affected area." This domain, which is more than 150 times larger, virtually ensures that no EJ effects will be detected.

[115] U.S. Nuclear Regulatory Commission Office of Nuclear Reactor Regulation (2013) at D-2.

[116] at D-2 to D-3.

a. Determine the location of minority and/or low-income populations; and
b. whether they may be affected by the proposed action.
c. If they may be affected:
    I. Determine whether these impacts are adverse; and
    II. Determine whether they are disproportionate.

These steps are logical, but implementation is problematic.

"Clear potential" is not defined, but it is assumed to exist if an EIS is required.[117] The NRC staff is directed to look for minority and/or low-income populations within a 50-mile radius of the proposed site,[118] but no rationale is given for expanding the radius of the "potentially affected area" from 4 miles to 50 miles, the area of the latter being 157 times larger. Further, the guidance does not explain how NRC staff are supposed to conduct a comparison between a control and treatment group when both have the same definition.

To implement this "comparison," the NRC staff is directed to identify minority and/or low-income populations at the Census block level and determine whether the project may have human health or environmental impacts on these populations. Once this is done, the NRC staff must determine whether these impacts are adverse, and ascertain whether adverse impacts are "disproportionately high." This key term is not defined. If "disproportionately high" impacts are discovered, the EJ analysis must "consider mitigation measures that could be taken to reduce the impact(s)."[119]

While LIC-203 is presumably well-intended, it is not effectively designed to detect disproportionately high adverse effects on minority and/or low-income populations if they exist. First, the 50-mile radius "potentially affected area" is likely to be too large. This area should be defined based on project-specific evidence of the spatial distribution of environmental impacts, not an arbitrary default, and certainly not one so large that EJ effects, if they exist, are lost in the noise. The magnitude of average effects declines as the size of the "potentially affected area" is increased.

Second, there is no reason to expect effects to be uniformly distributed. Virtually all environmental impacts of interest will occur close to the proposed facility. Previously, NUREG-1748 had directed NRC staff to examine impacts within a 4-mile radius, with the proviso that "the geographic scale should be commensurate with the potential impact area, and should include a sample of the surrounding population, e.g., at least several block

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117 at D-3.

118 at D-4.

119 at D-3 to D-9.

groups."[120] NUREG-1748 gave the NRC staff the discretion to tailor the area of potential concern to attributes of the site location; LIC-203 (Rev. 3) took it away.

Third, however the area of concern is defined it should never be identical to the area used for comparison. Comparisons are difficult if treatment and control groups overlap, but comparisons are impossible if the two groups are identical.

K. Information quality

NRC guidance explicitly states that CBAs conducted in support of Commission actions are "influential."[121] Further, a high level of compliance with information quality guidelines is required:

> To facilitate review by non-NRC stakeholders, the staff generally posts the analysis, with all the supporting documents, as publicly available documents in the Agencywide Documents Access and Management System (ADAMS) to allow public access to the analyses. *A good analysis should be transparent with reproducible results.* The assumptions, methods, data underlying the analysis, and discussion of the uncertainties associated with the estimates should be provided. Information obtained from outside the NRC, including that from parties interested in a proposed regulatory action, may be used in the regulatory analysis *after the staff has validated* the reasonableness of the information.[122]

Transparency and *reproducibility* are key procedural touchstones in the information quality guidelines. Reproducibility[123] is a prerequisite that must be met before a credible claim of

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[120] U.S. Nuclear Regulatory Commission (2003b) at C-4.

[121] U.S. Nuclear Regulatory Commission (2017) at 2-8.

[122] at 2-8, emphasis added.

[123] Office of Management and Budget (2002) at 8460: "'Reproducibility' means that the information is capable of being substantially reproduced, subject to an acceptable degree of imprecision. For information judged to have more (less) important impacts, the degree of imprecision that is tolerated is reduced (increased)… With respect to analytic results, 'capable of being substantially reproduced' means that independent analysis of the original or supporting data using identical methods would generate similar analytic results, subject to an acceptable degree of imprecision or error."

adherence to substantive information quality standards (utility, integrity, and objectivity) can be made.[124]

IV. Cost-Benefit Analysis in the Draft EIS for ISP's Proposed CISF

CBA is a structured method for objectively assembling and estimating all costs and benefits for a project or regulation. Chapter 8 of the Draft EIS summarizes the CBA for ISP's proposed CISF. As noted in Section III above, by its own terms this CBA is supposed to be comprehensive, though with important limitations. In particular, the CBA's purpose

> is not to exhaustively identify and quantify all of the potential costs and benefits, but instead, *focus on those benefits and costs of such magnitude or importance that their inclusion in this analysis can inform the decision-making process* (e.g., distinguish the proposed action from the No-Action alternative)… [T]he cost-benefit analysis provides input to determine the relative merits of various alternatives; however, the U.S. Nuclear Regulatory Commission (NRC) will ultimately base its decision on the protection of public health and safety.[125]

The exclusion of costs and benefits that are not "of such magnitude or importance that their inclusion in this analysis can inform the decision-making process" is standard professional practice in CBA. Thus, their exclusion in the Draft EIS CBA is neither unusual nor presumptive evidence of material incompleteness. The relevant question is whether, in the Draft EIS CBA, NRC has excluded costs and benefits that are (or could be) large enough to misinform the decision-making process concerning significant environmental impacts.

As explained below, the Draft EIS CBA does not comply with NRC guidelines. The CBA lacks analysis of alternatives, does not estimate social costs and benefits, fails to report net benefits in expected value terms, does not address uncertainty and include sensitivity

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[124] at 8459-8460. Of the three substantive information quality standards, <u>objectivity</u> often is the most important. To be *objective*, information must be substantively "accurate, reliable, and unbiased" and "presented in an accurate, clear, complete, and unbiased manner."

[125] U.S. Nuclear Regulatory Commission (2020d) at 8-1 (emphasis added), internal [U.S. Nuclear Regulatory Commission (2004b), U.S. Nuclear Regulatory Commission (2017)] omitted.

or uncertainty analysis, or report distributions for costs and benefits. Each of these provisions is mandatory.[126]

A. Scope

The scope of the Draft EIS CBA is limited to onsite and local environmental impacts related to facility construction, operations, and decommissioning, plus transportation related impacts, primarily related to SNF shipments. The Draft EIS and CBA assumes that environmental impacts at reactors are the same whether or not they ship SNF to ISP's proposed CISF.[127] It is further assumed that there are no environmental impacts from removing SNF from onsite reactor storage.[128]

B. Baseline

The Draft EIS correctly identifies the no-action alternative as the analytic baseline. SNF would be managed in accordance with the status quo – i.e., onsite by nuclear power plant licensees.[129] However, every environmental impact qualitatively described or quantitatively characterized in the Draft EIS is compared to a baseline in which there are *no* environmental impacts whatsoever.[130] That is, onsite reactor SNF storage has no impacts *on* neighboring land, local or regional geological resources, water resources, local or regional ecologies, air quality, climate change, historical or scenic resources, or public and occupational health and safety.

This assumption obviously has no merit, and it renders the Draft EIS CBA utterly useless. The purpose of a CBA is to estimate *net* changes from the status quo. This is impossible without estimates of the social costs and benefits for the baseline. Therefore, all

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[126] These requirements in Chapter 2 of U.S. Nuclear Regulatory Commission (2017) are summarized in Section III.C above.

[127] Continued onsite storage beyond a reactor's license term

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[129] U.S. Nuclear Regulatory Commission (2020d) at 2-21.

[130] See, e.g., at 4-6, stating that all land use impacts "would be avoided" (i.e., they are zero) in the baseline. Similarly incorrect statements are made with respect to geology and soils impacts (at 4-29), surface water resources (at 4-33), groundwater resources (at 4-37), ecological impacts (at 4-50), air quality impacts (at 4-55), climate (at 4-56), noise (at 4-61 to 4-62), historical and cultural resources (at 4-64), Visual and scenic resources (at 4-66), socioeconomic impacts (at 4-76), environmental justice (at 4-80 to 4-81), public and occupational health (at 4-87), and waste management (at 4-93 to 4-94). No statements are made about accident risks in the baseline.

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environmental impacts reported in the Draft EIS and its CBA are descriptions or estimates of *gross* environmental impact. The CBA provides no useful information for the Commission or the public.[131]

C. The proposed project

ISP seeks NRC licensure for the first phase of a potential eight phase CISF for SNF, Greater-Than-Class-C (GTCC) waste, and a small amount of mixed oxide fuel.[132] Because ISP's application concerns only to the phase, and subsequent NRC approvals would be necessary to license any of the remaining seven, the scope of the EIS is properly limited to the first phase. Costs and benefits are given negative and positive signs, respectively.[133]

D. Alternatives eliminated from detailed analysis in the Draft EIS

Four alternatives are reported to have been given preliminary consideration but eliminated from further analysis:[134]

1. Storage at a government-owned CISF operated by the U.S. Department of Energy (DOE).

Plans for a DOE-owned CISF were not sufficiently developed to permit detailed analysis.

2. Three alternative design or storage technologies.

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[131] Where the Draft EIS reports SMALL environmental impacts for ISP's proposed CISF, it can be inferred that *gross* environmental impacts are zero. However, it cannot be determined whether *net* environmental impacts are positive, which would occur if environmental impacts in the baseline are greater than SMALL. Similarly, where the Draft EIS reports MODERATE environmental impacts for ISP's proposed CISF, it cannot be determined whether net environmental impacts are negative, zero, or positive.

[132] U.S. Nuclear Regulatory Commission (2020d) at 1-2 to 1-3, 2-1.

[133] at 8-2.

[134] at 2-22 to 2-23. The same alternatives were discussed in the Draft EIS for the proposed Holtec CISF [U.S. Nuclear Regulatory Commission (2020e) at 2-20 to 2-25] and eliminated from further analysis.

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ISP's proposed CISF would rely on proprietary technologies owned by TN Americas LLC and NAC International, which are licensed by NRC.[135] The three other alternative technologies consist of (a) competing proprietary technology licensed by NRC to Holtec International and Energy Solutions; (b) an unlicensed conceptual alternative (Hardened Onsite Storage Systems ["HOSS"]; and (c) a technology suggested by commenters during scoping (Hardened Extended-Life Local Monitored Surface Storage ["HELMS"]) that is the subject of a rulemaking petition seeking approval.[136] All were eliminated from further analysis because they were either irrelevant to the application (the Holtec technology) or insufficiently developed to permit analysis.

3. Alternative locations

NRC deferred to ISP's conclusion that the proposed site "had the fewest environmental and operational impacts because of the availability of utilities, an established local nuclear-related labor culture, and an existing site railhead, along with readily available site characterization data and existing site infrastructure."[137] NRC staff "determined that the ISP site-selection process has a rational, objective structure and appears reasonable."[138]

4. Alternative facility layouts

No alternative facility layouts are discussed.

E. Alternatives examined in the Draft EIS CBA

The Draft EIS CBA includes no bona fide alternatives, which every CBA requires. The absence of any bona fide alternatives implies that no action other than licensure of the

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[135] ISP is a joint venture between Waste Control Specialists (WCS) and Orano CIS LLC, a subsidiary of Orano USA. TN Americas LLC also is a subsidiary of Orano USA.

[136] U.S. Nuclear Regulatory Commission (2020d) at 2-22 to 2-23.

[137] at 2-25. NRC characterizes ISP's site selection analysis as "quantitative," but that overstates the method's actual rigor. ISP's method relies exclusively on subjective ordinal rankings of multiple criteria combined into a subjective index. The existence of a railhead means fewer environmental impacts, but the NRC staff concluded that the environmental impacts of the construction and use of a rail spur in the Holtec Draft EIS were SMALL. See U.S. Nuclear Regulatory Commission (2020e) at 4-11, 4-25, 4-27, 4-28, 4-48, 4-53, 4-54, 4-89, 4-93, 4-94, 4-96, 4-97, and 4-100. See the text beginning at 19 for the meaning of SMALL and other semi-quantitative descriptors.

[138] U.S. Nuclear Regulatory Commission (2020d) at 2-25.

proposed ISP CISF could accomplish its intended purposes. This is patently false; in Section IV.F beginning on page 40, three bona fide alternatives are identified that should have been included in the Draft EIS CBA.

This error occurred, at least in part, because the baseline is improperly treated as if it were a bona fide alternative to the proposed project. But this cannot be so; bona fide alternatives are those which could substantially achieve the purposes and goals of the proposed project, which no-action cannot do.[139]

NRC staff apparently misinterpreted either NEPA or NRC guidance, more likely the latter:

> Inclusion of the No-Action alternative in the EIS is a NEPA requirement and serves as a baseline for comparison of environmental impacts of the proposed action.[140]

NEPA does not impose any such requirement, and NRC guidance does not say what the Draft EIS apparently attributed to it.

NRC has ample authority to *decide* not to issue a license to ISP – i.e., choose no-action as a policy. But the EIS cannot include no-action as *both* the analytic baseline (from which all incremental costs and benefits are estimated) *and* an alternative to the proposed CISF (which must be arguably capable of achieving the CISF's purposes and needs). Tasking no action unambiguously cannot achieve the CISF's purposes and needs, and the reason is not at all controversial: it's not an alternative, it's just the baseline).

This misunderstanding is clear when estimates of environmental impacts are compared. Consider just two of the 16 categories of environmental impacts in the Draft EIS: (a) impacts on ecology and (b) impacts and public and occupational health and safety. For the proposed CISF, the Draft EIS summarizes extensive information concerning these

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[139] Boardman, et al. (2018) at 6. Relevant NRC guidance on the selection of alternatives either conflicts with professional practice or has been misinterpreted by NRC staff. U.S. Nuclear Regulatory Commission (2017) at 2-10 says, "Taking no action should be viewed as a viable alternative…" However, this text appears to concern decision-making ("*Taking* no action," not *analyzing* no-action; emphasis added). If NRC intended this text to be construed to permit or require no-action be treated as an *analytic* alternative, it is incompatible with professional CBA practice and should be revised.

[140] U.S. Nuclear Regulatory Commission (2020d) at xxxviii.

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effects, and reaches conclusions about their magnitude.[141] But for the no-action "alternative," the Draft EIS has virtually nothing to say.[142] The reason is that the no-action "alternative" is identical to the baseline. It is impossible for such an "alternative" to have any impacts.

NRC guidance clearly distinguishes the baseline from bona fide alternatives. Once the problem and objective have been stated, every alternative examined must be arguably capable of solving the problem or achieving the objective. No-action is per se incapable of accomplishing either one.[143]

F. Alternatives that should have been included in the Draft EIS

At least three obvious alternatives should have been included. Neither the Commission nor the public are well served by their absence.

1. Multiple CISFs

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[141] at 4-37 to 4-50 [proposed project impacts on ecology] and 4-81 to 4-87 [proposed project impacts on public and occupational health and safety].

[142] at 4-37 to 4-50 ["no action" impacts on ecology] and 4-81 to 4-87 ["no action" impacts on public and occupational health and safety].

[143] As U.S. Nuclear Regulatory Commission (2017) states, "Cost and benefit estimates are performed relative to a baseline case, which is typically the no-action alternative" (at 5-7). Thus, for every bona fide alternative, net impacts are estimated by subtracting relevant baseline conditions from the estimated impacts of the alternative. Nothing in NRC guidance directs NRC staff to misconstrue the baseline as an alternative to the proposed action. Indeed, at several places NRC guidance notes that adjustments to the baseline may be needed to account for changes that are expected to occur to reflect "how things would be" without the proposed project. The key example given is adjustments for future industry initiatives (at 5-7 to 5-9), which may be included, included in part, or not included at all in the baseline, depending on the relevant facts and circumstances.

This approach is consistent with government-wide guidance, which also states that costs and benefits are normally defined in comparison to a no-action baseline. See Office of Management and Budget (2003) at 2. But the costs and benefits of every bona fide alternative are compared to the no-action baseline; the baseline itself is not an analytic alternative.

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Both the Draft EIS CBA for ISP's proposed CISF[144] and the Draft EIS CBA for Holtec's proposed CISF[145] should have explicitly and quantitatively included the costs and benefits of external environmental impacts of the other proposal, both as a distinct alternative and as a combined alternative in which both proposals are licensed. NRC has the authority to license neither of the proposals, one proposal but not the other, or both proposals. The Commission and the public deserve to have before them reliable information concerning their distinct and combined external environmental impacts.

As described below in Section IV.G.16 (beginning on page 66), cumulative impacts typically are difficult to estimate and subject to greater uncertainty. In this case, however, NRC staff should not have followed Commission guidance permitting cumulative impact analysis to be qualitative, which has limited information value. Rather, each draft EIS should have included the other proposal as an explicit, fully quantified alternative, with a section comparing their respective external environmental impacts. Further, each draft EIS should have explicitly included as alternative the licensing of both proposals. The external environmental impacts of licensing both CISFs are not necessarily equal to the sum of external impacts for each CISF.

For this reason, a key recommendation of these comments is that NRC prepare a supplement to both draft EIS CBAs that captures the environmental impacts of licensing both facilities. This supplement should identify any costs, benefits, or other external environmental impacts that would be redundant, and subtract them from the sum of costs, benefits, or other external environmental impacts. Similarly, the supplement also should identify any costs, benefits, or other external environmental impacts that are reasonably expected to result only from the licensing of both facilities. The current pair of EIS CBAs does not inform the Commission or the public about interactive environmental impacts.

2. Defueling to another CISF instead of a permanent waste repository.

According to the proposed ISP facility license, SNF stored at the proposed CISF would be removed before the expiration of the license and transferred to a permanent SNF repository. The Nuclear Waste Policy Act of 1982, as amended (NWPA), directed the U.S. Department of Energy (DOE) to obtain a license from NRC for the construction and operation of a permanent repository that would meet safety standards set by the U.S. Environmental Protection Agency (EPA).[146] Amendments to NWPA designated Yucca

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144 U.S. Nuclear Regulatory Commission (2020d)

145 U.S. Nuclear Regulatory Commission (2020e).

146 Nuclear Waste Policy Act, Pub. L. 97-425 (96 Stat. 2201).

Mountain as the site for the permanent repository. However, progress toward licensing has ranged from exceedingly slow or nonexistent.

If no permanent waste repository is licensed by the time SNF must be defueled, compliance with the license would require SNF to be moved to a different CISF. The Draft EIS should have accounted for the scenario in which SNF was defueled to another CISF instead of a permanent waste repository. Some environmental impacts could be greater and others small. The net change in environmental impacts cannot be estimated without analysis.

3. Storage for longer periods than proposed in the license application

Another plausible scenario is that the proposed ISP CISF (like the proposed Holtec CISF, if it is licensed) would in fact store SNF for periods longer than provided for in their initial applications. That is, ISP would apply for and NRC would approve an amendment to its license extending its operating lifetime. To the extent that the proposed ISP CISF (or the proposed Holtec CISF) is overengineered, term extension could be highly attractive to NRC.

For this reason, a key recommendation of these comments is that NRC quantitatively and objectively estimate the environmental impacts of an alternative in which SNF is stored at the proposed ISP CISF (as well as the proposed Holtec CISF) for substantially longer periods than those set forth in their respective license applications. A similar supplementary analysis should be performed for the proposed Holtec CISF. Both draft EIS CBAs appear to rule out this alternative for arbitrary reasons.[147] NRC appears to have substantial relevant information to inform this analysis in the form of its Continued Storage GEIS.[148]

Including these alternatives in both draft EIS CBAs need not prejudice the NRC's statutory decision-making authority, nor does it need to signal that the NRC is actively considering them. Rather, the purpose of conducting the alternatives analysis is to identify and quantify all significant external environmental impacts as long as they are reasonably foreseeable under well-defined conditions. Extensions of the license period are reasonably

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[147] See U.S. Nuclear Regulatory Commission (2020e) at 3-12 and U.S. Nuclear Regulatory Commission (2020d) at 3-9: "Unless and until Congress amends the statutory requirement [to establish a permanent waste repository], the NRC assumes that the transportation of SNF from the CISF to a permanent repository will be to a repository at Yucca Mountain, Nevada."

[148] U.S. Nuclear Regulatory Commission (2014a), U.S. Nuclear Regulatory Commission (2014b).

foreseeable given the absence of evidence suggesting that a permanent waste repository would be open for business prior to the expiration of the proposed licenses.

G. Categories and valuations of environmental impacts

The Draft EIS identifies 16 distinct categories of environmental impacts. These categories, NRC staff descriptions, estimates of their magnitude, and professional judgments about their merit are summarized in this subsection. In many cases, the identified environmental impacts are not externalities. ISP would bear all or virtually all of these impacts. When costs and benefits are borne by a project applicant, their inclusion is not normally understood as cognizable in an EIS CBA, the statutory purpose of which is to identify and quantify *external* effects that otherwise might not be accounted for in private decision-making.[149] Because the Draft EIS CBA includes no benefit estimates to ISP, all costs borne solely by ISP also should be excluded.

NRC characterizes the magnitude of environmental impacts in semi-quantitative terms:

> SMALL: The environmental effects are not detectable or are so minor that they would neither destabilize nor noticeably alter any important attribute of the resource considered.
>
> MODERATE: The environmental effects are sufficient to alter noticeably, but not destabilize, important attributes of the resource considered.
>
> LARGE: The environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource considered.[150]

SMALL effects can be economically interpreted as effects that have values indistinguishable from zero. Effects so small that they do not "noticeably alter" the environment cannot have

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[149] NRC clearly states that it "has no role in a company's business decision to submit a license application to operate a CISF at a particular location." IU.S. Nuclear Regulatory Commission (2020d) at xviii. Logically, then, NRC should ignore strictly onsite environmental impacts because they affect only the applicant. Instead, NRC devotes extraordinary attention to environmental impacts that have little or no importance to its licensing decision. The only relevant environmental impacts are those which are external or not accounted for in the applicant's private decision-making within the context of its license. See National Environmental Policy Act (1970), §102(B), which implies that analysis should be limited to "*presently unquantified* environmental amenities" (emphasis added).

[150] U.S. Nuclear Regulatory Commission (2020d) at xx, 2-25, 4-2, 5-11, and 9-1.

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value because they are too small to detect or notice. MODERATE effects are large enough to detect or notice, so a prerequisite for quantification is at least present. Additional information, including reliable and objective evidence of revealed or stated preferences for willingness-to-pay to avoid adverse environmental impacts or obtain beneficial environmental impacts is needed to monetize them. LARGE effects are unambiguously significant enough to have economic value, but estimating them also requires reliable and objective evidence of revealed or stated preference.[151]

For no adverse environmental impact does the Draft EIS CBA report monetized estimates, and the CBA does not account at all for beneficial environmental impacts. A persuasive case must be shown that beneficial environmental impacts are immaterial in order to exclude them. The CBA includes no such case.

1. Land use impacts[152]

The Draft EIS describes current land use within five miles of the proposed CISF project area.[153] The primary land use impact of the project (both Phase 1 and Phases 2-8) is the conversion of 320 acres of land adjacent to the currently operating WCS LLRW disposal facility and within the 14,000 acre WCS property boundary. No agricultural use besides cattle grazing is reported within the five mile radius. Grazing, and hunting are owner-prohibited on the WCS property (including the proposed ISP CISF project area), so the project cannot have environmental effects on these activities. Mineral extraction (oil and gas, sand and gravel) is present, as is oil and gas waste disposal.

Onsite land would be disturbed by construction of the facility and additional transportation infrastructure. As noted above, onsite impacts that are fully borne by the

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[151] Compensating variation is the amount of income an individual must receive to be indifferent between bearing or avoiding an adverse environmental impact. The shorthand term for this in CBA is *willingness-to-pay.* See Boardman, et al. (2018). Revealed preference is the direct method for estimating willingness-to-pay (WTP) in welfare economics. Various stated-preference tools also are available for estimating WTP where market prices are not observable or do not exist. Contrary to conventional CBA practice, the definition of environmental impacts is asymmetric in NRC's EIS methodology. Only *adverse* environmental impacts are cognizable; *positive* environmental impacts are not.

[152] U.S. Nuclear Regulatory Commission (2020d) at 3-2 to 3-5, 4-2 to 4-6.

[153] at 3-2. The Draft EIS for Holtec's proposed CISF used a six mile radius. See U.S. Nuclear Regulatory Commission (2020e) at 3-1. If NRC staff had used a six mile radius in the CBA for the ISP CISF, virtually the entire city of Eunice, New Mexico (population 2,922 in 2010) would have been included. Both radii are arbitrary, but their impacts on the CBA are not.

property owner or lessee do not belong in the CBA.[154] The Draft EIS characterizes these environmental impacts as SMALL (i.e., indistinguishable from zero),[155] and the CBA includes no valuation for environmental impacts.

Net land use impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

2. Transportation impacts[156]

a. Traffic impacts

The Draft EIS describes the existing transportation infrastructure near the project area and its environs in New Mexico and Texas. State data show that traffic volume on New Mexico State Route 18 and New Mexico/Texas Route 176 are approximately half their design volume. Traffic on U.S. Highway 385 south of Andrews TX also is reported, but the design volume is not.

Transportation-related environmental impacts are assessed for construction, operations, and decommissioning. During construction and operations, the volume of daily vehicle (truck) traffic on Texas State Route 176 was estimated to increase 4% (7%), with small increases more distant from the facility. During operations, an average of one truck shipment of non-radiological waste shipment was forecast from the facility every 10 days. The Draft EIS characterizes these impacts as SMALL (i.e., indistinguishable from zero),[157] and the CBA includes no valuation for environmental impacts. Net traffic impacts reasonably attributable to ISP's proposed CISF cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

Net traffic impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

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154 U.S. Nuclear Regulatory Commission (2020d) at 4-4 [construction] and 4-5 [operations, defueling, and decommissioning]

155 at 4-4 [construction], 4-5 [operations, defueling, and decommissioning].

156 at 4-6 to 4-25.

157 at 4-8 [construction] and 4-8 [inbound supply shipments and commuting]. Transportation impacts related to inbound SNF shipments are characterized as "minor" (at 4-10). "Minor" is not one of the NRC's three prescribed semi-quantitative descriptors for environmental impacts (SMALL, MEDIUM, and LARGE), and it cannot be synonymous with SMALL because SMALL is indistinguishable from zero.

b. Radiological risks from incident-free transportation of SNF

The Draft EIS characterizes radiological risks from incident-free transportation as "minor" or "negligible" based on prior NRC reports.[158] However, the approach taken in the Draft EIS to estimate these risks is problematic. Three quantities are relevant:

- transportation risk from onsite reactor storage to the ISP CISF;
- transportation risk from the ISP CISF to the permanent waste repository; and
- transportation risk from onsite reactor storage to the permanent waste repository

The preferred analytic approach is to subtract the third quantity from the sum of the first two. Net transportation risk could be positive (a cost) or negative (a benefit).

The approach taken in the Draft EIS CBA is unnecessarily complex, subject to confusion and misunderstanding, lacking in transparency, and irrelevant to decision-making. It consists of estimating the following two quantities:

- transportation risk from onsite reactor storage to the ISP CISF, less an arbitrary fraction of transportation risk from onsite reactor storage to the permanent waste repository; and
- transportation risk from the ISP CISF to the permanent waste repository, less the remaining amount of transportation risk from onsite reactor storage to the permanent waste repository

Unnecessary complexity arises because each quantity is purported to represent net risk. Confusion and misunderstanding arise because each quantity is supposed to represent net transportation risk from SNF shipments, but the accuracy of each calculation does not appear to be independently verifiable. Neither calculation is transparent in the Draft EIS, and it cannot be independently determined that the total deduction for baseline risk equals changes in baseline risk. Finally, the method employed in the Draft EIS provides no useful information for decision-making if the Commission is committed to cabin the license application to its stated terms. That is, the application for the proposed ISP CISF requires that there be two SNF shipments – one shipment from onsite reactor storage to the CISF and a second from the CISF to the permanent waste repository. Reporting these risks separately, with partial deductions for baseline transportation risks, suggests that the Commission is considering an entirely different project alternative – a de facto permanent

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[158] at 4-9 to 4-10, citing U.S. Nuclear Regulatory Commission (1977), U.S. Nuclear Regulatory Commission (2001), U.S. Nuclear Regulatory Commission (2014c). These documents have not been reviewed for this project.

storage facility, in which the second quantity would be zero. For all these reasons, this subsection and subsection (e) below should have been combined to show the net transportation risk of the ISP CISF as proposed in the license application.

The Draft EIS notes that SNF must be shipped in compliance with an array of NRC and U.S. Department of Transportation (DOT) regulations, and for incident-free transportation the Draft EIS assumes that these regulations are followed.[159] Previous NRC analyses characterized these risks as "negligible."[160] The Draft EIS further relies on a U.S. Department of Energy (DOE) analysis that estimated aggregate occupational and population risk in rail (plus some barge) transportation from reactors to a permanent waste repository.[161] These baseline risks were reported to be 1.7 latent cancer fatalities to workers and 0.7 latent cancer fatality to the public[162] over 24 years.[163]

The Draft EIS includes an upper-bound (i.e., "bounding") estimate of aggregate occupational radiological risk from incident-free transportation derived from the RADTRAN 6 transportation risk model and applied to a reasonable worst-case transportation route.[164] Using NRC default formulae, the value of avoiding this risk is

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[159] U.S. Nuclear Regulatory Commission (2020d) at 4-9. Radiological risks resulting from regulatory violations could exceed these estimates, but risks resulting from violations are not considered in the Draft EIS or its CBA.

[160] at 4-9 to 4-10, citing U.S. Nuclear Regulatory Commission (1977), U.S. Nuclear Regulatory Commission (2001), U.S. Nuclear Regulatory Commission (2014c). These documents have not been reviewed for this project.

[161] U.S. Nuclear Regulatory Commission (2020d) at 4-9 to 4-10, citing U.S. Department of Energy (2008). This document has not been reviewed for this report.

[162] For perspective, note that 1.7 latent occupational cancers discounted for 35 years (one-half of a standard lifetime) at 7% has a present value of 0.0123 cancer, which when valued at $9m per fatality (as prescribed by U.S. Nuclear Regulatory Commission (2015) yields present value 24-year nationwide costs of $110,680 for incident-free transportation. The equivalent present value for 0.7 latent population cancer is $45,574. Evaluating the merits and information quality compliance would require a separate review.

[163] The time period is not stated in the Draft EIS for the proposed ISP CISF. However, it is reported as 24 years in the Draft EIS for the proposed Holtec CISF. See U.S. Nuclear Regulatory Commission (2020e) at 4-13. Exclusion from the Draft EIS for the ISP CISF may reflect differences in how applicants reported information in their respective ERs and SARs, which NRC staff relied upon to prepare the respective draft EISs.

[164] U.S. Nuclear Regulatory Commission (2020d) at 4-10 to 4-15, citing U.S. Nuclear Regulatory Commission (2014c). Evaluating the merits and information quality compliance

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$262,140.[165] Using default NRC formulae, the value of avoiding *baseline* occupational radiological cancer risk is $7.3 billion, which is 227 times greater.[166] The Draft EIS characterizes the occupational radiological risk attributable to project-related SNF transportation as "minor,"[167] and it is not quantified in the CBA.

The Draft EIS also reports estimates of radiological risks to the public from project-related SNF transportation, as calculated by ISP.[168] Aggregate dose was estimated at 0.15 person-Sv, which implies an upper-bound valuation of $76,500.[169] The relevant background risk to the public is about 3 million times greater. As in the case of radiological

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of this document and the RADTRAN 6 transportation risk model would require a separate review.

[165] "Health effects" are defined as fatal cancer, nonfatal cancer, and severe hereditary effects, estimated by multiplying the population dose by the health risk coefficient of 5.7×10^{-2} health effects per person-Sv. See U.S. Nuclear Regulatory Commission (2020d) at Table 4.3-1. Footnote † in U.S. Nuclear Regulatory Commission (2020e), Table 4.3-1 is missing. The methodologies appear to be somewhat different, but they are not likely to differ with respect to how "health effects" are defined and estimated.

U.S. Nuclear Regulatory Commission (2015) at 25-26 attributes the default risk coefficient to International Commission on Radiological Protection (2007) – a risk *management* recommendation rather than an objective risk *assessment*. NRC values each person-rem (100 person-Sv) at $5,100 ($2014; see U.S. Nuclear Regulatory Commission (2015)). Thus, the estimated value of total project occupational risk is no more than 5.14 person-rem * $5,100/person-rem, or $262,140. This figure is not discounted or adjusted for latency, each of which would result in significant value reductions. Further evaluating the merits and information quality compliance of this calculation would require a separate review.

[166] U.S. Nuclear Regulatory Commission (2020d) at 4-15 [Table 4.3-2]. Footnote ‡ is missing from Table 4.3-2, but can be found in Table 4.3-2 in U.S. Nuclear Regulatory Commission (2020e).

[167] U.S. Nuclear Regulatory Commission (2020d) at 4-14. "Minor" is not one of the NRC's three prescribed semi-quantitative descriptors for environmental impacts (SMALL, MEDIUM, and LARGE), and it cannot be synonymous with SMALL because SMALL is indistinguishable from zero.

[168] at 4-15 to 4-17, with results reported in Table 4.3-2.

[169] 0.15 person-Sv * 100 person-Sv/rem * $5,100/rem = $76,500.

risks to workers in the transportation vector, the Draft EIS characterizes this risk as "minor,"[170] and it is not quantified in the CBA.

The Draft EIS correctly excludes the costs of infrastructure upgrades that may be required at reactor sites that are closed or decommissioned. Any such costs would have to be borne in the baseline to transport SNF to a permanent waste repository, and thus are not incremental to the proposed CSIF.[171]

Net radiological risks from incident-free transportation cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

c. Radiological risks from SNF transportation accidents

The Draft EIS asserts that "accidental release of canistered fuel during transportation [would] not occur under the most severe impacts studied, which encompasse[s] all historic or realistic accidents."[172] Occupational risk is characterized as "minor," and risk to the public is characterized as "likely to be zero."[173] Similarly, NRC staff

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[170] U.S. Nuclear Regulatory Commission (2020d) at 4-17. For the Holtec Draft EIS, NRC staff also estimated risk to the maximally exposed member of the public (MEI). The MEI was assumed to be located 30 m (98 ft) from the rail track and is exposed to all 10,000 passing rail shipments (i.e., after all 20 Phases of the Holtec CISF had been completed). According to the Draft EIS, the accumulated dose would be 0.006 rem (6 mrem), the value of which using NRC default formula is 0.006 rem * $5,100/rem = $30.60. If the MEI dose were instead spread out evenly over the 20-year period during which the 10,000 shipments of SNF would be transported, present value risk would be a small fraction of 0.006 rem, so its valuation would be a small fraction of $30.60. If cancer risk were properly lagged to reflect the latency of cancer realization and properly discounted, valuation would be indistinguishable from $0.

[171] If the ISP CSIF expedites the transportation of SNF stored onsite at closed or decommissioned reactors, fewer such reactors may require infrastructure upgrades to transport SNF, thus yielding a benefit reasonably attributable to the project.

[172] U.S. Nuclear Regulatory Commission (2020d) at 4-17, citing U.S. Department of Energy (2008), U.S. Nuclear Regulatory Commission (2001), U.S. Nuclear Regulatory Commission (2014c) and summarized in the Draft EIS. Evaluating the merits and information quality compliance of sources would require a separate review.

[173] U.S. Nuclear Regulatory Commission (2020d) at 4-17: "Because the proposed design of the CISF would require SNF to be contained within inner welded canisters, the transportation of the SNF to the proposed CISF would also require SNF to be in canisters that would be shipped in transportation casks similar to the configuration evaluated in

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did not model or estimate environmental impacts from accidents in which a release occurred because it concluded that "the consideration of accidents involving releases for canistered SNF to be excessively conservative."[174]

The value of avoiding "conservatively modeled" risks cannot be incorporated into CBA, but when such effects are "likely to be zero" even under such a scenario, no additional effort is warranted to derive objective, CBA-compliant estimates. One caveat applies, however. As noted above, the NRC staff analysis apparently assumes full regulatory compliance. Accidents caused by regulatory violations were not evaluated and their environmental impacts were not estimated.

These inferences are inappropriate for CBA. First, they are inconsistent with applicable NRC guidance, which establishes the default presumption that costs will be estimated "to the fullest extent practicable."[175] The practicality threshold is clearly exceeded because NRC estimated radiological risks to workers and the public from incident-free SNF transportation.[176] Second, however low radiological risks from the transportation vector might be, these risks exceed zero. Transparency requires that quantifiable and monetizable risks be reported. For CBA purposes, risks that exceed zero must be estimated, monetized, and included as costs unless a bounding analysis shows that they are insignificant.[177] Third, there is an extensive scholarly literature which guides risk

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NUREG–2125. Therefore, the NRC staff considers the conclusion in NUREG–2125 regarding the resiliency of the rail-steel cask to severe accident conditions (resulting in no release under severe accident conditions) applicable to the evaluation of potential CISF SNF transportation impacts under accident conditions." Evaluating the merits of NUREG-2125 and its information quality compliance would require a separate review. No valuation for these risks is included in the CBA.

[174] at 4-18.

[175] U.S. Nuclear Regulatory Commission (2017) at 4-2: "When cost-benefit analyses are required, they will, *to the fullest extent practicable*, quantify the various factors considered."

[176] U.S. Nuclear Regulatory Commission (2020d) at 4-17.

[177] Risk estimates "conservatively estimated" are useful for producing a bounding estimate but they are not appropriate for inclusion in CBA, which requires unbiased estimates. See Office of Management and Budget (2003) and, e.g., Dudley, et al. (2017), Boardman, et al. (2018), and Jenkins, et al. (2019). If NRC cannot estimate risk objectively, it should report "conservatively estimated" bounding risks separately from the main CBA. If the bounding estimate is sufficient to infer that an effect is not significant, NRC should

analysis for low-probability/high-consequence events.[178] Longstanding best practice in risk analysis has been to characterize potential outcomes and estimate them when feasible rather than assume them away.

The Draft EIS does not disclose any data about the frequency and severity of regulatory violations. Sufficient information about noncompliance, including environmental impacts when violations occur, are needed to provide a proper foundation for the conclusion that the expected value of these risks is negligible. A proper analysis of accident-related risk requires a prior assessment of the combined probability and severity of regulatory violations. Instead, the upper tail of the distribution of transportation risks has been simply cut off.

Net radiological risks from transportation accidents cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

d. Non-radiological risks from incident-free SNF transportation

Non-radiological occupational risks from incident-free SNF transportation primarily consist of occupational injuries. The Draft EIS characterizes these incremental risks as "minor" on the ground that 170 or fewer annual SNF railroad carloads "would not be a large addition to the existing railcar traffic of 22,500 railroad carloads per year" on the Texas-New Mexico Railroad,[179] and there is no reason to expect occupational risks to be higher for these 170 railroad carloads. The Draft EIS reports an estimate of 1.1 additional occupational injuries and 0.0031 occupational fatality.[180] Non-radiological risks to the public consisted of traffic fatalities at rail crossings and deaths resulting from trespassing. The Draft EIS reports an estimated 0.2 fatality resulting from shipping all SNF from reactors to the proposed CISF.[181] Based on these calculations, some of which are bounding

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report the estimate and its basis for making this inference. The Draft EIS includes no quantified bounding estimate and no basis for inferring that it is not significant.

[178] An early application of these methods can be found in U.S. Environmental Protection Agency Corvalis Environmental Research Laboratory (1978), especially Part III ["Case Study of Nuclear Waste Disposal"].

[179] U.S. Nuclear Regulatory Commission (2020d) at 4-20. 170/22,500 = 0.8% of the baseline.

[180] at 4-20. Unlike radiological transportation risks, estimates of non-radiological transportation risks appear to be based on actual accident data, which includes accidents resulting from regulatory violations.

[181] at 4-20.

estimates, NRC staff expect these impacts to be SMALL, which implies a monetized value of zero.

Net non-radiological risks from incident-free transportation cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

e. Transportation risks from defueling

The license for the proposed ISP CISF would be temporally finite. Before license expiration, SNF stored at the facility is assumed to be moved to a permanent waste repository.[182] The transfer of SNF from the ISP CISF to a permanent waste repository involves transportation risks. As noted in subsection (b) above, some (but not all) of these transportation risks would be incremental. In the baseline, SNF must be transported from onsite reactor storage to a permanent waste repository. Thus, the correct procedure for estimating incremental transportation risk is to estimate the sum of transportation risks from onsite reactor storage to the ISP CISF and transportation risks from the ISP CISF to a permanent repository, then deduct the transportation risks from onsite reactor storage to the permanent repository.

The Draft EIS includes estimates of upper-bound radiological and non-radiological risks resulting from incident-free transportation of SNF from the proposed CISF to a permanent waste repository, which was presumed to be Yucca Mountain.[183] These risks are summarized in Table 4.3-3 of the Draft EIS. Radiological health effects attributed to the proposed CISF were estimated at 0.024 for workers and 0.0043 to the public, which for context were reported as 0.2% of baseline occupational risk and 0.00004% of baseline public risk.[184] Using the NRC's default valuation formulae, avoiding these risks is worth $216,000 (occupational) and $38,500 (public).[185] At least the latter should have been

[182] SNF could be moved to a different CISF, or as suggested elsewhere, retained by the ISP CISF pursuant to a license amendment. Each scenario has distinct environmental impacts.

[183] U.S. Nuclear Regulatory Commission (2020d) at 4-21 to 4-24.

[184] The Draft EIS also reports in Table 4.3-3 risk estimates for all eight phases: 0.19 occupational health effects (1.9% of baseline) and 0.034 public health effects (0.00003% of baseline).

[185] 0.024 * $9 million = $216,000 [occupational] and 0.0043 * $9 million = $38,700 [public].

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included in the CBA, though discounting and latency would substantially reduce these amounts.

Net transportation risks from defueling cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

f. Transportation impacts from decommissioning

Once all SNF has been transported from the proposed ISP CISF to the permanent waste repository prior to the expiration of its license, the facility must be decommissioned. The Draft EIS identifies as transportation-related impacts from decommissioning activities the same types of impacts associated with construction. Like the impacts from construction, The Draft EIS concludes that these would be SMALL,[186] which implies a monetized value of zero.

The reliability of this inference depends on the NRC staff's assumption that no radiological releases occurred at the CISF during its operating life. To better inform the public, the Draft EIS should have included a sensitivity analysis of the environmental impacts likely to result if a radiological release had occurred, taking into account the probability of such events. The public is not well served by an EIS that excludes from the analysis their greatest concerns about the facility.

Net transportation impacts from decommissioning cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

3. Geology and soils impacts[187]

The environmental impacts related to onsite soils are insignificant. Further, because only the landowner and lessee are affected, they do not belong in the Draft EIS. Offsite impacts are relevant and potentially significant. These effects consist of soil erosion, stormwater runoff, and leaks and spills of oil and hazardous materials. They are subject to federal and state regulation under other authorities, and NRC staff expect the relevant agencies to ensure regulatory compliance. The NRC staff conclude that these impacts would be SMALL,[188] which implies a monetized value of zero.

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[186] U.S. Nuclear Regulatory Commission (2020d) at 4-24.

[187] at 3-9 to 3-21, 4-6 to 4-25.

[188] at 4-27.

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A significant external environmental impact to regional geology requires hazardous materials (including radioactive material) to be released from stored casks, breach the foundation, and migrate offsite. Any impact on oil and gas production requires, in addition, that offsite migration reach the Permian Basin and that the releases are not remediated sooner despite myriad regulatory requirements to do so. NRC staff believe the co-occurrence of the first three events is impossible.[189] The Draft EIS is silent concerning the fourth event.

NRC regulatory analysis guidance directs NRC staff to determine the "appropriate level of detail" based on five factors, the most relevant of which in this context is "the magnitude and likelihood of costs and benefits."[190] Infiltration of the Permian Basin with radioactive releases would surely qualify as an effect of "significant" magnitude, but information is scarce suggesting that it has a "significant" likelihood of occurring. Public commenters bear the burden of showing that the exclusion of a potential environmental impact from the Draft EIS was unreasonable.

Net geological impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

4. Water resources impacts[191]

According to the Draft EIS, there are no floodplains or wetlands onsite, and wetlands in the vicinity "are highly mineralized and therefore are not favorable for the development

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[189] at 4-35: "Because of the design and construction of the SNF storage systems and the geohydrologic conditions of the proposed project area, potential radiological contamination of local groundwater is *very unlikely*. SNF contains no liquid, and the dry storage casks would be sealed (welded shut) to *prevent* external liquid from contacting the SNF assemblies. Therefore, there is *no potential* for a liquid pathway (such as a leaking cask) to contaminate underlying groundwater" (internal citations omitted, emphasis added); and at 4-36: "[F]or the operation of the proposed action (Phase 1), because of the design of the SNF dry storage casks, geohydrologic conditions, the depth of the groundwater, and the discontinuity of shallow groundwater, potential radiological contamination of groundwater is *unlikely*" (emphasis added); "Similarly, because of the design and construction of the SNF storage systems, geohydrologic conditions, and the depth of groundwater, potential radiological contamination of groundwater is *very unlikely* during the operations stage of any phase" (emphasis added).

[190] U.S. Nuclear Regulatory Commission (2017) at 2-3.

[191] U.S. Nuclear Regulatory Commission (2020d) at 3-32 to 3-35 and 4-29 to 4-37.

of aquatic or riparian habitat."[192] NRC staff conclude that environmental impacts on surface water would be SMALL,[193] which implies a monetized value of zero.

According to the Draft EIS, potential impacts on groundwater could arise from onsite wells used to supply consumptive water demands and groundwater discharges. Potable water would be supplied by the City of Eunice NM, which would be buried along existing roadways and not have a significant environmental impact. Groundwater usage would be limited to the construction period and consume 2.5 million liters per year for about four years. Construction at depths up to 10 feet would not affect the nearest groundwater, located at least 90 feet below surface. Infiltration of shallow groundwater by surface runoff is possible but addressed by state permitting and accompanying regulations. NRC staff conclude that environmental impacts on groundwater would be SMALL,[194] which implies a monetized value of zero.

Net water resources impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

5. Ecological impacts[195]

The Draft EIS reports that, based on consultation with the U.S. Fish and Wildlife Service (FWS) and Texas Parks and Wildlife Department (TPWD), one federally endangered species (the Northern aplomado falcon [*Falco femoralis septentrionalis*]) "may occur at the proposed CISF project area" but "there are no known pairs of breeding falcons in west Texas" NRC staff have "determine[d] that this species is not likely to occur at the proposed CISF project area or the rail sidetrack." The project area is not FWS-designated critical habitat.[196] Potential impacts on other species of interest are noted.

NRC staff conclude that environmental impacts to ecological resources are expected to be SMALL for wildlife and MODERATE for vegetative communities.[197] SMALL impacts have a monetized value of zero. MODERATE impacts have the potential to be estimated. For costs greater than zero to be incorporated into the CBA, there must be a method for

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192 at 4-30 to 4-31.

193 at 4-31 to 4-33.

194 at 4-35 to 4-37.

195 at 3-35 to 3-52, 4-37 to 4-51.

196 at 4-37.

197 at 4-44 to 4-50 .

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monetizing the specific economic impacts. There is insufficient information in the Draft EIS or in any other references listed therein, to derive any valuations.

The Draft EIS evaluates potential radiological effects to wildlife based on precautionary assumptions concerning dose rates and exposure durations.[198] Based on these calculations, the Draft EIS reports the highest onsite dose rate of 8.64 mSv/d. NRC staff conclude that some effects on wildlife are possible, but persistent deleterious changes in populations or communities are not, and that "that estimated radiation levels at the controlled area boundary and beyond during any phase of the proposed CISF project would be generally protective of wildlife."[199]

Potential ecological impacts during operations and decommissioning would be SMALL to MODERATE within the CISF project area.[200] The cost of these impacts would be zero (if effects are SMALL) and greater than zero by an unknown amount if they were MODERATE. For costs greater than zero to be incorporated into the CBA, there must be a method for monetizing the specific economic impacts. There is insufficient information in the Draft EIS or in any other references listed therein, to derive any valuations.

Net ecological impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

6. Air quality impacts[201]

The Draft EIS characterizes peak-year air quality impacts,[202] concluding that even "when combined with background levels are well below the NAAQS for all pollutants."[203]

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[198] at 4-46 , citing U.S. Department of Energy (2019) [DOE-STD-1153-2019]. Evaluating the merits and information quality compliance of this reference would require a separate review.

[199] U.S. Nuclear Regulatory Commission (2020d) at 4-47.

[200] at 4-47.

[201] at 3-56 to 3-60, 4-51 to 4-55.

[202] at 4-51: "Peak-year emissions represent the highest emission levels associated with the proposed CISF in any single year and therefore also represent the greatest potential impact to air quality." Peak-year impacts are upper-bounds, however, and while upper-bound estimates can be useful for determining that effects are too small to be material, they are incompatible with CBA.

[203] at 4-52. For example, estimated 24-hour (annual) $PM_{2.5}$ concentrations were 7.6 μg/m^3 (7.6 μg/m^3) in background, and estimated peak project emissions were 0.47 μg/m^3

$PM_{2.5}$ and PM_{10} emissions are potentially relevant for CBA if there are sufficient human receptors, but the Draft EIS staff conclude that such receptors are absent and "the potential impacts to air quality from the proposed action (Phase 1) peak year emission levels would be minor."[204] The mass emission rate (in tons per year) of nitrogen oxides, PM_{10}, sulfur dioxide, and sulfuric acid divided by the distance in kilometers from Carlsbad Caverns (the nearest Class I airshed) would be 0.3; index values below 10 are "considered to have negligible impacts with respect to air quality-related values, and further analysis is not warranted."[205] Based on these estimates, NRC staff determined that air quality impacts would be SMALL,[206] which implies zero monetary value.

Net air quality impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

7. Climate change impacts[207]

Estimates of environmental impacts due to climate change are based on overall emissions of greenhouse gases released by all sources rather than individual sites such as the proposed ISP CISF. Spatial attribution of effects is not possible given the absence of a "strong cause-and-effect relationship between where the greenhouse gases are emitted and where the impacts occur."[208]

Analysis of climate change impacts is reported in the cumulative impacts section of the Draft EIS, not the section on environmental impacts from greenhouse gas emissions (GHG). NRC staff concludes that "the national cumulative impacts of greenhouse gas emissions are noticeable but not destabilizing,"[209] implying at most a MODERATE *aggregate* effect, but at most a SMALL effect reasonably attributed to the proposed ISP CISF, which is indistinguishable from zero. Peak $CO2_e$ emissions from the project were

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(0.39 μg/m³). Thus, project $PM_{2.5}$ were estimated to be 1.3% (2.6%) of the $PM_{2.5}$ NAAQS. See Table 4.7-1 at 4-53.

[204] at 4-52.

[205] at 4-52.

[206] at 4-53. NRC staff reach the same conclusion if Phases 2-8 are included.

[207] at 3-52 to 3-56, 3-60; 4-55 to 4-56.

[208] at 4-55.

[209] at 5-36.

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estimated to be 7,849 short tons.[210] This is 7.8% of the permitting threshold for new sources set by the U.S. Environmental Protection Agency in its Tailoring Rule (100,000 short tons per year).[211] Thus, NRC staff conclude that "the activities at the proposed CISF would generate low levels of greenhouse gases relative to other sources and would have a minor impact on air quality in terms of greenhouse gas emissions."[212]

The Draft EIS asserts that the transportation of SNF from onsite rector storage to the proposed ISP CISF, and from the proposed CISF to Yucca Mountain, would exceed the threshold in the Tailoring Rule.[213] However, NRC staff obtained that figure by prorating estimated emissions from the transportation of SNF from onsite reactors to Yucca Mountain.[214] This appears to be a case of double-counting. The proper way to calculate *incremental* GHG emissions is to sum emissions from onsite reactor storage to the CISF and GHS emissions from the CISF to Yucca Mountain, then subtract from this sum GHG emissions from onsite reactor storage to Yucca Mountain. The Draft EIS includes no estimates of GHG emissions incremental to the proposed ISP CISF, so the estimated exceedance of the permitting threshold in the Tailoring Rule is not evidence of a significant environmental impact.

Net climate change impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

8. Noise impacts[215]

The Draft EIS estimates that the highest noise level predicted at the southern boundary of the proposed CISF would be 20.3 dBA.[216] the loudest phase of the project. This is approximately equal to a silent study room.[217] The Draft EIS concludes that potential

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210 at 5-36. For context, the Draft EIS reports that this is 0.002% of total projected GHG in Texas and 0.0001% of total U.S. GHG emissions. See 5-37.

211 U.S. Environmental Protection Agency (2010) at 31516 .

212 U.S. Nuclear Regulatory Commission (2020d) at 5-36 to 5-37.

213 at 5-36 to 5-38.

214 at 5-37 to 5-38.

215 at 3-60 to 3-63, 4-56 to 4-4-62.

216 at 4-58 [Table 4.8-1].

217 Occupational Safety and Health Administration (2020).

noise impacts from construction, operations, and decommissioning would be SMALL,[218] which implies a negligible monetary value.

Net noise impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

9. Historical and cultural impacts[219]

The Draft EIS reports that surveys for historical and cultural resources were performed by ISP in 2015 and 2019. No such resources were identified onsite, and the nearest offsite resources were located outside the 1-mile buffer zone. NRC staff conclude that these resources "are at a distance where construction and operation activities for the proposed action (Phase 1) and full build-out (Phases 1-8) will cause impacts."[220] Because ISP would implement an inadvertent discovery plan, NRC staff determined that construction of the proposed ISP CISF (both Phase 1 and Phases 2-8, if subsequently licensed) would have only SMALL impacts on historical and cultural resources,[221] which implies a monetized value of zero. NRC staff reach similar conclusions for impacts during operations[222] and decommissioning.[223]

Net impacts on historical and cultural resources cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

10. Visual and scenic impacts[224]

The Draft EIS identifies potential impacts to visual and scenic resources as those arising from diminution of the value of the viewshed. The cask-handling building would be as much as 75 ft tall, making it potentially observable offsite. The main facility would be below grade and therefore not observable. NRC staff determined because "there are no regional or local high-quality viewing areas" near the project area, "the obstruction of existing views … would be similar to current conditions, leading to the conclusion that

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[218] U.S. Nuclear Regulatory Commission (2020d) at 4-58.

[219] at 3-63 to 3-66, 4-62 to 4-64.

[220] at 4-63.

[221] at 4-63.

[222] at 4-63.

[223] at 4-63 to 4-64.

[224] at 3-66 to 3-68, 4-64 to 4-66.

construction, operations, defueling, and decommissioning impacts on visual resources impacts would be SMALL,[225] implying a monetized value of zero.

Net visual and scenic impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

11. Socioeconomic impacts[226]

The Draft EIS includes a descriptive discussion of "socioeconomics."[227] Many communities were found with disproportionally large minority populations[228] or low-income populations.[229] Baseline conditions notwithstanding, the key analytic task is to estimate the extent to which each alternative is expected incrementally to have *disproportionate* impacts on these populations.[230]

The Draft EIS identifies potential socioeconomic impacts from the construction, operation, and decommissioning of the proposed CISF consisting of effects on employment and economic activity, population and housing, and public services and finances within the 3-county region of interest (Andrews and Gaines Counties TX and Lea County NM). The Draft EIS concludes that effects on regional employment, housing, and public services would be SMALL; effects on population would be SMALL to MODERATE; effects on local finances would be MODERATE; and the overall socioeconomic effect would be SMALL to MODERATE.[231] SMALL impacts have a monetized value of zero. MODERATE impacts have the potential for nonzero value, but it is unclear whether these values would be negative or positive.

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[225] at 4-64 to 4-66.

[226] at 3-68 to 3-84; 4-66 to 4-76; Appendix B.

[227] at 3-68 to 3-83.

