



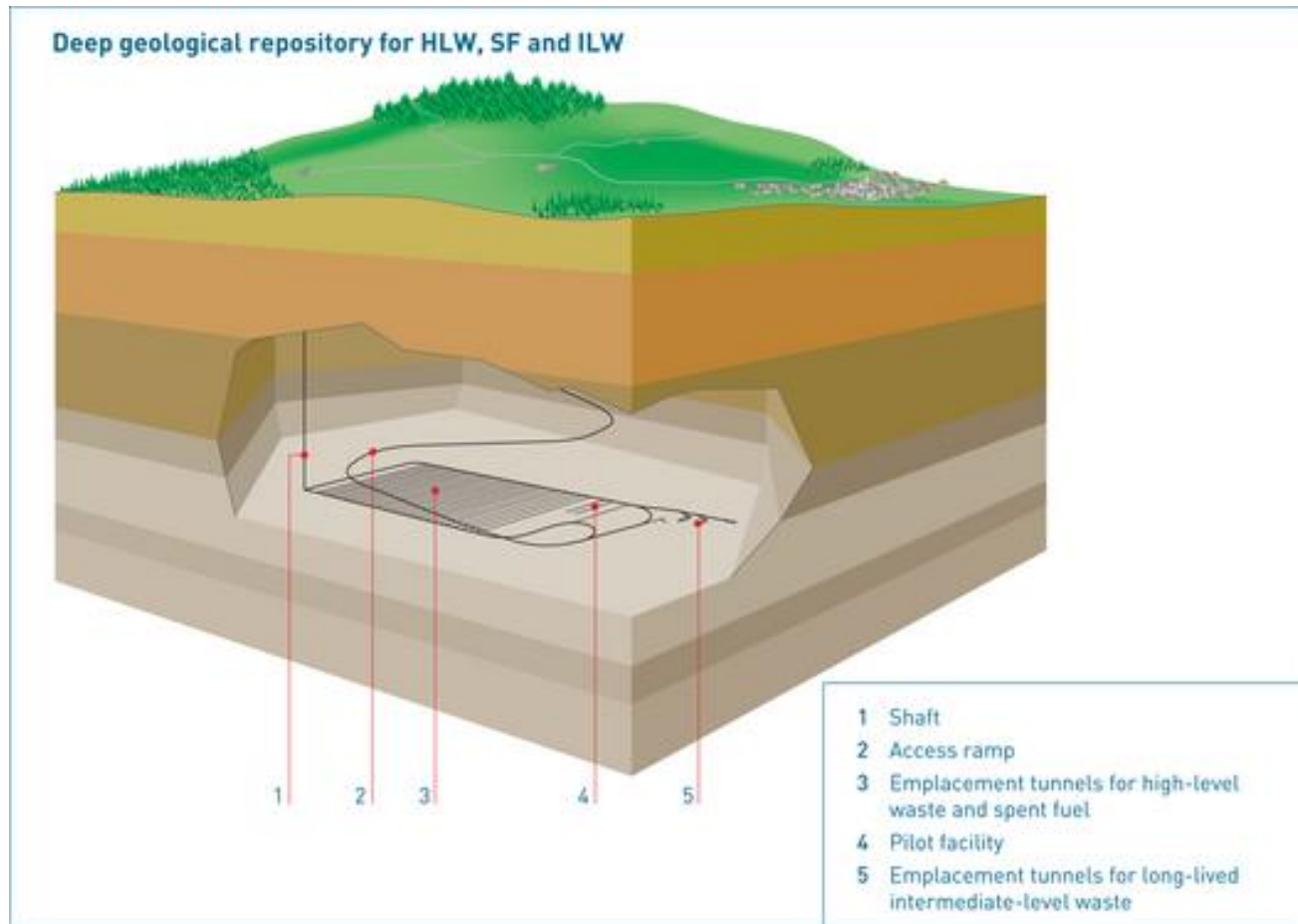
Recommendations on Postclosure Aspects of Generic Environmental Standards for the Disposal of High-Level Waste in the United States

American Nuclear Society
Special Committee on Generic Standards for Disposal of
High-Level Radioactive Waste

Presentation to the Nuclear and Radiation Studies Board of the National
Academies of Sciences, Engineering, and Medicine

