NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste

Site Performance Criteria

February 1981

NWTS Program Office
U.S. Department of Energy

National Waste Terminal Storage Program

DISCLAIMER

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A04
Microfiche copy: A01

DOE/NWTS-33(2)
Distribution Category UC-70

NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste

Site Performance Criteria

NWTS Program Office
U.S. Department of Energy

February 1981

Prepared by the Office of Nuclear Waste Isolation
Battelle Project Management Division
Columbus, Ohio 43201
Under Contract DE-AC06-76RLO 1830-ONWI
With the U.S. Department of Energy

ABSTRACT

This report states ten criteria governing the suitability of sites for mined geologic disposal of high-level radioactive waste. The Department of Energy will use these criteria in its search for sites and will reevaluate their use when the Nuclear Regulatory Commission issues radioactive waste repository rules.

This document is one of a series covering mined geologic disposal systems and their components. Reflected in this document are many concerns raised during its public review.

TABLE OF CONTENTS

APPENDICES

NWTS PROGRAM CRITERIA FOR MINED GEOLOGIC DISPOSAL OF NUCLEAR WASTES: SITE PERFORMANCE CRITERIA

1.0 INTRODUCTION

The objective of the National Waste Terminal Storage (NWTS) Program is to provide the technology and facilities for the disposal of radioactive wastes. Currently, the principal emphasis in the program is on disposal of these wastes by emplacement in mined repositories located in deep geologic formations on land.

This document is a part of the NWTS-33 series, which provides guidance for the NWTS Program. This guidance is provided in the form of program objectives, functional requirements, performance criteria, and specifications intended to ensure that the program results in the safe and environmentally acceptable disposal of radioactive waste. The program objectives adapt the policy and recommendations found in references 1,2 3, and 4. Functional requirements stipulate the capabilities that the mined geologic disposal system must provide to achieve the program objectives. Performance criteria designate how the disposal system and its components must perform to ensure that the functional requirements are met. These objectives, requirements, and criteria are applicable to the mined geologic disposal system in general. Specifications will be developed as necessary for geologic environments considered suitable for the site and for design options developed for the repository and waste package. These specifications will further define the performance criteria for the particular site or design option being considered.

NWTS-33(1) discusses program objectives, functional requirements, and performance criteria. NWTS-33(3) presents the repository performance criteria, and NWTS-33(4) presents the waste package performance criteria. This document, NWTS-33(2), discusses the site performance criteria—criteria that the Department of Energy (DOE) will use to screen sites and to evaluate the suitability of sites for the disposal of radioactive wastes. All projects within the DOE NWTS program will use the same criteria in evaluating sites. Specifications will appear in subsequent documents.

The DOE will recommend sites which it deems to be qualified for high-level waste disposal. The Nuclear Regulatory Commission (NRC), using standards promulgated by the Environmental Protection Agency, will ultimately determine what constitutes an acceptable site. Because the regulatory agencies will not develop final site criteria for some time, the DOE has formulated site performance criteria to guide the NWTS Program in searching the conterminous United States for suitable disposal sites. These criteria reflect current governmental policies and recommendations of the Interagency Review Group.[1,2,3,4]

The contents of this document include background discussion, site performance criteria, and appendices. The background section describes the waste disposal system, the application of the site criteria, and applicable criteria from NWTS-33(1)—*Program Objectives, Functional Requirements and System Performance Criteria*. Appendix A, entitled "Comparison with Other Siting Criteria" compares the NWTS criteria with those recommended by other agencies. Appendix B contains DOE responses to public comments received on the January 1980 draft of this document. Appendix C is a glossary.

2.0 BACKGROUND

Before criteria can be established for site performance, the overall waste disposal program must be understood. This section describes the mined geologic waste disposal system, explains the application of the criteria in the siting process, and reviews the NWTS Program policies and criteria given in NWTS-33(1). Section 3.0 discusses the site performance criteria.

2.1 System Description

The mined geologic disposal system is comprised of three subsystems: the site, the repository, and the waste package. Containment and isolation of the radionuclides will be achieved by emplacing the waste package in a repository hundreds of meters below the ground surface in a site selected for its favorable containment and isolation capabilities.

Once a repository is filled with radioactive waste and sealed, radionuclides contained in the waste can escape to the biosphere in only two ways: (1) by exposure of the rock mass that contains the radionuclides, either through exhumation or through physical movement of this mass to the surface; or (2) by dissolution of the waste by ground water and transport of the radionuclides by the ground water to the biosphere. The site criteria are formulated to ensure that all conceivable phenomena and activities that facilitate or hinder waste isolation are considered in determining site suitability.

In evaluating the system's performance three time periods are of interest:

(1) Operational period—the time when the repository is open, and waste can be emplaced or retrieved. This period is defined to include construction of the repository.

(2) Thermal period—the period after closure of the repository when radioactivity levels and heat production are dominated by fission product decay.

(3) Post-thermal period—the time following decay of the short-lived radionuclides (mainly fission products) during which the radiological hazard is dominated by the decay of actinides and their daughters.

The site performance criteria presented in this document address the site characteristics that influence system performance during these stages. During the operational period site characteristics important to safety are those that affect the difficulty of excavating and maintaining underground openings, the capability to construct surface facilities, and the possibility of repository flooding. The proximity of the site to population centers is also important. Site characteristics that determine the system response to the thermal, chemical, and mechanical stresses imposed by the waste are important to system performance during the thermal period. During the post-thermal period the site's ability to retard and limit radionuclide mobility and release to the biosphere is of principal concern. Throughout all of these stages natural and man-induced processes and phenomena affecting the site (such as climate changes, tectonic events, and human activity) must also be considered.

2.2 Application of the Criteria

The NWTS site exploration program encompasses three approaches, each of which is capable of identifying sites. In the first approach host rocks having properties suitable for waste isolation are selected, their distribution within the conterminous United States is determined, and successively smaller occurrences of the host rock are screened based on hydrologic and geologic characteristics. A second approach evaluates potentially suitable areas on some federal lands already committed to nuclear activities. A third approach, suggested by the Interagency Review Group[2], examines successively smaller units of land based on geohydrologic conditions and then assesses whether or not the rocks within a particular geohydrologic environment have properties favorable to waste containment and isolation; this approach ensures that potentially suitable, but otherwise unexamined rocks, will not be overlooked.

An essential element in this siting process is the development and use of site performance criteria so worded that all factors important to the containment and isolation capability, and environmental and social acceptability of candidate sites are considered in the siting process. No set of criteria can list all of the combinations of site conditions or processes that could result in satisfactory repository performance. The siting criteria are purposefully general to allow for analysis of the interrelationships of the characteristics of specific alternative geographic locations.

In searching for potentially suitable sites, criteria are used to narrow the range of alternatives as follows:

- Land areas, be they large regions or smaller areas, that may satisfy certain siting criteria become recommended candidates and are evaluated based on selective application of significant and distinguishing factors to identify those well suited for further consideration.

- Candidates that appear less favorable than the recommended candidates based on early comparison of reconnaissance level data are deferred from additional detailed study. These candidates remain available for later consideration should the recommended candidates prove unsuitable after acquiring additional information.

- Land area also may be deferred because of significant technical uncertainties which do not establish a safety inadequacy but may foretell either uniquely expensive testing requirements or intractable questions.

The range of candidates is thus narrowed as some portion survives a screening. The screening decisions involve suppositions about some undetermined characteristics, and these suppositions remain to be proved in subsequent phases of study.

Before a site can be determined to be suitable, the information must be complete on the full range of characteristics to allow comparison of chosen sites against all siting criteria. The ultimate suitability of an alternative site cannot be determined based on only one or two characteristics, such as tectonics or geochemistry; nor can it be expected that perfect locations will be found, where every characteristic is ideal. Geologic systems are found as they are, not engineered, so each candidate location will have distinctive advantages and disadvantages which will be compared in narrowing the range of alternatives or, ultimately, in selecting sites.

Whereas one geographic area might be considered less favorable based on an evaluation of tectonic factors alone, other characteristics such as land use or geohydrology may be so favorable as to counterbalance the low degree of compliance of the tectonic factors with the criteria for tectonic environment. The site performance criteria, therefore, when properly applied, ensure that all conditions or processes that enhance or diminish the containment and isolation capabilities, safety, and environmental and social acceptability of sites are addressed in the site suitability evaluation.

2.3 Applicable NWTS-33(1) Criteria

The site performance criteria found in this document expand and apply the objectives and criteria in NWTS-33(1)—*Program Objectives, Functional Requirements and System Performance Criteria* to siting. The objectives stated in that document refer to:

(1) Effective waste isolation

(2) Institutional and societal acceptability

(3) Technical conservatism

(4) Multiple, regional repositories

(5) Waste accommodation

(6) Effective resource utilization

(7) Use of near-term technology.

The functional requirements and performance criteria in NWTS-33(1) which are applicable to siting are highlighted below.

System Functional Requirements

(1) Operations

The mined geologic disposal system shall provide the facilities and capabilities necessary for waste receipt and emplacement.

(2) Containment and Isolation

The mined geologic disposal system shall provide the capability to adequately contain and isolate radionuclides to ensure that no releases resulting in unacceptable doses to the public occur.

System Performance Criteria

(1) Public Health and Safety

Applicable federal public health and safety criteria issued by the Nuclear Regulatory Commission and the Environmental Protection Agency shall be satisfied during the operational

phase of the mined geologic disposal system. In particular, the limits specified in 40 CFR Part 191 (when adopted) shall be met.

(2) Occupational Safety

Occupational radiological exposure to the repository personnel shall be maintained to within the limits specified in 10 CFR Part 20 and below these limits to as low as reasonably achievable levels. Applicable regulations of the Mining Safety and Health Administration (specifically, 30 CFR Part 57) and Occupational Safety and Health Administration shall be used to ensure the protection of repository personnel from mining and other occupational hazards.

(3) Long-Term Safety

The mined geologic disposal system shall meet all applicable standards and shall contain and isolate radioactive wastes to the extent necessary to ensure that releases of radionuclides to the biosphere do not result in an unacceptable increase in doses to individuals and to the general population. Expected and accidental releases shall meet the limits specified in 40 CFR 191 (when adopted).

(4) Environmental Requirements

Siting, developing, and operating the mined geologic disposal system shall be conducted in a manner that preserves the quality of the environment to the extent reasonably achievable and complies with current environmental legislation. The environmental impacts associated with the mined geologic disposal system shall be mitigated to the extent reasonably achievable.

(5) Quality Assurance and Standards

All components of the mined geologic disposal system, including equipment and instrumentation, shall be classified according to their importance to safety and, thus, the level of quality assurance required. A quality assurance program shall be established and implemented in order to provide adequate assurance that these components will satisfactorily perform their required safety functions. This program shall include quality standards for the design, fabrication or construction, and testing of repository components. The quality assurance program shall satisfy 10 CFR Part 50, Appendix B—Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants. The standards found in ANSI/ASME NQA-1-1979, Quality Assurance Program Requirements for Nuclear Power Plants shall be used as guidance in establishing a QA program which satisfies 10 CFR Part 50, Appendix B.

Site Functional Requirements

(1) Operations

The site shall provide a setting compatible with the type and magnitude of operations expected at the waste repository.

(2) Containment and Isolation

The site shall provide natural barriers that will effectively contain and isolate radionuclides. Thus, the site must provide capabilities to (1) contain the waste, (2) isolate the waste from man, and (3) assist in keeping man away from the waste.

3.0 NWTS SITE PERFORMANCE CRITERIA

These criteria delineate characteristics a site must have to ensure that the disposal system will perform as required. These criteria encompass site geometry, geohydrology, geochemistry, geologic characteristics, tectonic environment, human intrusion, surface characteristics, environment, and potential socioeconomic impacts.

In the criteria, a site characteristic that "unacceptably affects system performance" is one that might decrease the isolation capability of the disposal system to the point that releases of radionuclides might occur which are in excess of acceptable limits. The criteria appear in italics. Factors for consideration and evaluation follow each criterion.

3.1 Site Geometry

The site shall be located in a geologic environment that physically separates the radioactive wastes from the biosphere and that has geometry adequate for repository placement.

(1) The minimum depth of the repository waste emplacement area shall be such that credible human activities and natural processes acting at the surface will not unacceptably affect system performance.

In order to establish this depth, erosion and denudation rates, and other phenomena must be evaluated.

(2) The thickness and lateral extent of the geologic system surrounding the waste emplacement area shall be sufficient to accommodate the repository and a buffer zone and to ensure that impacts induced by construction of the repository and by waste emplacement will not unacceptably affect system performance.

Consideration of these impacts will include evaluation of induced stresses, heat, and radiation generated by the waste.

3.2 Geohydrology

The geohydrologic regime in which the site is located shall have characteristics compatible with waste containment, isolation, and retrieval.

(1) The site shall be located so that the present and probable future geohydrological regime will minimize contact between ground water and wastes and will prevent

radionuclide migration or transport from the repository to the accessible environment in unacceptable amounts.

The evaluation of the geohydrological regime will include characterization of ground-water residence times, travel times, recharge rates, potentiometric surfaces, and path lengths and orientations. These factors must be assessed to show that path lengths are long enough and transport times are slow enough under present and probable future conditions to constitute effective barriers to radionuclide transport.

(2) *The site shall be located so that the hydrological regime can be sufficiently characterized to permit modeling to show that present and probable future conditions have no unacceptable impact on repository performance.*

Evaluation of the geohydrologic regime shall include consideration of surface conditions or features such as impoundments or glaciers, and changes in subsurface conditions induced, for example, by aquifer pumping or injection, or thermally-induced ground-water flow.

(3) *The site shall be located so that the geohydrological regime allows construction of repository shafts and maintenance of shaft liners and seals.*

Existing aquifer systems, particularly in strata between the repository level and the land surface, must be isolated from the repository workings. Evaluations must include anticipated aquifer flow rates, reliability and effectiveness of sealing, and geohydrological perturbations of the aquifers induced by shaft construction and shaft liner emplacement.