[228] at 3-72 to 3-73.

[229] at 3-75 to 3-76.

[230] *Disproportionate* impacts are present if impacts are significantly different after control for confounding factors. *Disparate* impacts are present if impacts are significantly difference without controlling for confounding factors.

[231] U.S. Nuclear Regulatory Commission (2020d) at 5-45 to 5-46. The text is confusing in key places.

See at Table 4.11-1, describing how NRC staff classify socioeconomic effects as SMALL, MODERATE, or LARGE.

The socioeconomic impacts from increased economic activity are presumptively positive. Some of these increases would be offset by decreases elsewhere, however, and only net effects are incremental to the project. Increased local tax revenue would be new, but also offset in part by decreases elsewhere. However, in CBA all tax revenues are considered transfers; the "benefit" of receipts equal "costs" of payments. Social benefits arise only to the extent that local governments near the facility use them to create social value.

If the best estimate of the value of SMALL *adverse* environmental is zero, then symmetry requires that SMALL *beneficial* environmental effects also be zero. The value of MODERATE benefits depends, as suggested above, on how local governments spend their new tax revenues. In the best case, local governments allocate additional revenue to their communities' highest and best use – i.e., purposes for which benefits exceed costs by the greatest amount. But if local governments allocate the additional tax revenue based on other considerations, benefits produced may be as low as zero, or even negative.

Net socioeconomic impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

12. Environmental justice impacts[232]

As discussed above in Section III.J, NRC has two guidance documents that govern the estimation of EJ impacts in an EIS CBA: NUREG-1748 (2003) and LIC-203 (Rev. 3) (2013). They direct the NRC staff to use similar procedures, but both are poorly designed to detect EJ effects, if they exist, because they rely on arbitrary areas of concern instead of focusing on where project-related impacts are actually expected. The 4-mile radius area of concern in NUREG-1748 averages impacts over 50 square miles; the 50-mile radius in LIC-203 averages impacts over 7,750 square miles. For a project such as the proposed ISP CISF, the larger averaging zone reduces the likelihood that EJ effects, if they exist, will be detected. Moreover, by making the treatment zone identical to the control zone, LIC-203 prevents the NRC staff from performing any useful comparison between groups.

The EJ analysis defines the applicable zone of interest. NUREG-1748 is cited as the basis for this definition,[233] but it uses the 7,850 square mile zone (50-mile radius) prescribed in LIC-203 instead.[234] The larger domain virtually eliminates any capacity to detect the signal of EJ effects if they exist. Moreover, the Draft EIS uses the same area as the

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[232] at 3-73 to 3-76; 4-77 to 4-81; Appendix B.

[233] at 3-73 to 3-76.

[234] at 3-68 and 3-74 .

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domain for comparison. When the treatment and control groups are identical, differences are impossible.

The EJ analysis includes the prescribed demographic data for the selected impact area for every Census block within the zone.[235] There is convincing evidence that the proportion of the population which is minority or low-income varies substantially across census blocks, and that some census blocks surely include disproportionately large minority and/or low-income populations.[236]

Where the EJ analysis fails is it does not include actual analysis of disproportionate impacts. Even if this analysis had been performed, it almost certainly would not have detected any. The reasons are twofold. First, the treatment group (the "area of assessment") is identical to the control group, making no comparisons possible. Second, the use of an overly large zone (7,850 square miles) ensures that any "hot spots" that exist would be averaged out. In short, the methodology is incapable of detecting EJ impacts. Indeed, the EJ analysis consists of nothing more than a disclaimer stating that EJ analysis served no useful purpose:

> No credible accident scenarios for the proposed CISF were identified with potentially significant releases of radionuclides to the environment that could result in significant effects to any offsite populations (EIS Section 4.15). The overall environmental impact of the accidents at the proposed CISF during the license term is SMALL because safety-related structures, systems, and components are designed to function during and after these accidents. Thus, there is no mechanism for disproportionate environmental effects through accidents on minority residents near the proposed CISF.[237]

The inference at the end of this disclaimer is incorrect. Adverse effects that are indisputably SMALL when *averaged* over 7,850 square miles could be disproportionately LARGE in specific communities within this area. If the communities experiencing disproportionately adverse impacts also are minority or low-income communities, the EJ analysis would have detected them. In short, the methods NRC prescribes for EJ analysis ensure that no EJ impacts will be found.

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[235] at B-10 to B-15 [Table B-4].

[236] For example, in Lea County NM the fractions of individuals and families below the federal poverty line range from 0% to 55%, and the Hispanic ethnicity fraction ranges from 14% to 94%. Table B-4 does not report, for each census block, whether it is located within the 4-mile or 50-mile radius.

[237] U.S. Nuclear Regulatory Commission (2020d) at B-9.

Net environmental justice impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

13. Public and occupational health and safety impacts[238]

Incremental public health risks are externalities that cannot be captured in prices for market goods and services, and CBA requires that such risks be quantified and monetized unless they are insignificant. However, the potential public health risks discussed in the Draft EIS are subject to other NRC regulations and myriad federal and state regulation by other agencies. NRC staff therefore conclude that occupational public health risks related to construction, operations, and decommissioning are SMALL[239] – i.e., indistinguishable from zero. Compliance with NRC and other agencies' regulations does not eliminate public and occupational health risks, however, and regulatory violations often occur. Nonetheless, the conclusion in the Draft EIS that there would be no *public* health and safety risks during operations appears to be reasonable because no *public* exposures would occur. That inference may not apply, however, to *occupational* health and safety risks.

As noted in Section III.G.2 above, incremental occupational risks are capitalized in wage rates, and especially so in labor markets where risks are known, effectively communicated, and thoroughly regulated. Estimates of non-radiological occupational safety risks reported in Table 4.13-1 of the Draft EIS (presumably as costs) are thus incomplete because they do not account for worker wage premiums (which would be offsetting benefits). Similarly, in principle the radiological occupational health risks reported in Section 4.13.1.2 of the Draft EIS also should be quantified and monetized if they are significant. But as long as information about occupational risk is not substantially asymmetric, costs from risk-bearing are likely to be approximately equal to the wage premium for bearing risk. They would materially differ only if actual risks are substantially greater or less than expectations.

According to the Draft EIS, the magnitude of non-radiological occupational risks is low. The estimated annual fatality rate during construction (9.8×10^{-5}),[240] when multiplied by NRC's default valuation ($9 million; range: $5.5 million–$13.2 millions),[241] implies an annual monetized risk of $882 per worker, or $0.44 per hour over a 2,000 hour work-year.

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238 at 3-84 to 3-87, 4-81 to 4-87.

239 at 5-48.

240 at 4-83 [Table 4.13-1].

241 U.S. Nuclear Regulatory Commission (2015) at 26 [Table 3].

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The estimated market-clearing annual wage premium during operations ([1.3×10^{-4}] × \$9 million) is \$1,170, or \$0.59 per hour over a 2,000 hour work-year.[242] NRC staff should have obtained data on likely wage rates and determined whether these risk premia are so large that they are unlikely to be include in wage rates expected of facility workers.

The Draft EIS reports radiological occupational risks in operations bounded by compliance with NRC regulations (10 CFR Parts 72 and 20) prescribing ALARA, adjusting for site-specific factors[243] and relying on details provided in ISP's SAR.[244] Calculated occupational exposures are characterized as "very conservative" (i.e., health precautionary) because they are based on design basis transportation sources and source terms.[245] Maximum annual individual occupational dose estimate for a transfer operation is 4.5 mSv [450 mrem],[246] which when multiplied by NRC's default valuation of \$5,100/person-rem (\$2014),[247] yields a valuation of \$2,295. The wage premium that fully compensates a worker engaged 2,000 hour per year in an activity that actually entails this level of radiological risk is \$1.15 per hour. Risk premiums should be lower to the extent that the NRC bounding estimate overstates what workers believe actual risk to be, or if these risks are lower because they are intermittent. NRC staff did not subtract risk premiums from their calculations, or assess whether these risk premiums are too high, but nevertheless concluded that radiological impacts to workers during operations would be minor.[248]

Net public and occupational health and safety impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

14. Waste management impacts[249]

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[242] Wage premiums also include the monetized risk of non-fatal injury, but it is generally agreed among CBA practitioners that premature mortality risks weigh much more heavily in the calculation because of their much higher unit valuation.

[243] U.S. Nuclear Regulatory Commission (2020d) at 4-83 to 4-84.

[244] The internal reference is Interim Storage Partners LLC (2018), Appendices A.9, B.9, C.9, D.9, E.9, F.9, and G.9.

[245] at A.9-1.

[246] U.S. Nuclear Regulatory Commission (2020d) at 4-84.

[247] U.S. Nuclear Regulatory Commission (2015) at 26 [Table 3].

[248] U.S. Nuclear Regulatory Commission (2020d) at 4-84.

[249] at 3-87 to 3-89, 4-87 to 4-94.

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The Draft EIS reports that construction of Phase 1 would generate an estimated 2,378 metric tons of nonhazardous waste, equal to 2.7% of the annual volume of waste disposed at the Lea County Solid Waste Authority landfill, the nearest municipal landfill.[250] The project utilizes 0.6% of total landfill capacity. Projected hazardous waste volumes during construction are small enough that the facility likely would be classified as a Conditionally Exempt Small Quantity Generator, for which no RCRA Subtitle C permit is required.

Small amounts of non-hazardous and hazardous waste would be expected to be generated during operations and disposed at an offsite licensed facility. Liquid sanitary waste would be collected onsite and disposed offsite. The Draft EIS concludes that these amounts are "relatively minor" in comparison to facility capacities.[251]

Presumably, these would be arm's-length market transaction. Therefore, they are exchanges of landfill resources for cash, with a profit going to water managers, not external environmental impacts. In any case, NRC staff conclude that the waste management impacts are SMALL,[252] implying a monetized value of zero even if these impacts are counted.

Net waste management impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

15. Accident impacts[253]

Both the baseline and the proposed CISF analysis assume compliance with NRC regulations and guidance, including 10 CFR Part 72. Thus, substantial effort to prevent accidents is a requirement for licensing. The Draft EIS includes an extensive discussion of NRC regulations intended to prevent accidents or reduce their impacts. The Draft EIS appears to include only accidents that do not imply regulatory noncompliance.

Impacts resulting from regulatory noncompliance also matter, and their environmental impacts may be greater. The Draft EIS should not have excluded them. To be sure, noncompliance is infeasible for safety features built into facility design subject to NRC licensing requirements. But violations do occur, they may result in accidents, and these accidents may have substantial environmental impacts.

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[250] at 4-88.

[251] at 4-89.

[252] at 4-89 to 4-90, 4-91, 4-91 to 4-92, and 4-93.

[253] at 4-94 to 4-97.

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For purposes of CBA, however, risks managed by regulation are not zero risks. They should be considered incremental costs to the project and objectively estimated.[254] For CBA purposes (as opposed to NRC's licensing decision), what matters is the product of probability and magnitude. If this product implies a significant risk of an environmental impact, the CBA should include it in the EIS.

A more serious limitation in the Draft EIS is it does not account for the benefits of avoided accident impacts – i.e., impacts that would have occurred at reactor sites if SNF had not been transported to the ISP CISF. A key question the Draft EIS CBA should answer is whether the expected benefits of accidents avoided by the proposed CISF exceed the expected costs of accidents that occur because of the proposed CISF. Nothing in the Draft EIS illuminates this question because NRC's CBA methodology does not account for these environmental impacts.

The Draft EIS concludes that environmental impacts from Design I and II events, would be SMALL,[255] and implies a monetized value of zero. This conclusion is not justified by the analysis presented because the analysis does not account for accidents resulting from regulatory violations. The NRC staff conclusion can only be justified if analysis of environmental impacts resulting from regulatory violations shows the to be SMALL.

Net accident impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

16. Cumulative impacts[256]

Cumulative impact is "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions."[257] The Draft EIS discusses a range of past, present, and

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[254] at 4-94: "For some design basis events, such as tornadoes, this section describes how the proposed CISF would be designed and built to withstand the event without loss of systems, structures, and components necessary to ensure public health and safety. In these cases, the environmental impacts are small because no release of radioactive material would occur."

[255] at 4-95 to 4-97.

[256] at 5-1 to 5-63.

[257] at 5-1, citing 40 C.F.R. § 1508.7. This definition was not changed in Council on Environmental Quality (2020).

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reasonably foreseeable future energy-related actions related to ISP's proposed CISF, including:

- Mining
- Oil and gas development
- The Waste Isolation Pilot Plant (WIPP)
- The National Enrichment Facility (NEF)
- Possible amendment expanding the range of wastes eligible for disposal at WCS's co-located existing facility
- Holtec's proposed CISF, to be located in Lea County, New Mexico
- Solar, wind, and other energy projects
- Fluorine Products' depleted uranium deconversion facility
- A proposal to construct a Medical Isotopes Production Facility

The Draft EIS also discusses various foreseeable non-energy related development projects.

The Draft EIS characterizes cumulative impacts based on a CEQ methodology[258] and summarized them in Table 5.1-1. Impacts are characterized as SMALL for some categories, and SMALL to MODERATE for others. By definition, SMALL cumulative impacts have zero monetized value. The magnitude (and hence, monetized value) of MODERATE cumulative impacts is not clear. Their value depends on a more refined description of their nature, magnitude, and sign, and reasonable methods for monetizing them, which would be impact-specific. Necessary information for quantifying and monetizing MODERATE impacts are not included in the Draft EIS CBA.

Net cumulative impacts cannot be characterized or estimated because the Draft EIS includes no characterizations or estimates of such impacts in the baseline.

17. <u>Environment impacts not accounted for in the Draft EIS</u>

Despite its seeming comprehensiveness, the Draft EIS does not account for several obvious environmental impacts.

a. *<u>Environmental impacts from Interruptions in utility service and breaches of facility security</u>*

The Draft EIS includes painstaking details, often about minor or even trivial environmental impacts, some of them strictly onsite and thus irrelevant for NEPA purposes. Still, other environmental effects that could be highly significant are not included

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[258] Council on Environmental Quality (1997). Evaluating the merits and information quality compliance of this methodology would require a separate review.

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at all. For example, the Draft EIS does not account for the environmental impacts of plausible interruptions in utility services, whether due to natural events or human actions. The Draft EIS also does not identify or estimate the environmental impacts of the proposed facility's security risks. These risks include physical threats to the facility posed by natural events or human actions, or cyber threats that could adversely affect operations or operational security.

b. Environmental impacts from the removal of SNF from onsite rector storage

Notably absent from the Draft EIS CBA is any acknowledgement that shipment of SNF to the proposed CISF could have any environmental impacts related to onsite reactor storage. But it is difficult to imagine that no such impacts could occur. Yet the Draft EIS CBA asserts, without evidence, that this is the case.[259] Instead of assuming away these environmental impacts, the Draft EIS should have made the estimation of such impacts a key element of the Draft EIS.

c. Residual environmental impacts

The Draft EIS includes no discussion of residual risks that remain even after full compliance. Regulation prescribes the level of environmental impact deemed tolerable; it does not mean environmental impacts vanish. If residual environmental impacts are indeed insignificant, the Draft EIS should have documented the case.

d. Environmental impacts related to regulatory noncompliance

It is convenient for NRC staff to assume that regulated entities such as ISP will fully comply with all applicable regulations. It is also inaccurate. The sheer complexity of regulatory requirements ensures that violations will occur. NRC staff have available to them data concerning the frequency and severity of regulatory violations. Various plausible scenarios could have been identified and their environmental impacts modeled, estimated, and monetized. These impacts are missing from the Draft EIS.

There is an extensive economics literature about the social costs of noncompliance in a regime of ever-intensifying regulatory control. Enforcement is always incomplete, and it becomes only more so as stringency intensifies.[260] This literature persuasively shows

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[259] U.S. Nuclear Regulatory Commission (2020d) at 8-9. "[E]nvironmental impacts would continue to occur at the generation site ISFSIs, with the exception of any generation sites that are fully decommissioned such that NRC terminates its license and releases the property for other uses."

[260] The seminal paper in this area is Viscusi and Zeckhauser (1979).

that as regulatory stringency increases and enforcement effectiveness declines, the frequency of noncompliance increases, often as a rational business strategy. Where NRC has data indicating substantial environmental impacts from noncompliance, the Draft EIS should have included them as reasonably expected harms.[261]

e. Excluded but foreseeable environmental impacts

The Draft EIS includes discussion and analysis of environmental impacts of activities that are not part of ISP's application, most obviously for Phases 2-8 of the CISF. The inclusion of these activities, presumably for the purpose of public transparency, begs the question: What other activities not included in ISP's application are plausible and, in the interest of transparency, should be included in the Draft EIS?

There is an obvious answer to this question: ISP's application includes an explicit license termination date before which all SNF stored there must be transported to a permanent waste repository under the control of DOE. The Draft EIS assumes that this repository will be licensed, constructed, and operated, probably at Yucca Mountain, Nevada. The Draft EIS further assumes that this repository will be open for business before the expiration of the ISP license.

This assumption is at best counterfactual. There is little evidence that the Yucca Mountain repository (or an alternative site) will in fact be licensed and constructed during the CISF's license lifetime. Thus, it is plausible, if not likely, that SNF stored on an interim basis at ISP's proposed CISF would remain there longer than the license term. Even though this appears to be the most likely future scenario, the Draft EIS and its CBA ignore it.

These environmental impacts should have been estimated, and estimated symmetrically. That is, if the Yucca Mountain repository (or an alternative site) is not open before the expiration of the CISF license, then a substantial share of environmental impacts from transportation would not occur. This obviously includes SNF transportation-related environmental impacts from defueling, but it also includes SNF transportation-related environmental impacts in the baseline because SNF stored onsite at reactors also would not be transported to the repository. Moreover, keeping SNF in place beyond the CISF license term, whether at the CISF or onsite at reactors, has quantifiable environmental impacts. It is an empirical question whether net environmental impacts would be positive or negative, so analysis is required to help inform the Commission and the public.

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[261] To estimate the environmental impacts of noncompliance, NRC staff do not need to know the motivations of regulated entities. That is, it makes no difference to the environment whether noncompliance is willful, negligent, or the result of stochastic processes over which regulated entities have imperfect control at any cost.

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H. Material defects in the Draft EIS CBA

The Draft EIS CBA contains numerous material structural and technical defects, each of which is great enough to render the Draft EIS CBA inaccurate, misleading, and unreliable for informing the public or the Commission. Because these defects also appear in the Draft EIS CBA for the proposed Holtec CISF, NRC should treat these comments as supplementary comments on the Draft EIS CBA for the proposed Holtec CISF.[262]

1. Structural material defects

a. The Draft EIS CBA does not comply with 10 CFR § 51.70(b).

NRC's NEPA regulations, in 10 CFR §51.70(b) require among other things that "[t]he NRC staff will independently evaluate and be responsible for the reliability of all information used in the draft environmental impact statement." There is considerable evidence that NRC staff independently *evaluated* critical third-party information on which it relied. However, there is no affirmative evidence that the NRC staff evaluated its *reliability*.

Normally, only final agency actions are subject to judicial review under the Administrative Procedure Act (5 USC §§553 and 704). In this case, however, NRC's regulation applies to a *nonfinal* action – the publication of a draft (not final) EIS. To forestall litigation that would unnecessarily delay a conclusive decision on ISP's application, NRC should correct the errors listed in this paragraph and paragraph (2) below and republish the Draft EIS CBA.

b. Key sections of the Draft EIS CBA do not comply with 10 CFR §51.71(d).

To comply, 10 CFR § 51.71(d) requires that an EIS CBA include at least the following components:

- A preliminary analysis that considers and weighs the environmental effects, including any cumulative effects, of the proposed action;
- The environmental impacts of alternatives to the proposed action;
- Alternatives available for reducing or avoiding adverse environmental effects; and

[262] For original comments on the Draft EIS CBA for the proposed Holtec CISF, see Belzer (2020).

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- A consideration of the economic, technical, and other benefits and costs of the proposed action and alternatives.

A properly conducted EIS CBA (bullet #4) relies on unbiased information about environmental impacts (bullets #1 and #2) evaluated in the context of a range of alternatives including the proposed action (bullets #2 and #3).

Key components are missing from the Draft EIS CBA. The CBA does not include assessments of social costs and benefits; only private costs to the applicant are included. The CBA does not include credible analysis of the environmental impacts of alternatives to the proposed action; the only purported "alternative" is indistinguishable from the analytic baseline. The CBA does not include an estimate of net social benefits expected from the project and its alternatives, without which comparisons cannot be made.

c. The Draft EIS CBA does not adhere to key provisions of applicable NRC guidance.

The Draft EIS CBA is supposed to comply with several NRC guidance documents.[263] Key sections do not. These guidance documents require that the Draft EIS CBA include a credible analysis of alternatives, estimates of social costs, and estimates of social benefits. The Draft EIS CBA commits the elementary error of improperly treating certain transfers as social benefits, and it improperly calculates net benefits. Each of these defects is summarized in paragraph (2) below.

d. The Draft EIS does not comply with applicable information quality guidelines that parallel requirements in NRC's NEPA regulations.

As noted in subparagraph (a) above, NRC's NEPA regulations in 10 CFR §50.70(b) require the NRC staff to independently evaluate and be responsible for the reliability of all information used in the draft environmental impact statement. This requirement parallels government-wide information quality guidance published in 2002 by the Office of Management and Budget[264] and affirmed by NRC.[265] All federal agencies must perform pre-dissemination review to ensure the objectivity, utility, and integrity of influential

[263] Listed in reverse order of publication, major guidance documents are U.S. Nuclear Regulatory Commission (2017), U.S. Nuclear Regulatory Commission (2015), U.S. Nuclear Regulatory Commission Office of Nuclear Reactor Regulation (2013), U.S. Nuclear Regulatory Commission (2004b), and U.S. Nuclear Regulatory Commission (2003b).

[264] Office of Management and Budget (2002).

[265] U.S. Nuclear Regulatory Commission (2002).

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information they disseminate, such as the Draft EIS CBA.[266] There is no evidence in the Draft EIS CBA suggesting that the NRC staff conducted a pre-dissemination review.

Compliance with 10 CFR §51.71(b) and the information quality guidelines is essential for the public to have confidence in the quality of the Draft EIS CBA. NRC's failure to comply argues for a vote of no confidence.

e. *The Draft EIS CBA fails to fulfill NEPA's statutory purpose.*

NEPA § 102(2) requires environmental analysis to ensure that "presently unquantified environmental amenities and values" are taken into account in federal decision-making. NEPA's environmental review process exists to assure that this occurs. Thus, it is essential that Draft the EIS CBA quantify (and to the extent feasible, monetize) the social costs and benefits resulting from "presently unquantified environmental amenities and values." Completeness, transparency, and consistency with professional practice certainly support the inclusion of all social costs and benefits. Still, compliance with implied statutory requirements should not be optional. Nothing in the structure or purpose of NEPA suggest that an EIS CBA should, as this one does, fail to quantify (and to the extent feasible, monetize) "presently unquantified environmental amenities and values." Nor is there anything in the structure or purpose of NEPA to suggest that an EIS CBA should, as this one does, focus exclusively on private costs to the applicant. Considering every potential category of social costs and benefits, this one is the least relevant to NEPA.

f. *The environmental justice (EJ) analysis in the Draft EIS could not detect disproportionate and adverse effects on minority and/or low-income communities.*

Environmental justice (EJ) analysis is supposed to enable analysts to determine if there are minority or low-income communities that bear disproportionate adverse risks. The way the EJ analysis was performed, however, any such effects could not be detected. This occurred for two reasons. First, the area of concern was defined to be identical to the spatial area used as a control. No differences, no matter how large, can be detected when treatment and controls are identically defined. Second, the analysis failed to identify minority and low-income communities within the spatial reach of project-related environmental impacts and compare the expected impacts there with similarly situated communities elsewhere. These structural errors ensured that no EJ impacts would be detected, no matter how large.

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[266] Office of Management and Budget (2002) at 8459.

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2. <u>Material technical defects</u>

a. *<u>The scope of the Draft EIS CBA is technically incorrect.</u>*

The proposed project is the licensing, construction, and operation of a CISF at a particular place for a particular period of time. If licensed, ISP will accept SNF from any reactor on the United States. Therefore, the proper scope of the Draft EIS CBA is the entire United States.

The only environmental impacts considered by NRC staff are those which may be locally manifest, or associated with the transportation of SNF. To the extent that there are, for example, environmental impacts resulting from the removal of SNF from onsite reactor storage prior to transfer, the Draft EIS CBA improperly treats them as nonexistent. Further, it is inconceivable that the removal of SNF from onsite reactor storage would have neither short- nor long-term environmental impacts. These impacts should have been estimated, with net impact obtained by estimating the environmental impacts of removal to a permanent repository.

The Draft EIS CBA also has an incorrect scope with respect to which costs and benefits were included. The Draft EIS CBA should follow normal professional practices and address the question:

> "Are external environmental benefits of the proposed CSIF greater than external environmental costs"?

Instead, the Draft EIS purports to answer a question NRC is not qualified to address and is irrelevant to both NEPA and its statutory mission:

> "Is the operation of the proposed CSIF profitable to ISP?"

Even with respect to this incorrect and irrelevant question, the Draft EIS CBA fails to provide a reliable answer. The Draft EIS CBA incorrectly assumes that ISP can commandeer all cost savings realized by its potential customers.

b. *<u>The Draft EIS CBA includes no estimates of environmental impacts in the baseline.</u>*

Estimates of baseline impacts are required to derive monetized and/or quantified estimates of the incremental impacts of the project (as well as each credible alternative). Incremental impacts should be obtained by subtracting each relevant baseline impact from the estimated impact of the proposed facility.

The Draft EIS and CBA include no estimates of environmental impacts for the baseline. Worse, the Draft EIS and CBA implicitly assume that no environmental impacts, of any type or magnitude, actually occur in the baseline. This assumption is absurd. If it were valid, there would never be a reason to transport SNF to a CISF, or for that matter, to a permanent waste repository. The status quo – temporary but indefinite onsite storage at operating and decommissioned reactors – would be the optimal public policy for SNF management.

In addition to its lack of intuitive appeal, this inference is not consistent with the statement of purpose and need given in the Draft EIS. In this statement, the NRC staff say the proposed facility is necessary because continued onsite storage has significant environmental impacts:

> The proposed CISF is needed to provide away-from-reactor SNF storage capacity that would allow SNF, GTCC, and small quantities of MOX fuel to be transferred from existing reactor sites and stored for the 40-year license term before a permanent repository is available. Additional away-from-reactor storage capacity is needed, in particular, to provide the option for away-from-reactor storage so that stored SNF at decommissioned reactor sites may be removed so the land at these sites is available for other uses.[267]

This technical error may be the most significant. Unless it is corrected, even if every other structural and technical error is corrected, the Draft EIS CBA cannot reveal net environmental impacts or net benefits.

c. <u>The Draft EIS CBA lacks analysis of credible alternatives.</u>

Whereas 10 CFR §51.71(d) and NRC guidance[268] call for the analysis of reasonable alternatives, the Draft EIS CBA considers none. It purports to include no-action as an "alternative," but "no-action" is actually just the analytic baseline for evaluating costs and benefits of the proposed project and every *bona fide* alternative considered. This mistake is self-evident from the Draft EIS CBA: The no-action "alternative" has neither costs nor benefits; therefore, the purported analysis of the no-action "alternative" is a tautology, bereft of information value.

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[267] U.S. Nuclear Regulatory Commission (2020d), at xviii at 1-3. Similarly statements can be found in the Draft EIS for the proposed Holtec CISF. See U.S. Nuclear Regulatory Commission (2020e) at xxii and 1-2

[268] U.S. Nuclear Regulatory Commission (2004b), U.S. Nuclear Regulatory Commission (2017).

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d. The Draft EIS CBA includes analysis of an irrelevant alternative.

In conventional CBA practice, scope is defined by the problem to be solved by regulation or the objectives of the proposed project[269] – in this case, primarily the interim storage of SNF. Bona fide alternatives to the proposed project are those which could meet these objectives, or otherwise address the problem to be solved but in a different manner. Options that address a different project, or purport to solve a problem different from the one which motivates the project, are not bona fide alternatives.

Because ISP's application is limited to Phase 1, every bona fide alternative must be consistent with this scope and scale. The Draft EIS CBA violates this principle by including, as a sort of quasi-alternative, analysis of the buildout of all eight Phases.[270] This would have been justifiable within a sensitivity analysis on the ground that the additional information adds transparency given ISP's potential future submission of applications to license these phases. However, that does not make full buildout an *alternative* to Phase 1.

The Draft EIS CBA includes a brief discussion of a bona fide alternative in which a second and competing CISF is licensed by NRC,[271] but the CBA lacks any serious analysis of it. NRC has the authority to license one or both of these proposed CISFs. Both the Commission and the public would benefit from a comparative analysis of their external environmental impacts. That way, everyone could consider the merits of licensing one but not the other. But despite its obvious value of this information, no comparative analysis is presented. Without a comparative analysis, the Commission lacks an economic rationale for choosing to license only one proposed CISF. The public is unable to consider which proposal it prefers if NRC determines that at least one of them is essential.

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[269] Office of Management and Budget (2003), U.S. Nuclear Regulatory Commission (2004b), U.S. Nuclear Regulatory Commission (2017).

[270] The Draft EIS includes limited analysis of the full buildout "option" with only inscrutable explanations. See, e.g., U.S. Nuclear Regulatory Commission (2020d) at iii "[A]s a matter of discretion, the NRC staff considered these expansion phases in its description of the affected environment and impact determinations in this draft EIS, where appropriate"]; at xvii ["The NRC staff conducted this analysis as a matter of discretion because ISP provided the analysis of the environmental impacts of the future anticipated expansion of the proposed facility as part of its license application"]; and 8-1 ["(F)acilities and infrastructure completed as part of (Phase 1) and their associated costs are integral to the additional phases"]. Similarly inscrutable text can be found in U.S. Nuclear Regulatory Commission (2020e).

[271] U.S. Nuclear Regulatory Commission (2020d) at 8-5 to 8-6.

An second obvious alternative would have the combination of both proposed CISFs. But the Draft EIS CBA includes no analysis of this alternative, either. In lieu of analysis, the Draft EIS resorts to empty speculation. It acknowledges that "[t]he presence of a second CISF could impact the costs for the proposed ISP CISF in several ways."[272] But the NRC staff description is conceptually incomplete, speculative, and misleading. The transportation of SNF to the ISP CISF would not be "delayed," as the NRC staff claim; it would be partially diverted to the Holtec CISF. Transportation costs to the ISP CISF would indeed be lower if the Holtec CISF were licensed, but these reductions would be substantially offset by transportation costs resulting from shipments to the Holtec CISF. Missing from the discussion is an obvious question: What are the environmental impacts in transportation from the licensing and simultaneous operation of both proposed CISFs?

Similar technical error infects the Draft EIS CBA discussion of environmental impacts from construction, defueling, and decommissioning. If both proposed CISFs were built, construction-related impacts from the ISP CISF might be lower, but there would be offsetting construction-related impacts from the Holtec CISF. Missing from the discussion is an obvious question: What are the environmental impacts of simultaneous operation of both proposed CISFs?

Finally, licensure of both CISFs might well, as the NRC staff hypothesize, reduce the optimal size of buildout at the ISP facility. But this reduction would be offset by additional construction at the Holtec CISF (and of course potential reductions in its future expansion). In short, the discussion of a second CISF has no information value except to the extent that it states a few (but by no means all) obvious facts.

The Draft EIS CBA should formally include the licensure of both proposed CISFs as an alternative. A CBA that ignores this obvious alternative, even though each CISF is proposed for licensure, constitutes professional malpractice.

e. <u>The Draft EIS CBA does not monetize environmental impacts.</u>

Draft EIS CBA Table 8.3-1 summarizes the NRC staff assessment of environmental impacts, which the staff characterize semi-quantitatively as SMALL, MODERATE, or LARGE. By definition, SMALL impacts are indistinguishable from zero,[273] so they should have zero monetized value in the CBA. But the CBA includes no declarative statements to that effect, which predictably leads to public confusion.

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[272] at 8-5.

[273] at xx.

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MODERATE environmental impacts have positive value, however, which the CBA should have included. Metaphorically, MODERATE impacts are "larger than a breadbox but smaller than an elephant," but that level of quantification does not lend itself to monetization. The Draft EIS CBA does not indicate that the NRC staff made any effort to quantify MODERATE impacts in ways that could permit monetization, and thus inclusion in the CBA.[274]

Failure to monetize environmental impacts is not limited to those described in semi-quantitative terms, however, so the extent of this technical defect is considerably greater. The Draft EIS includes quantitative estimates of health and safety risks.[275] Each could have been monetized using default unit values prescribed by NRC or authoritatively published elsewhere, and adjusted for offsetting benefits. The Draft EIS CBA does not monetize these impacts.[276]

Notably absent from the Draft EIS CBA is any attempt to estimate net environmental impacts at reactor sites from which SNF would be transported to ISP's proposed CISF. It is difficult to imagine that the removal of SNF from temporary storage at a reactor would have no environmental impacts net of transfer to a permanent waste repository. Yet the Draft EIS CBA asserts, without evidence, that this is the case.[277] Instead of assuming away the environmental impacts related to removing SNF from onsite reactor storage, the Draft EIS should have made the estimation of net onsite impacts a key element of the Draft EIS and CBA.

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[274] There would be substantial value to the public if NRC were to convert the metaphorical terms "breadbox" and "elephant" into monetizable quantities. This way, NRC staff could provide insight concerning the range of monetized values likely to be implied by MODERATE or LARGE impacts.

[275] U.S. Nuclear Regulatory Commission (2020d) at 4-9 to 4-24 [transportation] and 4-81 to 4-86 [other public and occupational health and safety].

[276] Caution would have been warranted to avoid the misrepresentation of upper-bound risks as likely or representative. CBA requires risks be expressed and monetized as expected values.

[277] U.S. Nuclear Regulatory Commission (2020d) at 8-9. "[E]nvironmental impacts would continue to occur at the generation site ISFSIs, with the exception of any generation sites that are fully decommissioned such that NRC terminates its license and releases the property for other uses."

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f. The Draft EIS CBA does not estimate social costs.

Consistent with professional CBA practice,[278] NRC guidance is clear that an EIS CBA "should not be limited to a simple financial accounting of project costs."[279] However, the Draft EIS CBA contains *only* "a simple financial accounting of project costs."

The Draft EIS CBA includes only estimates of *ISP's* private expenditures and potential revenues. It does not include monetized estimates of others' private expenditures or social costs. At best, this design would replicate a private financial analysis performed to determine whether ISP should apply for a license to construct and operate a CISF. However, there is no reason to believe that NRC is better equipped than ISP to conduct a private financial analysis of the proposed project. Moreover, conducting a private CBA is incompatible with NRC's mission as the Commission understands it.[280]

g. The Draft EIS CBA lacks an assessment of social benefits.

Minimum practice in CBA requires that a CBA include a comprehensive assessment of social benefits as well as social costs.[281] CBAs for federal actions are required to quantify and monetize social benefits. This is the standard for federal regulation,[282] federal programs,[283] federally-funded highway projects[284] and aviation,[285] and federally-funded water resources projects,[286] just to name a few. It is also the standard for nuclear facility

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[278] See, e.g., Boardman, et al. (2018) at 2: "In CBA we try to consider *all of the costs and benefits to society* as a whole, that is, the social costs and the *social benefits*… *The broad purpose of CBA is to help **social** decision-making and to increase social value or, more technically, to improve allocative efficiency"* (italics in original, **bold underline** added).

[279] U.S. Nuclear Regulatory Commission (2017) at 4-3.

[280] See U.S. Nuclear Regulatory Commission (2020d) at xviii: "[T]he NRC has no role in a company's business decision to submit a license application to operate a CISF at a particular location."

[281] See, e.g., Office of Management and Budget (2003), Dudley, et al. (2017), Boardman, et al. (2018), Jenkins, et al. (2019).

[282] Office of Management and Budget (2003).

[283] Office of Management and Budget (1992).

[284] Federal Highway Administration (2018).

[285] Federal Aviation Administration (2020b).

[286] U.S. Water Resources Council (1983).

regulations and projects.[287] This is ratified in NRC guidance.[288] The Draft EIS CBA includes no benefits assessment, however. A purported CBA without a benefits assessment is just a cost assessment.[289]

The purported "benefits" in the Draft EIS CBA consist of expenditure reductions to ISP's putative customers. These "benefits" are the revenue ISP would obtain if it could compel reactor owners and operators to ship SNF to the ISP CISF, and ISP could legally and practically engage in first-degree price discrimination. This calculation is not equivalent to net social benefits, and it has no information value to the Commission or the public.

A social benefits assessment is necessary to allow social costs and benefits to be properly compared, and in particular, for social costs to be subtracted from social benefits to ascertain whether the project is expected to provide net social benefits. By failing to include a social benefits assessment, the Draft EIS CBA fails to fulfill the key purpose of every CBA.

h. <u>The Draft EIS CBA incorrectly characterizes transfers as benefits.</u>

Draft EIS CBA Table 8.3-2 purports to summarize the beneficial environmental impacts of the proposed ISP CISF. However, the only item listed is additional tax revenue received by local governments. Taxes are transfers, however, and they are not cognizable as benefits in CBA. Even if taxes were counted, local governments' tax receipts would exactly equal the sum of firms' and individuals' tax payments, resulting in a net impact of zero.[290]

If tax receipts were social benefits, the way to maximize them is to confiscate all private assets and the income they produce.

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[287] U.S. Nuclear Regulatory Commission (2017).

[288] at 5-1: "Cost-benefit analysis identifies and estimates the relevant costs *and benefits* likely to result from a proposed NRC action" (emphasis added).

[289] And a cost assessment that includes only private expenditures is just a financial analysis.

[290] Curiously, tax payments made to federal and state governments are not included in the Draft EIS CBA.

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i. The Draft EIS CBA incorrectly calculates net benefits

Leaving aside external environmental impacts (for which there is no market price), the proper way to estimate net social benefits for the CISF is to sum producer's and consumer's surplus.[291] Producer's surplus is the area above the CISF supply curve but below price. Consumer's surplus is the area below the market demand curve but above price. As noted above, what the Draft EIS CBA calls "benefits" are potential financial savings to ISP's presumed customers. The CBA then subtracts these potential financial savings from ISP's financial costs to derive something it calls "net value."[292] But the Draft EIS CBA does not use "net value" as that term is used in NRC guidance, which defines it synonymously with "net social benefit."[293]

j. Cost estimates in the Draft EIS CBA are suffused with excess precision.

The Draft EIS CBA reports private cost estimates with up to 11 significant figures. For example, the CBA reports total undiscounted private costs for the baseline as great as $10,771,948,925.[294] This level of precision implies accuracy ± $0.50. That level of precision is not merely misleading; it is impossible.

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[291] Boardman, et al. (2018) at 61 at 55.

[292] U.S. Nuclear Regulatory Commission (2020d) at 8-9 to 8-10: "The NRC staff generated net values by subtracting the proposed CISF costs from the associated No-Action alternative costs. If the results were positive, then the No-Action alternative costs were higher than the proposed CISF costs and the proposed project generated a net benefit. If the results were negative, then the No-Action alternative costs were lower than the proposed CISF costs and the proposed project generated a net cost."

[293] U.S. Nuclear Regulatory Commission (2017) at 1-1 , referencing Executive Order 12291: "E.O. 12291 directed that actions were not to be undertaken unless they resulted in a positive *net value* to society" (emphasis added). In fact, this Executive order refers to "net benefits," not "net value." See Reagan (1981) at Sec. 2(c) ["Regulatory objectives shall be chosen to maximize the *net benefits* to society"]; Sec. 2(e) ["Agencies shall set regulatory priorities with the aim of maximizing the aggregate *net benefits* to society..."]; and Sec.3(d)3) [Regulatory Impact Analyses "shall contain ... A determination of the potential *net benefits* of the rule, including an evaluation of effects that cannot be quantified in monetary terms" (emphasis added)].

[294] U.S. Nuclear Regulatory Commission (2020d) at 8-11 [Table 8.5-2].

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Excess precision is a violation of the information quality standard of presentational objectivity.[295] Estimates with excess precision cannot be "accurate, clear, [and] complete," even if they are "unbiased," as applicable information quality guidelines require. In this example, private costs differ between Scenarios 1 and 2 by $4,503,579,671 (± $0.50). The best possible characterization of that difference is a factor of 2.

k. The Draft EIS CBA does not account for uncertainty about the value of environmental impacts

Conventional practice[296] and NRC guidance[297] require CBAs to account for uncertainty. The Draft EIS CBA ignores uncertainty, however. Indeed, it does not even acknowledge that its *private* cost estimates are uncertain.

The Draft EIS CBA includes minimal sensitivity analysis, and only then for arbitrary scenarios with limited informational value. The CBA provides no information to the reader that would illuminate the degree of uncertainty present, and it denies the public sufficient information to conduct its own sensitivity analysis.

The CBA estimates private costs for the project (and full buildout) under two potential states of the world: Scenario B, in which the CISF receives SNF as projected by ISP; and Scenario A, in which ISP receives SNF only from currently decommissioning reactor sites. Scenario B warrants inclusion because it reflects ISP's publicly reported business judgment. On the other hand, Scenario A is simply an arbitrary assumption by NRC staff about the market demand for ISP's services. Yet from the outset the Draft EIS clearly states that the Commission's role is limited to ensuring safety, not second-guessing ISP's business judgment, which necessarily includes its estimates of market demand.[298] In short, the only factor distinguishing Scenarios A and B is the *NRC' staff's opinion about ISP's business judgment* – not any factor relevant to NEPA or NRC's statutory authority. Thus, Scenario A provides no useful information to the Commission or the public, and it implicitly places NRC staff in the position of making unjustifiable and presumptive characterizations of ISP's business judgment.

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[295] Office of Management and Budget (2002) at 8459 [Sec. V.3.a].

[296] See, e.g., Office of Management and Budget (2003) at 38-42, Dudley, et al. (2017) at 9-10, Boardman, et al. (2018) at Chapter 11, Jenkins, et al. (2019) at Chapter 6.

[297] U.S. Nuclear Regulatory Commission (2017) at 2-11, 2-12, and Appendix C.

[298] at xviii: "[T]he NRC has no role in a company's business decision to submit a license application to operate a CISF at a particular location."

V. Information Quality Review

The Draft EIS is silent with respect to information quality issues. Applicable information quality guidelines published by the Office of Management and Budget[299] and the NRC[300] apply to the EIS, but they are not cited. There is no text even asserting (much less demonstrating) that the information in the Draft EIS is capable of being reproduced. Similarly, the Draft EIS does not show that the information reported (including analytic results) satisfies the substantive information quality standards of objectivity and utility. Silence about information quality, combined with several obvious violations of key principles, strongly suggests that NRC staff are either unaware of the information quality guidelines, even though they were published 18 years ago, or they are aware of these guidelines but declined to comply with them.

Reproducibility is the means by which the information quality guidelines ensure that the goal of transparency is achieved. For that reason, federal agencies are generally forbidden from disseminating influential information that is not reproducible, and a formal Request for Correction may be a required remedy.[301]

The public may be harmed even more than the Commission by information quality noncompliance. The Commission can demand from the applicant any information it wants. The public relies on Commission disclosure for critical information that it would never otherwise be able to obtain. It therefore has a right to insist that the NRC staff rigorously comply with applicable information quality guidelines. Otherwise, the public cannot effectively exercise its legal right to fully participate in the licensing process.

A. The Draft EIS CBA is not reproducible.

Key tables (e.g., Tables 8.3-3, 8.4-1, 8.5-1, and 8.5-2) cannot be reproduced from the details provided in Appendix C. To the extent that NRC is relying on ISP's ERs and SARs, but these documents and their supporting materials must be reproducible by qualified third parties. If they are not reproducible, additional work will be required by the NRC staff to secure the necessary background information so that they are capable of being reproduced.

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[299] Office of Management and Budget (2002).

[300] U.S. Nuclear Regulatory Commission (2002).

[301] Agencies are required to establish and operate administrative procedures whereby the public can seek and obtain the correction of information disseminated by an agency that does not adhere to information quality guidelines. For government-wide requirements, see Office of Management and Budget (2002) at 8459 [Sec. II.3]. For the NRC's error correction procedures, see U.S. Nuclear Regulatory Commission (2002).

B. The Draft EIS does not show that information provided by ISP, and on which NRC staff relied, is reproducible.

NRC staff relied almost exclusively on ISP work products for relevant information to produce the Draft EIS. Indeed, the Draft EIS cites key ISP submissions 441 times.[302] But nowhere in the Draft EIS does NRC staff indicate that it actually reproduced ISP's work, much less conducted some form of validation to ensure accuracy. Information quality guidelines require NRC to do so, however.

Every item of information from a third party that NRC disseminates in a manner reasonably conveying agreement is subject to these guidelines.[303] Further, the NRC staff is required to conduct a pre-dissemination review to ensure information quality compliance.[304] The absence of any evidence of pre-dissemination review convincingly shows that it was not performed.

Failure to comply with information quality guidance in the Draft EIS is also a violation of NRC regulations. 10 CFR §51.70(b) states in part, "The NRC staff will independently evaluate and be responsible for the reliability *of all information used* in the draft environmental impact statement" (emphasis added). Violating its own regulations puts the application at grave legal risk.[305]

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[302] The Draft EIS cites Interim Storage Partners LLC (2018) (ER Rev. 2) and Interim Storage Partners LLC (2020) (SAR Rev. 3) 78 times and 363 times, respectively.

[303] Office of Management and Budget (2002) at 8454: "[I]f an agency, as an institution, disseminates information prepared by an outside party in a manner that reasonably suggests that the agency agrees with the information, this appearance of having the information represent agency views makes agency dissemination of the information subject to these guidelines."

[304] at 8459: "As a matter of good and effective agency information resources management, agencies shall develop a process for reviewing the quality (including the objectivity, utility, and integrity) of information before it is disseminated. Agencies shall treat information quality as integral to every step of an agency's development of information, including creation, collection, maintenance, and dissemination. This process shall enable the agency to substantiate the quality of the information it has disseminated through documentation or other means appropriate to the information."

[305] The same regulatory violation was committed in the Draft EIS for the proposed Holtec CISF.

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C. The Draft EIS does not show that other NRC documents, and other federal agency documents on which it relied, comply with information quality guidelines

The Draft EIS also relies on numerous NRC and other federal agency documents. To the extent that these documents affirmatively comply with applicable information quality guidelines, nothing besides an acknowledgement of this fact is required in the Draft EIS.[306] Because the Draft EIS is silent about information quality, however, it can be inferred that NRC staff did not attempt to determine which factual statements from the government documents on which it relied actually comply with information quality guidelines.

To the extent that other federal agency documents do not comply with applicable information quality guidelines, NRC staff have two choices. They can conduct the requisite pre-dissemination review before disseminating cited information in any manner reasonably implying NRC endorsement, or they can decline to rely on the federal agency document. A federal agency cannot simply rely on presumptive compliance by another federal agency when there is no evidence that the other federal agency actually complied.

Information quality guidelines include three substantive standards in addition to the procedural standard of reproducibility. Objectivity and utility stand out as likely to be the most important.

D. Objectivity

For information in the Draft EIS CBA to be objective, it must be "accurate, reliable, and unbiased," and "presented in an accurate, clear, complete, and unbiased manner." Objectivity is an essential attribute of a proper EIS and its CBA. The primary purpose of the EIS is to inform the Commission about reasonably foreseeable environmental impacts and enable it to use this information to guide decision-making. But if an EIS contains materially inaccurate, unreliable, or biased information, or information presented in an inaccurate, unclear, incomplete, or unbiased manner, the Commission is misled rather than informed.

E. Utility

For the Draft EIS CBA to have utility, it must provide information that informs public judgment and the Commission's decision-making process with respect to environmental impacts. If a CBA were never performed, it would have no information value and thus have no utility. To the extent that a CBA includes demonstrable error, or as shown here is riddled with multiple structural and technical defects, a CBA has disutility to the Commission and the public.

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306 The Draft EIS contains no such acknowledgements.

Each of the structural and technical defects summarized in Section IV. H above ensures that the Draft EIS CBA has at best no information value, and quite likely, its information value is negative. In key respects, the CBA conveys a mixture of false information and invalid inferences. Public and Commission reliance on this CBA would distort the licensure process. The CBA should be revised accordingly and distributed for a second round of public comment.

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VII. Expert Biographical Sketch

RICHARD B. BELZER

Affiliation: Independent strategic and technical consultant in regulation, risk, economics, and information quality.

Expertise: Public Policy

Education: PhD in Public Policy, Harvard University, Cambridge, Massachusetts;
MPP, Harvard University, Harvard Kennedy School, Cambridge Massachusetts;
MS, Agricultural Economics, University of California (Davis), Davis, California;
BS, Agricultural Economics, University of California (Davis), Davis California.

Experience Summary: Since 2001, Dr. Richard Belzer has been an independent consultant in regulation, risk, economics, and information quality. Previously he was a visiting professor of public policy at Washington University in St. Louis and staff economist in the Office of Information and Regulatory Affairs (OIRA) in the Office of Management and Budget (OMB). Current original research areas include methods for achieving economic feasibility in drinking water regulation; the analysis and implications of unreported variability in biomedical data; the development of objective economic indicators of adverse human health effects; and the improved integration of human health risk assessment into regulatory benefit-cost analysis. Dr. Belzer is a regular contributor to scholarly professions through journal peer review and service to professional societies. He was elected Treasurer of the Society for Risk Analysis (SRA) (1998, 2000) and served on its Executive Committee (1988-2003); and elected Secretary-Treasurer (2008, 2010, 2012) and Treasurer (2014) of the Society for Benefit-Cost Analysis (SBCA), and served on its Executive Committee (2009-2016). He has earned multiple awards for exemplary performance at OIRA and OMB, the SRA's Distinguished Service Award (2003), the SBCA's Richard O. Zerbe, Jr. Distinguished Service Award (2017). In 1995, he was named a Fellow of the Cecil and Ida Green Center for the Study of Science and Society.

Panel Experience: Dr. Belzer has served as a Member of the EPA Science Advisory Board's Economy-Wide Modeling Panel (2017-2018) and Member of its Reduced-Form Tools Panel (2020). He currently serves as Member of the SAB's Chemical Assessment Advisory Committee (2019-2021).

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Review of Draft EIS - Interim Storage Partners CISF

Review of Transportation Assessment

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REED HODGIN

Reed's 44-year professional background includes management and operational experience in nuclear emergency management, risk and hazard assessment, crisis decision-making, atmospheric modeling, meteorology, facilitation, and public process management.

Nuclear Emergency Management and Response: Reed has been an emergency manager and consequence assessment team leader for radioactive emergencies (reactors, production, laboratories, clean-up, waste, transportation, malicious events) for more than 30 years. He is expert in both safety and security aspects of response to nuclear incidents. As emergency consequence assessment manager for U.S. Department of Energy sites and Headquarters, he led plume modeling responses in thousands of exercise, contingency, and "real" activations. Reed is a consultant on emergency management and emergency response to multiple federal, state and local agencies and industrial operations.

Hazards and Risk Assessment: Hazards and risk assessment has been one focus of Reed's analytical efforts for over 30 years. He has developed probabilistic risk assessment software applications and evaluated impacts from potential accidents involving the release of radiological substances, hazardous chemicals, biological agents / toxins and explosives. Analyses have been directed toward emergency planning, facility design and security. He has helped to develop and implement innovative approaches to risk assessment and has applied these methods in the development of hundreds of hazards assessments for hazardous facilities and operations. Reed has also been engaged in public risk communication, perhaps the most challenging aspect of risk assessment.

Education: Reed graduated from the Massachusetts Institute of Technology in 1976 with a BS in Meteorology. He is a Certified Consulting Meteorologist.

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1 INTRODUCTION

Kanner & Whiteley, L.L.C. has engaged Toxicology Excellence for Risk Assessment (TERA) to conduct a review of a Draft Environmental Impact Statement (DEIS). The DEIS, prepared by the U.S. Nuclear Regulatory Commission (NRC), addresses a license application from Interim Storage Partners L.L.C (ISP) for a Consolidated Interim Storage Facility (CISP) in Andrews County, Texas [NRC, 2020, NUREG–2239, "Environmental Impact Statement for Interim Storage Partners LLC's License Application for a Consolidated Interim Storage Facility for Spent Nuclear Fuel in Andrews County, Texas. Draft Review for Comment," U.S. Nuclear Regulatory Commission, Washington, DC, May 2020.]

As subcontractor to TERA, AlphaTRAC, Inc. (AlphaTRAC) has conducted a review of the transportation assessment in the DEIS. This report provides that review.

2 DEIS TRANSPORTATION REVIEW COMMENTS

2.1 DEIS EXECUTIVE SUMMARY

1 (Hodgin) CONCERN. The Executive Summary: Transportation – Construction does not consider the impact of construction traffic on the remaining traffic capacity of Texas State Highway 176.

> BASIS: The EIS addresses the impact of incremental traffic from the project does not consider the impact of construction traffic on the remaining traffic capacity of Texas State Highway 176 after projected traffic from all other sources during operational period are accounted for.
>
> A proper EIS must consider the capacity of the major roadways and bridges along with the strategically projected traffic from all other sources during the construction period.

2 (Hodgin) CONCERN. The Executive Summary: Transportation – Operations does not consider that worker traffic will be unevenly distributed, peaking around shift changes for incoming and outgoing traffic.

> BASIS: Worker traffic will be unevenly distributed, peaking around shift changes for incoming and outgoing traffic. The current approach using daily average traffic does not consider that the traffic is unevenly distributed in time and may underestimate impacts.
>
> A proper EIS must consider the expected time variability of worker traffic, centered around shift changes.

3 (Hodgin) CONCERN. The Executive Summary: Transportation – Operations does not consider that, in a rural area where trains are infrequent, the frequency of marginally safe railroad crossings may be greater than a national average number.

> BASIS: In a rural area where trains are infrequent, the frequency of marginally safe railroad crossings may be greater than a national average number. Using a national average number may underestimate the potential impacts.
>
> A proper EIS must apply railroad crossing / accident values that are representative of a rural area with infrequent train traffic.

4 (Hodgin) CONCERN. The Executive Summary: Transportation – Operations does not consider that the frequency of marginally safe railroad crossings may be greater than a national average number at specific originating sites.

> BASIS: The frequency of marginally safe railroad crossings may be greater than a national average number at specific originating sites. Using a national average number may underestimate the potential impacts.
>
> A proper EIS must apply railroad crossing / accident values that are representative of expected originating sites.

2.2 DEIS SECTION 3, DESCRIPTION OF THE AFFECTED ENVIRONMENT

5 (Hodgin) CONCERN. Section 3.3.1: Description of the Affected Environment – Transportation – Regional and Local Transportation Characteristics does not consider that traffic data from 2015 may not be representative of the operational period for the project.

> BASIS: Traffic data from 2015 may not be representative of the operational period for the project.
>
> A proper EIS must project traffic conditions for the operational period of the project, using state and regional strategic projections, internal industrial projections and other available sources.

2.3 DEIS SECTION 4, ENVIRONMENTAL IMPACTS

6 (Hodgin) CONCERN. 4.3.1.2.2.1: Transportation – Radiological Impacts to Workers from Incident-Free Transportation of SNF inappropriately states that occupational incident-free collective doses for the proposed action are small fractions of the comparable background collective doses.

> BASIS: Use of the term "small" implies a value judgment that the reader should make for themselves. In fact, the projected occupational doses listed in the DEIS are

approximately 19% of background doses, which may not be considered small fractions by some readers.

A proper EIS must include actual data when presenting results and not make value-based judgments until drawing final subjective conclusions.