November 7, 2023

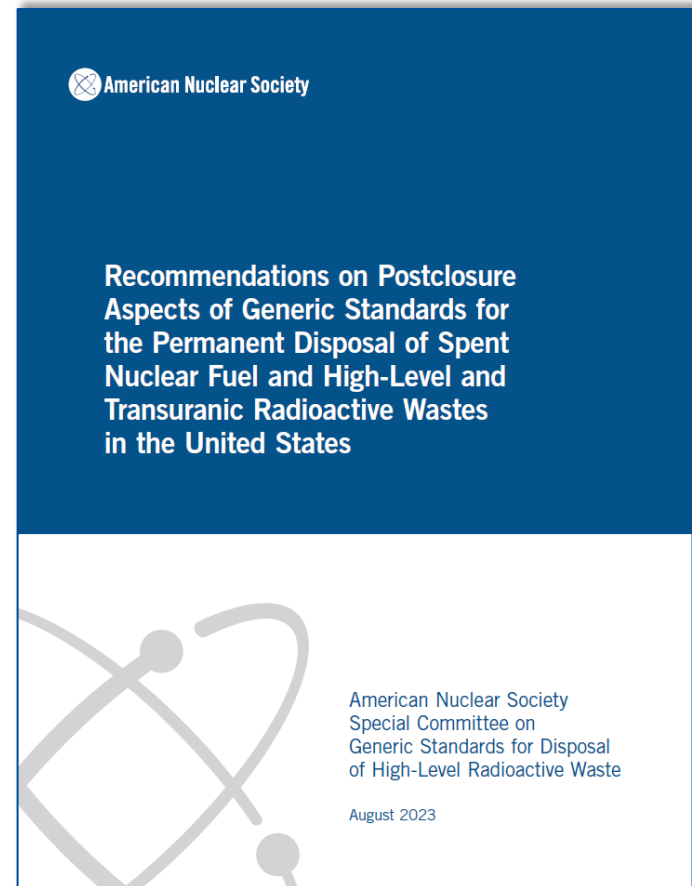
Background – Geologic Disposal



Conceptual Mined Geological Repository

ANS Project to Develop Recommendations on Generic Disposal Standards

- Current generic disposal standards at 40 CFR part 191
 - ✓ Out-of-date
 - ✓ In many cases inconsistent with the international state-of-the-practice
 - ✓ Implementing regulation (i.e., NRC 10 CFR part 60 also dates from the 1980s)
- Modern, transparent standards needed to support potential efforts to site and license a geologic disposal facility other than Yucca Mountain
- ANS Special Committee on Generic Standards for Disposal of High-Level Radioactive Waste established in 2021
 - ✓ Draft report issued February 17, 2023
 - ✓ Final report issued August 10, 2023 after revision in response to input from invited reviewers and the public



ANS Special Committee on Generic Standards for Disposal of High-Level Radioactive Waste

- Purpose: Develop recommendations regarding technical bases for updated generic public health and safety standards for disposal of used nuclear fuel and high-level radioactive waste (collectively, HLW) in a geological repository
 - ✓ Purpose consistent with recommendations from the Blue Ribbon Commission on America's Future (BRC 2012), American Nuclear Society (ANS 2020), the National Academies of Science, Engineering and Medicine (NASEM 2022), and others
- Members
 - Dr. John Kessler, JKessler and Associates (Chair)
 - Dr. Michael Apted, INTERA
 - Lake Barrett, Lake Barrett Consulting
 - Steven Nesbit, LMNT Consulting
 - Dr. Peter Swift, Consulting Scientist

Review of the February 2023 Draft Report

Invited peer reviewers

- Amir A. Bahadori, Kansas State University
- Neil A. Chapman, professor emeritus, Department of Materials Science and Engineering, University of Sheffield, UK
- Robert J. Halstead, energy and environmental policy consultant
- Don Hancock, Southwest Research and Information Center
- Bret Leslie
- Allison Macfarlane, University of British Columbia
- Tim McCartin
- Charles McCombie, McCombie Consulting, Switzerland
- Glenn Paulson, science advisor to the EPA Administrator (retired)

The authors of the report thank the reviewers for valuable inputs and perspectives. Conclusions of the report remain the responsibility of the ANS Special Committee and acknowledging the contribution of reviewers in no way implies that they agree or disagree with any content of the report.

Comments were also received from stakeholder and members of the public. Perhaps most notably, no respondents expressed the view that current disposal standards are adequate as-is.