(4) *The site shall be located so that subsurface rock dissolution that may be occurring, or is likely to occur, can be shown to have no unacceptable impact on system performance.*

Existing solution features must be analyzed to identify the rate of dissolution. The effects of further dissolution or of new dissolution features on system performance must be evaluated.

3.3 Geochemistry

The site shall have geochemical characteristics compatible with waste containment, isolation, and retrieval.

(1) *The site shall be located so that the chemical interactions between radionuclides, rock, ground water, or engineered components will not unacceptably affect system performance.*

The evaluation of the geochemical regime shall include characterization of factors that contribute to slowing or preventing radionuclide

transport, such as solubilities, sorption, dissolution, precipitation, redox environment, and pH. The evaluation of the geochemical regime shall consider any factors that may adversely affect the radionuclide containment capabilities provided by the waste package, repository, or geologic system.

3.4 Geologic Characteristics

The site shall have geologic characteristics compatible with waste containment, isolation, and retrieval.

(1) The site shall be located so that the subsurface setting can be sufficiently characterized to permit identification and evaluation of conditions that are potentially adverse or favorable to waste containment, isolation, and retrieval.

Characterization of the subsurface setting will include all pertinent physical, structural, mineralogical, and geochemical features of the rock units. The geologic conditions shall be shown to not unacceptably affect system performance.

(2) The site shall provide a geologic system which can be shown to accommodate anticipated geomechanical, chemical, thermal, and radiological stresses caused by waste/rock interactions.

Phenomena such as thermally induced fractures, hydration and dehydration of mineral components, brine migration, or other physical, chemical, or radiological phenomena must be evaluated to show that they would not unacceptably affect system performance.

(3) The site shall be located so that development, operation, and closure of underground areas can be accomplished without undue hazard to repository personnel.

Sites with subsurface conditions that preclude or make excessively difficult design and construction of the repository using practical procedures shall be avoided.

3.5 Tectonic Environment

The site shall be located such that credible tectonic phenomena will not degrade system performance below acceptable limits.

(1) The site shall be located so that its tectonic environment can be evaluated with a high degree of confidence to identify tectonic elements and their impact on system performance.

Potentially hazardous geologic elements, including faults of any age, volcanoes, and anomalous geothermal gradients, must be sufficiently

investigated to allow determination of their potential effects on system performance and to show that these effects will not unacceptably affect system performance.

(2) *The site shall be located so that Quaternary faults can be identified and shown to have no unacceptable impact on system performance.*

The evaluation of Quaternary faults will emphasize the determination of the potential for rupture in or adjacent to the site but will include evaluation of the likelihood and consequence of earthquake generation and plausible impacts on the regional hydrology.

(3) *The site shall be located so that the centers of Quaternary igneous activity can be identified and shown to have no unacceptable impact on system performance.*

The evaluation of the likelihood and impact of igneous activity on the disposal system will include thorough evaluations of the region's igneous history, with particular attention given to temporal and spatial distribution of activity, character of activity, and analysis of the possibility of migration or expansion of areas of active volcanism.

(4) *The site shall be located so that long-term, continuing uplift or subsidence rates can be shown to have no unacceptable impact on system performance.*

Evaluation of the rates of uplift or subsidence is required so that effects of such movement can be shown to cause no unacceptable reduction in repository performance.

(5) *The site shall be located so that ground motion associated with the maximum credible earthquake will not have unacceptable impact on system performance.*

The evaluation of seismic effects of the disposal system requires state-of-the-art definition of (1) regional historical seismicity (both instrumental and preinstrumental), (2) maximum-credible earthquake, and (3) related seismic-design parameters such as the level of vibratory ground motion, that can be accommodated at the site by practical design measures. The seismic evaluation must be performed considering the ground motion that can be accommodated by design.

3.6 Human Intrusion

The site shall be located to reduce the likelihood that past or future human activities would cause unacceptable impacts on system performance.

The level of evaluation necessary to assess the likelihood of human intrusion will increase with the value of and the proximity of the site to exploitable features or resources such as water, thermal energy, petroleum, or minerals.

(1) The site shall be located so that the exploration history or relevant past use of the site or adjacent areas can be determined and can be shown to have no unacceptable impact on system performance.

(2) The site shall be located on land for which the federal government can obtain ownership, control access, and obtain all surface and subsurface rights necessary to ensure that surface and subsurface activities at the site will not cause unacceptable impact on system performance.

3.7 Surface Characteristics

The site and its surrounding area shall be such that surface characteristics or conditions can be accommodated by engineering measures and can be shown to have no unacceptable impacts on repository operation and system performance.

(1) The site shall be located so that the surficial hydrological system, both during anticipated climatic cycles and during extreme natural phenomena, will not cause unacceptable impacts on repository operations or system performance.

Features to be considered include nearby surface water bodies, impoundments, embayments, streams, floodplains, runoff, and drainage. Consideration of such features must include evaluation of their impact on surface and subsurface facilities and onsite access corridors during both the operational phase of the repository and the long-term isolation phase of the disposal system.

(2) The site shall be located in an area where surface topographic features do not unacceptably affect repository operation.

Sites in which road and rail access routes encounter steep grades, sharp switchbacks, slope instability, or other potential sources of hazard to incoming waste shipments should be avoided.

(3) The site shall be located where meteorological phenomena can be accommodated by engineering measures and can be shown to have no unacceptable effect on repository operation.

(4) The site shall be located where present and projected effects from nearby industrial, transportation, and military installations and operations can be accommodated by engineering measures and can be shown to have no unacceptable impacts on repository operations.

3.8 Demography

The site shall be located to minimize the potential risk to and potential conflict with the population.

(1) The site shall be located in an area of low population density and at a distance away from population concentrations and urban areas.

(2) The site shall be located such that risk to the population from transportation of radioactive wastes and from repository operation can be reduced below acceptable levels to the extent reasonably achievable.

> "To the extent reasonably achievable" implies an evaluation must be made that takes " . . . into account the state of technology, and the economics of improvements in relation to benefits to the public health and safety and other societal and socio-economic consideration . . . " [10CFR20.34(a)].

3.9 Environmental Protection

The site shall be located with due consideration to: potential environmental impacts; air, water, and land use; and ambient environmental conditions.

(1) The site shall be located with due consideration to potential environmental impacts.

> The evaluation of such impacts will include assessment of air, water, land, aesthetic, ecological, noise, resource, and historical factors appropriate to repository construction, operation, and isolation.

(2) The site shall be located to reduce the likelihood or consequence of air, water, and land use conflicts.

> The consideration of air, water, and land use must include both surface use, subsurface use, and resource denial as currently regulated by local, state, and federal legislation. Current legislation and executive orders to be addressed include:
>
> - National Environmental Policy Act of 1969
> - The Wilderness Act of 1964
> - The Wild-and-Scenic Rivers Act of 1968
> - Wildlife Preservation Act of 1966
> - Endangered Species Act of 1973
> - National Wildlife Refuge Act of 1966
> - National Park Service Lands
> - National Historic Preservation Act of 1974
> - National Heritage Program

- Noise Control Act of 1972
- Resource Conservation and Recovery Act of 1976
- Clean Air Act, Amended 1977
- Clean Water Act, Amended 1977
- The Land Policy and Management Act of 1976
- Floodplain Management, Executive Order 11988
- Protection of Wetlands, Executive Order 11990, 1977
- Prime or Unique Farmlands U.S.D.A 101(b)4.

Consideration of sites covered by these and other applicable acts, orders, or legislation will include evaluation of mitigating measures that could be undertaken to allow repository construction and operation. Such mitigating measures might include removal or exploitation of resources or articles of value covered by the acts, or shifting location of repository surface systems to avoid such articles. Evaluation of subsurface resources will include assessment of the impact of the denial of mineral, geothermal energy, water, or petroleum resources and the archeological value of the site. Consideration will be given to whether or not these resources or articles of value can be exploited or removed to allow siting.

(3) The site shall be located with due consideration to normal and extreme environmental conditions.

The evaluation of such items as high winds, tornadoes, rainfall, and flooding will be included to ensure that environmental impacts that would result from construction runoff, erosion of spoil-piles, and other repository-related activities are eliminated, or mitigated to the extent practicable.

3.10 Socioeconomic Impacts

The site shall be selected giving due consideration to social and economic impacts on communities and regions affected by the repository.

(1) The site shall be located so that adverse social and/or economic impacts resulting from repository construction and operation can be accommodated by mitigation or compensation strategies.

Social and economic impacts include both positive and negative effects on individuals, communities, and institutions, such as: the influx of new workers into a town, the effect of population growth on housing markets and community services, the fiscal burden on the local government, the impacts on governmental processes, and changes in land use patterns. Some impacts may remain for which compensation or mitigation may be necessary.

(2) *The site shall be located so that adequate access and utility capability required for the repository either exists or can be provided without unacceptable impact on affected communities.*

The movement of construction equipment and supplies, and of waste to the repository during operation, can create burdens on highway and rail systems. Both systems need to be adequate to carry these loads, or may need to be upgraded if current capability is not adequate.

REFERENCES

(1) Presidential Message to the Congress, *Comprehensive Radioactive Waste Management Program*, Weekly Compilation of Presidential Documents, Vol. 16, No. 7, February 12, 1980.

(2) *Report to The President by The Interagency Review Group on Nuclear Waste Management*, TID-29442, March 1979.

(3) U.S. Department of Energy, *Statement of Position of the United States Department of Energy in the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste*, DOE/NE-0007, April 15, 1980.

(4) U.S. Department of Energy, *Cross-Statement of the United States Department of Energy in the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste* DOE/NE-0007, Suppl. September 5, 1980.

APPENDIX A

COMPARISON WITH OTHER SITING CRITERIA

APPENDIX A

COMPARISON WITH OTHER SITING CRITERIA

This appendix compares the relationship of the DOE Site Performance Criteria to draft or final criteria[1] issued previously by various government or international agencies. Pertinent sections of the *Final Environmental Impact Statement for Management of Commercially Generated Radioactive Waste*[2] are also compared to the DOE criteria for the convenience of the reader.

These comparative relationships are summarized in the following Table A-1. Details are provided in the text of this appendix.

DEPARTMENT OF ENERGY
NATIONAL WASTE TERMINAL STORAGE PROGRAM

3.1 SITE GEOMETRY

THE SITE SHALL BE LOCATED IN A GEOLOGIC ENVIRONMENT THAT PHYSICALLY SEPARATES THE RADIOACTIVE WASTES FROM THE BIOSPHERE AND THAT HAS GEOMETRY ADEQUATE FOR REPOSITORY PLACEMENT.

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCE

Section 3.1.1. The repository should be at a depth sufficient to separate the respository from any surficial process or event that might cause a breach of the repository.

Section 3.1.2. The size and shape of the specific body of rock in which a repository is to be constructed should be adequate to allow room for both the repository and also a sufficiently large buffer zone around the repository.

---

(1) National Research Council/National Academy of Sciences, *Geological Criteria for Repositories for High-Level Radioactive Waste*, August, 1978.

Nuclear Regulatory Commission. *Advanced Notice of Rulemaking on Technical Criteria for Regulating Geologic Disposal of High-Level Radioactive Waste, 10CFR60*, May, 1980.

International Atomic Energy Agency, Technical Reports No. 177 *Site Selection Factors for Repositories of Solid High-Level and Alpha-Bearing Wastes in Geologic Formations*, October, 1977.

Y/OWI/TM-47. *Geological Criteria for Radioactive Waste Repositories*, by G. D. Brunton and W. C. McClain, November 28, 1977, Contract W-7405-eng-26.

(2) DOE/EIS/0046-F, *Management of Commercially Generated Radioactive Waste, Final Environmental Impact Statement*, 3 Volumes, October, 1980, U.S. Department of Energy.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