7 (Hodgin) CONCERN. Section 4.3.1.2.2 of the DEIS considers shipments to and from the proposed CISF, but does not appear to consider impacts from:

- Elevated doses during shipment from canisters that fail to meet external contamination / radiation requirements upon arrival at the CISF
- The return of canisters that fail to meet external contamination / radiation requirements upon arrival at the CISF and are rejected

These shipments may add materially to the projected doses to workers and the public over the life of the project and may individually exceed the radiation dose assumptions in the NRC calculations and must be accounted for in NRC evaluation.

BASIS: The EIS does not include projected doses from shipments that fail to meet external contamination / radiation criteria upon arrival at the CISF, projected doses from the return of shipments that fail to meet external contamination / radiation requirements and projected doses from return of noncompliant transportation casks in its analysis of transportation doses to workers and the public. As identified by the U.S. Nuclear Waste Technical Review Board [U.S. Nuclear Waste Technical Review Board, 2019. "Preparing for Nuclear Waste Transportation," U.S. Nuclear Waste Technical Review Board, Washington, DC, September 2019]:

> NRC regulations applicable to transporting SNF [See 10 CFR Part 71] do not require an SNF canister to remain leak-tight. However, if a canister were to leak radioactive material during transportation, the resulting radioactive contamination inside the transportation cask may possibly require cleanup and recovery actions after transportation. Furthermore, the affected SNF canister might not be accepted for storage at the destination storage site without remediation.

8 (Hodgin) CONCERN. Section 4.3.1.2.2 of the DEIS determines that it is not necessary to addresses the potential impacts of this degraded transportation infrastructure or impacts of the actions necessary to bring the infrastructure into an operational condition and did not consider them further.

BASIS: A recent report to Congress from the U.S. Nuclear Waste Technical Review Board, titled "Preparing for Nuclear Waste Transportation," [U.S. Nuclear Waste Technical Review Board, 2019. "Preparing for Nuclear Waste Transportation," U.S. Nuclear Waste Technical Review Board, Washington, DC, September 2019] found that, at some decommissioned Nuclear facilities with SNF stored on site:

> "Previously usable transportation routes such as paved roads, railways, and barge docks are not being maintained any more than is necessary to allow for infrequent, periodic surveillance of the SNF storage facility."

A proper EIS must address the current and projected condition of transportation infrastructure in the vicinity of shipper sites, identify those that are or likely to become degraded, and included analysis of impacts from that infrastructure and the actions needed to upgrade it.

9 (Hodgin) CONCERN. Section 4.3.1.2.2 of the DEIS does not assess environmental impacts from concurrent shipping of SNF by the ISP project and the major DOE shipping campaign.

BASIS: The U.S. Nuclear Waste Technical Review Board report, titled "Preparing for Nuclear Waste Transportation," [U.S. Nuclear Waste Technical Review Board, 2019. "Preparing for Nuclear Waste Transportation," U.S. Nuclear Waste Technical Review Board, Washington, DC, September 2019] evaluated a proposed major rail shipping campaign for SNF and High-Level Radioactive Waste envisioned by the U. S. Department of Energy (DOE). The report indicates that DOE believes shipping could begin in as little as seven years. Nationally, DOE will be using the same railroad infrastructure for its major shipping program as the ISP project, with an overlapping period of performance.

A proper EIS must estimate environmental impacts from concurrent shipping of SNF by the ISP project and the major DOE shipping campaign. Impacts would be expected to include, but not be limited to, rail infrastructure wear and degradation, increased dose impacts to the public from stopped shipments, increased cumulative dose impacts to the public from both campaigns, and increased accident rates.

10 (Hodgin) CONCERN. 4.7.1.1: Transportation – Air Quality - Operations does not properly consider non-radiological air quality impacts from train movements.

BASIS: Rail emissions can be significant, even from a line source. The EIS considers railroad engine emissions to be averaged over a year, but actual train transport is expected to be more granular, with shipments varying by day. If emissions were analyzed and compared to 24-hour air quality standards the relative impacts may be assessed as more severe. The current approach is likely to underestimate the air quality impacts from the project.

A proper EIS must consider 24-hour non-radiological air quality impacts from railroad operations instead of the current, less conservative approach of evaluating annual average impacts.

11 (Hodgin) CONCERN. Section 4.15 of the DEIS makes inappropriate assumptions about the level of training and preparation of local emergency responders to respond to the radiological emergencies that could occur with SNF shipments.

> BASIS: The DEIS states that affected communities may be able to obtain emergency response financial assistance necessary for training and equipment from other sources or Federal programs or other sources. The assumption that rural and small community emergency responders will in some external way obtain the training, equipment and resources to effectively respond to a radiological emergency is unlikely and non-conservative. Without this training it is likely that the risk of radiological exposure to responders or the public would increase.
>
> A proper EIS must assume that emergency responders will arrive at the scene of a radiological incident with insufficient training, equipment and resources to respond to a radiological emergency, and would include this assumption in its analyses.

12 (Hodgin) CONCERN. Section 4.15 of the DEIS does not determine whether NUREG-2125 needs to be updated before relying on it for baseline SNF transportation risk assessment.

> BASIS: The DEIS utilizes the generic "Spent Fuel Transportation Risk Assessment: Final Report" [U.S. Nuclear Regulatory Commission, 2014, NUREG-2125, "Spent Fuel Transportation Risk Assessment," ADAMS Accession No. 15 ML14031A323, Washington, DC, U.S. Nuclear Regulatory Commission, January 2014.] as its transportation accident analysis. The report is now six years old. The data and assumptions on which the analysis is based would be reasonably expected to have changed in the intervening time.
>
> A proper EIS must determine whether NUREG-2125 needs to be updated before relying on it for baseline SNF transportation risk assessment. Alternatively, it does not seem to advance the EIS. The EIS must include any updated information, data and analyses in its assessment.

13 (Hodgin) CONCERN. Section 4.15 of the DEIS does not determine if the generic assumptions and analyses incorporated in NUREG-2125 properly represent the specific conditions in the area of the proposed facility.

> BASIS: The DEIS utilizes the "Spent Fuel Transportation Risk Assessment: Final Report" [U.S. Nuclear Regulatory Commission, 2014, NUREG-2125, "Spent Fuel Transportation Risk Assessment," ADAMS Accession No. 15 ML14031A323, Washington, DC, U.S. Nuclear Regulatory Commission, January 2014.] as its transportation accident analysis. NUREG-2125 is a generic analysis, intended to apply to any transportation of spent nuclear fuel in the United States. However, the conditions associated with the area in SW Texas and SE New Mexico where all of the waste-bearing trains converge are specific to the region and would not be expected to match the generic conditions applied in NUREG-2125 in some aspects. The area is remote and very rural. Transportation infrastructure is typical of those conditions, not the nation as a whole.

Examples include railroad condition, railroad grades, road traffic make-up, road traffic patterns, and vehicle driver behavior.

Additionally, although generic assumptions may make sense in certain contexts, they do not here, because of the unprecedented nature of the CISF taking waste from multiple sites over time in amounts greater than ever evaluated.

A proper EIS must evaluate NUREG-2125 and identify if the generic assumptions and analyses do not represent the specific conditions in the area of the proposed facility and the unprecedented nature of the CISF taking waste from multiple sites over time in amounts greater than ever evaluated and, if so, revise the baseline risk assessment accordingly. The EIS must include regionally-specific information, data and analyses in its assessment.

14 (Hodgin) CONCERN. Section 4.15 of the DEIS does not fully identify and analyze plausible accident scenarios in which release from containment could occur.

BASIS: The DEIS utilizes the generic "Spent Fuel Transportation Risk Assessment: Final Report" [U.S. Nuclear Regulatory Commission, 2014, NUREG-2125, "Spent Fuel Transportation Risk Assessment," ADAMS Accession No. 15 ML14031A323, Washington, DC, U.S. Nuclear Regulatory Commission, January 2014.] as its transportation accident analysis. The NRC in NUREG 2125 and in the DEIS determined that breach of containment and release of radioactive materials to the atmosphere would not occur under even the most severe accidents studied. As a result, release of radioactive material during a transportation accident and the associated impacts on workers, responders, the public and the environment were not analyzed.

The impossibility of a breach of containment and release of radioactive material to the environment during an accident is a defining assertion in the DEIS. But it is based on the spectrum of accidents chosen for consideration. Therefore, a follow-on question should be posed: "Is there ***any*** plausible accident scenario in which radioactive material could be released to the environment?" This is different than concluding that no release occurred under the scenarios postulated, which are bounded by the imagination, experience and effort available to the analysts.

As an illustrative example, we have identified plausible accident scenarios that could potentially exceed cask / canister damage levels considered in the DEIS and potentially release radioactive material from containment and into the atmosphere. Example scenarios include:

- Train Impact Exceeding Design Speed
- Train Engulfed in Wildfire

It was determined in a preliminary analysis that these scenarios met the test for plausibility and could result in the release of radioactive materials to the atmosphere.

A hazards assessment was conducted for the train impact scenario, using standard hazards assessment methods specified by the U. S. Department of Energy for accidents involving radioactive materials. The DOE HotSpot atmospheric dispersion model was employed to estimate atmospheric transport, dispersion and doses at selected locations downwind from an incident. The analysis included data from NRC analyses where possible.

Like similar NRC analyses, the hazards assessment was conducted to be conservative – to reasonably overestimate impacts in order to avoid unintended underestimation.

Key results from the hazards assessment included:

- The projected maximum radiation dose (Total Effective Dose [TED]) would be 2.60E+03 rem (2.6E+01 sv) and would occur at 22 m from the incident. This dose level would exceed the DOE Threshold of Early Lethality (100 rem [1 sv] TED).

- Radiation doses (TED) exceeding the DOE Threshold of Early Lethality (100 rem [1 sv] TED) were projected to occur out to 210 m from the incident. It is expected that emergency responders and members of the public could be within this distance at many locations along the transportation routes.

- Radiation doses (TED) exceeding the DOE Protective Action Criterion for considering sheltering or evacuation of the public (1 rem [0.01 sv] TED) were projected to occur out to 2 km from the incident. It is expected that emergency responders and members of the public would be within this distance at many locations along the transportation routes.

A proper EIS must identify and analyze plausible accident scenarios in which containment protective assumptions in NUREG-2125 do not apply.

15 (Hodgin) CONCERN. Section 4.15 of the DEIS does not consider a plausible impact-related accident scenario in which release from containment to the atmosphere would occur.

BASIS: The DEIS utilizes the generic "Spent Fuel Transportation Risk Assessment: Final Report" [U.S. Nuclear Regulatory Commission, 2014, NUREG-2125, "Spent Fuel Transportation Risk Assessment," ADAMS Accession No. 15 ML14031A323, Washington, DC, U.S. Nuclear Regulatory Commission, January 2014.] as its transportation accident analysis. A runaway train could plausibly exceed the maximum speed considered in the NUREG-2125 analysis and release radioactive material into the environment, resulting in a contaminated accident scene and atmospheric transport beyond the scene. Radiological impacts to workers, emergency responders and the public, significantly higher than those currently estimated, would be expected from this scenario.

The EIS is expected to analyze and determine the impacts from a spectrum of reasonable and foreseeable accident scenarios. Based on the analysis in NUREG-2125, the DEIS determines that release of radioactive material is not possible in a train impact scenario.

Release of radioactive material should have been but was not further analyzed for impact-related accidents involving the type of cask / canister configuration planned for the project. In addition, NUREG-2125 should have but did not consider if accident-related impact could degrade casks in the future.

A plausible project-specific accident scenario that is not considered in NUREG-2125 and would exceed the boundaries of the generic analysis is: a train carrying SNF casks exceeds the maximum impact speed considered in NUREG-2125 (120 MPH), derails and crashes. NUREG-2125 states that damage would begin to occur to the type of cask / canister configuration planned for this project at approximately 90 MPH impact speed but does not identify the speed at which canister rupture and release of spent fuel would occur. A runaway train could plausibly exceed the maximum speed considered in the NUREG-2125 analysis and release radioactive material into the environment, resulting in a contaminated accident scene and atmospheric transport beyond the scene.

A proper EIS must consider this plausible impact-related accident scenario in which impact speed and force assumptions in NUREG-2125 would be exceeded, resulting in a release of radioactive material to the atmosphere.

16 (Hodgin) CONCERN. Section 4.15 of the DEIS does not consider a plausible impact-related accident scenario in which release from containment to the atmosphere would occur.

BASIS: The DEIS utilizes the generic "Spent Fuel Transportation Risk Assessment: Final Report" [U.S. Nuclear Regulatory Commission, 2014, NUREG-2125, "Spent Fuel Transportation Risk Assessment," ADAMS Accession No. 15 ML14031A323, Washington, DC, U.S. Nuclear Regulatory Commission, January 2014.] as its transportation accident analysis. A wildfire in a wooded area could exceed the fire duration and heat assumptions in the NUREG-2125 analysis, resulting in rupture of the cask / canister configuration, producing a contaminated accident scene and atmospheric transport beyond the scene. Radiological impacts to workers, emergency responders and the public, significantly higher than those currently estimated, would be expected from this scenario.

NUREG-2125 considers only fuel pool fires using fuel included in the train. Based on this analysis the DEIS determines that release of radioactive material is not possible in a fire scenario. Release of radioactive material is not further analyzed for fire-related accidents involving the type of cask / canister configuration planned for the project. A plausible project-specific accident scenario that is not considered in NUREG-2125 and would exceed the boundaries of the generic analysis is: a train carrying SNF casks is involved in a wildfire that engulfs the train. The accident could occur along an approved transport route and the fire could develop while the train is in transit, without sufficient warning to stop or divert the train.

Wildland fires are becoming more common in the mountainous west [National Aeronautics and Space Administration, 2020, https://climate.nasa.gov/blog/2830/six-trends-to-know-about-fire-season-in-the-western-us/, Accessed on October 31. 2020]. A fully involved wildfire with high winds, low humidity and mature fire fuels could develop without warning (due, for example, from a lightning strike) and grow explosively. Temperatures in an extreme forest wildfire can exceed 1,200 deg C, which is significantly greater than the maximum 800 deg C considered in NUREG-2125 [Wotton, Mike & Gould, James & WL, McCaw & Cheney, N. & Taylor, S.W.. (2012). Flame temperature and residence time of fires in dry eucalypt forest. International Journal of Wildland Fire. 22. 10.1071/WF10127]. Temperatures can be even higher in fire tornadoes, now being experienced in some wildfires. The combination of higher temperatures and longer durations could plausibly rupture and release SNF, resulting in a contaminated accident scene and atmospheric transport beyond the scene.

Though typically not as hot or as long in duration as a forest fire, a grassland fire can exceed the 800 deg C considered in NUREG-2125 [Wotton, Mike, 2020. "Grass Fire Behaviour and Flame," http://www.firelab.utoronto.ca/behaviour/grass_fire.html, University of Toronto, Institute of Forestry and Conservation, Accessed October 31, 2020].

Expected routes for the SNF shipments traverse both forest and grassland areas.

A proper EIS must consider this plausible fire-related accident scenario in which fire temperature and duration assumptions in NUREG-2125 are exceeded.

17 (Hodgin) CONCERN. Section 4.15 of the DEIS does not, and should, provide a detailed presentation of the ISP analysis of transportation accidents involving breach of containment.

BASIS: ISP in its Environmental Report evaluated transportation accident scenarios involving breach of containment and release of radioactive material to the atmosphere. NRC reports the results of the ISP analysis and states that the analysis is not applicable because it is not possible for release of radioactive material from containment even under "the most severe accidents studied."

The DEIS states that ISP estimated a maximum individual occupational dose to a first responder of 7.71 rem for a one-day exposure at 33 m from the breached cask. A preliminary analysis, conducted as part of this review, of a transportation impact accident resulting in breach of containment project a total effective dose (TED) at 30 m from the incident of 2.2×10^3 rem TED. This estimate is more than 2 orders of magnitude higher than the ISP estimate.

A proper EIS must include a detailed presentation of the ISP analysis of transportation accidents involving breach of containment, so that these impacts can be verified and considered in evaluation of the EIS and in emergency planning.

18 (Hodgin) CONCERN. Section 4.15 of the DEIS does not consider accident scenarios in which multiple procedural assumptions in NUREG-2125 are not met, which would result in cask / canister failure.

BASIS: The DEIS utilizes the generic "Spent Fuel Transportation Risk Assessment: Final Report" [U.S. Nuclear Regulatory Commission, 2014, NUREG-2125, "Spent Fuel Transportation Risk Assessment," ADAMS Accession No. 15 ML14031A323, Washington, DC, U.S. Nuclear Regulatory Commission, January 2014.] as its transportation accident analysis. Failure to meet assumptions in NUREG-2125 regarding regulatory requirements and procedures (e.g., human error and other forms of noncompliance) could result in rupture of the cask / canister configuration, producing a contaminated accident scene and atmospheric transport beyond the scene. Radiological impacts to workers, emergency responders and the public, significantly higher than those currently estimated, would be expected from this scenario.

NUREG-2125 makes assumptions that regulatory and other requirements for cask manufacture, process quality control, SNF preparation, SNF loading and system sealing are met. However, most historical accidents involve failure of procedural (non-engineered) components of overall systems. For instance, the hydrogen buildup, container rupture and explosion that occurred at the Waste Isolation Pilot Plant (WIPP) in 2014 was the result of failing to follow requirements for the composition of kitty litter used to "solidify" liquid radioactive waste. The accident "could not happen" because procedures did not allow it. A hydrogen buildup scenario associated with, for instance, failure to properly fill a canister with inert gas, could result in container degradation, explosion and release of SNF into the environment. The specific scenarios are not important – history and experience have shown that humans will always find ways to fail in following procedural or substantive regulatory requirements. In fact, multi-point procedural failures are much more common than probability analysis might suggest (due, for instance, to cultural conditions and cascading events).

A proper EIS must consider scenarios in which multiple procedural assumptions (e.g., manufacturing specifications and regulatory / procedural requirements) in NUREG-2125 are not met, resulting in cask / canister failure.

19 (Hodgin) CONCERN. Section 4.15 of the DEIS does not, and should, evaluate the potential and consequences from a criticality event should a transportation accident result in a release and critical configuration of SNF.

BASIS: Since rail accidents involving breach of containers and release of contents are plausible, there is a potential that a critical configuration of SNF could occur, resulting in a criticality event.

A proper EIS must evaluate the potential and consequences from a criticality event should a transportation accident result in a release and critical configuration of SNF.

2.4 DEIS SECTION 5, CUMULATIVE IMPACTS

20 (Hodgin) CONCERN. Section 5.1.2: Cumulative Impacts - Methodology does not properly consider any state and local strategic traffic growth projections that would affect the highways during the project period.

> BASIS: The EIS projects a small incremental effect for traffic-related impacts for all project stages. The EIS does not consider any state and local strategic traffic growth projections that would affect the highways during the project period.
>
> A proper EIS must consider projected strategic growth and compared to the capacity and accident rates for the major roads. The EIS must identify and include formal studies or identify data that can be used for such.

21 (Hodgin) CONCERN. Section 5.3: Cumulative Impacts - Transportation does not consider the impact of project transportation on the overall capacity of the main rail line.

> BASIS: The EIS does not consider projected growth in rail transportation during the project period.
>
> A proper EIS must consider planned project rail traffic should along with projected overall railway use growth and compared to the capacity and accident rates for the rail mainline. The EIS must obtain and include data from BNSF Railroad that can be used for such.

22 (Hodgin) CONCERN. Section 5.3: Cumulative Impacts - Transportation does not consider projected future growth in road and rail transportation for non-project operations.

> BASIS: The EIS concludes that the potential cumulative public dose impacts from the other past, present, and reasonably foreseeable future actions would be SMALL.
>
> The EIS addresses current operating conditions for non-project activities in the area but does not consider projected future growth in road and rail transportation for those non-project operations in the area during the project period.
>
> A proper EIS must consider expected growth in transportation for these external facilities along with strategic growth for the area. Planned project road and rail traffic should be added to projected overall railway use growth and compared to the capacity and accident rates for the highways and rail mainline. The EIS must obtain and include data from external operations that can be used for such.

Review of Draft EIS - Interim Storage Partners CISF

Hazard Assessment of Containment Breach Accidents

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REED HODGIN

Reed's 44-year professional background includes management and operational experience in nuclear emergency management, risk and hazard assessment, crisis decision-making, atmospheric modeling, meteorology, facilitation, and public process management.

Nuclear Emergency Management and Response: Reed has been an emergency manager and consequence assessment team leader for radioactive emergencies (reactors, production, laboratories, clean-up, waste, transportation, malicious events) for more than 30 years. He is expert in both safety and security aspects of response to nuclear incidents. As emergency consequence assessment manager for U.S. Department of Energy sites and Headquarters, he led plume modeling responses in thousands of exercise, contingency, and "real" activations. Reed is a consultant on emergency management and emergency response to multiple federal, state and local agencies and industrial operations.

Hazards and Risk Assessment: Hazards and risk assessment has been one focus of Reed's analytical efforts for over 30 years. He has developed probabilistic risk assessment software applications and evaluated impacts from potential accidents involving the release of radiological substances, hazardous chemicals, biological agents / toxins and explosives. Analyses have been directed toward emergency planning, facility design and security. He has helped to develop and implement innovative approaches to risk assessment and has applied these methods in the development of hundreds of hazards assessments for hazardous facilities and operations. Reed has also been engaged in public risk communication, perhaps the most challenging aspect of risk assessment.

Education: Reed graduated from the Massachusetts Institute of Technology in 1976 with a BS in Meteorology. He is a Certified Consulting Meteorologist.

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Table of Contents

1 Summary

AlphaTRAC, Inc. (AlphaTRAC) has conducted a hazard assessment for accidents involving loss of containment and release of spent nuclear fuel (SNF). This report documents that hazard assessment.

Interim Storage Partners L.L.C (ISP) has requested authorization for the proposed project to store 5,000 metric tons (MTHM)[1] of SNF from decommissioned and decommissioning reactor sites, as well as from operating reactors prior to decommissioning for a 40-year license period. At full capacity, the facility could eventually store up to 40,000 MTHM of SNF.

ISP has developed and submitted an Environmental Report for the proposed Consolidated Interim Storage Facility (CISF) to the U.S. Nuclear Regulatory Commission (NRC). The report included analysis of potential accidents impacting casks and canisters during transportation and operations. Transportation accidents were of primary consideration because of the higher probability and severity of accidents. As part of its analysis, ISP evaluated transportation accident scenarios that assumed a release of radioactive material.

In evaluating accidents for an assessment such as an Environmental Impact Statement (EIS), a range of scenarios are postulated and then analyzed. The NRC primarily employs a risk-based approach, where the probability and consequence are jointly considered to determine the risk associated with the accident.

Emergency assessment and planning typically relies on a somewhat different approach. A spectrum of accident scenarios is identified, and the accidents are analyzed without regard to their probability. To be considered, the accidents must be plausible, which in this context means that they are realistic, credible and reasonable. The plausibility test is in part subjective, based on the judgment of an informed observer, such as a hazard analyst. Scenarios that are physically possible but are not realistic, credible or reasonable are excluded from the analysis.

The hazard-based approach is incorporated in the EIS process through the inclusion of "severe events" [10 CFR Part 51] A severe event is a scenario that is below the probability threshold that would normally be considered in a risk-based analysis but is plausible and may drive decision-making. The inclusion of severe events in accident

[1] Metric tons of heavy metal

assessments stems from a recognition that low probability events can and do happen - and can have defining effects on policy and practice.

The NRC has postulated and analyzed potential SNF transportation accidents, including severe events, resulting from fires and impacts. NRC has determined that releases from the type of cask / canister configuration to be used in the ISP project are not possible, even under the most severe conditions analyzed.

In the current analysis a follow-on question was posed: “Is there ***any*** plausible accident scenario in which radioactive material could be released to the environment?” Two example accidents were examined:

- Train carrying SNF Engulfed in Wildland fire
- Train carrying SNF Impact Exceeding Design Speed

It was determined in a preliminary analysis that these scenarios met the test for plausibility and could result in the release of radioactive materials to the atmosphere.

A hazards assessment was conducted for the train impact scenario, using standard hazards assessment methods specified by the U. S. Department of Energy for accidents involving radioactive materials (DOE, 2014). The DOE HotSpot atmospheric dispersion model was employed to estimate atmospheric transport, dispersion and doses at selected locations downwind from an accident. The analysis included data from NRC analyses where possible.

Like similar NRC analyses, the hazards assessment was conducted to be conservative – to reasonably bound impacts.

Key results from the hazards assessment include:

- The projected maximum radiation dose (Total Effective Dose [TED]) is 2.60E+03 rem (2.6E+01 Sv) and occurs at 22 m from the accident. This dose level exceeds the DOE Threshold of Early Lethality (DOE, 2014) of 100 rem [1 Sv] TED).
- Radiation doses (TED) exceeding the DOE Threshold of Early Lethality (100 rem [1 Sv] TED) are projected to occur out to 210 mm from the accident. It is expected that emergency responders and members of the public will be within this distance at many locations along the transportation routes.
- Radiation doses (TED) exceeding the DOE Protective Action Criterion (DOE, 2014) for considering sheltering or evacuation of the public (1 rem [0.01 Sv] TED) are projected to occur out to 2.0 km from the accident. It is expected that

emergency responders and members of the public will be within this distance at many locations along the transportation routes.

This analysis shows that the spectrum of accidents that should be considered in the DEIS must include severe accidents that will plausibly breach containment and release radioactive material into the atmosphere. If such a breach occurs, significant impacts to emergency responders and the public would be expected, resulting in the need for public protective actions. The DEIS is incomplete without such considerations.

2 INTRODUCTION

Kanner & Whiteley, L.L.C. has engaged Toxicology Excellence for Risk Assessment (TERA) to conduct a review of a Draft Environmental Impact Statement (DEIS). The DEIS, prepared by the NRC, addresses a license application from ISP for a CISF in Andrews County, Texas (NRC, 2020).

As subcontractor to TERA, AlphaTRAC, Inc. (AlphaTRAC) has conducted a hazard analysis for accidents involving loss of containment and release of SNF to the environment that should be included in the ISP DEIS. This report documents that hazard analysis.

3 THE PROPOSED ACTIVITY

The following description of the proposed activity is taken or paraphrased from the ISP DEIS (NRC, 2020).

ISP has requested authorization for the proposed project to store 5,000 MTHM of SNF from decommissioned and decommissioning reactor sites, as well as from operating reactors prior to decommissioning for a 40-year license period. ISP anticipates that it will subsequently request amendments to the license, under which it would store an additional 5,000 MTHM of SNF for each of seven planned expansion phases for the proposed CISF. At full capacity, the facility could eventually store up to 40,000 MTHM of SNF.

The proposed project area is situated about 0.6 km [0.37 mi] east of the Texas and New Mexico state boundary at a location in Andrews County, Texas, that is approximately 52 kilometers (km) [32 miles (mi)] west of Andrews, Texas, and 8 km [5 mi] east of Eunice, New Mexico (Figure 1). The proposed CISF would be built and operated on an approximately 130-hectare (ha) [320-acre (ac)] project area within a 5,666-ha [14,000-ac] parcel of land that is controlled by ISP joint venture member Waste Control Specialists (WCS) in Andrews County, Texas (ISP, 2020). The project area would be located north of WCS's existing waste management facilities, which include two Low Level Radioactive Waste (LLRW) disposal facilities, a LLRW / Mixed Low Level Waste (MLLW) disposal facility and a byproduct material disposal facility.

For the proposed action (Phase 1 of the overall program), ISP proposes to store SNF in TN Americas six existing dual-purpose 8 canister-based dry cask storage systems (DCSS) or NAC International (NAC) 9 DCSSs (ISP, 2018). The 6 TN Americas DCSS consist of 11 different SNF dry storage canisters (DSCs) and 5 different GTCC waste canisters stored in 5 overpacks. SNF is stored horizontally in the TN Americas systems and vertically in the NAC International systems.

ISP proposes to use dual-purpose canister-based systems for transportation and storage of the SNF. Canisters would be removed from storage overpacks at the originating site and transferred to NRC-licensed shipping casks for transportation to the proposed CISF.

Shipments will be transported to the CISF by way of road, barge and ultimately rail (in varying combinations depending on the current infrastructure or that which can be reasonably restored to support the shipment of SNF). Shipments would ultimately travel to Monahans, TX via national Union Pacific Railroad lines, then north to the CISF via the Texas New Mexico Railroad.

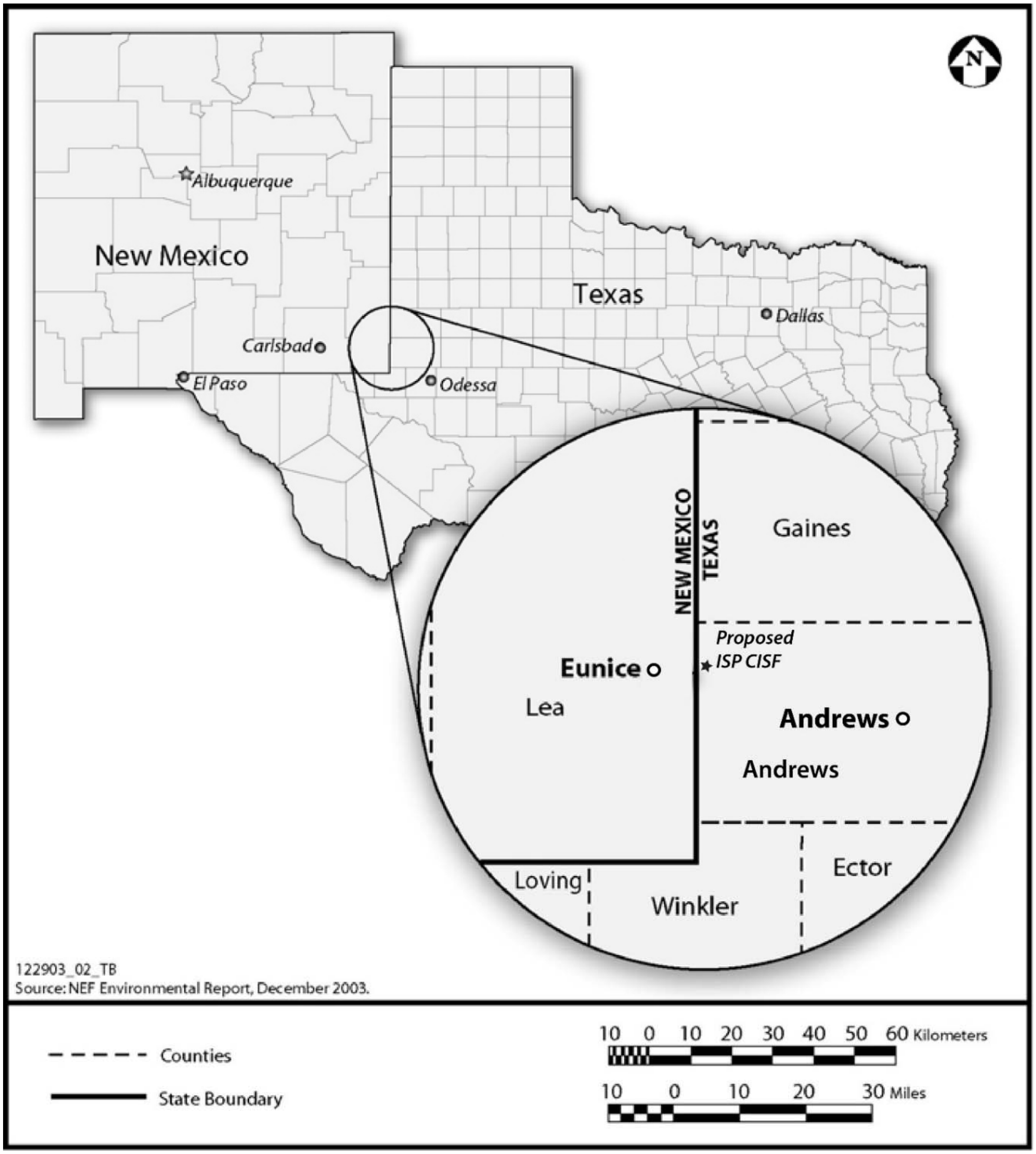

Figure 1 Location of Proposed ISP CISF in Andrews County, Texas (NRC, 2020

4 Background - NRC and ISP Analysis of Accidents for the Proposed Activity

ISP developed and submitted an Environmental Report for the proposed CISF to the NRC (ISP, 2020). The report included analysis of potential accidents impacting casks and canisters during transportation and operations.

ISP evaluated radiation doses and risks from transportation accidents where cask shielding would remain intact and where shielding had been damaged. ISP also evaluated transportation accident scenarios that assumed a release of radioactive material. AlphaTRAC did not review the ISP Environmental Report.

As part of developing the DEIS, NRC evaluated the ISP submittal, reviewed and applied the results of the NRC generic SNF transportation risk assessment [NUREG-2125 (NRC 2014), and conducted independent analyses of its own.

NRC reported in the DEIS that ISP acknowledged that its consideration of accidents involving a release for canistered SNF is conservative because of the conclusion in NUREG–2125 that no radioactive material would be released in an accident if SNF was contained in an inner welded canister.

Based on its reviews and analyses, NRC concluded that radioactive materials could not be released to the environment, even under the most severe accident scenarios and that direct radiation from SNF inside the canisters would be the only source of exposure to responders and the public (NRC, 2020).

5 Accident Analysis in the DEIS

5.1 Risk-based and Hazard-based Analyses

In evaluating accidents for an assessment such as an EIS, a range of scenarios are postulated and then each is analyzed to project consequences to the workers public, the environment or other end points. The NRC primarily employs a risk-based approach, where the probability and consequence are jointly considered to determine the risk associated with the accident. NRC uses the risk calculated for accidents to assess the impact of these accidents in the EIS.

Emergency assessment and planning typically relies on a somewhat different approach. A spectrum of accident scenarios is identified, and the accidents are analyzed without regard to their probability. To be considered, the accidents must be plausible, which in this context means that they are realistic, credible and reasonable. Scenarios that are physically possible but are not realistic, credible or reasonable are excluded from the analysis. The philosophy is that low probability events can and do happen, and an organization, facility or community should be prepared for response to them.

5.2 Severe Events

The hazard-based approach is incorporated in the EIS process through the inclusion of "severe events." A severe event is a scenario that is below the probability threshold that would normally be considered in a risk-based analysis, but is plausible and may drive decision-making (such as the level of impact determined in an EIS).

The inclusion of severe events in accident assessments stems from a recognition that low probability events can and do happen - and can have defining effects on policy and practice. The recent radiological accident in Fukushima, Japan led the U.S. government to require the inclusion of severe events in risk and emergency assessments.

The NRC has postulated and analyzed potential SNF transportation accidents, including severe events, resulting from fires and impacts in NUREG-2125 (NRC, 2014). As a result of its analysis, NRC determined that, for the type of container planned for the ISP program, "Even in the worst-case fires analyzed, no cask experienced a seal failure that could have led to a release of radioactive material from the spent fuel cask."

With regard to impact accidents, "… the steel shielded cask with inner welded canister and the DU-shielded cask have no release and no loss of gamma shielding effectiveness even under the most severe impacts studied, which encompass all historic or even realistic accidents."

The impossibility of a breach of containment and release of radioactive material to the environment during an accident is a defining conclusion in the DEIS. Therefore, a follow-on question should be posed: "Is there ***any*** plausible accident scenario in which radioactive material could be released to the environment?" This is different than concluding that no release occurred under the scenarios postulated, which are bounded by the imagination, experience and effort available to the analysts. This is not a criticism – it is a limitation faced by all hazard analysts.

5.3 Additional Severe Events

For illustrative purposes, a preliminary analysis was conducted for two additional severe event scenarios for the ISP transportation accident analysis:

- Train Engulfed in Wildland Fire
- Train Impact Exceeding Design Speed

5.3.1 Train Engulfed in Wildland Fire

NUREG-2125 fire scenarios are restricted to fuel pool fires using fuel included in the train. Based on this analysis, NUREG-2125 (and thus the DEIS) determines that release of radioactive material is not possible in a fire scenario. Release of radioactive material is not further analyzed for fire-related accidents involving the type of cask / canister configuration planned for the project. A plausible project-specific accident scenario that is not considered in NUREG-2125 and could exceed the boundaries of the generic analysis is: a train carrying SNF casks is involved in a wildland fire that engulfs the train. Such fires can initiate and spread very rapidly. A train shipment properly authorized based on current and projected conditions could become involved in a wildland fire that initiates and spreads while the train is enroute and before it can stop or divert.

Wildland fires are becoming increasingly common in the mountainous west (NASA, 2020). Large scale, rapidly moving wildland fires with high winds, low humidity and mature fire fuels are not only plausible but are occurring at record rates (previously low probability by definition) in the western United States.

Temperatures in an extreme wildland fire can exceed 1,200 deg C(Wotton et. Al, 2012; Wotton, 2020), which is significantly greater than the maximum 800 deg C considered in NUREG-2125 scenarios. Temperatures can be even higher in fire tornadoes, now being experienced in some wildland fires. The combination of higher temperatures and longer durations could plausibly rupture and release SNF from containment on a transporting train, resulting in a contaminated accident scene and atmospheric transport beyond the scene.

5.3.2 Train Impact Exceeding Design Speed

NUREG-2125 (and thus the DEIS) determines that release of radioactive material is not possible in a train impact scenario. Release of radioactive material is not further analyzed for impact-related accidents involving the type of cask / canister configuration planned for the project.

A plausible project-specific accident scenario that is not considered in NUREG-2125 and could exceed the boundaries of the generic analysis is: a train carrying SNF casks exceeds the maximum impact speed considered in NUREG-2125 (120 MPH), derails and crashes. A recent historical example that illustrates this plausibility is the rear-end collision accident that occurred on the Cima Grade near Kelso, CA on November 17, 1980 (NTSB, 1981). A freight train lost braking capability on a long downhill grade and reached speeds as high as 127 MPH before impacting the rear of another train (Trainboard, 2020).

NUREG-2125 states that damage would begin to occur to the type of cask / canister configuration planned for this project at approximately 90 MPH impact speed but does not identify the speed at which canister rupture and release of spent fuel would occur. A runaway train could plausibly exceed the maximum speed considered in the NUREG-2125 analysis and release radioactive material into the environment, resulting in a contaminated accident scene and atmospheric transport beyond the scene.

5.4 Conclusion Regarding Plausibility

Example plausible accident scenarios have been identified that could exceed the cask / canister damage levels considered in the DEIS and potentially release radioactive material from containment and into the atmosphere. In order to meet the requirements of 10 CFR Part 51, these plausible scenarios must be considered in the EIS.

Both of the additional plausible scenarios were considered for analysis. The wildland fire scenario would involve plume rise due to the heat of the fire, which would reduce ground level concentrations and resulting radiation doses. The train impact exceeding design speed would not involve a fire and plume rise, and thus would be the bounding scenario. As the bounding scenario, the train impact exceeding desing speed was selected for further analysis.

6 Hazard Analysis: Train Impact Exceeding Design Speed

The following sections present a hazard analysis for the train impact exceeding design speed scenario. The assessment is an emergency planning oriented hazard analysis rather than a risk analysis. With plausibility established, the consequences of the accident can be considered without regard to the accident's probability.

The SNF transportation impact accident was analyzed in a 3-step process:

1. Calculate the atmospheric release of a mixture of radionuclides from a transportation cask/canister breach
2. Estimate the consequences - atmospheric transport, atmospheric dispersion and human dose - at downwind locations
3. Compare the projected doses to protective action criteria for emergency response

The analytical approach employed is consistent and in compliance with a U.S. Government standard methodology employed and required by the U.S. Department of Energy for evaluation of radiological hazards from emergency accidents (DOE, 2016).

6.1 Calculate the Atmospheric Release

The radionuclide inventory and release parameters for this analysis were taken verbatim from NUREG-2125 (NRC, 2014). Appendix E, Section E.4 of the document presents NRC's analysis of releases of radioactive materials in accidents.

Since NRC did not analyze a rail-steel cask, the inventory associated with a rail-lead cask is presented in NUREG-2125 and used in this analysis.

6.1.1 Material at Risk

The fuel used in NRC's analysis was pressurized-water reactor (PWR) fuel, with a burnup of 45,000 megawatt-days per MTU, which had cooled for 9 years before transport). NRC determined the radionuclide inventory of this fuel using ORIGEN (Croff, 1980).

The projected inventory of the SNF contained a large number of radionuclides. NRC used a radiotoxicity ranking process to select twenty-four radionuclides that represented 99.9% of the radiotoxicity in the mixture. This representative mixture and radionuclide-specific radioactivities (material at risk [MAR]) are shown in Table 1.

6.1.2 Release Fractions

The concept of release fractions is used to determine the portion of the MAR that is released to the atmosphere for transport and dispersion. NRC's approach employed two release fractions:

- **Rod-to-Cask**: the fraction of the material that is released from the SNF through a breach in the fuel rod cladding to the interior of the transportation cask.
- **Cask-to-Environment** : the fraction of the material that is released from the interior of the transportation cask through the breach in the cask to the atmosphere.

NRC calculated the release fractions for dispersible particles for non-gaseous radionuclides, limited to activity mean aerodynamic diameters (AMAD) of 10 μm or less.

The release fractions for the radionuclides in the SNF mixture are presented in Table 1.

6.1.3 SOURCE TERMS

The amount of material released to the atmospheric for transport and dispersion is known as the "source term" (the terminology derives from the structure of the Gaussian dispersion equation, the basis for atmospheric modeling used in this analysis). The source term is the release amount entered to the atmospheric dispersion model for plume projections.

In the NUREG-2125 approach, the source term for each radionuclide is calculated as:

$$ST(i) = MAR(i) \times RtoC(j) \times CtoE(j) \qquad \textbf{Eq } 1$$

where ST(i) = source term (Ci,Bq) for radionuclide *i*

MAR(i) = material at risk (Ci, Bq) for radionuclide *i*

RtoC(j) = Rod-to-Cask release fraction (fraction) for physical form *j*

CtoE(j) = Cask-to-Environment release fraction (fraction) for physical form *j*

The individual radionuclide source terms, ST(i), are used to create a source term library that serves as the "source term" input for the HotSpot model.

The results of source term calculations for each radionuclide in the mixture is presented in Table 1.

Table 1 Radionuclide Inventory and Source Term Calculation for the Transportation Cask/Canister Breach Scenario

NUREG-2125 Source Term Analysis					
	NUREG-2125, Table E-15		NUREG-2125, Table E-16		
Radionuclide	Form	MAR (Ci)	Release Fractions		Source Term (Ci)
			Rod to Cask	Cask to Env	
Am-241	Particulate	5.21E+03	4.80E-06	7.00E-01	1.75E-02
Pu-240	Particulate	4.97E+03	4.80E-06	7.00E-01	1.67E-02
Pu-238	Particulate	4.85E+03	4.80E-06	7.00E-01	1.63E-02
Pu-241	Particulate	2.82E+05	4.80E-06	7.00E-01	9.48E-01
Y-90	Particulate	1.09E+06	4.80E-06	7.00E-01	3.66E+00
Sr-90	Particulate	1.09E+06	4.80E-06	7.00E-01	3.66E+00
CS-137	Volatile	1.36E+06	3.00E-05	5.00E-01	2.04E+01
Pu-239	Particulate	1.94E+03	4.80E-06	7.00E-01	6.52E-03
CM-244	Particulate	8.52E+02	4.80E-06	7.00E-01	2.86E-03
Cs-134	Volatile	8.18E+04	3.00E-05	5.00E-01	1.23E+00
Eu-154	Particulate	3.95E+03	4.80E-06	7.00E-01	1.33E-02
Ru-106*	Particulate	1.26E+04	4.80E-06	7.00E-01	4.23E-02
Cm-243	Particulate	3.13E+01	4.80E-06	7.00E-01	1.05E-04
Am-243	Particulate	2.69E+01	4.80E-06	7.00E-01	9.04E-05
Ce-144	Particulate	4.85E+03	4.80E-06	7.00E-01	1.63E-02
Pu-242	Particulate	1.66E+01	4.80E-06	7.00E-01	5.58E-05
Sb-125	Particulate	1.16E+04	4.80E-06	7.00E-01	3.90E-02
Eu-155	Particulate	1.64E+04	4.80E-06	7.00E-01	5.51E-02
Am-242m	Particulate	4.40E+00	4.80E-06	7.00E-01	1.48E-05
Am-242	Particulate	4.38E+00	4.80E-06	7.00E-01	1.47E-05
Co-60	CRUD	1.50E+03	1.00E+00	1.00E-03	1.50E+00
Te-125m	Particulate	2.84E+03	4.80E-06	7.00E-01	9.54E-03
U-234	Particulate	1.55E+01	4.80E-06	7.00E-01	5.21E-05
Kr-85	gas	9.01E+04	1.20E-01	8.00E-01	8.65E+03

*Ru-106 was included in the NRC-developed inventory but not modeled because the nuclide was not included in the model library for ingrowth / decay and dose assessment.

6.2 Estimate the Consequences

Atmospheric dispersion models are typically employed in hazards analyses and risk assessments to estimate the consequences from atmospheric releases of radionuclides. Atmospheric dispersion models calculate the transport, dilution, dispersion (spread) of a released plume, then determine the projected atmospheric concentrations and ground deposition at specified locations.

When radionuclides are involved, atmospheric dispersion models may also estimate ingrowth and decay of daughter products, direct penetrating radiation from the plume (plume immersion), direct penetrating radiation from deposited radionuclides (groundshine), rainout of radionuclides from the plume and wind-borne resuspension of deposited materials. Models may also calculate radiation doses to organs and the human system through multiple pathways for a mixture of radionuclides.

The release of radionuclides in this analysis was modeled using the HotSpot dispersion model (Homann, 2019). HotSpot was developed by the U.S. Department of Energy (DOE) specifically to analyze impacts from potential or actual releases of radioactive materials in emergency accidents. The atmospheric transport and dispersion algorithms employed in HotSpot are based on the Gaussian models for puffs and plumes, similar to the RADTRAN model employed by the NRC (Taylor and Daniel, 1977).

The HotSpot Health Physics Code provides a usually conservative means for estimation associated with an atmospheric release and the resulting radiation dose outcomes. The HotSpot atmospheric dispersion models are designed for near-surface releases, short-range (less than 10 km) dispersion, and short-term (less than 24 hours) release durations in unobstructed terrain and simple meteorological conditions.

HotSpot includes four general models of atmospheric dispersion and deposition: Plume, Explosion, Fire, and Resuspension. These models estimate the downwind radiological impact following the release of radioactive material resulting from a continuous or puff release, explosive release, fuel fire, or an area contamination event.

HotSpot calculates radiation doses to the human system using Federal Guidance Reports 11, 12, and 13 (FGR-11, FGR-12, FGR-13) Dose Conversion Factors (DCFs) for inhalation, immersion, and ground shine.

6.2.1 Transport and Dispersion Parameters for HotSpot Application

The HotSpot model includes transport and dispersion parameters that must be established for each model run. Key parameters used in the ISP SNF Transportation scenario are summarized in Table 2.

Table 2 HotSpot Transport and Dispersion Parameters Used in the ISP SNF Transportation Accident Analysis

Category	Parameter	Value
Setup	Terrain	Rural
	Radiological Units	Classic (rem, rad, Ci)
	Distance Units	Metric

Category	Parameter	Value
	Wind Input Height	10 m (Standard wind monitoring height)
	Source Geometry	Simple
	Mixing Layer	Not enabled
	Non-respirable Deposition Velocity	8 cm/s (default)
	Enable Rainout	Not enabled
	Explosion Model ARF Distribution	Not enabled (Not Applicable)
	Holdup Time	0 (Not applicable)
	Include Ground Shine	Enabled
	Include Resuspension	Enabled (Duration = 4 days)
	DCF Library	FGR 13
	Dose Contours – Inner	100 rem TED
	Dose Contours – Middle	1 rem TED
	Dose Contours – Outer	0.1 rem TED
	Deposition Units	dpm/100 cm^2
	Deposition Contours – Inner	10,000 dpm/100 cm^2
	Deposition Contours – Middle	1,000 dpm/100 cm^2
	Deposition Contours – Outer	100 dpm/100 cm^2
	Breathing Rate	4.17 E-04 m^3/s (DOE representative adult breathing rate)
Models	Atmospheric Dispersion Model	General Plume
Source Term	Radionuclides	Library created from Table 1
	Effective Release Height	2.0 m (specified in NUREG-2125)
	Damage Ratio	1 (not applicable)
	Leakpath Factor	1 (not applicable)
	Calculate plume rise	No
Meteorology	10-meter Wind Speed	1 m/s (Adverse conditions as defined in DOE O 151.1D)
	Pasquil-Gifford Stability Class	F (Adverse conditions as defined in DOE O 151.1D)
	Wind Direction	270 deg (not applicable – direction not considered in emergency planning application
Receptors	Receptors	Defined in Table 3
	Receptor Height	1.5 m (represents average breathing height)

6.1 Protective Action Criteria

Projected radiation doses are compared to Protective Action Criteria (PACs) to determine recommended protective actions for the ISP SNF transportation scenario.

The PACs used for radiological materials in this analysis are specified in DOE Order 151.1D (DOE, 2016):

- **PAC-2**: A radiological dose of 1 rem total effective dose (TED) or 5 rem effective dose (ED) to the thyroid, based on U.S. Environmental Protection Agency (EPA) Protective Action Guides (EPA, 1992)
- **PAC-3**: A radiological dose of approximately 100 rem TED

PAC-2 is used by DOE as the threshold for public protective actions (primarily shelter-in-place and evacuation). PAC-3 is used by DOE as a conservative threshold of early lethality (potential lethality due to acute radiation effects).

6.2 Accident Location and Modeling Receptors

The scenario as designed is a transportation accident and could occur at any point of travel from the origin of shipment (e.g., a nuclear power plant) to the ISP CISF. Accident locations would lie along national Union Pacific Railroad lines or Texas New Mexico Railroad lines used to transport the SNF shipments.

Modeling receptors are specified locations for calculation of concentrations, deposition and doses. In this analysis receptor distances begin at the accident location (see above) and extend radially outward. Receptor distances are non-directional, as direction of plume travel would not be known until an accident occurred.

The default locations specified in the HotSpot model were employed in this analysis, as shown in Table 3.

Table 3 Default HotSpot Receptor Distances used in the ISP SNF Transportation Scenario

Modeling Receptor Distance from Accident Location (km)	
0.03	1.0
0.10	2.0
0.20	4.0
0.30	6.0
0.40	8.0
0.50	10
06.0	20
0.70	40
0.80	60
0.90	80

6.3 Atmospheric Dispersion Modeling Results

The model input parameters described above were input the HotSpot dispersion model.

The HotSpot dispersion model produced output summary tables for the ISP SNF Transportation scenario. Modeling outputs include projected doses (TED) at each receptor as defined above. Exposed personnel are assumed to have no protection from radiation exposure.

Table 4 presents a summary of the model input and results for each receptor. Detailed modeling output (including organ-by-organ dose breakdowns) are presented in Appendix A.

Table 4 Summary of HotSpot Model Input and Results for the ISP SNF Transportation Scenario

```
HotSpot  Version 3.1.2 General Plume
Oct 27, 2020 2:30:35 PM

Source Term                 : C:\Users\rhodg\Desktop\ISP SNF - HotSpot\ISP SNF Breach 1.mix
(Mixture Scale Factor = 1.0000E+00)
                              ISP SNF Breach 1
Effective Release Height    : 2.00 m
Wind Speed (h=10 m)         : 1.00 m/s
Wind Speed (h=H-eff)        : 0.41 m/s
Stability Class             : F
Receptor Height             : 1.5 m
Inversion Layer Height      : None
Sample Time                 : 10.000 min
Breathing Rate              : 4.17E-04 m3/sec
Distance Coordinates        : All distances are on the Plume Centerline

Maximum Dose Distance       : 0.022 km
MAXIMUM  TED                : 2.62E+03 rem
Inner  Contour Dose         : 1.00E+02 rem
Middle Contour Dose         : 1.0 rem
Outer  Contour Dose         : 0.100 rem
Exceeds Inner  Dose Out To  : 0.21 km
Exceeds Middle Dose Out To  : 2.0 km
Exceeds Outer  Dose Out To  : 5.8 km


      Include Plume Passage Inhalation and Submersion
      Include Ground Shine (Weathering Correction Factor : None)
      Include Resuspension (Resuspension Factor : Maxwell-Anspaugh)
      Exposure Window:(Start: 0.00 days; Duration: 4.00 days)  [100% stay time].
      Initial Deposition and Dose Rate shown
      Ground Roughness Correction Factor: 1.000
```

DISTANCE km	T E D (rem)	RESPIRABLE TIME-INTEGRATED AIR CONCENTRATION (Ci-sec)/m3	GROUND SURFACE DEPOSITION (uCi/m2)	GROUND SHINE DOSE RATE (rem/hr)	ARRIVAL TIME (hour:min)
0.030	2.2E+03	3.3E+03	5.0E+03	7.5E-04	00:01
0.100	3.2E+02	4.6E+02	1.2E+06	1.7E-01	00:04
0.200	1.1E+02	1.6E+02	5.0E+05	7.5E-02	00:08
0.300	5.6E+01	7.8E+01	2.4E+05	3.6E-02	00:12
0.400	3.1E+01	4.3E+01	1.3E+05	2.0E-02	00:16
0.500	1.9E+01	2.7E+01	8.3E+04	1.2E-02	00:20
0.600	1.3E+01	1.8E+01	5.6E+04	8.4E-03	00:24
0.700	9.6E+00	1.3E+01	4.1E+04	6.1E-03	00:28
0.800	7.2E+00	1.0E+01	3.1E+04	4.6E-03	00:32
0.900	5.7E+00	7.9E+00	2.4E+04	3.6E-03	00:36
1.000	4.6E+00	6.4E+00	1.9E+04	2.9E-03	00:40
2.000	1.0E+00	1.4E+00	4.3E+03	6.4E-04	01:20
4.000	2.3E-01	3.2E-01	9.7E+02	1.5E-04	02:41
6.000	9.5E-02	1.3E-01	4.0E+02	5.9E-05	04:02
8.000	5.2E-02	7.2E-02	2.2E+02	3.3E-05	05:23
10.000	3.3E-02	4.6E-02	1.4E+02	2.1E-05	06:43
20.000	3.6E-03	5.0E-03	1.5E+01	2.2E-06	13:27
40.000	1.3E-04	1.7E-04	5.3E-01	7.8E-08	>24:00
60.000	6.7E-06	9.4E-06	2.8E-02	4.2E-09	>24:00
80.000	8.6E-07	1.2E-06	3.6E-03	5.3E-10	>24:00

7 Analysis

Analysis of the output from the HotSpot dispersion model leads to the following key determinations for the ISP SNF Transportation Severe Impact scenario:

- The projected maximum radiation dose (TED) is 2.62E+03 rem (2.62E+01 Sv) and occurred at 22 m from the accident. This is equivalent to the maximally exposed individual without protection. This dose level exceeds the DOE Threshold of Early Lethality (100 rem [1 Sv] TED). Note that distances closer than 30 m to the accident are considered uncertain in the HotSpot model and should be considered with caution.
- Radiation doses (TED) exceeding the DOE Threshold of Early Lethality (100 rem [1 Sv] TED) are projected to occur out to 210 m from the accident. It is expected that emergency responders and members of the public will be within this distance at many locations along the transportation routes.
- Radiation doses (TED) exceeding the DOE Protective Action Criterion (1 rem [0.01 Sv] TED) are projected to occur out to 2.0 km from the accident. It is expected that emergency responders and members of the public will be within this distance at many locations along the transportation routes.

It should be further noted that this analysis is expected to be bounding with respect to modeling parameters and meteorological conditions and thus would include worst-case radiation doses.