Revisions following Review

Clarifications

- ✓ Scope limited to postclosure radiation standards
- ✓ Recommendations apply only to EPA generic standards
 - ✓ Noting however that EPA standards would apply to both NRC-regulated repositories developed under the NWPA and non-NRC-regulated repositories developed outside the NWPA
- ✓ Recommendations do not advocate for or against any technologies
- ✓ Improved internal cross-referencing to supporting appendices, including in particular the international discussion

Enhanced discussions

- ✓ Individual protection standard / dose limit
- ✓ Retrievability
- ✓ Controlled area boundary

Added specific recommendations regarding

- ✓ Active and passive institutional controls
- ✓ Postclosure monitoring

Two Assumptions

- Basic roles and responsibilities of federal regulatory agencies remain the same as those defined in the Nuclear Waste Policy Act of 1982
 - ✓ U.S. Environmental Protection Agency (EPA): promulgation of environmental standards for disposal of HLW
 - ✓ U.S. Nuclear Regulatory Commission (NRC): approval or disapproval of licenses for disposal facilities developed under the NWPA, using requirements and criteria consistent with EPA's standards
- Existing generic disposal standards at 40 CFR part 191 and existing licensing criteria at 10 CFR part 60 will be replaced
 - ✓ 40 CFR part 191 will remain a site-specific regulation for the WIPP which is already certified by the EPA under it

Recommendations

- Adopt the existing Yucca Mountain regulations at 40 CFR Part 197 as the starting point for new generic standards
 - ✓ Older generic regulation (40 CFR part 191) and the more recent site-specific regulation are both highly protective of public health and the environment
 - ✓ Newer regulation closer to current U.S. and international practice
- Specific recommendations follow on aspects to **retain**, **modify**, and **add** for future generic standards
- Additional observations on other topics

§ 195.30

updating examinations) and increases/decreases in variable costs due to inflation and other factors. In order to calculate increases/decreases in costs due to inflation, EPA may use one of the three following indices: the Federal General Schedule (GS) pay scale, the Consumer Price Index (CPI), and/or a component of the CPI, such as services. Second, EPA will estimate the number of participants for each program. At a minimum, these participation rates will be based on past and current program participation rates. Third, EPA shall calculate the per capita costs that individuals and organizations should pay to enable it to recover its fixed and variable costs each year for each program. EPA shall also consider potential industry impacts as it adjusts to levels to ultimately achieve full cost recovery over the period of five years.

[60 FR 41816, Aug. 14, 1995]

§ 195.30 Failure to remit fee.

EPA will not process an application or continue a participant's listing in the National Radon Measurement Proficiency program, individual proficiency component of the RMP program, or the National Radon Contractor Proficiency program until the appropriate remittance provided in § 195.20(a) has been received by EPA. Failure by a currently EPA-listed organization or individual to remit the required fees in a timely manner will result in the loss of that organization's or individual's listing status as specified in § 195.20(c).

PART 197—PUBLIC HEALTH AND ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR YUCCA MOUNTAIN, NEVADA

Subpart A—Public Health and Environmental Standards for Storage

Sec.

- 197.1 What does subpart A cover?
- 197.2 What definitions apply in subpart A?
- 197.3 How is subpart A implemented?
- 197.4 What standard must DOE meet?
- 197.5 When will this part take effect?

40 CFR Ch. I (7–1–11 Edition)

Subpart B—Public Health and Environmental Standards for Disposal

- 197.11 What does subpart B cover?
- 197.12 What definitions apply in subpart B?
- 197.13 How is subpart B implemented?
- 197.14 What is a reasonable expectation?
- 197.15 How must DOE take into account the changes that will occur during the period of geologic stability?

INDIVIDUAL PROTECTION STANDARD

- 197.20 What standard must DOE meet?
- 197.21 Who is the reasonably maximally exposed individual?

HUMAN INTRUSION STANDARD

- 197.25 What standard must DOE meet?
- 197.26 What are the circumstances of the human intrusion?

GROUND WATER PROTECTION STANDARDS

- 197.30 What standards must DOE meet?
- 197.31 What is a representative volume?

ADDITIONAL PROVISIONS

- 197.35 [Reserved]
- 197.36 Are there limits on what DOE must consider in the performance assessments?

- 197.37 Can EPA amend this rule?
- 197.38 Are the Individual Protection and Ground Water Protection Standards Severe?