TABLE A-1. COMPARISON OF DOE AND OTHER SITING CRITERIA

DEPARTMENT OF ENERGY NATIONAL WASTE TERMINAL STORAGE PROGRAM NWTS-33(2) NWTS Criteria for the Geologic Disposal of Radioactive Wastes: Site Performance Criteria	DEPARTMENT OF ENERGY DOE/EIS-0046/F Final Environmental Impact Statement Management of Commercially Generated Radioactive Wastes, Vol. I (October 1980)	NATIONAL RESEARCH COUNCIL NATIONAL ACADEMY OF SCIENCE Geological Criteria for Repositories for High-Level Radioactive Wastes (August 1978)	NUCLEAR REGULATORY COMMISSION 10 CFR Part 60, Subpart D Draft (May, 1980)	INTERNATIONAL ATOMIC ENERGY AGENCY Technical Reports Series No. 177 Site Selection Factors for Repositories of Solid High-Level and Alpha-Bearing Wastes in Geological Formations (October 1977)	OFFICE OF WASTE ISOLATION Y/OWI/TM-47 Geological Criteria for Radioactive Waste Repositories (November 1977)
I. Site Geometry • Minimum Depth • Thickness • Lateral Extent	Section 5.1.1., Item 1. Geologic Environment Geometry	Section 3.1.1. Depth Section 3.1.2. Size and Shape of Rock Section 3.1.3. Geometry of Rock	60.122 (c)(2) - Minimum Depth 60.122 (a)(9) - Thickness 60.122 (a)(9) - Lateral Extent	Selection Factor 4.3.1 Depth Selection Factor 4.3.2. Thickness & Extent Selection Factor 4.8.1. Buffer Zone	Criterion 1: Depth Criterion 2: Vertical Extent Criterion 3: Lateral Extent
II. Geohydrology • Hydrological Regime/ Path Length/Travel Time • Water Bodies/Climatic Cycles • Aquifer Flow/Construction • Dissolution of Rock	Section 5.1.1., Item 3. Subsurface Hydrologic Characteristics	Section 3.3.1 Fluid Transport Section 3.3.3. Past Hydrological Conditions Section 3.4.3. Waste/Rock Interaction	60.122 (a)(1), (a)(2), (a)(3), (a)(4), (a)(9), (b)(3), (c)(1) and (c)(2) - Hydrological Regime/Path Length/Travel Time 60.122 (c)(2) - Water Bodies/Climatic Cycles 60.132 (c)(2) - Aquifer Flow/Construction 60.122 (a)(9), (c)(1) - Dissolution of Rock	Selection Factor 4.5.1 Permeability, Porosity, Dispersiveness Selection Factor 4.5.5. Sorption Capacity Selection Factor 4.5.6. Mineral Sources of Water Selection Factor 4.6.2. Ground Waters	Criterion 7: Hydrological Properties Criterion 8: Waste/Water Interaction Water Content of Host Rock
III. Geochemistry • Chemical Interactions • Radionuclide Retardation	Section 5.1.1., Item 3. Subsurface Geochemical Characteristics	Section 3.4.1. Heat/Radiation Effects Section 3.4.2. Waste/Rock Interaction Section 3.4.4. Waste/Water/Rock Geochemistry	60.122 (c)(1), (a)(4), (a)(9), (b)(4) Chemical Interactions 60.111 (c)(4), and 60.122 (c)(1) - Radionuclide Retardation	Selection Factor 4.5.4. Thermal Effects Selection Factor 4.5.5. Sorption Capacity Selection Factor 4.5.6. Mineral Sources of Water Selection Factor 4.5.7. Radiation Effects	Criterion 9: Radiation/Rock Interaction Criterion 10: Waste/Rock Interaction
IV. Geologic Characteristics • Stratigraphy • Host Rock Characteristics • Virgin Rock Strength	Section 5.1.1., Item 2. Geologic Characteristics	Section 3.1.3. Geometry and Properties of Host Rock Section 3.2.4. Mechanical/Geophysical Properties, State-of-Stress	60.122 (a)(1-4), (b)(2), (c)(2) - Stratigraphy/Host Rock Characteristics 60.122 (a)(9) - Virgin Rock Strength 60.111 (c)(4) - Geologic Stability	Selection Factor 4.3.3. Consistency, Homogeneity, Purity Selection Factor 4.3.4. Surrounding Beds Selection Factor 4.4.1. Dip Selection Factor 4.4.2. Faults & Joints Selection Factor 4.5.3. Rock Mechanics Selection Factor 4.5.4. Thermal Effects	Criterion 11: Mechanical Properties of Rock Criterion 12: State of Stress Criterion 14: Geological Setting
V. Tectonic Environment • Tectonic Elements • Quaternary Faults • Quaternary Igneous Activity • Uplift or Subsidence Rates • Seismicity	Section 5.1.1., Item 5. Tectonic Stability, Faulting, Deformation, Volcanic Activity	Section 3.2.1. Stability & Tectonic Boundaries Section 3.2.2. Faults Section 3.2.3. Volcanic Activity	60.122 (c)(1), (a)(3), (a)(4) - Tectonic Environment 60.122 (b)(2) - Tectonic Elements 60.122 (b)(2), (a)(2), (b)(3) - Quaternary Faults 60.122 (b)(2) - Quaternary Igneous Activity 60.122 (b)(2) - Uplife or Subsidence Rates 60.122 (b)(2) - Seismicity	Selection Factor 4.2. Tectonics & Seismicity Selection Factor 4.4.2. Faults & Joints Selection Factor 4.4.3. Diapirism	Criterion 4: Uplift/Subsidence Criterion 5: Faults Criterion 6: Igneous Activity Criterion 13: Seismicity

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

TABLE A-1. (CONTINUED)

DEPARTMENT OF ENERGY NATIONAL WASTE TERMINAL STORAGE PROGRAM	DEPARTMENT OF ENERGY	NATIONAL RESEARCH COUNCIL NATIONAL ACADEMY OF SCIENCE	NUCLEAR REGULATORY COMMISSION	INTERNATIONAL ATOMIC ENERGY AGENCY	OFFICE OF WASTE ISOLATION
VI. Human Intrusion • Resources • Exploration History • Ownership and Control	Section 5.1.1., Item 6. Resource Potential of Site	Section 4.1. Exploration History Section 4.2. Resource Analysis	60.122 (b)(1), (a)(2-4), (a)(8) -Resources 60.122 (b)(1), (a)(8) - Exploration History 60.121 - Ownership/Control	Selection Factor 4.8.2. Preexisting Boreholes and Excavations Selection Factor 4.9.1. Resource Potential (Economic) Selection Factor 4.9.4. Jurisdiction of Land Selection Factor 4.9.5. Existing Rights	Criterion 15: Mineral Resources Criterion 16: Water Resources
VII. Surface Characteristics • Hydrological System • Water Bodies • Topographic Features • Meteorological Phenomena • Industrial/Transportation/ Military Installations	Section 5.1.1., Item 4. Surficial Hydrologic System, Climatic Cycles	Section 4.3. Flooding (Dams)	60.122 (b)(3), (b)(1) - Hydrological System 60.122 (b)(1) - Water Bodies 60.122 (b)(1), (b)(3) - Topographic Features 60.132 (b)(3-5, 7) - Industrial Transportation/ Utility Hazards	Selection Factor 4.1. Topography Selection Factor 4.6.1. Surface Waters	Criterion 14: Geographic and Topographic
VIII. Demography • Urban Areas • Transportation	Not specifically addressed	Not specifically addressed	60.122 (c)(2) - Urban Areas Not specifically addressed - Transportation	Selection Factor 4.9.3. Population Density	Not specifically addressed
IX. Environmental Protection • Wilderness • Rivers • Wildlife • National Parks • Archaeology • National Heritage • Ambient Conditions	Not specifically addressed	Not specifically addressed	Not Specifically Addressed	Selection Factor 4.6.1. Surface Waters Selection Factor 4.8.6. Ecological Effects Selection Factor 4.9.2. Land Value & Use	Criterion 16: Water Resources Criterion 17: Land Use
X. Socioeconomic Impacts • Management of Impacts • Transportation Impacts	Not specifically addressed	Not specifically addressed	Not specifically addressed	Selection Factor 4.8.5. Waste Transporation Selection Factor 4.9.6. Accessibility & Services	Not specifically addressed

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

Section 3.1.3. Information on the geometry and physical, chemical, and mineralogical properties of the prospective host rock body and the associated rocks is essential in advance of development of the site.

NUCLEAR REGULATORY COMMISSION

60.122(a)(9). The Department shall determine by appropriate analyses the extent of the volume of rock within which the geologic framework, ground-water flow, ground-water chemistry, or geomechanical properties are anticipated to be significantly affected by construction of the geologic repository or by the presence of the emplaced wastes, with emphasis on the thermal loading of the latter. . . As a minimum, the Department shall assume that the volume will extend a horizontal distance of 2 kilometers from the limits of the repository excavation and a vertical distance from the surface to a depth of 1 kilometer below the limits of the repository excavation . . .

60.122(c)(2). The Department shall select the site so that to the extent practicable the volume of rock . . . (ii) possesses a geologic framework that permits effective sealing of shafts, drifts, and boreholes, and that permits excavation of a stable subsurface opening, and the emplacement of waste at a minimum depth of 300 meters from the ground surface, and (iii) possesses ground-water flow characteristics that—

(a) result in a host rock with very low water content;

(b) prevent ground-water intrusion or circulation of ground water in the host rock;

(c) prevent significant upward ground-water flow between hydrogeologic units or along shafts, drifts, and boreholes;

(d) result in low hydraulic gradients in the host rock and surrounding confining units;

(e) result in horizontal or downward hydraulic gradients in the host rock and surrounding confining units; and

(f) result in ground-water residence times under ambient conditions, between the repository and the accessible environment, that exceed 1000 years.

(iv) possesses geomechanical properties that provide stability during construction, operation, and under the influences of thermal load or other waste/rock/water interactions; (v) possesses a low population density; (vi) possesses a combination of meteorological characteristics (especially prevailing wind flow direction) and population distribution such as to assure that a radiological exposure of the population, which is within the limits of Part 20 of this chapter; and (vii) is in an area where climatic change is not expected to have an adverse impact on the geologic, tectonic, or hydrologic characteristics.

INTERNATIONAL ATOMIC ENERGY AGENCY

Section 4.3.1. Owing to weathering processes, most plastic rocks that lie within a hundred meters under the land surface contain an abundance of open fractures that are capable of transmitting water. This, coupled with the slow but relentless removal of the land surface through erosion, makes it imperative that prospective rock zones for a radioactive waste repository lie at a depth of at least two to three hundred meters.

Section 4.3.2. In general, the formation must be of such vertical and lateral extent that any fractures emanating from the immediate surroundings of the implaced waste will be absorbed or buffered so as not to reduce the effectiveness of the containment characteristics of the host rock.

Section 4.8.1. The buffer zone should have an extent which, in connection with those factors outlined in Section 4.9, would guarantee that the waste repository will not be damaged from outside activities.

OFFICE OF WASTE ISOLATION

Criterion 1. The repository rock shall be at a depth sufficient to separate the repository from surficial processes and other credible events that could result in a hazardous breach of the geological containment.

Criterion 2. The repository rock shall have sufficient vertical extent to preclude breaching of the geological containment during the subsurface excavation of the repository or by radioactive heat production after the wastes are implaced.

Criterion 3. The repository rock shall have sufficient lateral extent to provide adequate space to develop and operate the repository and to leave a buffer zone of undisturbed repository rock on all sides.

DEPARTMENT OF ENERGY

Section 5.1.1.2, Item 1. The repository site shall be located in a geologic environment with geometry adequate for repository placement.

DEPARTMENT OF ENERGY
NATIONAL WASTE TERMINAL STORAGE PROGRAM

3.2 GEOHYDROLOGY

THE GEOHYDROLOGIC REGIME IN WHICH THE SITE IS LOCATED SHALL HAVE CHARACTERISTICS COMPATIBLE WITH WASTE CONTAINMENT, ISOLATION, AND RETRIEVAL.

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCE

Section 3.3.1. Hydrologic analysis of the perturbed geologic system involving a repository must determine that fluid transport will not move hazardous material to the biosphere in amounts and rates above prescribed limits.

Section 3.3.3. The geological record of previous hydrological conditions, or the paleohydrological record, should be such that predictions can be made that are favorable for long-term hydrological isolation of the repository site in a perturbed geologic environment.

Section 3.4.3. Water in the repository, if present, should not react chemically or physically with the repository rock to increase its permeability, which would compromise geological containment.

NUCLEAR REGULATORY COMMISSION

60.122(a)(1). The Department shall select the site and environs so that they are not so complex as to preclude thorough investigation and evaluation of the site characteristics that are important to demonstrating that the performance objectives of §60.111 will be met.

60.122(a)(2). The Department shall investigate and evaluate the natural conditions . . . that can reasonably be expected to affect the design, construction, operation, and decommissioning of the geologic repository operations area. The natural conditions include geologic, tectonic, hydrologic, and climatic process. The Department shall evaluate the stability of the geologic repository and the isolation of radionuclides after decommissioning. (i) The Department shall conduct investigations on the order of 100 kilometers horizontal radius from the geologic repository operations area, and . . . (iii) the Department shall emphasize the first 10,000 years following decommissioning in their prediction of changes in natural conditions and the performance of the geologic repository.

60.122(d)(3). The Department shall conduct investigations that adequately characterize and provide representative and bounding values for those . . . natural events and conditions that may affect any of the following: (i) The design, construction, operation, and decommissioning

of the geologic repository operations area, (ii) demonstration of the stability of the geologic repository after decommissioning, and (iii) demonstration of the isolation of radionuclides from the accessible environment after decommissioning.

60.122(a)(4). The Department shall evaluate reasonably likely future variations in the site characteristics which may result from natural processes. . . .

60.122(a)(9). The Department shall at a minimum conduct investigations and tests to provide the following input data: . . . (ii) the presence of potential pathways such as fractures, discontinuities, solution features, unsealed faults, breccia pipes, and other permeable anomalies in the host rock and surrounding confining units, . . . (iii) the *in situ* determintion of the bulk geomechanical properties, pore pressures and ambient stress conditions of the host rock and surrounding confining units; (iv) the *in situ* determination of the bulk hydrogeologic properties of the host rock and surrounding confining units . . . and (vi) the *in situ* determination of the bulk response of the host rock and surrounding confining units to the anticipated thermal loading given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass. . . .

60.122(b). The Department shall demonstrate whether any of the (following) potentially adverse natural conditions are present. The presence of any of the (following) potentially adverse . . . natural conditions will give rise to a presumption that the geologic repository will not meet the performance objectives.

60.122(b)(3)(i). There is potential for significant changes in hydrologic conditions including hydraulic gradient, average pore velocity, storativity, permeability, natural recharge, piezometric level, and discharge points. Evaluation techniques include paleohydrologic analysis . . . (iv) There is a fault of fracture zone, irrespective of age of last movement, which has a horizontal length of more than a few hundreds of meters.

60.122(c)(1). The Department shall select the site so that to the extent practicable the candidate area—(i) exhibits demonstrable surface and subsurface . . . hydrologic stability since the beginning of the Quaternary Period; and (ii) contains a host rock and surrounding confining units that provide: (a) long ground-water residence times and long flow paths between the repository and the accessible environment, and (b) inactive ground-water circulation within the host rock and surrounding confining units, and little hydraulic communication with adjacent hydrogeologic units due to ground-water characteristics such as slow intrinsic permeability and low fracture permeability of the rock mass.

60.122(c)(2). The Department shall select the site so that to the extent practicable the volume of rock— . . . (iii) possesses ground-water flow characteristics that:

(a) result in a host rock with very low water content;

(b) prevent ground-water intrusion or circulation of ground water in the host rock;

(c) prevent significant upward ground-water flow between hydrogeologic units or along shafts, drifts, and boreholes;

(d) result in low hydraulic gradients in the host rock and surrounding confining units;

(e) result in horizontal or downward hydraulic gradients in the host rock and surrounding confining units; and

(f) result in ground-water residence times under ambient conditions, between the repository and the accessible environment, that exceed 1000 years.