8 Conclusions

The following key conclusions have been determined in this analysis:

- It is plausible for a breach of containment and release of radioactive materials to occur in severe fire and impact scenarios involving the cask/canister configuration planned for the ISP project.
- It is possible for released materials in a severe impact scenario to produce downwind doses that exceed the DOE threshold for early lethality out to 2 km from the accident.
- It is possible for released materials in a severe impact scenario to produce downwind doses that exceed the DOE protective action criterion for public protective actions out to 14 km from the accident.

This analysis shows that the spectrum of accidents that should be considered in the DEIS must include severe accidents that will plausibly breach containment and release radioactive material into the atmosphere. If such a breach occurs, significant impacts to emergency responders and the public would be expected, resulting in the need for public protective actions. The DEIS is incomplete without such considerations.

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APPENDIX A

DETAILED MODEL OUTPUT FROM HOTSPOT MODEL ANALYSIS – ISP SNF TRANSPORTATION SCENARIO

HotSpot Version 3.1.2 General Plume

Oct 27, 2020 2:32:02 PM

Source Term : C:\Users\rhodg\Desktop\ISP SNF - HotSpot\ISP SNF Breach 1.mix (Mixture Scale Factor = 1.0000E+00)

ISP SNF Breach 1

Effective Release Height : 2.00 m

Wind Speed (h=10 m) : 1.00 m/s

Wind Speed (h=H-eff) : 0.41 m/s

Stability Class : F

Receptor Height : 1.5 m

Inversion Layer Height : None

Sample Time : 10.000 min

Breathing Rate : 4.17E-04 m3/sec

Distance Coordinates : All distances are on the Plume Centerline

Maximum Dose Distance : 0.022 km

MAXIMUM TED : 2.62E+03 rem

Inner Contour Dose : 1.00E+02 rem

Middle Contour Dose : 1.0 rem

Outer Contour Dose : 0.100 rem

Exceeds Inner Dose Out To : 0.21 km

Exceeds Middle Dose Out To : 2.0 km

Exceeds Outer Dose Out To : 5.8 km

Include Plume Passage Inhalation and Submersion

Include Ground Shine (Weathering Correction Factor : None)

Include Resuspension (Resuspension Factor : Maxwell-Anspaugh)

Exposure Window:(Start: 0.00 days; Duration: 4.00 days) [100% stay time].

Initial Deposition and Dose Rate shown

Ground Roughness Correction Factor: 1.000

DISTANCE	T E D	RESPIRABLE TIME-INTEGRATED AIR CONCENTRATION	GROUND SURFACE DEPOSITION	GROUND SHINE DOSE RATE	ARRIVAL TIME
km	(rem)	(Ci-sec)/m3	(uCi/m2)	(rem/hr)	(hour:min)
0.030	2.2E+03	3.3E+03	5.0E+03	7.5E-04	00:01

Target Organ Committed Dose Equivalent (rem), at Location 0.030 km

Skin.........[2.9E+02] Lung.........[1.8E+03] thyroid......[1.3E+02]

Surface Bone.[7.1E+04] Red Marrow...[3.2E+03] Liver........[1.2E+04]

Spleen.......[1.3E+02] Ovaries......[1.1E+03] Adrenals.....[1.4E+02]

Breast.......[1.3E+02] Stomach Wall.[1.3E+02] SI Wall......[1.3E+02]

ULI Wall.....[1.4E+02] LLI Wall.....[1.7E+02] Bladder Wall.[1.3E+02]

Thymus.......[1.4E+02] Esophagus....[4.0E+02] Muscle.......[1.3E+02]

Kidneys......[3.1E+02] Testes.......[1.1E+03] Uterus.......[1.3E+02]

Pancreas.....[1.3E+02] Brain........[1.3E+02]

Inhalation : 2.20E+03 (Plume Passage)

Submersion : 3.33E+00 (Plume Passage)

Ground Shine: 7.11E-02

Resuspension: 1.00E-02

0.100 3.2E+02 4.6E+02 1.2E+06 1.7E-01 00:04

Target Organ Committed Dose Equivalent (rem), at Location 0.100 km

Skin.........[1.2E+03] Lung.........[2.6E+02] thyroid......[2.3E+01]

Surface Bone.[9.9E+03] Red Marrow...[4.5E+02] Liver........[1.7E+03]

Spleen.......[2.3E+01] Ovaries......[1.5E+02] Adrenals.....[2.3E+01]

Breast.......[2.4E+01] Stomach Wall.[2.3E+01] SI Wall......[2.3E+01]

ULI Wall.....[2.4E+01] LLI Wall.....[2.8E+01] Bladder Wall.[2.3E+01]

Thymus.......[2.3E+01] Esophagus....[5.9E+01] Muscle.......[2.3E+01]

Kidneys......[4.7E+01] Testes.......[1.5E+02] Uterus.......[2.2E+01]

Pancreas.....[2.3E+01] Brain........[2.2E+01]

Inhalation : 3.04E+02 (Plume Passage)

Submersion : 4.62E-01 (Plume Passage)

Ground Shine: 1.66E+01

Resuspension: 2.34E+00

0.200 1.1E+02 1.6E+02 5.0E+05 7.5E-02 00:08

Target Organ Committed Dose Equivalent (rem), at Location 0.200 km

Skin.........[5.3E+02] Lung.........[8.9E+01] thyroid......[8.3E+00]

Surface Bone.[3.4E+03] Red Marrow...[1.5E+02] Liver........[5.8E+02]

Spleen.......[8.2E+00] Ovaries......[5.2E+01] Adrenals.....[8.2E+00]

Breast.......[8.6E+00] Stomach Wall.[8.2E+00] SI Wall......[8.1E+00]

ULI Wall.....[8.7E+00] LLI Wall.....[9.8E+00] Bladder Wall.[8.1E+00]

Thymus.......[8.4E+00] Esophagus....[2.1E+01] Muscle.......[8.4E+00]

Kidneys......[1.6E+01] Testes.......[5.3E+01] Uterus.......[8.0E+00]

Pancreas.....[8.1E+00] Brain........[8.0E+00]

Inhalation : 1.04E+02 (Plume Passage)

Submersion : 1.57E-01 (Plume Passage)

Ground Shine: 7.14E+00

Resuspension: 1.01E+00

0.300 5.6E+01 7.8E+01 2.4E+05 3.6E-02 00:12

Target Organ Committed Dose Equivalent (rem), at Location 0.300 km

Skin.........[2.6E+02] Lung.........[4.4E+01] thyroid......[4.1E+00]

Surface Bone.[1.7E+03] Red Marrow...[7.6E+01] Liver........[2.9E+02]

Spleen.......[4.1E+00] Ovaries......[2.6E+01] Adrenals.....[4.1E+00]

Breast.......[4.3E+00] Stomach Wall.[4.1E+00] SI Wall......[4.0E+00]

ULI Wall.....[4.3E+00] LLI Wall.....[4.9E+00] Bladder Wall.[4.0E+00]

Thymus.......[4.2E+00] Esophagus....[1.0E+01] Muscle.......[4.2E+00]

Kidneys......[8.2E+00] Testes.......[2.6E+01] Uterus.......[4.0E+00]

Pancreas.....[4.0E+00] Brain........[4.0E+00]

Inhalation : 5.17E+01 (Plume Passage)

Submersion : 7.85E-02 (Plume Passage)

Ground Shine: 3.47E+00

Resuspension: 4.90E-01

0.400 3.1E+01 4.3E+01 1.3E+05 2.0E-02 00:16

Target Organ Committed Dose Equivalent (rem), at Location 0.400 km

Skin.........[1.4E+02] Lung.........[2.5E+01] thyroid......[2.3E+00]

Surface Bone.[9.4E+02] Red Marrow...[4.2E+01] Liver........[1.6E+02]

Spleen.......[2.3E+00] Ovaries......[1.4E+01] Adrenals.....[2.2E+00]

Breast.......[2.4E+00] Stomach Wall.[2.2E+00] SI Wall......[2.2E+00]

ULI Wall.....[2.4E+00] LLI Wall.....[2.7E+00] Bladder Wall.[2.2E+00]

Thymus.......[2.3E+00] Esophagus....[5.7E+00] Muscle.......[2.3E+00]

Kidneys......[4.5E+00] Testes.......[1.5E+01] Uterus.......[2.2E+00]

Pancreas.....[2.2E+00] Brain........[2.2E+00]

Inhalation : 2.87E+01 (Plume Passage)

Submersion : 4.36E-02 (Plume Passage)

Ground Shine: 1.90E+00

Resuspension: 2.68E-01

0.500 1.9E+01 2.7E+01 8.3E+04 1.2E-02 00:20

Target Organ Committed Dose Equivalent (rem), at Location 0.500 km

Skin.........[8.8E+01] Lung.........[1.5E+01] thyroid......[1.4E+00]

Surface Bone.[5.9E+02] Red Marrow...[2.7E+01] Liver........[1.0E+02]

Spleen.......[1.4E+00] Ovaries......[9.1E+00] Adrenals.....[1.4E+00]

Breast.......[1.5E+00] Stomach Wall.[1.4E+00] SI Wall......[1.4E+00]

ULI Wall.....[1.5E+00] LLI Wall.....[1.7E+00] Bladder Wall.[1.4E+00]

Thymus.......[1.4E+00] Esophagus....[3.6E+00] Muscle.......[1.4E+00]

Kidneys......[2.8E+00] Testes.......[9.2E+00] Uterus.......[1.4E+00]

Pancreas.....[1.4E+00] Brain........[1.4E+00]

Inhalation : 1.80E+01 (Plume Passage)

Submersion : 2.73E-02 (Plume Passage)

Ground Shine: 1.18E+00

Resuspension: 1.67E-01

0.600 1.3E+01 1.8E+01 5.6E+04 8.4E-03 00:24

Target Organ Committed Dose Equivalent (rem), at Location 0.600 km

Skin.........[6.0E+01] Lung.........[1.1E+01] thyroid......[9.8E-01]

Surface Bone.[4.0E+02] Red Marrow...[1.8E+01] Liver........[6.8E+01]

Spleen.......[9.6E-01] Ovaries......[6.2E+00] Adrenals.....[9.6E-01]

Breast.......[1.0E+00] Stomach Wall.[9.6E-01] SI Wall......[9.5E-01]

ULI Wall.....[1.0E+00] LLI Wall.....[1.1E+00] Bladder Wall.[9.5E-01]

Thymus.......[9.8E-01] Esophagus....[2.4E+00] Muscle.......[9.9E-01]

Kidneys......[1.9E+00] Testes.......[6.3E+00] Uterus.......[9.3E-01]

Pancreas.....[9.5E-01] Brain........[9.3E-01]

Inhalation : 1.23E+01 (Plume Passage)

Submersion : 1.86E-02 (Plume Passage)

Ground Shine: 8.01E-01

Resuspension: 1.13E-01

0.700 9.6E+00 1.3E+01 4.1E+04 6.1E-03 00:28

Target Organ Committed Dose Equivalent (rem), at Location 0.700 km

Skin.........[4.3E+01] Lung.........[7.6E+00] thyroid......[7.1E-01]

Surface Bone.[2.9E+02] Red Marrow...[1.3E+01] Liver........[4.9E+01]

Spleen.......[7.0E-01] Ovaries......[4.5E+00] Adrenals.....[6.9E-01]

Breast.......[7.3E-01] Stomach Wall.[6.9E-01] SI Wall......[6.9E-01]

ULI Wall.....[7.3E-01] LLI Wall.....[8.3E-01] Bladder Wall.[6.9E-01]

Thymus.......[7.1E-01] Esophagus....[1.8E+00] Muscle.......[7.1E-01]

Kidneys......[1.4E+00] Testes.......[4.5E+00] Uterus.......[6.8E-01]

Pancreas.....[6.8E-01] Brain........[6.8E-01]

Inhalation : 8.89E+00 (Plume Passage)

Submersion : 1.35E-02 (Plume Passage)

Ground Shine: 5.78E-01

Resuspension: 8.15E-02

0.800 7.2E+00 1.0E+01 3.1E+04 4.6E-03 00:32

Target Organ Committed Dose Equivalent (rem), at Location 0.800 km

Skin.........[3.2E+01] Lung.........[5.8E+00] thyroid......[5.3E-01]

Surface Bone.[2.2E+02] Red Marrow...[9.9E+00] Liver........[3.7E+01]

Spleen.......[5.3E-01] Ovaries......[3.4E+00] Adrenals.....[5.2E-01]

Breast.......[5.5E-01] Stomach Wall.[5.2E-01] SI Wall......[5.2E-01]

ULI Wall.....[5.5E-01] LLI Wall.....[6.3E-01] Bladder Wall.[5.2E-01]

Thymus.......[5.4E-01] Esophagus....[1.3E+00] Muscle.......[5.4E-01]

Kidneys......[1.1E+00] Testes.......[3.4E+00] Uterus.......[5.1E-01]

Pancreas.....[5.2E-01] Brain........[5.1E-01]

Inhalation : 6.73E+00 (Plume Passage)

Submersion : 1.02E-02 (Plume Passage)

Ground Shine: 4.36E-01

Resuspension: 6.15E-02

0.900	5.7E+00	7.9E+00	2.4E+04	3.6E-03	00:36

Target Organ Committed Dose Equivalent (rem), at Location 0.900 km

Skin.........[2.5E+01] Lung.........[4.5E+00] thyroid......[4.2E-01]

Surface Bone.[1.7E+02] Red Marrow...[7.8E+00] Liver........[2.9E+01]

Spleen.......[4.1E-01] Ovaries......[2.7E+00] Adrenals.....[4.1E-01]

Breast.......[4.3E-01] Stomach Wall.[4.1E-01] SI Wall......[4.1E-01]

ULI Wall.....[4.3E-01] LLI Wall.....[4.9E-01] Bladder Wall.[4.1E-01]

Thymus.......[4.2E-01] Esophagus....[1.0E+00] Muscle.......[4.2E-01]

Kidneys......[8.3E-01] Testes.......[2.7E+00] Uterus.......[4.0E-01]

Pancreas.....[4.1E-01] Brain........[4.0E-01]

Inhalation : 5.27E+00 (Plume Passage)

Submersion : 8.00E-03 (Plume Passage)

Ground Shine: 3.41E-01

Resuspension: 4.81E-02

1.000	4.6E+00	6.4E+00	1.9E+04	2.9E-03	00:40

Target Organ Committed Dose Equivalent (rem), at Location 1.000 km

Skin.........[2.0E+01] Lung.........[3.6E+00] thyroid......[3.4E-01]

Surface Bone.[1.4E+02] Red Marrow...[6.3E+00] Liver........[2.4E+01]

Spleen.......[3.3E-01] Ovaries......[2.1E+00] Adrenals.....[3.3E-01]

Breast.......[3.5E-01] Stomach Wall.[3.3E-01] SI Wall......[3.3E-01]

ULI Wall.....[3.5E-01] LLI Wall.....[4.0E-01] Bladder Wall.[3.3E-01]

Thymus.......[3.4E-01] Esophagus....[8.4E-01] Muscle.......[3.4E-01]

Kidneys......[6.7E-01] Testes.......[2.2E+00] Uterus.......[3.2E-01]

Pancreas.....[3.3E-01] Brain........[3.2E-01]

Inhalation : 4.25E+00 (Plume Passage)

Submersion : 6.44E-03 (Plume Passage)

Ground Shine: 2.74E-01

Resuspension: 3.87E-02

2.000 1.0E+00 1.4E+00 4.3E+03 6.4E-04 01:20

Target Organ Committed Dose Equivalent (rem), at Location 2.000 km

Skin.........[4.6E+00] Lung.........[8.2E-01] thyroid......[7.5E-02]

Surface Bone.[3.1E+01] Red Marrow...[1.4E+00] Liver........[5.3E+00]

Spleen.......[7.4E-02] Ovaries......[4.8E-01] Adrenals.....[7.4E-02]

Breast.......[7.8E-02] Stomach Wall.[7.4E-02] SI Wall......[7.3E-02]

ULI Wall.....[7.8E-02] LLI Wall.....[8.9E-02] Bladder Wall.[7.3E-02]

Thymus.......[7.6E-02] Esophagus....[1.9E-01] Muscle.......[7.6E-02]

Kidneys......[1.5E-01] Testes.......[4.9E-01] Uterus.......[7.2E-02]

Pancreas.....[7.3E-02] Brain........[7.2E-02]

Inhalation : 9.53E-01 (Plume Passage)

Submersion : 1.45E-03 (Plume Passage)

Ground Shine: 6.13E-02

Resuspension: 8.65E-03

4.000 2.3E-01 3.2E-01 9.7E+02 1.5E-04 02:41

Target Organ Committed Dose Equivalent (rem), at Location 4.000 km

Skin.........[1.0E+00] Lung.........[1.9E-01] thyroid......[1.7E-02]

Surface Bone.[7.1E+00] Red Marrow...[3.2E-01] Liver........[1.2E+00]

Spleen.......[1.7E-02] Ovaries......[1.1E-01] Adrenals.....[1.7E-02]

Breast.......[1.8E-02] Stomach Wall.[1.7E-02] SI Wall......[1.7E-02]

ULI Wall.....[1.8E-02] LLI Wall.....[2.0E-02] Bladder Wall.[1.7E-02]

Thymus.......[1.7E-02] Esophagus....[4.3E-02] Muscle.......[1.7E-02]

Kidneys......[3.4E-02] Testes.......[1.1E-01] Uterus.......[1.6E-02]

Pancreas.....[1.7E-02] Brain........[1.6E-02]

Inhalation : 2.16E-01 (Plume Passage)

Submersion : 3.28E-04 (Plume Passage)

Ground Shine: 1.39E-02

Resuspension: 1.96E-03

6.000 9.5E-02 1.3E-01 4.0E+02 5.9E-05 04:02

Target Organ Committed Dose Equivalent (rem), at Location 6.000 km

Skin.........[4.2E-01] Lung.........[7.6E-02] thyroid......[7.0E-03]

Surface Bone.[2.9E+00] Red Marrow...[1.3E-01] Liver........[4.9E-01]

Spleen.......[6.9E-03] Ovaries......[4.4E-02] Adrenals.....[6.9E-03]

Breast.......[7.2E-03] Stomach Wall.[6.9E-03] SI Wall......[6.8E-03]

ULI Wall.....[7.2E-03] LLI Wall.....[8.2E-03] Bladder Wall.[6.8E-03]

Thymus.......[7.0E-03] Esophagus....[1.7E-02] Muscle.......[7.1E-03]

Kidneys......[1.4E-02] Testes.......[4.5E-02] Uterus.......[6.7E-03]

Pancreas.....[6.8E-03] Brain........[6.7E-03]

Inhalation : 8.83E-02 (Plume Passage)

Submersion : 1.34E-04 (Plume Passage)

Ground Shine: 5.67E-03

Resuspension: 7.99E-04

8.000 5.2E-02 7.2E-02 2.2E+02 3.3E-05 05:23

Target Organ Committed Dose Equivalent (rem), at Location 8.000 km

Skin.........[2.3E-01] Lung.........[4.2E-02] thyroid......[3.8E-03]

Surface Bone.[1.6E+00] Red Marrow...[7.1E-02] Liver........[2.7E-01]

Spleen.......[3.8E-03] Ovaries......[2.4E-02] Adrenals.....[3.8E-03]

Breast.......[3.9E-03] Stomach Wall.[3.8E-03] SI Wall......[3.7E-03]

ULI Wall.....[4.0E-03] LLI Wall.....[4.5E-03] Bladder Wall.[3.7E-03]

Thymus.......[3.8E-03] Esophagus....[9.6E-03] Muscle.......[3.9E-03]

Kidneys......[7.6E-03] Testes.......[2.5E-02] Uterus.......[3.7E-03]

Pancreas.....[3.7E-03] Brain........[3.7E-03]

Inhalation : 4.84E-02 (Plume Passage)

Submersion : 7.32E-05 (Plume Passage)

Ground Shine: 3.10E-03

Resuspension: 4.38E-04

10.000 3.3E-02 4.6E-02 1.4E+02 2.1E-05 06:43

Target Organ Committed Dose Equivalent (rem), at Location 10.000 km

Skin.........[1.5E-01] Lung.........[2.7E-02] thyroid......[2.4E-03]

Surface Bone.[1.0E+00] Red Marrow...[4.6E-02] Liver........[1.7E-01]

Spleen.......[2.4E-03] Ovaries......[1.6E-02] Adrenals.....[2.4E-03]

Breast.......[2.5E-03] Stomach Wall.[2.4E-03] SI Wall......[2.4E-03]

ULI Wall.....[2.5E-03] LLI Wall.....[2.9E-03] Bladder Wall.[2.4E-03]

Thymus.......[2.5E-03] Esophagus....[6.1E-03] Muscle.......[2.5E-03]

Kidneys......[4.9E-03] Testes.......[1.6E-02] Uterus.......[2.3E-03]

Pancreas.....[2.4E-03] Brain........[2.3E-03]

Inhalation : 3.09E-02 (Plume Passage)

Submersion : 4.68E-05 (Plume Passage)

Ground Shine: 1.98E-03

Resuspension: 2.80E-04

20.000 3.6E-03 5.0E-03 1.5E+01 2.2E-06 13:27

Target Organ Committed Dose Equivalent (rem), at Location 20.000 km

Skin.........[1.6E-02] Lung.........[2.8E-03] thyroid......[2.6E-04]

Surface Bone.[1.1E-01] Red Marrow...[4.9E-03] Liver........[1.8E-02]

Spleen.......[2.6E-04] Ovaries......[1.7E-03] Adrenals.....[2.6E-04]

Breast.......[2.7E-04] Stomach Wall.[2.6E-04] SI Wall......[2.5E-04]

ULI Wall.....[2.7E-04] LLI Wall.....[3.0E-04] Bladder Wall.[2.5E-04]

Thymus.......[2.6E-04] Esophagus....[6.5E-04] Muscle.......[2.6E-04]

Kidneys......[5.2E-04] Testes.......[1.7E-03] Uterus.......[2.5E-04]

Pancreas.....[2.5E-04] Brain........[2.5E-04]

Inhalation : 3.31E-03 (Plume Passage)

Submersion : 5.00E-06 (Plume Passage)

Ground Shine: 2.12E-04

Resuspension: 2.99E-05

40.000 1.3E-04 1.7E-04 5.3E-01 7.8E-08 >24:00

Target Organ Committed Dose Equivalent (rem), at Location 40.000 km

Skin.........[5.6E-04] Lung.........[1.0E-04] thyroid......[9.2E-06]

Surface Bone.[3.8E-03] Red Marrow...[1.7E-04] Liver........[6.5E-04]

Spleen.......[9.1E-06] Ovaries......[5.9E-05] Adrenals.....[9.1E-06]

Breast.......[9.5E-06] Stomach Wall.[9.1E-06] SI Wall......[9.0E-06]

ULI Wall.....[9.5E-06] LLI Wall.....[1.1E-05] Bladder Wall.[9.0E-06]

Thymus.......[9.3E-06] Esophagus....[2.3E-05] Muscle.......[9.4E-06]

Kidneys......[1.8E-05] Testes.......[6.0E-05] Uterus.......[8.8E-06]

Pancreas.....[9.0E-06] Brain........[8.9E-06]

Inhalation : 1.17E-04 (Plume Passage)

Submersion : 1.76E-07 (Plume Passage)

Ground Shine: 7.50E-06

Resuspension: 1.06E-06

60.000 6.7E-06 9.4E-06 2.8E-02 4.2E-09 >24:00

Target Organ Committed Dose Equivalent (rem), at Location 60.000 km

Skin.........[3.0E-05] Lung.........[5.4E-06] thyroid......[5.0E-07]

Surface Bone.[2.1E-04] Red Marrow...[9.3E-06] Liver........[3.5E-05]

Spleen.......[4.9E-07] Ovaries......[3.2E-06] Adrenals.....[4.9E-07]

Breast.......[5.1E-07] Stomach Wall.[4.9E-07] SI Wall......[4.8E-07]

ULI Wall.....[5.1E-07] LLI Wall.....[5.7E-07] Bladder Wall.[4.8E-07]

Thymus.......[5.0E-07] Esophagus....[1.2E-06] Muscle.......[5.0E-07]

Kidneys......[9.9E-07] Testes.......[3.2E-06] Uterus.......[4.8E-07]

Pancreas.....[4.8E-07] Brain........[4.8E-07]

Inhalation : 6.28E-06 (Plume Passage)

Submersion : 9.46E-09 (Plume Passage)

Ground Shine: 4.03E-07

Resuspension: 5.69E-08

80.000	8.6E-07	1.2E-06	3.6E-03	5.3E-10	>24:00

Target Organ Committed Dose Equivalent (rem), at Location 80.000 km

Skin.........[3.8E-06] Lung.........[6.8E-07] thyroid......[6.3E-08]

Surface Bone.[2.6E-05] Red Marrow...[1.2E-06] Liver........[4.4E-06]

Spleen.......[6.2E-08] Ovaries......[4.0E-07] Adrenals.....[6.2E-08]

Breast.......[6.5E-08] Stomach Wall.[6.2E-08] SI Wall......[6.1E-08]

ULI Wall.....[6.5E-08] LLI Wall.....[7.2E-08] Bladder Wall.[6.1E-08]

Thymus.......[6.3E-08] Esophagus....[1.6E-07] Muscle.......[6.4E-08]

Kidneys......[1.3E-07] Testes.......[4.1E-07] Uterus.......[6.0E-08]

Pancreas.....[6.1E-08] Brain........[6.0E-08]

Inhalation : 7.98E-07 (Plume Passage)

Submersion : 1.20E-09 (Plume Passage)

Ground Shine: 5.11E-08

Resuspension: 7.22E-09

HotSpot User Mixture Database

User Mixture Name : s\rhodg\Desktop\ISP SNF - HotSpot\ISP SNF Breach 1.mix

ISP SNF Breach 1

Mixture Scale Factor : 1.0000E+00

Nuclide [01] : Am-241 M 432.2 y

Halflife (Years): 4.3220E+02

Inhalation 50-yr CEDE (Sv/Bq): 4.1700E-05

Submersion (Sv-m3)/(Bq-sec): 6.7200E-16

Ground Shine (Sv-m2)/(Bq-sec): 2.1800E-17

Skin Inhalation (Sv/Bq): 2.8800E-06

Skin Submersion (Sv-m3)/(Bq-sec): 1.1900E-15

Skin Ground Sv-m2)/(Bq-sec): 6.0400E-17

Lung Inhalation (Sv/Bq): 3.7000E-05

Lung Submersion (Sv-m3)/(Bq-sec): 6.7600E-16

Lung Ground Sv-m2)/(Bq-sec): 2.0000E-17

Thyroid Inhalation (Sv/Bq): 2.8800E-06

Thyroid Submersion (Sv-m3)/(Bq-sec): 7.7700E-16

Thyroid Ground Sv-m2)/(Bq-sec): 2.1200E-17

Surface Bone Inhalation (Sv/Bq): 1.7000E-03

Surface Bone Submersion (Sv-m3)/(Bq-sec): 2.8600E-15

Surface Bone Ground Sv-m2)/(Bq-sec): 9.0100E-17

Red Marrow Inhalation (Sv/Bq): 5.8000E-05

Red Marrow Submersion (Sv-m3)/(Bq-sec): 5.2000E-16

Red Marrow Ground Sv-m2)/(Bq-sec): 1.6400E-17

Liver Inhalation (Sv/Bq): 1.0400E-04

Liver Submersion (Sv-m3)/(Bq-sec): 5.6500E-16

Liver Ground Sv-m2)/(Bq-sec): 1.8000E-17

Spleen Inhalation (Sv/Bq): 2.8800E-06

Spleen Submersion (Sv-m3)/(Bq-sec): 5.6200E-16

Spleen Ground Sv-m2)/(Bq-sec): 1.8100E-17

Ovaries Inhalation (Sv/Bq): 3.3100E-05

Ovaries Submersion (Sv-m3)/(Bq-sec): 3.7700E-16

Ovaries Ground Sv-m2)/(Bq-sec): 1.4700E-17

Adrenals Inhalation (Sv/Bq): 2.8800E-06

Adrenals Submersion (Sv-m3)/(Bq-sec): 4.5600E-16

Adrenals Ground Sv-m2)/(Bq-sec): 1.4700E-17

Breast Inhalation (Sv/Bq): 2.8800E-06

Breast Submersion (Sv-m3)/(Bq-sec): 1.0400E-15

Breast Ground Sv-m2)/(Bq-sec): 3.0200E-17

ULI Wall Inhalation (Sv/Bq): 2.8900E-06

ULI Wall Submersion (Sv-m3)/(Bq-sec): 4.5500E-16

ULI Wall Ground Sv-m2)/(Bq-sec): 1.5800E-17

Thymus Inhalation (Sv/Bq): 2.8800E-06

Thymus Submersion (Sv-m3)/(Bq-sec): 6.5300E-16

Thymus Ground Sv-m2)/(Bq-sec): 1.9400E-17

Bladder Wall Inhalation (Sv/Bq): 2.8800E-06

Bladder Wall Submersion (Sv-m3)/(Bq-sec): 5.1900E-16

Bladder Wall Ground Sv-m2)/(Bq-sec): 1.7600E-17

Esophagus Inhalation (Sv/Bq): 9.3700E-06

Esophagus Submersion (Sv-m3)/(Bq-sec): 3.7600E-16

Esophagus Ground Sv-m2)/(Bq-sec): 1.1900E-17

LLI Wall Inhalation (Sv/Bq): 2.9000E-06

LLI Wall Submersion (Sv-m3)/(Bq-sec): 4.1700E-16

LLI Wall Ground Sv-m2)/(Bq-sec): 1.5400E-17

Muscle Inhalation (Sv/Bq): 2.8800E-06

Muscle Submersion (Sv-m3)/(Bq-sec): 7.2100E-16

Muscle Ground Sv-m2)/(Bq-sec): 2.5300E-17

Stomach Wall Inhalation (Sv/Bq): 2.8800E-06

Stomach Wall Submersion (Sv-m3)/(Bq-sec): 5.5700E-16

Stomach Wall Ground Sv-m2)/(Bq-sec): 1.7900E-17

Kidneys Inhalation (Sv/Bq): 8.7300E-06

Kidneys Submersion (Sv-m3)/(Bq-sec): 6.0200E-16

Kidneys Ground Sv-m2)/(Bq-sec): 1.8800E-17

Testes Inhalation (Sv/Bq): 3.2800E-05

Testes Submersion (Sv-m3)/(Bq-sec): 8.4500E-16

Testes Ground Sv-m2)/(Bq-sec): 2.8600E-17

Uterus Inhalation (Sv/Bq): 2.8800E-06

Uterus Submersion (Sv-m3)/(Bq-sec): 3.9000E-16

Uterus Ground Sv-m2)/(Bq-sec): 1.4400E-17

Brain Inhalation (Sv/Bq): 2.8800E-06

Brain Submersion (Sv-m3)/(Bq-sec): 6.2600E-16

Brain Ground Sv-m2)/(Bq-sec): 1.5500E-17

SIWall Inhalation (Sv/Bq): 2.8800E-06

SIWall Submersion (Sv-m3)/(Bq-sec): 4.1100E-16

SIWall Ground Sv-m2)/(Bq-sec): 1.4700E-17

Pancreas Inhalation (Sv/Bq): 2.8800E-06

Pancreas Submersion (Sv-m3)/(Bq-sec): 3.8700E-16

Pancreas Ground Sv-m2)/(Bq-sec): 1.3900E-17

Total Activity Released (Ci) : 1.7500E-02

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [02] : Pu-240 M 6537 y

Halflife (Years) : 6.5370E+03

Inhalation 50-yr CEDE (Sv/Bq) : 5.0200E-05

Submersion (Sv-m3)/(Bq-sec) : 3.2900E-18

Ground Shine (Sv-m2)/(Bq-sec) : 5.6800E-19

Skin Inhalation (Sv/Bq): 2.7300E-06

Skin Submersion (Sv-m3)/(Bq-sec): 3.7500E-17

Skin Ground Sv-m2)/(Bq-sec): 8.9000E-18

Lung Inhalation (Sv/Bq): 3.3400E-05

Lung Submersion (Sv-m3)/(Bq-sec): 1.1000E-18

Lung Ground Sv-m2)/(Bq-sec): 7.4800E-20

Thyroid Inhalation (Sv/Bq): 2.7300E-06

Thyroid Submersion (Sv-m3)/(Bq-sec): 3.7400E-18

Thyroid Ground Sv-m2)/(Bq-sec): 3.0800E-19

Surface Bone Inhalation (Sv/Bq): 1.5500E-03

Surface Bone Submersion (Sv-m3)/(Bq-sec): 8.9000E-18

Surface Bone Ground Sv-m2)/(Bq-sec): 1.1100E-18

Red Marrow Inhalation (Sv/Bq): 7.3900E-05

Red Marrow Submersion (Sv-m3)/(Bq-sec): 1.6200E-18

Red Marrow Ground Sv-m2)/(Bq-sec): 1.7700E-19

Liver Inhalation (Sv/Bq): 3.2600E-04

Liver Submersion (Sv-m3)/(Bq-sec): 9.0800E-19

Liver Ground Sv-m2)/(Bq-sec): 6.3500E-20

Spleen Inhalation (Sv/Bq): 2.7300E-06

Spleen Submersion (Sv-m3)/(Bq-sec): 8.1200E-19

Spleen Ground Sv-m2)/(Bq-sec): 4.4400E-20

Ovaries Inhalation (Sv/Bq): 2.0300E-05

Ovaries Submersion (Sv-m3)/(Bq-sec): 4.7400E-19

Ovaries Ground Sv-m2)/(Bq-sec): 8.5800E-20

Adrenals Inhalation (Sv/Bq): 2.7300E-06

Adrenals Submersion (Sv-m3)/(Bq-sec): 6.4800E-19

Adrenals	Ground	Sv-m2)/(Bq-sec): 4.6800E-20
Breast	Inhalation	(Sv/Bq): 2.7300E-06
Breast	Submersion	(Sv-m3)/(Bq-sec): 1.1600E-17
Breast	Ground	Sv-m2)/(Bq-sec): 1.7400E-18
ULI Wall	Inhalation	(Sv/Bq): 2.7400E-06
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 6.1500E-19
ULI Wall	Ground	Sv-m2)/(Bq-sec): 2.9500E-20
Thymus	Inhalation	(Sv/Bq): 2.7300E-06
Thymus	Submersion	(Sv-m3)/(Bq-sec): 1.4400E-18
Thymus	Ground	Sv-m2)/(Bq-sec): 1.2200E-19
Bladder Wall	Inhalation	(Sv/Bq): 2.7300E-06
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 9.2800E-19
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 8.1400E-20
Esophagus	Inhalation	(Sv/Bq): 8.9400E-06
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 4.8500E-19
Esophagus	Ground	Sv-m2)/(Bq-sec): 1.4900E-20
LLI Wall	Inhalation	(Sv/Bq): 2.7400E-06
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 5.4200E-19
LLI Wall	Ground	Sv-m2)/(Bq-sec): 2.8700E-20
Muscle	Inhalation	(Sv/Bq): 2.7300E-06
Muscle	Submersion	(Sv-m3)/(Bq-sec): 4.9300E-18
Muscle	Ground	Sv-m2)/(Bq-sec): 1.0400E-18
Stomach Wall	Inhalation	(Sv/Bq): 2.7300E-06
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 9.4500E-19
Stomach Wall	Ground	Sv-m2)/(Bq-sec): 7.2300E-20
Kidneys	Inhalation	(Sv/Bq): 6.3800E-06
Kidneys	Submersion	(Sv-m3)/(Bq-sec): 1.3100E-18
Kidneys	Ground	Sv-m2)/(Bq-sec): 1.4000E-19
Testes	Inhalation	(Sv/Bq): 2.0700E-05
Testes	Submersion	(Sv-m3)/(Bq-sec): 6.0300E-18

Testes Ground Sv-m2)/(Bq-sec): 1.3400E-18

Uterus Inhalation (Sv/Bq): 2.7300E-06

Uterus Submersion (Sv-m3)/(Bq-sec): 5.0700E-19

Uterus Ground Sv-m2)/(Bq-sec): 2.2700E-20

Brain Inhalation (Sv/Bq): 2.7300E-06

Brain Submersion (Sv-m3)/(Bq-sec): 8.2500E-19

Brain Ground Sv-m2)/(Bq-sec): 2.3800E-20

SIWall Inhalation (Sv/Bq): 2.7300E-06

SIWall Submersion (Sv-m3)/(Bq-sec): 5.3900E-19

SIWall Ground Sv-m2)/(Bq-sec): 2.4500E-20

Pancreas Inhalation (Sv/Bq): 2.7300E-06

Pancreas Submersion (Sv-m3)/(Bq-sec): 4.8300E-19

Pancreas Ground Sv-m2)/(Bq-sec): 1.8100E-20

Total Activity Released (Ci) : 1.6700E-02

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [03] : Pu-238 M 87.74 y

Halflife (Years) : 8.7740E+01

Inhalation 50-yr CEDE (Sv/Bq) : 4.6200E-05

Submersion (Sv-m3)/(Bq-sec) : 3.3600E-18

Ground Shine (Sv-m2)/(Bq-sec) : 5.9900E-19

Skin Inhalation (Sv/Bq): 2.4300E-06

Skin Submersion (Sv-m3)/(Bq-sec): 3.9600E-17

Skin Ground Sv-m2)/(Bq-sec): 9.4500E-18

Lung Inhalation (Sv/Bq): 3.6600E-05

Lung Submersion (Sv-m3)/(Bq-sec): 1.0300E-18

Lung	Ground	Sv-m2)/(Bq-sec): 7.5100E-20
Thyroid	Inhalation	(Sv/Bq): 2.4300E-06
Thyroid	Submersion	(Sv-m3)/(Bq-sec): 3.8100E-18
Thyroid	Ground	Sv-m2)/(Bq-sec): 3.2200E-19
Surface Bone	Inhalation	(Sv/Bq): 1.3900E-03
Surface Bone	Submersion	(Sv-m3)/(Bq-sec): 8.9100E-18
Surface Bone	Ground	Sv-m2)/(Bq-sec): 1.1600E-18
Red Marrow	Inhalation	(Sv/Bq): 6.8900E-05
Red Marrow	Submersion	(Sv-m3)/(Bq-sec): 1.6100E-18
Red Marrow	Ground	Sv-m2)/(Bq-sec): 1.8400E-19
Liver	Inhalation	(Sv/Bq): 2.9400E-04
Liver	Submersion	(Sv-m3)/(Bq-sec): 8.4700E-19
Liver	Ground	Sv-m2)/(Bq-sec): 6.3500E-20
Spleen	Inhalation	(Sv/Bq): 2.4300E-06
Spleen	Submersion	(Sv-m3)/(Bq-sec): 7.4600E-19
Spleen	Ground	Sv-m2)/(Bq-sec): 4.3200E-20
Ovaries	Inhalation	(Sv/Bq): 1.8300E-05
Ovaries	Submersion	(Sv-m3)/(Bq-sec): 4.2100E-19
Ovaries	Ground	Sv-m2)/(Bq-sec): 8.8200E-20
Adrenals	Inhalation	(Sv/Bq): 2.4300E-06
Adrenals	Submersion	(Sv-m3)/(Bq-sec): 5.9200E-19
Adrenals	Ground	Sv-m2)/(Bq-sec): 4.6600E-20
Breast	Inhalation	(Sv/Bq): 2.4300E-06
Breast	Submersion	(Sv-m3)/(Bq-sec): 1.2100E-17
Breast	Ground	Sv-m2)/(Bq-sec): 1.8400E-18
ULI Wall	Inhalation	(Sv/Bq): 2.4300E-06
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 5.5900E-19
ULI Wall	Ground	Sv-m2)/(Bq-sec): 2.7900E-20
Thymus	Inhalation	(Sv/Bq): 2.4300E-06
Thymus	Submersion	(Sv-m3)/(Bq-sec): 1.3900E-18

Thymus Ground Sv-m2)/(Bq-sec): 1.2500E-19

Bladder Wall Inhalation (Sv/Bq): 2.4300E-06

Bladder Wall Submersion (Sv-m3)/(Bq-sec): 8.7700E-19

Bladder Wall Ground Sv-m2)/(Bq-sec): 8.2600E-20

Esophagus Inhalation (Sv/Bq): 8.8900E-06

Esophagus Submersion (Sv-m3)/(Bq-sec): 4.3600E-19

Esophagus Ground Sv-m2)/(Bq-sec): 1.3300E-20

LLI Wall Inhalation (Sv/Bq): 2.4400E-06

LLI Wall Submersion (Sv-m3)/(Bq-sec): 4.8800E-19

LLI Wall Ground Sv-m2)/(Bq-sec): 2.7100E-20

Muscle Inhalation (Sv/Bq): 2.4300E-06

Muscle Submersion (Sv-m3)/(Bq-sec): 5.0900E-18

Muscle Ground Sv-m2)/(Bq-sec): 1.1000E-18

Stomach Wall Inhalation (Sv/Bq): 2.4300E-06

Stomach Wall Submersion (Sv-m3)/(Bq-sec): 8.8700E-19

Stomach Wall Ground Sv-m2)/(Bq-sec): 7.2900E-20

Kidneys Inhalation (Sv/Bq): 6.0300E-06

Kidneys Submersion (Sv-m3)/(Bq-sec): 1.2700E-18

Kidneys Ground Sv-m2)/(Bq-sec): 1.4500E-19

Testes Inhalation (Sv/Bq): 1.8600E-05

Testes Submersion (Sv-m3)/(Bq-sec): 6.2300E-18

Testes Ground Sv-m2)/(Bq-sec): 1.4200E-18

Uterus Inhalation (Sv/Bq): 2.4300E-06

Uterus Submersion (Sv-m3)/(Bq-sec): 4.5700E-19

Uterus Ground Sv-m2)/(Bq-sec): 2.1100E-20

Brain Inhalation (Sv/Bq): 2.4300E-06

Brain Submersion (Sv-m3)/(Bq-sec): 7.4600E-19

Brain Ground Sv-m2)/(Bq-sec): 2.1900E-20

SIWall Inhalation (Sv/Bq): 2.4300E-06

SIWall Submersion (Sv-m3)/(Bq-sec): 4.8600E-19

SIWall Ground Sv-m2)/(Bq-sec): 2.2900E-20

Pancreas Inhalation (Sv/Bq): 2.4300E-06

Pancreas Submersion (Sv-m3)/(Bq-sec): 4.3200E-19

Pancreas Ground Sv-m2)/(Bq-sec): 1.6400E-20

Total Activity Released (Ci) : 1.6300E-02

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [04] : Pu-241 M 14.4 y

Halflife (Years) : 1.4400E+01

Inhalation 50-yr CEDE (Sv/Bq) : 9.0100E-07

Submersion (Sv-m3)/(Bq-sec) : 6.1500E-20

Ground Shine (Sv-m2)/(Bq-sec) : 1.4300E-21

Skin Inhalation (Sv/Bq): 5.6300E-08

Skin Submersion (Sv-m3)/(Bq-sec): 9.8500E-20

Skin Ground Sv-m2)/(Bq-sec): 2.7700E-21

Lung Inhalation (Sv/Bq): 6.5700E-08

Lung Submersion (Sv-m3)/(Bq-sec): 6.3900E-20

Lung Ground Sv-m2)/(Bq-sec): 1.3700E-21

Thyroid Inhalation (Sv/Bq): 5.6300E-08

Thyroid Submersion (Sv-m3)/(Bq-sec): 6.7500E-20

Thyroid Ground Sv-m2)/(Bq-sec): 1.4100E-21

Surface Bone Inhalation (Sv/Bq): 3.1200E-05

Surface Bone Submersion (Sv-m3)/(Bq-sec): 2.1300E-19

Surface Bone Ground Sv-m2)/(Bq-sec): 4.2300E-21

Red Marrow Inhalation (Sv/Bq): 1.2300E-06

Red Marrow Submersion (Sv-m3)/(Bq-sec): 5.5200E-20

Red Marrow Ground Sv-m2)/(Bq-sec): 1.3000E-21

Liver Inhalation (Sv/Bq): 6.4700E-06

Liver Submersion (Sv-m3)/(Bq-sec): 5.5800E-20

Liver Ground Sv-m2)/(Bq-sec): 1.2800E-21

Spleen Inhalation (Sv/Bq): 5.6300E-08

Spleen Submersion (Sv-m3)/(Bq-sec): 5.5600E-20

Spleen Ground Sv-m2)/(Bq-sec): 1.3000E-21

Ovaries Inhalation (Sv/Bq): 4.1000E-07

Ovaries Submersion (Sv-m3)/(Bq-sec): 4.3300E-20

Ovaries Ground Sv-m2)/(Bq-sec): 1.1600E-21

Adrenals Inhalation (Sv/Bq): 5.6400E-08

Adrenals Submersion (Sv-m3)/(Bq-sec): 4.8100E-20

Adrenals Ground Sv-m2)/(Bq-sec): 1.1500E-21

Breast Inhalation (Sv/Bq): 5.6300E-08

Breast Submersion (Sv-m3)/(Bq-sec): 8.0500E-20

Breast Ground Sv-m2)/(Bq-sec): 1.6400E-21

ULI Wall Inhalation (Sv/Bq): 5.6400E-08

ULI Wall Submersion (Sv-m3)/(Bq-sec): 4.8600E-20

ULI Wall Ground Sv-m2)/(Bq-sec): 1.2300E-21

Thymus Inhalation (Sv/Bq): 5.6300E-08

Thymus Submersion (Sv-m3)/(Bq-sec): 6.0600E-20

Thymus Ground Sv-m2)/(Bq-sec): 1.2500E-21

Bladder Wall Inhalation (Sv/Bq): 5.6300E-08

Bladder Wall Submersion (Sv-m3)/(Bq-sec): 5.1600E-20

Bladder Wall Ground Sv-m2)/(Bq-sec): 1.3000E-21

Esophagus Inhalation (Sv/Bq): 6.1100E-08

Esophagus Submersion (Sv-m3)/(Bq-sec): 4.4900E-20

Esophagus Ground Sv-m2)/(Bq-sec): 1.0700E-21

LLI Wall Inhalation (Sv/Bq): 5.6400E-08

LLI Wall Submersion (Sv-m3)/(Bq-sec): 4.6000E-20

LLI Wall	Ground	Sv-m2)/(Bq-sec): 1.2200E-21
Muscle	Inhalation	(Sv/Bq): 5.6300E-08
Muscle	Submersion	(Sv-m3)/(Bq-sec): 6.3000E-20
Muscle	Ground	Sv-m2)/(Bq-sec): 1.5500E-21
Stomach Wall	Inhalation	(Sv/Bq): 5.6300E-08
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 5.4500E-20
Stomach Wall	Ground	Sv-m2)/(Bq-sec): 1.2800E-21
Kidneys	Inhalation	(Sv/Bq): 9.5700E-08
Kidneys	Submersion	(Sv-m3)/(Bq-sec): 5.6200E-20
Kidneys	Ground	Sv-m2)/(Bq-sec): 1.2900E-21
Testes	Inhalation	(Sv/Bq): 4.1700E-07
Testes	Submersion	(Sv-m3)/(Bq-sec): 6.8500E-20
Testes	Ground	Sv-m2)/(Bq-sec): 1.6300E-21
Uterus	Inhalation	(Sv/Bq): 5.6300E-08
Uterus	Submersion	(Sv-m3)/(Bq-sec): 4.4400E-20
Uterus	Ground	Sv-m2)/(Bq-sec): 1.1900E-21
Brain	Inhalation	(Sv/Bq): 5.6300E-08
Brain	Submersion	(Sv-m3)/(Bq-sec): 6.2900E-20
Brain	Ground	Sv-m2)/(Bq-sec): 1.2000E-21
SIWall	Inhalation	(Sv/Bq): 5.6300E-08
SIWall	Submersion	(Sv-m3)/(Bq-sec): 4.5600E-20
SIWall	Ground	Sv-m2)/(Bq-sec): 1.1700E-21
Pancreas	Inhalation	(Sv/Bq): 5.6400E-08
Pancreas	Submersion	(Sv-m3)/(Bq-sec): 4.4700E-20
Pancreas	Ground	Sv-m2)/(Bq-sec): 1.1400E-21

Total Activity Released (Ci) : 9.4800E-01

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [05] : Y-90 M 64.0 h

Halflife (Years) : 7.3059E-03

Inhalation 50-yr CEDE (Sv/Bq) : 1.3900E-09

Submersion (Sv-m3)/(Bq-sec) : 7.9100E-16

Ground Shine (Sv-m2)/(Bq-sec) : 1.1000E-16

Skin Inhalation (Sv/Bq): 3.5800E-12

Skin Submersion (Sv-m3)/(Bq-sec): 6.2300E-14

Skin Ground Sv-m2)/(Bq-sec): 1.0500E-14

Lung Inhalation (Sv/Bq): 6.9400E-09

Lung Submersion (Sv-m3)/(Bq-sec): 1.7700E-16

Lung Ground Sv-m2)/(Bq-sec): 4.7500E-18

Thyroid Inhalation (Sv/Bq): 3.5800E-12

Thyroid Submersion (Sv-m3)/(Bq-sec): 1.8700E-16

Thyroid Ground Sv-m2)/(Bq-sec): 5.0100E-18

Surface Bone Inhalation (Sv/Bq): 1.0400E-10

Surface Bone Submersion (Sv-m3)/(Bq-sec): 4.4300E-16

Surface Bone Ground Sv-m2)/(Bq-sec): 1.1700E-17

Red Marrow Inhalation (Sv/Bq): 1.0300E-10

Red Marrow Submersion (Sv-m3)/(Bq-sec): 1.6200E-16

Red Marrow Ground Sv-m2)/(Bq-sec): 4.5700E-18

Liver Inhalation (Sv/Bq): 1.0200E-10

Liver Submersion (Sv-m3)/(Bq-sec): 1.5600E-16

Liver Ground Sv-m2)/(Bq-sec): 4.4400E-18

Spleen Inhalation (Sv/Bq): 3.5800E-12

Spleen Submersion (Sv-m3)/(Bq-sec): 1.5600E-16

Spleen Ground Sv-m2)/(Bq-sec): 4.4600E-18

Ovaries Inhalation (Sv/Bq): 3.5800E-12

Ovaries Submersion (Sv-m3)/(Bq-sec): 1.2700E-16

Ovaries	Ground	Sv-m2)/(Bq-sec): 4.1600E-18
Adrenals	Inhalation	(Sv/Bq): 3.5800E-12
Adrenals	Submersion	(Sv-m3)/(Bq-sec): 1.4000E-16
Adrenals	Ground	Sv-m2)/(Bq-sec): 4.0400E-18
Breast	Inhalation	(Sv/Bq): 3.5800E-12
Breast	Submersion	(Sv-m3)/(Bq-sec): 2.2000E-16
Breast	Ground	Sv-m2)/(Bq-sec): 5.7100E-18
ULI Wall	Inhalation	(Sv/Bq): 2.7100E-09
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 1.3900E-16
ULI Wall	Ground	Sv-m2)/(Bq-sec): 4.2400E-18
Thymus	Inhalation	(Sv/Bq): 3.5800E-12
Thymus	Submersion	(Sv-m3)/(Bq-sec): 1.6700E-16
Thymus	Ground	Sv-m2)/(Bq-sec): 4.4700E-18
Bladder Wall	Inhalation	(Sv/Bq): 1.6800E-11
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 1.4400E-16
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 4.4600E-18
Esophagus	Inhalation	(Sv/Bq): 1.0200E-09
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 1.3400E-16
Esophagus	Ground	Sv-m2)/(Bq-sec): 3.6700E-18
LLI Wall	Inhalation	(Sv/Bq): 6.3000E-09
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 1.3400E-16
LLI Wall	Ground	Sv-m2)/(Bq-sec): 4.2300E-18
Muscle	Inhalation	(Sv/Bq): 3.5800E-12
Muscle	Submersion	(Sv-m3)/(Bq-sec): 1.7600E-16
Muscle	Ground	Sv-m2)/(Bq-sec): 5.4200E-18
Stomach Wall	Inhalation	(Sv/Bq): 2.1400E-10
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 1.5400E-16
Stomach Wall	Ground	Sv-m2)/(Bq-sec): 4.4400E-18
Kidneys	Inhalation	(Sv/Bq): 3.5800E-12
Kidneys	Submersion	(Sv-m3)/(Bq-sec): 1.5700E-16

Kidneys Ground Sv-m2)/(Bq-sec): 4.5500E-18

Testes Inhalation (Sv/Bq): 3.5800E-12

Testes Submersion (Sv-m3)/(Bq-sec): 1.8900E-16

Testes Ground Sv-m2)/(Bq-sec): 5.7400E-18

Uterus Inhalation (Sv/Bq): 3.5800E-12

Uterus Submersion (Sv-m3)/(Bq-sec): 1.2900E-16

Uterus Ground Sv-m2)/(Bq-sec): 4.0700E-18

Brain Inhalation (Sv/Bq): 3.5800E-12

Brain Submersion (Sv-m3)/(Bq-sec): 1.8100E-16

Brain Ground Sv-m2)/(Bq-sec): 4.2100E-18

SIWall Inhalation (Sv/Bq): 5.0600E-10

SIWall Submersion (Sv-m3)/(Bq-sec): 1.3200E-16

SIWall Ground Sv-m2)/(Bq-sec): 4.0800E-18

Pancreas Inhalation (Sv/Bq): 3.5800E-12

Pancreas Submersion (Sv-m3)/(Bq-sec): 1.3000E-16

Pancreas Ground Sv-m2)/(Bq-sec): 3.8700E-18

Total Activity Released (Ci) : 3.6600E+00

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [06] : Sr-90 M 29.12 y

Halflife (Years) : 2.9120E+01

Inhalation 50-yr CEDE (Sv/Bq) : 3.5600E-08

Submersion (Sv-m3)/(Bq-sec) : 8.8900E-16

Ground Shine (Sv-m2)/(Bq-sec) : 1.1200E-16

Skin Inhalation (Sv/Bq): 2.8000E-10

Skin Submersion (Sv-m3)/(Bq-sec): 7.1500E-14

Skin	Ground	Sv-m2)/(Bq-sec): 1.0600E-14
Lung	Inhalation	(Sv/Bq): 2.0500E-07
Lung	Submersion	(Sv-m3)/(Bq-sec): 1.9300E-16
Lung	Ground	Sv-m2)/(Bq-sec): 4.9700E-18
Thyroid	Inhalation	(Sv/Bq): 2.8000E-10
Thyroid	Submersion	(Sv-m3)/(Bq-sec): 1.9400E-16
Thyroid	Ground	Sv-m2)/(Bq-sec): 5.2600E-18
Surface Bone	Inhalation	(Sv/Bq): 1.6100E-07
Surface Bone	Submersion	(Sv-m3)/(Bq-sec): 4.6600E-16
Surface Bone	Ground	Sv-m2)/(Bq-sec): 1.2500E-17
Red Marrow	Inhalation	(Sv/Bq): 7.0600E-08
Red Marrow	Submersion	(Sv-m3)/(Bq-sec): 1.6700E-16
Red Marrow	Ground	Sv-m2)/(Bq-sec): 4.7600E-18
Liver	Inhalation	(Sv/Bq): 2.8000E-10
Liver	Submersion	(Sv-m3)/(Bq-sec): 1.6200E-16
Liver	Ground	Sv-m2)/(Bq-sec): 4.6400E-18
Spleen	Inhalation	(Sv/Bq): 2.8000E-10
Spleen	Submersion	(Sv-m3)/(Bq-sec): 1.6200E-16
Spleen	Ground	Sv-m2)/(Bq-sec): 4.6600E-18
Ovaries	Inhalation	(Sv/Bq): 2.8000E-10
Ovaries	Submersion	(Sv-m3)/(Bq-sec): 1.3100E-16
Ovaries	Ground	Sv-m2)/(Bq-sec): 4.3200E-18
Adrenals	Inhalation	(Sv/Bq): 2.8000E-10
Adrenals	Submersion	(Sv-m3)/(Bq-sec): 1.4500E-16
Adrenals	Ground	Sv-m2)/(Bq-sec): 4.2100E-18
Breast	Inhalation	(Sv/Bq): 2.8000E-10
Breast	Submersion	(Sv-m3)/(Bq-sec): 2.3000E-16
Breast	Ground	Sv-m2)/(Bq-sec): 6.0600E-18
ULI Wall	Inhalation	(Sv/Bq): 2.6400E-09
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 1.4400E-16