APPENDIX A TO PART 197—CALCULATION OF ANNUAL COMMITTED EFFECTIVE DOSE EQUIVALENT

AUTHORITY: Sec. 801, Pub. L. 102-486, 106 Stat. 2921, 42 U.S.C. 10141 n.

SOURCE: 66 FR 22132, June 13, 2001, unless otherwise noted.

Subpart A—Public Health and Environmental Standards for Storage

- § 197.1 What does subpart A cover?

This subpart covers the storage of radioactive material by DOE in the Yucca Mountain repository and on the Yucca Mountain site.

- § 197.2 What definitions apply in subpart A?

Annual committed effective dose equivalent means the effective dose equivalent received by an individual in one year from radiation sources external to the individual plus the committed effective dose equivalent.

Requirements to Retain

- Retain the individual protection standard as the primary quantitative metric
 - ✓ Preferable to setting limits on total release or total dose to a population
 - ✓ Preferable to setting limits on risk, as proposed in 1995 by the NAS Committee on Technical Bases for Yucca Mountain Standards
- Retain the concept of “reasonable expectation”
 - ✓ “..absolute proof is impossible to attain for disposal due to the uncertainty of projecting long-term performance” (40 CFR 197.14(a))

Requirements to Retain (cont.)

- Continue to base the characteristics of the potentially exposed individuals on current practice
 - ✓ The “reasonably maximally exposed individual ... [h]as a diet and living style representative of the people who now reside” in the vicinity of the repository (40 CFR 197.21)
 - ✓ Reasonable and conservative approach (Appendix C of the ANS report)
- Retain the requirements for the identification and screening of potentially relevant features, events, and processes
 - ✓ Worked for both the Waste Isolation Pilot Plant and the proposed Yucca Mountain repository
 - ✓ Note: remove the site-specific 10 CFR Part 197 requirements for consideration of Yucca-Mountain-site-specific events and processes after 10,000 years

Requirements to Retain (cont.)

- Base the human intrusion standard on consideration of a single stylized intrusion event
 - ✓ Modify the scenario specified for Yucca Mountain to be applicable to generic sites
 - ✓ For example, consider drilling for other natural resources at the site rather than just groundwater, and consider pathways to overlying as well as underlying aquifers

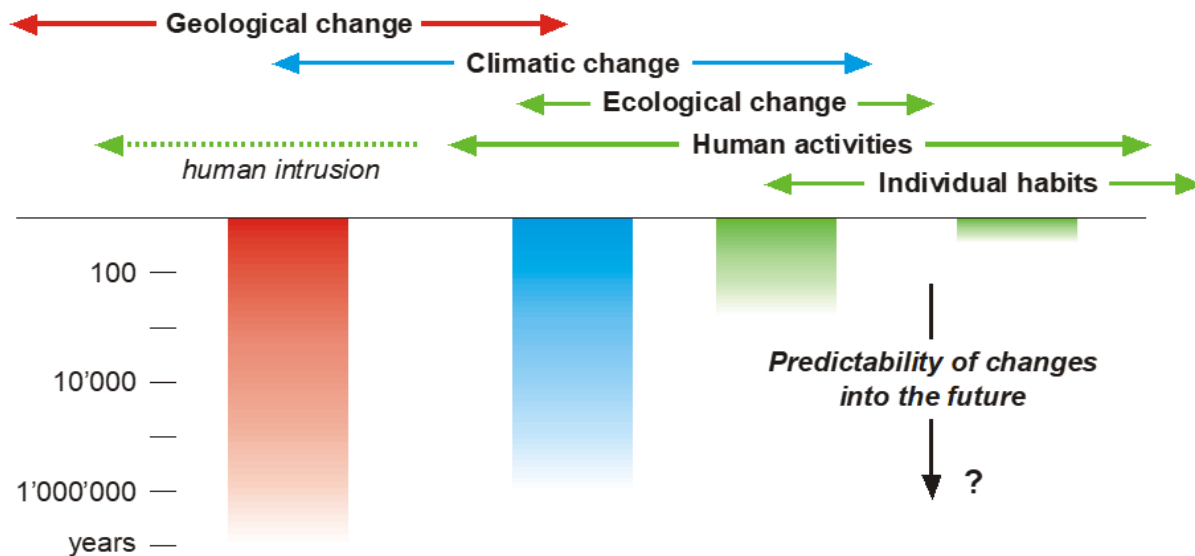
Requirements to Modify or Add

- Limit the time period for **quantitative** standards to 10,000 years
 - ✓ Basing regulatory decisions on quantitative estimates over extremely long time periods is false precision
 - ✓ Decision-making process in extremely long-time frames can be better informed by consideration of all available information (next slide)

Elements to be represented



Changes acting on these elements



NEA 2002; see Appendix B of the ANS report for further discussion

Requirements to Modify or Add (cont.)