INTERNATIONAL ATOMIC ENERGY AGENCY

Selection Factor 4.5.1. Rocks that possess low permeabilities (interconnecting pore space) are favored for radioactive waste disposal.

Selection Factor 4.5.5. . . . Therefore, it is important that the absorption potential and groundwater flow be carefully examined at each individual site. Additionally, the effects of heating on the sorption capacity of each host rock should be examined.

Selection Factor 4.5.6. Significant quantities of hydrated minerals may create undesirable conditions in rocks that are candidates for implacement of high-level, heat-generating wastes as these minerals release water at elevated temperatures . . . If . . . hydrated materials occur in the vicinity of the disposal zone they must be considered as potential sources of water. Such factors as the rate of dewatering and the mechanism(s) and path(s) by which the free water might escape or be recombined must be evaluated.

Selection Factor 4.6.2. . . . Circulating groundwater poses the main real threat to the containment of radioactive wastes placed in geological formations. Thus, the nature and characteristics of water bearing formations that lie in proximity to a potential disposal zone, as well as the host rock for the repository, are critical elements in establishing its suitability.

OFFICE OF WASTE ISOLATION

Criterion 7. The hydrological properties of the repository rock, together with those of the surrounding geological material, shall not permit the transport of hazardous amounts of radionuclides by groundwater to the biosphere.

Criterion 8. The water content of the repository rock shall be sufficiently low that water liberated by heat from radioactive decay will not compromise the geological containment by underground chemical reactions with the waste or repository rock.

DEPARTMENT OF ENERGY

Section 5.1.1.2, Item 3. The repository site shall have subsurface hydrologic and geochemical characteristics compatible with waste isolation.

DEPARTMENT OF ENERGY
NATIONAL WASTE TERMINAL STORAGE PROGRAM

3.3 GEOCHEMISTRY

THE SITE SHALL HAVE GEOCHEMICAL CHARACTERISTICS COMPATIBLE WITH WASTE CONTAINMENT, ISOLATION, AND RETRIEVAL.

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCE

Section 3.4.1. Radioactive heat and radiation should not reach levels high enough to produce physical and chemical reactions in the repository rock that would compromise the geological containment.

Section 3.4.2. The interaction of water, repository rock, and the waste material should be controlled in such a way as to minimize the rate of dissolution of the waste form.

Section 3.4.4. The properties of the geochemical system of the radionuclides, the repository rock, and its associated water should be such as to restrict or prevent the mobility of the radionuclides and to delay or prevent their migration to the active biosphere.

NUCLEAR REGULATORY COMMISSION

60.111(c)(4). (ii) The Department shall provide reasonable assurance that the site exhibits properties which promote isolation and that their capability to inhibit the migration of radionuclides will not significantly decrease over the long term.

60.121(a)(4). The Department shall evaluate reasonably likely future variations in the site characteristics which may result from . . . waste/rock/water interactions.

60.121(a)(9). . . . the Department shall at a minimum conduct investigations and tests to provide the following input data . . . (v) The *in situ* determination of the bulk geochemical conditions, particularly the redox potential, of the host rock and surrounding confining units; (vi) The *in situ* determination of the bulk response of the host rock and surrounding confining units to the anticipated thermal loading given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass.

60.122(b). The Department shall demonstrate whether any of the potentially adverse . . . natural conditions are present. The presence of any of the (following) potentially adverse . . . natural conditions will give rise to a presumption that the geologic repository will not meet the performance objectives . . . (b)(4) The rock units between the repository and the accessible environment exhibit low retardation for most of the radionuclides contained in the radioactive waste . . .

60.122(c)(1). The Department shall select the site so that to the extent practicable the candidate area— (i) exhibits demonstrable surface and subsurface .. . geochemical . . . stability since the beginning of the Quaternary Period; and (ii) contains a host rock and surrounding confining units that provide: . . . (c) geochemical properties, such as reducing conditions which result in low solubility of radionuclides, and near-normal pH, or a lack of complexing agents.

INTERNATIONAL ATOMIC ENERGY AGENCY

Selection Factor 4.5.4. Preferably, rocks to be utilized for the disposal of high-level, heat-generating waste should possess thermal properties that promote rapid dissipation of the radiodecay heat and whose stabilities are not adversely affected in the presence of elevated temperatures. . . . To determine the effects of imposed thermal loading on the temperature distributions and the structural stabilities of various host rocks, the appropriate thermal transport and mechanical strength-related properties, including thermal conductivity, specific heat, coefficient of expansion, rupture stress and creep rate, must be investigated and determined.

Selection Factor 4.5.5. . . . Therefore, it is important that the absorption potential and groundwater flow be carefully examined at each individual site. Additionally, the effects of heating on the sorption capacity of each host rock should be examined.

Selection Factor 4.5.6. Significant quantities of hydrated minerals may create undesirable conditions in rocks that are candidates for implacement of high-level, heat-generating wastes as these minerals release water at elevated temperatures . . . If . . . hydrated materials occur in the vicinity of the disposal zone they must be considered as potential sources of water. Such factors as the rate of dewatering and the mechanism(s) and path(s) by which the free water might escape or be recombined must be evaluated.

Selection Factor 4.5.7. . . . It is essential to establish the identity and magnitude of radiation effects on the various types of rocks that would be otherwise potentially suitable for the disposal of high-level radioactive wastes.

OFFICE OF WASTE ISOLATION

Criterion 9. Radiation from the stored wastes shall not affect the repository rock in such a way as to compromise the geological containment.

Criterion 10. The repository rock shall not react chemically with the radioactive waste or the waste form or with its container in such a way as to compromise the geological containment or operational safety.

DEPARTMENT OF ENERGY

Section 5.1.1.2, Item 3. The repository site shall have subsurface hydrologic and geochemical characteristics compatible with waste isolation.

DEPARTMENT OF ENERGY
NATIONAL WASTE TERMINAL STORAGE PROGRAM

3.4 GEOLOGIC CHARACTERISTICS

THE SITE SHALL HAVE GEOLOGIC CHARACTERISTICS COMPATIBLE WITH WASTE CONTAINMENT, ISOLATION, AND RETRIEVAL.

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCE

Section 3.1.3. Information on the geometry and physical, chemical, and mineralogical properties of the prospective host rock body and the associated rocks is essential in advance of development of the site.

Section 3.2.4 The mechanical and geophysical properties and the state of stress in the repository host rock should be such as to ensure the stability of the repository during its operation.

NUCLEAR REGULATORY COMMISSION

60.111(c)(4)(i). The Department shall provide reasonable assurance that the degree of stability exhibited by the geologic environment at present will not significantly decrease over the long term.

60.122(a)(1). The Department shall select the site and environs so that they are not so complex as to preclude thorough investigation and evaluation of the site characteristics that are important to demonstrating that the performance objectives of §60.111 will be met.

60.122(a)(2). The Department shall investigate and evaluate the natural conditions . . . that can reasonably be expected to affect the design, construction, operation, and decommissioning of the geologic repository operations area. The natural conditions include geologic, tectonic, hydrologic, and climatic process. The Department shall evaluate the stability of the geologic repository and the isolation of radionuclides after decommissioning. (i) The Department shall conduct investigations on the order of 100 kilometers horizontal radius from the geologic repository operations area . . . (iii) The Department shall emphasize the first 10,000 years following decommissioning in their prediction of changes in natural conditions and the performance of the geologic repository.

60.122(a)(3). The Department shall conduct investigations that adequately characterize and provide representative and bounding values for those . . . natural events and conditions that may affect any of the following: (i) The design, construction, operation, and decommissioning of the geologic repository operations area. (ii) Demonstration of the stability of the geologic repository after decommissioning. (iii) Demonstration of the isolation of radionuclides from the accessible environment after decommissioning.

60.122(a)(4). The Department shall evaluate reasonably likely future variations in the site characteristics which may result from natural processes . . .

60.122(a)(9). The Department shall at a minimum conduct investigations and tests to provide the following input data: (i) The pattern, distribution and origin of fractures, discontinuities, and heterogeneities in the host rock and surrounding confining units; . . . (iii) The *in situ* determination of the bulk geomechanical properties, pore pressures and ambient stress conditions of the host rock and surrounding confining units; . . . (vi) The *in situ* determination of the bulk response of the host rock and surrounding confining units to the anticipated thermal loading given the pattern of fractures and other discontinuities and the heat transfer properties of the rock mass.

60.122(b). The Department shall demonstrate whether any of the (following) potentially adverse . . . natural conditions are present. The Department shall document all investigations.

The presence of any of the (following) potentially adverse . . . natural conditions will give rise to a presumption that the geologic repository will not meet the performance objectives: (ii) There is evidence of dissolutioning, such as karst features, breccia pipes, or insoluble residues.

60.122(c)(2). The Department shall select the site so that to the extent practicable the volume of rock: (iv) possesses geomechanical properties that provide stability during construction, operation, and under the influences of thermal load or other waste/rock/water interactions; . . . (vii) is in an area where climatic change is not expected to have an adverse impact on the geologic, tectonic, or hydrologic characteristics.

INTERNATIONAL ATOMIC ENERGY AGENCY

Selection Factor 4.3.3. In general, a high degree of homogeneity or consistency is a desirable feature of rocks being considered for implacement of radioactive wastes.

Selection Factor 4.3.4. Although the primary geological containment for radioactive waste implacement in rock formations exists, for the most part, within the host rocks, it is apparent that additional protection and/or containment may be gained through impervious beds that might surround the host rocks.

Selection Factor 4.4.1. In bedded sedimentary rocks, excepting salt diapirs, the preferred dip or inclination of strata for waste implacement should be generally less than a few degrees. . . .

Factor 4.4.2. In summary, favored areas for waste repositories are those having no or few faults or joints which, if they are present, are locatable, so that they can be avoided or circumvented in the excavations for waste implacement.

Selection Factor 4.5.3. For all rocks that are potentially suitable for the implacement of radioactive wastes, it must be established that the transient and permanent rock deformations (displacements, strains, and stresses) induced in the rocks will not produce conditions leading to a breach of the integrity of a long-term containment.

Selection Factor 4.5.4. Preferably, rocks to be utilized for the disposal of high-level, heat-generating wastes should possess thermal properties that promote rapid dissipation of the radiodecay heat and whose stabilities are not adversely affected in the presence of elevated temperatures.

OFFICE OF WASTE ISOLATION

Criterion 11. The repository rock shall not have mechanical properties that will jeopardize the construction, operation, and physical integrity of the repository.

Criterion 12. The repository rock and its surroundings shall not be under a state of stress that could jeopardize the construction, operation, and physical integrity of the repository.

Criterion 14. The geological, geographical, and topographic setting of the repository shall be compatible with site development, including transportation, utilities, and disposal of excavated materials.

DEPARTMENT OF ENERGY

Section 5.1.1.2, Item 2. The repository site shall have geologic characteristics compatible with waste isolation.

DEPARTMENT OF ENERGY
NATIONAL WASTE TERMINAL STORAGE PROGRAM

3.5 TECTONIC ENVIRONMENT

THE SITE SHALL BE LOCATED SUCH THAT CREDIBLE TECTONIC PHENOMENA WILL NOT DEGRADE SYSTEM PERFORMANCE BELOW ACCEPTABLE LIMITS.

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCE

Section 3.2.1. The repository should lie within a structurally stable geologic block and not near a tectonic boundary.

Section 3.2.2. Faults along which rupture could occur must be avoided.

Section 3.2.3. Areas with abnormally high geothermal gradients or with evidence of relatively recent volcanic activity are possible candidates for future volcanic events and should be avoided.

NUCLEAR REGULATORY COMMISSION

60.122(a)(2). The Department shall investigate and evaluate the natural conditions . . . that can reasonably be expected to affect the design, construction, operation, and decommissioning of the geologic repository operations area. The natural conditions include geologic, tectonic, hydrologic, and climatic processes. The Department shall evaluate the stability of the geologic repository and the isolation of radionuclides after decommissioning.

(i) The Department shall conduct investigations on the order of 100 kilometers horizontal radius from the geologic repository operations area.

(ii) The Department shall emphasize those natural conditions active anytime since the start of the Quaternary Period in their investigations.

(iii) The Department shall emphasize the first 10,000 years following decommissioning in their prediction of changes in natural conditions and the performance of the geologic repository.

60.122(a)(3). The Department shall conduct investigations that adequately characterize and provide representative and bounding values for those . . . natural events and conditions that may affect any of the following: (i) The design, construction, operation, and decommissioning of the geologic repository operations area. (ii) Demonstration of the stability of the geologic repository after decommissioning. (iii) Demonstration of the isolation of radionuclides from the accessible environment after decommissioning.

60.122(a)(4). The Department shall evaluate reasonably likely future variations in the site characteristics which may result from natural processes . . .

60.122(b). The Department shall demonstrate whether any of the (following) potentially adverse . . . natural conditions are present. The presence of any of the (following) potentially adverse . . . natural conditions will give rise to a presumption that the geologic repository will not meet the performance objectives . . . (2):

(i) There is evidence of extreme bedrock incision since the start of the Quaternary Period . . .

(iii) There is evidence of processes in the candidate area which could result in structural deformation in the volume of rock such as uplift, diapirism, subsidence, folding, faulting, or fracture zones.

(iv) The geologic repository operations area lies within the near field of a fault that has been active since the start of the Quaternary Period.

(v) There is an area characterized by higher seismicity than that of the surrounding region or there is an area in which there are indications, based on correlations of earthquakes with tectonic processes and features, that seismicity may increase in the future.

(vi) There is evidence of intrusive igneous activity since the start of the Quaternary Period.

(vii) There is a high and anomalous geothermal gradient relative to the regional geothermal gradient.

INTERNATIONAL ATOMIC ENERGY AGENCY

Selection Factor 4.2. As all rocks are adversely affected by major crustal disturbances, areas of tectonic stability and low seismicity are favored for waste disposal facilities.