ULI Wall	Ground	Sv-m2)/(Bq-sec): 4.4200E-18
Thymus	Inhalation	(Sv/Bq): 2.8000E-10
Thymus	Submersion	(Sv-m3)/(Bq-sec): 1.7300E-16
Thymus	Ground	Sv-m2)/(Bq-sec): 4.6800E-18
Bladder Wall	Inhalation	(Sv/Bq): 6.9400E-10
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 1.4900E-16
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 4.6600E-18
Esophagus	Inhalation	(Sv/Bq): 8.8100E-09
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 1.3800E-16
Esophagus	Ground	Sv-m2)/(Bq-sec): 3.8100E-18
LLI Wall	Inhalation	(Sv/Bq): 8.7000E-09
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 1.3800E-16
LLI Wall	Ground	Sv-m2)/(Bq-sec): 4.4000E-18
Muscle	Inhalation	(Sv/Bq): 2.8000E-10
Muscle	Submersion	(Sv-m3)/(Bq-sec): 1.8300E-16
Muscle	Ground	Sv-m2)/(Bq-sec): 5.7100E-18
Stomach Wall	Inhalation	(Sv/Bq): 3.8600E-10
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 1.5900E-16
Stomach Wall	Ground	Sv-m2)/(Bq-sec): 4.6400E-18
Kidneys	Inhalation	(Sv/Bq): 2.8000E-10
Kidneys	Submersion	(Sv-m3)/(Bq-sec): 1.6300E-16
Kidneys	Ground	Sv-m2)/(Bq-sec): 4.7700E-18
Testes	Inhalation	(Sv/Bq): 2.8000E-10
Testes	Submersion	(Sv-m3)/(Bq-sec): 1.9700E-16
Testes	Ground	Sv-m2)/(Bq-sec): 6.0700E-18
Uterus	Inhalation	(Sv/Bq): 2.8000E-10
Uterus	Submersion	(Sv-m3)/(Bq-sec): 1.3300E-16
Uterus	Ground	Sv-m2)/(Bq-sec): 4.2300E-18
Brain	Inhalation	(Sv/Bq): 2.8000E-10
Brain	Submersion	(Sv-m3)/(Bq-sec): 1.8700E-16

Brain Ground Sv-m2)/(Bq-sec): 4.3800E-18

SIWall Inhalation (Sv/Bq): 5.3600E-10

SIWall Submersion (Sv-m3)/(Bq-sec): 1.3600E-16

SIWall Ground Sv-m2)/(Bq-sec): 4.2400E-18

Pancreas Inhalation (Sv/Bq): 2.8000E-10

Pancreas Submersion (Sv-m3)/(Bq-sec): 1.3400E-16

Pancreas Ground Sv-m2)/(Bq-sec): 4.0200E-18

Total Activity Released (Ci) : 3.6600E+00

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [07] : Ce-137 M 9.0 h

Halflife (Years) : 1.0274E-03

Inhalation 50-yr CEDE (Sv/Bq) : 1.0100E-11

Submersion (Sv-m3)/(Bq-sec) : 8.4800E-16

Ground Shine (Sv-m2)/(Bq-sec) : 3.2500E-17

Skin Inhalation (Sv/Bq): 2.2300E-13

Skin Submersion (Sv-m3)/(Bq-sec): 1.6000E-15

Skin Ground Sv-m2)/(Bq-sec): 6.9800E-17

Lung Inhalation (Sv/Bq): 1.3400E-11

Lung Submersion (Sv-m3)/(Bq-sec): 8.0600E-16

Lung Ground Sv-m2)/(Bq-sec): 2.8500E-17

Thyroid Inhalation (Sv/Bq): 2.2500E-13

Thyroid Submersion (Sv-m3)/(Bq-sec): 1.0100E-15

Thyroid Ground Sv-m2)/(Bq-sec): 3.6200E-17

Surface Bone Inhalation (Sv/Bq): 2.5900E-12

Surface Bone Submersion (Sv-m3)/(Bq-sec): 2.3800E-15

Surface Bone Ground	Sv-m2)/(Bq-sec):	1.0900E-16
Red Marrow Inhalation	(Sv/Bq):	6.9500E-13
Red Marrow Submersion	(Sv-m3)/(Bq-sec):	7.0800E-16
Red Marrow Ground	Sv-m2)/(Bq-sec):	2.3200E-17
Liver Inhalation	(Sv/Bq):	1.6500E-12
Liver Submersion	(Sv-m3)/(Bq-sec):	6.8700E-16
Liver Ground	Sv-m2)/(Bq-sec):	2.4900E-17
Spleen Inhalation	(Sv/Bq):	6.3400E-13
Spleen Submersion	(Sv-m3)/(Bq-sec):	6.7800E-16
Spleen Ground	Sv-m2)/(Bq-sec):	2.4700E-17
Ovaries Inhalation	(Sv/Bq):	3.4000E-12
Ovaries Submersion	(Sv-m3)/(Bq-sec):	4.6300E-16
Ovaries Ground	Sv-m2)/(Bq-sec):	1.6500E-17
Adrenals Inhalation	(Sv/Bq):	6.1200E-13
Adrenals Submersion	(Sv-m3)/(Bq-sec):	5.8600E-16
Adrenals Ground	Sv-m2)/(Bq-sec):	2.0300E-17
Breast Inhalation	(Sv/Bq):	5.5300E-13
Breast Submersion	(Sv-m3)/(Bq-sec):	1.3900E-15
Breast Ground	Sv-m2)/(Bq-sec):	5.0500E-17
ULI Wall Inhalation	(Sv/Bq):	2.8800E-11
ULI Wall Submersion	(Sv-m3)/(Bq-sec):	5.6900E-16
ULI Wall Ground	Sv-m2)/(Bq-sec):	2.0300E-17
Thymus Inhalation	(Sv/Bq):	6.2700E-13
Thymus Submersion	(Sv-m3)/(Bq-sec):	7.9300E-16
Thymus Ground	Sv-m2)/(Bq-sec):	2.8700E-17
Bladder Wall Inhalation	(Sv/Bq):	4.9700E-13
Bladder Wall Submersion	(Sv-m3)/(Bq-sec):	6.4200E-16
Bladder Wall Ground	Sv-m2)/(Bq-sec):	2.5400E-17
Esophagus Inhalation	(Sv/Bq):	1.3800E-10
Esophagus Submersion	(Sv-m3)/(Bq-sec):	5.0200E-16

Esophagus	Ground	Sv-m2)/(Bq-sec): 1.3500E-17
LLI Wall	Inhalation	(Sv/Bq): 2.7000E-11
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 5.2500E-16
LLI Wall	Ground	Sv-m2)/(Bq-sec): 1.8700E-17
Muscle	Inhalation	(Sv/Bq): 8.3800E-13
Muscle	Submersion	(Sv-m3)/(Bq-sec): 9.3600E-16
Muscle	Ground	Sv-m2)/(Bq-sec): 3.9800E-17
Stomach Wall	Inhalation	(Sv/Bq): 5.9000E-12
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 6.8100E-16
Stomach Wall	Ground	Sv-m2)/(Bq-sec): 2.4900E-17
Kidneys	Inhalation	(Sv/Bq): 4.0400E-13
Kidneys	Submersion	(Sv-m3)/(Bq-sec): 7.6300E-16
Kidneys	Ground	Sv-m2)/(Bq-sec): 2.9800E-17
Testes	Inhalation	(Sv/Bq): 1.2100E-13
Testes	Submersion	(Sv-m3)/(Bq-sec): 1.1100E-15
Testes	Ground	Sv-m2)/(Bq-sec): 4.8500E-17
Uterus	Inhalation	(Sv/Bq): 1.1700E-12
Uterus	Submersion	(Sv-m3)/(Bq-sec): 4.9000E-16
Uterus	Ground	Sv-m2)/(Bq-sec): 1.7400E-17
Brain	Inhalation	(Sv/Bq): 1.4900E-13
Brain	Submersion	(Sv-m3)/(Bq-sec): 7.7000E-16
Brain	Ground	Sv-m2)/(Bq-sec): 1.9500E-17
SIWall	Inhalation	(Sv/Bq): 1.1000E-11
SIWall	Submersion	(Sv-m3)/(Bq-sec): 5.1800E-16
SIWall	Ground	Sv-m2)/(Bq-sec): 1.8100E-17
Pancreas	Inhalation	(Sv/Bq): 8.0600E-13
Pancreas	Submersion	(Sv-m3)/(Bq-sec): 4.8800E-16
Pancreas	Ground	Sv-m2)/(Bq-sec): 1.5600E-17
Total Activity Released		(Ci) : 2.0400E+01
Airborne Fraction		: 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [08] : Pu-239 M 24065 y

Halflife (Years) : 2.4065E+04

Inhalation 50-yr CEDE (Sv/Bq) : 5.0200E-05

Submersion (Sv-m3)/(Bq-sec) : 3.7700E-18

Ground Shine (Sv-m2)/(Bq-sec) : 3.0600E-19

Skin Inhalation (Sv/Bq): 2.7300E-06

Skin Submersion (Sv-m3)/(Bq-sec): 2.0300E-17

Skin Ground Sv-m2)/(Bq-sec): 4.0400E-18

Lung Inhalation (Sv/Bq): 3.3300E-05

Lung Submersion (Sv-m3)/(Bq-sec): 2.8900E-18

Lung Ground Sv-m2)/(Bq-sec): 8.6600E-20

Thyroid Inhalation (Sv/Bq): 2.7300E-06

Thyroid Submersion (Sv-m3)/(Bq-sec): 4.1900E-18

Thyroid Ground Sv-m2)/(Bq-sec): 1.9100E-19

Surface Bone Inhalation (Sv/Bq): 1.5500E-03

Surface Bone Submersion (Sv-m3)/(Bq-sec): 1.0600E-17

Surface Bone Ground Sv-m2)/(Bq-sec): 6.3400E-19

Red Marrow Inhalation (Sv/Bq): 7.3900E-05

Red Marrow Submersion (Sv-m3)/(Bq-sec): 2.8700E-18

Red Marrow Ground Sv-m2)/(Bq-sec): 1.2900E-19

Liver Inhalation (Sv/Bq): 3.2600E-04

Liver Submersion (Sv-m3)/(Bq-sec): 2.5100E-18

Liver Ground Sv-m2)/(Bq-sec): 7.7800E-20

Spleen Inhalation (Sv/Bq): 2.7300E-06

Spleen Submersion (Sv-m3)/(Bq-sec): 2.4700E-18

Spleen Ground Sv-m2)/(Bq-sec): 6.9800E-20

Ovaries Inhalation (Sv/Bq): 2.0400E-05

Ovaries Submersion (Sv-m3)/(Bq-sec): 1.8700E-18

Ovaries Ground Sv-m2)/(Bq-sec): 8.4800E-20

Adrenals Inhalation (Sv/Bq): 2.7300E-06

Adrenals Submersion (Sv-m3)/(Bq-sec): 2.1600E-18

Adrenals Ground Sv-m2)/(Bq-sec): 6.5600E-20

Breast Inhalation (Sv/Bq): 2.7300E-06

Breast Submersion (Sv-m3)/(Bq-sec): 8.1500E-18

Breast Ground Sv-m2)/(Bq-sec): 8.3100E-19

ULI Wall Inhalation (Sv/Bq): 2.7400E-06

ULI Wall Submersion (Sv-m3)/(Bq-sec): 2.1400E-18

ULI Wall Ground Sv-m2)/(Bq-sec): 6.0500E-20

Thymus Inhalation (Sv/Bq): 2.7300E-06

Thymus Submersion (Sv-m3)/(Bq-sec): 2.9000E-18

Thymus Ground Sv-m2)/(Bq-sec): 1.0400E-19

Bladder Wall Inhalation (Sv/Bq): 2.7300E-06

Bladder Wall Submersion (Sv-m3)/(Bq-sec): 2.3700E-18

Bladder Wall Ground Sv-m2)/(Bq-sec): 8.6100E-20

Esophagus Inhalation (Sv/Bq): 8.9400E-06

Esophagus Submersion (Sv-m3)/(Bq-sec): 1.9800E-18

Esophagus Ground Sv-m2)/(Bq-sec): 4.7700E-20

LLI Wall Inhalation (Sv/Bq): 2.7500E-06

LLI Wall Submersion (Sv-m3)/(Bq-sec): 2.0200E-18

LLI Wall Ground Sv-m2)/(Bq-sec): 6.0000E-20

Muscle Inhalation (Sv/Bq): 2.7300E-06

Muscle Submersion (Sv-m3)/(Bq-sec): 4.5600E-18

Muscle Ground Sv-m2)/(Bq-sec): 5.2100E-19

Stomach Wall Inhalation (Sv/Bq): 2.7300E-06

Stomach Wall Submersion (Sv-m3)/(Bq-sec): 2.4900E-18

Stomach Wall Ground Sv-m2)/(Bq-sec): 8.1600E-20

Kidneys Inhalation (Sv/Bq): 6.3800E-06

Kidneys Submersion (Sv-m3)/(Bq-sec): 2.7100E-18

Kidneys Ground Sv-m2)/(Bq-sec): 1.1200E-19

Testes Inhalation (Sv/Bq): 2.0700E-05

Testes Submersion (Sv-m3)/(Bq-sec): 5.2300E-18

Testes Ground Sv-m2)/(Bq-sec): 6.5400E-19

Uterus Inhalation (Sv/Bq): 2.7300E-06

Uterus Submersion (Sv-m3)/(Bq-sec): 1.9300E-18

Uterus Ground Sv-m2)/(Bq-sec): 5.5700E-20

Brain Inhalation (Sv/Bq): 2.7300E-06

Brain Submersion (Sv-m3)/(Bq-sec): 2.7900E-18

Brain Ground Sv-m2)/(Bq-sec): 5.7700E-20

SIWall Inhalation (Sv/Bq): 2.7300E-06

SIWall Submersion (Sv-m3)/(Bq-sec): 2.0000E-18

SIWall Ground Sv-m2)/(Bq-sec): 5.6400E-20

Pancreas Inhalation (Sv/Bq): 2.7300E-06

Pancreas Submersion (Sv-m3)/(Bq-sec): 1.9400E-18

Pancreas Ground Sv-m2)/(Bq-sec): 5.1500E-20

Total Activity Released (Ci) : 6.5200E-03

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [09] : Cm-244 M 18.11 y

Halflife (Years) : 1.8110E+01

Inhalation 50-yr CEDE (Sv/Bq) : 2.6600E-05

Submersion (Sv-m3)/(Bq-sec) : 4.0000E-18

Ground Shine (Sv-m2)/(Bq-sec) : 5.8500E-19

Skin Inhalation (Sv/Bq): 1.2800E-06

Skin Submersion (Sv-m3)/(Bq-sec): 3.6100E-17

Skin Ground Sv-m2)/(Bq-sec): 7.7000E-18

Lung Inhalation (Sv/Bq): 3.9200E-05

Lung Submersion (Sv-m3)/(Bq-sec): 1.6700E-18

Lung Ground Sv-m2)/(Bq-sec): 9.9700E-20

Thyroid Inhalation (Sv/Bq): 1.2800E-06

Thyroid Submersion (Sv-m3)/(Bq-sec): 4.7800E-18

Thyroid Ground Sv-m2)/(Bq-sec): 3.7200E-19

Surface Bone Inhalation (Sv/Bq): 9.2100E-04

Surface Bone Submersion (Sv-m3)/(Bq-sec): 9.6300E-18

Surface Bone Ground Sv-m2)/(Bq-sec): 1.2100E-18

Red Marrow Inhalation (Sv/Bq): 3.8600E-05

Red Marrow Submersion (Sv-m3)/(Bq-sec): 2.2900E-18

Red Marrow Ground Sv-m2)/(Bq-sec): 1.9900E-19

Liver Inhalation (Sv/Bq): 7.5100E-05

Liver Submersion (Sv-m3)/(Bq-sec): 1.4300E-18

Liver Ground Sv-m2)/(Bq-sec): 8.5500E-20

Spleen Inhalation (Sv/Bq): 1.2800E-06

Spleen Submersion (Sv-m3)/(Bq-sec): 1.3100E-18

Spleen Ground Sv-m2)/(Bq-sec): 6.0900E-20

Ovaries Inhalation (Sv/Bq): 1.8200E-05

Ovaries Submersion (Sv-m3)/(Bq-sec): 9.3400E-19

Ovaries Ground Sv-m2)/(Bq-sec): 9.3100E-20

Adrenals Inhalation (Sv/Bq): 1.2800E-06

Adrenals Submersion (Sv-m3)/(Bq-sec): 1.1200E-18

Adrenals Ground Sv-m2)/(Bq-sec): 5.7400E-20

Breast Inhalation (Sv/Bq): 1.2800E-06

Breast Submersion (Sv-m3)/(Bq-sec): 1.2900E-17

Breast	Ground	Sv-m2)/(Bq-sec): 1.7500E-18
ULI Wall	Inhalation	(Sv/Bq): 1.2900E-06
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 1.0800E-18
ULI Wall	Ground	Sv-m2)/(Bq-sec): 4.0800E-20
Thymus	Inhalation	(Sv/Bq): 1.2800E-06
Thymus	Submersion	(Sv-m3)/(Bq-sec): 2.1100E-18
Thymus	Ground	Sv-m2)/(Bq-sec): 1.6000E-19
Bladder Wall	Inhalation	(Sv/Bq): 1.2800E-06
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 1.4500E-18
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 1.0900E-19
Esophagus	Inhalation	(Sv/Bq): 7.9100E-06
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 9.7100E-19
Esophagus	Ground	Sv-m2)/(Bq-sec): 2.0500E-20
LLI Wall	Inhalation	(Sv/Bq): 1.3000E-06
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 1.0000E-18
LLI Wall	Ground	Sv-m2)/(Bq-sec): 3.7600E-20
Muscle	Inhalation	(Sv/Bq): 1.2800E-06
Muscle	Submersion	(Sv-m3)/(Bq-sec): 5.7400E-18
Muscle	Ground	Sv-m2)/(Bq-sec): 1.0400E-18
Stomach Wall	Inhalation	(Sv/Bq): 1.2800E-06
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 1.4800E-18
Stomach Wall	Ground	Sv-m2)/(Bq-sec): 9.6800E-20
Kidneys	Inhalation	(Sv/Bq): 6.2000E-06
Kidneys	Submersion	(Sv-m3)/(Bq-sec): 1.9600E-18
Kidneys	Ground	Sv-m2)/(Bq-sec): 1.8500E-19
Testes	Inhalation	(Sv/Bq): 1.8100E-05
Testes	Submersion	(Sv-m3)/(Bq-sec): 7.1300E-18
Testes	Ground	Sv-m2)/(Bq-sec): 1.3900E-18
Uterus	Inhalation	(Sv/Bq): 1.2800E-06
Uterus	Submersion	(Sv-m3)/(Bq-sec): 9.4900E-19

Uterus Ground Sv-m2)/(Bq-sec): 2.9700E-20

Brain Inhalation (Sv/Bq): 1.2800E-06

Brain Submersion (Sv-m3)/(Bq-sec): 1.3700E-18

Brain Ground Sv-m2)/(Bq-sec): 3.1600E-20

SIWall Inhalation (Sv/Bq): 1.2900E-06

SIWall Submersion (Sv-m3)/(Bq-sec): 9.9400E-19

SIWall Ground Sv-m2)/(Bq-sec): 3.4000E-20

Pancreas Inhalation (Sv/Bq): 1.2800E-06

Pancreas Submersion (Sv-m3)/(Bq-sec): 9.2600E-19

Pancreas Ground Sv-m2)/(Bq-sec): 2.3800E-20

Total Activity Released (Ci) : 2.8600E-03

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [10] : Cs-134 M 2.062 y

Halflife (Years) : 2.0620E+00

Inhalation 50-yr CEDE (Sv/Bq) : 9.1700E-09

Submersion (Sv-m3)/(Bq-sec) : 7.0700E-14

Ground Shine (Sv-m2)/(Bq-sec) : 1.4800E-15

Skin Inhalation (Sv/Bq): 2.0400E-09

Skin Submersion (Sv-m3)/(Bq-sec): 9.4500E-14

Skin Ground Sv-m2)/(Bq-sec): 2.1700E-15

Lung Inhalation (Sv/Bq): 5.0200E-08

Lung Submersion (Sv-m3)/(Bq-sec): 7.3700E-14

Lung Ground Sv-m2)/(Bq-sec): 1.4600E-15

Thyroid Inhalation (Sv/Bq): 3.1700E-09

Thyroid Submersion (Sv-m3)/(Bq-sec): 7.5700E-14

Thyroid	Ground	Sv-m2)/(Bq-sec): 1.5200E-15
Surface Bone	Inhalation	(Sv/Bq): 3.3300E-09
Surface Bone	Submersion	(Sv-m3)/(Bq-sec): 1.2000E-13
Surface Bone	Ground	Sv-m2)/(Bq-sec): 2.1200E-15
Red Marrow	Inhalation	(Sv/Bq): 3.5800E-09
Red Marrow	Submersion	(Sv-m3)/(Bq-sec): 7.1900E-14
Red Marrow	Ground	Sv-m2)/(Bq-sec): 1.4800E-15
Liver	Inhalation	(Sv/Bq): 4.4600E-09
Liver	Submersion	(Sv-m3)/(Bq-sec): 6.6500E-14
Liver	Ground	Sv-m2)/(Bq-sec): 1.3900E-15
Spleen	Inhalation	(Sv/Bq): 4.1000E-09
Spleen	Submersion	(Sv-m3)/(Bq-sec): 6.6900E-14
Spleen	Ground	Sv-m2)/(Bq-sec): 1.3900E-15
Ovaries	Inhalation	(Sv/Bq): 2.8900E-09
Ovaries	Submersion	(Sv-m3)/(Bq-sec): 5.8900E-14
Ovaries	Ground	Sv-m2)/(Bq-sec): 1.3900E-15
Adrenals	Inhalation	(Sv/Bq): 5.0200E-09
Adrenals	Submersion	(Sv-m3)/(Bq-sec): 6.1600E-14
Adrenals	Ground	Sv-m2)/(Bq-sec): 1.3100E-15
Breast	Inhalation	(Sv/Bq): 4.4200E-09
Breast	Submersion	(Sv-m3)/(Bq-sec): 8.4300E-14
Breast	Ground	Sv-m2)/(Bq-sec): 1.5300E-15
ULI Wall	Inhalation	(Sv/Bq): 3.6300E-09
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 6.1400E-14
ULI Wall	Ground	Sv-m2)/(Bq-sec): 1.3700E-15
Thymus	Inhalation	(Sv/Bq): 5.4000E-09
Thymus	Submersion	(Sv-m3)/(Bq-sec): 6.8400E-14
Thymus	Ground	Sv-m2)/(Bq-sec): 1.3700E-15
Bladder Wall	Inhalation	(Sv/Bq): 2.4100E-09
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 6.0900E-14

Bladder Wall	Ground	Sv-m2)/(Bq-sec):	1.3900E-15
Esophagus	Inhalation	(Sv/Bq):	1.2400E-08
Esophagus	Submersion	(Sv-m3)/(Bq-sec):	6.1900E-14
Esophagus	Ground	Sv-m2)/(Bq-sec):	1.2500E-15
LLI Wall	Inhalation	(Sv/Bq):	5.2300E-09
LLI Wall	Submersion	(Sv-m3)/(Bq-sec):	6.0600E-14
LLI Wall	Ground	Sv-m2)/(Bq-sec):	1.4100E-15
Muscle	Inhalation	(Sv/Bq):	3.1000E-09
Muscle	Submersion	(Sv-m3)/(Bq-sec):	7.2000E-14
Muscle	Ground	Sv-m2)/(Bq-sec):	1.5800E-15
Stomach Wall	Inhalation	(Sv/Bq):	3.5600E-09
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec):	6.5700E-14
Stomach Wall	Ground	Sv-m2)/(Bq-sec):	1.3800E-15
Kidneys	Inhalation	(Sv/Bq):	3.1000E-09
Kidneys	Submersion	(Sv-m3)/(Bq-sec):	6.6100E-14
Kidneys	Ground	Sv-m2)/(Bq-sec):	1.4000E-15
Testes	Inhalation	(Sv/Bq):	1.9900E-09
Testes	Submersion	(Sv-m3)/(Bq-sec):	7.4000E-14
Testes	Ground	Sv-m2)/(Bq-sec):	1.6000E-15
Uterus	Inhalation	(Sv/Bq):	2.6900E-09
Uterus	Submersion	(Sv-m3)/(Bq-sec):	5.7500E-14
Uterus	Ground	Sv-m2)/(Bq-sec):	1.3500E-15
Brain	Inhalation	(Sv/Bq):	1.9100E-09
Brain	Submersion	(Sv-m3)/(Bq-sec):	7.9100E-14
Brain	Ground	Sv-m2)/(Bq-sec):	1.3800E-15
SIWall	Inhalation	(Sv/Bq):	2.9800E-09
SIWall	Submersion	(Sv-m3)/(Bq-sec):	5.9300E-14
SIWall	Ground	Sv-m2)/(Bq-sec):	1.3600E-15
Pancreas	Inhalation	(Sv/Bq):	4.4100E-09
Pancreas	Submersion	(Sv-m3)/(Bq-sec):	5.8500E-14

Pancreas Ground Sv-m2)/(Bq-sec): 1.2800E-15

Total Activity Released (Ci) : 1.2300E+00

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [11] : Eu-154 M 8.8 y

Halflife (Years) : 8.8000E+00

Inhalation 50-yr CEDE (Sv/Bq) : 5.3200E-08

Submersion (Sv-m3)/(Bq-sec) : 5.7800E-14

Ground Shine (Sv-m2)/(Bq-sec) : 1.1700E-15

Skin Inhalation (Sv/Bq): 7.8500E-09

Skin Submersion (Sv-m3)/(Bq-sec): 8.2100E-14

Skin Ground Sv-m2)/(Bq-sec): 2.6500E-15

Lung Inhalation (Sv/Bq): 1.0000E-07

Lung Submersion (Sv-m3)/(Bq-sec): 6.0200E-14

Lung Ground Sv-m2)/(Bq-sec): 1.1400E-15

Thyroid Inhalation (Sv/Bq): 7.5300E-09

Thyroid Submersion (Sv-m3)/(Bq-sec): 6.1900E-14

Thyroid Ground Sv-m2)/(Bq-sec): 1.1600E-15

Surface Bone Inhalation (Sv/Bq): 4.1000E-07

Surface Bone Submersion (Sv-m3)/(Bq-sec): 9.5100E-14

Surface Bone Ground Sv-m2)/(Bq-sec): 1.7100E-15

Red Marrow Inhalation (Sv/Bq): 9.1600E-08

Red Marrow Submersion (Sv-m3)/(Bq-sec): 5.9000E-14

Red Marrow Ground Sv-m2)/(Bq-sec): 1.1700E-15

Liver Inhalation (Sv/Bq): 3.3700E-07

Liver Submersion (Sv-m3)/(Bq-sec): 5.4500E-14

Liver	Ground	Sv-m2)/(Bq-sec): 1.1000E-15
Spleen	Inhalation	(Sv/Bq): 1.2000E-08
Spleen	Submersion	(Sv-m3)/(Bq-sec): 5.4700E-14
Spleen	Ground	Sv-m2)/(Bq-sec): 1.1000E-15
Ovaries	Inhalation	(Sv/Bq): 1.2600E-08
Ovaries	Submersion	(Sv-m3)/(Bq-sec): 5.0400E-14
Ovaries	Ground	Sv-m2)/(Bq-sec): 1.0400E-15
Adrenals	Inhalation	(Sv/Bq): 4.2500E-08
Adrenals	Submersion	(Sv-m3)/(Bq-sec): 5.0100E-14
Adrenals	Ground	Sv-m2)/(Bq-sec): 1.0300E-15
Breast	Inhalation	(Sv/Bq): 1.1600E-08
Breast	Submersion	(Sv-m3)/(Bq-sec): 6.8500E-14
Breast	Ground	Sv-m2)/(Bq-sec): 1.1900E-15
ULI Wall	Inhalation	(Sv/Bq): 2.1600E-08
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 5.0500E-14
ULI Wall	Ground	Sv-m2)/(Bq-sec): 1.0900E-15
Thymus	Inhalation	(Sv/Bq): 1.2400E-08
Thymus	Submersion	(Sv-m3)/(Bq-sec): 5.6500E-14
Thymus	Ground	Sv-m2)/(Bq-sec): 1.0600E-15
Bladder Wall	Inhalation	(Sv/Bq): 5.8800E-09
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 4.9800E-14
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 1.1000E-15
Esophagus	Inhalation	(Sv/Bq): 1.8600E-08
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 5.1200E-14
Esophagus	Ground	Sv-m2)/(Bq-sec): 9.8700E-16
LLI Wall	Inhalation	(Sv/Bq): 1.5800E-08
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 5.0000E-14
LLI Wall	Ground	Sv-m2)/(Bq-sec): 1.1200E-15
Muscle	Inhalation	(Sv/Bq): 1.2400E-08
Muscle	Submersion	(Sv-m3)/(Bq-sec): 5.8800E-14

Muscle Ground Sv-m2)/(Bq-sec): 1.2400E-15

Stomach Wall Inhalation (Sv/Bq): 1.5400E-08

Stomach Wall Submersion (Sv-m3)/(Bq-sec): 5.3700E-14

Stomach Wall Ground Sv-m2)/(Bq-sec): 1.1000E-15

Kidneys Inhalation (Sv/Bq): 2.8900E-08

Kidneys Submersion (Sv-m3)/(Bq-sec): 5.4100E-14

Kidneys Ground Sv-m2)/(Bq-sec): 1.1100E-15

Testes Inhalation (Sv/Bq): 3.3000E-09

Testes Submersion (Sv-m3)/(Bq-sec): 6.0300E-14

Testes Ground Sv-m2)/(Bq-sec): 1.2500E-15

Uterus Inhalation (Sv/Bq): 9.1600E-09

Uterus Submersion (Sv-m3)/(Bq-sec): 4.7700E-14

Uterus Ground Sv-m2)/(Bq-sec): 1.0600E-15

Brain Inhalation (Sv/Bq): 8.0700E-09

Brain Submersion (Sv-m3)/(Bq-sec): 6.4500E-14

Brain Ground Sv-m2)/(Bq-sec): 1.0800E-15

SIWall Inhalation (Sv/Bq): 1.6400E-08

SIWall Submersion (Sv-m3)/(Bq-sec): 4.9100E-14

SIWall Ground Sv-m2)/(Bq-sec): 1.0800E-15

Pancreas Inhalation (Sv/Bq): 3.1400E-08

Pancreas Submersion (Sv-m3)/(Bq-sec): 4.8300E-14

Pancreas Ground Sv-m2)/(Bq-sec): 1.0200E-15

Total Activity Released (Ci) : 1.3300E-02

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [12] : Cm-243 M 28.5 y

Halflife		(Years)	: 2.8500E+01
Inhalation	50-yr CEDE	(Sv/Bq)	: 3.1500E-05
Submersion		(Sv-m3)/(Bq-sec)	: 5.3300E-15
Ground Shine		(Sv-m2)/(Bq-sec)	: 1.1800E-16
Skin	Inhalation	(Sv/Bq):	1.7400E-06
Skin	Submersion	(Sv-m3)/(Bq-sec):	9.7800E-15
Skin	Ground	Sv-m2)/(Bq-sec):	1.8300E-16
Lung	Inhalation	(Sv/Bq):	3.9800E-05
Lung	Submersion	(Sv-m3)/(Bq-sec):	5.5200E-15
Lung	Ground	Sv-m2)/(Bq-sec):	1.1500E-16
Thyroid	Inhalation	(Sv/Bq):	1.7400E-06
Thyroid	Submersion	(Sv-m3)/(Bq-sec):	5.7800E-15
Thyroid	Ground	Sv-m2)/(Bq-sec):	1.1700E-16
Surface Bone	Inhalation	(Sv/Bq):	1.1600E-03
Surface Bone	Submersion	(Sv-m3)/(Bq-sec):	1.5100E-14
Surface Bone	Ground	Sv-m2)/(Bq-sec):	2.7300E-16
Red Marrow	Inhalation	(Sv/Bq):	4.5200E-05
Red Marrow	Submersion	(Sv-m3)/(Bq-sec):	5.0100E-15
Red Marrow	Ground	Sv-m2)/(Bq-sec):	1.1200E-16
Liver	Inhalation	(Sv/Bq):	8.5300E-05
Liver	Submersion	(Sv-m3)/(Bq-sec):	4.8900E-15
Liver	Ground	Sv-m2)/(Bq-sec):	1.0800E-16
Spleen	Inhalation	(Sv/Bq):	1.7400E-06
Spleen	Submersion	(Sv-m3)/(Bq-sec):	4.8900E-15
Spleen	Ground	Sv-m2)/(Bq-sec):	1.0900E-16
Ovaries	Inhalation	(Sv/Bq):	2.2800E-05
Ovaries	Submersion	(Sv-m3)/(Bq-sec):	3.9700E-15
Ovaries	Ground	Sv-m2)/(Bq-sec):	1.0300E-16
Adrenals	Inhalation	(Sv/Bq):	1.7400E-06
Adrenals	Submersion	(Sv-m3)/(Bq-sec):	4.3500E-15

Adrenals Ground Sv-m2)/(Bq-sec): 9.9800E-17

Breast Inhalation (Sv/Bq): 1.7400E-06

Breast Submersion (Sv-m3)/(Bq-sec): 6.6900E-15

Breast Ground Sv-m2)/(Bq-sec): 1.3000E-16

ULI Wall Inhalation (Sv/Bq): 1.7400E-06

ULI Wall Submersion (Sv-m3)/(Bq-sec): 4.3600E-15

ULI Wall Ground Sv-m2)/(Bq-sec): 1.0500E-16

Thymus Inhalation (Sv/Bq): 1.7400E-06

Thymus Submersion (Sv-m3)/(Bq-sec): 5.2100E-15

Thymus Ground Sv-m2)/(Bq-sec): 1.0500E-16

Bladder Wall Inhalation (Sv/Bq): 1.7400E-06

Bladder Wall Submersion (Sv-m3)/(Bq-sec): 4.5300E-15

Bladder Wall Ground Sv-m2)/(Bq-sec): 1.0800E-16

Esophagus Inhalation (Sv/Bq): 8.4100E-06

Esophagus Submersion (Sv-m3)/(Bq-sec): 4.1700E-15

Esophagus Ground Sv-m2)/(Bq-sec): 9.2800E-17

LLI Wall Inhalation (Sv/Bq): 1.7600E-06

LLI Wall Submersion (Sv-m3)/(Bq-sec): 4.1700E-15

LLI Wall Ground Sv-m2)/(Bq-sec): 1.0500E-16

Muscle Inhalation (Sv/Bq): 1.7400E-06

Muscle Submersion (Sv-m3)/(Bq-sec): 5.4200E-15

Muscle Ground Sv-m2)/(Bq-sec): 1.2700E-16

Stomach Wall Inhalation (Sv/Bq): 1.7400E-06

Stomach Wall Submersion (Sv-m3)/(Bq-sec): 4.7900E-15

Stomach Wall Ground Sv-m2)/(Bq-sec): 1.0800E-16

Kidneys Inhalation (Sv/Bq): 7.0800E-06

Kidneys Submersion (Sv-m3)/(Bq-sec): 4.8800E-15

Kidneys Ground Sv-m2)/(Bq-sec): 1.0800E-16

Testes Inhalation (Sv/Bq): 2.2600E-05

Testes Submersion (Sv-m3)/(Bq-sec): 5.7800E-15

Testes Ground Sv-m2)/(Bq-sec): 1.3200E-16

Uterus Inhalation (Sv/Bq): 1.7400E-06

Uterus Submersion (Sv-m3)/(Bq-sec): 4.0400E-15

Uterus Ground Sv-m2)/(Bq-sec): 1.0200E-16

Brain Inhalation (Sv/Bq): 1.7400E-06

Brain Submersion (Sv-m3)/(Bq-sec): 5.6200E-15

Brain Ground Sv-m2)/(Bq-sec): 1.0400E-16

SIWall Inhalation (Sv/Bq): 1.7400E-06

SIWall Submersion (Sv-m3)/(Bq-sec): 4.1300E-15

SIWall Ground Sv-m2)/(Bq-sec): 1.0100E-16

Pancreas Inhalation (Sv/Bq): 1.7400E-06

Pancreas Submersion (Sv-m3)/(Bq-sec): 4.0900E-15

Pancreas Ground Sv-m2)/(Bq-sec): 9.7300E-17

Total Activity Released (Ci) : 1.0500E-04

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [13] : Am-243 M 7380 y

Halflife (Years) : 7.3800E+03

Inhalation 50-yr CEDE (Sv/Bq) : 4.1200E-05

Submersion (Sv-m3)/(Bq-sec) : 1.9200E-15

Ground Shine (Sv-m2)/(Bq-sec) : 4.9600E-17

Skin Inhalation (Sv/Bq): 2.9000E-06

Skin Submersion (Sv-m3)/(Bq-sec): 2.8400E-15

Skin Ground Sv-m2)/(Bq-sec): 7.8500E-17

Lung Inhalation (Sv/Bq): 3.4800E-05

Lung Submersion (Sv-m3)/(Bq-sec): 1.9900E-15

Lung Ground Sv-m2)/(Bq-sec): 4.9200E-17

Thyroid Inhalation (Sv/Bq): 2.9000E-06

Thyroid Submersion (Sv-m3)/(Bq-sec): 2.1600E-15

Thyroid Ground Sv-m2)/(Bq-sec): 4.9400E-17

Surface Bone Inhalation (Sv/Bq): 1.7000E-03

Surface Bone Submersion (Sv-m3)/(Bq-sec): 7.7300E-15

Surface Bone Ground Sv-m2)/(Bq-sec): 1.9300E-16

Red Marrow Inhalation (Sv/Bq): 5.7300E-05

Red Marrow Submersion (Sv-m3)/(Bq-sec): 1.6000E-15

Red Marrow Ground Sv-m2)/(Bq-sec): 4.2600E-17

Liver Inhalation (Sv/Bq): 1.0300E-04

Liver Submersion (Sv-m3)/(Bq-sec): 1.6900E-15

Liver Ground Sv-m2)/(Bq-sec): 4.5400E-17

Spleen Inhalation (Sv/Bq): 2.9000E-06

Spleen Submersion (Sv-m3)/(Bq-sec): 1.6900E-15

Spleen Ground Sv-m2)/(Bq-sec): 4.5700E-17

Ovaries Inhalation (Sv/Bq): 3.2900E-05

Ovaries Submersion (Sv-m3)/(Bq-sec): 1.2100E-15

Ovaries Ground Sv-m2)/(Bq-sec): 4.0300E-17

Adrenals Inhalation (Sv/Bq): 2.9200E-06

Adrenals Submersion (Sv-m3)/(Bq-sec): 1.4100E-15

Adrenals Ground Sv-m2)/(Bq-sec): 3.8700E-17

Breast Inhalation (Sv/Bq): 2.9000E-06

Breast Submersion (Sv-m3)/(Bq-sec): 2.7000E-15

Breast Ground Sv-m2)/(Bq-sec): 5.7200E-17

ULI Wall Inhalation (Sv/Bq): 2.9100E-06

ULI Wall Submersion (Sv-m3)/(Bq-sec): 1.4200E-15

ULI Wall Ground Sv-m2)/(Bq-sec): 4.1900E-17

Thymus Inhalation (Sv/Bq): 2.9000E-06

Thymus Submersion (Sv-m3)/(Bq-sec): 1.8900E-15

Thymus Ground Sv-m2)/(Bq-sec): 4.7500E-17

Bladder Wall Inhalation (Sv/Bq): 2.9000E-06

Bladder Wall Submersion (Sv-m3)/(Bq-sec): 1.5600E-15

Bladder Wall Ground Sv-m2)/(Bq-sec): 4.4700E-17

Esophagus Inhalation (Sv/Bq): 9.2200E-06

Esophagus Submersion (Sv-m3)/(Bq-sec): 1.2400E-15

Esophagus Ground Sv-m2)/(Bq-sec): 3.3800E-17

LLI Wall Inhalation (Sv/Bq): 2.9200E-06

LLI Wall Submersion (Sv-m3)/(Bq-sec): 1.3200E-15

LLI Wall Ground Sv-m2)/(Bq-sec): 4.1100E-17

Muscle Inhalation (Sv/Bq): 2.9000E-06

Muscle Submersion (Sv-m3)/(Bq-sec): 2.0000E-15

Muscle Ground Sv-m2)/(Bq-sec): 5.3500E-17

Stomach Wall Inhalation (Sv/Bq): 2.9000E-06

Stomach Wall Submersion (Sv-m3)/(Bq-sec): 1.6700E-15

Stomach Wall Ground Sv-m2)/(Bq-sec): 4.4900E-17

Kidneys Inhalation (Sv/Bq): 8.6000E-06

Kidneys Submersion (Sv-m3)/(Bq-sec): 1.7500E-15

Kidneys Ground Sv-m2)/(Bq-sec): 4.5400E-17

Testes Inhalation (Sv/Bq): 3.2600E-05

Testes Submersion (Sv-m3)/(Bq-sec): 2.2700E-15

Testes Ground Sv-m2)/(Bq-sec): 5.6700E-17

Uterus Inhalation (Sv/Bq): 2.9000E-06

Uterus Submersion (Sv-m3)/(Bq-sec): 1.2600E-15

Uterus Ground Sv-m2)/(Bq-sec): 3.9300E-17

Brain Inhalation (Sv/Bq): 2.9100E-06

Brain Submersion (Sv-m3)/(Bq-sec): 1.8900E-15

Brain Ground Sv-m2)/(Bq-sec): 4.0600E-17

SIWall Inhalation (Sv/Bq): 2.9100E-06

SIWall Submersion (Sv-m3)/(Bq-sec): 1.3100E-15

SIWall Ground Sv-m2)/(Bq-sec): 3.9600E-17

Pancreas Inhalation (Sv/Bq): 2.9100E-06

Pancreas Submersion (Sv-m3)/(Bq-sec): 1.2600E-15

Pancreas Ground Sv-m2)/(Bq-sec): 3.8100E-17

Total Activity Released (Ci) : 9.0400E-05

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [14] : Ce-144 M 284.3 d

Halflife (Years) : 7.7890E-01

Inhalation 50-yr CEDE (Sv/Bq) : 3.6000E-08

Submersion (Sv-m3)/(Bq-sec) : 7.3500E-16

Ground Shine (Sv-m2)/(Bq-sec) : 1.7300E-17

Skin Inhalation (Sv/Bq): 1.7500E-09

Skin Submersion (Sv-m3)/(Bq-sec): 2.9300E-15

Skin Ground Sv-m2)/(Bq-sec): 2.4000E-17

Lung Inhalation (Sv/Bq): 1.8700E-07

Lung Submersion (Sv-m3)/(Bq-sec): 7.3900E-16

Lung Ground Sv-m2)/(Bq-sec): 1.6900E-17

Thyroid Inhalation (Sv/Bq): 1.7700E-09

Thyroid Submersion (Sv-m3)/(Bq-sec): 7.9500E-16

Thyroid Ground Sv-m2)/(Bq-sec): 1.7800E-17

Surface Bone Inhalation (Sv/Bq): 4.9100E-08

Surface Bone Submersion (Sv-m3)/(Bq-sec): 2.3600E-15

Surface Bone Ground Sv-m2)/(Bq-sec): 5.1300E-17

Red Marrow Inhalation (Sv/Bq): 2.7700E-08

Red Marrow Submersion (Sv-m3)/(Bq-sec): 6.4600E-16

Red Marrow	Ground	Sv-m2)/(Bq-sec): 1.5600E-17
Liver	Inhalation	(Sv/Bq): 1.4500E-07
Liver	Submersion	(Sv-m3)/(Bq-sec): 6.4500E-16
Liver	Ground	Sv-m2)/(Bq-sec): 1.5700E-17
Spleen	Inhalation	(Sv/Bq): 1.8200E-09
Spleen	Submersion	(Sv-m3)/(Bq-sec): 6.4300E-16
Spleen	Ground	Sv-m2)/(Bq-sec): 1.5800E-17
Ovaries	Inhalation	(Sv/Bq): 1.7900E-09
Ovaries	Submersion	(Sv-m3)/(Bq-sec): 5.0100E-16
Ovaries	Ground	Sv-m2)/(Bq-sec): 1.3300E-17
Adrenals	Inhalation	(Sv/Bq): 2.0400E-09
Adrenals	Submersion	(Sv-m3)/(Bq-sec): 5.5800E-16
Adrenals	Ground	Sv-m2)/(Bq-sec): 1.4000E-17
Breast	Inhalation	(Sv/Bq): 1.8300E-09
Breast	Submersion	(Sv-m3)/(Bq-sec): 9.5400E-16
Breast	Ground	Sv-m2)/(Bq-sec): 1.9900E-17
ULI Wall	Inhalation	(Sv/Bq): 7.3300E-09
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 5.6200E-16
ULI Wall	Ground	Sv-m2)/(Bq-sec): 1.4700E-17
Thymus	Inhalation	(Sv/Bq): 1.8600E-09
Thymus	Submersion	(Sv-m3)/(Bq-sec): 7.0500E-16
Thymus	Ground	Sv-m2)/(Bq-sec): 1.5500E-17
Bladder Wall	Inhalation	(Sv/Bq): 1.7500E-09
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 5.9700E-16
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 1.5800E-17
Esophagus	Inhalation	(Sv/Bq): 8.5300E-09
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 5.2000E-16
Esophagus	Ground	Sv-m2)/(Bq-sec): 1.2400E-17
LLI Wall	Inhalation	(Sv/Bq): 1.7800E-08
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 5.3100E-16

LLI Wall	Ground	Sv-m2)/(Bq-sec): 1.4400E-17
Muscle	Inhalation	(Sv/Bq): 1.8100E-09
Muscle	Submersion	(Sv-m3)/(Bq-sec): 7.3900E-16
Muscle	Ground	Sv-m2)/(Bq-sec): 1.8700E-17
Stomach Wall	Inhalation	(Sv/Bq): 2.1500E-09
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 6.3100E-16
Stomach Wall	Ground	Sv-m2)/(Bq-sec): 1.5600E-17
Kidneys	Inhalation	(Sv/Bq): 1.9000E-09
Kidneys	Submersion	(Sv-m3)/(Bq-sec): 6.5600E-16
Kidneys	Ground	Sv-m2)/(Bq-sec): 1.6200E-17
Testes	Inhalation	(Sv/Bq): 1.7200E-09
Testes	Submersion	(Sv-m3)/(Bq-sec): 8.1100E-16
Testes	Ground	Sv-m2)/(Bq-sec): 2.0100E-17
Uterus	Inhalation	(Sv/Bq): 1.7700E-09
Uterus	Submersion	(Sv-m3)/(Bq-sec): 5.1200E-16
Uterus	Ground	Sv-m2)/(Bq-sec): 1.4000E-17
Brain	Inhalation	(Sv/Bq): 1.7400E-09
Brain	Submersion	(Sv-m3)/(Bq-sec): 7.2900E-16
Brain	Ground	Sv-m2)/(Bq-sec): 1.4400E-17
SIWall	Inhalation	(Sv/Bq): 2.6900E-09
SIWall	Submersion	(Sv-m3)/(Bq-sec): 5.2600E-16
SIWall	Ground	Sv-m2)/(Bq-sec): 1.3900E-17
Pancreas	Inhalation	(Sv/Bq): 1.9700E-09
Pancreas	Submersion	(Sv-m3)/(Bq-sec): 5.1600E-16
Pancreas	Ground	Sv-m2)/(Bq-sec): 1.3300E-17

Total Activity Released (Ci) : 1.6300E-02

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [15] : Pu-242 M 3.763E5 y

Halflife (Years) : 3.7630E+05

Inhalation 50-yr CEDE (Sv/Bq) : 4.7600E-05

Submersion (Sv-m3)/(Bq-sec) : 6.4300E-18

Ground Shine (Sv-m2)/(Bq-sec) : 5.5600E-19

Skin Inhalation (Sv/Bq): 2.6000E-06

Skin Submersion (Sv-m3)/(Bq-sec): 3.9200E-17

Skin Ground Sv-m2)/(Bq-sec): 8.1400E-18

Lung Inhalation (Sv/Bq): 3.0900E-05

Lung Submersion (Sv-m3)/(Bq-sec): 4.6700E-18

Lung Ground Sv-m2)/(Bq-sec): 1.2800E-19

Thyroid Inhalation (Sv/Bq): 2.6000E-06

Thyroid Submersion (Sv-m3)/(Bq-sec): 7.0200E-18

Thyroid Ground Sv-m2)/(Bq-sec): 3.2700E-19

Surface Bone Inhalation (Sv/Bq): 1.4800E-03

Surface Bone Submersion (Sv-m3)/(Bq-sec): 1.2800E-17

Surface Bone Ground Sv-m2)/(Bq-sec): 1.0400E-18

Red Marrow Inhalation (Sv/Bq): 7.0300E-05

Red Marrow Submersion (Sv-m3)/(Bq-sec): 5.0900E-18

Red Marrow Ground Sv-m2)/(Bq-sec): 2.1800E-19

Liver Inhalation (Sv/Bq): 3.1000E-04

Liver Submersion (Sv-m3)/(Bq-sec): 4.2000E-18

Liver Ground Sv-m2)/(Bq-sec): 1.1600E-19

Spleen Inhalation (Sv/Bq): 2.6000E-06

Spleen Submersion (Sv-m3)/(Bq-sec): 4.1200E-18

Spleen Ground Sv-m2)/(Bq-sec): 9.9900E-20

Ovaries Inhalation (Sv/Bq): 1.9300E-05

Ovaries Submersion (Sv-m3)/(Bq-sec): 3.5800E-18

Ovaries Ground Sv-m2)/(Bq-sec): 1.3400E-19

Adrenals Inhalation (Sv/Bq): 2.6000E-06

Adrenals Submersion (Sv-m3)/(Bq-sec): 3.7200E-18

Adrenals Ground Sv-m2)/(Bq-sec): 9.7700E-20

Breast Inhalation (Sv/Bq): 2.6000E-06

Breast Submersion (Sv-m3)/(Bq-sec): 1.4100E-17

Breast Ground Sv-m2)/(Bq-sec): 1.5600E-18

ULI Wall Inhalation (Sv/Bq): 2.6000E-06

ULI Wall Submersion (Sv-m3)/(Bq-sec): 3.7300E-18

ULI Wall Ground Sv-m2)/(Bq-sec): 8.7200E-20

Thymus Inhalation (Sv/Bq): 2.6000E-06

Thymus Submersion (Sv-m3)/(Bq-sec): 4.7900E-18

Thymus Ground Sv-m2)/(Bq-sec): 1.6600E-19

Bladder Wall Inhalation (Sv/Bq): 2.6000E-06

Bladder Wall Submersion (Sv-m3)/(Bq-sec): 4.0000E-18

Bladder Wall Ground Sv-m2)/(Bq-sec): 1.3500E-19

Esophagus Inhalation (Sv/Bq): 8.6500E-06

Esophagus Submersion (Sv-m3)/(Bq-sec): 3.6600E-18

Esophagus Ground Sv-m2)/(Bq-sec): 6.9200E-20

LLI Wall Inhalation (Sv/Bq): 2.6100E-06

LLI Wall Submersion (Sv-m3)/(Bq-sec): 3.6400E-18

LLI Wall Ground Sv-m2)/(Bq-sec): 8.7800E-20

Muscle Inhalation (Sv/Bq): 2.6000E-06

Muscle Submersion (Sv-m3)/(Bq-sec): 7.8500E-18

Muscle Ground Sv-m2)/(Bq-sec): 9.6400E-19

Stomach Wall Inhalation (Sv/Bq): 2.6000E-06

Stomach Wall Submersion (Sv-m3)/(Bq-sec): 4.1900E-18

Stomach Wall Ground Sv-m2)/(Bq-sec): 1.2400E-19

Kidneys Inhalation (Sv/Bq): 6.0600E-06

Kidneys Submersion (Sv-m3)/(Bq-sec): 4.5100E-18

Kidneys Ground Sv-m2)/(Bq-sec): 1.8200E-19

Testes Inhalation (Sv/Bq): 1.9700E-05

Testes Submersion (Sv-m3)/(Bq-sec): 8.8500E-18

Testes Ground Sv-m2)/(Bq-sec): 1.2200E-18

Uterus Inhalation (Sv/Bq): 2.6000E-06

Uterus Submersion (Sv-m3)/(Bq-sec): 3.5100E-18

Uterus Ground Sv-m2)/(Bq-sec): 8.0400E-20

Brain Inhalation (Sv/Bq): 2.6000E-06

Brain Submersion (Sv-m3)/(Bq-sec): 4.6900E-18

Brain Ground Sv-m2)/(Bq-sec): 8.1500E-20

SIWall Inhalation (Sv/Bq): 2.6000E-06

SIWall Submersion (Sv-m3)/(Bq-sec): 3.5900E-18

SIWall Ground Sv-m2)/(Bq-sec): 8.2500E-20

Pancreas Inhalation (Sv/Bq): 2.6000E-06

Pancreas Submersion (Sv-m3)/(Bq-sec): 3.5200E-18

Pancreas Ground Sv-m2)/(Bq-sec): 7.4200E-20

Total Activity Released (Ci) : 5.5800E-05

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [16] : Sb-125 M 2.77 y

Halflife (Years) : 2.7700E+00

Inhalation 50-yr CEDE (Sv/Bq) : 4.7900E-09

Submersion (Sv-m3)/(Bq-sec) : 1.9000E-14

Ground Shine (Sv-m2)/(Bq-sec) : 4.1400E-16

Skin Inhalation (Sv/Bq): 3.4800E-10

Skin Submersion (Sv-m3)/(Bq-sec): 2.6800E-14

Skin Ground Sv-m2)/(Bq-sec): 6.0700E-16

Lung Inhalation (Sv/Bq): 3.2400E-08

Lung Submersion (Sv-m3)/(Bq-sec): 1.9700E-14

Lung Ground Sv-m2)/(Bq-sec): 4.0500E-16

Thyroid Inhalation (Sv/Bq): 5.5100E-10

Thyroid Submersion (Sv-m3)/(Bq-sec): 2.0400E-14

Thyroid Ground Sv-m2)/(Bq-sec): 4.2800E-16

Surface Bone Inhalation (Sv/Bq): 8.7200E-09

Surface Bone Submersion (Sv-m3)/(Bq-sec): 3.5800E-14

Surface Bone Ground Sv-m2)/(Bq-sec): 6.6000E-16

Red Marrow Inhalation (Sv/Bq): 1.7300E-09

Red Marrow Submersion (Sv-m3)/(Bq-sec): 1.9000E-14

Red Marrow Ground Sv-m2)/(Bq-sec): 4.0800E-16

Liver Inhalation (Sv/Bq): 1.3800E-09

Liver Submersion (Sv-m3)/(Bq-sec): 1.7700E-14

Liver Ground Sv-m2)/(Bq-sec): 3.8200E-16

Spleen Inhalation (Sv/Bq): 8.1700E-10

Spleen Submersion (Sv-m3)/(Bq-sec): 1.7800E-14

Spleen Ground Sv-m2)/(Bq-sec): 3.8300E-16

Ovaries Inhalation (Sv/Bq): 4.6300E-10

Ovaries Submersion (Sv-m3)/(Bq-sec): 1.4900E-14

Ovaries Ground Sv-m2)/(Bq-sec): 3.9400E-16

Adrenals Inhalation (Sv/Bq): 1.1800E-09

Adrenals Submersion (Sv-m3)/(Bq-sec): 1.6400E-14

Adrenals Ground Sv-m2)/(Bq-sec): 3.5600E-16

Breast Inhalation (Sv/Bq): 1.0400E-09

Breast Submersion (Sv-m3)/(Bq-sec): 2.3000E-14

Breast Ground Sv-m2)/(Bq-sec): 4.4400E-16

ULI Wall Inhalation (Sv/Bq): 9.7900E-10

ULI Wall Submersion (Sv-m3)/(Bq-sec): 1.6200E-14

ULI Wall	Ground	Sv-m2)/(Bq-sec): 3.7500E-16
Thymus	Inhalation	(Sv/Bq): 1.2100E-09
Thymus	Submersion	(Sv-m3)/(Bq-sec): 1.8300E-14
Thymus	Ground	Sv-m2)/(Bq-sec): 3.8800E-16
Bladder Wall	Inhalation	(Sv/Bq): 3.2500E-10
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 1.6400E-14
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 3.8800E-16
Esophagus	Inhalation	(Sv/Bq): 5.8100E-09
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 1.6200E-14
Esophagus	Ground	Sv-m2)/(Bq-sec): 3.3900E-16
LLI Wall	Inhalation	(Sv/Bq): 1.9800E-09
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 1.5800E-14
LLI Wall	Ground	Sv-m2)/(Bq-sec): 3.8100E-16
Muscle	Inhalation	(Sv/Bq): 6.0200E-10
Muscle	Submersion	(Sv-m3)/(Bq-sec): 1.9400E-14
Muscle	Ground	Sv-m2)/(Bq-sec): 4.4600E-16
Stomach Wall	Inhalation	(Sv/Bq): 6.9000E-10
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 1.7500E-14
Stomach Wall	Ground	Sv-m2)/(Bq-sec): 3.8000E-16
Kidneys	Inhalation	(Sv/Bq): 5.5300E-10
Kidneys	Submersion	(Sv-m3)/(Bq-sec): 1.7700E-14
Kidneys	Ground	Sv-m2)/(Bq-sec): 3.8700E-16
Testes	Inhalation	(Sv/Bq): 2.1000E-10
Testes	Submersion	(Sv-m3)/(Bq-sec): 2.0100E-14
Testes	Ground	Sv-m2)/(Bq-sec): 4.5900E-16
Uterus	Inhalation	(Sv/Bq): 3.5200E-10
Uterus	Submersion	(Sv-m3)/(Bq-sec): 1.5100E-14
Uterus	Ground	Sv-m2)/(Bq-sec): 3.6600E-16
Brain	Inhalation	(Sv/Bq): 2.9000E-10
Brain	Submersion	(Sv-m3)/(Bq-sec): 2.1000E-14