- Evaluate multiple lines of evidence when assessing performance beyond 10,000 years
 - ✓ Demonstrate a reasonable expectation that the disposal system will continue to function as intended during the period between 10,000 and 1,000,000 years following disposal
 - ✓ Identify credible features, events, and processes that have the potential to have significantly different impacts on the safety functions of the disposal system after 10,000 years for consideration in licensing
- Remove the concept of “period of geologic stability” while retaining an upper bound on the regulatory period of one million years

Requirements to Modify or Add (cont.)

- Adopt requirements for multiple barriers consistent with the approach taken for generic repositories in 40 CFR Part 191.14(d) and implemented by the NRC for Yucca Mountain in 10 CFR Part 63
 - ✓ Provides a sound basis for the evaluation of defense in depth
 - ✓ Consistent with international practice regarding “safety functions” of system components (Appendix B of the ANS report)
- Adopt requirements for retrievability of the wastes
 - ✓ Prescribed by the NWPA Section 122 for repositories regulated by the NRC: “any repository constructed on a site approved under this subtitle shall be designed and constructed to permit the removal of any spent nuclear fuel placed in such repository during an appropriate period of operation”
 - ✓ Implemented by the NRC for Yucca Mountain in 10 CFR Part 63: “...any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission”
 - ✓ Leave site-specific details such as “reasonable schedule” and the estimated duration of operations to the implementing regulations

Requirements to Modify or Add (cont.)

- Adopt requirements for active and passive institutional controls consistent with the approach taken by the NRC in 10 CFR Part 63
 - Clarify expectations regarding efficacy of controls regarding reducing the likelihood of human intrusion
- Adopt requirements for postclosure monitoring consistent with approaches in both EPA 40 CFR Part 191 and NRC 10 CFR Part 63
 - Clarify expectations for activities required after the site license is terminated

Requirements to Modify or Add (cont.)

- Adopt a modified definition of the controlled area provided in 40 CFR Part 191
 - Retain “no more than 5 km from the waste” but delete “no more than 100 square km”
 - Leave site-specific details to the implementor and the implementing regulator
- Remove specificity regarding the establishment of the U.S. Department of Energy as the implementing organization for disposal of the regulated radioactive wastes

Requirements to Modify or Add (cont.)

- Make generic standards applicable to deep borehole disposal concepts
 - ✓ Consistent with the EPA's intent in the 1985 promulgation of 10 CFR part 191: "Although disposal of these materials in mined geologic repositories has received the most attention, the disposal standards apply to disposal by any means, except disposal directly into the oceans or ocean sediments."
- Three specific recommendations
 - ✓ Define a borehole repository to include all disposal holes at a single site, rather than treating each hole as separate facility, while allowing for flexibility in phased disposal operations
 - ✓ Revisit the human intrusion standard consistent with the lower probability of intersecting vertical borehole repositories
 - ✓ With respect to retrievability, allow for consideration of operational periods shorter than those anticipated for mined repositories