Selection Factor 4.4.2. In summary, favored areas for waste repositories are those having no or few faults or joints which, if they are present, are locatable, so that they can be avoided or circumvented in the excavations for waste implacement.

Selection Factor 4.4.3. Nevertheless, for some salt and argillaceous deposits that are thick, deeply buried and exhibit extreme surface relief, geological examinations must be made to ascertain that incipient diapirism is not at present taking place and that geological processes during the next hundred thousand years or so will not create conditions conducive to such movements.

OFFICE OF WASTE ISOLATION

Criterion 4. The rate and amount of predictable regional uplift and/or subsidence of bedrock shall not pose a threat to the physical integrity of the repository.

Criterion 5. Faults or other structural characteristics of the repository site shall not compromise the repository operations, engineering design, or the geologic containment.

Criterion 6. Expected igneous activities shall not compromise the geological containment.

Criterion 13. Predicted seismic activity in the region of the repository shall be low enough so as not to pose a threat to safe operation or to the physical integrity of the repository.

DEPARTMENT OF ENERGY

Section 5.1.1.2, Item 5. The repository site shall be located in a geologic setting that is known to have been stable or free from major disturbances such as faulting, deformation and volcanic activity for long time periods.

DEPARTMENT OF ENERGY
NATIONAL WASTE TERMINAL STORAGE PROGRAM

3.6 HUMAN INTRUSION

THE SITE SHALL BE LOCATED TO REDUCE THE LIKELIHOOD THAT PAST OR FUTURE HUMAN ACTIVITIES WOULD CAUSE UNACCEPTABLE IMPACTS ON SYSTEM PERFORMANCE.

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCE

Section 4.1. No area with a present or past record of resource extraction, other than for bulk materials won by surface quarrying, should be considered as a geological site for radioactive wastes.

Section 4.2. No area should be considered as a potential for a repository unless sufficient geological information is at hand to provide a basis for a reasonable analysis of resource potential.

NUCLEAR REGULATORY COMMISSION

60.121(a). The Department shall locate the geologic repository operations area in and on lands that are either acquired lands under the jurisdiction and control of the Department or lands permanently withdrawn and reserved for its use. The Department shall hold such lands free and clear of all significant encumbrances (including rights arising under the general mining laws, easements for right-of-way, and all other rights arising under lease, rights of entry, deed, patent, mortgage, appropriation, prescription, or otherwise).

60.121(b). The Department shall establish a "Control Zone" surrounding the geologic repository operations area. The Department shall exercise such jurisdiction and control with respect to surface and subsurface estates in the control zone as may be necessary to prevent adverse human actions that could significantly reduce the ability of the natural or engineered barriers to isolate radioactive materials from the accessible environment. The Department's rights may take the form of appropriate possessory interest, servitudes, or withdrawals from location or patent under the general mining laws.

60.121(c). The Department shall identify the geologic repository operations area by the most permanent markers and records practicable. The markers shall be inscribed in several languages as well as English. In addition, the Department shall deposit records of the location of the geologic repository operations area and the nature and hazard of the waste in the major archives of the world. For the purpose of demonstrating compliance with §60.111 (Performance Objectives), the Department shall assume that other institutional controls will not persist for more than one hundred years.

60.122(a)(2). The Department shall investigate and evaluate the . . . human activities that can reasonably be expected to affect the design, construction, operation, and decommissioning of the geologic repository operations area . . . (i) The Department shall conduct investigations on the order of 100 kilometers horizontal radius from the geologic repository operations area . . .

60.122(a)(3). The Department shall conduct investigations that adequately characterize and provide representative and bounding values for those human activities . . . that may affect any of the following: (i) The design, construction, operation, and decommissioning of the geologic repository operations area. (ii) Demonstration of the stability of the geologic repository after decommissioning. (iii) Demonstration of the isolation of radionuclides from the accessible environment after decommissioning.

60.122(a)(4). The Department shall evaluate reasonably likely future variations in the site characteristics which may result from . . . human activities (or) construction of the repository . . .

60.122(a)(8). The Department shall perform a resource assessment for the region within 100 km of the site using available information. The Department shall include estimates of both known and undiscovered deposits of all resources that (1) have been or are being exploited or (2) have not been exploited but are exploitable under present technology and market conditions. The Department shall estimate undiscovered deposits by reasonable inference based on geologic and geophysical information. The Department shall estimate both gross and net value of resource deposits. The estimate of net value shall take into account development, extraction and marketing costs.

60.122(b). The Department shall demonstrate whether any of the (following) potentially adverse human activities . . . are present. . . . The presence of any of the (following) potentially adverse human activities . . . will give rise to a presumption that the geologic repository will not meet the performance objectives . . . (b)(1):

(i) There is or has been conventional or *in situ* subsurface mining for resources.

(ii) Except holes drilled for investigations of the geologic repository, there is or has been drilling for whatever purpose to depths below the lower limit of the accessible environment.

(iii) There are resources which are economically exploitable using existing technology under present market conditions.

(iv) Based on a resource assessment, there are resources that have either higher gross or net value than the average for other areas of similar size in the region in which the geologic repository is located. . . .

(vii) There is indication that present or reasonably anticipatable human activities can significantly affect the hydrogeologic framework. Human activities include groundwater withdrawals, extensive irrigation, subsurface injection of fluids, underground pumped storage facilities or underground military activities.

INTERNATIONAL ATOMIC ENERGY AGENCY

Selection Factor 4.8.2. A careful survey must be made throughout every area or site to determine whether or not the host rock or rocks in actual or potential hydrologic continuity would contain pre-existing boreholes, mine shafts, solution cavities or other man-made excavations.

Selection Factor 4.9.1. The geological formation under consideration or the overlying or underlying formations may contain useful minerals or other natural resources. The reponsible governing authority should weigh the present or potential need for extracting materials against the need for the waste repository and the availability of other formations for waste disposal. . . . Items to be considered in these evaluations are the compatibility of the operations, impact on the repository horizon resulting from extraction operations and the possibility of contaminating the resource by the repository contents.

Selection Factor 4.9.4. Once a site is selected as a repository for radioactive waste, it should be insured that its control is transferred to appropriate national government authorities.

Selection Factor 4.9.5. Appropriate records should be reviewed to ascertain all existing rights, e.g., mineral rights or rights of way or easements above the proposed repository area. Each of these rights would have to be evaluated to determine if exercise of the right would be incompatible with, or adversely affect, the safety of the disposal operations.

OFFICE OF WASTE ISOLATION

Criterion 15. Areas potentially attractive for development of mineral resources shall be avoided as much as possible.

Criterion 16. Areas potentially attractive for development of surface or subsurface water resources shall be avoided as much as possible.

DEPARTMENT OF ENERGY

Section 5.1.1.2, Item 6. The repository site shall be located in an area that does not contain desirable or needed mineral resources, or to the extent presently determinable, resources that may become valuable in the future.

DEPARTMENT OF ENERGY
NATIONAL WASTE TERMINAL STORAGE PROGRAM

3.7 SURFACE CHARACTERISTICS

THE SITE AND ITS SURROUNDING AREA SHALL BE SUCH THAT SURFACE CHARACTERISTICS OR CONDITIONS CAN BE ACCOMMODATED BY ENGINEERING MEASURES AND CAN BE SHOWN TO HAVE NO UNACCEPTABLE IMPACTS ON REPOSITORY OPERATION AND SYSTEM PERFORMANCE.

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCE

Section 4.3. No area adjacent to an actual or potential major dam site should be considered as a potential site for a repository.

NUCLEAR REGULATORY COMMISSION

60.122(b). The Department shall demonstrate whether any of the potentially adverse . . . natural conditions are present. . . . The presence of any of the (following) potentially adverse . . . natural conditions will give rise to a presumption that the geologic repository will not meet the performance objectives. . . . (b)(1)

(v) There is reasonable potential that failure of human-made impoundments could cause flooding of the geologic repository operations area prior to decommissioning.

(vi) There is reasonable potential based on existing geologic and hydrologic conditions and methods of construction for construction of large-scale impoundments which may affect the regional ground-water flow system.

60.122(b)(3). (ii) The geologic repository operations area is located where there would be long term and short term adverse impacts associated with the occupancy and modification of floodplains. (Executive Order 11988). (iii) There is reasonable potential for natural phenomena such as landslides, subsidence, or volcanic activity to create large-scale impoundments that may affect the regional ground-water flow system. . . .

60.132(a)(3)(i). The Department shall . . . locate structures, systems, and components important to safety to accommodate the effects of and to be compatible with site characteristics and environmental conditions associated with normal operation, maintenance and testing at any time prior to decommissioning.

60.132(a)(3)(ii). The Department shall . . . locate structures, systems and components important to safety to withstand the most severe of natural phenomena that are likely to occur at the site including seismic, meteorologic and hydrologic events without loss of capability to perform their safety function.

60.132(a)(4). The Department shall . . . locate structures, systems and components important to safety to resist dynamic effects that could result from equipment failure, missile impacts, the dropping of crane loads in transit, and similar events and conditions.

60.132(a)(5)(i). The Department shall . . . locate structures, systems, and components important to safety to minimize the potential for impairment of their ability to perform their safety functions during fires or explosions. . . .

60.132(a)(7)(i). The Department shall . . . locate structures, systems, and components important to safety to assure safe storage of radioactive waste, prompt termination of operations and evacuation of personnel during an emergency.

INTERNATIONAL ATOMIC ENERGY AGENCY

Selection Factor 4.1. In general, low relief and gently sloping terrain should characterize the topography of waste repository sites.

Selection Factor 4.6.1. . . . However, it must be ascertained that the [surface] waters would not interfere with the short-term operation of a disposal facility or jeopardize the long-term geologic containment of any implaced waste. . . In any event, it is clear that the effects of the future behavior of surface streams must be predicted to insure that geological containment can be maintained for the required period of time.

OFFICE OF WASTE ISOLATION

Criterion 14. The geological, geographical, and topographic setting of the repositories shall be compatible with site development, including transportation, utilities, and disposal of excavated materials.

DEPARTMENT OF ENERGY

Section 5.1.1.2, Item 4. The repository site shall be located so that the surficial hydrologic system, both during anticipated climatic cycles and during extreme natural phenomena, shall not cause unacceptable adverse impact on repository performance.

DEPARTMENT OF ENERGY
NATIONAL WASTE TERMINAL STORAGE PROGRAM

3.8 DEMOGRAPHY

THE SITE SHALL BE LOCATED TO MINIMIZE THE POTENTIAL RISK TO AND POTENTIAL CONFLICT WITH THE POPULATION.

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCE

Not Specifically Addressed

NUCLEAR REGULATORY COMMISSION

60.122(c)(2). The Department shall select the site so that to the extent practicable the volume of rock—. . . (iv) possesses a combination of meteorological characteristics (especially prevailing wind flow direction) and population distribution such as to assure that a radiological exposure of the population, which is within the limits of (10CFR20) . . . (v) possesses a low population density . . .

INTERNATIONAL ATOMIC ENERGY AGENCY

Selection Factor 4.9.3. As noted later, it would be advantageous to have normal community activities available in the vicinity, but the presence of a large community, industrial activities, etc., over the repository may introduce complicating factors.

OFFICE OF WASTE ISOLATION

Not Specifically Addressed

DEPARTMENT OF ENERGY

Not Specifically Addressed

DEPARTMENT OF ENERGY
NATIONAL WASTE TERMINAL STORAGE PROGRAM

3.9 ENVIRONMENTAL PROTECTION

THE SITE SHALL BE LOCATED WITH DUE CONSIDERATION TO: POTENTIAL ENVIRONMENTAL IMPACTS; AIR, WATER, AND LAND USE; AND AMBIENT ENVIRONMENTAL CONDITIONS.

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCE

Not Specifically Addressed

NUCLEAR REGULATORY COMMISSION

Not Specifically Addressed

INTERNATIONAL ATOMIC ENERGY AGENCY

Selection Factor 4.6.1. The mere presence of surface streams, lakes, ponds, etc., above otherwise suitable repository sites, would not necessarily rule out their use. However, it must be ascertained that these waters would not interfere with the short-term operation of a disposal facility or jeopardize the long-term geological containment of any implaced wastes.

Selection Factor 4.8.6. Nevertheless, the ecological effects, which might occur in connection with the construction, operation, and existence of such a repository, have to be carefully investigated and evaluated, such as those connected with disposal of the spoil. . .

Selection Factor 4.9.2. Although the remaining land surface above the entire repository area need not be reserved from other uses, some restrictions may have to be imposed, depending upon the type of formation being considered for the repository as well as the types of surrounding formations. Such restrictions could include any activities which would be expected to adversely affect the safety of the repositories such as drilling, blasting, pounding of water, etc. . . . Possible restrictions should be considered thoroughly before making a final decision of a selection of a possible disposal site, taking into account the best national and local projections on land use, including the needs for industrial, urban, agricultural, and recreational activities.

OFFICE OF WASTE ISOLATION

Criterion 16. Areas potentially attractive for development of surface or subsurface water resources shall be avoided as much as possible.

Criterion 17. Anticipated conflicts involving land use will be minimized.

DEPARTMENT OF ENERGY

Not Specifically Addressed

DEPARTMENT OF ENERGY
NATIONAL WASTE TERMINAL STORAGE PROGRAM

3.10 SOCIOECONOMIC IMPACTS

THE SITE SHALL BE LOCATED WITH DUE CONSIDERATION TO SOCIAL AND ECONOMIC IMPACTS ON COMMUNITIES AND REGIONS AFFECTED BY THE REPOSITORY.

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCE

Not Specifically Addressed

NUCLEAR REGULATORY COMMISSION

Not Specifically Addressed

INTERNATIONAL ATOMIC ENERGY AGENCY

Selection Factor 4.8.5. Waste transportation is an important part of the total waste management system. . . . For the selection of a waste repository site, however, it is important either that there already exist proper systems of transportation like railways or highways or that they can be constructed.