Brain Ground Sv-m2)/(Bq-sec): 3.7700E-16

SIWall Inhalation (Sv/Bq): 5.3100E-10

SIWall Submersion (Sv-m3)/(Bq-sec): 1.5500E-14

SIWall Ground Sv-m2)/(Bq-sec): 3.6700E-16

Pancreas Inhalation (Sv/Bq): 8.9900E-10

Pancreas Submersion (Sv-m3)/(Bq-sec): 1.5400E-14

Pancreas Ground Sv-m2)/(Bq-sec): 3.4600E-16

Total Activity Released (Ci) : 3.9000E-02

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [17] : Eu-155 M 4.96 y

Halflife (Years) : 4.9600E+00

Inhalation 50-yr CEDE (Sv/Bq) : 6.9600E-09

Submersion (Sv-m3)/(Bq-sec) : 2.1700E-15

Ground Shine (Sv-m2)/(Bq-sec) : 5.3900E-17

Skin Inhalation (Sv/Bq): 2.3300E-10

Skin Submersion (Sv-m3)/(Bq-sec): 3.4500E-15

Skin Ground Sv-m2)/(Bq-sec): 7.0900E-17

Lung Inhalation (Sv/Bq): 1.8800E-08

Lung Submersion (Sv-m3)/(Bq-sec): 2.2400E-15

Lung Ground Sv-m2)/(Bq-sec): 5.3800E-17

Thyroid Inhalation (Sv/Bq): 2.6100E-10

Thyroid Submersion (Sv-m3)/(Bq-sec): 2.4300E-15

Thyroid Ground Sv-m2)/(Bq-sec): 5.5200E-17

Surface Bone Inhalation (Sv/Bq): 1.1800E-07

Surface Bone Submersion (Sv-m3)/(Bq-sec): 8.1500E-15

Surface Bone	Ground	Sv-m2)/(Bq-sec): 1.9200E-16
Red Marrow	Inhalation	(Sv/Bq): 1.0400E-08
Red Marrow	Submersion	(Sv-m3)/(Bq-sec): 1.8600E-15
Red Marrow	Ground	Sv-m2)/(Bq-sec): 4.7500E-17
Liver	Inhalation	(Sv/Bq): 3.7300E-08
Liver	Submersion	(Sv-m3)/(Bq-sec): 1.9300E-15
Liver	Ground	Sv-m2)/(Bq-sec): 4.9500E-17
Spleen	Inhalation	(Sv/Bq): 4.5200E-10
Spleen	Submersion	(Sv-m3)/(Bq-sec): 1.9200E-15
Spleen	Ground	Sv-m2)/(Bq-sec): 5.0100E-17
Ovaries	Inhalation	(Sv/Bq): 4.8600E-10
Ovaries	Submersion	(Sv-m3)/(Bq-sec): 1.4200E-15
Ovaries	Ground	Sv-m2)/(Bq-sec): 4.2100E-17
Adrenals	Inhalation	(Sv/Bq): 1.8800E-09
Adrenals	Submersion	(Sv-m3)/(Bq-sec): 1.6300E-15
Adrenals	Ground	Sv-m2)/(Bq-sec): 4.2900E-17
Breast	Inhalation	(Sv/Bq): 4.2600E-10
Breast	Submersion	(Sv-m3)/(Bq-sec): 2.9700E-15
Breast	Ground	Sv-m2)/(Bq-sec): 6.0600E-17
ULI Wall	Inhalation	(Sv/Bq): 1.1200E-09
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 1.6400E-15
ULI Wall	Ground	Sv-m2)/(Bq-sec): 4.6000E-17
Thymus	Inhalation	(Sv/Bq): 4.9600E-10
Thymus	Submersion	(Sv-m3)/(Bq-sec): 2.1400E-15
Thymus	Ground	Sv-m2)/(Bq-sec): 4.9900E-17
Bladder Wall	Inhalation	(Sv/Bq): 1.9200E-10
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 1.7800E-15
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 4.9700E-17
Esophagus	Inhalation	(Sv/Bq): 3.0700E-09
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 1.4700E-15

Esophagus	Ground	Sv-m2)/(Bq-sec): 3.8100E-17
LLI Wall	Inhalation	(Sv/Bq): 1.3200E-09
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 1.5400E-15
LLI Wall	Ground	Sv-m2)/(Bq-sec): 4.5200E-17
Muscle	Inhalation	(Sv/Bq): 4.9400E-10
Muscle	Submersion	(Sv-m3)/(Bq-sec): 2.2500E-15
Muscle	Ground	Sv-m2)/(Bq-sec): 5.7600E-17
Stomach Wall	Inhalation	(Sv/Bq): 6.3500E-10
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 1.8900E-15
Stomach Wall	Ground	Sv-m2)/(Bq-sec): 4.9200E-17
Kidneys	Inhalation	(Sv/Bq): 1.4100E-09
Kidneys	Submersion	(Sv-m3)/(Bq-sec): 1.9800E-15
Kidneys	Ground	Sv-m2)/(Bq-sec): 5.0400E-17
Testes	Inhalation	(Sv/Bq): 8.1600E-11
Testes	Submersion	(Sv-m3)/(Bq-sec): 2.5100E-15
Testes	Ground	Sv-m2)/(Bq-sec): 6.1300E-17
Uterus	Inhalation	(Sv/Bq): 3.2700E-10
Uterus	Submersion	(Sv-m3)/(Bq-sec): 1.4700E-15
Uterus	Ground	Sv-m2)/(Bq-sec): 4.3500E-17
Brain	Inhalation	(Sv/Bq): 2.8800E-10
Brain	Submersion	(Sv-m3)/(Bq-sec): 2.1600E-15
Brain	Ground	Sv-m2)/(Bq-sec): 4.4900E-17
SIWall	Inhalation	(Sv/Bq): 6.8700E-10
SIWall	Submersion	(Sv-m3)/(Bq-sec): 1.5200E-15
SIWall	Ground	Sv-m2)/(Bq-sec): 4.3400E-17
Pancreas	Inhalation	(Sv/Bq): 1.4800E-09
Pancreas	Submersion	(Sv-m3)/(Bq-sec): 1.4700E-15
Pancreas	Ground	Sv-m2)/(Bq-sec): 4.1500E-17
Total Activity Released		(Ci) : 5.5100E-02
Airborne Fraction		: 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [18] : Am-242m M 152 y

Halflife (Years) : 1.5200E+02

Inhalation 50-yr CEDE (Sv/Bq) : 3.7000E-05

Submersion (Sv-m3)/(Bq-sec) : 1.9800E-17

Ground Shine (Sv-m2)/(Bq-sec) : 2.0700E-18

Skin Inhalation (Sv/Bq): 2.8700E-06

Skin Submersion (Sv-m3)/(Bq-sec): 1.2300E-16

Skin Ground Sv-m2)/(Bq-sec): 2.2900E-17

Lung Inhalation (Sv/Bq): 8.7600E-06

Lung Submersion (Sv-m3)/(Bq-sec): 1.2200E-17

Lung Ground Sv-m2)/(Bq-sec): 5.3100E-19

Thyroid Inhalation (Sv/Bq): 2.8700E-06

Thyroid Submersion (Sv-m3)/(Bq-sec): 2.3700E-17

Thyroid Ground Sv-m2)/(Bq-sec): 1.4800E-18

Surface Bone Inhalation (Sv/Bq): 1.6700E-03

Surface Bone Submersion (Sv-m3)/(Bq-sec): 6.0700E-17

Surface Bone Ground Sv-m2)/(Bq-sec): 4.7600E-18

Red Marrow Inhalation (Sv/Bq): 5.5000E-05

Red Marrow Submersion (Sv-m3)/(Bq-sec): 1.2900E-17

Red Marrow Ground Sv-m2)/(Bq-sec): 8.1300E-19

Liver Inhalation (Sv/Bq): 9.5200E-05

Liver Submersion (Sv-m3)/(Bq-sec): 1.0400E-17

Liver Ground Sv-m2)/(Bq-sec): 4.6400E-19

Spleen Inhalation (Sv/Bq): 2.8700E-06

Spleen Submersion (Sv-m3)/(Bq-sec): 9.9200E-18

Spleen	Ground	Sv-m2)/(Bq-sec): 3.7900E-19
Ovaries	Inhalation	(Sv/Bq): 3.2300E-05
Ovaries	Submersion	(Sv-m3)/(Bq-sec): 6.8600E-18
Ovaries	Ground	Sv-m2)/(Bq-sec): 4.3300E-19
Adrenals	Inhalation	(Sv/Bq): 2.8700E-06
Adrenals	Submersion	(Sv-m3)/(Bq-sec): 8.2900E-18
Adrenals	Ground	Sv-m2)/(Bq-sec): 3.2900E-19
Breast	Inhalation	(Sv/Bq): 2.8700E-06
Breast	Submersion	(Sv-m3)/(Bq-sec): 5.2000E-17
Breast	Ground	Sv-m2)/(Bq-sec): 5.8300E-18
ULI Wall	Inhalation	(Sv/Bq): 2.8700E-06
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 8.1600E-18
ULI Wall	Ground	Sv-m2)/(Bq-sec): 2.8600E-19
Thymus	Inhalation	(Sv/Bq): 2.8700E-06
Thymus	Submersion	(Sv-m3)/(Bq-sec): 1.3600E-17
Thymus	Ground	Sv-m2)/(Bq-sec): 7.3500E-19
Bladder Wall	Inhalation	(Sv/Bq): 2.8700E-06
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 1.0000E-17
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 5.4800E-19
Esophagus	Inhalation	(Sv/Bq): 5.2000E-06
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 7.1200E-18
Esophagus	Ground	Sv-m2)/(Bq-sec): 1.8200E-19
LLI Wall	Inhalation	(Sv/Bq): 2.8800E-06
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 7.5000E-18
LLI Wall	Ground	Sv-m2)/(Bq-sec): 2.6600E-19
Muscle	Inhalation	(Sv/Bq): 2.8700E-06
Muscle	Submersion	(Sv-m3)/(Bq-sec): 2.5800E-17
Muscle	Ground	Sv-m2)/(Bq-sec): 3.5300E-18
Stomach Wall	Inhalation	(Sv/Bq): 2.8700E-06
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 1.0500E-17

Stomach Wall Ground Sv-m2)/(Bq-sec): 5.0500E-19

Kidneys Inhalation (Sv/Bq): 7.9900E-06

Kidneys Submersion (Sv-m3)/(Bq-sec): 1.2500E-17

Kidneys Ground Sv-m2)/(Bq-sec): 8.2600E-19

Testes Inhalation (Sv/Bq): 3.2000E-05

Testes Submersion (Sv-m3)/(Bq-sec): 3.1800E-17

Testes Ground Sv-m2)/(Bq-sec): 4.7500E-18

Uterus Inhalation (Sv/Bq): 2.8700E-06

Uterus Submersion (Sv-m3)/(Bq-sec): 7.1400E-18

Uterus Ground Sv-m2)/(Bq-sec): 2.3200E-19

Brain Inhalation (Sv/Bq): 2.8700E-06

Brain Submersion (Sv-m3)/(Bq-sec): 1.0700E-17

Brain Ground Sv-m2)/(Bq-sec): 2.4700E-19

SIWall Inhalation (Sv/Bq): 2.8700E-06

SIWall Submersion (Sv-m3)/(Bq-sec): 7.4500E-18

SIWall Ground Sv-m2)/(Bq-sec): 2.5000E-19

Pancreas Inhalation (Sv/Bq): 2.8700E-06

Pancreas Submersion (Sv-m3)/(Bq-sec): 7.0500E-18

Pancreas Ground Sv-m2)/(Bq-sec): 2.0400E-19

Total Activity Released (Ci) : 1.4800E-05

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [19] : Am-242 M 16.02 h

Halflife (Years) : 1.8288E-03

Inhalation 50-yr CEDE (Sv/Bq) : 1.7300E-08

Submersion (Sv-m3)/(Bq-sec) : 6.1100E-16

Ground Shine (Sv-m2)/(Bq-sec) : 1.6100E-17

Skin Inhalation (Sv/Bq): 1.1800E-10

Skin Submersion (Sv-m3)/(Bq-sec): 8.2600E-15

Skin Ground Sv-m2)/(Bq-sec): 2.6300E-16

Lung Inhalation (Sv/Bq): 1.1600E-07

Lung Submersion (Sv-m3)/(Bq-sec): 5.5100E-16

Lung Ground Sv-m2)/(Bq-sec): 1.2100E-17

Thyroid Inhalation (Sv/Bq): 1.1800E-10

Thyroid Submersion (Sv-m3)/(Bq-sec): 5.9200E-16

Thyroid Ground Sv-m2)/(Bq-sec): 1.3400E-17

Surface Bone Inhalation (Sv/Bq): 9.2500E-08

Surface Bone Submersion (Sv-m3)/(Bq-sec): 1.8700E-15

Surface Bone Ground Sv-m2)/(Bq-sec): 4.0300E-17

Red Marrow Inhalation (Sv/Bq): 6.3100E-09

Red Marrow Submersion (Sv-m3)/(Bq-sec): 4.7700E-16

Red Marrow Ground Sv-m2)/(Bq-sec): 1.1700E-17

Liver Inhalation (Sv/Bq): 2.4200E-08

Liver Submersion (Sv-m3)/(Bq-sec): 4.8100E-16

Liver Ground Sv-m2)/(Bq-sec): 1.1300E-17

Spleen Inhalation (Sv/Bq): 1.1800E-10

Spleen Submersion (Sv-m3)/(Bq-sec): 4.7900E-16

Spleen Ground Sv-m2)/(Bq-sec): 1.1300E-17

Ovaries Inhalation (Sv/Bq): 1.6500E-09

Ovaries Submersion (Sv-m3)/(Bq-sec): 3.7100E-16

Ovaries Ground Sv-m2)/(Bq-sec): 1.0100E-17

Adrenals Inhalation (Sv/Bq): 1.1800E-10

Adrenals Submersion (Sv-m3)/(Bq-sec): 4.1300E-16

Adrenals Ground Sv-m2)/(Bq-sec): 1.0100E-17

Breast Inhalation (Sv/Bq): 1.1800E-10

Breast Submersion (Sv-m3)/(Bq-sec): 7.2600E-16

Breast	Ground	Sv-m2)/(Bq-sec): 1.8700E-17
ULI Wall	Inhalation	(Sv/Bq): 4.4200E-10
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 4.1800E-16
ULI Wall	Ground	Sv-m2)/(Bq-sec): 1.0700E-17
Thymus	Inhalation	(Sv/Bq): 1.1800E-10
Thymus	Submersion	(Sv-m3)/(Bq-sec): 5.2500E-16
Thymus	Ground	Sv-m2)/(Bq-sec): 1.1300E-17
Bladder Wall	Inhalation	(Sv/Bq): 1.1900E-10
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 4.4500E-16
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 1.1600E-17
Esophagus	Inhalation	(Sv/Bq): 1.4700E-08
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 3.8500E-16
Esophagus	Ground	Sv-m2)/(Bq-sec): 9.2600E-18
LLI Wall	Inhalation	(Sv/Bq): 6.0700E-10
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 3.9500E-16
LLI Wall	Ground	Sv-m2)/(Bq-sec): 1.0600E-17
Muscle	Inhalation	(Sv/Bq): 1.1800E-10
Muscle	Submersion	(Sv-m3)/(Bq-sec): 5.5500E-16
Muscle	Ground	Sv-m2)/(Bq-sec): 1.6000E-17
Stomach Wall	Inhalation	(Sv/Bq): 1.5600E-10
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 4.7000E-16
Stomach Wall	Ground	Sv-m2)/(Bq-sec): 1.1300E-17
Kidneys	Inhalation	(Sv/Bq): 1.8800E-09
Kidneys	Submersion	(Sv-m3)/(Bq-sec): 4.8600E-16
Kidneys	Ground	Sv-m2)/(Bq-sec): 1.1700E-17
Testes	Inhalation	(Sv/Bq): 1.6300E-09
Testes	Submersion	(Sv-m3)/(Bq-sec): 6.0700E-16
Testes	Ground	Sv-m2)/(Bq-sec): 1.7800E-17
Uterus	Inhalation	(Sv/Bq): 1.1800E-10
Uterus	Submersion	(Sv-m3)/(Bq-sec): 3.8200E-16

Uterus Ground Sv-m2)/(Bq-sec): 1.0300E-17

Brain Inhalation (Sv/Bq): 1.1800E-10

Brain Submersion (Sv-m3)/(Bq-sec): 5.4100E-16

Brain Ground Sv-m2)/(Bq-sec): 1.0400E-17

SIWall Inhalation (Sv/Bq): 2.0100E-10

SIWall Submersion (Sv-m3)/(Bq-sec): 3.9200E-16

SIWall Ground Sv-m2)/(Bq-sec): 1.0200E-17

Pancreas Inhalation (Sv/Bq): 1.1800E-10

Pancreas Submersion (Sv-m3)/(Bq-sec): 3.8400E-16

Pancreas Ground Sv-m2)/(Bq-sec): 9.7900E-18

Total Activity Released (Ci) : 1.4700E-05

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [20] : Co-60 M 5.271 y

Halflife (Years) : 5.2710E+00

Inhalation 50-yr CEDE (Sv/Bq) : 1.0200E-08

Submersion (Sv-m3)/(Bq-sec) : 1.1900E-13

Ground Shine (Sv-m2)/(Bq-sec) : 2.3000E-15

Skin Inhalation (Sv/Bq): 2.4000E-09

Skin Submersion (Sv-m3)/(Bq-sec): 1.4500E-13

Skin Ground Sv-m2)/(Bq-sec): 2.7700E-15

Lung Inhalation (Sv/Bq): 5.2400E-08

Lung Submersion (Sv-m3)/(Bq-sec): 1.2400E-13

Lung Ground Sv-m2)/(Bq-sec): 2.2700E-15

Thyroid Inhalation (Sv/Bq): 3.8100E-09

Thyroid Submersion (Sv-m3)/(Bq-sec): 1.2700E-13

Thyroid	Ground	Sv-m2)/(Bq-sec): 2.2500E-15
Surface Bone	Inhalation	(Sv/Bq): 3.9300E-09
Surface Bone	Submersion	(Sv-m3)/(Bq-sec): 1.7700E-13
Surface Bone	Ground	Sv-m2)/(Bq-sec): 3.1000E-15
Red Marrow	Inhalation	(Sv/Bq): 4.4000E-09
Red Marrow	Submersion	(Sv-m3)/(Bq-sec): 1.2300E-13
Red Marrow	Ground	Sv-m2)/(Bq-sec): 2.3300E-15
Liver	Inhalation	(Sv/Bq): 8.6000E-09
Liver	Submersion	(Sv-m3)/(Bq-sec): 1.1300E-13
Liver	Ground	Sv-m2)/(Bq-sec): 2.1900E-15
Spleen	Inhalation	(Sv/Bq): 5.3300E-09
Spleen	Submersion	(Sv-m3)/(Bq-sec): 1.1300E-13
Spleen	Ground	Sv-m2)/(Bq-sec): 2.1900E-15
Ovaries	Inhalation	(Sv/Bq): 3.1400E-09
Ovaries	Submersion	(Sv-m3)/(Bq-sec): 1.0700E-13
Ovaries	Ground	Sv-m2)/(Bq-sec): 2.0400E-15
Adrenals	Inhalation	(Sv/Bq): 6.9000E-09
Adrenals	Submersion	(Sv-m3)/(Bq-sec): 1.0400E-13
Adrenals	Ground	Sv-m2)/(Bq-sec): 2.0400E-15
Breast	Inhalation	(Sv/Bq): 6.1700E-09
Breast	Submersion	(Sv-m3)/(Bq-sec): 1.3900E-13
Breast	Ground	Sv-m2)/(Bq-sec): 2.3400E-15
ULI Wall	Inhalation	(Sv/Bq): 3.9600E-09
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 1.0500E-13
ULI Wall	Ground	Sv-m2)/(Bq-sec): 2.1800E-15
Thymus	Inhalation	(Sv/Bq): 7.3200E-09
Thymus	Submersion	(Sv-m3)/(Bq-sec): 1.1700E-13
Thymus	Ground	Sv-m2)/(Bq-sec): 2.1000E-15
Bladder Wall	Inhalation	(Sv/Bq): 2.4700E-09
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 1.0400E-13

Bladder Wall Ground Sv-m2)/(Bq-sec): 2.2200E-15

Esophagus Inhalation (Sv/Bq): 1.6300E-08

Esophagus Submersion (Sv-m3)/(Bq-sec): 1.0700E-13

Esophagus Ground Sv-m2)/(Bq-sec): 1.9800E-15

LLI Wall Inhalation (Sv/Bq): 4.8500E-09

LLI Wall Submersion (Sv-m3)/(Bq-sec): 1.0500E-13

LLI Wall Ground Sv-m2)/(Bq-sec): 2.2500E-15

Muscle Inhalation (Sv/Bq): 3.8100E-09

Muscle Submersion (Sv-m3)/(Bq-sec): 1.2100E-13

Muscle Ground Sv-m2)/(Bq-sec): 2.4500E-15

Stomach Wall Inhalation (Sv/Bq): 4.5600E-09

Stomach Wall Submersion (Sv-m3)/(Bq-sec): 1.1100E-13

Stomach Wall Ground Sv-m2)/(Bq-sec): 2.1800E-15

Kidneys Inhalation (Sv/Bq): 4.0300E-09

Kidneys Submersion (Sv-m3)/(Bq-sec): 1.1200E-13

Kidneys Ground Sv-m2)/(Bq-sec): 2.2100E-15

Testes Inhalation (Sv/Bq): 1.9400E-09

Testes Submersion (Sv-m3)/(Bq-sec): 1.2300E-13

Testes Ground Sv-m2)/(Bq-sec): 2.4500E-15

Uterus Inhalation (Sv/Bq): 2.8300E-09

Uterus Submersion (Sv-m3)/(Bq-sec): 1.0000E-13

Uterus Ground Sv-m2)/(Bq-sec): 2.1300E-15

Brain Inhalation (Sv/Bq): 1.9600E-09

Brain Submersion (Sv-m3)/(Bq-sec): 1.3400E-13

Brain Ground Sv-m2)/(Bq-sec): 2.1600E-15

SIWall Inhalation (Sv/Bq): 3.3700E-09

SIWall Submersion (Sv-m3)/(Bq-sec): 1.0300E-13

SIWall Ground Sv-m2)/(Bq-sec): 2.1700E-15

Pancreas Inhalation (Sv/Bq): 5.7600E-09

Pancreas Submersion (Sv-m3)/(Bq-sec): 1.0100E-13

Pancreas Ground Sv-m2)/(Bq-sec): 2.0500E-15

Total Activity Released (Ci) : 1.5000E+00

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [21] : Te-125m M 58 d

Halflife (Years) : 1.5890E-01

Inhalation 50-yr CEDE (Sv/Bq) : 3.3700E-09

Submersion (Sv-m3)/(Bq-sec) : 3.3600E-16

Ground Shine (Sv-m2)/(Bq-sec) : 2.6800E-17

Skin Inhalation (Sv/Bq): 1.7500E-11

Skin Submersion (Sv-m3)/(Bq-sec): 1.9500E-15

Skin Ground Sv-m2)/(Bq-sec): 9.4600E-17

Lung Inhalation (Sv/Bq): 2.6100E-08

Lung Submersion (Sv-m3)/(Bq-sec): 2.2300E-16

Lung Ground Sv-m2)/(Bq-sec): 1.7700E-17

Thyroid Inhalation (Sv/Bq): 2.5600E-10

Thyroid Submersion (Sv-m3)/(Bq-sec): 4.6300E-16

Thyroid Ground Sv-m2)/(Bq-sec): 3.1000E-17

Surface Bone Inhalation (Sv/Bq): 4.8400E-09

Surface Bone Submersion (Sv-m3)/(Bq-sec): 1.2100E-15

Surface Bone Ground Sv-m2)/(Bq-sec): 1.0100E-16

Red Marrow Inhalation (Sv/Bq): 4.2000E-10

Red Marrow Submersion (Sv-m3)/(Bq-sec): 1.8600E-16

Red Marrow Ground Sv-m2)/(Bq-sec): 1.3600E-17

Liver Inhalation (Sv/Bq): 5.1600E-11

Liver Submersion (Sv-m3)/(Bq-sec): 1.7100E-16

Liver	Ground	Sv-m2)/(Bq-sec): 1.4500E-17
Spleen	Inhalation	(Sv/Bq): 3.9100E-11
Spleen	Submersion	(Sv-m3)/(Bq-sec): 1.5600E-16
Spleen	Ground	Sv-m2)/(Bq-sec): 1.3600E-17
Ovaries	Inhalation	(Sv/Bq): 3.7000E-11
Ovaries	Submersion	(Sv-m3)/(Bq-sec): 4.4800E-17
Ovaries	Ground	Sv-m2)/(Bq-sec): 5.5600E-18
Adrenals	Inhalation	(Sv/Bq): 4.7500E-11
Adrenals	Submersion	(Sv-m3)/(Bq-sec): 1.1200E-16
Adrenals	Ground	Sv-m2)/(Bq-sec): 9.7600E-18
Breast	Inhalation	(Sv/Bq): 4.8900E-11
Breast	Submersion	(Sv-m3)/(Bq-sec): 8.4700E-16
Breast	Ground	Sv-m2)/(Bq-sec): 5.7600E-17
ULI Wall	Inhalation	(Sv/Bq): 4.5500E-10
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 1.0100E-16
ULI Wall	Ground	Sv-m2)/(Bq-sec): 8.9200E-18
Thymus	Inhalation	(Sv/Bq): 4.1100E-11
Thymus	Submersion	(Sv-m3)/(Bq-sec): 2.6500E-16
Thymus	Ground	Sv-m2)/(Bq-sec): 2.0200E-17
Bladder Wall	Inhalation	(Sv/Bq): 3.8000E-11
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 1.6800E-16
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 1.5600E-17
Esophagus	Inhalation	(Sv/Bq): 3.0400E-09
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 5.1900E-17
Esophagus	Ground	Sv-m2)/(Bq-sec): 2.7400E-18
LLI Wall	Inhalation	(Sv/Bq): 1.2600E-09
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 7.3000E-17
LLI Wall	Ground	Sv-m2)/(Bq-sec): 6.7800E-18
Muscle	Inhalation	(Sv/Bq): 3.9300E-11
Muscle	Submersion	(Sv-m3)/(Bq-sec): 4.2600E-16

Muscle Ground Sv-m2)/(Bq-sec): 3.7900E-17

Stomach Wall Inhalation (Sv/Bq): 5.8600E-11

Stomach Wall Submersion (Sv-m3)/(Bq-sec): 1.7300E-16

Stomach Wall Ground Sv-m2)/(Bq-sec): 1.4800E-17

Kidneys Inhalation (Sv/Bq): 2.0100E-10

Kidneys Submersion (Sv-m3)/(Bq-sec): 2.5700E-16

Kidneys Ground Sv-m2)/(Bq-sec): 2.2300E-17

Testes Inhalation (Sv/Bq): 1.2800E-11

Testes Submersion (Sv-m3)/(Bq-sec): 5.9500E-16

Testes Ground Sv-m2)/(Bq-sec): 5.2400E-17

Uterus Inhalation (Sv/Bq): 1.7000E-11

Uterus Submersion (Sv-m3)/(Bq-sec): 6.0400E-17

Uterus Ground Sv-m2)/(Bq-sec): 5.6300E-18

Brain Inhalation (Sv/Bq): 1.7200E-11

Brain Submersion (Sv-m3)/(Bq-sec): 1.5200E-16

Brain Ground Sv-m2)/(Bq-sec): 7.4600E-18

SIWall Inhalation (Sv/Bq): 9.6100E-11

SIWall Submersion (Sv-m3)/(Bq-sec): 7.5200E-17

SIWall Ground Sv-m2)/(Bq-sec): 6.7400E-18

Pancreas Inhalation (Sv/Bq): 2.8800E-11

Pancreas Submersion (Sv-m3)/(Bq-sec): 4.9600E-17

Pancreas Ground Sv-m2)/(Bq-sec): 4.2800E-18

Total Activity Released (Ci) : 9.5400E-03

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [22] : U-234 M 2.445E5 y

Halflife (Years) : 2.4450E+05

Inhalation 50-yr CEDE (Sv/Bq) : 3.4800E-06

Submersion (Sv-m3)/(Bq-sec) : 6.1400E-18

Ground Shine (Sv-m2)/(Bq-sec) : 5.8000E-19

Skin Inhalation (Sv/Bq): 1.3700E-07

Skin Submersion (Sv-m3)/(Bq-sec): 4.2300E-17

Skin Ground Sv-m2)/(Bq-sec): 9.0600E-18

Lung Inhalation (Sv/Bq): 2.7200E-05

Lung Submersion (Sv-m3)/(Bq-sec): 4.4300E-18

Lung Ground Sv-m2)/(Bq-sec): 1.4100E-19

Thyroid Inhalation (Sv/Bq): 1.3700E-07

Thyroid Submersion (Sv-m3)/(Bq-sec): 6.7000E-18

Thyroid Ground Sv-m2)/(Bq-sec): 3.1800E-19

Surface Bone Inhalation (Sv/Bq): 3.9000E-06

Surface Bone Submersion (Sv-m3)/(Bq-sec): 2.0000E-17

Surface Bone Ground Sv-m2)/(Bq-sec): 1.2100E-18

Red Marrow Inhalation (Sv/Bq): 4.0300E-07

Red Marrow Submersion (Sv-m3)/(Bq-sec): 4.2200E-18

Red Marrow Ground Sv-m2)/(Bq-sec): 2.2000E-19

Liver Inhalation (Sv/Bq): 5.3400E-07

Liver Submersion (Sv-m3)/(Bq-sec): 3.7800E-18

Liver Ground Sv-m2)/(Bq-sec): 1.2600E-19

Spleen Inhalation (Sv/Bq): 1.3700E-07

Spleen Submersion (Sv-m3)/(Bq-sec): 3.7000E-18

Spleen Ground Sv-m2)/(Bq-sec): 1.1400E-19

Ovaries Inhalation (Sv/Bq): 1.3700E-07

Ovaries Submersion (Sv-m3)/(Bq-sec): 2.6600E-18

Ovaries Ground Sv-m2)/(Bq-sec): 1.4300E-19

Adrenals Inhalation (Sv/Bq): 1.3700E-07

Adrenals Submersion (Sv-m3)/(Bq-sec): 3.1000E-18

Adrenals	Ground	Sv-m2)/(Bq-sec): 1.0700E-19
Breast	Inhalation	(Sv/Bq): 1.3700E-07
Breast	Submersion	(Sv-m3)/(Bq-sec): 1.4400E-17
Breast	Ground	Sv-m2)/(Bq-sec): 1.6200E-18
ULI Wall	Inhalation	(Sv/Bq): 1.4100E-07
ULI Wall	Submersion	(Sv-m3)/(Bq-sec): 3.0900E-18
ULI Wall	Ground	Sv-m2)/(Bq-sec): 9.7100E-20
Thymus	Inhalation	(Sv/Bq): 1.3700E-07
Thymus	Submersion	(Sv-m3)/(Bq-sec): 4.4900E-18
Thymus	Ground	Sv-m2)/(Bq-sec): 1.6600E-19
Bladder Wall	Inhalation	(Sv/Bq): 1.3700E-07
Bladder Wall	Submersion	(Sv-m3)/(Bq-sec): 3.5400E-18
Bladder Wall	Ground	Sv-m2)/(Bq-sec): 1.3800E-19
Esophagus	Inhalation	(Sv/Bq): 6.0400E-06
Esophagus	Submersion	(Sv-m3)/(Bq-sec): 2.7000E-18
Esophagus	Ground	Sv-m2)/(Bq-sec): 7.4600E-20
LLI Wall	Inhalation	(Sv/Bq): 1.4800E-07
LLI Wall	Submersion	(Sv-m3)/(Bq-sec): 2.8700E-18
LLI Wall	Ground	Sv-m2)/(Bq-sec): 9.6700E-20
Muscle	Inhalation	(Sv/Bq): 1.3700E-07
Muscle	Submersion	(Sv-m3)/(Bq-sec): 7.6200E-18
Muscle	Ground	Sv-m2)/(Bq-sec): 1.0200E-18
Stomach Wall	Inhalation	(Sv/Bq): 1.3700E-07
Stomach Wall	Submersion	(Sv-m3)/(Bq-sec): 3.7400E-18
Stomach Wall	Ground	Sv-m2)/(Bq-sec): 1.3200E-19
Kidneys	Inhalation	(Sv/Bq): 1.4300E-06
Kidneys	Submersion	(Sv-m3)/(Bq-sec): 4.1300E-18
Kidneys	Ground	Sv-m2)/(Bq-sec): 1.7900E-19
Testes	Inhalation	(Sv/Bq): 1.3700E-07
Testes	Submersion	(Sv-m3)/(Bq-sec): 8.7800E-18

Testes Ground Sv-m2)/(Bq-sec): 1.2300E-18

Uterus Inhalation (Sv/Bq): 1.3700E-07

Uterus Submersion (Sv-m3)/(Bq-sec): 2.7300E-18

Uterus Ground Sv-m2)/(Bq-sec): 8.9500E-20

Brain Inhalation (Sv/Bq): 1.3700E-07

Brain Submersion (Sv-m3)/(Bq-sec): 4.1200E-18

Brain Ground Sv-m2)/(Bq-sec): 9.3100E-20

SIWall Inhalation (Sv/Bq): 1.3700E-07

SIWall Submersion (Sv-m3)/(Bq-sec): 2.8400E-18

SIWall Ground Sv-m2)/(Bq-sec): 8.9900E-20

Pancreas Inhalation (Sv/Bq): 1.3700E-07

Pancreas Submersion (Sv-m3)/(Bq-sec): 2.7200E-18

Pancreas Ground Sv-m2)/(Bq-sec): 8.3000E-20

Total Activity Released (Ci) : 5.2100E-05

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

Nuclide [23] : Kr-85 1.0720E+01 y

Halflife (Years) : 1.0756E+01

Inhalation 50-yr CEDE (Sv/Bq) : 0.0000E+00

Submersion (Sv-m3)/(Bq-sec) : 2.4100E-16

Ground Shine (Sv-m2)/(Bq-sec) : 1.0500E-17

Skin Inhalation (Sv/Bq): 0.0000E+00

Skin Submersion (Sv-m3)/(Bq-sec): 1.3200E-14

Skin Ground Sv-m2)/(Bq-sec): 8.0300E-16

Lung Inhalation (Sv/Bq): 0.0000E+00

Lung Submersion (Sv-m3)/(Bq-sec): 1.1500E-16

Lung Ground Sv-m2)/(Bq-sec): 2.4700E-18

Thyroid Inhalation (Sv/Bq): 0.0000E+00

Thyroid Submersion (Sv-m3)/(Bq-sec): 1.1900E-16

Thyroid Ground Sv-m2)/(Bq-sec): 2.6100E-18

Surface Bone Inhalation (Sv/Bq): 0.0000E+00

Surface Bone Submersion (Sv-m3)/(Bq-sec): 2.2200E-16

Surface Bone Ground Sv-m2)/(Bq-sec): 4.5000E-18

Red Marrow Inhalation (Sv/Bq): 0.0000E+00

Red Marrow Submersion (Sv-m3)/(Bq-sec): 1.1000E-16

Red Marrow Ground Sv-m2)/(Bq-sec): 2.4600E-18

Liver Inhalation (Sv/Bq): 0.0000E+00

Liver Submersion (Sv-m3)/(Bq-sec): 1.0300E-16

Liver Ground Sv-m2)/(Bq-sec): 2.3200E-18

Spleen Inhalation (Sv/Bq): 0.0000E+00

Spleen Submersion (Sv-m3)/(Bq-sec): 1.0400E-16

Spleen Ground Sv-m2)/(Bq-sec): 2.3200E-18

Ovaries Inhalation (Sv/Bq): 0.0000E+00

Ovaries Submersion (Sv-m3)/(Bq-sec): 8.4900E-17

Ovaries Ground Sv-m2)/(Bq-sec): 2.3800E-18

Adrenals Inhalation (Sv/Bq): 0.0000E+00

Adrenals Submersion (Sv-m3)/(Bq-sec): 9.5200E-17

Adrenals Ground Sv-m2)/(Bq-sec): 2.1400E-18

Breast Inhalation (Sv/Bq): 0.0000E+00

Breast Submersion (Sv-m3)/(Bq-sec): 1.3500E-16

Breast Ground Sv-m2)/(Bq-sec): 2.7700E-18

ULI Wall Inhalation (Sv/Bq): 0.0000E+00

ULI Wall Submersion (Sv-m3)/(Bq-sec): 9.3900E-17

ULI Wall Ground Sv-m2)/(Bq-sec): 2.2700E-18

Thymus Inhalation (Sv/Bq): 0.0000E+00

Thymus Submersion (Sv-m3)/(Bq-sec): 1.0700E-16

Thymus Ground Sv-m2)/(Bq-sec): 2.3800E-18

Bladder Wall Inhalation (Sv/Bq): 0.0000E+00

Bladder Wall Submersion (Sv-m3)/(Bq-sec): 9.5600E-17

Bladder Wall Ground Sv-m2)/(Bq-sec): 2.3600E-18

Esophagus Inhalation (Sv/Bq): 0.0000E+00

Esophagus Submersion (Sv-m3)/(Bq-sec): 9.2800E-17

Esophagus Ground Sv-m2)/(Bq-sec): 2.0300E-18

LLI Wall Inhalation (Sv/Bq): 0.0000E+00

LLI Wall Submersion (Sv-m3)/(Bq-sec): 9.1400E-17

LLI Wall Ground Sv-m2)/(Bq-sec): 2.2900E-18

Muscle Inhalation (Sv/Bq): 0.0000E+00

Muscle Submersion (Sv-m3)/(Bq-sec): 1.1300E-16

Muscle Ground Sv-m2)/(Bq-sec): 2.7400E-18

Stomach Wall Inhalation (Sv/Bq): 0.0000E+00

Stomach Wall Submersion (Sv-m3)/(Bq-sec): 1.0200E-16

Stomach Wall Ground Sv-m2)/(Bq-sec): 2.3100E-18

Kidneys Inhalation (Sv/Bq): 0.0000E+00

Kidneys Submersion (Sv-m3)/(Bq-sec): 1.0300E-16

Kidneys Ground Sv-m2)/(Bq-sec): 2.3500E-18

Testes Inhalation (Sv/Bq): 0.0000E+00

Testes Submersion (Sv-m3)/(Bq-sec): 1.1800E-16

Testes Ground Sv-m2)/(Bq-sec): 2.8400E-18

Uterus Inhalation (Sv/Bq): 0.0000E+00

Uterus Submersion (Sv-m3)/(Bq-sec): 8.7300E-17

Uterus Ground Sv-m2)/(Bq-sec): 2.2100E-18

Brain Inhalation (Sv/Bq): 0.0000E+00

Brain Submersion (Sv-m3)/(Bq-sec): 1.2200E-16

Brain Ground Sv-m2)/(Bq-sec): 2.2700E-18

SIWall Inhalation (Sv/Bq): 0.0000E+00

SIWall Submersion (Sv-m3)/(Bq-sec): 8.9700E-17

SIWall Ground Sv-m2)/(Bq-sec): 2.2100E-18

Pancreas Inhalation (Sv/Bq): 0.0000E+00

Pancreas Submersion (Sv-m3)/(Bq-sec): 8.8900E-17

Pancreas Ground Sv-m2)/(Bq-sec): 2.0900E-18

Total Activity Released (Ci) : 8.6500E+03

Airborne Fraction : 1.0000E+00

Respirable Fraction : 1.0000E+00

Respirable Deposition Velocity (cm/sec) : 3.0000E-01

Non-resp. Deposition Velocity (cm/sec) : 8.0000E+00

The following variables were used in the above HotSpot calculations:

Terrain = Standard

DistanceUnits = Classic

Inner = 100

Middle = 1

Outer = .1

InnerDep = 0.45045045045045

MiddleDep = 0.045045045045045

OuterDep = 0.0045045045045045

ReceptorHeight = 1.5

WindSpeedHeight = 10

Geometry = Simple

RainOutConstant = 0

D1 = 0.03

D2 = 0.1

D3 = 0.2

D4 = 0.3

D5 = 0.4

D6 = 0.5

D7 = 0.6

D8 = 0.7

D9 = 0.8

D10 = 0.9

D11 = 1

D12 = 2

D13 = 4

D14 = 6

D15 = 8

D16 = 10

D17 = 20

D18 = 40

D19 = 60

D20 = 80

InversionHeight = 5001

Coordinates = Geodetic

Ellipsoid = WGS 84

SetupDefaultLocation = 35.00722N106.43690W

MapScale = 250

HoldUpTime = 0

BreathingRate = 0.000417

DCFData = FGR13

SampleTime = 10

NonRespirableDepositionVelocity = 8

LocationOfAttack = KNOWN

D1CheckBox = 1

D2CheckBox = 1

D3CheckBox = 1

D4CheckBox = 1

D5CheckBox = 1

D6CheckBox = 1

D7CheckBox = 1

D8CheckBox = 1

D9CheckBox = 1

D10CheckBox = 1

D11CheckBox = 1

D12CheckBox = 1

D13CheckBox = 1

D14CheckBox = 1

D15CheckBox = 1

D16CheckBox = 1

D17CheckBox = 1

D18CheckBox = 1

D19CheckBox = 1

D20CheckBox = 1

TypeOfCoordinates = Rectangular

IncludeGroundShine = 4

TypeOfRelease = General Plume

ScenarioMixFileName = C:\Users\rhodg\Desktop\ISP SNF - HotSpot\ISP SNF Breach 1.mix

SourceTerm = 1

ReleaseDuration = N/A

ReleaseHeight = 2

PercentTritiumOxide = 100

AlphaSpecificActivity = 0.00000239

HighExplosive = N/A

SourceRadius = 0

ReleaseFraction = 1

StabilityClass = F

SigmaTheta = 25.0

WindSpeed = 1

DepositionVelocity = 0.3

SunStatus = None

FuelFire = N/A

OtherFire = N/A

HeatInput = N/A

VolumeOfFuel = N/A

AirTemperature = N/A

CombustionHeat = N/A

DurationOfBurn = N/A

HeatEmissionRate = N/A

ResuspensionFactor = N/A

WindDirection = 270

PlumeCenterline = True

PercentU235 = N/A

TypeOfUranium = N/A

ContaminationAge = N/A

ComplexSourceGeometry = None

HorizontalDiameter = N/A

VerticalDiameter = N/A

DepositionUnits = uCi/m2

SystemName = HotSpot

AirborneFraction = 1

RespirableFraction = 1

PhysicalStackHeight = N/A

StackExitVelocity = N/A

StackDiameter = N/A

StackEffluentTemperature = N/A

EnvironmentalTemperature = N/A

IncludeMomentum = False

UseHeatEmission = False

StackPlumeRise = False

LeakpathFactor = 1.00E+00

PhysicalFireHeight = N/A

FireCloudTop = N/A

SourceAltitude = 0

NuclearYield = N/A

EffectiveWindSpeed = = N/A

InnerNuclearDoseContour = N/A

MiddleNuclearDoseContour = N/A

OuterNuclearDoseContour = N/A

HelpFileLocation = C:\Users\rhodg\AppData\Roaming

ShowVirtualInstruments = False

BendAllowed = False

PlumeBendRadius1 = 0.00

WindDirection1 =

EnableBend1 = False

PlumeBendRadius2 = 0.00

WindDirection2 =

EnableBend2 = False

PlumeBendRadius3 = 0.00

WindDirection3 =

EnableBend3 = False

PlumeBendRadius4 = 0.00

WindDirection4 =

EnableBend4 = False

FalloutDoseTimePeriod =

ContourExtentUnits = km

InnerContourExtent = N/A

MiddleContourExtent = N/A

OuterContourExtent = > 200

ContourAreaUnits = km2

InnerContourArea = N/A

MiddleContourArea = N/A

OuterContourArea = N/A

ShelterDescription = No Shielding

ExpHeight5Fraction = 0.20000

ExpHeight4Fraction = 0.35000

ExpHeight3Fraction = 0.25000

ExpHeight2Fraction = 0.16000

ExpHeight1Fraction = 0.04000

ChurchCF = 1.0000

ResuspensionMethod = (Resuspension Factor : Maxwell-Anspaugh)

WeatherCorrectionFactor = (Weathering Correction Factor : None)

UserGroundRoughnessCF = False

GroundRoughnessCF = 1.000

IncludeGroundShine = True

IncludeResuspension = True

GroundExposureStartTime = 0.000

GroundExposureStartUnit = days

GroundExposureDurationTime = 4.000

GroundExposureDurationUnit = days

PromptNeutronRBE = 3.0

DamageRatio = 1.0000E+00

PlumeFormat = .KML

DisplayGoogleContourValues = True

InnerGoogleContourColor = REMOVE ME

MiddleGoogleContourColor = REMOVE ME

OuterGoogleContourColor = REMOVE ME

GoogleLineWidth = REMOVE ME

TypeOfPromptContour = Combo

Visibility = 80 km

EyeSunStatus = Day

ConstantResuspensionFactor = 0.00001

FalloutPowerOne = -1.2000

FalloutPowerTwo = -2.2000

TimeZoneDeltaHours = -8.0

BallisticOption = False

BallisticParticleDensity = 2.50000

Ballistic100Bin = 0.09000

Ballistic200Bin = 0.10000

Ballistic300Bin = 0.12000

Ballistic400Bin = 0.11000

Ballistic500Bin = 0.11000

Ballistic600Bin = 0.11000

Ballistic700Bin = 0.10000

Ballistic800Bin = 0.09500

Ballistic900Bin = 0.08500

Ballistic1000Bin = 0.08000

ModifiedCloudHeightMode = True

Surface Roughness Length (cm)= 0.0

HotSpotVersion = 3.1.2

Regarding: Environmental Impact Statement for Interim Storage Partners LLC's License Application for a Consolidated Interim Storage Facility for Spent Nuclear Fuel in Andrews County, Texas

Review of Bernard Gadagbui

Substantive Comments

Chapter 4. ENVIRONMENTAL IMPACTS

- **Section 4-1. Introduction - Assessing Environmental Impacts**

Throughout this in the Environmental Impacts chapter, the NRC used the following standards of significance for assessing environmental impacts (page 4-2):

- SMALL: The environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource considered.
- MODERATE: The environmental effects are sufficient to alter noticeably but not destabilize important attributes of the resource considered.
- LARGE: The environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource considered.

To a large extent, these categories have been adhered to, but in some instances, NRC staff concludes that the impacts are "minor", or "minimal", which is in contrast to the standards specified: see page 4-17, line 14; page 4-19, line 21; page 4-20, line 15; page 4-40, lines 31, 46; page 4-41, line 16; page 4-42, line 30.

- **Sections 4.6.1, 4.12.1 and 9.1: MODERATE Impacts on Ecological Resources**

In multiple places in the DEIS, it is stated that there will be MODERATE impacts on vegetation (pages, 4-41, 4-44 to 4-50, 4-78, 4-79, and Table 9.1-1).

Twenty- to 40-year of even MODERATE impacts (as defined above) on vegetation should constitute a worthy concern and recommendations should be cited to alleviate such impacts.

- **Section 4.3: Restoration of Site**

In some places in the DEIS Section 4.3, it is stated, for example, that:

- Land used during construction for contractor parking and laydown areas would be restored (i.e., returned to its original state) after completion of the proposed action (Phase 1) or, if the NRC approves, the construction stage of Phase 8 (or earlier final expansion phase) (page 4-3).

- o Decommissioning and reclamation activities would restore the site to a condition similar to the preconstruction condition, but establishment of mature native plant community may require decades (see pages, xxix, 4-40, 4-42, 4-49, and 5-31).

However, no alternative plans were advanced should it become impossible to return the site to preconstruction conditions. The DEIS should consider the habitat equivalency analysis (HEA) or resource equivalency analysis (REA) or the Habitat-Based Resource Equivalency Method (HaBREM) (Baker et al., 2020)[1] type of formula to make up for the delay in restoring the site to preconstruction condition.

- **Section 4.7.1: Peak-year Emissions**

In some places in DEIS Section 4.7.1 (see, for example, AERMOD Modeling Results in Table 4.7.1), peak-year emissions of carbon dioxide, carbon monoxide, nitrogen dioxide, particulate matter PM2.5, particulate matter PM10, sulfur dioxide, and volatile organic compounds were modeled estimates used to determine the potential impacts to air quality.

The actual measurements (see DEIS Chapter 7.3) would determine if these emissions will not pose any health threats to the receptors. However, there is no discussion of whether the peak-year emissions were observed on a day, over a week or more and their implications to receptors. Also, the DEIS should discuss if the long-term contamination of the environment will lead to re-exposure over time.

- **Section 4.6: Recommendations**

Several recommendations have been made in the DEIS to mitigate problems to be followed by ISP. The following are some of such recommendations:

- o Page 4-43: Avoiding vegetation removal or disturbance between March through August, conducting bird nest surveys prior to disturbance, and establishing vegetation barriers if nests are found and proposes them as additional mitigation measures (see also DEIS Chapter 6)

- o Page 4-43: Voluntarily enrolling in the Range-Wide Conservation Plan for the species (for example, the lesser prairie-chicken) intended to conserve suitable habitat.

- o Page 4-44: Mitigating impacts on the Texas horned lizard and dunes sagebrush lizard and consulting with TPWD to develop a survey plan for the Texas horned lizard and dunes sagebrush lizard. Also, following TPWD-provided fence designs that TPWD deems appropriate to use during the CISF construction activities**.**

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[1] Baker, M., Domanski, A., Hollweg, T. et al. 2020. Restoration Scaling Approaches to Addressing Ecological Injury: The Habitat-Based Resource Equivalency Method. Environmental Management 65, 161–177. https://doi.org/10.1007/s00267-019-01245-9

- o Page 4-44: Educating all employees, contractors, and/or site visitors of relevant rules and regulations that protect wildlife.

Following these recommendations is likely to protect these receptors and should be required instead of just being recommended.

- **Sections 4.2 and 6.2: Mitigation Measures**

Several mitigation measures have been listed in Chapter 4 and a summary of additional mitigation measures is provided in Table 6.3-2.

Following these mitigating measures would likely protect receptors and should be required.

- **Sections 4.3, 7.2, and 9.1: Radiological and Health and Safety Impacts**

The radiological and health impacts to workers and the public from this project-specific transportation have been evaluated and both incident-free and accident conditions have been considered (see DEIS Section 4.3 and Table 9.1-1). Radiation doses have been estimated and actual measurements will be conducted (DEIS Chapter 7.2) and this would help confirm if the radiation doses pose any health concerns to any receptors.

- On page 4-46, lines 36-45, it is stated that no further action is needed if the greatest dose rate in the field exceeds 1 mGy/d [0.1 rad/d].

  However, the following absorbed doses have been reported for:

  - o The average human on the accessible surface of a loaded storage module (see page 4-46):
    - o 8.64 mGy/d [0.864 rad/d] at the top of a loaded HSM Model 80 storage cask.
    - o 13.3 µGy/d [1.33 mrad/d] near the proposed controlled area boundary of the CISF at approximately 941 m [1029 yd] from the proposed storage pads.
    - o 0.179 µGy/d [17.9 µrad/d] at a distance of 1,006 m [3,300 ft] from the center of the proposed CISF.

Monitoring the radiation dose as discussed in DEIS Chapter 7.2 would determine the actual absorbed dose rates and necessary actions taken if there are exceedances.

  - o Wildlife (page 4-47). Although the DEIS acknowledged that the highest absorbed dose rate at the surface of a storage cask of 8.64 mGy/d [0.0864 rad/d] exceeds the U.S. Department of Energy (DOE, 2002[2]) initial threshold demonstrated protection of wildlife, it is also stated that this dose rate is below the threshold of 100 mGy/d [10 rad/d] for persistent deleterious changes in populations or communities (DOE, 2002, citing the

[2] DOE (U.S. Department of Energy). 2002. DOE Standard. DOE Standard: A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota. DOE-STD-1153-2019. Washington, DC: U.S. Department of Energy. https://www.standards.doe.gov/standards-documents/1100/1153-AStd-2002/@@images/file. Accessed 01/27/2020.

International Atomic Energy Agency (IAEA, 1992[3]) report). The IAEA (1992) report also noted that "the dose rate range 0.5-10 rad.d-1 (5-100 mGy.d-1) would encompass the level at which a variety of low level effects on reproduction, development and genetic integrity are detectable in sensitive tissues and organisms."