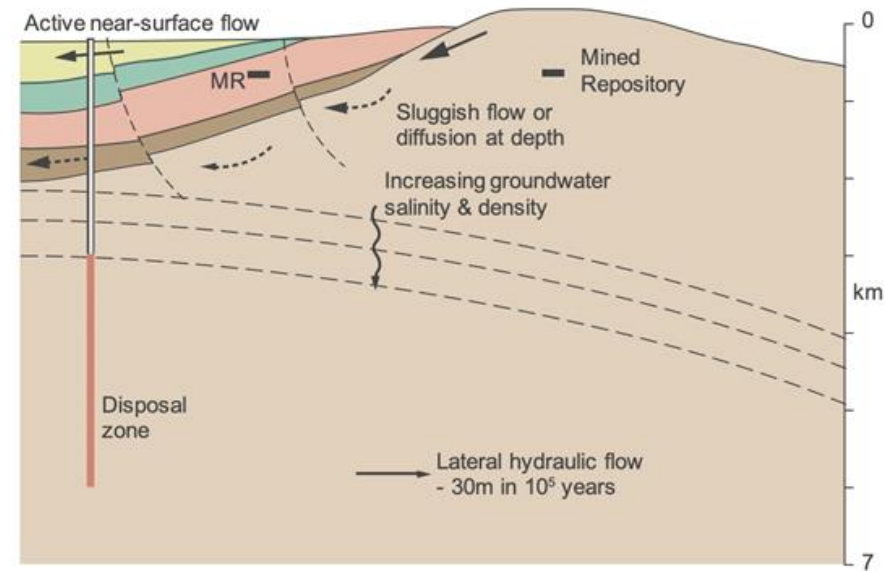


Figure from BRC 2012; after Chapman and Gibb, 2003

Other Topics

- Consider updating guidance and requirements for radiation dose assessments to be consistent with the most recent recommendations of the International Commission on Radiation Protection
 - ✓ Re-evaluate the basis specified in Appendix A of 40 CFR Part 197 for calculating annual committed effective dose equivalent in the light of newer information that has become available since the mid 1990s
- Consider removing the groundwater protection standards
 - ✓ Authors concur with comments made by the NRC in 1999 specific to the EPA's then-proposed groundwater protection standards (NRC 1999b)
 - ✓ The existing requirements provide no additional protection
 - ✓ If included in generic standards, could introduce the potential for incentivizing the selection of sites with otherwise pristine groundwater
- No specific recommendation is made for the value of a dose limit
 - ✓ The authors note the current EPA limit for 10,000 years is 0.15 mSv/year (15 mrem/year) dose equivalent
 - Below the IAEA suggestion of 0.30 mSv/year (30 mrem/year)
 - Fraction of typical natural background (U.S. average is 3.1 mSv/year or 310 mrem/year)

Questions and Comments?



American Nuclear Society

Glossary

Borehole disposal – the disposal of waste in stable geologic media accessed by a drilled borehole.

Disposal - the emplacement in a repository of high-level radioactive waste, spent nuclear fuel, or other highly radioactive material with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste. (NWPA - paraphrased)

Dose equivalent - A measure of the biological damage to living tissue as a result of radiation exposure. Units of dose equivalent are sievert (international) and rem (U.S.). (U.S. Nuclear Regulatory Commission, supplemented)

Generic disposal standards – applicable to any site.

Geologic repository – a system which is intended to be used for, or may be used for, the disposal of radioactive wastes in excavated geologic media. (10 CFR Part 60)

Groundwater - water that is below the land surface and in a saturated zone. (40 CFR Part 197)

Glossary (cont.)

High-level radioactive waste (HLW) - the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and other highly radioactive material that the Nuclear Regulatory Commission determines by rule requires permanent isolation. (NWPA – paraphrased)

Human intrusion - breaching of any portion of a disposal system, within the repository footprint, by any human activity. (40 CFR Part 197, paraphrased)

Mined geological disposal – the disposal of waste in stable geologic media accessed by ramps or shafts excavated by standard mining techniques.

Nuclear Waste Policy Act (NWPA) of 1982 – U.S. legislation establishing a framework for the management and disposal of spent nuclear fuel and HLW.

Spent nuclear fuel - fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing. (NWPA) (also referred to as “used nuclear fuel”)

Glossary (cont.)

Repository - any system that is intended to be used for, or may be used for, the permanent deep geologic disposal of high-level radioactive waste and spent nuclear fuel, whether or not such system is designed to permit the recovery, for a limited period during initial operation, of any materials placed in such system. (NWPAA – paraphrased)

Waste Isolation Pilot Plant (WIPP) – a disposal facility for DOE defense-generated transuranic waste located near Carlsbad, New Mexico, and in operation since 1999. (DOE WIPP website – paraphrased)

Yucca Mountain – a proposed site for a DOE disposal facility for spent nuclear fuel and HLW which was characterized in accordance with the NWPAA but never built.

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- Blue Ribbon Commission on America's Nuclear Future (BRC), Report to the Secretary of Energy, January 2012.
- National Academies of Sciences, Engineering, and Medicine (NASEM), “Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors, pre-publication copy, 2022.
- National Research Council, Technical Bases for Yucca Mountain Standards, National Academies Press, Washington, D.C., 1995.
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- U.S. Nuclear Regulatory Commission (NRC), letter from William D. Travers to Stephen D. Paige, dated November 2, 1999, ML99336025. 1999.