Selection Factor 4.9.6. Accessibility to a site for movements of personnel and materials during construction as well as the movement of operating personnel and radioactive waste during the waste implacement phase is of importance.

OFFICE OF WASTE ISOLATION

Not Specifically Addressed

DEPARTMENT OF ENERGY

Not Specifically Addressed

APPENDIX B

RESPONSE TO COMMENTS

ON

NWTS CRITERIA FOR THE GEOLOGIC DISPOSAL OF NUCLEAR WASTES: SITE QUALIFICATION CRITERIA JANUARY 1980 DRAFT

APPENDIX B

RESPONSE TO COMMENTS

This appendix presents a compilation of comments made to the Department of Energy on the first draft of this document. The first draft was issued to over 800 people and comments were solicited by a letter (bound into that document) signed by Sheldon Meyers, Acting Deputy Assistant Secretary for Nuclear Waste Management, U.S. Department of Energy.

Comments were received from twenty-four parties outside the Department as listed on Table B-1. Comments made by these parties were not necessarily the views of their associated organizations. The number of members in each group that commented is:

Universities — 5

State governments — 5

Federal Government Agencies or Departments
External to DOE — 4

Consultants/Industry — 3

National Laboratories — 3

Utilities — 2

Interest Groups/Citizens — 2.

This distribution appears to represent a wide cross section, though small number, of parties interested in the nuclear waste disposal problem.

The major points raised by those comments are discussed below with a description of changes, if any, that were made to address the comments. The discussion of general comments is followed by a compilation of specific comments by criterion and how they were addressed.

General

Comment

Three reviewers indicated that the project time period over which these criteria apply was not specified and that it would be useful to do so.

Response

The performance objectives for a geologic isolation system have been incorporated by reference to the Department of Energy Statement of Position, April 15, 1980, which specifies the time period over which disposal system performance is needed. The background section of this document describes the time periods over which these criteria apply.

TABLE B-1. LIST OF REVIEWERS OF ONWI-33(2)
January 1980 Draft

1-Universities

E. E. Angino
The University of Kansas

G. R. Choppin
The Florida State University

N.G.W. Cook
University of California, Berkeley

C. J. Vitaliano
Indiana University

H. S. Yoder, Jr.
Carnegie Institution of Washington

2-State/Local Government

J. F. Davis
State of California

L. A. Hester
State of Florida

D. C. Le Van
Commonwealth of Virginia

R. H. Neill
State of New Mexico

A. N. Turcan, Jr.
State of Louisiana

3-Government Agencies/Federal Departments External to DOE

R. J. Augustine,
U.S. Environmental
Protection Agency

M. J. Bell
U.S. Nuclear Regulatory Commission

G. D. DeBuchananne
United States Geological Survey

W. Johnson
United States Department of Interior,
Bureau of Mines

4-Consultants/Industry

F. J. Keneshea
Nuclear Services Corporation

R. A. Langley, Jr.
Bechtel National, Inc.

J. A. Lieberman
Nuclear Safety Associates, Inc.

5-National Laboratories

A. L. Lotts
Oak Ridge National Laboratory

R. J. Vidal
Los Alamos Scientific Laboratory

R. D. Widrig
Battelle Pacific Northwest
Laboratories

6-Utilities

L. Bernath
San Diego Gas & Electric Company

V. S. Boyer
Philadelphia Electric Company

7-Interest Groups/Citizens

M. K. Hubbert, former member
(1955-1965) National Academy of
Sciences—National Research
Council Committee on Geologic
Aspects of Radioactive Waste
Disposal

G. Yuan and T. R. Lash
Natural Resources Defense
Council, Inc.

Comment

The terms used in the document need clearer or more prominent definition.

Response

Definitions of terms that are key to understanding these criteria have been given prominence in the text or appear in the glossary.

Comment

". . . the subject of climatic variation during the prescribed geologic time for which the geologic barriers of the site must isolate the waste from the surface environment is not dealt with. . ."

Response

On the contrary, old Section 2.1.1 stated "The minimum depth of the repository horizon shall be such that credible **natural processes** acting at the surface will not unacceptably affect repository performance." Further, Section 2.4 stated, "The repository site shall be located so that the surficial hydrological system, both during anticipated **climatic cycles** and during extreme natural phenomena will not cause unacceptable adverse impact on repository performance,". (emphasis added) The words "under present or **future** climatological conditions" also appeared in Section 2.4.1.

Comment

One reviewer stated that criteria are actually observations and do not reflect the analysis which must take place in interrelating these criteria to reach a conclusion regarding the effectiveness of the geologic barriers in limiting the access of nuclear waste to the surface environment. Another reviewer suggested that the general criteria statements "improperly shift the basis for site selection from (favorable or unfavorable) 'physical properties' to the determination of 'acceptable risk'".

Response

These two comments, though appearing to be diametrically opposed, represent two approaches to siting and to evaluating site suitability that are not mutually exclusive. In fact, elements of both approaches are used by DOE in its siting efforts. During the geographic screening process, regions containing unfavorable characteristics are considered less favorable.

The suitability of a site cannot, however, be determined based on one or two characteristics of a site, such as tectonics or geochemistry. Rather, it is each characteristic's contribution to, or detraction from, the overall capability of the site or disposal system to

isolate waste in accordance with the criteria that must be evaluated. Therefore, whereas a site might be considered less favorable based on an evaluation of tectonics alone, other characteristics such as land use or geohydrology may be so favorable as to counterbalance a low "degree of compliance" of the site with the tectonic environment criterion. No set of criteria can list all of the combinations of site conditions or processes that are adverse or favorable to repository performance.

The siting criteria, therefore, when properly applied, ensure that all conditions and processes that enhance or diminish the containment and isolation capabilities of sites are addressed in the site evaluation.

The DOE in its cross statement (DOE CS at II-32) in the matter of the Waste Confidence Rulemaking states that . . . "The desirability or undesirability of a given site feature depends on how the feature affects the system performance. It's the overall performance of a site-specific system that is important, not the generically presumed attributes of particular features. Prematurely established (quantitative) criteria could eliminate potentially superior sites on the basis of perceived flaws that may in actuality be important to the effectiveness of a site-specific disposal system."

The siting process is a complex set of choices and tradeoffs that can be made in any number of ways, but the eventual proof of the suitability of a selected site will be based on the assessment of its (acceptable) performance.

Comment

Site qualification criteria should follow, not precede, performance criteria.

Response

The system performance criteria development effort has been paralleling development of this criteria document. The system performance criteria which will be implemented, in part, by application of these criteria have been added as Section 2.3.

Comment

One reviewer suggested adding criteria regarding multiple barriers to radionuclide release and the detectability, consequences, and correctability of failures (including sabotage) of such barriers. The same reviewer suggested that "sites should minimize the distance that wastes must be transported' . . . and "should be chosen in recognition of the ability to quickly evacuate the surrounding area."

Response

The second two concerns are addressed by (new) 3.8, Demography. Evaluations made to date (WIPP SAR) postulate no known normal or accidental condition that will release radioactivity beyond the exclusion zone that does not meet the benchmark dose guidelines set

for other nuclear facilities (10 CFR 20, 10 CFR 100). The need for plans to evacuate an area that should not be exposed to a radiation hazard seems moot. Nonetheless an area of low population density is being sought for reasons similar to those for other facilities (lower population risk and easier evacuation potential).

Application of the (new) criterion 3.8.2 incorporates the concept of minimizing waste transportation distances where it can be shown that travel distance reduction will also result in a reasonably achievable lowering of risk of the nuclear waste management system.

Regarding the first concern, the DOE performance objectives for any high-level waste isolation system form a set of requirements suitable sites must also meet and have been incorporated by reference. Consideration of "Multiple barriers" is made in the DOE Statement of Position (DOE, April 1980) objective 5 beginning on p. II-16 and including the words "Conservative measures might include . . . multiple containment and isolation barriers with sufficient independence and residual effectiveness to assure compliance with appropriate radiation standards over the range of credible failures."

Comment

The resolution of these (site performance) guidelines into precise definitions, quantification of criteria where possible, and effective coordination of multidisciplinary efforts in both a general and site-specific sense should reflect the highest possible degree of interagency communication and mutual agreement.

Response

The DOE is committed to the processes of interagency coordination, consultation and concurrence with state and local governments, and independent peer review (DOE Cross Statement p II-6, II-11, II-22 and II-32).

Comment

Once the detailed siting criteria are developed by the appropriate agency (NRC, EPA, etc.), will DOE return to the regional level analysis or will only the sites identified in the preliminary analysis be evaluated?

Response

DOE is keeping abreast of the technical criteria being developed by NRC and EPA regarding the siting process and the future evaluation of site suitability. The DOE criteria are broadly stated to encompass the detailed criteria being developed by these agencies. The question to be answered is whether or not the DOE sites meet the criteria that are promulgated. This question will be answered only for the candidate sites identified by DOE when the regulatory criteria become effective and without returning to a previous step in the siting process.

The DOE envisions only a limited number of circumstances that would necessitate returning to some previous stage of the siting process:

(a) No site could meet the NRC criteria

(b) The NRC criteria considered substantive factors regarding the containment, isolation, safety capabilities, and environmental and socioeconomical acceptability of sites that were not considered by DOE.

Both of these situations seem unlikely because DOE is keeping abreast of the criteria development efforts of NRC and EPA and will make appropriate "course corrections" during the siting process.

Comment

Describe in the introductory material why these criteria are necessarily broad.

Response

Comment incorporated. See Section 2.2—Application of the Criteria.

Comment

The report would be more useful with at least a brief mention of the waste characteristics and principal geologic formations of interest.

Response

The DOE Final Environmental Impact Statement for Management of Commercially Generated Radioactive Waste (1980) contains discussion of possible waste forms and the formations of interest. It is believed that this information is amply covered in this and other DOE documents.

Comment

What is the reason for including excerpts (in Appendix A) of criteria issued by other agencies?

Response

Preparation of the DOE criteria involved an evaluation of other criteria development efforts to ensure previous concerns regarding isolation of high-level waste in geologic media were considered along with current thinking. These comparisons are included in Appendix A, Table A-1 to illustrate the range, yet similarity, of concerns expressed by independent and knowledgeable groups.

Comment

One reviewer recommended that criteria be added to select a site such that waste could be retrieved from it during the time "the radiological hazard persists" and to select a site that is amenable "to the monitoring of leakage or any indirect parameter that may result in leakage".

Response

The DOE plans to locate and develop sites that enable retrieval of wastes at any time prior to repository closure. Criterion 3.4 (new) now states that, "The site shall have geologic characteristics compatible with waste containment, isolation and **retrieval**". The radiological hazard will decrease in time with the decay of radioactive material and is further reduced by the absence of direct paths for even small releases of wastes to move from sealed, deep repositories to the surface. Provision of ready access for retrieval would eliminate the barriers associated with repository backfilling and sealing and result in just the sort of direct paths for waste movement toward the surface which are not desirable. Also, open shafts and tunnels would ease inadvertent human intrusion and thus obligate future generations to the burden of continued diligent surveillance.

Any retrievability provision which eased inadvertent human intrusion would have the effect of extending the period of time the radiological hazard persists. After a few thousand to 10,000 years the hazard would be reduced to something comparable to a body of uranium ore. At that point, the hazard could be judged negligible if the repository were sealed and buried; but either the repository or a uranium ore body would constitute continued hazard in some measure if entry to it is made easy.

Regarding a "monitoring" criterion, sites will be selected such that the host-rock units can be shown to accommodate phenomena that may disrupt repository performance (new Section 3.4.2). A "monitoring" requirement is included to the extent that monitoring is needed to demonstrate system performance.

Comment

A number of reviewers questioned the criteria, because they were so general that they become vague and repetitious of the same ideas.

Response

The background section has been revised to explain that these criteria need to remain general. These criteria subsume the substantive concerns of most previous criteria sets. This set of broad statements provides a single set of requirements against which the variety of site environments to be investigated can be judged. All of the factors that are important to site performance will have to be identified and evaluated before these criteria can be met.

Comment

Several reviewers questioned how these general criteria could be applied. The vagueness of some of the statements made their usefulness doubtful.

Response

Specificity has been added to the document by incorporating into the criteria the idea that adverse conditions or features are avoided, other factors being equal, and favorable conditions are sought. The level of investigation and characteristics that allow differentiation between alternative geographic areas and sites will influence how the criteria are applied. For example, to establish a site repository depth, glaciation is considered. Glacial scour and sea level changes are evaluated for the different regions and may cause different repository depths to be selected for different regions.

Regions subject to scour are not necessarily avoided, if a few hundred feet of additional depth will compensate for the scour uncertainty, and the region area or site has other offsetting favorable characteristics. This approach is consistent with that proposed in the May 13, 1980, draft of the 10 CFR 60 technical siting criteria.

These criteria would be too restrictive, and thus less useful, if all characteristics shown or perceived to be unfavorable were avoided without some performance assessment. All faults, for example, are not categorically avoided. Rock underlying nearly every part of the country is faulted. Faults come in various sizes, and ages, and have been generated by different mechanisms; some are still active, and some are detrimental to repository performance. An assessment is made of potentially capable faults only at sites that are superior in other ways. If such a fault is too close to a potential site and may unacceptably affect site performance, the site is avoided. If all faults were categorically avoided, geologic disposal would not be a meaningful concept, because probably no areas would be fault-free.

Comment

Several reviewers do not believe Criterion 10.2 (old) can be implemented. Others asked to what level of government is the criterion applicable. Still others thought that it was not a technical criterion and should be deleted.

Response

Based on our review of these concerns, Criterion 10.2 (old) was deleted from the document.

Comment

One reviewer suggested reordering the criteria to place the most important considerations first and the least important last. Another suggested separating geochemistry from geohydrology to give it more weight via more visibility.

Response

The general order reflected in the revised criteria is that of containment and isolation first, environment second, and institutional considerations third. Geochemistry and geohydrology

have been separated. Topography and surface hydrology have been combined into one new criterion, surface characteristics.