Although the DEIS has not acknowledged that there is a range of absorbed dose rate of 0.5-10 rad/d for these persistent deleterious changes and that the range encompasses the estimated 0.864 rad/d, wildlife presence at this location and the ecological concern would be small. However, it is important to protect all receptors against an unacceptable and harmful radiation.

- Workers and the public. These estimates for the workers and the public considered both incident-free and accident conditions. For the workers, the transportation crew, escorts, inspectors, and possibly rail yard workers were identified as those with the highest occupational exposures because they would spend the most time within close proximity to loaded SNF transportation casks. The DEIS Section 4.3.1.2.2 1 details the scenarios thought to be conservative for estimating the potential health impacts to workers from incident-free transportation and accident conditions. DEIS Table 4.3.2 the estimated population doses and health effects from proposed transportation of SNF to the proposed CISF along a representative route with nonproject baseline cancer from incident-free transportation and accident conditions.

  - The legends for † and ‡ in the DEIS Table 4.3.2 have been replaced with the numbers 1 and 2 and are incorrect.
  - Sample calculations were not provided (preferably as appendix) to show how the collective doses (person-Sv), health effects, and nonproject baseline cancer were calculated under the incident-free and accident conditions.

The radiological impacts to the general public from normal operation (incident-free transportation) of the proposed CISF project and under accidental were also evaluated. The radiological impacts to the general public were considered to be of no health concern.

The radiological impacts to workers and the public based on estimates appear to be below the regulatory limit (except for instances to which attention has been drawn to above for the human receptor and wildlife). ISP has indicated that environmental monitoring program would be instituted to detect potential radiological contamination (pages 4-31, 4-32, and DEIS Section 7.2). This monitoring program is necessary to determine the actual impact to the receptors.

- **Section 4.3: Transportation of Waste**

Transportation of waste is expected at least twice (once from decommissioned site to ISP and then from ISP to permanent storage – even more if a contaminated canister must be returned to sender). Within the transportation cask, there is (1) no current understanding of how a now-leaking spent fuel would behave in this unanalyzed environment or (2) how long it could be

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[3] IAEA (International Atomic Energy Agency). 1992. Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards. Technical Reports Series No. 332. IAEA, Vienna.

safely contained or (3) how a transportation cask could be moved or transported while holding a leaking canister that violates its certification requirements. These are significant matters of operations and transportation with attendant impacts to the workers, the public and the environment that have not been analyzed.

Compliance with the NRC rules may mitigate any concerns. However, a best practice should be finding a permanent geologic repository instead of the temporary solution.

- The DEIS Section 4-15 addresses the environmental impacts of postulated accidents involving the storage of SNF at the proposed CISF project. While NRC-licensed dry cask storage systems included in the ISP CISF proposal are reportedly designed to withstand all normal and off-normal events and postulated design basis accidents with no loss of the safety functions (page 4-97), the potential effects of climate changes over time would be addressed as needed by NRC oversight and required corrective actions.

However, there is no discussion on how such an accident would be addressed.

Expert Biographical Sketch

BERNARD GADAGBUI

Dr. Gadagbui has over 19 years of cumulative experience in evaluating human health risks posed by a variety of chemicals, with the last 16 years working in the area of human health risk assessment and in reviewing human health risk assessment documents. He currently serves as a Senior Toxicologist and Manager of TERA's Global Dose Response Assessment Training Program. Dr. Gadagbui has been involved in and has led numerous projects that require an in-depth understanding of mechanisms of toxicity, current methods for assessing toxicology outcomes, data analysis, appropriate interpretation of toxicology and human health data, and weight of evidence analysis for deriving risk assessment values (e.g., reference doses/concentrations, occupational exposure limits, health based exposure levels) for chemicals (including pesticides), active and inactive ingredients in cosmetic and personal care products, botanicals and botanical preparations, and pharmaceutical molecules). He has co-authored toxicological assessments e.g., for U.S. EPA's Integrated Risk Information System, U.S. EPA's Office of Water, National Institute of Occupational Safety and Health, and Health Canada. He has also been involved in conducting environmental health assessments for energetic compounds and provides expert toxicological, risk assessment, and other scientific support to states and reviews site-specific human health and site remediation risk assessments

Tab 68

Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title:	Oral Arguments In the Matter of Interim Storage Partners, LLC
Docket Number:	72-1050-ISFSI
Location:	Midland, Texas
Date:	July 10, 2019
Work Order No.:	NRC-0430 Pages 1-207

NEAL R. GROSS AND CO., INC.
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Washington, D.C. 20005
(202) 234-4433

just one time that one license applicant has a hypothetical in their application. This is something that now is -- could be said perhaps to be regular.

We think it's a Pandora's box that this licensing board has opened. In both of these cases, we now have circumstances requiring local citizens to muster their resources, to challenge an application that is based on future changes to the law that may never happen. Who knows how many more hypotheticals the industry may dream up out of their eagerness to get a business advantage by becoming the first in line, so that their position to have the license in hand after the law -- just in the law should change the way they want it to change?

Allowing such hypothetical applications to be considered and approved is an incredible waste of the NRC's and the public's limited resources.

JUDGE RYERSON: Ms. Curran, if I can just stop you there for a moment, I think where we may differ is on your statement that this is an application based on changes in the law.

MS. CURRAN: Uh-huh.

JUDGE RYERSON: I think one can fairly read the Holtec decision as saying -- at least I think this is what we tried to say, is that when you look at the record as developed in that adjudicatory proceeding, it is clear that what the NRC is saying is that if a license is granted, it would be a license to engage in lawful sales, and that might change in the future the scope of lawful sales.

I suppose a state could have a 21-year-old drinking age and change it to 18. But that doesn't mean normally, I think, that everyone who has a liquor license has to go out and get a new liquor license to sell to people between 18 and 21, that the thrust of the application is to sell to all lawful applicants, of which there are -- customers, rather, of which there are potentially two kinds.

There would be utilities themselves or to sell interim storage to DOE, if that were lawful, if that becomes lawful, which, as you know, is a realistic possibility. We're not saying it has to happen, and as far as I can tell, the application does not purport, at least, to be dependent on that. But there's certainly a possibility that DOE -- Congress could make DOE a lawful customer here.

So do you have a response to that view?

MS. CURRAN: Yes. Well, I can't imagine that in, say, a liquor licensing context, that the -- a county government would give a liquor license that

Tab 69

NUREG-0404, Volume 1
Executive Summary
Text

draft

generic environmental impact statement

on

HANDLING AND STORAGE OF SPENT LIGHT WATER POWER REACTOR FUEL

MARCH 1978

Project No. M-4

1561 222

7911150524

U. S. Nuclear Regulatory Commission • Office of Nuclear Material Safety and Safeguards

NUREG-0404, Vol. 1

DRAFT - GENERIC ENVIRONMENTAL IMPACT STATEMENT

ON

HANDLING AND STORAGE OF SPENT LIGHT WATER POWER REACTOR FUEL

EXECUTIVE SUMMARY AND TEXT

March 1978

Office of Nuclear Material Safety and Safeguards
U S Nuclear Regulatory Commission

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EXECUTIVE SUMMARY

List of Tables

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EXECUTIVE SUMMARY

1 0 SCOPE

The Generic Environmental Impact Statement on spent fuel storage was prepared by the Nuclear Regulatory Commisson staff in response to a directive from the Commissioners published in the Federal Register, September 16, 1975 (40 FR 44801) T e C sion directed the staff to analyze alternatives for the handling and storage of light water power reactor fuel with particular emphasis on developing long range policy Accordingly, the scope of this statement examines alternative methods of spent fuel storage as well as the pos le restriction or termination of the generation of spent fuel through nuclear power plant shutdown

Since the Commission's directive was issued, there have been significant policy developments In this regard, the President has stated that the U S should defer domestic plutonium recycle in order to search for better solutions to the proliferation problem In light of the President's views and public comments, the NRC terminated on December 2, 1977, its proceedings on the Generic Environmental Statement on Mixed Oxide Fuel (GESMO), pending license applications, and other matters related to the reprocessing and recycle of spent light water reactor fuel This policy decision highlights the importance of this GEIS

On October 18, 1977, the Department of Energy (DOE) announced that the Federal Government would accept and take title to spent nuclear fuel from utilities upon payment of one time storage fees The new policy is designed to meet the needs of nuclear reactors for both interim and permanent disposition of spent fuel The DOE policy actions presume continued light water reactor power generation with discharge of spent fuel and government responsibility for the storage and disposition of spent fuel Thus, these policy actions also address the issues examined in this document However, this document does continue to serve the function of supporting the need for rulemaking for away-from-reactor (AFR) spent fuel storage facilities In addition, DOE has stated that this NRC statement is one of the sources that it will use in the generic environmental impact statement on their announced spent fuel policy

The storage of spent fuel addressed in this generic environmental impact statement is considered to be an interim action, not a final solution The Commission announcement of September 16, 1975 outlining this study stipulated that the Staff was to examine the period through the mid-1980 s In the absence of a national policy directed to final disposition of spent fuel, the staff extended the time period of this study to year 2000 This extension provided a conservative upper bound to the interim spent fuel storage situation at a date that constituted a practical limit to the forecasting that may logically be used as a basis for today's decisionmaking

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The study covers the following:

(1) The magnitude of the possible shortage of spent fuel storage capacity

(2) The options for dealing with the problem, including, but not necessarily limited to

- Permitting the expansion of spent fuel storage capacity at nuclear power plants,

- Permitting the expansion of spent fuel storage capacity at reprocessing plants;

- Licensing of independent spent fuel storage facilities,

- Storage of spent fuel from one or more reactors at the storage pools of other reactors (transshipment between reactors), and

- Ordering the generation of spent fuel be stopped or restricted (by shutting down reactors)

(3) A cost-benefit analysis of the alternatives listed in (2) above along with other reasonably feasible options, including

- Impacts on the public health and safety and the common defense and security,

- Environmental, social and economic costs and benefits,

- Commitments of resources,

- Implications regarding options available for the intermediate and long range storage of nuclear waste materials, and

- Relationships between the local short-term uses of the environment and long-term productivity

(4) The impacts of possible additional transportation of spent fuel that may be required should one or more of the options be adopted,

(5) The need for more definitive regulations and guidance covering the licensing of one or more of the options for dealing with the problem, and

(6) The possible need for amendments to 10 CFR 51 20(e)--the S-3 table which summarizes environmental consideration for the nuclear fuel cycle

The scope of this study is limited to considerations pertinent to the interim storage of spent fuel Other issues related to the "back end" of the fuel cycle, such as reprocessing and waste management, are covered elsewhere, e g , NUREG Reports, 0002 for plutonium recycle (GESMO), 0116 and 0216 for waste management

2.0 THE POTENTIAL MAGNITUDE OF THE SPENT FUEL STORAGE PROBLEM

The factors which affect the quantity of spent fuel requiring storage in excess of that which can be accommodated at nuclear power plants are

- The projected generation of spent fuel--which is a function of the growth rate of nuclear power installed capacity, the assumed average annual reactor capacity factor and the reactor fuel management plans

- The extent to which conventional spent fuel storage pools at nuclear power plants can be modified to increase the spent fuel storage capacity

- The option of the plant owner to maintain storage reserve capacity to accommodate a full core discharge, and

- The time to develop a means for the permanent disposition of spent fuel by reprocessing or waste management

2 1 GENERATION OF SPENT FUEL

Through 1985, the Staff projected an installed capacity of 105 GWe, based on identifiable plants For the period 1986-2000, the schedule used was that of the GESMO 1 proceeding* "super low" growth projection (414 GWe in year 2000) Assumed capacity factors were 60% for the period 1976 to 1985, and 70% for the period 1986 to 2000 On this basis, the projected quantity of spent fuel generated is shown in Table ES-1 The cumulative total of 95,000 metric tons of heavy metal (MTHM) is shown for the year 2000

Table ES-1

PROJECTED GENERATION OF SPENT FUEL

Year	MTHM-Cumulative
1980	7,200
1985	18,000
1990	33,000
1995	59,000
2000	95,000

2 2 AT REACTOR (AR) STORAGE CAPACITY

The spent fuel storage capacity at nuclear power plants has conventionally been designed to accommodate one full core plus one discharge, i e , about 1-1/3 cores The rationale was that spent fuel from a given discharge would be shipped offsite for reprocessing before the next annual discharge and capacity would be reserved to accommodate a full core if conditions made it desirable to unload the plant reactor ** However , most pools were

*Generic Environmental Impact Statement on the Use of Mixed Oxide Fuels in Light Water Cooled Reactors, Health, Safety and Environmental Issues

**This capacity is termed full core reserve (FCR)

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equipped with spent fuel storage racks which did not fully utilize the available floor space in the pool. In many cases it is now possible to increase at-reactor spent fuel storage capacity by a factor of about 2 5 This compact storage is accomplished by the replacement of existing racks with new racks designed for closer spacing of fuel assemblies and utilizing previously unused floor space

The maintenance of reserve capacity sufficient to accommodate the full reactor core in the spent fuel storage pool at a nuclear power plant is not a safety matter However, many power plant owners may consider the maintenance of full core reserve capacity desirable for operational flexibility Experience has shown that the capacity for fully unloading a reactor has been useful in making modifications and repairs to reactor structural components and for periodic reactor vessel inspections Such reserve capacity is effectively unused space in the spent fuel storage pool and has the net effect of reducing the available at-reactor spent fuel storage capacity for successive spent fuel discharges

2 3 REQUIRED AWAY FROM-REACTOR (AFR) STORAGE

The magnitude of the projected shortfall in AR spent fuel storage capacit, equates to the net requirement for away from reactor storage Assuming no curtailment of nuclear power production, the bounding conditions used to estimate the required AFR storage capacity are

- No modification of power plant pools (no compact storage of fuel), and
- Feasible modifications of power plant pools (compact storage of fuel)

A range or upper bound of AFR storage requirements for each of these two basic bounds may be established by considering (a) no full core storage reserve, and (b) maintenance of a full core reserve (FCR)

The AFR requirements are summarized for five year periods for these conditions in Table ES-2 below

Table ES-2

AWAY FROM-REACTOR SPENT FUEL STORAGE REQUIREMENTS (MTHM)

Year	w/o Compact Storage w/o FCR	w/o Compact Storage w/FCR	with Compact Storage w/o FCR	with Compact Storage w/FCR
1980	1,300	4,700	39	190
1985	5,300	12,000	450	1,900
1990	13,000	25,000	2,200	5,800
1995	24,000	46,000	5,400	17,000
2000	45 000	79,000	10,000	41,000

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3.0 METHODS FOR DEALING WITH THE PROBLEM OF EXTENDED SPENT FUEL STORAGE

3.1 PERMITTING THE EXPANSION OF SPENT FUEL STORAGE CAPACITY AT NUCLEAR POWER PLANTS (COMPACT STORAGE)

In its announcement dated September 16, 1975, the Commission stated its position that, in the public interest, there should be no deferral of individual licensing actions on the expansion of at-reactor spent fuel storage capacity during the period required for the preparation of this assessment In line with this policy as of November 1977, the owner of 44 nuclear power plants at some 33 sites had applied to construct pools with compact storage at new plants or for license modifications covering the expansion of their present at-reactor spent fuel storage capacity Such modifications have covered both the installation of newer racks with closer spacing of the spent fuel storage positions and the installation of spent fuel storage racks in previously unused spaces

The actions can be taken without significant effect on public health and safety, and as of November 1977 20 of these applications have been approved and actions are proceeding as planned Each of these applications was evaluated on an individual basis th findings in each case that

- At-reactor spent fuel storage can be increased,
- The actions can be taken with no sacrifice of public health and safety, and
- The environmental impact of the proposed increase at reactor spent fuel storage was negligible

It should be kept in mind that increased at-reactor spent fuel storage involves only aged fuel (at least one year since discharge) which has orders of magnitude less hazard potential than fuel freshly discharged from a reactor

3.2 PERMITTING THE EXPANSION OF SPENT FUEL STORAGE CAPACITY AT REPROCESSING PLANTS

There are no reprocessing plants in operation at the present time Until the policy questions involving reprocessing and recycle are resolved, there is little commercial incentive for investment in new reprocessing facilities The expansion of spent fuel storage at reprocessing plants is technically feasible, but it is not considered a viable alternative for dealing with the problem of spent fuel storage because of the limited potential spaces at the remaining potential reprocessing plant, Allied General Nuclear Services at Barnwell, S C , which has storage pool capacity for about 400 metric tons

The proposed Exxon Fuel Recycle Facility is designed for an initial spent fuel storage capacity of 3,500 MTHM, expandable later to 7,000 MTHM However, the timing is such that this could not be considered to provide any relief to the spent fuel storage problem before at least the mid-1980's

3.3 LICENSING OF INDEPENDENT SPENT FUEL STORAGE INSTALLATIONS

This alternative represents the major means of providing interim AFR spent fuel storage

The former Nuclear Fuel Services, Inc reprocessing plant is now licensed and operating as an independent spent fuel storage installation. However, NFS has announced its withdrawal from the reprocessing business and this plant is no longer receiving spent fuel from utilities for extended storage

The General Electric Company's planned reprocessing plant at Morris, Illinois, has now been declared and licensed as an independent spent fuel storage installation. The initial licensed spent fuel storage capacity of about 100 MTU has been increased to about 750 MTU by installing spent fuel storage racks in its former high level waste storage pool The plant operation as a "storage only" facility has shown that an independent spent fuel storage installation can be operated with adequate protection of the health and safety of the public

Currently, an increasing interest in independent spent fuel storage installations is being shown by the nuclear power industry One architect-engineer company has submitted a standard design of such a facility to NRC for review and general approval

The methods of expanding spent fuel storage capacity considered in this assessment show negligible difference in environmental impact and cost with the exception that at-reactor storage pool compact storage is least costly economically, and does not require additional transportation of spent fuel In view of this, the reference case alternative for expanded spent fuel storage assumes that most additional storage capacity will be provided by AR storage pool compact storage with additional required storage capacity being provided by away-from-reactor (AFR) storage facilities using the available means of wet or dry storage discussed in this statement

3.4 STORAGE OF SPENT FUEL FROM ONE OR MORE REACTORS AT THE STORAGE POOLS OF OTHER REACTORS (TRANSSHIPMENT)

Temporary relief for the spent fuel storage problem being faced by some of the older nuclear power plants could be alleviated in some cases by shipping spent fuel to newer plants with unused available storage capacity However, facility operators can be expected to be reluctant to accept spent fuel that may result in prematurely filling their reactor spent fuel storage pools and potentially impacting the supply of electric power to their regions

Currently, only one application has been approved by the NRC covering this alternative. The staff's analysis shows that transshipment provides some relief for about the first decade This, however, runs the risk of precipitating the problems associated with an industry wide shortfall of storage space all at once after this period. Because it represents only a short-term solution which could result in a later problem, it is not

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expected that this alternative will make more than a minor impact on the existing situation, principally as an emergency solution for individual reactors rather than for the industry as a whole.

3 5 ORDERING THE GENERATION OF SPENT FUEL TO BE STOPPED OR RESTRICTED (TERMINATION OF NUCLEAR POWER PRODUCTION)

The replacement of nuclear power generating capacity by coal fired plants because of filled reactor plant storage pools is technically feasible. However, the economic, social and environmental costs would be severe. Particularly in regions far removed from U.S coal fields such as the Northeast, a conversion back to coal fired power generation would impose significant economic disadvantage which would be difficult to overcome Even in regions that are advantageously located in relation to coal supplies, the need to raise the necessary capital for replacement coal plants could put a severe financial strain on the utilities involved.

4 0 COST-BENEFIT ANALYSES OF ALTERNATIVES

4 1 IMPACTS ON THE PUBLIC HEALTH AND SAFETY AND THE COMMON DEFENSE AND SECURITY

All of the benefits of nuclear generated power are assigned to the individual plants at the time of their licensing Therefore, this analysis deals only with the incremental costs of the alternatives considered.

The environmental impacts-costs of interim storage of spent fuel are essentially negligible, regardless of where such spent fuel is stored.

The physical security measures required for protection against sabotage of stored spent fuel are essentially the same at both reactor and away-from-reactor sites, hence, increased spent fuel storage at either location has little relative safeguards significance

Because the spent fuel involved in increased storage, regardless of where this storage takes place, is aged, and short-lived radionuclides have decayed, the consequences of credible potential accidents are orders of magnitude less than those with freshly discharged fuel

A comparison of the impacts-costs of the various alternatives considered reduces down to a comparison of providing for the continued generation of nuclear power versus its replacement by coal fired power generation. The differences in the environmental impacts-costs, expressed in terms of potential excess mortality, of nuclear versus coal fired power generation, calculated on a per GWY basis are shown in Table ES-3

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Table ES-3

COMPARISON OF POTENTIAL EXCESS MORTALITY OF NUCLEAR VERSUS COAL POWER GENERATION PER 0.8 GWY(e)

Fuel Cycle Component	Nuclear	Coal
Resource Recovery (mining, drilling, etc.)	0.24	0.3 - 8.0
Processing	0.049	10
Power Generation	0.12	3 - 100
Fuel Storage	~0	~0
Transportation	0.01	1.2
Waste Management	0.001	~0
TOTALS	0.42	15 - 120

4.1.2 Economics

The choice to construct a new nuclear power station is made on the individual economic benefit of such construction in comparison with alternative sources of power However, in the bounding case considered in this statement where spent fuel generation is terminated, the costs of replacing existing nuclear stations (with coal fired plants) before the end of their normal lifetime makes this termination alternative uneconomical

4.1.3 Commitments of Resources

Extended storage of spent fuel requires a minor commitment of land, water and materials of construction. Replacement of 414 GWe of nuclear power by the year 2000 would require a major commitment of resources, particularly, coal, transportation facilities, materials of construction of new power plants and land fill sites for waste disposal These are not all particularly strategic resources, but the magnitude of the resources needed could impose severe economic strains

4.1 4 Implications Regarding Options Available for the Intermediate and Long-Range Storage of Nuclear Waste Materials

Extended spent fuel storage, per se, does not foreclose any options on the future storage and possible ultimate disposal of spent fuel as nuclear waste materials Rather, storage of spent fuels for a period of time could be beneficial as it would provide time for the decay of short-lived radionuclides, subsequent storage and disposal need then only provide for the long-lived radionuclides.

4 1.5 Relationships Between the Local Short-Term Uses of the Environment and Long-Term Productivity

For the purposes of this statement, short-term is defined as one to two decades

In the individual licensing actions, the short-term environmental impacts of nuclear power plants are assessed to be acceptable based on their contribution to the long-term produc-

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tivity of a region. The maintenance of the power base for this productivity is important, and nuclear power plants represent an option important to national productivity over the long-term.

A replacement of nuclear generating capacity by coal fired plants could meet this need. Hence, the only real option, if the power base is to be maintained, is to continue generating electricity. Replacement of nuclear with coal fired units will have a more adverse impact on the overall long-term environmental quality of the nation.

5.0 THE IMPACTS OF POSSIBLE ADDITIONAL TRANSPORTATION REQUIREMENTS

Increasing at-reactor spent fuel storage does not in itself involve any additional transportation of spent fuel.

The provisions of away-from-reactor spent fuel storage, assuming offsite locations, could involve an additional transportation step This could be a significant incremental addition to the transportation requirements of the nuclear industry However, the environmental impact increment from this spent fuel transportation is insignificant

6.0 THE NEED FOR MORE DEFINITIVE STANDARDS AND CRITERIA TO GOVERN THE LICENSING OF ONE OR MORE OF THE ALTERNATIVES CONSIDERED

In the judgment of the staff:

- Providing more at-reactor spent fuel storage is adequately covered by existing regulations and regulatory practices

- There is a need for a more definitive regulatory base for new "storage only" facilities The present regulations covering the possession of special nuclear materials in an independent spent fuel storage installation (ISFSI) lack specificity for this application. The development of a new regulation, the proposed 10 CFR Part 72, and its augmentation by Regulatory Guides on safety-related aspects of ISFSI licensing actions are planned to meet this need. At present drafts are undergoing internal review by NRC staff

- The environmental costs of extended spent fuel storage are incrementally small, and are essentially now incorporated in the previously recognized costs assigned to the uranium fuel cycle. Consequently, no modifications to 10 CFR Part 51 §51 20(e), including the S-3 Table, indicating environmental impact summaries are necessary

7.0 ACCIDENTS AND SAFEGUARDS CONSIDERATIONS

Restrictions on the handling of heavy loads in the vicinity of spent fuel pools imposed on individual nuclear power plants during modifications of their spent fuel storage racks limit the potential consequences of such accidents to values which are not significantly different from the consequences of spent fuel handling accidents reported in the final environmental statement (FES) for each plant

An increase in the amount of spent fuel stored at a nuclear power plant does not significantly increase its accident potential. The spent fuel placed in the compact storage pool is normally aged fuel and the potentially hazardous short-lived radionuclides have decayed.

Away-from-reactor spent fuel storage involves shipping and storage in "storage only" type facilities

As noted in 10 CFR Part 73 §73.6(b) spent fuel is exempted from the requirements outlined in §§73.30 through 73.36, "Physical Protection of Special Nuclear Material in Transit," and §73.72, "Requirement for Advance Notice of Shipment of Special Nuclear Material " This in-transit exemption is based upon the substantial protection against removal or dispersal of the radioactive inventory by terrorist acts provided by the spent fuel shipping cask In addition, the localized direct radiation hazard would be lethal to those who might try to remove the contents by disassembly of the cask end covers.

Based on both the cumulative experience of 30 years of spent fuel shipments, both military and commercial, and extensive analyses of potential accidents, the risk to the health and safety of the public from spent fuel shipping accidents is very small

Because of the physical characteristics and the conditions of storage, that include specific security provisions, in deep water pools, the potential risk to the public health and safety due to accidents or acts of sabotage at a "storage only" facility also appear to be extremely small.

8.0 FINDINGS

8.1 INTRODUCTION

The storage of spent fuel in water pools is a well established technology, and under the static conditions of storage represents a low environmental impact and low potential risk to the health and safety of the public It makes little difference whether spent fuel is stored at a nuclear power plant or in an independent away-from-reactor facility designed for this purpose This conclusion is based on existing water pool storage technology Because of the physical characteristics of aged spent fuel, the alternative dry storage techniques expected to be available within the time frame of this study would have comparable negligible impacts

The viable spent fuel storage methods include

- The increase of the storage capacity at nuclear power plants by modifications to existing pools, and

- The building of additional away-from-reactor facilities designed specifically for spent fuel storage.

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In addition, on a limited basis, unused spent fuel storage capacity at newer power plants could be used until the space was needed by that plant. This alternative was considered although it appears to provide no more than a transient solution for providing adequate interim spent fuel storage capacity

Although the Staff is confident that action will be taken on policy issues pertaining to the ultimate disposition of spent fuel by mid-1980's, the situation is manageable for some time beyond then, provided that the planning for AFR storage is initiated in a timely fashion.

8 2 FINDINGS

1 The lack of sufficient spent fuel storage capacity at nuclear power plants has been alleviated by ongoing and planned modifications of at-reactor spent fuel storage pools. Modifications of at-reactor spent fuel storage pools by redesigning fuel racks and making more efficient use of available pool floor space can increase spent fuel storage capacity, on the average, by a factor of 2.5.

As of November 1977, NRC had received applications for modifications of spent fuel storage plans at 44 power reactors. Twenty applications have been approved to date.

2 Licensing reviews of these applications have shown that the modifications are technically and economically feasible and justified. Licensing of these actions is adequately covered by existing regulations and established regulatory practices. This statement supports the finding that increasing the capacities of individual spent fuel storage pools is environmentally acceptable

Because there are many variations in storage pool designs and limitations caused by spent fuel already in some pools, the licensing reviews must be done on a case-by-case basis Modifications in the Technical Specifications applicable to the reactor plant involved, covering safety considerations both during the construction phase of the proposed modifications and subsequent operations, are made where necessary

3. Table ES-2 contains upper bound requirements for AFR storage for both no compact storage and with compact storage of spent fuel at reactor pools. The reference case selected for this study is the upper bound storage capacity considering compact storage of fuel in reactor pools that has negligible environmental impact The AFR storage requirements assume that the FCR option will be selected by plant owners for operational reasons. The timing and magnitude of the AFR spent fuel storage requirements are as follows:

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Year	MTHM
1980	190
1985	1,900
1990	5,800
1995	17,000
2000	41,000

Assuming that the national objective of an operational geologic repository for high-level nuclear wastes and possible disposal of spent fuel by 1985 is attained, the amount of spent fuel requiring away-from-reactor storage is not great Only if there is a serious slippage in the startup date for such a facility will a large amount of spent fuel require away-from-reactor storage in the last decade of this century. Even under these circumstances, only 6 storage pools of the size of the projected Exxon facility (7,000 MT) would be required by the year 2000.

4. The storage of LWR spent fuels in water pools has an insignificant impact on the environment, whether at AR or AFR sites Primarily this is because the physical form of the material, sintered ceramic oxide fuel pellets heremetically sealed in Zircaloy cladding tubes Zircaloy is a zirconium-tin alloy which was developed for nuclear power applications because of its high resistance to water corrosion in addition to its favorable nuclear properties Even in cases where defective tubes expose the fuel material to the water environment, there is little attack on the ceramic fuel

   The technology of water pool storage is well developed; radioactivity levels are routinely maintained at about 5×10^{-4} µCi/ml Maintainance of this purity requires continuous treatment (filtration and ion exchange) of the pool water. Radioactive waste that is generated is readily confined and represents little potential hazard to the health and safety of the public.

   There may be small quantities of ^{85}Kr released to the environment from defective fuel elements However, for the fuel involved (fuel at least 1 year after discharge), experience has shown this to be not detectable beyond the immediate environs of a storage pool

   There is no need for a discharge of radioactive liquid effluents from a spent fuel storage operation as all waste will be in solid form.

   This statement supports the finding that the storage of spent fuel in away-from-reactor facilities is economically and environmentally acceptable.

5. Although relatively small and manageable, assuming the power reactor industry continues to increase at-reactor spent fuel storage capacity, there is a continuing need for away-from-reactor spent fuel storage through the mid-1980's This is primarily due to the older nuclear power plants where there is a limited capability for the expansion of their spent fuel storage capacity Based on the experience to date with

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under water storage, the construction and operation of "storage only" facilities is assessed to be both technically feasible and environmentally acceptable.

The use of alternative dry passive storage techniques for aged fuel, now being investigated by the Department of Energy, appears to be equally feasible and environmentally acceptable

6. Two existing "storage only" facilities are now licensed. One, the NFS West Valley plant under 10 CFR Part 50, and the G E. Morris plant, under 10 CFR Part 70. However, neither of these regulations addresses the specific requirements of a spent fuel "storage only" type of facility There is a recognized need for a more definitive regulatory basis for the licensing of future facilities of this type Action is now underway to meet this need by the development of the proposed 10 CFR Part 72, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation." Supporting regulatory guides are also in preparation.

7 Curtailment of the generation of spent fuel by ceasing the operation of existing nuclear power plants when their spent fuel pools become filled is found to be undesirable, and the prohibition of construction of new nuclear plants is not necessary As shown in this statement, viable measures can be instituted to alleviate the spent fuel storage capacity shortfall Such measures are economically and environmentally preferable to replacing nuclear generated power with coal fired power plants The societal costs would also be significant as the excess mortality rates and environmental impacts of coal fired power generation are much higher than those for nuclear power

8 No modification of 10 CFR 51 20(e) (the summary of environmental considerations for the uranium fuel cycle) appears necessary for spent fuel storage considerations

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Tab 70

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG-2157
Volume 1

Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel

Final Report

Office of Nuclear Material Safety and Safeguards

ES.12 How did the NRC Evaluate the Continued Storage of Spent Fuel in this GEIS?

The NRC looked at potential environmental impacts of continued storage in three timeframes: short-term storage, long-term storage, and indefinite storage (see Figure ES-1). The short-term and long-term storage timeframes include an assumption that a permanent geologic repository becomes available by the end of those timeframes. The indefinite storage timeframe assumes that a repository never becomes available. For a detailed discussion of the three timeframes, see Section 1.8.2.

The NRC has analyzed three timeframes that represent various scenarios for the length of continued storage that may be needed before spent fuel is sent to a repository. The first, most likely, timeframe is the short-term timeframe, which analyzes 60 years of continued storage after the end of a reactor's licensed life for operation. The NRC acknowledges, however, that the short-term timeframe, although the most likely, is not certain. Accordingly, the GEIS also analyzed two additional timeframes. The long-term timeframe considers the environmental impacts of continued storage for an additional 100 years after the short-term timeframe for a total of 160 years after the end of a reactor's licensed life for operation. Finally, although the NRC considers it highly unlikely, the GEIS includes an analysis of an indefinite timeframe, which assumes that a repository does not become available.

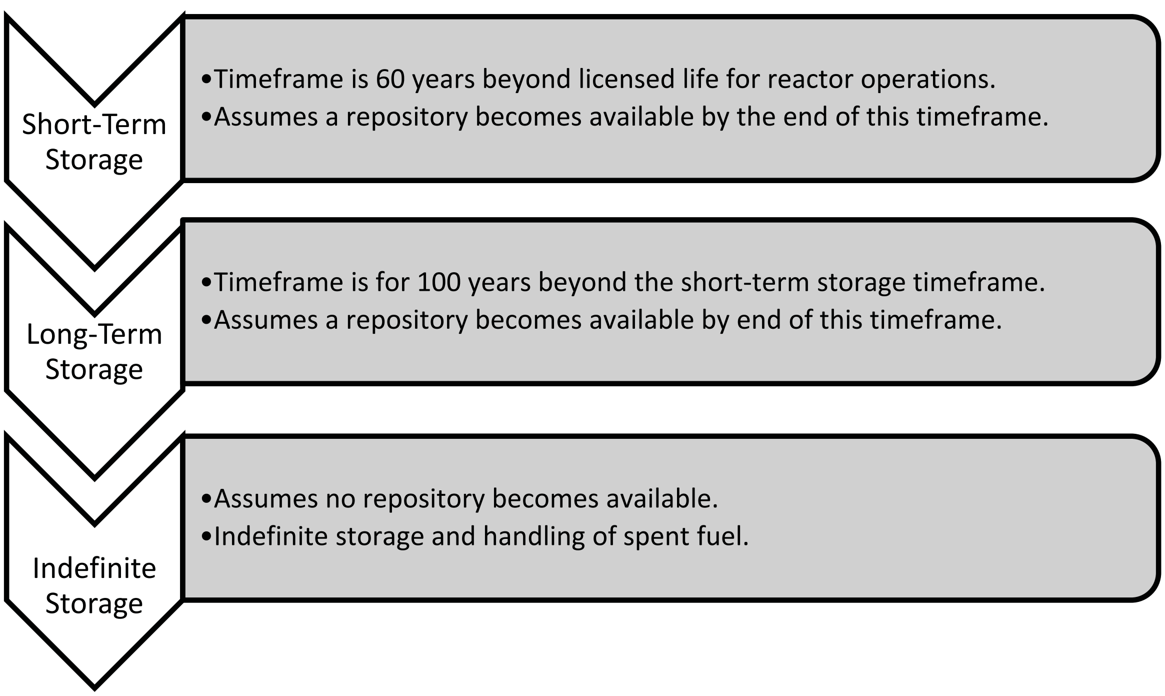


Figure ES-1. Three Storage Timeframes Addressed in this GEIS have already been constructed and are operating during reactor operations. Therefore, many of the impacts of at-reactor continued spent fuel storage can be determined by comparing onsite activities that occur during reactor operations to the reduced activities that occur during continued storage. Where appropriate, the environmental impacts during reactor operations are drawn from the License Renewal GEIS (NRC 2013d), which evaluates the impacts of continued reactor operation. In addition, this GEIS uses analyses in EAs prepared for ISFSIs and renewals of those ISFSI licenses.

For the impacts of continued storage at an-away-from-reactor ISFSI (Chapter 5), the NRC evaluated the impacts of an ISFSI of the same size as described in the *Final Environmental Impact Statement for the Construction and Operation of an Independent Spent Nuclear Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and Related Transportation Facility in Tooele County, Utah* (NRC 2001). Chapter 5 contains a list of the assumptions used in that analysis. Unlike in Chapter 4, the generic analysis for away-from-reactor storage at an ISFSI includes a general discussion of the construction of the facility. However, the site-specific impacts of the construction and operation of any proposed away-from-reactor ISFSI would be evaluated by NRC as part of that ISFSI's licensing process.

For both the at-reactor and away-from-reactor storage sites, the NRC assumes that the construction, operation, and replacement of a dry transfer system (DTS) facility is necessary at some point to handle the transfer of fuel. The physical characteristics of a DTS, which is based on well-understood technology, are explained in more detail in Chapter 2 (see Section 2.1.4).

The GEIS accounts for the age of storage facilities in the evaluation of impacts. For example, a storage cask that was loaded with spent fuel 40 years prior to the end of the licensed life for reactor operations has already been in service for 40 years at the beginning of the short-term timeframe and is assumed to be replaced at the beginning of the long-term timeframe (40 years of service at the beginning of the short-term timeframe plus 60 years of service over the short-term timeframe results in a total service time of 100 years, which is the assumed replacement period for dry cask storage facilities).

1.8.2 Timeframes Evaluated

The NRC evaluated the environmental impacts of continued storage in three timeframes that begin once the licensed life of the reactor ends—short-term storage, long-term storage, and indefinite storage (see Figure 1-1).

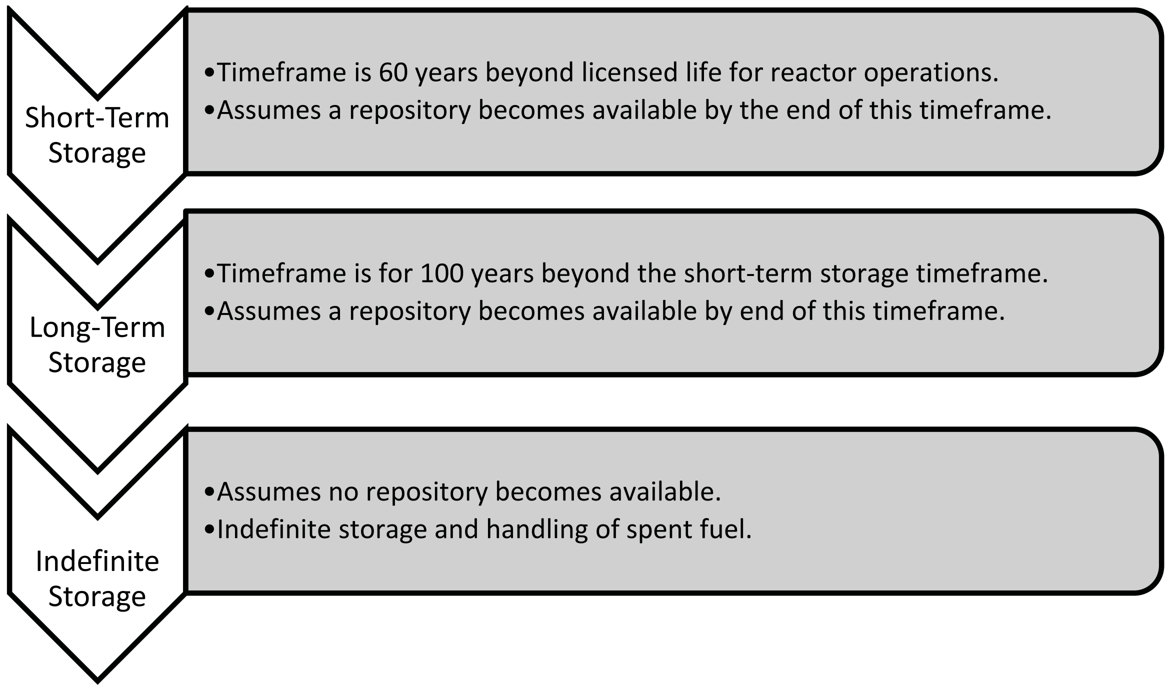


Figure 1-1. Continued Storage Timeframes

The first timeframe—*short-term storage*—lasts for 60 years and begins after the end of a reactor's licensed life for operations. The NRC evaluated the environmental impacts resulting from the following activities that occur during the short-term storage timeframe:

- continued storage of spent fuel in spent fuel pools (at-reactor only) and ISFSIs,
- routine maintenance of at-reactor spent fuel pools and ISFSIs (e.g., maintenance of concrete pads),
- construction and operation of an away-from-reactor ISFSI (including routine maintenance), and
- handling and transfer of spent fuel from spent fuel pools to ISFSIs.

The next timeframe—*long-term storage*—is 100 years and begins immediately after the short-term storage timeframe. The NRC evaluated the environmental impacts resulting from the following activities that occur during long-term storage:

- continued storage of spent fuel in ISFSIs, including routine maintenance,
- one-time replacement of ISFSIs and spent fuel canisters and casks, and
- construction and operation of a DTS (including replacement).

For the long-term storage timeframe, the NRC assumes that all spent fuel has already been moved from the spent fuel pool to dry cask storage by the end of the short-term storage timeframe. The spent fuel pool would be decommissioned within 60 years after permanent cessation of operation, as required by 10 CFR 50.82 or 10 CFR 52.110.

The third timeframe—*indefinite storage*—assumes that a geologic repository does not become available. In this timeframe, at-reactor and away-from-reactor ISFSIs would continue to store spent fuel in dry casks indefinitely. For the evaluation of environmental impacts if no repository becomes available, the following activities are considered:

- continued storage of spent fuel in ISFSIs, including routine maintenance,
- replacement of ISFSIs and spent fuel canisters and casks every 100 years,
- construction and operation of an away-from-reactor ISFSI (including replacement every 100 years), and
- construction and operation of a DTS (including replacement every 100 years).

These activities are the same as those that would occur for long-term storage, but without a repository, they would occur repeatedly.

1.8.3 Analysis Assumptions

To evaluate the potential environmental impacts of continued storage, this GEIS makes several assumptions.

- Although the NRC recognizes that the precise time spent fuel is stored in pools and dry cask storage systems will vary from one reactor to another, this GEIS makes a number of reasonable assumptions regarding the length of time the fuel can be stored in a spent fuel pool and in a dry cask before the fuel needs to be moved or the facility needs to be replaced. With respect to spent fuel pool storage, the NRC assumes that all spent fuel is removed from the spent fuel pool and placed in dry cask storage in an ISFSI no later than 60 years after the end of the reactor's licensed life for operation. With respect to dry cask storage, the NRC assumes that the licensee uses a DTS during long-term and indefinite storage timeframes to move the spent fuel to a new dry cask every 100 years. Similarly, the NRC assumes that the DTS and the ISFSI pad are replaced every 100 years. For an ISFSI that reaches 100 years of age near the end of the short-term storage timeframe, the NRC assumes that the replacement would occur during the long-term storage timeframe.
- Based on its knowledge of and experience with the structure and operation of the various facilities that will provide continued storage, including the normal life of those facilities, the NRC believes that spent fuel pool storage could last for about 60 years beyond the licensed life for operation of the reactor where it is stored, and that each ISFSI will last about 100 years.

from the Skull Valley Band's village. The proposed PFS ISFSI has not been constructed. Despite the PFS facility not having been constructed, issuance of the PFS license supports the assumption in this GEIS that an away-from-reactor ISFSI is feasible and that the NRC can license an away-from-reactor storage facility. Thus, the NRC's analysis of construction, operation, and decommissioning activities and impacts for an away-from-reactor ISFSI in NUREG–1714 are reflected in this GEIS (NRC 2001).

Consolidated Storage

On January 29, 2010, the President of the United States directed the Secretary of Energy to establish a "Blue Ribbon Commission on America's Nuclear Future." The Blue Ribbon Commission was tasked with conducting a comprehensive review of policies for managing the back end of the nuclear fuel cycle and recommending a new strategy. The Blue Ribbon Commission issued its findings and conclusions in January 2012 (BRC 2012). Among the findings and conclusions related to continued storage of spent fuel was a strategy for prompt efforts to develop one or more consolidated storage facilities.

In January 2013, DOE published its response to the Blue Ribbon Commission recommendations titled, *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste* (DOE 2013). This strategy implements a program over the next 10 years that, with congressional authorization, will:

- site, design, construct, license, and begin operation of a pilot interim storage facility by 2021 with an initial focus on accepting spent fuel from shutdown reactor sites,
- advance toward the siting and licensing of a larger interim storage facility to be available by 2025 with sufficient capacity to provide flexibility in the waste-management system and allow for acceptance of enough spent fuel to reduce expected government liabilities, and
- make demonstrable progress on the siting and characterization of repository sites to facilitate the availability of a geologic repository by 2048.

The Federal government's support for interim storage supports the NRC's decision to consider this type of facility as one of the reasonably foreseeable interim solutions for spent fuel storage pending ultimate disposal at a repository.

2.1.4 Dry Transfer System

Although there are no dry transfer systems (DTSs) at U.S. nuclear power plant sites today, the potential need for a DTS, or facility with equivalent capability, to enable retrieval of spent fuel from dry casks for inspection or repackaging will increase as the duration and quantity of fuel in dry storage increases. A DTS would enhance management of spent fuel inspection and repackaging at all ISFSI sites and provide additional flexibility at all dry storage sites by enabling repackaging without the need to return the spent fuel to a pool. A DTS would also help reduce risks associated with unplanned events or unforeseen conditions and facilitate storage reconfiguration to meet future storage, transport, or disposal requirements (Carlsen and Raap 2012).

Several DTS designs and related concepts have been put forward over the past few decades. Among these designs is a design developed by Transnuclear, Inc. in the early 1990s under a cooperative agreement between DOE and EPRI. Although the conceptual design was based on transferring spent fuel from a 30-ton 4-assembly source cask to a 125-ton receiving cask, the DTS could be adapted to be suitable for any two casks (Carlsen and Raap 2012).

On September 30, 1996, the DOE submitted to the NRC for review a topical safety analysis report on the Transnuclear-EPRI DTS design (DOE 1996). In November 2000, the NRC issued an assessment report in which it found the DTS concept has merit. The NRC’s assessment was based on the DTS meeting the applicable requirements of 10 CFR Part 72 for spent fuel storage and handling and 10 CFR Part 20 for radiation protection. However, the DOE has not yet requested a Part 72 license for the DTS (NRC 2000).

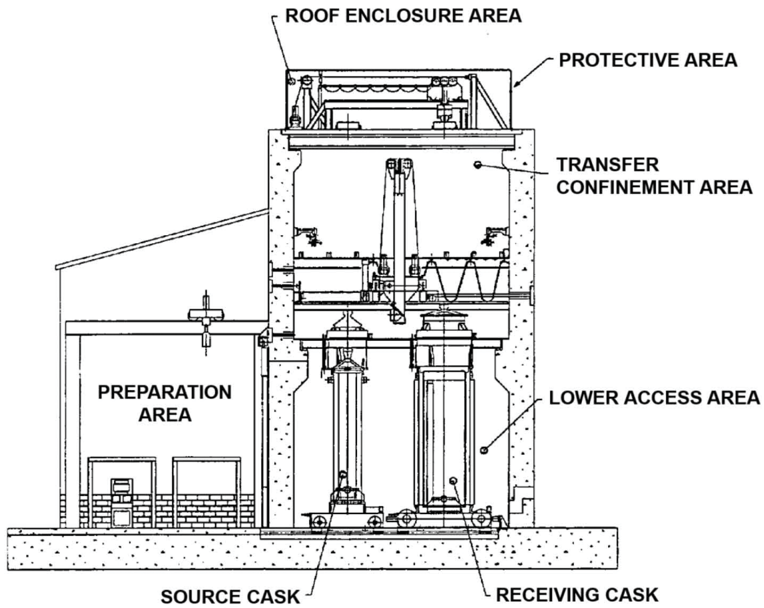
Construction of a DTS is considered a continued storage activity in the long-term and indefinite timeframes. Based on EPRI data (EPRI 1995), the NRC estimates a construction cost of $8.58M for the development of a DTS to handle bare spent fuel that could accommodate repackaging, as needed, to replace casks. The NRC assumed that estimated construction costs for the DTS are the same for both the at-reactor and away-from-reactor facilities.

The reference DTS considered in this GEIS is a two-level concrete and steel structure with an attached single-level weather-resistant preengineered steel building. The concrete and steel structure provides both confinement and shielding during fuel transfer operations. The DTS was designed to enable loading of one receiving cask in 10 24-hour days and unloading one source cask in one 24-hour day.

The key facility parameters and characteristics described in the September 30, 1996, topical safety analysis report are summarized below.

The reference DTS is a reinforced-concrete rectangular box structure with internal floor dimensions of about 8 × 5.5 m (26 × 18 ft) and about 14 m (47 ft) tall. The system also includes an attached, prefabricated, aluminum Butler-type building referred to as the preparation area with dimensions of about 11.6 x 7.6 m (38 × 25 ft) wide and 11.6 m (38 ft) tall. The basemat for the facility measures 14.9 × 21.9 m (49 × 72 ft), and the security zone would be about 76 × 91 m (250 × 300 ft) (i.e., less than 0.7 ha [2 ac]).

As shown in Figure 2-3, the preparation area is located at ground level of the DTS. The lower access area is next to the preparation area and directly below the transfer confinement area.



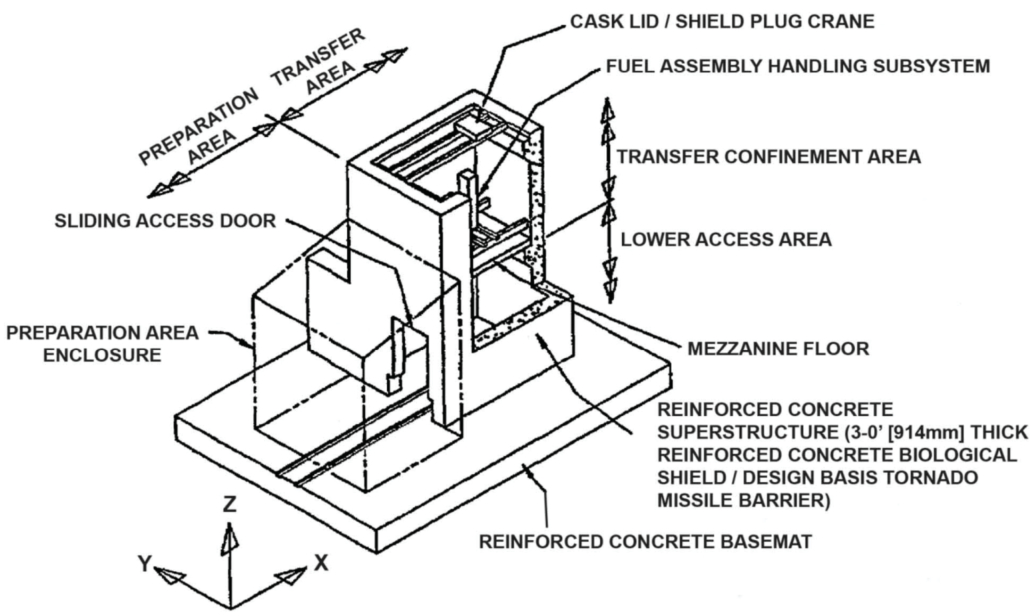


Figure 2-3. Conceptual Sketches of a Dry Transfer System (DOE 1996)

The lower access area provides shielding, confinement, and positioning for the open source and receiving casks during spent fuel transfers. An 18- to 23-cm (7- to 9-in.)-thick steel sliding door separates the lower access area from the preparation area. The transfer confinement area is the upper level of the DTS, directly above the lower access area. The transfer confinement area provides the physical confinement boundary and radiation shielding between spent fuel and the environment.

Transnuclear-EPRI found that radioactive waste generation from dry transfer activities could not be readily quantified, as it depends strongly on reactor-specific conditions, primarily the crud levels on the fuel assemblies. Table 6.1-1 of the topical safety analysis report (DOE 1996) showed the expected waste sources, including decontamination wastes, spalled material in a crud catcher, and prefilters and high-efficiency particulate air filters used in the heating ventilation and air conditioning system. Other wastes considered included mechanical lubricants and precipitation runoff. The DTS does not rely on water-supply lines. Water is brought to the facility in bottles and used for general purpose cleaning only.

The reference DTS, if licensed, would operate under the radiological protection requirements of 10 CFR Part 20, “Standards for Protection against Radiation.” Occupational doses for various tasks performed in the DTS are provided in Table 7.4-1 of the topical safety analysis report (DOE 1996). Total estimated occupational doses from loading a single cask are about 0.5 person-rem.

Maximum offsite doses reported in Table 7.6-1 of the topical safety analysis report were estimated to range from 44 mrem per year at 100 m to 2 mrem per year at 500 m.

As with other facilities licensed under 10 CFR Part 72, the design events identified in ANSI/ANS 57.9 (ANSI/ANS 1992) form the basis for the accident analyses performed for the DTS. The bounding accident results for a distance of 100 m are a stuck fuel assembly (47 mrem) and a loss-of-confinement barrier (721 mrem).

This GEIS considers the environmental impacts of constructing a reference DTS to provide a complete picture of the environmental impacts of continued storage. This GEIS does not license or approve construction or operation of a DTS. A separate licensing action would be necessary before a licensee may construct and operate a site-specific DTS.

For the purposes of analysis in this GEIS, the NRC relies primarily on the facility description of the Transnuclear-EPRI DTS described above. However, for some impact assessments in this GEIS, the NRC has drawn from the *Environmental Impact Statement for the Proposed Idaho Spent Fuel Facility at the Idaho National Engineering and Environmental Laboratory in Butte County, Idaho* (NRC 2004b). The NRC licensed the Idaho Spent Fuel Facility in November 2004, but DOE has not constructed the facility. However, the proposed facility has the capability to handle bare spent fuel for the purposes of repackaging and storing spent fuel from

Peach Bottom Unit 1; the Shippingport Atomic Power Station; and various training, research, and isotope reactors built by General Atomics. Because the Idaho Spent Fuel Facility, like the DTS, includes design features that allow bare fuel-handling operations to repackage spent fuel from DOE transfer casks to new storage containers, the NRC has concluded that some environmental impacts of the facility would be comparable to those of a DTS.

2.2 Generic Activity Descriptions

As described in Chapter 1, this GEIS analyzes environmental impacts of the continued storage of spent fuel in terms of three storage timeframes: short-term, long-term, and indefinite storage. As described below, the activities at spent fuel storage facilities during the short-term timeframe coincide with nuclear power plant decommissioning activities. By the beginning of the long-term timeframe, reactor licensees will have removed all spent fuel from the spent fuel pool and decommissioned all remaining nuclear power plant structures. At that point, all spent fuel will be stored in either an at-reactor or away-from-reactor ISFSI. During the long-term storage timeframe, the NRC has conservatively assumed for the purpose of analysis in this GEIS that the need will arise for the transfer of spent fuel assemblies from aged dry cask storage systems to newer systems of the same or newer design. In addition, the NRC assumes that storage pads and modules would need to be replaced periodically. Section 1.8.2 identifies the continued storage activities for which the NRC evaluated the environmental impacts in this GEIS. This section provides the costs for those activities, as well as costs for transporting spent fuel to an away-from-reactor ISFSI during continued storage; the environmental impacts of transporting spent fuel to an away-from-reactor ISFSI are analyzed in Chapter 5.

2.2.1 Short-Term Storage Activities

As depicted in the generic timeline in Figure 2-4, after about 35 years of operation at low fuel burnups, or about 46 years of high-burnup operation, the spent fuel pool at a typical reactor reaches capacity and spent fuel must be removed from the pool to ensure full core offload capability. The inventory of spent fuel that exceeds spent fuel pool capacity may be transferred to dry cask storage at an at-reactor or away-from-reactor ISFSI. This GEIS focuses on the activities and impacts associated with continued storage in a spent fuel pool and dry cask. This section explains the activities that occur during short-term storage:

- decommissioning of the plant systems, structures, and components not required for continued storage of spent fuel,
- routine maintenance of the pool and ISFSI, and
- transfer of spent fuel from the pool to the at-reactor or away-from-reactor ISFSI.

(see Section 2.1.3). EPRI estimated the total annual routine costs for operation and maintenance during "caretaker" periods (i.e., when loading and unloading is not occurring) (EPRI 2009). This estimate included administrative costs, labor costs, and other operating costs (excluding railroad freight fees and State inspection fees). Based on EPRI's estimates, the NRC estimates annual costs for "caretaker" periods of $11.6M.

Continued storage costs will include transportation activities to move spent fuel to an away-from-reactor ISFSI. These transportation costs include initial costs for cask procurement and loading, additional labor costs associated with loading and unloading transportation casks (i.e., labor cost beyond the annual routine caretaker costs), and shipping costs (i.e., railroad freight fees). As described in Section 2.1.3, transportation casks and other transportation equipment capital costs are accounted for in the storage facility construction cost. The costs for initial cask procurement and loading are assumed to be the same as the costs for the at-reactor facility, which are estimated to be $1.34M (see Section 2.2.1.2). EPRI also estimated annual transportation of 200 casks (i.e., 2,000 MTU of spent fuel) to an away-from-reactor ISFSI (EPRI 2009). Based on EPRI's estimates, the NRC estimates additional annual labor costs of $5.3M for loading and unloading the transportation casks and $41.5M in railroad fees and State inspection fees.

To completely fill a 40,000 MTU (assuming 4,000 casks) capacity away-from-reactor facility costs $5,350,000,000 ($5.35B) for initial cask procurement and loading, $106M for the additional labor associated with loading and unloading transportation casks, and $830M for transportation fees. The total cost for initially constructing and filling a 40,000 MTU capacity away-from-reactor ISFSI is $6.97B.

2.2.2 Long-Term Storage Activities

As described below, the new activities associated with long-term storage include continued facility maintenance, construction, and operation of a DTS, and storage facility replacement. The maintenance activities during the long-term storage activities are the same as for the short-term, including any additional monitoring and inspections that may arise as part of implementation of ongoing aging management programs. The annual costs for routine ISFSI operation and maintenance described in Section 2.2.1.3 in the short-term timeframe would continue throughout the long-term timeframe.

2.2.2.1 Construction and Operation of a DTS

As described in Section 2.1.4, the NRC assumes a DTS, or its equivalent, would be used to transfer fuel as needed for inspection or repackaging. For the purposes of this GEIS, the NRC assumes the reference DTS would be constructed, operated, and replaced once during the long-term storage timeframe, and every 100 years thereafter. The reference DTS would occupy about 0.04 ha (0.1 ac) and would have a total restricted access area of 0.7 ha (2 ac). The NRC assumes that construction of a reference DTS would take 1 to 2 years. Section 2.1.4 discusses construction costs for a DTS. Operation costs for the DTS, described in Section 2.2.2.2, are associated with the labor to transfer spent fuel from old casks to new casks.

DOE has described the operation of a reference DTS in the *Dry Transfer System Topical Safety Analysis Report* (DOE 1996). A summary is provided here to illustrate the process of spent fuel repackaging.

The reference DTS includes three major areas:

- preparation area,
- lower access area, and
- transfer confinement area.

As shown in Figure 2-3, receiving casks and source casks enter the preparation area and exit the DTS on rail-mounted trolleys. To begin spent fuel transfer operations, a receiving cask (i.e., the cask into which fuel will be transferred) is transported to the DTS. The receiving cask is positioned and loaded on a receiving cask transfer trolley at the DTS and rolled into the preparation area. Next, the receiving cask lid and outer and inner canister lids are removed. Finally, the receiving cask is moved into the lower access area and mated to the transfer confinement area.

A source cask (i.e., the cask from which fuel will be transferred) follows a similar path as the receiving cask into the lower access area and is mated to the transfer confinement area. No personnel are present in the lower access area for the transfer operations; all transfer operations are controlled remotely. The lids on both the receiving cask and source cask are removed to prepare for spent fuel transfer. The fuel-assembly-handling subsystem in the transfer confinement area is used to grab and lift a spent fuel assembly from the source cask. The spent fuel assembly is lifted inside a transfer tube and then moved over an empty position in the receiving cask. The spent fuel assembly is lowered into the receiving cask and detached from the lifting device. When spent fuel transfers are complete, both casks are closed, detached from the transfer confinement area, and ultimately removed from the lower access area back to the preparation area.

Maintenance and monitoring activities at the DTS would include routine inspections and testing of the spent fuel and cask transfer and handling equipment (e.g., lift platforms and associated mechanical equipment) and process and effluent radiation monitoring.

Damaged Fuel

As stated in Section 2.1.4, one reason DTSs may be needed in the future is to reduce risks associated with unplanned events (e.g., the need to repackage spent fuel that becomes damaged or that becomes susceptible to damage while in dry cask storage). The NRC defines damaged spent fuel as any fuel rod or fuel assembly that can no longer fulfill its fuel-specific or system-related functions (NRC 2007). These functions include criticality safety, radiation shielding, confinement, and retrievability of the fuel. Appendix B of this GEIS describes spent fuel degradation mechanisms that could occur during continued storage. These include a mechanism (i.e., hydride reorientation) in which high-burnup spent fuel cladding can become less ductile (more brittle) over time as cladding temperatures decrease. Taking actions (e.g., repackaging or providing supplemental structural support) can reduce risks posed by damaged fuel by maintaining fuel-specific or system-related safety functions.

The Transnuclear-EPRI DTS described by DOE in its topical safety analysis report (DOE 1996) and summarized in Section 2.1.4 of this GEIS does not have the capability to handle damaged spent fuel, which the DOE defined as spent fuel that is not dimensionally or structurally sound and spent fuel that cannot be handled by normal means. However, as a result of its experience with damaged spent fuel, described in more detail in the following paragraphs, the nuclear power industry has developed specialized tools that could be deployed if damaged spent fuel needs to be retrieved from a dry cask storage system. Therefore, NRC considers it reasonable to assume that a DTS similar to the Transnuclear-EPRI DTS could be designed, constructed, and equipped to handle damaged fuel.

International experience provides a broad understanding of the technical feasibility of various methods for handling damaged fuel. An International Atomic Energy Agency (IAEA 2009) technical report documented the types of methods that have been used separately or in combination to handle damaged spent fuel under a variety of circumstances while maintaining specific safety functions. The methods include removinging rods, canning, replacing or repairing damaged structural components, and providing supplemental structural support. When a single rod in a fuel assembly is damaged, the damaged rod can be removed to restore the integrity of the fuel assembly, but that process leaves a gap in the fuel assembly. Rod replacement involves replacing the damaged rod with a steel rod to maintain the structural integrity of the assembly to facilitate transfer. Structural repair or replacement involves repairing or replacing damaged components in the assembly (e.g., grid spacers, vanes, and tie plates) to restore stability of the assembly. Supplemental structural support involves adding mechanical strengthening to the assembly to address loss of capabilities from a damaged part.

The NRC requires that spent fuel classified as damaged for storage be protected during storage (e.g., placed in a can designed for damaged fuel, referred to as a damaged fuel can or damaged fuel container (NRC 2007).[12] A damaged fuel can is designed to ensure that the fuel-specific or system-related functions continue to be met. When a spent fuel assembly is placed

[12] An acceptable alternative approved by the NRC is to confine damaged spent fuel using top and bottom “end caps” in dry cask storage system basket cells (Transnuclear, Inc. 2011).

in a damaged fuel can, one or more of the necessary safety functions, depending on the type of can, are performed by the can instead of the spent fuel assembly (IAEA 2009). A damaged fuel can will confine fuel particles, debris, and the damaged spent fuel to a known volume in a cask; ensure compliance with criticality safety, shielding, thermal, and structural requirements; and permit normal handling and retrieval of spent fuel from a cask. An additional example of a method approved by the NRC for providing supplemental structural support to damaged fuel involves using instrument tube tie rods to reinforce PWR spent fuel assembly top nozzles that have suffered inter-granular stress corrosion cracking (74 FR 26285).

In current dry cask storage system designs, damaged fuel cans are placed in a limited number of positions inside the canister or cask (Transnuclear, Inc. 2011). Because a damaged fuel can performs the safety functions of undamaged fuel components (i.e., criticality safety, shielding, confinement, retrievability, etc.), the presence of damaged fuel cans in dry cask storage systems would not cause environmental impacts during continued storage different from casks containing undamaged spent fuel. For this reason, this GEIS does not further consider generic environmental impacts associated with use of damaged fuel cans or their alternatives.

2.2.2.2 Replacement of Storage and Handling Facilities

For purposes of analysis in this GEIS, the NRC assumes that storage facilities will require complete replacement over the long-term storage timeframe (100 years). Replacement activities are assumed to occur as needed throughout the long-term storage timeframe, but not all at once over a relatively short interval (e.g., 2 years). Replacement activities include the following:

- construction of new ISFSI pads near the initial pads,
- construction of replacement storage casks or HSMs,
- movement of canisters in good condition to new casks or HSMs,
- use of the initial and replacement DTS to transfer fuel to new canisters and casks, as necessary, and
- replacement of the DTS.

Continued storage activities include replacing the storage facility (for either an at-reactor or an away-from reactor ISFSI), the DTS, and the spent fuel canisters and casks. Replacing the ISFSI and DTS requires dismantling the existing facilities and constructing new ones. The costs for dismantling the existing ISFSIs are based on decommissioning activities. Using decommissioning costs conservatively bounds the dismantling costs because there would be fewer activities associated with dismantling than for decommissioning as the site is not being released for other uses. Dismantling costs for at-reactor ISFSIs are based on licensee information (Nuclear Management Company, LLC 2005) and dismantling costs for away-from-reactor ISFSIs are based on EPRI information (EPRI 2009).

The NRC estimates costs for dismantling the existing facility at $7.6M for an at-reactor ISFSI and $248M for an away-from-reactor ISFSI. The cost for dismantling the DTS is the same for both the at-reactor and away-from-reactor facilities. Although the decommissioning cost for a DTS is not known, the decommissioning cost of an away-from reactor ISFSI is about 40 percent of the initial construction costs (see Section 2.1.3). Applying this same 40 percent difference between the DTS construction and demolition costs results in an estimated DTS dismantling cost of $3.43M. Construction of a replacement at-reactor facility costs $107M (see Section 2.1.2.2) and construction of a replacement away-from-reactor facility costs $215M (see Section 2.1.3). Construction of a replacement DTS costs $8.58M (see Section 2.1.4). Using the costs for initial construction as estimates for constructing replacement facilities can be considered conservative because start-up costs (e.g., design, engineering, and licensing cost) may be lower for subsequent construction at the same location.

Replacing a cask requires procurement of a new cask and the labor to unload the fuel from the old cask and then load the fuel into the new cask. EPRI estimated costs for cask procurement and loading (EPRI 2012). Based on EPRI's estimates, the NRC estimates that replacing a single cask costs $1.66M, which includes procuring a new cask at $1.02M, unloading fuel from the old cask at $321,000, and subsequent loading of spent fuel into the new cask at $321,000. The initial transfer of spent fuel into a dry cask costs $1.34M per cask (see Section 2.2.1.2) because the unloading of spent fuel from the old cask is not required. The labor costs for replacing a single cask can be considered conservative because the unloading of the old cask and loading of the new cask occur essentially as one operation. Replacing all 160 casks for a 1,600 MTU at-reactor ISFSI (assuming 10 MTU per cask) can then be estimated to cost $265M, and replacing all 4,000 casks for a 40,000 MTU away-from-reactor ISFSI (assuming 10 MTU per cask) costs $6.64B. The total cost for complete replacement of an at-reactor storage facility (i.e., dismantling the old ISFSI and DTS, building a new ISFSI and DTS, procuring new casks, and transferring the spent fuel from the old facilities to the new facilities) is about $392M. The total cost for complete replacement of an away-from-reactor facility is about $7.11B.

2.2.3 Indefinite Storage Activities

Should a repository not become available within the long-term storage timeframe, then activities described for the long-term storage timeframe in Section 2.2.2 are assumed to continue indefinitely. For purposes of analysis in this GEIS, the NRC assumes that storage facilities (i.e., an ISFSI and its associated DTS) would be replaced once every 100 years. The costs for replacement of storage and handling facilities discussed in Section 2.2.2.2 would therefore be realized every 100 years as well. The annual costs for routine ISFSI operation and maintenance described in Section 2.2.1.3 for the short-term timeframe would continue.

Although a successful act of sabotage or terrorism by an armed attack is low in probability, the consequences of such an act could be severe. A discussion of a postulated spent fuel pool fire resulting from loss of pool water, which could result from a successful attack, is provided in Appendix F. The conditional consequences described in Appendix F include downwind collective radiation doses above one million person-rem, up to 191 early fatalities, and economic damages exceeding $50 billion. However, given the very low probability of a successful attack with these consequences, the NRC determined that the risk of successful attack is small.

4.19.2 Attacks on ISFSIs and DTS

Before September 11, 2001, the NRC's regulations that apply to future DTS[7] licensees and current and future ISFSI licensees required licensees to comply with the security requirements specified in 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste," and 10 CFR Part 73, "Physical Protection of Plants and Materials." After the attacks of September 11, 2001, the NRC enhanced security for all facilities licensed to store spent fuel through a combination of the existing security regulations and the issuance of Security Orders to individual ISFSI licensees. These orders ensured that a consistent, comprehensive protective strategy was in place for all ISFSIs.

As discussed in Chapter 2, two types of ISFSI licenses (general and specific) are available for the storage of spent fuel; a future DTS would be licensed under the specific license provisions of 10 CFR Part 72. Physical security requirements for these licensees appear in various sections of 10 CFR Part 73, depending on the type of licensee. The regulations in 10 CFR 72.212(b)(9), "Conditions of General License Issued under §72.210," require general ISFSI licensees to establish a physical protection program that protects the spent fuel against the design basis threat for radiological sabotage in accordance with applicable security requirements imposed on nuclear power reactor licensees under 10 CFR 73.55, "Requirements for Physical Protection of Licensed Activities in Nuclear Power Reactors Against Radiological Sabotage." For general-license ISFSIs, neither 10 CFR 72.212(b)(9) nor 10 CFR 73.55 imposes a dose limit for security events (i.e., acts of radiological sabotage). For specifically licensed ISFSIs and DTSs, NRC regulations at 10 CFR 73.51, "Requirements for the Physical Protection of Stored Spent Nuclear Fuel and High-Level Radioactive Waste," require licensees to establish and maintain a physical protection system that provides high assurance that licensed activities do not constitute an unreasonable risk to public health and safety. The physical protection system must protect against the loss of control of the ISFSI or DTS that could be sufficient to cause a radiation exposure exceeding the dose limitation in 10 CFR 72.106 (NRC 2007g).

[7] As described in Section 2.1.4 of this GEIS, there are currently no DTS licensees, but these requirements would apply to persons that seek to build and operate a DTS.

In general, the potential for theft or diversion of light water reactor spent fuel from the ISFSI with the intent of using the contained special nuclear material for nuclear explosives is not considered credible because of (1) the inherent protection afforded by the massive reinforced-concrete storage module and the steel storage canister; (2) the unattractive form of the contained special nuclear material, which is not readily separable from the radioactive fission products; and (3) the immediate hazard posed by the high radiation levels of the spent fuel to persons not provided radiation protection (NRC 1991c, 1992).

The immediate hazard posed by the high radiation levels of the spent fuel will, however, diminish over time, depending on burnup and the level of radiation deemed to provide adequate self-protection. Self-protection refers to the incapacitation inflicted upon a recipient from inherent radiation emissions in a timeframe that prevents the recipient from completing an intended task (Coates et al. 2005). This means that spent fuel could become more susceptible to possible theft or diversion over long periods of time. This susceptibility depends on the burnup; higher burnup spent fuel provides adequate self-protection for longer time periods. The Blue Ribbon Commission on America's Nuclear Future: Report to the Secretary of Energy (BRC 2012) concluded:

> As the duration of storage is extended, the amount of penetrating radiation emitted by spent fuel will diminish. In the process, the fuel loses a degree of "self-protection" against theft or diversion: in other words, unshielded exposure to the fuel becomes less immediately debilitating and hence creates less of a deterrent to handling by unauthorized persons. This means that over long time periods (perhaps a century or more, depending on burnup and the level of radiation that is deemed to provide adequate self-protection), the fuel could become more susceptible to possible theft or diversion (although other safeguards would remain in place). This in turn could change the security requirements for older spent fuel. Extending storage to timeframes of more than a century could thus require increasingly demanding and expensive security protections at storage sites.

Further, for non-light water reactor spent fuel, the period of self-protection may be lower than that of light water reactor spent fuel, depending on the burnup of the spent fuel and the isotopic composition of the special nuclear material (i.e., the attractiveness of the material for diversion).

Thus, additional security requirements may be necessary in the future if spent fuel remains in storage for a substantial period of time. Under those circumstances, it is reasonable to assume that, if necessary, the NRC will issue orders or enhance its regulatory requirements for ISFSI and DTS security, as appropriate, to ensure adequate protection of public health and safety and the common defense and security.

The NRC has determined that the measures described above, coupled with the robust nature of dry cask storage systems, make the probability of a successful terrorist attack, although numerically indeterminable, very low. Furthermore, the probability of successfully detonating an improvised nuclear device (IND) is even more remote because there are significant steps required to manufacture an IND from spent fuel, including theft of the spent fuel, removal of the spent fuel from the site, and significant chemical and metallurgical processing steps to manufacture an IND.

The conditional consequence of a successful theft and diversion attack that ultimately results in detonation of an IND would be catastrophic. The National Academies and U.S. Department of Homeland Security have estimated environmental effects caused by detonation of an IND. For a 10-kiloton device, the shockwave could kill exposed persons within 0.6 km (0.4 mi); the heat effects could kill persons within 1.8 km (1.1 mi); and initial radiation doses would exceed 4 Gy (400 rad) up to 1.3 km (0.8 mi) away. Radioactive fallout could result in doses above 4 Gy (400 rad) out to 9.7 km (6 mi). Long-term environmental effects would include contaminated property and food supplies, death and illness, loss of jobs, and costs to local, State, and Federal governments to restore property and goods (National Academies 2005).

With respect to the potential for radiological sabotage, after the NRC issued the license for the Diablo Canyon ISFSI in March 2004, the Ninth Circuit reviewed the licensing action and, as discussed, required the NRC to consider terrorist acts in its environmental review associated with this licensing action. In response to the Ninth Circuit decision, the NRC supplemented its EA and finding of no significant impact for the Diablo Canyon ISFSI to address the likelihood and the potential consequences of a terrorist attack directed at the ISFSI (NRC 2007g):

> The NRC staff reviewed the analyses performed for generic ISFSI security assessments, and compared their assumptions to the relevant features of the Diablo Canyon ISFSI. Based on this comparison, the staff determined that the assumptions used in these generic security assessments regarding storage cask design, source term (amount of radioactive material released), and atmospheric dispersion, were representative, and in some cases, conservative, relative to the actual conditions at the Diablo Canyon ISFSI. In fact, because of the specific characteristics of the spent fuel authorized for storage at the Diablo Canyon ISFSI (lower burnup fuel), and the greater degree of dispersion of airborne radioactive material likely to occur at the site, any dose to affected residents nearest to the Diablo Canyon site will tend to be much lower than the doses calculated for the generic assessments. Based on these considerations, the dose to the nearest affected resident, from even the most severe plausible threat scenarios – the ground assault and aircraft impact scenarios – would likely be below 5 rem. In many scenarios, the hypothetical dose to an individual in the affected population could be substantially less than 5 rem, or none at all. In some situations, emergency planning actions could provide an additional measure of protection to mitigate the consequences, in the unlikely event that a successful attack were carried out at the Diablo Canyon ISFSI.

The specific dose results from the 2007 Diablo Canyon ISFSI EA Supplement were derived from the generic analysis performed as part of ISFSI security assessments (NRC 2003). The site-specific assumption in the EA Supplement was the distance to the nearest resident from the Diablo Canyon ISFSI, which is about 2.4 km (1.5 mi). By comparison, this is more than the average distance to nearby residences for other specifically licensed ISFSIs, which is about 1.6 km (1 mi). Doses at closer residences could be larger, but are likely to remain well below levels that could cause immediate health effects. The NRC took both the estimated dose and the likelihood into consideration in making a finding of no significant impact. Thus, the NRC determines that the environmental risk is SMALL. In addition, the environmental risk of impacts on property and land resulting from downwind settling of airborne radioactive material would be SMALL.

In February 2011, after a challenge to the Supplemental Environmental Assessment, the Ninth Circuit issued a decision affirming its sufficiency (*San Luis Obispo Mothers for Peace v. NRC*).

The consequences of successful radiological sabotage at a DTS would be similar to the consequences of postulated accidents at a DTS. For example, Section 4.18.1.2 of this GEIS describes a design basis event at a DTS involving 21 damaged spent fuel assemblies in an open cask that results in a release of radioactive material through an inoperable ventilation system. The total dose to a person standing 100 m (330 ft) away is estimated to be 7.21 mSv (721 mrem).

4.19.3 Conclusion

The NRC finds that even though the environmental consequences of a successful attack on a spent fuel pool during continued storage would be large, the very low probability of a successful attack ensures that the environmental risk is SMALL. Similarly, for operational ISFSIs and DTSs during continued storage, the NRC finds that the environmental risk is SMALL.

4.20 Summary

The impact determinations for at-reactor storage for each resource area for each timeframe are summarized in Table 4-2. For most of the resource areas, the impact determinations for all three timeframes are SMALL. Continued storage is not expected to adversely affect special species and habitats. For accidents (design basis and severe) and terrorism considerations, the environmental risks of continued storage are SMALL.

However, for a few resource areas, impact determinations are greater than SMALL and varied for the three timeframes. For the long-term storage and indefinite storage timeframes, during which ground-disturbing activities may occur, impacts on historic and cultural resources range from SMALL to LARGE. The impacts from management and disposal of nonradioactive waste would be SMALL for both the short-term and long-term timeframes but SMALL to MODERATE for indefinite storage.

The NRC therefore concludes that these results are representative of the impacts for an away-from-reactor ISFSI at a different location. Therefore, the NRC concludes that the impacts of postulated accidents would be SMALL during the three storage timeframes.

5.19 Potential Acts of Sabotage or Terrorism

Section 4.19 provides background regarding the NRC approach to addressing acts of terrorism in relation to dry cask storage. That information is also applicable to an away-from-reactor ISFSI. As with the accident impacts analysis in Section 5.18, the impacts from terrorist acts are substantially the same across the three timeframes—short-term, long-term, and indefinite—and are therefore discussed only once.

The same safeguards regulations (10 CFR Part 72, Subpart H) apply to both an at-reactor ISFSI under a site-specific license and an away-from-reactor ISFSI. Safeguard requirements at at-reactor specifically licensed ISFSIs are described in Section 4.19.2 of this GEIS. In that section, the NRC concluded that both the probability and consequences of a successful attack on an at-reactor ISFSI are low and, therefore, the environmental risk is SMALL. Therefore, the NRC concludes that the results from Section 4.19.2 would also be applicable to an away-from-reactor ISFSI, and the associated impacts would be SMALL during the three storage timeframes.

5.20 Summary

The impact levels determined by the NRC in the previous sections for away-from-reactor dry cask storage of spent fuel are summarized in Table 5-1. For most impact areas, the impact levels are denoted as SMALL, MODERATE, and LARGE as a measure of their expected adverse environmental impacts. In other impact areas, the impact levels are denoted according to the types of findings required under applicable regulatory or statutory schemes (e.g., "disproportionately high and adverse" for environmental justice impacts).

For a number of the resource areas, the impact determinations for all three timeframes are SMALL. For air quality and terrestrial ecology, there is the potential for a MODERATE impact during the construction of the ISFSI. For environmental justice, special status species and habitats, and historic and cultural resources, the results are highly site-specific. While it is possible the ISFSI could be built and operated with no noticeable impacts on these resources, a definitive conclusion cannot be drawn in this GEIS. For socioeconomics (taxes), aesthetics, and traffic, there are impacts that could be greater than SMALL that will continue throughout the existence of the ISFSI. The tax impacts are beneficial in nature. Finally, there is the potential for a MODERATE impact from the disposal of nonradioactive waste in the indefinite timeframe if that waste exceeds the capacity of nearby landfills.

6.3.2.2 Decommissioning of the Reactor Power Block (including the spent fuel pool), DTS, and ISFSI

Decommissioning includes activities to remove radioactive materials from structures, systems, and components to demonstrate compliance with NRC release limits in 10 CFR Part 20, Subpart E. Reactor decommissioning of facilities not related to spent fuel storage could occur from the time that the licensee certifies that it has permanently ceased power operations until the license is terminated. To facilitate decommissioning at some sites, the operator may construct a new spent fuel pool cooling system to allow the spent fuel pool to be isolated from other reactor plant systems.

Decommissioning of the spent fuel pool could begin after stored spent fuel has been transferred to dry storage. The NRC generically evaluated the environmental impacts from reactor decommissioning including the spent fuel pool (but not ISFSIs) in NUREG–0586, *Final Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, Supplement 1* (Decommissioning GEIS) (NRC 2002). The NRC previously evaluated the environmental impacts of decommissioning an away-from-reactor ISFSI in NUREG–1714, *Final Environmental Impact Statement for the Construction and Operation of an Independent Spent Fuel Storage Installation on the Reservation of the Skull Valley Band of Goshute Indians and the Related Transportation Facility in Tooele County, Utah* (PFSF EIS) (NRC 2001a) and in site-specific at-reactor ISFSIs in the Calvert Cliffs, Humboldt Bay, H.B. Robinson, Surry, Oconee, and Diablo Canyon EAs (NRC 2003, 2005a–c, 2009, 2012b). Decommissioning of the DTS is only applicable for long-term and indefinite storage. Also see the description of decommissioning activities in Section 2.2.

6.3.2.3 Activities to Prepare the Spent Fuel for Transportation to a Repository for Final Disposal

These activities would include transferring spent fuel that was stored in dual-purpose canisters from the storage casks to transportation packages and then loading the transportation packages on conveyances before transportation to a repository. Spent fuel stored in storage-only casks or that would otherwise require bare fuel handling (as described in Chapter 2) would be transferred to transportation-certified packages using the spent fuel pool for short-term storage and the DTS long-term storage timeframe. These transportation-related activities could begin when a repository begins accepting shipments of spent fuel from power reactors. This activity would only occur for short-term and long-term storage, because indefinite storage assumes that a repository is never built.

6.3.2.4 Transportation of Spent Fuel from an At-Reactor or Away-From-Reactor Storage Facility to a Repository for Disposal

As described in Section 1.1, the Federal government has adopted deep geologic disposal as the national solution for spent fuel disposal (Nuclear Waste Policy Act of 1982) and the U.S. Department of Energy (DOE) has reaffirmed the Federal government's commitment to the ultimate disposal of spent fuel (DOE 2013). When a repository is available to accept shipments of spent fuel, facility operators would ship spent fuel in NRC-approved transportation packages from facility locations across the United States to a repository site. Shipments would be required to comply with applicable NRC and U.S. Department of Transportation regulations for the transportation of radioactive materials in 10 CFR Part 71 and 49 CFR Parts 171 through 180. Transportation of spent fuel to a repository would only occur during short-term and long-term storage because indefinite storage assumes a repository is never built.

6.4 Resource-Specific Analyses

6.4.1 Land Use

This section evaluates the effects of continued storage on land use when added to the aggregate effects of other past, present, and reasonably foreseeable future actions. As described in Sections 4.1 and 5.1, the incremental impacts from continued storage on land use would be SMALL for all timeframes at both at-reactor and away-from-reactor storage facilities.

The geographic area considered in the cumulative land use analysis includes all affected land surrounding the at-reactor and away-from-reactor storage facilities. Residential, commercial, industrial, agricultural, forested, and recreational lands typically surround spent fuel storage facilities. Depending on the site, the land surrounding a spent fuel storage facility could include private and public lands in a range of political jurisdictions including towns, townships, service districts, counties, and parishes. In addition, State, Federal, and Native American lands are present within the area considered for this analysis.

6.4.1.1 Potential Cumulative Impacts from General Trends and Activities

Cumulative impacts on land use include (1) changing and disturbing existing land-use conditions, (2) restricting access or establishing right-of-way access, (3) restricting agricultural or recreational activities, and (4) altering ecological or historic and cultural resources (e.g., NRC 2011a–e, 2012a, 2013a–c). Cumulative impacts could occur from the activities described in Section 6.3.1, such as constructing and operating new and existing energy projects and infrastructure (e.g., replacement power), water development projects, and constructing housing units, commercial buildings, roads, bridges, and rail lines (e.g., NRC 2011a–e, 2012a, impacts during shutdown were evaluated in the License Renewal GEIS in which the NRC (2013a) determined traffic impacts to be SMALL for operating plants. Combined nonradiological and radiological traffic impacts from reactor decommissioning were previously evaluated by the NRC in the Decommissioning GEIS for nuclear reactors (NRC 2002). In that analysis, the NRC evaluated the number of shipments of dismantled equipment, material, and debris from decommissioning. Although the number of shipments can be relatively large, the decommissioning period extends over several years. As a result, the number of LLW shipments per day is low, with an average of less than one shipment per day from the plant (NRC 2002). The materials transported offsite would include all wastes generated onsite. Nonradiological impacts would include increased traffic volume, additional wear and tear on roadways, and potential traffic accidents (NRC 2002). This information supported a conclusion that the transportation impacts from nuclear power plant decommissioning would not be detectable (NRC 2002).

Additional radiological impacts would occur from transportation of (1) spent fuel to a repository for disposal and (2) LLW from decommissioning the reactor, spent fuel pool, and ISFSI. Radiological impacts would include exposure of transportation workers and the general public along the transportation routes. The NRC previously determined that radiological impacts on the public and workers of spent fuel and waste shipments from a reactor are SMALL in several evaluations. For example, the NRC made a generic impact determination in Table S–4 in 10 CFR 51.52 and the supporting analysis (AEC 1972) that the environmental impacts of transportation of fuel and waste to and from a 1,000- to 1,500-MW(e) light water reactor would be SMALL under incident-free and accident conditions. The results of subsequent analyses of transportation impacts in *Final Environmental Statement on Transportation of Radioactive Material by Air and Other Modes* (NRC 1977) and *Reexamination of Spent Fuel Shipment Risk Estimates* (Sprung et al. 2000) confirmed spent fuel transportation impacts are small. Additional site-specific analyses of transportation impacts for power plants that did not meet the conditions of 10 CFR 51.52 also concluded the transportation radiological impacts would be SMALL (NRC 2006, 2008, 2011a–e, 2013c). In the License Renewal GEIS (NRC 2013a), the NRC also concluded that impacts from uranium fuel cycle transportation, including transportation of spent fuel to a repository for disposal, are SMALL for all nuclear plants. More recently, the NRC calculated spent fuel transportation risks for individual shipments in *Spent Fuel Transportation Risk Assessment: Final Report* (NRC 2014) based on current models, data, and assumptions. The analysis modeled responses of transportation packages to accident conditions such as impact force and fire, and calculated risks considering a range of truck and rail accidents of different severities including those involving no release or loss of shielding, loss of shielding only, or loss of shielding and release. That analysis reconfirmed that the radiological impacts from spent fuel transportation conducted in compliance with NRC regulations are low. The NRC also concluded that the regulations for transportation of radioactive material were adequate to protect the public against unreasonable risk (NRC 2014). Based on the generic determination in Table S–4 of 10 CFR 51.52 and the subsequent spent fuel transportation impact analyses and risk assessments cited above, the NRC concludes the radiological impacts for incident-free and accident transportation of spent fuel from a single at-reactor storage facility to a repository would be small.

Radiological impacts may accumulate along the transportation route for an away-from-reactor ISFSI because the same overall transportation route would be used to transfer the entire inventory of spent fuel from an away-from-reactor ISFSI to a repository. To evaluate these impacts from an away-from-reactor ISFSI, the NRC reviewed other past evaluations of transportation of spent fuel from an away-from-reactor ISFSI to a repository. For example, the NRC previously evaluated the radiological and nonradiological impacts from a comparable (full inventory) transportation scenario for PFSF and concluded that the impacts would be SMALL (NRC 2001a). That analysis calculated incident-free and accident risks from 4,000 shipments of spent fuel from Maine to Utah over a 20-year period. The resulting cumulative dose to the maximally exposed individual (an individual that is assumed for the purpose of performing a bounding analysis of incident-free transportation to be exposed to the radiation from all shipments) at the end of the 20-year period was 0.022 mSv (2.2 mrem). For comparison, the annual NRC public dose limit in 10 CFR Part 20 is 1 mSv (100 mrem). The NRC (2001a) also concluded that the radiological impacts from transportation of a single reactor's spent fuel from an away-from-reactor ISFSI to a repository would be bounded by, or comparable to, impacts evaluated in Table S–4 in 10 CFR 51.52. Based on these analyses, the NRC concludes that the additional accumulated impacts from transportation of the entire inventory of spent fuel from an away-from-reactor ISFSI to a repository would be minor.

6.4.15.3 Conclusion

Cumulative impacts on transportation include the incremental effects from continued storage when added to the aggregate effects of other past, present, and reasonably foreseeable future actions. As described in Sections 4.16 and 5.16, the incremental impacts from continued storage on transportation is SMALL for all timeframes at an at-reactor ISFSI and SMALL to MODERATE for all timeframes at an away-from-reactor ISFSI. In addition, past, present, and reasonably foreseeable activities take place in the geographic area of interest that could contribute to cumulative effects to transportation. The cumulative impacts from continued storage when added to other past, present, and reasonably foreseeable Federal and non-Federal activities (such as construction of energy, water, military, or urbanization projects) would range from SMALL to MODERATE for nonradiological transportation and SMALL for radiological transportation.

6.4.16 Public and Occupational Health

This section evaluates the effects of continued storage on public and occupational health when added to the aggregate effects of other past, present, and reasonably foreseeable future actions. As described in Sections 4.17 and 5.17, the incremental impacts from continued

Appendix B

Technical Feasibility of Continued Storage and Repository Availability

B.1 Introduction

In this *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel* (GEIS), the U.S. Nuclear Regulatory Commission (NRC) addresses the environmental impacts of continuing to store spent nuclear fuel (spent fuel) at a reactor site or at an away-from-reactor storage facility, after the end of a reactor's licensed life for operation until final disposition in a geologic repository ("continued storage"). This GEIS provides a regulatory basis for the NRC's proposed amendment to Title 10 of the *Code of Federal Regulations* (CFR) Part 51. Historically, past Waste Confidence proceedings included a Decision with five findings that addressed technical feasibility of a mined geologic repository, the degree of assurance that disposal would be available by a certain time, and the degree of assurance that spent fuel and commercial high-level waste could be managed safely without significant environmental impacts for a certain period beyond the expiration of plants' operating licenses. Preparation of and reliance upon a GEIS is a fundamental departure from the approach used in past Waste Confidence proceedings. This GEIS acknowledges the uncertainties in the Commission's prediction of repository availability and provides an environmental analysis of three possible storage timeframes. To this end the GEIS considers impacts for three possible timeframes constrained by repository availability, including the impacts from indefinite storage, should a repository never become available.

The NRC's underlying conclusions regarding the technical feasibility of continued storage and a repository continue to undergird its environmental analyses. These underlying conclusions, which are relevant to an analysis of the potential environmental impacts assessed in this GEIS, are discussed as two broad issues in this appendix: the NRC's technical information regarding the availability of a repository for disposal of spent fuel generated in a power reactor (Section B.2) and the technical feasibility of safe storage of spent fuel in an at-reactor or away-from-reactor storage facility until sufficient repository capacity becomes available (Section B.3). These two broad issues were addressed in the five findings contained in the Waste Confidence Decision from past Waste Confidence proceedings; this appendix addresses these issues under two broad topic areas rather than five findings. Section B.4 provides a summary of the conclusions reached in this appendix.

B.2 Repository will be Available to Dispose of Spent Fuel

Based on the analysis below and elsewhere in this GEIS, the NRC believes that the most-likely scenario is that a repository will become available to dispose of spent fuel by the end of the short-term timeframe (within 60 years of the end of a reactor's licensed life for operation). The NRC's belief is based on the resolution of two questions: whether a repository is technically feasible and, if so, how long will it take to site, license, construct, and open a repository. "Technical feasibility" simply means whether a geologic repository is technically possible using existing technology (i.e., without any fundamental breakthroughs in science and technology). If technically feasible, then the question becomes what is a reasonable timeframe for the siting, licensing, construction, and opening of a geologic repository. Both questions are discussed in detail below in Sections B.2.1 (Technical Feasibility of a Repository) and B.2.2 (Availability of a Repository).

B.2.1 Technical Feasibility of a Repository

The Commission has consistently determined that current knowledge and technology support the technical feasibility of deep geologic disposal. In its original 1984 Waste Confidence proceeding, the NRC stated that "[t]he Commission finds that safe disposal of [high-level radioactive waste and spent nuclear fuel] is technically *possible* and that it is achievable using *existing* technology" (49 FR 34658) (emphasis added). The Commission then stated: "Although a repository has not yet been constructed and its safety and environmental acceptability demonstrated, no fundamental breakthrough in science or technology is needed to implement a successful waste disposal program." Although the Commission has conducted Waste Confidence proceedings since 1984, this focal point—whether a fundamental breakthrough in science or technology is needed—continues to guide the Commission's consideration of the feasibility of spent fuel disposal. Since 1984, the technical feasibility of a geological repository has moved significantly beyond a theoretical concept.

Today, the consensus within the scientific and technical community engaged in nuclear waste management is that safe geologic disposal is achievable with currently available technology (see, e.g., Blue Ribbon Commission on America's Nuclear Future [BRC 2012], Section 4.3). Currently, 25 countries, including the United States, are considering disposal of spent or reprocessed nuclear fuel in deep geologic repositories. Repository programs in other countries, which continue to provide additional information useful to the U.S. program, are actively considering crystalline rock, clay, and salt formations as repository host media (IAEA 2005). Many of these programs have researched these geologic media for several decades.

Ongoing research in both the United States and other countries supports a conclusion that geological disposal remains technically feasible and that acceptable sites can be identified. After decades of research into various geological media, no insurmountable technical or scientific problem has emerged to challenge the conclusion that safe disposal of spent fuel and high-level radioactive waste can be achieved in a mined geologic repository. Over the past two decades, significant progress has been made in the scientific understanding and technological development needed for geologic disposal. There is now a better understanding of the processes that affect the ability of repositories to isolate waste over long periods (e.g., the International Atomic Energy Agency's [IAEA's] *Scientific and Technical Basis for the Geologic Disposal of Radioactive Wastes, Technical Reports Series No. 413* [IAEA 2003a] and Ahn and Apted's *Geological Repository Systems for Safe Disposal of Spent Nuclear Fuels and Radioactive Wastes* [Ahn and Apted 2010]).

Further, the ability to characterize and quantitatively assess the capabilities of geologic and engineered barriers has been repeatedly demonstrated (see the Organisation for Economic Cooperation and Development, Nuclear Energy Agency's *Lessons Learnt from Ten Performance Assessment Studies* [NEA 1997]). In addition, specific sites have been investigated and extensive experience has been gained in underground engineering (see IAEA's *Radioactive Waste Management Studies and Trends, IAEA/WMDB/ST/4* [IAEA 2005] and *The Use of Scientific and Technical Results from Underground Research Laboratory Investigations for the Geologic Disposal of Radioactive Waste* [IAEA 2001]). These advances and others throughout the world (e.g., IAEA's *Joint Convention on Safety of Spent Fuel Management and on Safety of Radioactive Waste Management, INFCIRC/546* [IAEA 1997]) continue to confirm the soundness of the basic concept of deep geologic disposal (IAEA 1997). In the United States, the technical approach for safe high-level radioactive waste disposal has remained unchanged for several decades—a deep geologic repository containing natural barriers to hold canisters of high-level radioactive waste with additional engineered barriers to further retard radionuclide release. Although some elements of this technical approach have changed in response to new knowledge, safe disposal remains feasible with current technology. The recent report by the Blue Ribbon Commission on America's Nuclear Future (BRC 2012) supported geologic disposal by concluding that:

> geologic disposal in a mined repository is the most promising and technically accepted option available for safely isolating high-level nuclear wastes for very long periods of time. This view is supported by decades of expert judgment and by a broad international consensus. All other countries with spent fuel and high-level waste disposal programs are pursuing geologic disposal. The United States has many geologic media that are technically suitable for a repository.

In addition, support for the feasibility of geologic disposal can be drawn from experience gained from the review of the U.S. Department of Energy's (DOE's) license application for a high-level nuclear waste repository at Yucca Mountain, Nevada (DOE 2008a). On June 3, 2008, the DOE submitted an application for a construction authorization to the NRC, and on September 8, 2008, the NRC notified DOE that it found the application acceptable for docketing (73 FR 53284) and began its review. DOE subsequently filed a motion with an NRC Atomic Safety and Licensing Board seeking permission to withdraw the license application

(NRC 2010a). In recognition of budgetary limitations, the Commission directed the Atomic Safety and Licensing Board to complete all necessary and appropriate case management activities, and the Atomic Safety and Licensing Board suspended the proceeding. The NRC staff completed three technical review documents (i.e., NRC 2011a,b,c) covering the operational period and the postclosure period (i.e., the period after permanent closure of the repository) and one safety evaluation report on general information (NRC 2010b). The NRC staff's technical review did not identify any issues that would challenge the feasibility of geological disposal as a general matter. However, these technical reports did not include conclusions as to whether or not DOE's proposed Yucca Mountain repository satisfies the Commission's regulations and do not constitute a final judgment or determination of the acceptability of the DOE construction application.

In August 2013, the U.S. Court of Appeals for the District of Columbia Circuit (Court of Appeals) issued a writ of mandamus and directed the NRC to resume the licensing process for DOE's license application. In response, the Commission directed the NRC staff to complete and issue the safety evaluation report associated with the license application (NRC 2013). Currently, the NRC is working on completing its safety review of DOE's license application and plans to publish the remaining volumes of its safety evaluation report by January 2015.

The technical feasibility of a deep geologic repository is further supported by current DOE defense-related activities. The DOE sited and constructed, and since March 1999 has been operating, a deep geologic repository for defense-related transuranic radioactive wastes near Carlsbad, New Mexico. At this site, the DOE has successfully disposed of transuranic waste from nuclear weapons research and testing operations. This Waste Isolation Pilot Plant (WIPP) is located in the Chihuahauan Desert of southeastern New Mexico, approximately 42 km (26 mi) east of Carlsbad. The facility is used to store transuranic waste from nuclear weapons research and testing operations from past defense activities. Project facilities include mined disposal rooms 655 m (2,150 ft) underground.

The NRC recognizes the incident at WIPP on February 14, 2014, which resulted in the release of americium and plutonium from one or more transuranic (TRU) waste containers into the environment. Trace amounts of americium and plutonium are believed to have leaked through unfiltered exhaust ducts and escaped aboveground. No personnel were determined to have received external contamination; however, 21 individuals were identified through bioassay to have initially tested positive for low level amounts of internal contamination. No adverse health impacts have been reported. The DOE has issued a Phase 1 accident report on the incident (DOE 2014). Despite the event, the NRC continues to conclude that a repository is technically feasible.

In January 2013, the DOE released *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste*, a response to the Blue Ribbon Commission on America's Nuclear Future's report (DOE 2013). In this strategy document, DOE presents a framework for "moving toward a sustainable program to deploy an integrated system capable of transporting, storing, and disposing of [spent] nuclear fuel and high-level radioactive waste from civilian nuclear power generation…" (DOE 2013). This new DOE strategy includes a nuclear waste-management system consisting of a pilot interim storage facility, a larger full-scale interim storage facility, and a geologic repository. U.S. policy remains that geologic disposal is the appropriate long-term solution for disposition of spent fuel and high-level radioactive waste.

Finally, the activities of European countries support the technical feasibility of a deep geologic repository. In late 2012, a Finnish nuclear-waste-management company (Posiva) submitted a construction license application for a geological repository for spent fuel to Finland's Radiation and Nuclear Safety Authority, and in spring 2011, Swedish nuclear authorities accepted an application from the Swedish Nuclear Fuel and Waste Management Company for permission to build a repository for spent fuel. Based on the national and international research, proposals, and experience with geologic disposal, the NRC concludes that a geologic repository continues to be technically feasible.

B.2.2 Availability of a Repository

Given the consensus that geologic repositories are technically feasible, experience to date is also relevant in determining the timeframe to successfully site, license, construct, and open a repository. Of the 24 countries other than the United States considering disposal of spent or reprocessed nuclear fuel in deep geologic repositories, 10 have established target dates for the availability of a repository.[1] The majority of the 14 countries with no established target date for repository availability rely on centralized interim storage, which may include a protracted period of at-reactor storage before shipment to a centralized facility.

While some countries have struggled with specific implementation issues, the international consensus regarding an approach to disposal in a deep geologic repository and a reasonable timeframe for a repository to become available has not been abandoned.

In 1997, the United Kingdom rejected an application for the construction of a rock characterization facility at Sellafield, leaving the country without a path forward for long-term management or disposal of intermediate-level waste or spent fuel. In 1998, an inquiry by the United Kingdom House of Lords endorsed geologic disposal but specified that public acceptance was required. As a result, the United Kingdom Government embraced a repository plan based on the principles of voluntarism and partnership between communities and

[1] The three countries with target dates that plan direct disposal of spent fuel are: Czech Republic (2050), Finland (2020), and Sweden (2025). The seven countries with target dates for disposal of reprocessed spent fuel and high-level radioactive waste are: Belgium (2035), China (2050), France (2025), Germany (2025), Japan (2030s), Netherlands (2103), and Switzerland (2042).

implementers. This led to the initiation of a national public consultation and major structural reorganization within the United Kingdom program. In 2008, the UK Government called for potential volunteers to host the repository and was expecting the repository would open around 2040 (MRWS 2012). In 2013, the Cumbria County Council voted to withdraw from the United Kingdom process to find a host community for an underground radioactive waste disposal facility and to end the site-selection process in West Cumbria. In responding to the outcome of the votes in West Cumbria, the Secretary of State for Energy and Climate Change published a Written Ministerial Statement on January 31, 2013, that made clear that the United Kingdom Government remains committed to geological disposal for the safe and secure management of higher activity radioactive waste (DECC 2013) . In July 2014, the United Kingdom continued to support geological disposal and provided a revised policy framework for implementing geological disposal that favors a voluntarist approach based on working with communities that are willing to participate in the siting process (DECC 2014). The formal process for working with communities is expected to begin in 2016.

In Germany, a large salt dome at Gorleben had been under study since 1977 as a potential spent fuel repository. After suspension of exploration in 2000, Germany resumed exploration of Gorleben as a potential spent fuel repository in 2010. In July 2013, the Site Selection Act became effective in Germany. Currently, a 33-member commission made up of representatives from societal groups, academia, and the German government is preparing proposals for site selection procedures, which are due by the end of 2015.

Initial efforts in France during the 1980s also failed to identify potential repository sites, using solely technical criteria. Failure of these attempts led to the passage of nuclear waste legislation that prescribed 15 years of research. Reports on generic disposal options in clay and granite media were prepared and reviewed by the French Nuclear Safety Authority in 2005. In 2006, the French Parliament passed new legislation designating a single site for deep geologic disposal of intermediate- and high-level radioactive waste. This facility, to be located near the town of Bure in northeastern France, is scheduled to open in 2025, about 34 years after passage of the original Nuclear Waste Law of 1991, and 19 years after site selection. On May 6, 2014, the French National Agency for Radioactive Waste Management (ANDRA) announced the actions it intends to take resulting from recent public debate on geological disposal. ANDRA announced plans for a pilot facility and improvements for greater public involvement. ANDRA anticipates completion of the license application at the end of 2017 and, subject to approvals, construction of the facility could begin in 2020 and a pilot phase could begin in 2025.

In Switzerland, after detailed site investigations in several locations, the Swiss National Cooperative for Radioactive Waste Disposal proposed, in 1993, a deep geologic repository for low- and intermediate-level waste at Wellenberg. In 1998, Swiss authorities found that technical feasibility of the disposal concept had been successfully demonstrated; however, in 2002, a public cantonal referendum rejected the proposed repository. Despite difficulties with public acceptance, Swiss authorities have gathered more than 25 years of high-quality field and laboratory research and are anticipating constructing and operating a deep geologic repository after 2040, less than 30 years from today. A site selection plan was approved by the Federal Council in 2008 and three geological siting areas were identified by 2011 for deep geological disposal of high-level waste. A second phase is currently underway and involves regional participation and comparative studies with safety as the decision criterion.

In 1998, an independent panel reported to the Governments of Canada and Ontario on its review of Atomic Energy of Canada Ltd.'s concept of geologic disposal (CEAA 1998). The panel concluded that broad public support is necessary in Canada to ensure the acceptability of a concept for managing spent fuel. The panel also found that technical safety is a key part, but only one part, of acceptability. To be considered acceptable in Canada, the panel found that a concept for managing nuclear fuel wastes must (1) have broad public support; (2) be safe from a technical perspective; (3) have been developed within a sound ethical and social assessment framework; (4) have the support of Aboriginal people; (5) be selected after comparison with the risks, costs, and benefits of other options; and (6) be advanced by a stable and trustworthy proponent and overseen by a trustworthy regulator. Resulting legislation mandated a nationwide consultation process and widespread organizational reform.

In 2007, the Government of Canada announced its selection of the Adaptive Phased Management approach and directed the Nuclear Waste Management Organization to take at least 2 years to develop a "collaborative community-driven site-selection process." The Nuclear Waste Management Organization is using this process to open consultations with citizens, communities, Aboriginals, and other interested parties to find a suitable site in a willing host community. Nuclear Waste Management Organization's site-selection process was initiated in May 2010. For financial planning and cost estimation purposes only, the Nuclear Waste Management Organization assumes the availability of a deep geological repository in 2035, 27 years after initiating development of new site-selection criteria, 30 years after embarking on a national public consultation, and 37 years after rejection of the original geologic disposal concept (NWMO 2008). At the end of 2012, 21 communities had expressed interest in learning more about the project (NWMO 2013). As of June 2014, 14 of the initial 21 communities are still actively engaged in the siting process. In particular, four communities are continuing with more detailed analyses having completed preliminary assessments; 10 communities are still in the preliminary assessment phase; and seven communities are no longer being considered in the site selection process.

Repository development programs in Finland and Sweden are further along than in other countries but have taken time to build support from potential host communities. In Finland, preliminary site investigations started in 1986, and detailed characterizations of four locations were performed between 1993 and 2000. In 2001, the Finnish Parliament ratified the government's decision to proceed with a repository project at a chosen site only after the 1999 approval by the municipal council of the host community. In December 2012, Posiva (i.e., the nuclear-waste-management company in Finland) submitted a construction permit application for a final repository that will hold spent fuel from Finland's nuclear reactors. In June 2014, the Radiation and Nuclear Safety Authority (STUK) in Finland estimated that it can complete its safety assessment report for the construction permit application in January 2015. Finland expects this facility to begin receipt of spent fuel for disposal in 2020, 34 years after the start of preliminary site investigations.

Between 1993 and 2000, Sweden conducted feasibility studies in eight municipalities. One site was found technically unsuitable, and two sites were eliminated by municipal referenda. Three of the remaining five sites were selected for detailed site investigations. Municipalities adjacent to two of these sites agreed to be potential hosts, and one refused. Since 2007, detailed site investigations were conducted at Östhammar and Oskarshamn, both of which already host nuclear power stations. On June 3, 2009, the Swedish Nuclear Fuel and Waste Management Company (SKB) selected the Forsmark site located in the Östhammar municipality for the Swedish spent fuel repository and, in spring 2011, SKB submitted a license application. At the request of the Swedish government, the Nuclear Energy Agency organized an international team to review the SKB license application. In June 2012, the international review team completed its review and report stating: "SKB's post-closure radiological safety analysis report, SR-Site, is sufficient and credible for the licensing decision at hand. SKB's spent fuel disposal programme is a mature programme—at the same time innovative and implementing best practice—capable in principle to fulfil the industrial and safety-related requirements that will be relevant for the next licensing steps" (NEA 2012). In April 2014, the Swedish Radiation Safety Authority, as part of its review process, circulated the license application for comment to other public authorities and environmental organizations. A government decision is expected in 2015. If Swedish authorities authorize construction, the repository could be available for disposal around 2025, about 30 years after feasibility studies began.

In the United States, the DOE is the agency responsible for carrying out the national policy to site and build a repository, which includes designing, constructing, operating, and decommissioning the repository. The time DOE will need to develop a repository site will depend upon a variety of factors, including Congressional action and funding. Public acceptance will also influence the time it will take to implement geologic disposal. The NRC, by contrast, is the agency responsible for reviewing, licensing, and overseeing the construction and operation of the repository.

In 2012, the Blue Ribbon Commission on America's Nuclear Future recommended "prompt efforts to develop one or more geologic disposal facilities" (BRC 2012). In response to the Blue Ribbon Commission's report, the DOE (2013) stated that its "…goal is to have a repository sited by 2026; the site characterized, and the repository designed and licensed by 2042; and the repository constructed and its operations started by 2048." Based on the evaluation of international experience with geologic repository programs—including the issues some countries have overcome—and the affirmation by the Blue Ribbon Commission of the geologic repository approach, the NRC continues to believe that 25 to 35 years is a reasonable period for repository development (i.e., candidate site selection and characterization, final site selection, licensing review, and initial construction for acceptance of waste).

Although the NRC believes that 25 to 35 years is a reasonable timeframe for repository development, it acknowledges that there is sufficient uncertainty in this estimate that the possibility that more time will be needed cannot be ruled out. International and domestic experience have made it clear that technical knowledge and experience alone are not sufficient to bring about the broad social and political acceptance needed to construct a repository. The time needed to develop a societal and political consensus for a repository could add to the time to site and license a repository or overlap it to some degree.

Because the availability of a repository can be substantially affected by whatever process is employed to achieve a national consensus on repository site selection, and consistent with the decision of the Court of Appeals in *New York v. NRC*, this GEIS offers three timeframes for continued storage that reflect significant differences in the availability of the repository. The short-term timeframe assumes a repository is available 60 years after the end of a reactor's licensed life for operation. The long-term timeframe assumes a repository is not available for an additional 100 years beyond the short-term timeframe, which means a repository would be available 160 years after the end of a reactor's licensed life for operation. In recognition of the uncertainty in reaching a national consensus on repository site selection, the third timeframe assumes that a repository does not become available and the spent fuel continues to be stored indefinitely.

In the 2010 Waste Confidence decision, the Commission assessed the length of time that would be needed to site, license, construct, and open a repository. This analysis moved away from the Commission's historical practice of specifying a "target date" and instead concluded that a repository would be available "when necessary." The Commission's reluctance to select a target date was not indicative of an inability to predict the length of the process for siting, constructing, licensing, and opening a repository, but rather that identification of a specific year as a starting point was uncertain. In sum, based on experience in licensing similarly complex facilities in the United States and national and international experience with repositories already in progress, the NRC concludes a reasonable period of time for the development of a repository is approximately 25 to 35 years.

B.3 Technical Feasibility of Safe Storage

Spent fuel removed from a reactor is initially placed in a spent fuel pool for cooling. After several years (about 5 years for low-burnup fuel and up to 20 years for high-burnup fuel), the spent fuel is sufficiently cooled that it can be placed in dry cask storage assuming current