Comment

The criterion on Proximity to Population Centers drew varied comments:

- The criterion is of little value because potential risk is very low.
- Transportation risk is important, but is confusing when discussed under "Proximity to Population Centers".
- This criterion has considerable history in the industry and should be amenable to more specific treatment.

Response

This criterion was revised to place risk in perspective and to address regulatory precedent. Demographic criteria for nuclear power reactors, though conservative, are not directly applicable to repository siting. Ionizing radiation constitutes the hazard of nuclear waste and simple passive shielding is known to absorb that radiation. In contrast to the harnessed power of nuclear reactors, nuclear waste has inherently no potential for sudden disruptive forces to breach the barriers between the waste material and man. Dissipation of the residual heat of nuclear wastes occurs through entirely passive conduction through the host rock; no coolants, machines, or human intervention are involved, as in nuclear power reactors. Thus, a different set of potential accidents must be considered for repositories than for nuclear power reactors.

Transportation risk receives emphasis under site and system considerations. Each site needs to be viewed as part of a system of repositories as well as needing to minimize transportation risks individually.

2.1 SITE GEOMETRY

(New 3.1 Site Geometry)

Comment

Several reviewers requested that the terms used in the criteria statements be defined.

Response

The glossary, Appendix C, has been expanded to include words or terms that reviewers thought should be defined. Some words are also defined in the revised introduction and background, Sections 1.0 and 2.0.

Comment

One reviewer stated, "It is important not to overlook the relevance of depth from the point of view of human intrusion; shallow drill holes are much more common, cheap, and easy to drill than are deep ones. There is a current, and historical, technological distinction between shallow and deep about 1 km below the surface".

Another reviewer thought the criterion should have given consideration to man-caused events, especially nuclear warfare. This reviewer questioned whether or not protection against meteorite impact was implied by this criterion.

Response

The concept of physically separating the waste from the biosphere and placing the repository deep enough to prevent credible human activities at the surface from unacceptably affecting repository performance has been added to Criterion 3.1 (new). The criterion words "In order to establish this depth . . . other phenomena must be evaluated" do imply that meteorite impacts and warfare be given consideration.

Comment

It should be acknowledged that the geometry will be partly a function of the repository dimensions, in which case it seems that some minimum dimensions can be stated.

Response

Minimum dimensions will depend not only on repository size, but also on buffer zone size and the heat and radiation output of the waste. It would be misleading to state a minimum dimension based on a functional requirement of only one part of the isolation system, repository size.

Comment

Why not combine 2.1.2 with 2.1.3?

Response

Done. See revised Section 3.1.2 (new).

Comment

If a buffer zone is necessary or desirable in addressing lateral extent of host-rock, it should be (desirable) for the factors of depth and thickness.

Response

The buffer zone consideration now covers thickness and lateral extent of the geologic system, Criterion 3.1.2 (new). The geologic system includes both the rock in which the waste is emplaced and surrounding formations that contribute to isolation. Because Criteria 3.1.1 and 3.1.2 must both be satisfied, the buffer zone consideration need not be stated in Criterion 3.1.2 (new).

Comment

One reviewer suggested adding a Criterion 2.1.4 that would state "Site geometry should consider climatic change as it affects the rate of erosion and ultimately the **depth** of the repository".

Response

More than site geometry may be affected by climatic changes. Therefore, several criteria (3.1.1, 3.2.2, 3.7.1, 3.7.2 new) are worded to require that consideration be given to the effects of climatic changes. Criterion 3.1.1 (new), for example, requires that the depth of the repository be selected such that "**natural processes** acting at the surface will not unacceptably affect system performance" (emphasis added). Climatic change is considered a "natural process". Criterion 3.2.2 requires that hydrological regimes be defined to show that probable future conditions have no undesirable impact on repository performance. Some range of climatic variation will need to be considered to meet this criterion. Climatic change is a cause of other phenomena, such as glaciation, stream cutting, sea level fluctuation, and attendant changes in aquifer permeability and flow gradients, all of which need to be considered to adequately address this criterion.

2.2 TECTONIC ENVIRONMENT

(New 3.5 Tectonic Environment)

Comment

An addition to Section 2.2 should be included to insure consideration of the geologically-old basement rock features. Such features occur mid-continent or in the eastern United States and are related to past global plate boundaries, which remain potentially active for millions of years with unpredictable near-term seismic disturbances.

Response

The revised criterion states that "the site shall be located so that its tectonic environment can be evaluated with a high degree of confidence to identify tectonic elements and their impact on system performance" Such a statement does not preclude consideration of "geologically-old basement rock features". Because such features are part of the tectonic environment, the analysis that provides the number used for the ground motion accompanying a maximum credible earthquake must consider the historic seismic record along with

all proven and hypothesized geologic structures. Tectonic structure or elements other than Quaternary ones will be evaluated in the performance assessment of candidate sites where proximity to such structures or elements makes it prudent to do so. The criteria statements do not exclude such considerations because proven and postulated structures, such as the old crustal plate boundaries, may be part of the "tectonic environment" to be characterized for a particular site.

Where undisturbed Quaternary rocks overlie basement structures, postulated or real, there has not been sufficient movement to disrupt the overlying rocks for one to two million years. Therefore, isolation is likely for the necessary period of performance.

Comment

What is a credible tectonic event?

Response

A tectonic event is defined in the glossary as "an event causing or resulting from deformation of the Earth's crust . . ." To be considered credible, the scientific evidence should offer reasonable grounds for believing such an event will occur.

The rule proposed by the U.S. Environmental Protection Agency (draft No. 16 of 40 CFR 191—"Environmental Standards and Federal Radiation Protection Guidance for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes", October 1981) suggests 10,000 years as the period over which this definition is operable in demonstrating repository site suitability. Therefore, the consequence of any event that "is credible" during this period should be evaluated.

Comment

One reviewer stated, . . . "The criteria merely address individual conditions. The tectonic environment . . . must be viewed in context of indicating long-term stability. In addition to the characteristics in the criteria, ambient stress and geothermal gradients should be included." Another reviewer stated, ". . . The (criteria) statement would be improved if a phrase could be included to the effect that credible tectonic events will be avoided where possible and accommodated where they ' . . . can be shown to cause no unacceptable reduction in repository performance.'"

Response

"Stable" tectonic environments will be sought in the search for sites, but will not be a singular basis for deferral of "committed land use" sites until the degree of stability needed for long-term performance is justified. "Stability" varies by degree and is subject to interpretation. These ideas, along with addressing geothermal gradients, have been added to Criteria 3.5 and 3.5.5, respectively. The time scale over which these criteria apply has been described in revised Section 2.0. Ambient stress is now considered in the context of Criterion 3.4. Both ambient

stresses and induced stress changes are important to repository construction, operation, and isolation.

Comment

Several reviewers expressed concern over the order of presentation of criteria or subcriteria. A reordering of the tectonic subcriteria was suggested, to list the statements in the order they would need to be considered, that was also linked to the importance of one relative to another. Quaternary faulting, for example, is avoided because accommodation of such faulting may be beyond the state of the art. The subcriteria that deal with phenomena of earthquake ground motion and uplift or subsidence can normally be accommodated within certain ranges.

Response

The subcriteria under Tectonic Environment have been reordered in accordance with the above concern.

2.3 SUBSURFACE HYDROLOGY AND GEOCHEMISTRY

(New 3.2 Geohydrology and 3.3 Geochemistry)

Comment

Grouping of subsurface hydrology and geochemistry dramatically deemphasizes the significance of each relative to the other. These criteria should be treated separately.

Response

"Subsurface Hydrology and Geochemistry" has been separated into "Geohydrology" and "Geochemistry" to aid clarification of both the significance and different nature of the factors of concern. See revised Criteria 3.2 and 3.3.

Comment

The hydrogeologic regime should also minimize the water access to the underground facility. This was not specified.

Response

Criterion 3.2 (new) now provides for "geohydrological regimes (that) will minimize contact between groundwater and wastes . . ."

Comment

Hydrogeologic stability (past and future) is not addressed and should be sought. The criteria should include consideration of the past, present, and future in the context of waste emplacement and repository/site interactions.

Response

While "tectonic stability" contains two words that have been defined and widely used by the geologic community, we are unable to say the same for "hydrogeologic stability".

The time element for consideration of factors that may affect repository performance have been made more visible in this and other criteria by words such as those in Criterion 3.2 (new), ". . . So that the present and probable future geohydrological regime . . ."

Comment

One reviewer suggested that an evaluation of the hydrological and geochemical regime should include assessment of the thermal and geomechanical effects of repository construction and waste storage in addition to the natural phenomena indicated in (old) 2.3.1. Another reviewer stated a criterion was needed to the effect that the ". . .hydrological and geochemical regimes shall be compatible with waste package materials . . ."

Response

The geohydrological and geochemical regime, as stated in revised Criteria 3.2 and 3.3, must be compatible with waste containment and, therefore, the materials to contain wastes identified by the waste package program task. Regarding inclusion of "thermal and geomechanical effects" in the criteria, revised Criterion 3.2 states, the "evaluation of geohydrologic regime shall include consideration of ". . . thermally-induced ground-water flow" to show that any changes induced in the geohydrologic regime will not unacceptably affect repository performance. Revised Criterion 3.3 states, "The evaluation of geochemical regime shall consider any factors that may adversely affect the radionuclide containment capabilities provided by waste package, repository, or geologic system".

Comment

Two reviewers expressed concern over the levels or amounts of radionuclides that may potentially escape from the repository. One suggested that, "the repository should be so designed as to prevent 'any' radionuclides from reaching the biosphere", while the other correctly stated that the use of the words "unacceptable amounts" would require a determination of what constitutes maximum acceptable levels.

Response

This question is addressed in the DOE Confidence Rulemaking Statement[B.1] and is repeated below. With regard to establishing a standard by which to measure the acceptability of releases, natural background radiation has been a common point of reference in nearly all radiological evaluations. For example, the Commission, in its environmental impact statements for reactor licensing, commonly compares doses from postulated routine releases to doses experienced by the same population due to natural background radiation. The relationship between natural background radiation and health effects has been the subject of extensive study. In one study[B.2], the Commission staff concluded that the information reviewed through the time of that study:

> . . . supports the 1972 BEIR[B.3] estimates that whatever health effects *may* be caused by natural background radiation, if they exist, they must represent a small part of the total health effects being observed in the real world.

Although some may protest receiving routine radiation exposures of a few millirems per year from fuel cycle facilities, radiation exposures on that order from other sources are routinely accepted without question. For example, there is no apparent societal discrimination with regard to radiological impacts in choosing geographic locations in which to live, in choosing common building materials for housing, or in choosing the activities in which to engage. The following are examples of routine radiation exposures:

(1) Background radiation variations due to geographic location differences range from approximately 100 to 250 mrem/year within presently populated areas in the United States.[B.4]

(2) Notwithstanding background radiation differences due to geographical locations in Item 1 above, background radiation exposure to persons living in wooden houses versus brick houses differs by as much as 150 mrem/year.[B.5]

(3) Background radiation due to a transcontinental flight in a modern jet airliner is approximately 4 mrem/flight.[B.6]

(4) Background radiation from typical domestic activities (e.g., watching TV) is approximately 1.6 mrem/year for an average U.S. citizen.[B.7]

Each of the above-noted activities involves a choice that directly affects an individual's exposure to radiation. The lack of societal discrimination on the basis of the resultant radiological exposure indicates society's implicit acceptance of or lack of interest in low radiological risks compared to the benefits perceived to be associated with these risks. Item 1 above shows the range of background radiation exposures in the United States to be large. An incremental exposure of a few millirem due to a low probability release from a waste disposal system would be small relative to the variations in background radiation and should be acceptable, since similar or larger variations incurred by human choice are apparently acceptable. The objective suggests that postulated repository-induced exposures should be nearly indistinguishable from background radiation with regard to magnitude of exposure. For the general population, an incremental exposure equal to a few percent of natural background radiation would appear reasonably low.

2.4 SURFACE HYDROLOGY
(New 3.7 Surface Characteristics)

Comment

Reviewers of Section 2.4 had the following comments:

- No mention is made of flooding due to failure of human-made impoundments.
- Hazards from surface hydrological systems may be avoided by judicious siting or accommodated if this would not unacceptably affect repository performance.
- Does this criterion apply to future changes in water supplies which could lead to decreased transport times and unacceptably high releases? The repository should be located sufficiently far from water supplies used by humans or involved in the human food chain so that credible changes in the size or location of that water supply will not increase radionuclide releases to unacceptable levels.

Response

The criterion of surface hydrology and each of the comments expressed above regarding old Criterion 2.4 are addressed in revised Criterion 3.7.

2.5 GEOLOGIC CHARACTERISTICS
(New 3.4 Geology)

Comment

Substantive concerns raised in the review of Criterion 2.5 included:

- The concept of "stratigraphic setting" implies that no consideration would be given to igneous or metamorphic rocks.
- Another criterion is needed to assume that the geologic characteristics are compatible with safe retrieval of the waste throughout the retrievability period.
- It is also very important to adequately define adverse conditions and favorable characteristics to add to the "weight of the technical evidence".
- The subsurface and surface hydrological regimes should not be so complex that they cannot be understood through proven modeling techniques.
- Criterion 2.5.3 should be expanded to cover safety of repository personnel during both development of disposal areas and all other underground activities related to repository operation and decommissioning.
- Rock mechanics aspects such as rockfalls, gas seepage, and underground flooding need to be avoided in site location only where the conditions are extreme and are beyond practical accommodation by design or construction procedures. They are more likely to be avoided because of their greater impact on time and cost of construction rather than just their impact on safety of personnel.

Response

Each of the comments above listed valid points that have been incorporated into the wording of the revised criterion, 3.4 Geologic Characteristics.

2.6 SURFACE TOPOGRAPHY
(New 3.7 Surface Characteristics)

Comment

The general concern raised was that surface topography dealt principally with transportation and had little to do with repository performance.

Response

The revisions of the site suitability criteria make more visible the concern for safe repository operation in addition to acceptable repository performance. Incoming waste cask shipments from several parts of the country will converge on the site area transportation routes. Other factors being equal, a flatter site will be considered more favorable than a site in steep terrain.

2.7 HUMAN INTRUSION
(New 3.6 Human Intrusion)

Comment

Several comments were reviewed regarding "resources" as an incentive for human intrusion.

- . . ."How can one anticipate what resources are likely, in the undefined future, to attract intrusion?"
- "There is a distinct possibility that spent fuel may come to be regarded as a resource worth mining at some future date, so that burial of spent fuel may prove to be an incentive for human intrusion."
- "Mining or subsurface activities for purposes other than resources should also be included."
- The criteria should be ". . . written in such a way as to permit a comparison of the relative attractiveness of the resource values versus beneficial features of the site. ." The criterion might be worded, "Unless there are compelling reasons otherwise, the site and nearby area shall not contain potentially significant and exploitable petroleum, mineral or ground-water resources whose credible attractiveness and utilization would lead to unacceptable releases of radionuclides to the biosphere".
- . . ."The resource potential of the surrounding area" should also be addressed.

Response

The last three bullets are addressed in revised Criterion 3.6. The logic for addressing the first two bullets has been addressed by the DOE *Statement of Position in the Matter of Waste Confidence Rulemaking*. "It is a basic premise" in the statement "that . . .this generation bears responsibility for any risks which arise from deliberate and informed acts which they choose to perform" (p. II-189, Reference B.1). This premise presumes that any society that knows spent fuel is buried in a particular spot and considers spent fuel a resource will be knowledgeable of the attendant risks of exhuming the repository contents.

Regarding what other "resources . . . in the undefined future" are likely to attract intrusion, the DOE position states, "at issue is the protection of the public health and safety from waste releases unintentionally initiated by future human activities". Resource development in an undefined future at the repository site can be considered such an activity if the developer has no knowledge of the repository. The complete prevention of such human-induced releases "is desirable, but probably not reasonable". Reasonable objectives would be to "(i) reduce the likelihood of human-induced releases, and (ii) mitigate the consequences of human-induced releases" (p. II-189, DOE). The position statement continues (p. II-191) that "although future societies may actively seek materials that are not now regarded as significant resources, the likelihood of their needing to recover resources from a repository site can be controlled . . . 'by careful siting and by incorporating measures'". The issue, then, is not necessarily what future "resources" are likely to attract intrusion, but finding sites with low "attractiveness" by today's values and, beyond that, building in protective measures "to communicate knowledge" of the existence of the repository.

Comment

Several reviewers suggested the criteria be expanded to consider resources such as ground water, thermal energy, and other exploitable features such as suitability for oil storage.

Response

The above resource factors are included in revised Criterion 3.6.

2.8 PROXIMITY TO POPULATION CENTERS

(New 3.8 Demography)

Comment

The criterion on proximity to population centers drew varied comments:

- The criterion is of little value because potential risk is very low.
- Transportation risk is important, but is confusing when discussed under "Proximity to Population Centers".
- This criterion has considerable history in the industry and should be amenable to more specific treatment.

Response

The revised criterion, 3.8 Demography, is more representative of "history in the industry". Numbers, such as 25,000 persons to define a population center or formulas for calculation of numbers such as those used to compute the low population zone (LPZ) for nuclear power reactors (Regulatory Guide 4.2), have not been added, however. Direct application of specific numbers used in reactor site evaluations might be conservative, but they are more restrictive than they need to be when applied to repositories. The numbers used for reactor site suitability evaluations may be used as benchmarks for comparative repository site studies, but have not been adopted as the standards against which repository site suitability will be judged.

Even though the potential risk from the repository may be shown to be low, the risk will be reduced by proper siting and design to below benchmark or acceptability levels to the extent that is reasonably achievable.

"Minimizing transportation risk" is both a site and a waste management system requirement and will be considered in the process of finding suitable sites, in the site suitability determination, and in optimization studies of the system of repositories and transportation routes to minimize overall risk. The general and system performance criteria take into account the "transportation risk" factor.

2.9 ENVIRONMENT

(New 3.9 Environmental Protection)

Comment

Three types of comments were received on this criterion.

- "Considering mitigation of land-use conflicts . . . is particularly worthwhile in helping to assure that no potentially acceptable site would be excluded prematurely."
- Safety and environmental factors are confused in the criterion statements. A new category "Surface Characteristics" should be added to include Surface Hydrology, Surface Topography, and Environmental Consideration that might affect repository safety.
- Consideration of local and state environmental requirements should also be met and added to the criteria.

Response

The criterion has been expanded to include consideration of local and state environmental legislation and revised to clean up the confusion between "environment" and "safety". The criterion has been retitled so there is no mistake that the intention is to protect the environment both in the siting process and during site development. Environmental factors that potentially affect repository safety have been deleted from this criterion and inserted into others where most appropriate.

2.10 SOCIAL, POLITICAL AND ECONOMIC
(New 3.10 Socioeconomic Impacts)

Comment

Several reviewers do not believe Criterion 2.10.2 can be implemented. Others asked what level of government is responsible for implementing the criterion. Still others thought that it was not a technical criterion and should be deleted.

Response

Based on a review of these concerns, Criterion 2.10.2 has been deleted from the document.

Comment

"The repository site (should) be selected on the basis of lowest cost, considering both capital and operating costs, so long as the site meets all other siting criteria."

Response

The criteria in this document encompass only those factors necessary to determine site suitability. In this context "suitability" is used to mean "adapted for use" as a repository site based on scientific and technical considerations. A site shown to be suitable will be reserved for possible selection by DOE after several technically suitable sites are found. Factors such as cost, cost/benefit, institutional arrangements, and societal pressures will influence which of the technically suitable sites are "acceptable" for development, and thus will influence site selection. The possible effects of the other factors on site selection are being evaluated and will be described in future documents.

Comment

A number of issues were left out of the discussion under this criterion, e.g., effects on schools, utilities, roads, city services, emergency services, and taxes.

Response

The revised criterion, 3.10 Socioeconomic Impacts, addresses these concerns, although all such factors may not be listed.

REFERENCES

B.1 U.S. Department of Energy, *Statement of Position of the United States Department of Energy in the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste*, DOE/NE-0007, April 15, 1980.

B.2 U.S. Nuclear Regulatory Commission Response to the "Jeannine Honicker Petition for Emergency and Remedial Action: An Overview Regarding Radiation Exposure as Related to the Nuclear Fuel Cycle", 1978.

B.3 Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR) of the National Academy of Sciences (NAS-BEIR) Report, 1972.

B.4 National Academy of Sciences, *Forum on Radioactive Waste Management*, Washington, D.C., November 1979.

B.5 Eisenbud, M., *Environmental Radioactivity*, p. 197, Academic Press, New York, NY, 1973.

B.6 U.S. Environmental Protection Agency, *Estimates of Ionizing Radiation Doses in the United States*, ORP/CSD 72-1, pp. 7-15, 1972.

APPENDIX C
GLOSSARY

APPENDIX C
GLOSSARY

Area	An area of hundreds of square miles.
Barrier	Feature of a waste disposal system that acts to contain or isolate radioactive waste.
Basalt	A dark- to medium-dark-colored mafic (iron-magnesium rich) igneous rock composed chiefly of feldspar (Ca-plagioclase) and pyroxene in a glassy or fine-grained groundmass.
Biosphere	The zone of the Earth which contains living organisms.
Buffer zone	A portion of the site that surrounds the repository facility and is composed of essentially undisturbed geologic and surficial environment.
Closed hydrologic basin	A ground-water basin from which no water exits except by evapo-transpiration.
Component	A part of the subsystem of interest.
Construction	Activities required to build the repository and ancilliary facilities.
Containment	Confining the radioactive wastes within prescribed boundaries, e.g., within a waste package.
Criterion	A standard rule or test by which something can be judged.
Decommissioning	Activities associated with backfilling, shaft sealing, and the end of surface-facility use (including demolition, dismantling, etc.).
Denudation	The sum of the natural processes by which the Earth's surface is progressively worn away and, thereby, lowered.
Disposal	The permanent placement of radioactive waste, with no intent to retrieve.
Dissolution	The process by which fluids take solids into solution.
Engineered barrier	An addition to the geological environment which has been designed, fabricated, and emplaced to minimize or preclude radionuclide transport.

Erosion	The general natural process by which materials at the surface of the Earth are loosened, worn down, and transported from their original locations.
Factor	A characteristic that is evaluated to determine whether a criterion is fulfilled.
Fault	A fracture in the Earth's crust along which there has been displacement of the sides relative to one another parallel to the fracture.
Functional criterion	A criterion establishing the capabilities required of a system or subsystem.
Geochemical	Of or pertaining to geochemistry (the chemical characteristics of materials which constitute the Earth).
Geologic environment	That volume of the Earth's crust which is affected by repository construction, operation, and decommissioning and which may be a potential transport path to the biosphere.
Geologic medium	Natural Earth materials of any kind (shale, alluvium, salt, etc.).
Geologic system	The host rock(s) or host rock units and surrounding rocks that provide radionuclide containment and isolation.
Granite	An intrusive igneous rock consisting essentially of feldspar and quartz.
Ground motion	Vibration of the Earth's crust caused by earthquakes. Ground motion has both horizontal and vertical components. Also called vibratory ground motion and measured as a decimal fraction of the acceleration due to gravity (e.g., .12g).
Ground water	Subsurface water existing in the zone of saturation.
Ground-water path length	The distance from a point where material is introduced into ground water to the point where the ground water discharges.
Ground-water recharge rate	The rate at which water is absorbed and added to the zone of saturation.
Ground-water residence time	The time that ground water remains in an aquifer or aquifer system.

Ground-water travel time	The time required for ground water to flow along a path length.
High-level radioactive waste (HLW)	The liquid wastes resulting from the operation of the first-cycle extraction system and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel. Also, solids into which such wastes have been converted.
Historical seismicity	Earthquake activity that occurred during man's recorded history, including those reported before seismographs existed (pre-instrumental) and those recorded by seismographs (instrumental).
Host rock	Rock within which radioactive waste is emplaced for disposal.
Hydrological regime	The distribution, characteristics, and interrelationships of the aqueous components of the geologic environment.
Instrumental seismicity	Earthquakes recorded on a seismograph (a unit specially designed to detect and record earthquakes).
Isolation	Segregation of wastes from the accessible environment (biosphere) to the extent required to meet applicable radiological standards.
Maximum credible earthquake	The highest magnitude earthquake that, considering the known earthquake history and the tectonic setting of a place, could be expected to occur during the operation of the repository.
Mined geologic disposal system	A waste management system in which radioactive waste is emplaced in rooms, excavated deep in a stable geologic formation.
Natural barrier	The physical, mechanical, chemical, and hydrological characteristics of the geological environment that, individually and collectively, act to minimize or preclude radionuclide transport.
Operation	Activities associated with waste receiving, handling, emplacement, and storage prior to backfilling and sealing.
Performance criterion	A criterion establishing qualitative operational, safety, or environmental limits.
Pre-instrumental seismicity	Earthquakes which occurred before seismographs were available, but that were felt and reported by people.

Quaternary faults	Faults that have formed or experienced movement during the Quaternary period.
Quaternary igenous activity	Emplacement (intrusion) or expulsion (extrusion) of molten rock material into or onto the Earth's crust during the Quaternary period.
Quaternary period	A geologic time period covering the past 1.75 million years.
Radionuclide	A radioactive atomic species.
Radionuclide retardation factor	A component of the hydrological or geochemical regime that slows the migration or transport of a radionuclide by sorption or other processes.
Reasonably achievable (to the extent)	That which is shown to be reasonable considering the costs and benefits of potential mitigative measures or reasonable courses of action in accordance with requirements of the National Environmental Policy Act of 1969 and the Council on Environmental Quality.
Region	A geographic area of thousands of square miles.
Repository	The engineered portion of the disposal system excluding the waste package.
Retrievability	Capability to remove waste from its place of isolation using planned engineering procedures.
Salt	Used here to refer to the common mineral species halite (NaCl) and any included impurities.
Screening	The process of evaluating an area, on the basis of criteria, to identify places which best fulfill the criteria.
Seismic activity	The occurrence of earthquakes.
Seismicity	The spatial distribution of earthquake activity.
Site	The place, both at and below the surface, where the repository and ancillary facilities are constructed. This includes surrounding buffer zones and has a surface area of several square miles.
Specification	A performance criterion for a selected design or siting option—often quantitative.
Stratigraphic setting	The characteristics of the rock layers or other units in the geologic environment.

Subsidence	Sinking of a part of the Earth's crust relative to adjacent parts.
Subsurface facilities	Engineered facilities (including shafts and drifts) that are designed to function underground.
Surface facilities	Engineered facilities on the Earth's surface.
Surface water	Water at the Earth's surface including lakes, impoundments, rivers, and streams.
Tectonic element	A feature, or group of features, constituting a portion of the tectonic environment, e.g., a fault, fold, volcano, arch, joint.
Tectonic environment	The broad architecture of the Earth's crust, particularly its structural and deformational features and the interrelationships among them.
Tectonic event	An event causing or resulting from deformation of the Earth's crust, e.g., faulting, earthquake, folding, uplift.
Tectonics	Of, or pertaining to, the forces involved in, or the structures or features produced by, deformation of the Earth's crust.
Transport path	A route along which radionuclides could migrate.
Transuranic (TRU) waste	Waste measured or assumed to contain more than a specified concentration of alpha-emitting radionuclides (including U-233 and its daughter products) of long half-life and high specific radiotoxicity that requires isolation. In current usage, this concentration is defined as greater than 10 nCi/gm of waste.
Uplift	The process that results in elevation of a portion of the Earth's crust relative to an adjacent portion.
Volcanism	The processes by which magma and its associated gases rise into the crust and are extruded onto the Earth's surface and into the atmosphere.
Waste	Material with no currently designated value or use.